HEXAGON

myVGL

Reference manual

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Welcome

Welcome

Thank you for choosing Hexagon products. This document is the Reference Manual of myVGL and serves as a reference to the ribbon tabs, options, and dialogs as well as a guide to more resources, such as help and support options and tutorials.

All documentation is part of the product; please read it carefully. Make sure to have the complete documentation available throughout the lifetime of this product. In case of change of ownership (as far as compliant with the terms and conditions), make sure to provide the new user with the full installation package, including all supplementary material. Updating your software installation might include a new documentation version or additional material. Please ensure that you always use the correct version of all product and supplementary materials.

About this Product

myVGL is a software for the visualization and documentation of voxel data projects (*.vgl*, *.vgarchive*, or *.mvgl* files) created in VGSTUDIO MAX, VGSTUDIO, or VGMETROLOGY. It is used in a variety of areas, such as industrial CT, medical research, life sciences, animation, and many others.

Table 1-1: Product details

Feature	Description
Product name	myVGL
Release	2025.3
Scope of delivery	Installation package (download), platform-specific as ordered, documentation, and supplementary material, such as example data
Document ID	ReferenceManual-1021-v024-001-en

☞ myVGL contains the Volume Graphics Metrology Kernel VGMK 2023.1.0, which passed the PTB test for “Evaluation software based on least-squares method for coordinate measuring machines” and the PTB test for “Evaluation software based on minimum-zone method for coordinate measuring machines” and was verified by the NIST “Algorithm Testing and Evaluation Program for Coordinate Measuring Systems.” The test results were obtained under Windows (64 bit).

System Requirements

For information on system requirements and troubleshooting, download the current System Requirements from your download account or from our website: https://volumegraphics.hexagon.com/en/.

Before First Usage

The installation instructions provided with the e-mail containing the download link or available in your download account will tell you how to install myVGL.

If you have any questions regarding your download account, do not hesitate to contact us:

- For Europe, Middle East, and Africa:
  Write an e-mail to sales@volumegraphics.com or call +49 6221 73920 744.
- For Japan:
  Write an e-mail to sales@volumegraphics.jp or call +81 52 508 9682.
- For the Americas:
  Write an e-mail to sales-us@volumegraphics.com or call +1 704 248 7736.
- For China, including Mainland China, Hong Kong, Macao, and Taiwan:
  Write an e-mail to sales@volumegraphics.cn or call +86 10 8532 6305.
- For Singapore and other parts of Asia (except China and Japan), Australia, and parts of Oceania:
  Write an e-mail to sales@volumegraphics.sg or call +65 6665 0310.

Running More Than One Program Instance

Problems may arise when you run more than one instance of the application.

Typical effects are problems with the user interface, such as incomplete or misplaced interface elements or errors in the display of images. User settings, such as presets or workspace layout may inadvertently be overwritten. Processor capacity and main memory will be shared between instances of the application and may prove insufficient. This may result in dramatically low system performance or even application crashes, especially if parts of the information need to be swapped to disk because of high memory consumption.

Preparations/Warnings

If the font in myVGL appears to be blurry, verify the settings of the Microsoft function **ClearType**.

Your work may require considerable system resources. Shut down all other applications that take up large amounts of main memory or processor power before launching myVGL. When the mouse pointer changes to an arrow with a wait cursor, it is strongly recommended not to perform any actions that would change the contents of the scene.

Your work with myVGL may be subject to legal restrictions or company-specific regulations. Contact your supervisors for details.

Specifications are subject to change without prior notice. Errors are excepted. Some features described in this manual may not be available in your software version. Availability of features may vary with operating system, software version, hardware, license, licensed modules, etc.

Conventions Used in the Documentation

Throughout the documentation, you will find the following conventions:

- Each ribbon tab, tool, analysis, and/or add-on module is described in a separate manual chapter.
- Cross-references like “see chapter 2 *Workspace*” are highlighted in blue. Click the link to follow it.
- Controls of the user interface, such as tabs, options, buttons, input fields, and keys are highlighted in **bold**.
- The mouse buttons are abbreviated as follows:
  - LMB = left mouse button
  - MMB = middle mouse button, often identical with the mouse wheel

    Alternatively, you can use **Alt** + LMB almost anywhere in the application; this is particularly useful if your mouse does not have a middle mouse button or a mouse wheel.
  - MW = mouse wheel
  - RMB = right mouse button
- Text in angle brackets <> indicates a placeholder, e.g., <unit>.
- File names, directories, and paths are highlighted in *italics*.
- The dark theme color scheme was used for the screenshots and icons in this documentation; colors in the light theme may differ slightly.
- The following conventions are used for denoting quantities and operations:
  - Scalar quantities are denoted with italic letters, e.g., x.
  - Vector-valued quantities are marked with an underline, e.g., $\underline{x}$.
  - The i-th component of a vector-valued quantity is written as x_i.
  - Tensor-valued quantities are denoted with bold letters, e.g., $\mathbf{x}$.
  - The matrix component (i, j) of a tensor-valued quantity is written as x_{ij}.
  - The partial derivative of a function $f(\underline{r})$ with respect to the i-th component of the vector $\underline{r}$ is denoted by $f_{,i}(\underline{r})$.
  - The dependence on the position vector $\underline{r}$ is sometimes omitted for a clearer appearance of formulas, e.g., instead of $s_{ij}(\underline{r})$, we will simply write s_{ij}.

Throughout the documentation, four types of notes are used. The order of the notes indicates their increasing importance:

Tip: Provides additional information that will help you use the software more efficiently.

Note: Provides you with background information.

Important note: Provides you with important information that is required, for example, to perform an action correctly.

Warning: Indicates that failure to follow the corresponding advice may entail malfunction or undesired results, e.g., loss of data.

Rounding Rules

Values in myVGL will be interpreted according to DIN EN ISO 8015, i.e., non-indicated decimals of values such as nominal values and tolerance values will be zero:

- 2 = 2.000000000000
- 2.00 = 2.0000000000000
- 2.49 = 2.4900000000000

Additional Information

This Reference Manual is part of the documentation of myVGL. Other documents address specific tasks or topics. Go to the **Help** tab in the ribbon and click **Show tutorials** to browse the tutorials[1]. Go to your download account to browse other documents, e.g., the installation instructions.

Some documents are available in different languages. In case of differences between the documents, the English version shall prevail.

If you are interested in more extensive functionality than the one offered by myVGL, you have the chance to evaluate our other products, VGSTUDIO, VGMETROLOGY, or VGSTUDIO MAX, by requesting an evaluation license on our website:

https://volumegraphics.hexagon.com/en/products/evaluation

For further questions about our product portfolio, please contact us:

- For Europe, Middle East, and Africa:
  Write an e-mail to sales@volumegraphics.com or call +49 6221 73920 744.
- For Japan:
  Write an e-mail to sales@volumegraphics.jp or call +81 52 508 9682.
- For the Americas:
  Write an e-mail to sales-us@volumegraphics.com or call +1 704 248 7736.
- For China, including Mainland China, Hong Kong, Macao, and Taiwan:
  Write an e-mail to sales@volumegraphics.cn or call +86 10 8532 6305.
- For Singapore and other parts of Asia (except China and Japan), Australia, and parts of Oceania:
  Write an e-mail to sales@volumegraphics.sg or call +65 6665 0310.

Training

Hexagon provides training in the use of the VG software products. Ask for the next public course at VG Academy or order on-site training at your premises:

[1] PDF file type must be associated with a dedicated PDF viewer to follow the links.

- For Europe, the Americas, and Africa:
  academy@volumegraphics.com
- For Japan:
  jpnch-support.mi@volumegraphics.com
- For China, including Mainland China, Hong Kong, Macao, and Taiwan:
  support@volumegraphics.cn
- For Singapore and other parts of Asia (except China and Japan), Australia, and parts of Oceania:
  support@volumegraphics.sg

Workspace

Introduction

A workspace is an arrangement of elements, such as the windows and tools for visualizing the data.

The workspace of myVGL consists of the following elements (see Figure 2-1):

- Title bar (1): Displays the path and name of the project currently loaded in the workspace and includes the Quick Access Toolbar.
- Ribbon with tabs (2): Provides access to all functions of the software.
- Tool docks (3): Provide access to the tool windows (see section *Tool Dock* on page 33).
- Workspace windows (4): Allow you to visualize and analyze the CT data (2D windows, 3D window, etc.). Each workspace window features a set of controls and a context menu, which allow you to modify the content or the behavior of the window.
- Status bar (5): Provides information on system usage.

The following figure shows an example of a typical workspace:

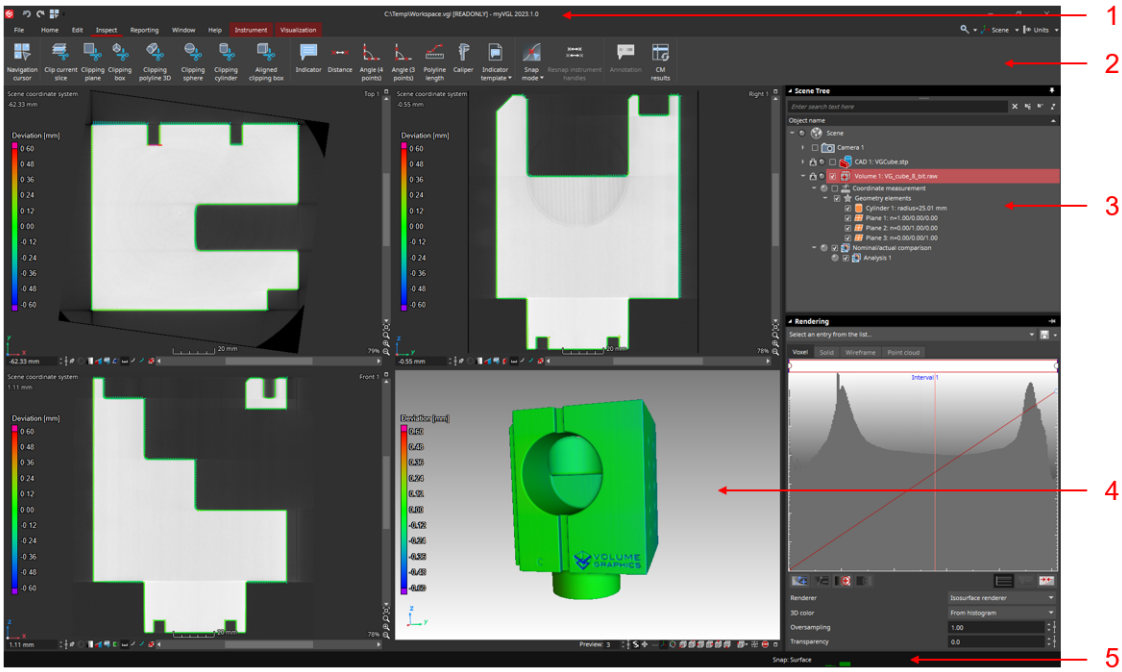


Figure 2-1: Overview of the workspace

Clicking in a workspace window will select this window; this is indicated by a frame around the window.

In order to resize a workspace window, move the mouse pointer over its borders. The mouse pointer will change its shape to indicate the directions in which you can drag it to resize the workspace window.

3D Window

The 3D window shows the image resulting from the rendering process.

The rendering parameters can be defined by using the **Rendering** tool (see chapter 17 *Rendering Tool* on page 192).

The camera tripod in the lower left corner of the 3D window indicates the orientation of the currently selected coordinate system.

In order to select an object, you can

- highlight its entry in the Scene Tree or
- directly select it in the 3D window.

To select an object in the 3D window, you have the following options:

Table 2-1: Selecting an object in the 3D window

Control	Description
double-click with LMB	Selects an object.
hold down **Ctrl** + double-click with LMB	Selects multiple objects.
double-click background with LMB	Deselects all objects.

When a volume, CAD model, or mesh is selected in the Scene Tree (and the checkbox in front of it is checked to make it visible), its bounding box and its rotation center (if the **Show origin tripod** option in the preferences is set to **Show at rotation center**) will be displayed when you move the mouse pointer into or within the 3D view. When a region of interest (ROI) is selected, the bounding box and the rotation center of the ROI (if the **Show origin tripod** option in the preferences is set to **Show at rotation center**) as well as the bounding box of the volume will be displayed.

By default, the bounding box is displayed only temporarily after you have moved the mouse pointer into or within the 3D view. The behavior of the bounding box can be changed in the preferences under **File > Preferences > General > Window > 3D window** (see section *General Preferences* on page 57 in chapter 3 *File Tab*).

Most of the corners of the bounding box are bright red when you are in **Rotate** mode and bright green when you are in **Move** mode. The lines that are none of these colors represent the x (dark red), y (dark green), and z (blue) axes of the object coordinate system.

Controls in the 3D Window

This section gives an overview of the controls available at the bottom of the 3D window. The following figure shows an example of a 3D window:

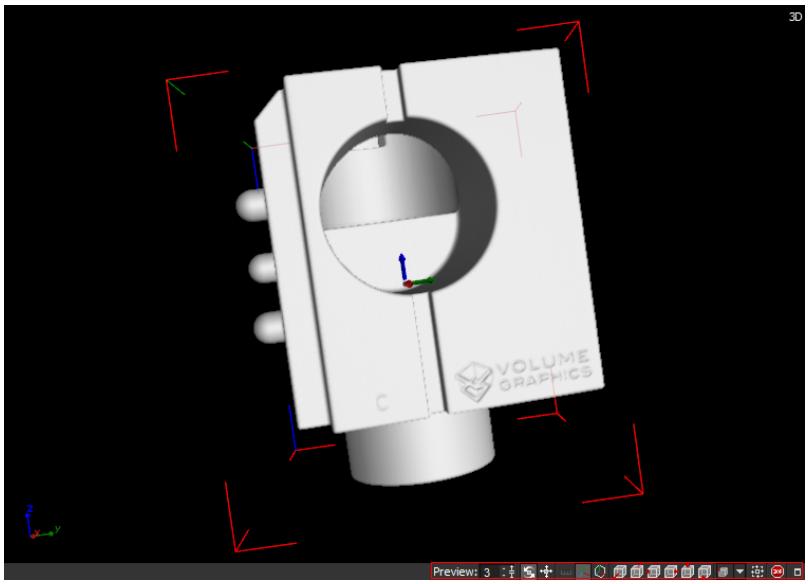


Figure 2-2: Example of a 3D window

Preview Spin Box

The preview factor is a reduction factor by which the rendering of voxel data sets is reduced while the scene is being manipulated. Higher reduction factors will lead to a smoother interaction. This is especially helpful on computers with low overall performance.

With a preview factor larger than 1, some rendering effects, e.g., shadows, will not be rendered while the scene is being manipulated.

Rotate/Move Mode

An object can be transformed, i.e., rotated or moved within the scene, only if it is unlocked in the Scene Tree. If it is locked, you will change the rotation and location of the camera instead. For details, see section *Rotate/Move Mode* on page 98 in chapter 5 *Edit Tab*.

Show scale bar

Shows/hides the scale bar.

In the 3D window, this option is enabled only if **Parallel** is selected in the **Projection mode** field of the **Camera** tool.

Show tripod

Shows/hides the camera tripod. You can modify the size of the tripod in the preferences. See section *Coordinate system display Settings* on page 75 in chapter 3 *File Tab*.

Hovering with the mouse pointer over the tripod in the 3D window will change the tripod to a cube that can be used for adjusting the camera view. The cube will disappear when you stop hovering the mouse pointer over it.

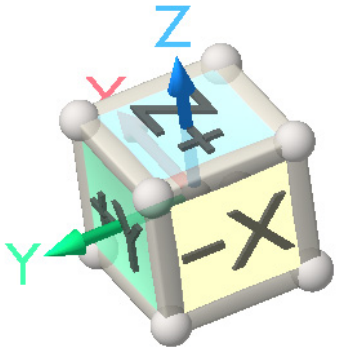


Figure 2-3: Tripod changed to a cube

Table 2-2: Controls of the cube

Control	Description
click a cube face	Aligns the camera view so that the observer is looking at the face head-on. The tripod axes will be aligned with the screen axes.
double-click a cube face	Aligns the camera view so that the observer is looking at the face head-on. If you double-click the +Z- or -Z-face, the x-axis will point to the right; otherwise the z-axis will point upwards. The resulting views correspond to the default camera views, which can also be selected via the buttons at the bottom of the 3D window.
click a cube edge	Aligns the camera view so that the observer is looking at the edge head-on. The tripod axes will be aligned with the screen axes.
double-click a cube edge	Aligns the camera view so that the observer is looking at the edge head-on and the z-axis points upwards.
click a cube corner	Aligns the camera view so that the observer is looking at the corner head-on.

Control	Description
double-click a cube corner	Aligns the camera view so that the observer is looking at the corner head-on and the z-axis points upwards. The resulting views correspond to the default camera views, which can also be selected via the buttons at the bottom of the 3D window.
click and drag the tripod	Rotates the camera around the object.
hold down MMB + move up/down	Rotates the camera counterclockwise/clockwise.

Show box

Shows/hides the grid box of the coordinate system.

Default Camera Views

These icons provide shortcuts to various default camera views, relative to the selected coordinate system. They can be used for quickly adjusting the camera point of view. These default views are along the three major axes (in both directions) as well as from positions along each of the four diagonals (one position for each corner).

Center and focus camera

Centers the currently selected object and adjusts the zoom level so that the object becomes fully visible in the 3D window.

When the **Spherical** navigation mode is selected in the preferences, you can also double-click the middle mouse button in the 3D window to center the object and adjust the zoom level.

Freeze rendering

Stops the rendering of your object. This can be useful if you want to make changes to your data without showing the results in the 3D window after each step.

Toggle fullscreen state

Toggles the corresponding window between full screen size and current window layout.

You can also use the **F11** key for toggling between full screen size of the selected window and current window layout.

Origin Tripod

Depending on the settings in the preferences (**File > Preferences > General > Window > 3D window**), the origin tripod will either be shown in the origin of the current coordinate system or in the rotation center of the selected object, or it will be hidden.

When the object is unlocked, i.e., the padlock in the Scene Tree is open, the tripod will change to an active tripod, which will be located in the center of rotation selected on the **Transform** contextual tab or—in case several objects are selected and **Center of bounding box of individual object** is selected—in the center of the common bounding box. The active tripod can be used for transforming the object. The translation and rotation will be synchronized with the corresponding **X**, **Y**, and **Z** spin boxes on the **Transform** contextual tab. The **Apply** and **Cancel** buttons will be disabled, and the transformation will be applied instantly.

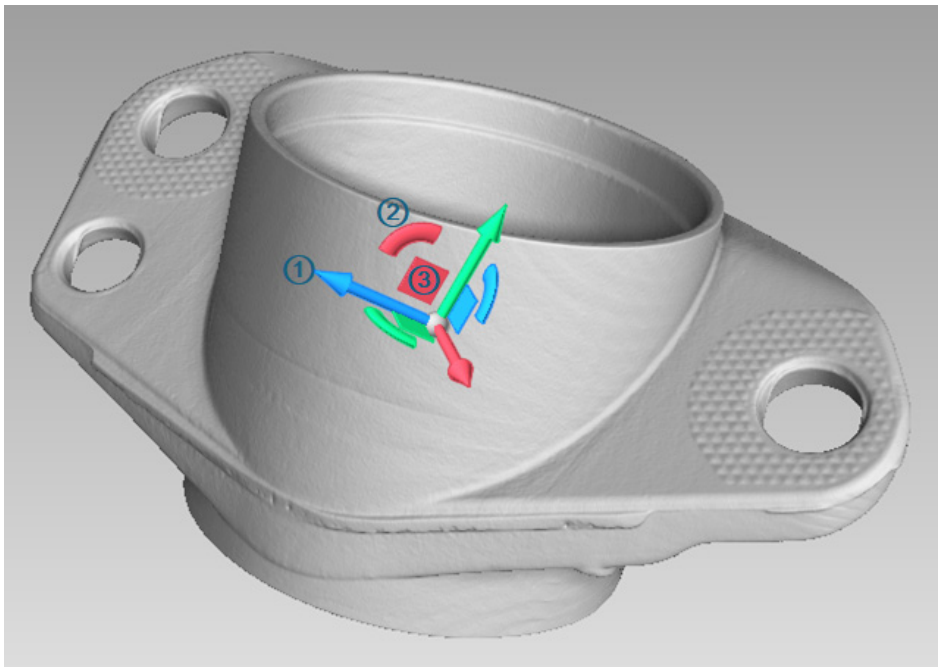


Figure 2-4: Active tripod: 1 = tripod axis; 2 = tripod arc; 3 = planar handle

Table 2-3: Controls of the active tripod

Control	Description
click and drag a tripod axis	Moves the object along the corresponding axis. A label that indicates the current translation distance will appear. During or after dragging, you can also enter a value into the label.
hold down **Shift** + click + drag a tripod axis	Moves the object along the corresponding axis in steps of 100 length units (e.g., mm).
hold down **Ctrl** + click + drag a tripod axis	Moves the object along the corresponding axis in steps of 10 length units (e.g., mm).
hold down **Ctrl**+**Shift** + click + drag a tripod axis	Moves the object along the corresponding axis in steps of 1 length unit (e.g., mm).
click and drag a tripod arc	Rotates the object around the corresponding axis. A label that indicates the current rotation angle will appear. During or after dragging, you can also enter a value into the label.
hold down **Shift** + click + drag a tripod arc	Rotates the object around the corresponding axis in steps of 45 degrees.
hold down **Ctrl** + click + drag a tripod arc	Rotates the object around the corresponding axis in steps of 5 degrees.
hold down **Ctrl**+**Shift** + click + drag a tripod arc	Rotates the object around the corresponding axis in steps of 1 degree.
click and drag a planar handle	Moves the object in the plane that is orthogonal to the corresponding axis.

Zooming in/out

To zoom in or out in the 3D window, hover the mouse pointer over the point of interest and scroll the mouse wheel.

If you are using a laptop without a mouse, you can touch the touchpad with two fingers and move them apart or together to zoom (make sure the **Pinch to zoom** option is activated in the Windows touchpad settings). Alternatively, you can drag two fingers up and down (make sure the **Drag two fingers to scroll** option is activated in the Windows touchpad settings).

To reverse the zoom direction, check the **Reverse mouse wheel zoom** option in the **3D window** section of the **Preferences > General > Window** dialog.

Context Menu of the 3D Window

You can access the context menu of the 3D window by right-clicking anywhere in the 3D window.

Color bar preferences

Available only when you right-click the color bar of an analysis.

Opens the **Preferences** dialog, where you can modify the properties of the color bars. For details, see section *Color bars Settings* on page 70 in chapter 3 *File Tab*.

Edit color lookup table

Available only when you right-click the color bar of an analysis.

Opens the **Colors** tab of the corresponding analysis dialog, where you can specify the color-coding scheme used for the representation of the analysis results. For details, see the "**Colors** tab" chapter of the corresponding analysis.

You can also double-click the color bar of an analysis in the 2D and 3D windows to open the **Colors** tab.

Color bar position

Available only when you right-click the color bar of an analysis.

Here you can directly specify the location of the color bar for the individual analysis type within the 2D and 3D windows: **Left**, **Right**, **Top**, **Bottom**, **All - automatic**, **Left or right - automatic**, **Top or bottom - automatic**.

Annotation result

Available only when you right-click anywhere within the annotation label.

This menu item allows you to select the property to be displayed as the default result for the annotation. The selected property is highlighted in bold in the annotation label and displayed in the Scene Tree next to the annotation name.

If available, the **Follow active column** option is checked by default, i.e., the property selected as active column is displayed as the default result for the annotation.

Annotations

Allows you to modify the display of the currently visible annotations. See section *Annotations Drop-down List* on page 171 in chapter 8 *Window Tab*.

Clipping

For details on the various clipping modes, see section *Clipping Icon Group* on page 103 in chapter 6 *Inspect Tab*.

Tripod/Box

The **Tripod/Box** menu item consists of the following submenu entries:

Table 2-4: Controls of the **Tripod/Box** menu

Control	Description
Show camera tripod	Shows/hides the camera tripod.
Show box	Shows/hides the grid box of the coordinate system.
Adjust box to selection	Only enabled when the grid box is visible: Adjusts the grid box to include the currently selected object(s).
Configure...	Opens the **Preferences** dialog, where you can modify the properties for the coordinate system display. For details, see section *Colors & Styles Preferences* on page 68 in chapter 3 *File Tab*.

3D background

The **3D background** menu item consists of the following submenu entries:

Table 2-5: Controls of the **3D background** menu

Control	Description
Apply default	Applies the default 3D background setting.
Edit	Opens the **Background color** dialog, where you can specify the settings for the background. For details, see section *3D background* on page 166 in chapter 8 *Window Tab*.
Save as default	Saves the current 3D background setting as default.

Scale bar

The **Scale bar** menu item consists of the following submenu entries:

Table 2-6: Controls of the **Scale bar** menu

Control	Description
Show scale bar	Toggles the display of the scale bar. In the 3D window, this option is enabled only if **Parallel** is selected in the **Projection mode** field of the **Camera** tool.
Configure...	Opens the **Preferences** dialog, where you can modify the properties for the coordinate system display. For details, see section *Colors & Styles Preferences* on page 68 in chapter 3 *File Tab*.

Text overlay

The **Text overlay** menu item consists of the following submenu entries:

Table 2-7: Controls of the **Text overlay** menu

Control	description
Default/<name of preset>	Allows you to select the default text overlay preset or a user-defined text overlay preset. To define a text overlay preset, select the **Configure...** menu item.
Configure...	Opens the **Configure text overlay** dialog, where you can define a text overlay preset. For details, see section *Text overlay editor* on page 172 in chapter 8 *Window Tab*.

Reset transformation

Resets any transformations applied to the selected object. This control is enabled only if the padlock in the Scene Tree is open.

Ambient occlusion

Available on Windows and Linux operating systems only.

When this option is activated, depth perception in the 3D view will be enhanced by adding shadows to areas in which nearby objects or surfaces would occlude ambient lighting.

On some GPUs, the rendering performance might be improved when this option is deactivated.

Freeze rendering

Stops the rendering of your object. This can be useful if you want to make changes to your data without showing the results in the 3D window after each step.

3D image quality

The **3D image quality** menu item consists of the following submenu entries:

Table 2-8: Controls of the 3D image quality menu

Control	Description
Full resolution	Renders every pixel and leads to the most accurate rendering.
2x reduced	Renders every 4th pixel, which leads to a faster rendering.
4x reduced	Renders every 16th pixel, which leads to the fastest rendering.

Copy to clipboard

Copies a screenshot of the active window to the clipboard so that you can paste it into another application.

Properties

Displays information on the object selected in the Scene Tree.

Except for views, you can also open the **Properties** dialog by double-clicking the object in the Scene Tree.

The type of properties dialog depends on the type of object selected:

- If the selected object is a *geometry element*, the **Geometry element properties** dialog will open. For details, see section *Geometry element properties Dialog* on page 256 in chapter 24 *Coordinate Measurement*.
- If the selected object is a *dimensioning feature*, the **CM results** dialog will open. For details, see section *CM results dialog* on page 264 in chapter 6 *Inspect Tab*.
- If the selected object is a *tolerance feature*, the **CM results** dialog will open. For details, see section *CM results dialog* on page 264 in chapter 6 *Inspect Tab*.
- If the selected object is an *analysis*, the **Properties** dialog of the pertaining analysis will open. For details, see the chapter on the corresponding analysis.
- If the selected object is a *volume object*, a *CAD model,* a *surface mesh*, or an *ROI*, the **Object properties** dialog will open. For details, see section *Object properties Dialog* on page 79 in chapter 5 *Edit Tab*.
- If the selected object is a *tetrahedral mesh*, the **Tetrahedral mesh** dialog will open. For details, see section *Tetrahedral mesh Dialog* on page 97 in chapter 5 *Edit Tab*.

Rotate/Move

Toggle between **Rotate** mode and **Move** mode for the selected object(s) in the 3D window. The current mode can be identified by the color of the bounding box of the object in the 3D window: A red bounding box indicates **Rotate** mode, and a green bounding box indicates **Move** mode. For more details, see section *Rotate/Move Mode* on page 8 in chapter 2 *Workspace*.

Set rotation center

Sets the camera rotation center to the position at which you right-clicked before the context menu is opened. This menu item is available only if the **Default** navigation mode is selected in the preferences under **File > Preferences > General > Window > 3D window** (see section *General Preferences* in chapter 3 *File Tab*).

Reset rotation center

Resets the camera rotation center to the center of the bounding box of the selected objects. This menu item is available only if the **Default** navigation mode is selected in the preferences under **File > Preferences > General > Window > 3D window** (see section *General Preferences* in chapter 3 *File Tab*).

Configuring a Color Bar

Double-clicking an analysis color bar in the 2D and 3D windows directly opens the **Colors** tab of the corresponding analysis dialog, where you can specify the color-coding scheme used for the representation of the analysis results.

Right-clicking an analysis color bar opens a context menu that provides direct access to the color bar preferences and the options for the color bar position.

2D Windows

The 2D windows show slices of the currently visible objects as seen from the front (along the y-axis), top (along the z-axis), or right (along the x-axis) of the current coordinate system or around a specified rotation axis. Apart from that, non-planar and/or custom-path views may be available, provided these views were saved with the project in VGSTUDIO MAX or VGSTUDIO.

Voxel data is shown in gray values, whereas mesh and CAD models and ROIs are displayed as colored outlines in the 2D windows.

Controls in the 2D Windows

This section gives an overview of the controls available at the bottom and to the right of the 2D windows.

The following figure shows an example of a 2D window:

Figure 2-5: Example of a 2D window

Slice Position Spin Box

Allows you to scroll through the slices in the corresponding 2D window.

In the rotation view, you can rotate around the specified axis.

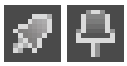
In the thick slab mode, a 2D view shows an overlay of several slices instead of only one slice. The current slice position is the middle of the thick slab.

In order to scroll through the slices, you can

- click the up/down arrows of the slice position spin box,
- move the mouse pointer on the scroll area to the right of the up/down arrows until the mouse pointer changes its shape and drag the mouse up/down while pressing the left mouse button,
- position the mouse pointer anywhere on the spin box and scroll the mouse wheel,
- change the value of the text box, or
- position the mouse pointer in the window and scroll the mouse wheel (if the **Mouse wheel** option in the preferences under **File > Preferences > General > Window > 2D windows** is set to **Scroll slices**), or
- position the mouse pointer in the window, hold down the **Ctrl** key, and scroll the mouse wheel (if the **Mouse wheel** option is set to **Zoom view**), or
- press the **Page Up** or **Page Down** keyboard keys.

In order to navigate to the first slice in the data set, hold down the **Ctrl** key and press the **Home** key; in order to navigate to the last slice in the data set, hold down the **Ctrl** key and press the **End** key.

Lock slice position



Locks and unlocks the slice position for this 2D window. When locked, the slice position in this window will not change when you, for example, move an instrument or the **Navigation cursor** in another 2D window. However, it is possible to modify the slice position deliberately by changing the value in the slice position spin box at the bottom left.

An action that changes the coordinate system, e.g., by selecting a tolerance, does not consider the setting for the **Lock slice position** option.

Level/Window mode

The settings for the brightness (**Level**) and contrast (**Window**) values affect the display of all objects in all 2D windows. For details, see section *Level/Window mode* on page 170 in chapter 8 *Window Tab*.

This button can be shown/hidden by checking/unchecking the **Level/Window mode** checkbox in the preferences under **File > Preferences > General > Window > 2D windows** (see section *General Preferences* on page 57 in chapter 3 *File Tab*). It is shown by default. The button is enabled in **Original display mode** and in **Color mode**; it is disabled in **Color and opacity mode**.

Original display mode

Toggles between showing the slice images in their original brightness, contrast, and color and showing them in the settings specified in the **Rendering** tool.

See also section *Display mode Drop-down List* on page 168 in chapter 8 *Window Tab*.

Color mode/Color and opacity mode

Specifies the user-defined rendering settings to be displayed in the 2D windows: only the colors or the colors and the opacity settings.

See also section *Display mode Drop-down List* on page 168 in chapter 8 *Window Tab*.

Create/replace clipping plane using slice position

Creates or replaces a clipping plane aligned to the view represented by the selected 2D window. Use this function to show the interior of the object at the current slice position. A second click on this button will flip the normal of the clipping plane.

For more detailed information on clipping, see section *Clipping Icon Group* on page 103 in chapter 6 *Inspect Tab* and chapter 20 *Clipping Tool* on page 215.

Navigation plane mode

Switches the display of the navigation planes in the 2D and 3D windows. Navigation planes indicate the position of the currently selected 2D views in the data set.

Clicking the button subsequently switches to the following states:

- **automatic**: The navigation plane is displayed only temporarily after a 2D view is changed. The time period after which the navigation plane disappears can be specified via the **Display duration** option in the preferences under **File > Preferences > General > Window > 2D windows** (see section *Window Settings* on page 58 in chapter 3 *File Tab*).
- **permanent**: The navigation plane is always displayed. How long the navigation plane is highlighted in the 3D window after a 2D view is changed can be specified via the **Display duration** option in the preferences under **File > Preferences > General > Window > 2D windows** (see section *Window Settings* on page 58 in chapter 3 *File Tab*).

  off: The navigation plane is never displayed.

The navigation planes are color-coded:

Table 2-9: Colors of the navigation planes

Icon	Color	Description
	blue	xy-plane
	red	yz-plane
	green	xz-plane
	orange	navigation plane for custom path view
	magenta	navigation plane for non-planar view
	yellow	navigation plane for rotation view

When the **Thick slab** mode is activated in one of the 2D views, its navigation plane in the other views will consist of three planes: The middle plane is highlighted and displays the slice position (the middle of the thick slab), while the outer two planes display the edges of the thick slab.

To change the position of the navigation plane, click and drag a navigation plane in a 2D or 3D window.

The **X-Ray** and **Sum along Ray** renderers do not render a true 3D view of the selected object (see chapter 17 *Rendering Tool*). Therefore, if one of these renderers is selected in the **Rendering** tool, the position of the navigation planes in the 3D view will not be informative.

Show scale bar

Shows/hides the scale bar.

In the 3D window, this option is enabled only if **Parallel** is selected in the **Projection mode** field of the **Camera** tool.

Surface lines

Clicking this button toggles between the following states:

Table 2-10: Options for showing surface lines

Icon	Option	Description
	Default	Shows the surface line of the selected volume on top and all other surface lines that are not concealed by overlying volumes.
	All on top	Shows all surface lines of all volumes.
	Off	Shows no surface lines.

When the surface lines are switched on, the line color will be taken from the **Line/surface color** setting on the **Solid** tab of the **Rendering** tool. See also chapter 17 *Rendering Tool* on page 192.

Region of interest lines

Clicking this tri-state button toggles between the following states:

Table 2-11: Options for showing ROI borders

Icon	Option	Description
	Default	Shows the ROI borders of the selected volume on top and all other ROI borders that are not concealed by overlying volumes.
	All on top	Shows all ROI borders of all volumes.
	Off	Shows no ROI borders.

This option only modifies the display of the ROI borders. If ROI render settings are activated, the settings for color or transparency, for example, will not be changed when you toggle between the region of interest lines modes.

Surface fill

Clicking this button toggles the display of a constant fill color for the material in the 2D windows. When the fill mode is *on*, the fill color will be taken from the **2D fill color** setting on the **Solid** tab of the **Rendering** tool. If ROI render settings are activated for an ROI, the material lying within the ROI will be rendered in the color selected for the ROI.

The volume object must have a determined surface.

See also chapter 17 *Rendering Tool* on page 192.

Scroll Bars

Scroll the contents in the corresponding 2D window in the horizontal or vertical directions. You can also use the left/right and up/down arrow keys.

Using the middle mouse button, you can also drag the slice view around in the 2D window.

Zoom in/out

Zooms into or out of the corresponding 2D window. You can also press the **Ctrl++** or **Ctrl+–** keys to zoom in or zoom out.

If you want to zoom in on a POI (point of interest) of the object, set the **Navigation cursor** to that POI and click the **Zoom in** button.

A very fast and convenient method to zoom in on a POI is to position the mouse pointer over it and scroll the mouse wheel while holding down the **Ctrl** key (if the **Mouse wheel** option in the preferences under **File > Preferences > General > Window > 2D windows** is set to **Scroll slices**) or simply scroll the mouse wheel (if the **Mouse wheel** option is set to **Zoom view**).

Reset zoom

Resets the zoom of the 2D window. You can also hold down the **Ctrl** key and press the **0** key to reset the zoom.

Focus selected object

Centers the slice view of the selected parent object in the 2D window. When you double-click, the first click centers the current slice and the second click changes the view to the slice that contains the center of the data set.

If the selected object is an ROI, the ROI is centered and the slice is zoomed so that the entire data set is shown in the slice view. If the currently selected slice does not contain the ROI, the slice that contains the center of the ROI will be shown. When you double-click, the first click centers the slice and the second click changes the view to the slice that contains the center of the ROI.

Slices are always displayed in the current coordinate system. Note that locking the slice with **Lock slice position** does not disable this function.

When the **Spherical** navigation mode is selected in the preferences (**File > Preferences > General > Window > 3D window**), you can also double-click the middle mouse button in the 2D window to center the slice view of the object and adjust the zoom level.

Toggle fullscreen state

Toggles the corresponding window between full screen size and current window layout.

You can also use the **F11** key for toggling between full screen size of the selected window and current window layout.

Configuring a Color Bar

Double-clicking an analysis color bar in the 2D and 3D windows directly opens the **Colors** tab of the corresponding analysis dialog, where you can specify the color-coding scheme used for the representation of the analysis results.

Right-clicking an analysis color bar opens a context menu that provides direct access to the color bar preferences and the options for the color bar position.

Context Menu of the 2D Window

You can access the context menu of a 2D window by right-clicking anywhere in the 2D window.

Color bar preferences

Available only when you right-click the color bar of an analysis.

Opens the **Preferences** dialog, where you can modify the properties of the color bars. For details, see section *Color bars Settings* on page 70 in chapter 3 *File Tab*.

Edit color lookup table

Available only when you right-click the color bar of an analysis.

Opens the **Colors** tab of the corresponding analysis dialog, where you can specify the color-coding scheme used for the representation of the analysis results. For details, see the "**Colors** tab" chapter of the corresponding analysis.

You can also double-click the color bar of an analysis in the 2D and 3D windows to open the **Colors** tab.

Color bar position

Available only when you right-click the color bar of an analysis.

Here you can directly specify the location of the color bar for the individual analysis type within the 2D and 3D windows: **Left**, **Right**, **Top**, **Bottom**, **All - automatic**, **Left or right - automatic**, **Top or bottom - automatic**.

Annotation result

Available only when you right-click anywhere within the annotation label.

This menu item allows you to select the property to be displayed as the default result for the annotation. The selected property is highlighted in bold in the annotation label and displayed in the Scene Tree next to the annotation name.

If available, the **Follow active column** option is checked by default, i.e., the property selected as active column is displayed as the default result for the annotation.

Clipping > Create/replace clipping plane using slice position

Creates or replaces a clipping plane aligned to the view represented by the selected 2D window. Use this function to show the interior of the object at the current slice position. A second click on this button will flip the normal of the clipping plane.

For more detailed information on clipping, see section *Clipping Icon Group* on page 103 in chapter 6 *Inspect Tab* and chapter 20 *Clipping Tool* on page 215.

Zoom

Controls the zoom setting of the selected 2D view. See section *Zoom Icon Group* on page 167 in chapter 8 *Window Tab*.

Coordinate system

Specifies a reference coordinate system for the selected 2D window. Other 2D windows will not be affected by this choice. Select **Follow global coordinate system** to use the coordinate system active in the coordinate system drop-down list in the ribbon.

Display mode

Here you can choose if you want the display of the 2D windows

- in their original brightness, contrast, and color settings,
- overlaid with colors defined in the **Rendering** tool, or
- overlaid with both colors and opacity settings defined in the **Rendering** tool.

See also section *Display mode Drop-down List* on page 168 in chapter 8 *Window Tab*.

Thick slab...

Opens the **Thick slab settings** dialog (see section *Thick slab* on page 169 in chapter 8 *Window Tab*). In **Thick slab** mode, a 2D view shows an overlay of several slices instead of only one slice. The current slice position is the middle of the thick slab.

Slice step width...

Opens the **Set slice step width** dialog, where you can define the step width to be used for scrolling through the slices in the 2D windows. The default value is the resolution of the data set. This menu item is enabled only when you are not in a grid coordinate system.

Non-planar resampling

Only available when the **Non-planar** window is selected. Opens the **Resample volume** dialog:

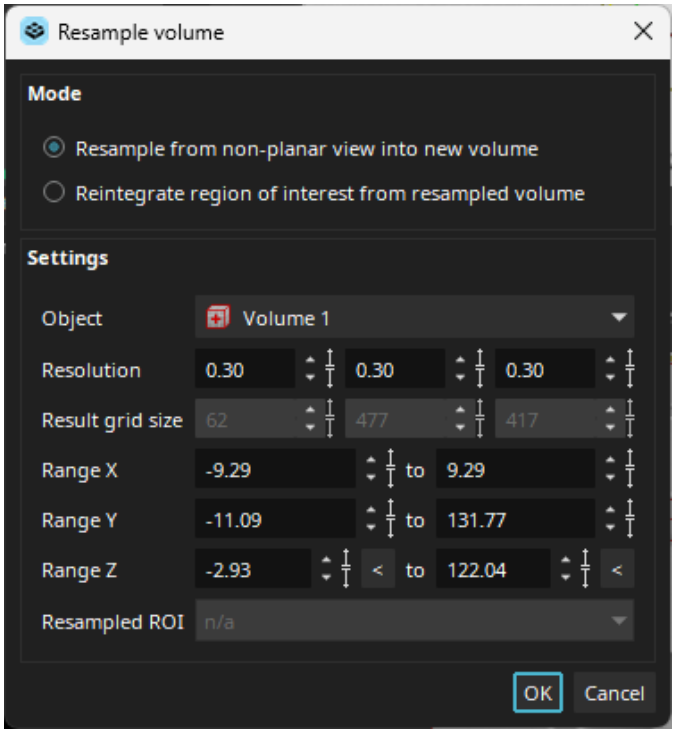


Figure 2-6: **Resample volume** dialog

The following modes are available:

- **Resample from non-planar view into new volume** mode: Use this mode to create a new volume that consists of the slices as calculated for the **Non-planar** view.

You can use all segmentation tools on the resampled volume.

- **Reintegrate region of interest from resampled volume** mode: Use this mode to transfer an ROI created on a resampled volume back to the original volume.

The following settings are available for the **Resample from non-planar view into new volume** mode:

Table 2-12: Controls for the **Resample from non-planar view into new volume** mode

Control	Description
Object drop-down list	Specifies the object to be resampled.
Resolution spin boxes	Specify the resolution in the x-, y-, and z-directions of the volume to be resampled.
Result grid size fields	Indicate the grid size resulting from the specified resolution and the specified range.
Range X, **Y**, **Z** spin boxes	Specify the range in the x-, y-, and z-directions of the volume to be resampled.

The following settings are available for the **Reintegrate region of interest from resampled volume** mode:

Table 2-13: Controls for the **Reintegrate region of interest from resampled volume** mode

Control	Description
Object drop-down list	Specifies the object to which the ROI is to be transferred.
Resampled ROI drop-down list	Specifies the ROI to be transferred.

Level/Window mode

Switches the settings dialog for the brightness (**Level**) and contrast (**Window**) values on and off. For details, see section *Level/Window mode* on page 170 in chapter 8 *Window Tab*.

2D background

The **2D background** menu item consists of the following submenu entries:

Table 2-14: Controls of the **2D background** menu

Control	Description
Default	Applies the default 2D background setting.
Predefined colors	Applies the selected color to the 2D background setting.
Select color	Opens the **Select Color** dialog, where you can specify the settings for the background.
Save as default	Saves the current 2D background setting as default.

Annotations

Allows you to modify the display of the currently visible annotations. See section *Annotations Drop-down List* on page 171 in chapter 8 *Window Tab*.

Text overlay

The **Text overlay** menu item consists of the following submenu entries:

Table 2-15: Controls of the **Text overlay** menu

Control	description
Default/<name of preset>	Allows you to select the default text overlay preset or a user-defined text overlay preset. To define a text overlay preset, select the **Configure...** menu item.
Configure...	Opens the **Configure text overlay** dialog, where you can define a text overlay preset. For details, see section *Text overlay editor* on page 172 in chapter 8 *Window Tab*.

Interpolation mode

When this option is set to **On**, the gray values between the voxels will be interpolated, thus providing “soft” transitions between neighboring voxels. When this option is set to **Off**, the individual voxels will be clearly discernible.

Scale bar

The **Scale bar** menu item consists of the following submenu entries:

Table 2-16: Controls of the **Scale bar** menu

Control	Description
Show scale bar	Toggles the display of the scale bar. In the 3D window, this option is enabled only if **Parallel** is selected in the **Projection mode** field of the **Camera** tool.

Control	Description
Configure...	Opens the **Preferences** dialog, where you can modify the properties for the coordinate system display. For details, see section *Colors & Styles Preferences* on page 68 in chapter 3 *File Tab*.

Tripod overlay

The **Tripod overlay** menu item consists of the following submenu entries:

Table 2-17: Controls of the **Tripod overlay** menu

Control	description
Show 2D tripod	Shows/hides the tripod in the 2D windows.
Configure...	Opens the **Preferences** dialog, where you can modify the properties for the coordinate system display. For details, see section *Colors & Styles Preferences* on page 68 in chapter 3 *File Tab*.

Reset transformation

Resets any transformations applied to the selected object. This control is enabled only if the padlock in the Scene Tree is open.

Copy to clipboard

Copies a screenshot of the active window to the clipboard so that you can paste it into another application.

Properties

Displays information on the object selected in the Scene Tree.

Except for views, you can also open the **Properties** dialog by double-clicking the object in the Scene Tree.

The type of properties dialog depends on the type of object selected:

- If the selected object is a *geometry element*, the **Geometry element properties** dialog will open. For details, see section *Geometry element properties Dialog* on page 256 in chapter 24 *Coordinate Measurement*.
- If the selected object is a *dimensioning feature*, the **CM results** dialog will open. For details, see section *CM results dialog* on page 264 in chapter 6 *Inspect Tab*.
- If the selected object is a *tolerance feature*, the **CM results** dialog will open. For details, see section *CM results dialog* on page 264 in chapter 6 *Inspect Tab*.

- If the selected object is an *analysis*, the **Properties** dialog of the pertaining analysis will open. For details, see the chapter on the corresponding analysis.
- If the selected object is a *volume object*, a *CAD model,* a *surface mesh*, or an *ROI*, the **Object properties** dialog will open. For details, see section *Object properties Dialog* on page 79 in chapter 5 *Edit Tab*.
- If the selected object is a *tetrahedral mesh*, the **Tetrahedral mesh** dialog will open. For details, see section *Tetrahedral mesh Dialog* on page 97 in chapter 5 *Edit Tab*.

Profile Window

In the profile window, you can see the data profile along the line defined by a distance instrument. See section *Instruments Icon Group* on page 113 in chapter 6 *Inspect Tab* for more information on these instruments.

The profile window can be accessed by selecting the **Quad profile** preset from the layout selection icon group on the **Window** tab.

The profile window is active only in conjunction with the **Distance**, the **Min./max. distance**, or the **Caliper** instrument.

Controls in the Profile Window

This section gives an overview of the controls available at the bottom of the profile window.

The following screenshot shows an example of a profile window:

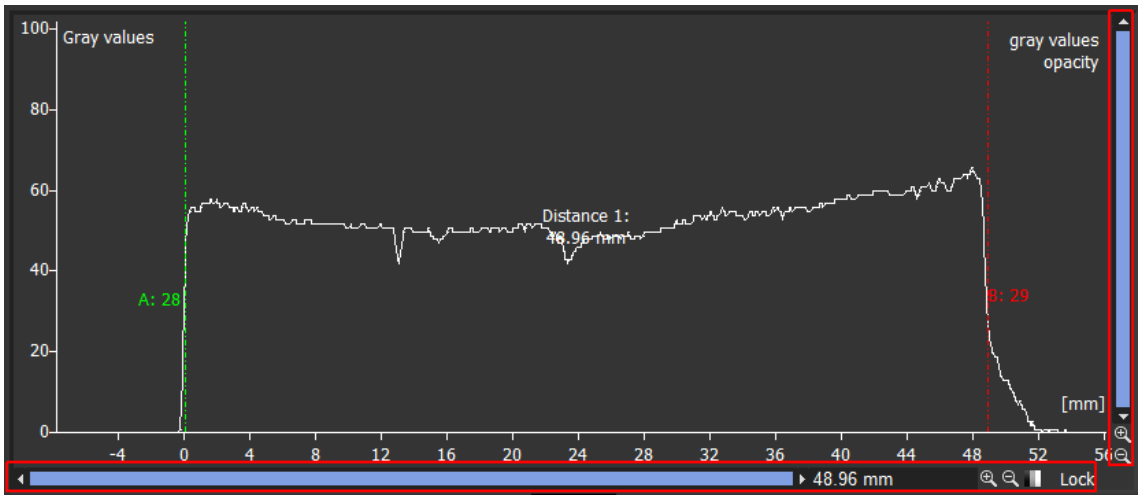


Figure 2-7: Example of a profile window

The position of the handles of the instrument is displayed by a vertical green dashed line (A) for the start point of the distance and a vertical red dashed line (B) for the end point of the distance. Lines A and B directly correspond to the start and end points of the respective distance instrument in the slice window, i.e., moving the points in the slice view moves the lines in the profile window and vice versa. You can click each line and drag it to an arbitrary position (exception: you cannot drag a line above or beyond the other line).

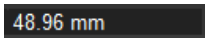
The number next to each line denotes the gray value or opacity at this point.

Between both lines, the measured distance is displayed together with the name of the respective instrument.

Zoom in/Zoom out

Zooms into or out on the x- or y-axis.

Distance Field



Shows the distance measured by the instrument. You can edit this value to create a customized scale bar.

Material mode

Toggles between the gray value profile and the opacity profile.

Changing the material mode deletes all intervals.

Lock

Prevents the histogram from updating when the current instrument is deselected in the Scene Tree.

Using the lock function deletes all intervals.

Context Menu of the Profile Window

You can access the context menu of a profile window by right-clicking anywhere in the profile window.

Reset zoom level

Resets the zoom of the profile window.

Create interval

Creates a new analysis interval.

On the right hand side of a selected analysis interval, statistical information on the voxels that lie within its borders is displayed:

Table 2-18: Statistical information in an analysis interval

Item	Description
min	Indicates the minimum gray or opacity value within the interval.
max	Indicates the maximum gray or opacity value within the interval.
mean	Indicates the mean gray or opacity value within the interval.
cor	Indicates the correlation of the gray or opacity values within the interval.
dev	Indicates the standard deviation of the gray or opacity values within the interval.
slope	Indicates the slope of the regression line.

The following controls are available for the analysis interval:

Table 2-19: Controls for the analysis interval

Control	Description
use LMB to click and drag interval	Moves the interval.
use LMB to click and drag interval border	Moves the interval border thus increasing or decreasing the interval width.
scroll MW	Uniformly resizes the interval.
hold down **Shift** key + scroll MW	Resizes the interval faster.
hold down **Ctrl** key + click inside several intervals	Displays the values of all selected intervals.

When toggling between gray value and opacity mode, all user-defined intervals will disappear.

Delete interval

Deletes the currently selected analysis interval.

Export as CSV...

Exports the values of the entire graph as a *.csv* (comma separated values) file.

Export range A->B as CSV…

Exports the values between the instrument handles, i.e., between start point A and end point B, as a *.csv* (comma separated values) file.

Export interval as CSV…

Exports the values in the selected interval as a *.csv* (comma separated values) file.

Copy to clipboard

Copies a screenshot of the active window to the clipboard so that you can paste it into another application.

Quick Access Toolbar

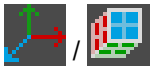
The **Quick Access Toolbar** is located on the left-hand side of the ribbon and provides access to the most frequently used tools, such as undo/redo, save and navigation cursor.

Search

If you are looking for a specific function in the application, you can click the search icon on the right-hand side of the ribbon. A text field in which you can enter a search term will appear. The corresponding function(s) will be listed along with their locations in the drop-down list below the text field. Clicking a search result will directly execute the corresponding function if it is applicable in the current context. Additional functions, such as unit selector, minimize ribbon, and customization options, are also accessible via the search function.

You can access the search function by pressing the **F1** key and select a search result from the list using the up and down arrow keys. To execute the selected result, press the **Enter** key.

Coordinate System Drop-down List



The coordinate system drop-down list, which is located on the right-hand side of the ribbon, allows you to quickly switch between the coordinate systems available in the project.

Units Drop-down List

The **Units** drop-down list, which is located on the right-hand side of the ribbon, allows you to change the units for length, area, volume, angle, time, storage, ratio values, etc.

The **Unit preferences** button at the bottom of the list opens the **Unit** section of the **Preferences** dialog (**File > Preferences > General > Unit**, see section *Unit Settings* on page 65 in chapter 3 *File Tab*).

Tool Dock

The tool docks are used for docking the various tool windows.

By default, there is one tool dock located on the right-hand side of the workspace, but you can open another tool dock on the left-hand side of the workspace by dragging and dropping tool windows there.

You can resize a tool dock by dragging the border between tool dock and workspace to the desired direction.

You can arrange the tool windows in an arbitrary order by dragging and dropping them at the desired position in the tool dock.

To have a tool displayed or hidden in the tool dock, activate or deactivate the corresponding entry in the **Tools** drop-down list on the **Window** tab in the ribbon.

The following icons are available in the title bars of the tool windows:

Table 2-20: Icons in the title bars of the tool windows

Icon	Description
	Tool window is expanded. Click this icon or the window title bar to collapse the tool window.
	Tool window is collapsed. Click this icon or the window title bar to expand the tool window.
	Tool window is “unpinned,” which means it will collapse if another tool window is opened in the same tool dock. Click this icon to “pin” the tool window.
	Tool window is “pinned,” which means it will stay open if another tool window is opened in the same tool dock. Click this icon to “unpin” the tool window.

Status Bar

The status bar is located at the bottom of the workspace and provides the following information:

- Notes on the operation of the currently selected function.
- In case of errors, a warning triangle may appear. Clicking the warning triangle will open a dialog that displays details on the error. To obtain assistance, send the information provided in the table to your local Hexagon support team. To do so, you can click the **Copy to clipboard** button and paste the table contents in an e-mail or click the **Send by e-mail** button to create a new e-mail with your default mail program and paste the table contents in this e-mail.
- Status of the snap mode.
- Graphical indicators showing the current state of CPU and memory usage. Hovering the mouse pointer over them provides more detailed information.

If the color of the graphical indicators changes to orange or red, make sure to reduce the system usage (e.g., close other applications or clear the undo queue).

File Tab

Introduction

The **File** tab of myVGL provides access to recently used projects as well as options for loading projects and saving images or image stacks. You can configure keyboard shortcuts and ribbon tabs.

Menu entries currently not available are disabled and displayed in gray.

Welcome Page

The **Welcome** page is the start page of myVGL. It allows you to quickly access the projects you have recently used.

Recently used projects

This section provides quick access to the most recently used projects, which are represented as thumbnails. The thumbnails also indicate the file path as well as the date and time you last accessed the project.

Table 3-1: Controls in the **Recently used projects** section

Control	Description
click a thumbnail	Opens the project.
	Removes the corresponding thumbnail from the list of recently opened projects.
Clear list	Clears the entire project list.

New

Select this option if you want to exit the current project and create an empty scene. You would typically proceed by opening a project or a scene.

In order to create an empty scene, you can also press the **Ctrl+N** keys.

Open

Opens a project saved in the following file formats:

- *.vgl*, the project file format of VGSTUDIO MAX and VGSTUDIO,
- *.vgarchive*, the compact archive format created by using the **Pack and Go** function of VGSTUDIO MAX and VGSTUDIO, or
- *.mvgl*, the project file format saved with VGMETROLOGY or exported from VGSTUDIO MAX or VGSTUDIO.

You can either open the file that includes the analyses, material settings, etc., or just load a single volume from the file.

When you open a *.vgl* file, make sure the project directory and object file(s) are available as well.

In Windows, the details of a project file can be displayed without opening the project. The project details include a preview of the scene as well as information about the project (e.g., volume dimensions, resolution, and referenced files).

Select a *.vgl*, *.mvgl*, or *.vgarchive* file in the Windows Explorer, right-click to open the context menu, and select **Preview**.

Some CT scanners may create rudimentary *.vgl* files that can be read by VGSTUDIO MAX or VGSTUDIO, but not by myVGL. Therefore, to ensure the readability of *.vgl* files through myVGL, the files have to be opened and saved once in VGSTUDIO MAX or VGSTUDIO.

In order to open the **Open project...** dialog, you can also press the **Ctrl+O** keys.

You can also open a *.vgl*, *.mvgl,* or *.vgarchive* file by dragging it from a file browser window into myVGL.

You cannot open *.vgi* files in myVGL.

If you open an existing project that was created with an evaluation license, captured images, such as bookmarks or snapshots, and reports need to be recreated manually to remove the evaluation label.

A sophisticated **Open** wizard will lead you through the open process (see section *Open Options* on page 37).

In the **Open** wizard, defaults will be set to the values you specified in the last import or, where applicable, to information automatically retrieved from the files (such as resolution, which is included in some file formats).

While opening the file, myVGL will scan the data file(s) (e.g., to provide you with default values and a preview). Copy the files to your local hard disk to speed up the process as well as to avoid problems caused by networking or CD/DVD drive lags.

When the wizard has gathered enough information on the volume to be imported, it will display the memory needed to load the data based on the specifications so far as well as the memory available on your system.

If the memory needed exceeds the memory available, the field will be highlighted in red. In this case, reduce the amount of data by mapping to a “smaller” data type, by applying a region of interest, or by setting a skip factor. These options will be available during the open process and are explained below (see section *Open Options* on page 37) in the sections for the respective dialogs. The memory values will be updated continuously.

If the memory available is larger than the memory needed, the field will be highlighted in green, and you can load and display the object. Note that performing analysis tasks requires additional memory.

Open Options

Depending on the file(s) you want to open and the options you have specified so far, the myVGL **Open** wizard will show you a series of dialogs. The dialogs and their options are explained below. Note that you will only see the dialogs relevant to your object.

☞ After a file is selected, you can see the contents of the file in the preview window on the left-hand side of the **Open** wizard.

The **Open** wizard provides the following options:

Table 3-2: Controls of the **Open** wizard

Control	Description
Open project button	Opens the complete file, including analyses, material settings, geometry elements, etc.
Import single volume button	Loads only a single volume from the file, either as a whole or as a specified region of interest (ROI). This option might have been disallowed by the creator of the *.vgl* file.

Load project Dialog

This dialog appears will appear when you click the **Open project** button in the **Open** wizard.

- **Resolution reduction (skip)** option

  Allows you to load a very large project into a low-capacity system by completely unloading the gray value information or by specifying the number of voxels to be skipped. A skip rate of 1 will only load every other voxel on each of the three axes so that the memory needed will be reduced by a factor of 8. A skip rate of 2 will skip two voxels on each of the three axes, load one voxel, then again skip two voxels, and so on. Moving the skip slider fully to the right will completely unload the gray value information or—if not possible—skip the maximum possible number of voxels. The currently selected resolution reduction state is displayed to the right of the skip slider. The memory needed to load the gray value information will be updated accordingly in the **Included information** section.

  Completely unloading the gray value information is possible only if the surface of the corresponding volume was determined using the advanced mode and the project was saved with

the volume data loaded. If a project contains more than one volume, this option will only affect the volumes with an advanced surface determination. For volumes without surface determination, only skipping is possible. For volumes with isosurface determination, neither skipping nor unloading is possible. Apart from that, the unload gray value information option might be disallowed by the creator of the *.vgl* file.

Unloading the gray value information or applying a skip factor will not affect the accuracy of the analysis results.

Using the skip slider for reloading volume data of a project that was saved with the volume data unloaded is not possible.

- **Included information** section

  Allows you to reduce the memory needed by unchecking items that are not to be loaded.

  Table 3-3: Controls in the **Included information** section

Control	Description
Load checkbox	Allows you to uncheck an item that is not to be loaded. Items referenced by a selected analysis can only be unchecked when the corresponding analysis is also unchecked.
Description	Lists all analyses, CAD models or surface meshes, and the gray value information of the project.
MB needed	Indicates the memory needed to load the corresponding item.
Status	Provides additional information on the status of the corresponding item, if available.

- **Total memory needed/Total memory available** fields

  When the wizard has gathered enough information on the project to be loaded, it will display the memory required for loading the data based on the specifications so far as well as the memory available on your system.

  If the memory available is smaller than the memory needed, the **Total memory needed** field will be highlighted in red. In this case, reduce the amount of data. The memory values will be updated continuously.

  If the memory available is larger than the memory needed, the **Total memory needed** field will be highlighted in green and you can load and display the project.

File Selection Dialog

This dialog and the dialogs described in the following sections will appear when you click the **Import single volume** button in the **Open** wizard. Select the volume you want to open from the list.

Load as Dialog

Several parameters determine how the data is to be loaded. For example, the type of data loaded can be different from the type of data stored on disk. The dialog will only show the parameters applicable to your data.

- **Resolution** section

  Table 3-4: Controls in the **Resolution** section

Control	Description
X, Y, Z fields	Specify the voxel size in the x-, y-, and z-direction.
Override resolution checkbox	Some data formats provide the information on the resolution automatically. In this case, the resolution input fields will be disabled and show the given numbers. When this option is checked, the **X,Y, Z** fields will be enabled and the given numbers can be modified.
Force isotropic resampling checkbox	If the data has significant differences (e.g., factor 3 or more) in voxel size for x, y, and z, the resulting pictures will show elongated steps in the corresponding direction. Check this option in order to improve the visual presentation. myVGL will then interpolate intermediate slices. Forcing isotropic resampling might change analysis results. Use this option only if you want to optimize the visual presentation of the data for creating screenshots, *.avi* files, etc.
No slice interpolation beyond [<length unit>] checkbox and field	You can import data sets with varying slice distances. If the object has been scanned with small slice distances in certain areas only, the resolution will have great differences. In this case, you may not want to resample the data set. Use this option to prevent slice distances larger than the number specified from being padded with interpolated slices.

- **Data raw range** section

  Table 3-5: controls in the **Data raw range** section

Control	Description
Automatic data range checkbox	Checking this option enables the **Lower/Upper boundary at** spin boxes.
Lower/Upper boundary at spin boxes	Specify the percentage of voxels that should lie outside the relevant gray value range. The lowest and highest gray values of the relevant gray value range are automatically calculated.

Control	Description
Lowest gray value/Highest gray value spin boxes	Specify the lowest and highest values of the relevant gray value range. All voxels will be loaded, but gray values below the lowest gray value and gray values above the highest gray value will be set according to the mapping type setting in the **Map to** field. For details, see Table 3-6: *Controls in the Load as section*. As an alternative, you can specify the relevant gray value range by clicking and dragging the red lines in the histogram (for details, see section *Import histogram Dialog* on page 44). Shifting a line to a new position will adapt the values in the **Lowest gray value/Highest gray value** fields and vice versa.

- **Load as** section

  Specifies the data type and the range the gray values are to be mapped to.

  Table 3-6: Controls in the **Load as** section

Control	Description
Map to field: data type drop-down list	Specifies the data type the data is to be mapped to on import, which will define the maximum number of different gray values for the object. The corresponding values will be automatically entered into the **Lowest gray value** and **Highest gray value** fields. Selecting a lower data type (i.e., a data type with a lower number of gray values) than the type in which the files are available may reduce accuracy, because the object will be described by a lower number of gray values. In contrast, it is not possible to increase accuracy by selecting a higher data type. For an overview of the available data types, see section *Data Types* on page 975 in chapter 50 *Appendix*. Loading floating data requires a lot of main memory. If your scanner has 32-bit float as output and your system is not capable of dealing with this amount of data, choose a data type mapping (e.g., 16-bit unsigned).

Control	Description
Map to field: mapping type drop-down list	Specifies how the values outside the gray value range are to be handled: • **Ramp** The gray values below the lower limit will be set to the value of the lower limit, and the gray values above the upper limit will be set to the value of the upper limit. The values inside the gray value range will be imported with their original gray values. This is the default setting. Shape: • **Inverse Ramp** The gray values below the lower limit will be set to the value of the lower limit, and the gray values above the upper limit will be set to the value of the upper limit. In addition, the gray values will be flipped (e.g., a gray value of 0 will be set to 255, whereas a gray value of 255 will be set to 0). Apply this option to obtain high gray values for material and low gray values for air if your data has low gray values for material and high gray values for air. Shape: • **Sawtooth** Both the gray values below the lower limit and the gray values above the upper limit will be set to the lower limit. The values inside the gray value range will be imported with their original gray values. Shape: • **Inverse Sawtooth** Both the gray values below the lower limit and the gray values above the upper limit will be set to the lower limit. In addition, the gray values will be flipped (e.g., a gray value of 0 will be set to 255, whereas a gray value of 255 will be set to 0). Apply this option to obtain high gray values for material and low gray values for air if your data has low gray values for material and high gray values for air. Shape:

Control	Description
Lowest gray value/Highest gray value spin boxes	Allow you to additionally specify the lower and upper limits of a gray value range to which the gray value range specified in the **Data raw range** section is to be mapped. This option can be used for applying an offset to the gray value range (for example, if you want to achieve the same gray value range for different scans). If this gray value range is smaller than the range specified in the **Data raw range** section, several consecutive gray values may be mapped to a single gray value, which will result in lower accuracy. If this gray value range is larger than the range specified in the **Data raw range** section, gaps may occur in the gray values.

- **Reset** button

  Discards any changes to the settings in the **Data raw range** and **Load as** sections and restores the original values.

ROI and Skip selection Dialog

Offers options to reduce the memory needed to load the object.

- **Region of interest** section

  The scanned object will usually be surrounded by air. Reducing (but not eliminating) the surrounding air by applying a region of interest (ROI) reduces the memory needed.

  Table 3-7: Controls in the **Region of interest** section

Control	Description
Min/Max X/Y/Z	Imports only the slices from **Min** to **Max** (in the x-, y-, and z-directions). You can also click the **Preview** button for defining the ROI graphically (see section *Import preview Dialog* on page 46).
Auto region of interest mode checkbox	Check this option to automatically define an ROI. This option considers the gray value mapping (specified via the **Load as** dialog or the import histogram) and therefore the resulting visual contrast to choose a ROI position and size. To immediately see the effect when you adapt the gray value mapping, it is recommended that you view the **Preview** and **Import histogram** windows in parallel. For an example, see Figure 3-1.

Control	Description

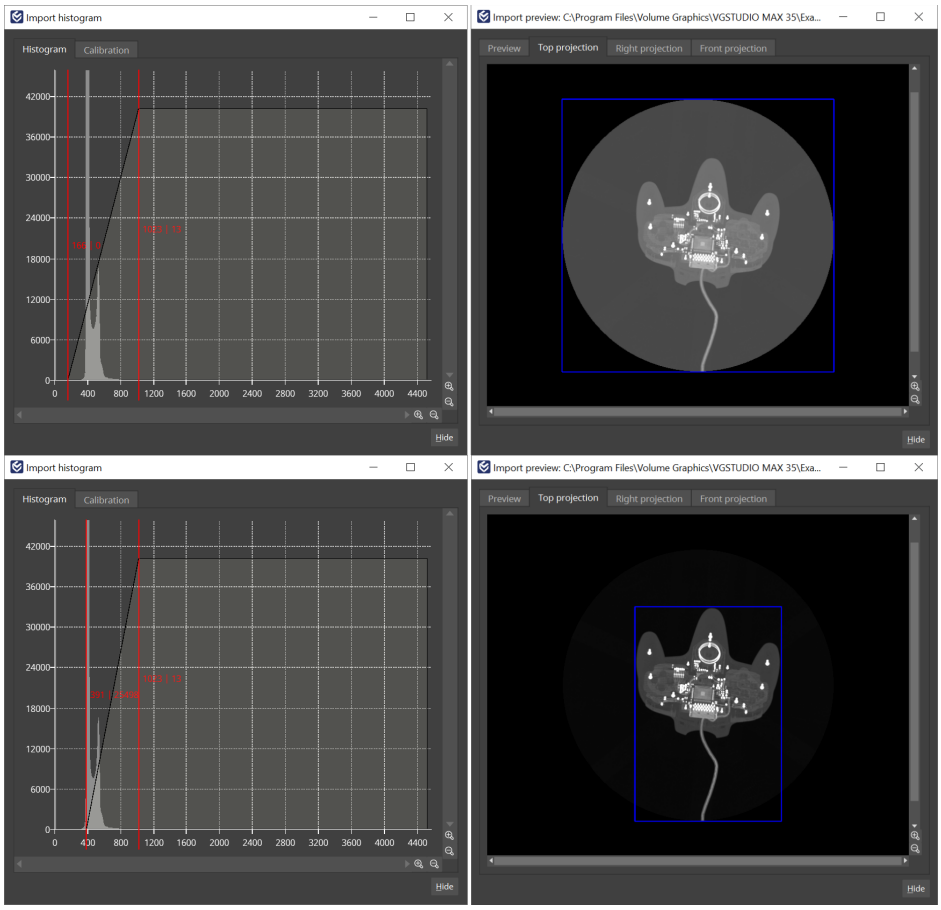


Figure 3-1: Example of the effect of the gray value mapping (left) on the size and position of the automatically created ROI (right, blue rectangle)

Using the **Auto region of interest mode** option requires high-contrast data. If the data set contains a lot of noise or artifacts, this option might not give optimal results. Always check the ROI in the preview before finishing import.

Make sure to include some surrounding air when you import the object. The borders of the ROI should not lie on the object surface or within the object. This would destroy the partial voxel effect and thus imprecise measurement results.

- **Skip** section

  When your object is surrounded by a large number of background (air) voxels, applying an ROI reduces the memory needed very efficiently without negatively affecting the quality. In other cases, you may have to apply the **Skip** option to be able to load a very large object into a low-capacity system.

  The **X**, **Y**, and **Z** spin boxes specify the number of voxels to be skipped in the respective direction. A skip rate of 0 applies no skipping. A skip rate of 1 for one axis will load only

every other slice so that the memory needed is reduced by half. A skip rate of 5 will skip five slices, load one slice, then again skip five slices, and so on.

Applying a skip factor will reduce the resolution of the voxel data and may lead to significantly less accurate analysis results.

Manipulation Dialog

Allows you to swap or mirror the axes in order to display the object in a preferred or real-world orientation.

- **Mirror axes** checkboxes

  Mirror the object along the chosen axis or axes (e.g., activating the checkbox for the x-axis will place the voxel with the highest value for x at the origin of the x-axis). You can select more than one axis for mirroring.
- **Swap axes** drop-down list

  Changes the axes in the coordinate system so that instead of xyz, the coordinates will be interpreted in the chosen sequence. For example, selecting xzy instead of xyz will keep the position on the x-axis but change the y-coordinate to z and vice versa. The result is a rotation by 90° around the x-axis followed by a mirroring along the y-axis.

Scanner manufacturer info Dialog

Shows the manufacturer information supported by the imported data (e.g., **Name, Address, Homepage, Device name, Acquisition software**, manufacturer logo).

Scan info Dialog

Shows the scan information supported by the imported data (e.g., **Tube voltage, Tube current, Scan time, Reconstruction time, Total process time, Reconstruction algorithm, Scan method, Geometry, Integration time, Filter, Number of projections, Date time, User**).

Component info Dialog

Shows the information on the scanned part supported by the imported data (e.g., **Description, Lot number, Serial number**).

Import histogram Dialog

Clicking the **Histogram** button in the **Load as** dialog opens the **Import histogram** dialog, which consists of the **Histogram** tab and the **Calibration** tab.

***Histogram** Tab*

The **Histogram** tab shows the gray values of the voxels of the CT data set on the x-axis and the number of voxels on the y-axis.

Two vertical red lines are initially positioned at the far left (at the lowest gray value) and the far right (at the highest gray value) of the diagram. Each red line is labeled with two numbers; the

first indicates the gray value at the current position of the line, and the second indicates the number of voxels in the CT data set that have this gray value.

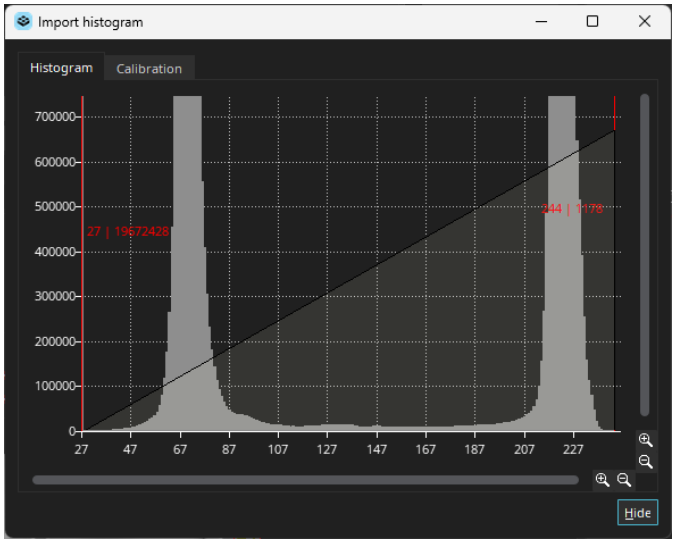


Figure 3-2: **Import histogram** dialog: **Histogram** tab

Table 3-8: Controls in the **Preview** tab

Control	Description
use LMB to click and drag vertical gray value lines in histogram	Moves the line to a new position, thus adapting the corresponding gray value entry in the **Data raw range** section of the **Load as** dialog and vice versa. You can also change the mapping type in the **Load as** dialog while the histogram is displayed. Use either of the methods to define an interval of significant gray values, i.e., the interval in which there is a high probability of gray values varying in accordance with a variation of the material. A typical histogram has one peak for each material in the data set plus one peak for the air. Make sure not to cut out any of these peaks. Always keep the air peak, since the software needs the surrounding air for the interpretation of the partial voxel effect which is the basis for analysis results.
Zoom in/out	Zooms the corresponding axis in/out.

Calibration *Tab*

The **Calibration** tab allows you to perform a gray value calibration within the import process by dynamically selecting material and background gray values and assigning them to destination gray values. The main area of the **Calibration** tab shows a single slice of the object.

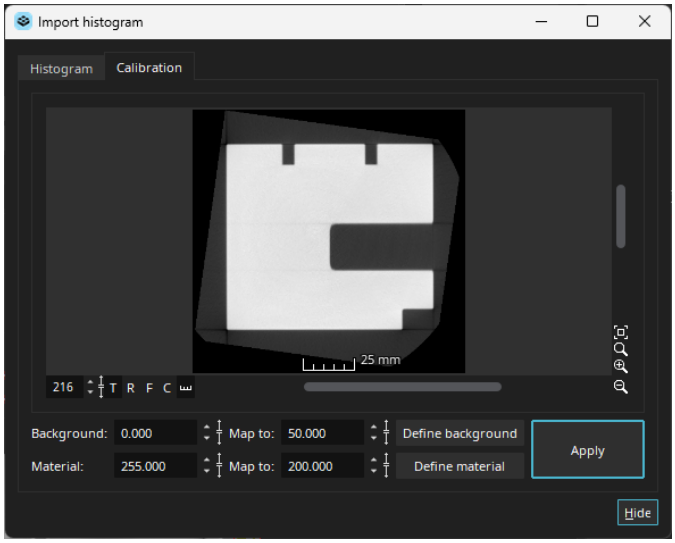


Figure 3-3: **Import histogram** dialog: **Calibration** tab

Table 3-9: Controls in the **Calibration** tab

Control	Description
slice position spin box	Specifies the slice number.
T/R/F buttons	Select the axis along which to slice: • **T** = top view • **R** = right view • **F** = front view
C button	Automatically enhances the contrast. By default, the preview will be rendered taking into account the data range settings. Activating auto contrast will analyze the data set and apply a ramp mapping to the data range covered by the voxels in the current slice.
Define background/Define material buttons	Allow you to draw a rectangle with the mouse button in the preview window. The area inside the rectangle is considered for background or material selection, respectively.
Apply button	Applies the acquired values to the data range mapping of the **Load as** dialog.
Background/Material fields	Display the mean of the gray values selected by the rectangle.
Map to spin boxes	Allow you to specify the target gray values.

Import preview Dialog

Clicking the **Preview** button, which is available in a number of import dialogs, opens the **Import preview** dialog.

This dialog provides 2D previews and projections of your object so you can:

- Control the parameters specified so far

  If you can only see black and white stripes or a grainy image, check the data type and/or size specified earlier.

- Define a region of interest (ROI)

  Use the left mouse button to modify the ROI settings by adjusting the blue frame in the slice preview or one of the projections. You can also modify the settings in the **ROI and Skip selection** dialog (see section *ROI and Skip selection Dialog* on page 42).

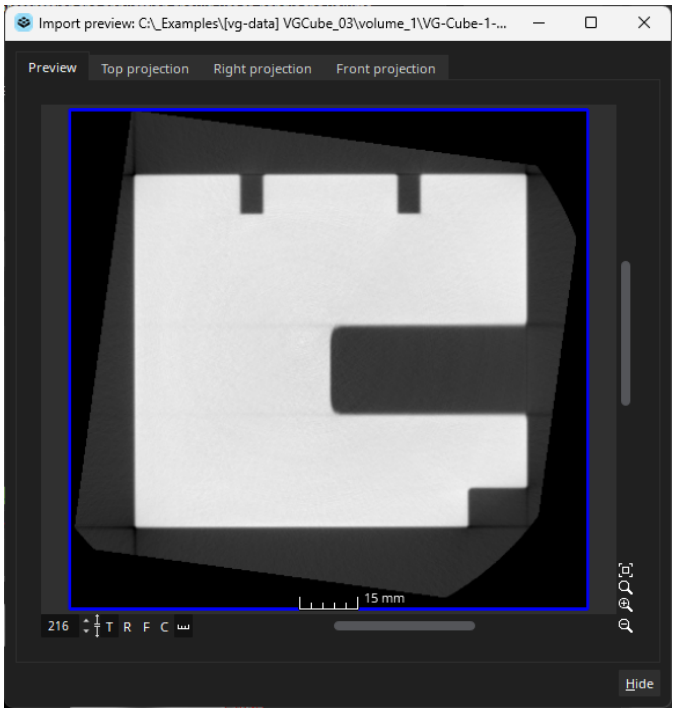


Figure 3-4: **Import Preview** dialog: **Preview** tab

The preview does not take into account the position of the slices. This should be considered if you are importing data sets with varying slice distances. Varying slice distances are supported by BIR, DICOM, DICONDE, Toshiba, and YXLON image stacks as well as TIFF images with slice position.

The following tabs are available:

- **Preview** tab

  The main area of the **Preview** tab shows a single slice of your object. The following controls are available on this tab:

  Table 3-10: Controls in the **Preview** tab

Control	Description
slice position spin box	Specifies the slice number.

Control	Description
T/R/F buttons	Select the axis along which to slice: • **T** = top view • **R** = right view • **F** = front view
C button	Automatically enhances the contrast. By default, the preview will be rendered, taking into account the data range settings. Activating auto contrast will analyze the data set and apply a ramp mapping to the data range covered by the voxels in the current slice.
Zoom in/out	Zooms the corresponding axis in/out.
Reset zoom	Resets the zoom of the histogram.

- **Top projection** tab

  Click this tab for a projection along the z-axis. All xy-planes of your object will be projected into one 2D view.
- **Right projection** tab

  Click this tab for a projection along the x-axis. All yz-planes of your object will be projected into one 2D view.
- **Front projection** tab

  Click this tab for a projection along the y-axis. All xz-planes of your object will be projected into one 2D view.

Save image(s)

Captures the current workspace area into an image.

- **Preview** section

  Shows a preview of the image according to the current settings.
- **Views** section

  Allows you to choose whether you want to save screenshots of the view shown in the current workspace layout, in the currently selected window or in predefined windows.
  - **Current workspace layout** radio button

    When this option is selected, the saved image will be an exact representation of the current workspace layout, including all visible windows with their current visualization state.
  - **Currently active workspace window** radio button

    When this option is selected, only the window that is currently selected in the workspace will be taken into account for the final image.
  - **Defined windows** radio button

When this option is selected, the list of currently available windows will be enabled. To select the window to be taken into account for the final image, check the checkbox of the corresponding entry.

When opening the dialog again, the checked option will be remembered and the window(s) to be taken into account for the final image will be selected accordingly.

- **Custom image size** section

  Allows you to specify an image size different from the default size.

  Table 3-11: Controls in the **Custom image size** section

Control	Description
Width/Height spin boxes	Allow you to change the size of the image in pixels.
/ button	• Button is pressed : The image is scaled uniformly, i.e., the width/height ratio is maintained. • Button is released : The image width and height can be changed independently of each other.
R button	Resets the width/height values.

- **Overlays** section

  Allows you to enable/disable graphical overlays like analysis results, geometry elements and measurements for the image to be saved.

- **DPI/Font size** section

  Use the **Scale** spin box to control the size of handles, fonts and other display-relative elements. You can use it for saving images at higher resolution and still maintain the proportions of these elements. This will affect all overlays (e.g., the text overlay, the tripod, the surface, the ROI borders).

- **Slice position indicator** section

  When this option is checked, an additional 2D or 3D image is displayed either within the selected 2D view or next to it.

This function is available only for 2D and if exactly one 2D view is selected in the **Views** section.

Table 3-12: Controls in the **Slice position indicator** section

Control	Description
View drop-down list	Selects the additional 2D or 3D image.
Side by Side checkbox	Displays the selected 2D view and the additional image of the same size next to each other.
Picture in Picture checkbox	Displays the additional image within the selected 2D view. • **Position** checkboxes: Specify the position of the additional image within the selected view. • **Size** slider: Changes the size of the additional image (10 %…100 % of the slice image size).

Control	Description
As seen in 3D/2D view checkbox	When this option is checked, the additional image has the same aspect ratio and displays all overlays, analyses, annotations, etc. as seen in the original view.

- **Decorations** section

  Provides options for displaying additional information within the image.

  Table 3-13: Controls in the **Decorations** section

Control	Description
Show headline option	When you check this option, the text entered in the text field will appear above the image.
Show logo in headline option	Allows you to define a custom logo that will appear above the text specified in the headline text field if the **Show headline** option is checked.
Show legend option	When you check this option, the current slice position, the current coordinate system and the window type will be added below the image for the respective window.

- **Reset to default** button

  Clicking this button will reset all fields to their default values, except for the **Views** section.
- **Save...** button

  Opens a file browser where you can select a path and file name for saving the image(s). For the supported file formats, see section *File Formats* on page 975 in chapter 50 *Appendix*.
- **Cancel** button

  Discards all changes and closes the dialog.

In order to directly open the file browser and save the image(s) with the last saved settings, you can press the **Ctrl+Shift+G** keyboard shortcut.

Save movie/image stack

Saves the slices of one of the 2D views to a movie or image stack.

Creating movies is only possible on Microsoft Windows systems.

- **Preview** section

  The **Preview** section shows the slices according to the current settings.

If you do not want the movie/image stack to contain the complete data set, use the slice position spin box at the bottom left to navigate to the desired slice. The background color of the slice position spin box will change to red if the value lies outside the range specified in the **Slice range** section. Clicking the **s** or **e** button will define the **Start** or **End** slice, respectively, of the **Slice range** section.

- **2D view** section

  Allows you to select the 2D view for specifying the orientation. The images will be created parallel to this view.

- **Viewport** section

  Select the **As seen in 2D view** option to create a movie/image stack according to the display in the selected 2D view if you do not want the movie/image stack to show the complete object(s).

- **Display mode** section

  Allows you to specify the coloring of the resulting image (for details on display modes, see section *Display mode Drop-down List* on page 168 in chapter 8 *Window Tab*).

- **Image size** section

  Allows you to specify an image size different from the default size.

  Table 3-14: Controls in the **Image size** section

Control	Description
Width/Height spin boxes	Allow you to change the size of the images in pixels. If you want to save a movie in *.wmv* format, the width and height values have to be a multiple of four.
/ button	• Button is pressed : the image is scaled uniformly, i.e., the width/height ratio is maintained. • Button is released : the image width and height can be changed independently of each other.

- **Overlays** section

  Allows you to enable and disable graphical overlays (e.g., analysis results, geometry elements, and measurement) for the image stack or movie to be saved.

- **DPI/Font size** section

  Use the **Scale** spin box to control the size of handles, fonts, and other display-relative elements. You can use it for saving images at a higher resolution and still maintain the proportions of these elements. This will affect all overlays (e.g., the text overlay, the tripod, the surface, and the ROI borders).

- **Slice position indicator** section

  When this option is checked, an additional 2D or 3D image will be displayed either within the selected 2D view or next to it.

  Table 3-15: Controls in the **Slice position indicator** section

Control	Description
View drop-down list	Selects the additional 2D or 3D image.

Control	Description
Side by Side checkbox	Displays the selected 2D view and the additional image of the same size next to each other.
Picture in Picture checkbox	Displays the additional image within the selected 2D view. • **Position** checkboxes: Specify the position of the additional image within the selected 2D view. • **Size** slider: Changes the size of the additional image (0%…100% of the slice image size).
As seen in 3D/2D view checkbox	When this option is checked, the additional image will have the same aspect ratio and display all overlays, analyses, annotations, etc., as they are seen in the original view.

- **Boundary** option

  Allows you to apply an additional offset to the original image. It will not change the image size; instead it will allow you to zoom into or out of the current viewport.

- **Stack settings** section

  The stack settings apply to the complete data set in the current orientation.

  Table 3-16: Controls in the **Stack settings** section

Control	Description
Unit option	Specifies the unit for the **Dist** field.
No. of slices field	Specifies the number of slices for the movie or image stack. Modifying the number of slices will recalculate the slice distance and vice versa: distance x (number of slices – 1) = height of complete data set.
Dist field	Specifies the distance between the slices for the movie or image stack. Modifying the slice distance will recalculate the number of slices and vice versa: distance x (number of slices – 1) = height of complete data set. The unit for the distance can be defined in the **Unit** field.
POI wait field	Specifies the time (in seconds) during which the slice with the label of the **Indicator** instrument or analysis annotation selected in the Scene Tree will be shown in the movie. Make sure the **Indicator visible in all slices** or **Annotation visible in all slices** option is not checked in the preferences for the instrument or analysis annotation, respectively (see section *Coordinate measurement Settings* on page 71 and section *Analysis annotations Settings* on page 68 in chapter 3 *File Tab*).

- **Slice range** section

The slice range parameters specify the part of the slices to be exported. The slices will be resampled by applying the stack settings so that one of the slices will be positioned at the start value. The first slice to be exported will be defined by the **Start** value, and the second slice will be at position (start value + slice distance). The **End** value will specify the last slice.

You can change the direction of the movie/image stack by swapping the **Start** and **End** values.

You can also set the **Start** and **End** values by navigating to the desired position in the **Preview** and clicking the **s** button for **Start** or the **e** button for **End**.

Modifying the slice range will change the number of slices but not the slice distance. The **No. of slices** and **Dist** parameters specify how fine the data should be sampled within the given slice range.

If a rotation view is selected in the **2D view** field, you can define the angle range instead of the slice range.

- **Export queue** section

  Displays a list of the queued movies and image stacks with their respective paths and file names. Entries that have already been processed are marked with a green checkmark.

- **Reset to default** button

  Clicking this button will reset all fields to their default values except for the **2D view** field. The 2D view will be specified by the view currently selected in the 2D window. Entries in the **Export queue** section will remain unchanged.

- **Save...** button

  Opens the **Save image** dialog, where you can specify a path and file name for saving the movie or image stack. For the supported file formats, see section *File Formats* on page 975 in chapter 50 *Appendix*.

- **Queue...** button

  Opens the **Save image** dialog, where you can specify the path and file name for the movie or image stack to be added to the export queue for later saving.

- **Cancel** button

  Discards all changes and closes the dialog.

- **Process** button

  Saves all movies or image stacks listed in the export queue one after the other.

- **Remove** button

  Removes the selected and not yet saved movies or image stacks from the export queue.

Customize

With the functions provided in this section, you can freely customize all tabs of the ribbon, including the **Home** tab. It is also possible to change existing shortcuts or add new shortcuts. Customized tabs, shortcut settings, and the configuration of the application tools can be exported as re-usable user interface preset.

Configure shortcuts

Opens the **Edit shortcuts** dialog where you can manually input your own shortcuts for frequently used actions.

Table 3-17: Controls of the **Edit shortcuts** dialog

Control	Description
filter input field	Allows you to enter a search term to show only actions related to your search term.
table area	Lists the columns described in Table 3-18.
Restore defaults button	Resets the default shortcuts for all actions.
Close button	Saves modifications and closes the dialog.

Table 3-18: Columns in the table area of the **Edit shortcuts** dialog

Column	Description
Ribbon tab	Indicates the tabs in which the actions listed in the **Action name** column are located. For each action listed in the **Action name** column, lists the tab where it is located.
Action name	Lists all available actions. If a search term was entered in the filter input field, only related actions will be listed.
Shortcut	Displays the current shortcuts for the actions listed in the **Action name** column. Double-clicking a shortcut enables an input field where you can enter a new shortcut. If no shortcut exists for the selected action yet, you can enable the input field and define a shortcut by clicking next to an action in the **Shortcut** column.
Alternative shortcut	Allows you to add an alternative shortcut to the selected action.

Configure tabs

Opens the **Customization** dialog, where you can customize the ribbon layout.

You can also open the **Customization** dialog by right-clicking anywhere in the ribbon and selecting **Configure tabs** from the context menu.

- **Settings** section
  These settings persist across application restarts.

Table 3-19: Controls of the **Settings** section

Control	Description
Show quick access above ribbon/**Show quick access below ribbon** radio buttons	Set the location of the quick access buttons. Note that the quick access toolbar will not be visible when it is located below the ribbon and the **File** tab is selected.
Minimize ribbon when not in use checkbox	If the ribbon bar is minimized, it will only show up when a tab name is clicked, leaving more room for the workspace. Tip: You can always minimize or maximize the ribbon by right-clicking the tabs at the top of the ribbon and selecting **Minimize ribbon** from the context menu. Alternatively, double-clicking the tabs will also minimize or maximize the ribbon.

- **Layout** section

  Existing tabs and their groups can be hidden, renamed, or rearranged. New tabs and groups can also be created. Layout changes persist across application restarts and can also be exported and shared.

  Table 3-20: Controls of the **Layout** section

Control	Description
Available elements column	• **Custom tab**: Allows you to create a new tab under the **Standard tabs** entry in the **Current layout** column. To add a new tab, highlight the standard tab below which you want it added and click the right arrow. There is a minimum of one group required under a custom tab. • **Custom group**: Allows you to create a new group under the **Home tabs** or the **Standard tabs** entry in the **Current layout** column. To add a new group, highlight the group below which you want it added and click the right arrow. • **Home tabs**: Lists the groups and actions of the **Home** tabs that can be added to the **Current layout** column. • **Standard tabs**: Lists the groups and actions of the standard tabs that can be added to the **Current layout** column. • **File menu**: Lists the groups and actions of the **File** menu that can be added to the **Current layout** column. • **Additional functions**: Lists additional actions that can be added to the **Current layout** column. Note that actions can only be added to custom groups and the quick access toolbar.

Control	Description
Current layout column	Displays the elements (tabs, groups, actions) currently available in the ribbon. Click the checkbox in front of an entry to show or hide the corresponding tab or group. You can remove custom tabs or groups as well as referenced groups or actions by highlighting and clicking the left arrow. Note that built-in tabs and groups cannot be removed.
up/down arrows	Allow you to rearrange the standard tabs, the groups of the **Home** tabs and the standard tabs, and the items in the quick access toolbar.
Display size drop-down list	Enabled for actions of a custom tab: • **Prefer large**: If possible, a large icon with a label will be used for the highlighted action. • **Prefer small**: If possible, a small icon with a label will be used for the highlighted action. • **Prefer small without text**: A small icon without a label will be used for the highlighted action.
Set name button	Allows you to rename the highlighted tab or group.
Reset name button	Resets the name of the highlighted tab or group to its default.
Reset layout button	Resets any customization.
Accept button	Accepts the customization and closes the dialog.
Cancel button	Allows you to discard the changes and close the dialog.

Export preset

Exports a preset with the settings of the graphical user interface (GUI) of myVGL, which can later be imported via **File > Customize > Import preset**. Selecting this option opens the **Export user interface preset…** dialog, where you can specify the path and name for saving the preset file (*.preset*).

Import preset

Imports a preset for the settings of the graphical user interface (GUI) of myVGL previously stored via **File > Customize > Export preset**. Selecting this option opens the **Import user interface preset…** dialog, where you can select the path and name of the preset file (*.preset*).

Preferences

Allows you to set general application parameters and options according to your preferences. These settings apply to myVGL in general and not only to a specific project.

You can save these settings as presets in order to load them at a later time. Presets can also be deleted, exported, and imported (for details, see section *Customize* on page 53).

Preset selection Section

Table 3-21: Controls in the **Preset selection** section

Icon	Item	Description
	drop-down list	Specifies the preset to be applied, to be edited, or to be taken as a basis for a new preset. The following icons are used: • default preset (if available) • customized preset • appears next to the icon of a preset that has been modified but not yet saved
	Save preset	Saves the selected preset under the specified name.
	Remove preset	Removes the selected preset from the preset drop-down list.
	Import preset	Imports a preset from the specified location.
	Export preset	Exports the selected preset to the specified location.

General Preferences

General Settings

Table 3-22: Options for the General settings

Option	Description
Undo section	• **Max. memory**: Specifies how much memory can be used by the **Undo** function.

Option	Description
Application user interface section	• **Viewport icon size:** Choose a scale factor from the drop-down list to use larger icons for the controls at the bottom and to the right of the 2D and 3D windows. • **Dark theme**: Switches the style of the user interface to the dark theme. • **Light theme**: Switches the style of the user interface to the light theme. • **Show once message box settings**: Click the **Clear** button if once message boxes should be displayed again after you have checked the **Never show this dialog again** checkbox in the message box. • **Number of recent files**: Specifies the number of recently used files shown on the **Welcome** page.
Notifications section	Supported for Windows and Linux operating systems: • **Never**: Notifications will not be shown. • **When application is running in the background**: Notifications about processes that have already finished will only be shown if the application is running in the background. • **Always**: Notifications will always be shown. • **Notify about background processing of the data**: When this option is checked, notifications about processes currently running in the background will be shown. • **Notification duration [s]**: Specifies the period of time a notification is to be displayed.

Window Settings

- **2D windows** section

  Table 3-23: Options for the 2D window settings

Option	Description
Medical mode option	When this option is checked, the slices in the 2D window that show the xy-plane are viewed from the bottom instead from the top. This only becomes effective if the window is in one of the standard layouts.
Level/Window mode option	When this option is checked, the **Level/Window mode** button will be available in the slice views.

Option	Description
Background color field	Double-clicking the field opens the **Select Color** dialog, where you can set the default background color of the 2D views. Clicking the **Reset** button resets the color to the default color of the selected theme (light or dark theme).
Fixed navigation plane size option	When this option is checked, the size of the navigation planes will be based on the largest edge of the bounding box. When this option is unchecked, the size of the navigation planes will be defined by the size of the corresponding 2D view.
Display duration spin box	Defines how long the navigation planes are displayed (**Automatic** mode) or highlighted (**Permanent** mode) after a slice view is changed.
Reverse mouse wheel zoom option	Reverses the mouse wheel zoom for the 2D windows. When this option is checked, scrolling the mouse wheel up will zoom in, and scrolling the mouse wheel down will zoom out.
Mouse wheel drop-down list	• **Scroll slices**: When this option is selected, scrolling the mouse wheel in a 2D window scrolls through the slices, and scrolling the mouse wheel while the **Ctrl** key is pressed will zoom in or out. • **Zoom view**: When this option is selected, scrolling the mouse wheel in a 2D window will zoom in or out, and scrolling the mouse wheel while the **Ctrl** key is pressed will scroll through the slices.

- **3D window** section

Table 3-24: Options for the 3D window settings

Option	Description
Background blend mode drop-down list	• **Flat**: Fills the background with the color specified in the **Background color** field. • **Vertical gradient**/**Horizontal gradient**/**Radial gradient**: Applies a vertical, horizontal, or radial color gradient—starting with the color specified in the **Background color** field—to the color specified in the **Background blend color** field.
Background color field	Double-clicking the field opens the **Select Color** dialog, where you can specify the color for the flat background or the first color for the gradient.
Background blend color field	Double-clicking the field opens the **Select Color** dialog, where you can specify the second color for the gradient.

Option	Description
	Swaps the background and the blend color.
Enable ambient occlusion checkbox	Available on Windows and Linux operating systems only. When this option is activated, depth perception in the 3D view will be enhanced by adding shadows to areas in which nearby objects or surfaces would occlude ambient lighting. The setting of this option determines the default behavior for newly created projects. Note that it also determines the default behavior when you open projects that were saved with software versions that did not yet have this option available. On some GPUs, the rendering performance might be improved when this option is deactivated.
Show bounding box in offscreen rendering drop-down list	Defines the visibility of the bounding box when the 3D view is written to a file or copied to the clipboard. • **Off**: Never shows the bounding box. • **Follow**: The visibility of the bounding box depends on its visibility in the 3D view.
Show origin tripod drop-down list	Specifies the location and visibility of the origin tripod: • **Show at rotation center**: Displays the origin tripod at the rotation center of the selected object. • **Show at origin of current coordinate system**: Displays the origin tripod at the origin of the currently selected coordinate system. • **Hide**: Hides the origin tripod.
Use dynamic rotation center drop-down list	Available for **Default** navigation mode. • **Always**: Uses the position you click at as the rotation center. • **Hotkey (Shift)**: Uses the position you click at while holding down the **Shift** key as the rotation center. • **Never**: Uses the center of the bounding box of the selected objects as the rotation center.
Rotate around navigation cursor option	Available for **Default** navigation mode. When this option is checked and the **Navigation Cursor** is activated, the position of the **Navigation Cursor** will be used as rotation center. This setting will not be effective if a dynamic rotation center is used.

Option	Description
Navigation mode drop-down list	Specifies the mode for viewing an object in the 3D window: • **Default**: When this option is selected, the **Rotate** and **Move** buttons will be enabled at the bottom of the 3D window as well as the corresponding icons on the **Edit** tab in the ribbon. If the object is not locked in the scene (padlock in front of the object is open), interaction with the mouse will change the orientation and position of the object in the scene. If the object is locked, interaction with the mouse will change the rotation and location of the camera instead. • **Spherical**: This mode is an intuitive approach of viewing an object by zooming in and out, rotating, and moving it. This does not transform the object in the scene (i.e., this mode is effective only if the object is locked in the scene), but changes the position of the camera. Hold down **Shift** and click on the surface of the object to manually set the rotation center. Use LMB to click and drag the object in order to rotate it in all degrees of freedom around a sphere as the center of rotation. Use MMB to click and drag the object in order to move it in the desired direction.
Rotation speed slider	Specifies the rotation speed of the camera in the 3D window.
Adjust rotation center depth in long shot option	Available for **Spherical** navigation mode. When this option is checked, the rotation center of a long, narrow object will be placed approximately in the middle of the bounding box when it is viewed from a distance (long shot). This is helpful, for example, when you rotate the camera around the object while changing between detailed view (close-up) and overall view (long shot) to ensure that the object is rotated at the point of interest (close-up) or as a whole (long shot).
Long shot distance slider	Available for **Spherical** navigation mode. Specifies the distance between camera and object for a view to be considered a long shot. Moving the slider to the left decreases the distance, while moving it to the right increases it.

Option	Description
Show camera sphere option	Available for **Spherical** navigation mode. When this option is checked, the sphere that indicates the rotation center will be displayed in the 3D window while the camera is being rotated or moved.
Bounding box mode drop-down list	• **Automatic**: The bounding box is displayed only temporarily after the mouse pointer is moved into or within the 3D view. • **Permanent**: The bounding box is always displayed.
Display duration spin box	Specifies how long the bounding box and the rotation center are displayed in **Automatic** mode after the mouse pointer is moved.
Reverse mouse wheel zoom option	Reverses the mouse wheel zoom for the 3D window. When this option is checked, scrolling the mouse wheel up will zoom in, and scrolling the mouse wheel down will zoom out.

Volume import Settings

- **Rendering settings for imported data**

  Table 3-25: Options for the rendering settings for imported data

Option	Description
Default preset drop-down list	Specifies the rendering preset to be applied to newly imported volume data sets. This option overrides the **Default 3D renderer** setting. You can change the rendering presets for each volume object in the **Rendering** tool independently of this default setting at any time.
Default 3D renderer drop-down list	Specifies the rendering algorithm to be applied to newly imported volume data sets. You can change the 3D renderer for each volume object in the **Rendering** tool independently of this default setting at any time.
Shadow on side light source checkbox	When this option is checked, a shadow will be enabled for the lateral light source **Light source 2** by default. This option will take effect only after a new scene has been created. You can switch off the shadow for **Light source 2** in the **Light** tool at any time.

CAD and surface mesh Settings

Specifies the render settings for CAD and surface mesh objects.

- **Defaults for new CAD objects** section

  Table 3-26: Options for the rendering settings for new CAD objects

Option	Description
Default rendering preset drop-down list	Specifies the rendering preset to be applied to newly imported CAD data sets. You can change the rendering presets for each CAD object in the **Rendering** tool independently of this default setting at any time.
Enable hue color cycling for new objects checkbox	When this option is checked, a color automatically picked by shifting the hue color cycle will be assigned to new objects. Objects of the same type will share the same hue color cycle, and similar colors of the existing objects will be avoided.

- **Defaults for new surface meshes** section

  Table 3-27: Options for the rendering settings for new surface mesh objects

Option	Description
Default rendering preset drop-down list	Specifies the rendering preset to be applied to newly imported surface meshes. You can change the rendering presets for each mesh object in the **Rendering** tool independently of this default setting at any time.
Enable hue color cycling for new objects checkbox	When this option is checked, a color automatically picked by shifting the hue color cycle will be assigned to new objects. Objects of the same type will share the same hue color cycle, and similar colors of the existing objects will be avoided.

Language Settings

Specifies the language to be used in the user interface.

Changes will not take effect until the next start of myVGL.

Result data export Settings

Table 3-28: Options for the Result data export settings

Option	Description
Style for CSV export section	Allows you to specify the number format and table column separator when you use the **Export as CSV...** command. The number format is also applicable to the **Copy to clipboard** function. • **Use system settings**: When this option is checked, the **List separator**, **Decimal symbol**, and **Digit grouping symbol** settings of the operating system will be used for exporting CSV files. When this option is unchecked, you can manually specify these settings using the drop-down lists below. • **Use digit grouping symbol**: When this option is checked, the exported numbers will include a digit grouping symbol. • **List separator**: Specifies the column separator (semicolon (“**;**”), comma (“**,**”), or **Tab**). • **Decimal symbol**: Specifies the decimal symbol (point (“**.**”) or comma (“**,**”)). • **Digit grouping symbol**: Specifies the digit grouping symbol (point (“**.**”) or comma (“**,**”)). • **Example**: Provides a preview of the specified format.
Result data export section	• **Show unit in tables if ambiguous**: When this option is checked, units will be displayed in table cells if they cannot be identified unambiguously.
Export via Excel section	• **Template file**: Indicates the path and file name of the template file currently used for VGRF-based exports. If the entry is truncated because of its length, hover the mouse pointer over the field to get a tooltip with the complete information. By default, the template file *VG_Report_Format.xlsx* is located in the **Reporting** subdirectory of the application directory of myVGL. If you have customized the template and saved it to a different location, click the **Browse** button to specify the new path. • **Enable Excel Add-In**: Click the **Enable** button once for each Windows user to enable the Excel add-in for VGRF-based exports.

Using the Excel add-in for VGRF-based exports is currently only supported for Windows.

Excel templates used for VGRF-based exports need to be saved in the **Normal** or in the **Page Break Preview** view (in Excel: **View > Normal/Page Break Preview**).

Snap frame Settings

Specify the default settings for the snap mode.

Table 3-29: Options for the snap frame settings

Option	Description
Default mode drop-down list	Defines the default snap mode. For details on the snap modes, see section *Snap mode Drop-down List* on page 122 in chapter 6 *Inspect Tab*.
Area size spin box	Specifies the size of the snap frame; the unit depends on the mode selected in the **Area size mode** field.
Area size mode drop-down list	Defines the mode for specifying the size of the snap frame: • **Display relative**: The size (in pixels) of the snap frame is relative to the screen, i.e., the size remains the same when you zoom in or out. • **Scene relative**: The size (in physical units, e.g., mm) of the snap frame is relative to the scene, i.e., the size changes when you zoom in or out.

Unit Settings

- **Basic** settings

  Specify the number format for displaying the length, area, volume, angle, time, and storage values.
- **Scientific** settings

  Specify the number format for displaying ratio values and normalized vectors (e.g., normal or direction vectors) as well as some physical values used for the **Transport Phenomena Simulation** module.

Table 3-30: Options for the unit settings

Option	Description
Show values with ... decimal places spin box	Specifies the number of decimal places.
Show values with precision up to ... spin box and drop-down list	Specifies an absolute precision value and the corresponding unit.

Option	Description
Show values in scientific mode with ... significant digits spin box	Specifies the number of significant digits to be displayed, either in decimal style (-000.000) or in exponential style (-0.000e-00). Exponential style will be used if the exponent is less than -4 or greater than or equal to the number of significant digits. Examples of numbers displayed with three significant digits: • 0.00345 • 34.5 • 3.45e15

Expert Settings

- **Directory settings** section

  Click the **Browse...** button next to the **Temporary files** field to specify the directory for all log and temporary files written by myVGL. To see the currently set path completely in a tooltip, hover the mouse pointer over the field.

☞ To ensure short access times, it is recommended that the directory is located on a local drive.

☞ Make sure there is at least 5 GB of free space in this storage location. Depending on the amount of data, more free space may be required.

☞ If the application crashes, dump files are typically saved to the path specified in the **Temporary files** field (by default *C:\Users\<user name>\AppData\Local\Temp\Volume Graphics\myVGL\2025.3*). Please forward the dump file (*.dmp*) and the associated *.txt* file to your local VG Support team.

- **Hardware renderer** section

  Displays the graphics card used by the hardware renderer. When the **Memory override** option is checked, the **Memory** field, where you can determine how much memory of the graphics card can be used for rendering, will be enabled.

☞ The graphics card selected in the system settings for OpenGL is the one that is also used by the hardware renderer.

☞ If you are working with Linux, you will always need to manually set the correct value for GPU memory.

- **File integrity check settings** section

  When you open a previously saved *.vgl* project that references volume data stored in a file system, myVGL will perform a digest check to verify that the referenced data has not been modified.

Table 3-31: Options of the **File integrity check** drop-down list

Option	Description
Full	Performs a full digest check. Note that a full digest check may result in low system performance, especially if the data is stored on a network share.
Fast	Performs a faster digest check.

- **User log settings** section

Table 3-32: Options for the **User log settings**

Option	Description
User actions checkbox	By default, this option is deactivated. When this option is checked, a log file with the user actions will be stored in the path specified in the **Temporary files** field of the **Directory settings** section in the **Expert** settings.
General diagnostics checkbox	By default, this option is deactivated. When this option is checked, a log file with the diagnostic messages generated by the user actions will be stored in the path specified in the **Temporary files** field of the **Directory settings** section in the **Expert** settings.
Deep learning diagnostics checkbox	By default, this option is deactivated. When this option is checked, a log file with the deep learning diagnostic messages will be stored in the path specified in the **Temporary files** field of the **Directory settings** section in the **Expert** settings.
Select all button	Selects all logging options at once.
Select none button	Deselects all logging options at once.
Number of files kept spin box	Allows you to specify the maximum number of log files maintained. If the number of log files exceeds this value, the older log files will be overwritten.
Log file location	If logging is activated, a link will be displayed that will directly open the log file.

- **File dialog settings** section

The **Search path mode** field specifies the search path to be used for opening or saving files.

Table 3-33: Options for the **File dialog settings**

Option	Description
Individual	Allows you to use separate search paths for each file format.

Option	Description
Global	Uses the last search path for all file formats.
VG Project	Uses the path to the currently open project file.

- **Multithread settings** section

  When the **Thread count override** option is checked, the **Thread count** field, where you can manually restrict the number of threads to be used, will be enabled.

  If you use hard disk drives as USB drives or in a network, set the value in the **Image stack import thread count** field to **1** for optimal performance. In all other cases use a high value for the thread count.

- **User log settings** section

  Table 3-34: Options in the **User log settings** section

Option	Description
Mode drop-down list	• **Disabled**: No log files of the user actions will be written. • **Log user actions**: A log file with the user actions will be stored in the path specified in the **Temporary files** field of the **Directory settings** section in the **Expert** settings. • **Log user actions and diagnostics**: A log file with the user actions and diagnostic messages generated by these actions will be stored in the path specified in the **Temporary files** field of the **Directory settings** section in the **Expert** settings.
Number of files kept spin box	Allows you to specify the maximum number of log files maintained. If the number of log files exceeds this value, the older log files will be overwritten.

- **Factory reset** section

  Click the **Factory reset** button to delete all customized application settings and reset the settings to the factory default.

Factory reset will not take effect until the next start of myVGL and cannot be reverted.

- **Dump core file** section

  When the **Write core dump** option is checked, a core dump will be executed when the program terminates unexpectedly.

Colors & Styles Preferences

Analysis annotations Settings

Specify the look of annotations of the various analyses.

Table 3-35: Options for the **Analysis annotations** settings

Option	Description
Cursor size mode drop-down list	Defines the mode for specifying the size of the annotation cursor: • **Display relative**: The size (in pixels) of the annotation cursor is relative to the screen, i.e., the size remains the same when you zoom in or out. • **Scene relative**: The size (in physical units, e.g., mm) of the annotation cursor is relative to the scene, i.e., the size changes when you zoom in or out.
Cursor size spin box	Specifies the size of the annotation cursor; the unit depends on the mode selected in the **Cursor size mode** field.
Cursor color follows overlay checkbox	3D only: When this option is checked, the annotation cursor will be colored according to the color coding of the analysis result at this position.
Default annotation size drop-down list	• **Full size**: Maximizes a newly created annotation. • **Minimal**: Minimizes a newly created annotation.
Annotation visible in all slices checkbox	2D display settings only: If checked, the annotations will be visible in all slices. If unchecked, the annotations will be visible just at their cursor position.

Annotation layout Settings

Determine the behavior of the **Annotations > Arrange** function.

Table 3-36: Options for the **Annotation layout** settings

Option	Description
Allow overlap drop-down list	Specifies which objects may be concealed by the annotations: **Object only**, **Color table only**, **Both**, or **None**.
Strategy drop-down list	Specifies where the annotations should be positioned: at the **Window border** or **Around object**.
Alignment X/Y drop-down lists	Specify how annotations of non-uniform size should be positioned with respect to each other.
Center drop-down list	Specifies if the distribution of the annotations should be determined by the center of the **Object**, of the **Window**, or automatically (**Auto**).
Margin spin boxes	Specify the spacing between annotations. The first setting determines the x-value, and the second setting determines the y-value.
Border spin boxes	Specify the minimum distance between window border and annotations. The first setting determines the x-value, and the second setting determines the y-value.

Option	Description
Grid snap checkbox	Specifies whether the annotations should snap to a grid when you shift them manually.
Grid snap step spin boxes	When the **Grid snap** checkbox is checked, you can specify the grid spacing. The first setting determines the x-value, and the second setting determines the y-value.
Grid snap offset spin boxes	When the **Grid snap** checkbox is checked, you can specify the grid origin. The first setting determines the x-value, and the second setting determines the y-value.
Max. visible annotations spin box	Specifies the maximum number of visible annotations in a window. If this value is exceeded, all annotations will be hidden.
Font option	Opens the **Select Font** dialog, where you can specify the font type and size for all annotations.

Color bars Settings

Specify the settings for the color bars for the analysis results and for the fit points.

Table 3-37: Settings for the color bar

Option	Description
Color bar thickness spin box	Specifies the thickness of the color bar.
Color bar stretch spin box	Specifies the length of the color bar with respect to the 2D or 3D window.
Default analysis color bar position drop-down list	Specifies the default location of the analysis color bars within the 2D and 3D windows for newly created projects: **Left, Right, Top, Bottom, All - automatic, Left or right - automatic, Top or bottom - automatic**. You can change the location of the color bar for the individual analysis types by modifying the settings in the **Color bar** section on the **Colors** tab of the analysis dialog.
Default fit point color bar position drop-down list	Specifies the default location of the fit points color bar within the 2D and 3D windows for newly created projects: **Left, Right, Top, Bottom, All - automatic, Left or right - automatic, Top or bottom - automatic**. You can also change the location of the color bar by modifying the settings in the **Color bar** section on the **Colors** tab of the **Geometry element properties** dialog.
Font, Font color, Font outline, Font outline color options	Specify the look of the color bar headline and scale legend.
Restore defaults button	Resets all color bar settings to their default values.

Coordinate measurement Settings

Features > General *Settings*

- **General** section

  Table 3-38: Options for the feature settings

Option	Description
Handle size mode drop-down list	Defines the mode for specifying the size of the feature handles, e.g., arrows: • **Display relative**: The size (in pixels) of the feature handles is relative to the screen, i.e., the size remains the same when you zoom in or out. • **Scene relative**: The size (in physical units, e.g., mm) of the feature handles is relative to the scene, i.e., the size changes when you zoom in or out.
Handle size spin box	Specifies the size of the feature handles; the unit depends on the mode selected in the **Handle size mode** field.
Handle display type drop-down list	Specifies the look of the feature arrows.
Snap to grid option	When this option is checked, the feature handles snap to the grid specified by the **Grid distance**.
Grid distance spin box	Specifies the grid spacing for the **Snap to grid** option.

- **GD&T annotation** section

  Table 3-39: Options for the GD&T annotation settings

Option	Description
Hide default datum checkbox	When this option is checked, the label of a **Position** tolerance will be displayed without the default datum elements **Base XY**, **Base XZ**, and **Base YZ**.
Show datum element group name only when expanded checkbox	When this option is checked, the label of a tolerance will only show the group names of the datum elements if it is expanded. When this option is unchecked, the group names of the datum elements will always be shown.
Default tolerancing annotation size drop-down list	• **Full size**: Maximizes a newly created tolerancing annotation. • **Minimal**: Minimizes a newly created tolerancing annotation.

Option	Description
Tolerancing annotation cursor size spin box	Specifies the size of the tolerancing annotation cursor. The size is always relative to the screen, i.e., the size remains the same when you zoom in or out. The color of the cursor follows the color of the color overlay.

- **Text** section

  Specifies the font type, color, size, and outline for feature descriptions. Apart from that, the **Status icon** option can be used for switching the display of the evaluation indicator in front of the dimension in the 2D windows and in the 3D window on or off.

Features > Color, selected instrument *Settings*

Specifies the look of selected projected features or of features that belong to a selected instrument: You can specify the color and width of the respective subsidiary lines, handles, the selected feature itself, and unselected features that belong to the same selected instrument (see “dimensioning-style feature” in section *Instruments Icon Group* on page 113 in chapter 6 *Inspect Tab*).

Each subsection allows you to set a specific style for items in the slice plane, behind the slice plane, and in front of the slice plane.

Features > Color, unselected instrument *Settings*

Specifies the look of unselected projected features or of features that belong to an unselected instrument: You can specify the color and width of the respective subsidiary lines, handles, and features that belong to the same instrument (see “dimensioning-style feature” in section *Instruments Icon Group* on page 113 in chapter 6 *Inspect Tab*).

Each subsection allows you to set a specific style for items in the slice plane, behind the slice plane, and in front of the slice plane.

Geometry elements > 2D display settings/3D display settings > General *Settings*

Table 3-40: General Options for the 2D and 3D display settings

Option	Description
Point size mode drop-down list	Defines the mode for specifying the size of points, such as fit points and auxiliary points (e.g., the center points of cylinders): • **Display relative**: The size (in pixels) of the points is relative to the screen, i.e., the size remains the same when you zoom in or out. • **Scene relative**: The size (in physical units, e.g., mm) of the points is relative to the scene, i.e., the size changes when you zoom in or out.
Point size spin box	Specifies the size of the points; the unit depends on the mode selected in the **Point size mode** field.

Option	Description
Point display type drop-down list	Specifies the look of the points.
Geometry element grid spacing spin box	3D display settings only: Specifies the grid spacing for the visual representation of the geometry element in the 3D window.
Display annotations (when selected) checkbox	When this option is checked, the label of the selected geometry element will be displayed in the 2D or 3D windows.

Geometry elements > 2D display settings/3D display settings > Color *Settings*

In the **Color** subsection of both the **2D display settings** and **3D display settings** sections, you can define the look of selected, highlighted, and unselected geometry elements. Highlighted geometry elements are geometry elements that belong to a selected geometric tolerance.

In the **2D display settings** section, you can set a specific style for items in the slice plane, behind the slice plane, and in front of the slice plane.

When the **Transparent overlay** option in the **3D display settings** section is activated, geometry elements will shine through the material. This option is activated by default for selected and highlighted geometry elements, and deactivated by default for unselected geometry elements.

Instruments > General *Settings*

- **Indicator** section

  Table 3-41: Options for the indicator settings

Option	Description
Indicator size spin box	Specifies the size of the indicator cursor in pixels.
Default indicator type drop-down list	Specifies the look of the indicator cursor in the 2D windows: **Cross-hairs open** (always display relative) or **Circle** (always scene relative). Tip: To toggle between the two display types in the 2D windows, you can also double-click the indicator cursor in one of the 2D windows or the 3D window.
Indicator label visible in all slices checkbox	When this option is checked, the label(s) of the indicator(s) selected in the Scene Tree will always be displayed in the 2D windows, independently of the slices it belongs/they belong to. Note that the indicator cursor(s) will always be shown in all slices.

- **Instruments** section

Table 3-42: Options for the instrument settings

Option	Description
Handle size mode drop-down list	Defines the mode for specifying the size of the instrument handles: • **Display relative**: The size (in pixels) of the handles is relative to the screen, i.e., the size remains the same when you zoom in or out. • **Scene relative**: The size (in physical units, e.g., mm) of the handles is relative to the scene, i.e., the size changes when you zoom in or out.
Handle size spin box	Specifies the size of the instrument handles; the unit depends on the mode selected in the **Handle size mode** field.

- **Navigation cursor** section

Table 3-43: Options for the **Navigation cursor** settings

Option	Description
Size mode drop-down list	Defines the mode for specifying the size of the **Navigation cursor**: • **Display relative**: The size (in pixels) of the **Navigation cursor** is relative to the screen, i.e., the size remains the same when you zoom in or out. • **Scene relative**: The size (in physical units, e.g., mm) of the **Navigation cursor** is relative to the scene, i.e., the size changes when you zoom in or out.
Size spin box	Specifies the size of the **Navigation Cursor**; the unit depends on the mode selected in the **Size mode** field.
Set size automatically option	Clicking the **Auto** button automatically calculates the **Scene relative** size of the **Navigation cursor**.
Show center point checkbox	When this option is checked, the center of the **Navigation cursor** is displayed as a dot.

Instruments > Color, selected *Settings*

Specifies the look of selected instruments (without features), selected instruments with features (see “dimensioning-style feature” in section *Instruments Icon Group* on page 113 in chapter 6 *Inspect Tab*), and their handles.

Each subsection allows you to set a specific style for items in the slice plane, behind the slice plane, and in front of the slice plane.

Instruments > Color, unselected *Settings*

Specifies the look of unselected instruments (without features), unselected instruments with features (see “dimensioning-style feature” in section *Instruments Icon Group* on page 113 in chapter 6 *Inspect Tab*), and their handles.

Each subsection allows you to set a specific style for items in the slice plane, behind the slice plane, and in front of the slice plane.

Coordinate system display Settings

Box *Settings*

Specify the look of the coordinate system box: You can modify the font, color, outline, alignment, and style of the labels. Furthermore, you can specify if you want to show the box frame, ticks, labels, grid, and background. You can also extend the box by a certain distance in each direction. The color of the box background, box frame, ticks, and grid can also be specified.

Scale bar *Settings*

Specify the look of the scale bar. You can modify the font, font color, font outline, and the font outline color. You can also specify the distance of the scale bar from the bottom of the window (**Cell border**), the approximate relative size of the scale bar with regard to the window size, and the number of ruler sections.

Tripod *Settings*

Specify the size of the tripod and the colors of the tripod axes.

Isosurface Settings

The **Line color attenuation** spin box specifies the attenuation of the line color for displaying the surface of unselected objects in the 2D views.

Region of interest Settings

Specify the look of the ROI lines in the 2D views, both for selected and unselected ROIs as well as for the ROIs of unselected volumes.

Apart from that, you can specify the color for newly created ROIs in the 3D window; in the 2D windows, this color will be applied to the surface lines of the object that lie within the ROI. The specified color will be applied when the **Highlight ROI after creating it** option is checked in the **Selection mode** dialog prior to creating the ROI.

Text overlay Settings

Specify the look of the text overlays.

Table 3-44: Options for the text overlay settings

Option	Description
Font, Font color, Font outline, Font outline color options	Define the font properties.
Cell border spin box	Specifies the distance between text overlay and border of the 2D/3D window.
Text	Clicking the **Configure...** button opens the **Text overlay editor** (see section *Text overlay editor* on page 172 in chapter 8 *Window Tab*).

Quit

Closes the application.

You can also press the **Alt+F4** keyboard shortcut to close the application.

Home Tab

The **Home** tab provides a collection of relevant functions of myVGL. The functions are still available on the various dedicated tabs, which are always present.

To customize the **Home** tab for the various workflows, go to **File > Customize** and click **Configure tabs** (see section *Configure tabs* on page 54 in chapter 3 *File Tab*).

Edit Tab

Introduction

On the **Edit** tab of myVGL, you can access the undo and redo functions as well as the cut, copy, and paste functions. The tab also allows you to unload and reload the volume data.

Undo/Redo

Most actions can be undone (and redone to reestablish the situation before “undoing” it). Actions that change the underlying data or otherwise require a lot of memory (e.g., filtering) may not be available for undo/redo.

The amount of memory allocated for the undo queue can be set by editing the preferences (see section *Preferences* on page 57 in chapter 3 *File Tab*). Should the last issued command require more storage space in the undo queue than is currently available, myVGL will start deleting entries in the queue—beginning with the oldest command in the queue and proceeding chronologically until enough storage space becomes available. If a command requires more space than is available for the undo queue, the command will not be stored and the current command history will be erased.

If you think you might want to undo an action that requires a lot of memory, save the desired images or image stacks prior to the action.

In order to *undo* an action, you can also press the **Ctrl+Z** keys.

In order to *redo* an action, you can also press the **Ctrl+Y** keys.

Free memory/Clear undo queue

The command history of the current myVGL session is stored in the undo queue. **Free memory/Clear undo queue** will erase the accumulated command history.

The command history will be deleted automatically if an action requires more memory than is available to the undo queue.

Delete

Deletes the selected object(s) from the scene. The object(s) can be (partially) restored using **Edit > Undo**. Analysis results (e.g., from a nominal/actual comparison) are not restored.

In order to delete the selected object(s) from the scene, you can also press the **Del** key.

Properties

Displays information on the object selected in the Scene Tree.

Except for views, you can also open the **Properties** dialog by double-clicking the object in the Scene Tree.

The type of properties dialog depends on the type of object selected:

- If the selected object is a *geometry element*, the **Geometry element properties** dialog will open. For details, see section *Geometry element properties Dialog* on page 256 in chapter 24 *Coordinate Measurement*.
- If the selected object is a *dimensioning feature*, the **CM results** dialog will open. For details, see section *CM results dialog* on page 264 in chapter 6 *Inspect Tab*.
- If the selected object is a *tolerance feature*, the **CM results** dialog will open. For details, see section *CM results dialog* on page 264 in chapter 6 *Inspect Tab*.
- If the selected object is an *analysis*, the **Properties** dialog of the pertaining analysis will open. For details, see the chapter on the corresponding analysis.
- If the selected object is a *volume object*, a *CAD model,* a *surface mesh*, or an *ROI*, the **Object properties** dialog will open. For details, see section *Object properties Dialog* on page 79 in chapter 5 *Edit Tab*.
- If the selected object is a *tetrahedral mesh*, the **Tetrahedral mesh** dialog will open. For details, see section *Tetrahedral mesh Dialog* on page 97 in chapter 5 *Edit Tab*.

Object properties Dialog

Opens the **Object properties** dialog. This dialog shows the properties of the selected volume object, CAD model, surface mesh, or ROI and consists of several tabs that will be described in the following paragraphs. The tabs available as well as the information provided on the **General** tab depend on the selected object.

General Tab for Volume Objects

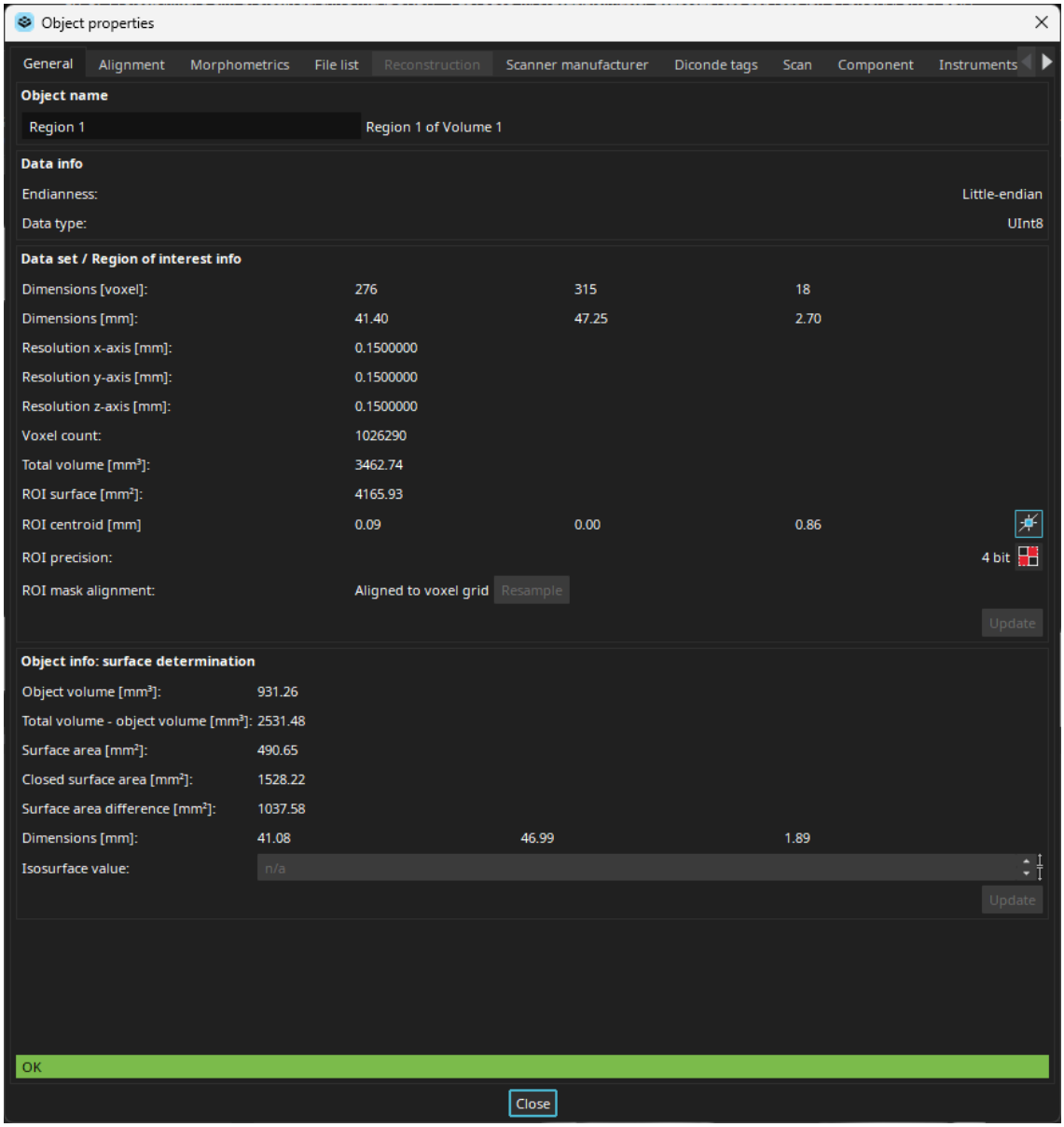


Figure 5-1: General properties of volume objects or ROIs

- **Object name** section

  Indicates the name of the selected object. The field can be edited to rename the object.
- **Data info** section

  Provides information about the endianness and the data type of the CT data.
- **Data set / Region of interest info** section

  Provides information on the data set or the ROI, which is delimited by the bounding box along the voxel grid. Generally, the bounding box also comprises the area surrounding the scanned object or the ROI (e.g., air).

  If applicable, the values will be indicated in the unit specified for the scene (e.g., mm or in^2).

Table 5-1: Controls in the **Data set / Region of interest info** section

Control	Description
Dimensions [voxel] fields	Indicate the dimensions of the bounding box of the selected object in the x-, y-, and z-directions of the volume object coordinate system in voxels.
Dimensions [<length unit>] fields	Indicate the dimensions of the bounding box of the selected object in the x-, y-, and z-directions of the volume object coordinate system in length units.
Resolution x-/y-/z-axis [<length unit>] fields	Indicate the resolution of the data set, i.e., the size of a voxel, on the x-, y-, and z-axis.
Voxel count field	Indicates the total number of voxels in the bounding box of the selected volume object or in the selected ROI.
Total volume [<length unit>³] field	Indicates the total volume of the bounding box of the selected volume object or of the selected ROI.
ROI surface [<length unit>²] field	For ROIs only: Indicates the surface of the selected ROI.
ROI centroid [<length unit>] field	For ROIs only: Indicates the coordinates of the centroid of the selected ROI.
ROI precision field	For ROIs only: Indicates the mask precision of the ROI: 1 bit, 2 bit, 4 bit, or 8 bit.
ROI mask alignment field	Indicates whether the ROI mask is aligned with the voxel grid of its parent volume.
Update button	Recalculates the parameters.

- **Object info** section

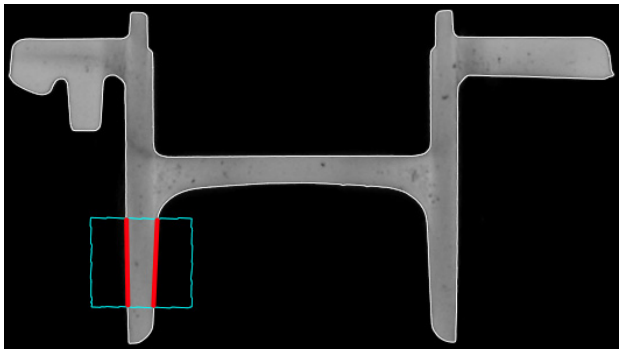
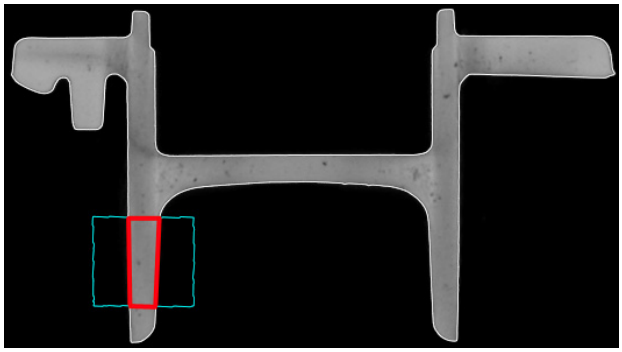
  Provides information on the scanned object based on the surface determination. If there is no surface determination available, the information will be calculated using the manually set isosurface value.

  For volume objects consisting of several volume components, only the outer surface of all united components will be considered.

  If applicable, the values will be indicated in the unit specified for the scene (e.g., mm or in^2).

  Table 5-2: Controls in the **Object info** section

Control	Description
Object volume [<length unit>³] field	Indicates the volume of the material of the selected object based on the surface determination or the manually set isosurface value.

Control	Description
Total volume - object volume [<length unit>³] field	If the selected object is a volume object: Indicates the volume of the area surrounding the material by subtracting the **Object volume** from the **Total volume**. If the selected object is an ROI: Indicates the volume of the area surrounding the material in the ROI by subtracting the **Object volume** from the **Total volume**.
Surface area [<length unit>²] field	Indicates the actual material surface of the entire data set or of the ROI.  Figure 5-2: Surface area
Closed surface area [<length unit>²] field	For ROIs or partially scanned objects only: Indicates the material surface as well as the ROI surface or data set boundary in the material.  Figure 5-3: Closed surface area
Surface area difference [<length unit>²] field	For ROIs or partially scanned objects only: Indicates the difference between the **Closed surface area** and the **Surface area**.
Dimensions [<length unit>] fields	Indicates the smallest possible bounding box around the object in the x-, y-, and z-directions in the selected coordinate system.
Isosurface value field	Indicates the manually set isosurface value used for calculation if no surface determination is available.

Control	Description
Update button	Recalculates the parameters.

- **Close** button
  Closes the **Object properties** dialog.

General Tab for CAD Models/Surface Meshes

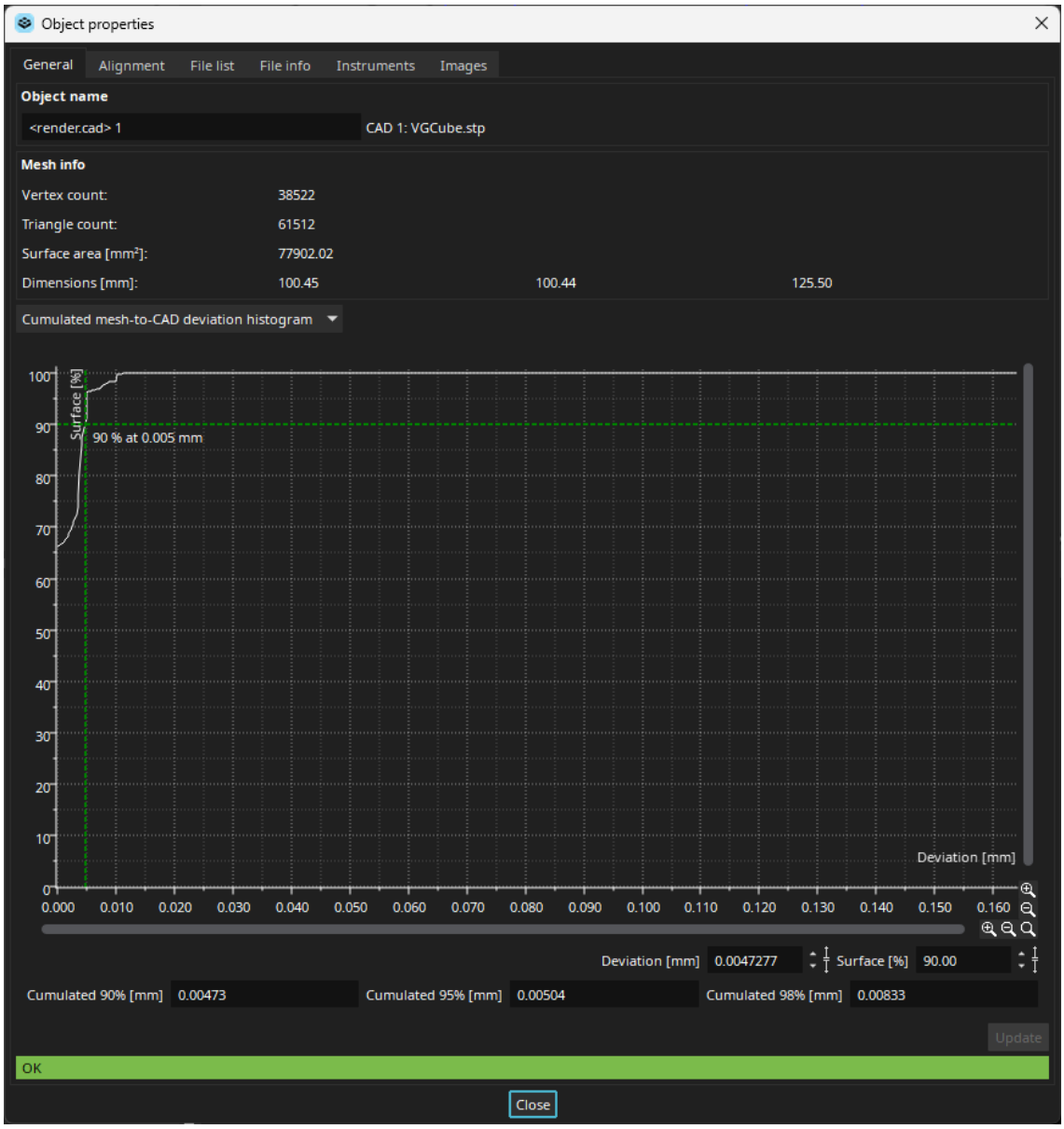


Figure 5-4: General properties of CAD models/surface meshes

- **Object name** section
  Indicates the name of the selected object. The field can be edited to rename the object.

- **Mesh info** section

  If applicable, the values are indicated in the unit specified for the scene (e.g., mm or in^2).

  Table 5-3: Controls in the **Mesh info** section

Control	Description
Vertex count field	Indicates the number of vertices that define the CAD model or surface mesh.
Triangle count field	Indicates the number of triangles that define the CAD model or surface mesh.
Surface area [<unit>] field	Indicates the surface area of the CAD model or surface mesh.
Dimensions [<unit>] fields	Describe the smallest possible bounding box around the selected object in the x-, y-, and z-directions. The dimensions of the bounding box depend on the currently selected coordinate system.

- **Scan info** section

  This section is only available for scan objects.

  Table 5-4: Controls in the **Scan info** section

Control	Description
Used scanner(s) field	Indicates the scanner(s) used for acquiring the points of the scan object.
Scanned points field	Indicates the number of points scanned for the scan object.
Patches field	Indicates the number of patches scanned for the scan object.

- **Mesh generation** section

  Table 5-5: Controls in the **Mesh generation** section

Control	Description
Minimum point distance [<length unit>] field	Indicates the minimum point distance used for mesh generation (for details, see section **Edit mesh generation presets *dialog* on page 5**).
Maximum edge length [<length unit>] field	Indicates the maximum edge length used for mesh generation (for details, see section **Edit mesh generation presets *dialog* on page 5**).
Point alignment field	Available for scan objects. Indicates the alignment method used for mesh generation (for details, see section **Edit mesh generation presets *dialog* on page 5**).

- Histogram section

The following table gives an overview of the controls in the histogram section:

Table 5-6: Controls in the histogram section

Control	Description
Update button	Displays a histogram in the histogram section.
drop-down list	For CAD models only: Specifies the type of histogram: • **Interior angle histogram**: Analyzes the angles in the triangles and displays the number of occurrences of the angles. • **Mesh-to-CAD deviation histogram**: Analyzes the distance between CAD surface and generated mesh and displays the deviation over the surface. • **Cumulated mesh-to-CAD deviation histogram**: Displays the deviation values over the percentage of the surface. For example, it indicates what percentage of the surface has a certain deviation value.
Deviation [<unit>] spin box	Indicates the deviation value that corresponds to the cumulated percentage of the surface with the deviation indicated in the **Surface** field. You can also specify a deviation value for which you want to obtain the corresponding percentage of the surface. This control is synchronized with the green cross-hairs that indicate the corresponding position on the curve.
Surface [%] spin box	Indicates the percentage of the surface area that corresponds to the maximum deviation value indicated in the **Deviation** field. You can also specify the percentage of the surface for which you want to obtain the maximum deviation value. This control is synchronized with the green cross-hairs that indicate the corresponding position on the curve.
Cumulated 90%/95%/98% fields	Indicate the maximum deviation values for 90%, 95%, or 98% of the surface, respectively.
use LMB to click and drag green cross-hairs lines	Moves the green cross-hairs along the curve, which indicates the percentage of the surface within a given deviation (or, alternatively, the maximum deviation for a given percentage).
use RMB to click the chart area	Displays a context menu (see below).
scroll MW in chart area or x-axis up/down	Zooms the x-axis of the chart out/in.
scroll MW in y-axis up/down	Zooms the y-axis of the chart out/in.

Control	Description
use LMB to click and drag the x-axis	Scrolls the x-axis.
use LMB to click and drag the y-axis	Scrolls the y-axis.
Zoom in/out	Zooms the corresponding axis in/out.
Reset zoom	Fits the entire chart to the current window size.

Right-clicking anywhere in the chart area opens a context menu with the following options:

Table 5-7: Context menu in the histogram section

Control	Description
Copy to clipboard	Copies a screenshot of the chart to the system clipboard so that you can paste it into another application.
Hide/Show x/y grid	Toggles the visibility of the grid lines for the corresponding axis.
Reset zoom	Fits the entire chart to the current window size.

- **Close** button
  Closes the **Object properties** dialog.

Alignment Tab

Provides information on the alignment method and corresponding tolerance settings, if available.

- **Alignment information** section

  Table 5-8: Controls in the **Alignment information** section

Control	Description
Alignment approach	Indicates the method used for aligning the actual part.
Aligned object	Indicates the name of the actual part.
Reference object	Indicates the name of the nominal part, if applicable.

- **Tolerance settings** section
  Available only if a tolerance can be applied to the alignment. The information provided depends on the alignment method used.

  Table 5-9: Controls in the **Tolerance settings** section

Control	Description
Distance measure field	Indicates a measure for the distance between actual and nominal part.
Surface overlap field	Indicates the percentage of coverage between actual and nominal part.

Control	Description
Tolerance alignment checkbox	Checking this option activates tolerancing the alignment and enables the corresponding spin boxes.
Max. distance measure spin box	Specifies the maximum permissible value for the distance measure between actual and nominal part.
Min. surface overlap spin box	Specifies the minimum permissible percentage of coverage between actual and nominal part.
Max. surface overlap spin box	Specifies the maximum permissible percentage of coverage between actual and nominal part.
Status of relevant geometry elements field	• **OK**: All geometry elements relevant for the alignment are properly fitted to the object surface. • **Element(s) in undefined state**: At least one geometry element relevant for alignment indicates a warning status.

File list Tab

Displays a list of the files containing the data of the selected object. The information refers to the data as stored in the file. Thus, the volume size can vary from the volume size of the object in the scene (for example, if the object has been imported after applying an ROI).

Source list Tab

Indicates the source objects of the selected volume object if it was created via object conversion.

Reconstruction Tab

Shows information on the reconstruction settings (e.g., **Projection**, **Geometry**, **Files**, **Clamping**, **Skip**, and **Calibration**).

This information is only available if the volume data has been reconstructed using one of the optional **CT Reconstruction** modules of VGSTUDIO MAX/VGSTUDIO.

Scanner manufacturer Tab

- List section

  Shows the scanner manufacturer information available in the project file (e.g., **Name**, **Address**, **Homepage**, **Device name**, **Acquisition software**, and manufacturer logo).

  All information provided on this tab can be searched for using the Windows search function.

If the search does not yield any results, make sure the searched directory is indexed for search by Windows. The relevant settings can be made in Windows via **Indexing Options > Modify**.

- **Import** button

You can import the information to be provided on the **Scanner manufacturer**, **Scan**, and **Component** tabs from a *.csv* file. Clicking the **Import** button opens the **Sections** dialog, where you can specify the information to be imported by checking or unchecking the corresponding checkboxes. Content that is already available in a field will be overwritten.

- **Export** button

  You can export the information provided on the **Scanner manufacturer**, **Scan**, and **Component** tabs to a *.csv* file. Clicking the **Export** button opens the **Sections** dialog, where you can specify the information to be exported by checking or unchecking the corresponding checkboxes.

Diconde tags Tab

Shows the tags specified by the DICONDE standard. You can edit the DICONDE tags and then export the volume data to a DICONDE data set. A padlock icon in front of a DICONDE tag indicates that the tag is derived from the volume data and cannot be edited.

Exporting to a DICONDE data set is supported for 8 bit and 16 bit data sets only.

Scan Tab

- List section

  Shows the scan information available in the project file (e.g., **Tube voltage, Tube current, Scan time, Reconstruction time, Total process time, Reconstruction algorithm, Scan method, Geometry, Integration time, Filter, Number of projections, Date time, User**).

  All information provided on this tab can be searched for using the Windows search function.

If the search does not yield any results, make sure the searched directory is indexed for search by Windows. The relevant settings can be made in Windows via **Indexing Options > Modify**.

- **Import** button

  You can import the information to be provided on the **Scanner manufacturer**, **Scan**, and **Component** tabs from a *.csv* file. Clicking the **Import** button opens the **Sections** dialog, where you can specify the information to be imported by checking or unchecking the corresponding checkboxes. Content that is already available in a field will be overwritten.

- **Export** button

  You can export the information provided on the **Scanner manufacturer**, **Scan**, and **Component** tabs to a *.csv* file. Clicking the **Export** button opens the **Sections** dialog, where you can specify the information to be exported by checking or unchecking the corresponding checkboxes.

Component Tab

- List section

  Shows the information on the scanned part available in the project file (e.g., **Description, Lot number, Serial number**).

  All information provided on this tab can be searched for using the Windows search function.

If the search does not yield any results, make sure the searched directory is indexed for search by Windows. The relevant settings can be made in Windows via **Indexing Options > Modify**.

- **Import** button

  You can import the information to be provided on the **Scanner manufacturer**, **Scan**, and **Component** tabs from a *.csv* file. Clicking the **Import** button opens the **Sections** dialog, where you can specify the information to be imported by checking or unchecking the corresponding checkboxes. Content that is already available in a field will be overwritten.

- **Export** button

  You can export the information provided on the **Scanner manufacturer**, **Scan**, and **Component** tabs to a *.csv* file. Clicking the **Export** button opens the **Sections** dialog, where you can specify the information to be exported by checking or unchecking the corresponding checkboxes.

Instruments Tab

Lists all instruments of the selected object and their properties.

To open the **Object properties** dialog directly on the **Instruments** tab, you can also double-click an instrument or the **Instruments** entry in the Scene Tree.

The individual columns of the **Instruments** table are:

Table 5-10: Columns of the **Instruments** table

Column	Description
Group	Indicates the name of the group that the instrument belongs to.
Name	Indicates the name of the instrument. This column can be edited.
Type	Indicates the instrument type: **Distance**, **Min./max. distance**, **Polyline**, **Angle**, **Caliper**, or **Indicator**.
Actual	Indicates the numerical value of the instrument. For an angle instrument, the value is displayed in the current angle unit; for all other instrument types, it is displayed in the current length unit. For an indicator, you can double-click the annotation in a 2D or 3D window to enter a customized text that will be shown in this column.
Nominal [<length unit>/<angle unit>]	Indicates the nominal value for the measurement instrument. This cell can be edited. Based on the **Tolerance (lo)/(hi)** settings, the software will determine whether the feature is within the specified tolerance range and set the feature status accordingly. The evaluation will only be performed if both the nominal value and the tolerance values have been set.

Column	Description
Tolerance (lo)/(hi) [<length unit>/<angle unit>]	Specifies the allowed tolerance of the actual value towards the given nominal value of the measurement instrument. These cells can be edited. If both values have not yet been set, you can create a symmetric tolerance range by entering a **Tolerance (hi)** value. **Tolerance (lo)** will automatically be set to the same value, but with a negative sign. Similarly, you can enter a negative **Tolerance (lo)** value; **Tolerance (hi)** will then be automatically set to the same value, but with a positive sign. You can also change both tolerances independently (for example, to enter two negative or two positive tolerances, respectively).
Status	Provides status information on the instrument. • **OK**: No errors or warnings. The instrument handles have snapped to the surface. A tolerance range has been defined and the measurement instrument meets the tolerance. The evaluation indicator in the Scene Tree is shown in green. • **Out of tolerance**: The instrument handles have snapped to the surface, but the actual value of the measurement instrument lies outside the specified tolerance range. The evaluation indicator in the Scene Tree is shown in red. • **Handles not snapped**: One or more instrument handles have not snapped to the surface. No evaluation is possible. The evaluation indicator in the Scene Tree is shown in gray and has a warning sign. • **n/a**: No tolerance range has been defined. The evaluation indicator in the Scene Tree is shown in gray.
Position X/Y/Z [<length unit>]	Indicates the position of the instrument. For indicators, these fields can be edited.
Direction X/Y/Z	Available for distance and caliper instruments. Indicates the direction of the instrument (from the start to the end point).

Column	Description
Image	Allows you to add a detailed 2D image and object description on a separate page of the report. • **Off**: No image is created (default). • **Orthographic projection**: Creates three orthogonal views. • **Top/Bottom/Left/Right/Front/Back**: Creates a single 2D view in the specified orientation. The image orientation corresponds to the currently selected coordinate system. The generated image will only contain the reported instrument and its parent volume object or surface mesh. All other instruments, geometry elements, GD&T features, analyses, etc., will be hidden. The instrument is always shown in a “highlighted” visual state. The 2D slice position used for taking the image is determined by the position of the instrument. The zoom factor of the image is chosen so that the entire parent volume object or surface mesh is visible.
Focused image	This option is almost identical to the **Image** option, but will generate an image that focuses on the respective item and is zoomed in by the **Zoom factor** specified during report creation or VGRF-based export.
Captures	Indicates the number of images captured for this object with the **Capture from** button in the **Screenshots** section.

General Table Controls

- List section

  The following table provides an overview of the general controls available in the various list views:

  Table 5-11: Controls in the list section

Control	Description
button	Opens a submenu for selecting the filter/search mode.

Control	Description
Filter	Clicking the **Click to add a filter or search criterion** field to the right of the icon opens a series of drop-down lists from which you can select a table column, an operator, and—depending on the column—a value. If a column does not offer a value drop-down list, you can type in a value. When the selection is complete, the table shows the rows matching the filter criterion. Clicking the **+** button or the **Click to add a filter or search criterion** field allows you to specify more filter criteria. Clicking the **x** button removes the filter.
Search	Clicking the **Click to add a filter or search criterion** field to the right of the icon opens a series of drop-down lists from which you can select a table column, an operator, and—depending on the column—a value. If a column does not offer a value drop-down list, you can type in a value. When the selection is complete, the table rows matching the search criterion are highlighted. Clicking the **+** button or the **Click to add a filter or search criterion** field allows you to specify more search criteria. Pressing **F3** jumps to the next search result in the list. Clicking the **x** button removes the search.
Full-text filter	Entering a value or text string into the input field to the right of the icon filters the table accordingly and shows the rows that match the filter criterion.
Full-text search	Entering a value or text string into the input field to the right of the icon searches the table accordingly and highlights the rows that match the search criterion.
use LMB to click on a table row	Selects the row and the corresponding object in the Scene Tree. In analysis result lists, the result, e.g., the component, is marked by a cross-hairs cursor in each of the 2D views.
hold **Ctrl** key + use LMB to click on several table rows	Selects the rows and the corresponding objects in the Scene Tree.
hold **Shift** key + use LMB to click on two separate table rows	Selects the two rows, including all rows between the two as well as the corresponding objects in the Scene Tree.
hold **Shift** key + use up/down arrow keys	Selects the rows and the corresponding objects in the Scene Tree.

Control	Description
press **Ctrl+A**	Selects all table rows.
use up and down arrow keys	Steps up and down through the table rows.
use RMB to click into the table area	Displays a context menu. See below.
use LMB to click a column heading	Sorts the table according to the values of the column. Clicking subsequently toggles between ascending and descending.
use LMB to click and drag column heading to new position, then release LMB	Inserts the column at the new position.
use LMB to double-click cell highlighted in white (light theme) or medium gray (dark theme)	If applicable: Allows you to edit the contents of the cell.

- **Screenshots** section (if available)

  The **Screenshots** section below the list section allows you to capture images from one of the 2D windows, the 3D window, or the current window layout for the item currently selected in the table. Only available if exactly one row is selected.

  Table 5-12: Controls in the **Screenshots** section

Control	Description
Capture from button	Adds the image of the view selected from the drop-down list to the preview area above.
use LMB to click and drag one or more images, then release LMB	Moves the image(s) to the new position.
double-click the image	Opens the **Snapshot display** window showing the image: • **Zoom in**/**Zoom out** button: Zooms the image in/out. You can also move the mouse pointer in the image area and turn the mouse wheel. • **Fit to window** button: Resets the zoom so that the image fits into the window.
click the **<no description>** placeholder twice (first click to select, second click to enable renaming)	Allows you to label the image.
Delete selected button	Deletes the selected image from the preview area.

Table Context Menu

Right-clicking anywhere in the table area shows a context menu with the following options:

Table 5-13: Context menu items

Control	Description
Columns	Allows you to toggle the visibility of each column by checking/unchecking the respective item. • **Show all**: Checks all columns to set them to visible. • **Hide all**: Unchecks all columns to set them to invisible. • **Hide empty**: Unchecks all not editable columns which are empty or **n/a** to set them to invisible.
Trim columns	Resizes all columns to their smallest possible size.
Apply default column layout	Applies the default column layout previously saved by the user to the current table. If no default column layout has been saved, the original column layout will be applied.
Save as default column layout	Saves modifications applied to the table—e.g., the visibility of a column, the order in which the columns appear, the column width—as default column layout. This layout will be applied when you create a new project.
Apply original column layout	Restores the original table layout and discards any modifications applied by the user. The original table layout is predefined and cannot be modified by the user.
Remove entries	If applicable: Deletes the selected row(s) from the table.
Create annotations	If applicable: Creates annotations for the selected items.
Export as CSV...	Opens the **Export as CSV...** dialog for exporting the table values as **.csv* file. This option always exports the complete table even if a filter was applied. In order to export only the filtered rows, press **Ctrl** + **A** to highlight all filtered rows and use the **Copy to clipboard** menu item.
Copy to clipboard	Copies the selected rows as well as the column heading into the system clipboard. The clipboard information is provided both as plain text and rich-text table, so when pasting into a rich-text-capable application like a word processor, you will see a proper table with cell borders and bold headings.

Control	Description
Paste	For annotation tables: Pastes previously copied coordinates and—optionally—snap directions to create new annotations in the table. For annotations of a nominal/actual comparison, the search distance specified on the **Settings** tab of the analysis will be considered. Note: Pasted annotations will be interpreted in the selected coordinate system at the time of pasting. The information in the clipboard must have the following structure: • x-, y-, and z-coordinate of the annotation or • x-, y-, and z-coordinate of the annotation as well as x-, y-, and z-component of the vector for the snap direction The parameters can be separated by space, tab, semicolon, or comma (if a comma is already used as a decimal mark or digit grouping symbol, the values must be enclosed in double quotation marks). Example: 8.89;25.82;-0.55;1;0;0 You can also copy the information directly from the cells of a spreadsheet. In order to paste the annotation information, you can also press the **Ctrl** + **V** keyboard shortcut.
Set as active column	If applicable: Makes the current column the active column, i.e., the results of this column are color-coded according to their values as defined by the color lookup table and the colors specified in the **Sections** section of the **Colors** tab.
Unset active column	If applicable: Deselects the currently active column and sets the **Active column** drop-down list on the corresponding **Settings** tab to **Uncoded**, i.e., removes any color coding.
Enter/change value (all items)	If applicable: Opens the **Enter value** dialog (see below) where you can enter the desired value for the selected parameter. This value will be applied to all entries in the table.
Enter/change value (selected items)	If applicable: Opens the **Enter value** dialog (see below) where you can enter the desired value for the selected parameter. This value will be applied to the selected entries in the table.
Delete selected items	If applicable: Removes the selected items from the scene.

The **Enter value** dialog includes the following controls:

Table 5-14: Controls in the **Enter value** dialog

Control	Description
Enter value field	Allows you to enter the desired value.
OK button	Sets the selected parameter to the specified value.
Reset button	For analyses only: Resets the selected parameter to undefined.
Set from tolerance settings button	For analyses only: Enters the value specified in the tolerance settings of the analysis for the selected parameter.
Cancel button	Discards the changes and closes the dialog.

Images Tab

Allows you to take screenshots of the selected workspace views and/or add bookmark references to the report. In the final report, the captured images will be listed separately from the screenshots created on other tabs.

- **Snapshots** section

  Table 5-15: Controls in the **Snapshots** section

Control	Description
Capture from button	Adds the image of the view selected from the drop-down list to the preview area above.
Delete selected button	Deletes the selected image(s) from the preview area.
use LMB to click and drag one or more images, then release LMB	Moves the image(s) to the new position.
double-click the image	Opens the **Snapshot display** window showing the image: • **Zoom in**/**Zoom out** button: Zooms the image in/out. You can also move the mouse pointer on the image area and turn the mouse wheel. • **Fit to window** button: Resets the zoom so that the image fits into the window.
click the **<no description>** placeholder twice (first click to select, second click to enable renaming)	Allows you to label the image.

- **Automatic 3D images** section (if available)

  Check the corresponding checkbox to include the desired 3D view (e.g., **Top**, **Front**, **Top-left-front**, and **Current camera settings**) in the report without changing the 3D view.

- **Bookmark references** section

Allows you to add bookmark references via drag and drop from the **Bookmarks and views** tool or the **Bookmark editor** to the preview area. The images of the referenced bookmarks will then be included in VGRF-based reports.

When you open a project with missing bookmark images, placeholders will be shown instead.

Bookmark references are stored in evaluations and can be used in automation scenarios.

You will still need to import a bookmark template containing the actual bookmarks in these cases, as evaluations store only references to them.

Table 5-16: Controls in the **Bookmark references** section

Control	Description
New bookmark button	Adds a bookmark of the current view to the preview area.
Remove button	Removes the bookmark currently selected in the preview area.
click the bookmark title twice (first click to select, second click to enable renaming) or press the **F2** key	Allows you to rename the bookmark. The changes made on the **Images** tab will also affect the **Bookmark editor** and the **Bookmarks and views** tool. If the renamed bookmark is referenced by one or more objects for reporting, a warning message will be displayed indicating that the referenced bookmark will also be renamed for all these objects in the report.

The global concept of bookmark references allows for multiple objects to reference the same bookmark and for objects to reference bookmarks that show arbitrary information, e.g., other analyses or objects.

Tetrahedral mesh Dialog

The **Tetrahedral mesh** dialog shows the properties of the selected tetrahedral mesh or tetrahedral mesh component and consists of several tabs. For details, see chapter 41 *Volume Meshing Module* on page 683.

Properties of view Dialog

To open the **Properties of view** dialog,

- right-click the view in the Scene Tree and select **Properties** from the context menu, or
- highlight the view in the Scene Tree, go to the **Edit** tab, and click **Properties**.

Table 5-17: Controls of the **Properties of view** dialog

Icon	Item	Description
	snapshot section	Shows a thumbnail of the view when it was created, updated, or replaced. You can double-click the thumbnail to open a larger version of the thumbnail. Depending on changes to involved objects, applying the view might yield a different visualization that what is shown here.
	Apply view	Applies the selected view, changing the current visualization and workspace settings. To apply a view, you can also double-click it in the Scene Tree. For details, see chapter 22 *Bookmarks and views Tool* on page 235.
	Replace view	Replaces the selected view with a new one that uses the current visualization and workspace settings. For details, see chapter 22 *Bookmarks and views Tool* on page 235.
	Update view	Applies a view and then immediately replaces it. If any of the objects referenced by the view are no longer present, they will no longer be referenced by the updated view. This can be used to turn invalidated views into valid ones. For details, see chapter 22 *Bookmarks and views Tool* on page 235.
	main area	Displays a list of the objects and their scene paths that are referenced by the view. A view may reference any objects below the object it is attached to, or objects from its direct parental lineage. As the one exception to this rule, it may also indirectly reference objects that are used by analyses that the view includes.
	Close button	Closes the dialog.

Rotate/Move Mode

An object can be transformed, i.e., rotated or moved within the scene, only if it is unlocked in the Scene Tree. If it is locked, you will change the rotation and location of the camera instead. If there is only one object visible, you might not notice a difference between the two cases, but it becomes important when there are multiple objects involved, when you perform measurements, or when you are in the scene coordinate system.

There are two basic transformation modes for the 3D window:

- **Rotate** mode

- **Move** mode

To toggle between **Rotate** or **Move** mode, you can

- click **Rotate** or **Move** on the **Edit** tab,
- select the corresponding entry from the context menu,
- press the **Ctrl+Shift+R** (rotate) or **Ctrl+Shift+M** (move) keyboard shortcuts, or
- use the MMB to double-click in the 3D window.

You can also transform objects via the active tripod in the 3D window (see section *Origin Tripod* on page 11) or the **Transform** contextual tab (see chapter 16 *Transform Contextual Tab* on page 189).

Rotate Mode

- The following table lists the controls available in the 3D window for rotating an object in the scene (object is unlocked):

  Table 5-18: Controls in **Rotate** mode (rotate object)

Control	Description
hold down LMB + drag	Rotates the object.
hold down **Ctrl** + LMB + drag	When the **Use dynamic rotation center** option is set to **Never**: Rotates the object more slowly.
hold down **Shift** + LMB + drag	When the **Use dynamic rotation center** option is set to **Never**: Rotates the object around either the vertical or horizontal screen axis.
hold down **Ctrl** + **Shift** + LMB + drag	When the **Use dynamic rotation center** option is set to **Never**: Rotates the object more slowly around either the vertical or horizontal screen axis. When the **Use dynamic rotation center** option is set to **Always** or **Hotkey**: Rotates the object around either the vertical or horizontal screen axis.
hold down MMB + move up/down	Rotates the object counterclockwise/clockwise.
scroll MW up/down	Zooms the object at the POI (point of interest), i.e., at the current mouse pointer position out/in. You can reverse the zoom direction by checking the **Reverse mouse wheel zoom** option in the preferences under **File > Preferences > General > Window > 3D window**.

- The following table lists the controls available in the 3D window for rotating the camera around the object (object is locked):

  Table 5-19: Controls in **Rotate** mode (rotate camera)

Control	Description
hold down LMB + drag	Rotates the camera around the object.

Control	Description
hold down **Ctrl** + LMB + drag	When the **Use dynamic rotation center** option is set to **Never**: Rotates the camera more slowly around the object.
hold down **Shift** + LMB + drag	When the **Use dynamic rotation center** option is set to **Never**: Rotates the camera around either the vertical or horizontal screen axis. When the **Use dynamic rotation center** option is set to **Hotkey**: Rotates the camera using the current mouse pointer position as rotation center.
hold down **Ctrl** + **Shift** + LMB + drag	When the **Use dynamic rotation center** option is set to **Never**: Rotates the camera more slowly around either the vertical or horizontal screen axis. When the **Use dynamic rotation center** option is set to **Always** or **Hotkey**: Rotates the camera around either the vertical or horizontal screen axis.
hold down MMB + move up/down	Rotates the camera counterclockwise/clockwise.
scroll MW up/down	Zooms the object at the POI (point of interest), i.e., at the current mouse pointer position out/in. You can reverse the zoom direction by checking the **Reverse mouse wheel zoom** option in the preferences under **File > Preferences > General > Window > 3D window**.
press left/right arrow key	Rotates the camera around the vertical screen axis.
press up/down arrow key	Rotates the camera around the horizontal screen axis.

Move Mode

- The following table lists the controls available in the 3D window for moving an object in the scene (object is unlocked):

  Table 5-20: Controls in **Move** mode (move object)

Control	Description
hold down LMB + drag	Moves the object.
hold down **Ctrl** + LMB + drag	When the **Use dynamic rotation center** option is set to **Never**: Moves the object more slowly.
hold down **Shift** + LMB + drag	When the **Use dynamic rotation center** option is set to **Never**: Moves the object along either the vertical or horizontal screen axis.

Control	Description
hold down **Ctrl** + **Shift** + LMB + drag	When the **Use dynamic rotation center** option is set to **Never**: Moves the object more slowly along either the vertical or horizontal screen axis. When the **Use dynamic rotation center** option is set to **Always** or **Hotkey**: Moves the object along either the vertical or horizontal screen axis.
hold down MMB + move up/down	Moves the object to the back/to the front.
scroll MW up/down	Zooms the object at the POI (point of interest), i.e., at the current mouse pointer position out/in. You can reverse the zoom direction by checking the **Reverse mouse wheel zoom** option in the preferences under **File > Preferences > General > Window > 3D window**.

- The following table lists the controls available in the 3D window for moving the camera (object is locked):

Table 5-21: Controls in **Move** mode (move camera)

Control	Description
hold down LMB + drag	Moves the camera along the object.
hold down **Ctrl** + LMB + drag	When the **Use dynamic rotation center** option is set to **Never**: Moves the camera more slowly along the object.
hold down **Shift** + LMB + drag	When the **Use dynamic rotation center** option is set to **Never**: Moves the camera along either the vertical or horizontal screen axis.
hold down **Ctrl** + **Shift** + LMB + drag	When the **Use dynamic rotation center** option is set to **Never**: Moves the camera more slowly along either the vertical or horizontal screen axis. When the **Use dynamic rotation center** option is set to **Always** or **Hotkey**: Moves the camera along either the vertical or horizontal screen axis.
hold down MMB + move up/down	Moves the camera to the back/to the front.
scroll MW up/down	Zooms the object at the POI (point of interest), i.e., at the current mouse pointer position out/in. You can reverse the zoom direction by checking the **Reverse mouse wheel zoom** option in the preferences under **File > Preferences > General > Window > 3D window**.
press left/right arrow key	Moves the camera along the vertical screen axis.
press up/down arrow key	Moves the camera along the horizontal screen axis.

Unload volume data

Unloads the voxel data of a volume object for which an advanced surface determination has been performed. This option is useful for reducing memory consumption.

Advanced surface determination is a feature of VGSTUDIO MAX. It is not available for myVGL. However, if an advanced surface determination was performed for an object, the results can be viewed in myVGL.

Reload volume data

Reloads the voxel data of a volume object for which an advanced surface determination has been performed.

Advanced surface determination is a feature of VGSTUDIO MAX. It is not available for myVGL. However, if an advanced surface determination was performed for an object, the results can be viewed in myVGL.

Copy visual state/Paste visual state

These commands allow you to copy the visualization information (render settings, active column, visibility of child objects, etc.) of an object in the Scene Tree to one or more other objects in the Scene Tree.

The **Copy visual state**/**Paste visual state** function does not affect the common **Cut**/**Copy**/**Paste** function.

When copying and pasting the visual state between objects of the same type and structure in the Scene Tree, the entire visualization information will be transferred; in all other cases, only the minimal common set of visualization information will be transferred.

If the structure in the Scene Tree between the objects does not match, pasting may lead to minor side effects.

Inspect Tab

Navigation cursor

Activates/deactivates the **Navigation cursor**, which allows for easy navigation in the scene.

The navigation cursor can be positioned and modified in both the 2D windows and the 3D window.

Table 6-1: Controls for the navigation cursor

Control	Description
hold down **Ctrl** + use LMB to click a point in any (2D or 3D) window	Positions the navigation cursor at this point. The specified position will be shown in the other three windows; the 2D windows will update their slice position accordingly. In the 2D windows and the 3D window, the position of the navigation cursor will be displayed as red crosshairs. In the status bar at the bottom of the workspace, the coordinates of the current position in the current coordinate system will be displayed, together with the gray value of the voxel at this position.
use LMB to click and drag navigation cursor	Modifies the position of the navigation cursor. Position and gray value information will be continuously updated according to the new position.

If you are interested in a specific point located on the surface of the object, position the navigation cursor on this point in the 3D window. Each 2D window will display the slice for this position so that you can examine it further.

To return to the navigation cursor position after having scrolled away from it in the 2D windows, you can click the red crosshairs in one of the 2D windows or the 3D window.

Clipping Icon Group

Create a clipping plane, a clipping box, a clipping polyline 3D, an aligned clipping box, a clipping sphere, or a clipping cylinder for the selected object(s).

Using clipping objects allows you to render parts of a volume, CAD, or mesh object transparent, independently of the render settings of the object. This is achieved by cutting away parts of the object using a geometric object, such as a plane or box.

For tetrahedral meshes, only clipping planes can be created.

In order to create a clipping object,

- select **Inspect > <clipping object>**,
- select the **Clipping > <clipping object>** menu item from the context menu of the 3D window, or
- select the **Create > <clipping object>** menu item from the context menu of the Scene Tree.

In order to create a clipping plane that is automatically located at the current slice location in the 2D window from which the clipping plane is created,

- click the icon at the bottom of the 2D window, or
- select the **Clipping >** **Create/replace clipping plane using slice position** menu item from the context menu of the 2D window.

Using one of the clipping objects opens the **Clipping** contextual tab (see section *Clipping Contextual Tab* on page 180).

In order to reset the transformation and scaling of a clipping object to its default values, select the **Reset transformation** menu item from the context menu of the Scene Tree, a 2D window, or the 3D window.

Multiple clipping objects can be combined to achieve more complex clipping regions.

To share a clipping object between multiple volume, CAD, or surface mesh objects, group these objects and define the clipping object for the group. To clip all objects, create a clipping object for the scene.

Clip current slice

Creates or replaces a clipping plane aligned to the view represented by the selected 2D window. Use this function to show the interior of the object at the current slice position. A second click on this button will flip the normal of the clipping plane.

For more detailed information on clipping, see section *Clipping Icon Group* on page 103 in chapter 6 *Inspect Tab* and chapter 20 *Clipping Tool* on page 215.

Clipping plane

Defines a planar object for clipping. Any parts of the volume, CAD, or mesh object that lie above the plane in the direction of its surface normal will be clipped.

- **Rotate** mode

Table 6-2: Controls for the clipping plane in **Rotate** mode

Control	Description
use LMB to click and drag	Rotates the clipping plane around its origin.
hold **Ctrl** key + use LMB to click and drag	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Slowly rotates the clipping plane around its origin.
use MMB to click and drag	Rotates the clipping plane around its origin and the viewing direction.
hold **Ctrl** key + use MMB to click and drag	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Slowly rotates the clipping plane around its origin and the viewing direction.

- **Move** mode

Table 6-3: Controls for the clipping plane in **Move** mode

Control	Description
use LMB to click and drag	Moves the clipping plane relative to the 3D view, i.e., perpendicularly to the viewing direction.
hold **Shift** key + use LMB to click and drag	Moves the clipping plane relative to the 3D view, i.e., perpendicularly to the viewing direction, restricting the movement to the horizontal or vertical direction.
hold **Ctrl** key + use LMB to click and drag	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Slowly moves the clipping plane relative to the 3D view, i.e., perpendicularly to the viewing direction.
hold **Shift** + **Ctrl** keys + use LMB to click and drag	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Slowly moves the clipping plane relative to the 3D view, i.e., perpendicularly to the viewing direction, restricting the movement to the horizontal or vertical direction.
use MMB to click and drag	Moves the clipping plane in/out relative to the 3D view, i.e., along the viewing direction.
hold **Ctrl** key + use MMB to click and drag	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Slowly moves the clipping plane in/out relative to the 3D view, i.e., along the viewing direction.

Clipping box

Specifies a box for clipping. Any parts of the volume object, CAD model, or surface mesh outside the box will be clipped.

- **Rotate** mode

  Table 6-4: Controls for the clipping box in **Rotate** mode

Control	Description
use LMB to click and drag yellow handles	Resizes the clipping box perpendicularly to the sides of the clipping box.
use LMB to click and drag	Rotates the clipping box around its origin.
hold **Ctrl** key + use LMB to click and drag	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Slowly rotates the clipping box around its origin.
use MMB to click and drag	Rotates the clipping box around its origin and the viewing direction.
hold **Ctrl** key + use MMB to click and drag	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Slowly rotates the clipping box around its origin and the viewing direction.

- **Move** mode

  Table 6-5: Controls for the clipping box in **Move** mode

Control	Description
use LMB to click and drag yellow handles	Resizes the clipping box perpendicularly to the sides of the clipping box.
use LMB to click and drag	Moves the clipping box relative to the 3D view, i.e., perpendicularly to the viewing direction.
hold **Shift** key + use LMB to click and drag	Moves the clipping box relative to the 3D view, i.e., perpendicularly to the viewing direction, restricting the movement to the horizontal or vertical direction.
hold **Ctrl** key + use LMB to click and drag	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Slowly moves the clipping box relative to the 3D view, i.e., perpendicularly to the viewing direction.

Control	Description
hold **Shift** + **Ctrl** keys + use LMB to click and drag	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Slowly moves the clipping box relative to the 3D view, i.e., perpendicularly to the viewing direction, restricting the movement to the horizontal or vertical direction.
use MMB to click and drag	Moves the clipping box in/out relative to the 3D view, i.e., along the viewing direction.
hold **Ctrl** key + use MMB to click and drag	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Slowly moves the clipping box in/out relative to the 3D view, i.e., along the viewing direction.

Clipping polyline 3D

Creates a polygonal clipping object in the 3D window by connecting multiple control points with line segments and extending the polygon into the third dimension.

For CAD, surface mesh, and point cloud objects, only the object faces will be clipped.

Table 6-6: Controls for the clipping polyline 3D

Control	Description
hold **Ctrl** key + click with LMB	Creates control points for the polyline. A new point is connected to the previous point by a line segment.
hold **Alt** key + use LMB to click a control point	Removes the control point.
use LMB to click and drag red control point	Moves the control point to a new position.
use LMB to click and drag yellow line segment	Moves the line segment to a new position.
use LMB to click and drag yellow polyline area	Moves the polyline to a new position.

Control	Description
click with MMB	Closes the polyline and extends it into the third dimension along the view direction in the 3D window, thus creating the clipping polygon. The clipping region will be inverted automatically so that the part of the object inside the clipping polygon will be clipped. The shape of the clipping polygon along the view direction depends on the **Projection Mode** selected in the **Camera** tool.
use LMB to click and drag yellow handles at top and bottom of clipping polygon	Resizes the polygon perpendicularly to the top and bottom faces.

☞ The clipping polygon can be created only if the line segments do not cross each other. If the polyline includes crossed line segments, they will be displayed in blue instead of yellow.

The following controls are available for the clipping polygon in the corresponding transformation mode:

☞ Since the clipping polygon is automatically locked on creation, make sure to open the padlock before you apply any of the mouse actions below.

- **Rotate** mode

  Table 6-7: Controls for the clipping polygon in **Rotate** mode

Control	Description
use LMB to click and drag	Rotates the clipping polygon around its origin.
hold **Ctrl** key + use LMB to click and drag	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Slowly rotates the clipping polygon around its origin.
use MMB to click and drag	Rotates the clipping polygon around its origin and the viewing direction.
hold **Ctrl** key + use MMB to click and drag	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Slowly rotates the clipping polygon around its origin and the viewing direction.

- **Move** mode

  Table 6-8: Controls for the clipping polygon in **Move** mode

Control	Description
use LMB to click and drag	Moves the clipping polygon relative to the 3D view, i.e., perpendicularly to the viewing direction.

Control	Description
hold **Shift** key and use LMB to click and drag	Moves the clipping polygon relative to the 3D view, i.e., perpendicularly to the viewing direction, restricting the movement to the horizontal or vertical direction.
hold **Ctrl** key + use LMB to click and drag	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Slowly moves the clipping polygon relative to the 3D view, i.e., perpendicularly to the viewing direction.
hold **Shift** + **Ctrl** keys + use LMB to click and drag	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Slowly moves the clipping polygon relative to the 3D view, i.e., perpendicularly to the viewing direction, restricting the movement to the horizontal or vertical direction.
use MMB to click and drag	Moves the clipping polygon in/out relative to the 3D view, i.e., along the viewing direction.
hold **Ctrl** key + use MMB to click and drag	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Slowly moves the clipping polygon in/out relative to the 3D view, i.e., along the viewing direction.

Clipping sphere

Creates a spherical/ellipsoid object for clipping. Any parts of the volume object outside the sphere/ellipsoid will be clipped.

For CAD, surface mesh, and point cloud objects, only the object faces will be clipped.

- **Rotate** mode

  Table 6-9: Controls for the clipping sphere/ellipsoid in **Rotate** mode

Control	Description
use LMB to click and drag yellow handles	Resizes the clipping sphere/ellipsoid.
hold **Ctrl** key + use LMB to click and drag yellow handles	Resizes the clipping sphere/ellipsoid proportionally.
hold **Alt** key + use LMB to click and drag yellow handles	Forces a clipping sphere and resizes it proportionally.

Control	Description
use LMB to click and drag	Rotates the clipping sphere/ellipsoid around its origin.
hold **Ctrl** key + use LMB to click and drag	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Slowly rotates the clipping sphere/ellipsoid around its origin.
use MMB to click and drag	Rotates the clipping sphere/ellipsoid around its origin and the viewing direction.
hold **Ctrl** key + use MMB to click and drag	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Slowly rotates the clipping sphere/ellipsoid around its origin and the viewing direction.

- **Move** mode

Table 6-10: Controls for the clipping sphere/ellipsoid in **Move** mode

Control	Description
use LMB to click and drag yellow handles	Resizes the clipping sphere/ellipsoid.
hold **Ctrl** key + use LMB to click and drag yellow handles	Resizes the clipping sphere/ellipsoid proportionally.
hold **Alt** key + use LMB to click and drag yellow handles	Forces a clipping sphere and resizes it proportionally.
use LMB to click and drag	Moves the clipping sphere/ellipsoid relative to the 3D view, i.e., perpendicularly to the viewing direction.
hold **Shift** key + use LMB to click and drag	Moves the clipping sphere/ellipsoid relative to the 3D view, i.e., perpendicularly to the viewing direction, restricting the movement to the horizontal or vertical direction.
hold **Ctrl** key + use LMB to click and drag	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Slowly moves the clipping sphere/ellipsoid relative to the 3D view, i.e., perpendicularly to the viewing direction.

Control	Description
hold **Shift** + **Ctrl** keys + use LMB to click and drag	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Slowly moves the clipping sphere/ellipsoid relative to the 3D view, i.e., perpendicularly to the viewing direction, restricting the movement to the horizontal or vertical direction.
use MMB to click and drag	Moves the clipping sphere/ellipsoid in/out relative to the 3D view, i.e., along the viewing direction.
hold **Ctrl** key + use MMB to click and drag	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Slowly moves the clipping sphere/ellipsoid in/out relative to the 3D view, i.e., along the viewing direction.

Clipping cylinder

Creates a cylindrical/conical object for clipping. Any parts of the volume object outside the cylinder/cone will be clipped.

For CAD, surface mesh, and point cloud objects, only the object faces will be clipped.

- **Rotate** mode

  Table 6-11: Controls for the clipping cylinder/cone in **Rotate** mode

Control	Description
use LMB to click and drag yellow handles	Resizes the clipping cylinder/cone.
hold **Ctrl** key + use LMB to click and drag yellow handles	Forces a clipping cylinder.
hold **Alt** key + use LMB to click and drag yellow handle of cone tip	Allows you to form a truncated cone from a cone.
use LMB to click and drag	Rotates the clipping cylinder/cone around its origin.
hold **Ctrl** key + use LMB to click and drag	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Slowly rotates the clipping cylinder/cone around its origin.

Control	Description
use MMB to click and drag	Rotates the clipping cylinder/cone around its origin and the viewing direction.
hold **Ctrl** key + use MMB to click and drag	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Slowly rotates the clipping cylinder/cone around its origin and the viewing direction.

- **Move** mode

Table 6-12: Controls for the clipping cylinder/cone in **Move** mode

Control	Description
use LMB to click and drag yellow handles	Resizes the clipping cylinder/cone.
hold **Ctrl** key + use LMB to click and drag yellow handles	Forces a clipping cylinder.
hold **Alt** key + use LMB to click and drag yellow handle of cone tip	Allows you to form a truncated cone from a cone.
use LMB to click and drag	Moves the clipping cylinder/cone relative to the 3D view, i.e., perpendicularly to the viewing direction.
hold **Shift** key + use LMB to click and drag	Moves the clipping cylinder/cone relative to the 3D view, i.e., perpendicularly to the viewing direction, restricting the movement to the horizontal or vertical direction.
hold **Ctrl** key + use LMB to click and drag	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Slowly moves the clipping cylinder/cone relative to the 3D view, i.e., perpendicularly to the viewing direction.
hold **Shift** + **Ctrl** keys + use LMB to click and drag	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Slowly moves the clipping cylinder/cone relative to the 3D view, i.e., perpendicularly to the viewing direction, restricting the movement to the horizontal or vertical direction.
use MMB to click and drag	Moves the clipping cylinder/cone in/out relative to the 3D view, i.e., along the viewing direction.

Control	Description
hold **Ctrl** key + use MMB to click and drag	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Slowly moves the clipping cylinder/cone in/out relative to the 3D view, i.e., along the viewing direction.

Aligned clipping box

Specifies an aligned box for clipping. The box is aligned to the axes of the bounding box. Any parts of the volume object outside the box will be clipped.

The aligned clipping box is only available for volume objects. It is not available if the scene or a CAD or mesh object is selected.

Table 6-13: Controls for the Aligned clipping box

Control	Description
use LMB to click and drag yellow handles	Resizes the clipping box perpendicularly to the sides of the aligned clipping box.

The aligned clipping box cannot be rotated, moved, or scaled to be any larger than the original volume object on which it was defined.

Clipping Contextual Tab

Instruments Icon Group

With the utilities available in the Instruments icon group of myVGL, you can perform various measurements like distances, angles, and more on your data. Each new instrument will be accompanied by a label that contains the corresponding measured value(s) and represented by an entry in the Scene Tree (see chapter 21 *Scene Tree Tool* on page 218). When you select one of the instruments, the **Instrument** contextual tab, where you can specify their settings, will show up in the ribbon.

Double-clicking an instrument or the **Instruments** entry in the Scene Tree will directly open the **Instruments** tab of the **Object properties** dialog.

Clicking an instrument in a 2D window will highlight the corresponding entry in the Scene Tree.

For useful results, a surface determination of the object must have been performed. Surface determination is a feature available on VGSTUDIO MAX.

General Information

Handling Instruments

To create a dimensioning-style feature from an instrument, click and drag the green measurement line in 2D while the **Dimensioning** dialog is open. This function is available for the **Distance**, **Angle (4 points)**, **Angle (3 points)**, **Min./max. distance**, and **Caliper** instruments.

Displaying Instruments

An instrument is always displayed in the 2D windows, regardless of whether the instrument is located in the current slice. The way the instrument is displayed is subject to its position relative to the current slice. You can modify the instrument properties in the various subsections of the **Preferences** dialog under **File > Preferences > Color & Styles > Coordinate measurement > Instruments** (see section *Colors & Styles Preferences* on page 68 in chapter 3 *File Tab*). The default settings are as follows:

- Display of punctiform measurement instruments (**Indicator** and **Navigation Cursor**):
  - If located in the **current** slice (**Basic style (in the slice plane)**), the lines of the cross-hairs are displayed as solid red lines.
  - If located in a slice **above** the current one (**Near style (in front of the slice plane)**), the lines of the cross-hairs are displayed as dotted red lines.
  - If located in a slice **below** the current one (**Far style (behind the slice plane)**), the lines of the cross-hairs are displayed as dashed red lines.
- Display of linear measurement instruments:
  - If located in the **current** slice (**Basic style (in the slice plane)**), the measurement line is displayed as a solid green line with red handles.
  - If located in a slice **above** the current one (**Near style (in front of the slice plane)**), the measurement line is displayed as a dotted green line with red handles.
  - If located in a slice **below** the current one (**Far style (behind the slice plane)**), the measurement line is displayed as a dashed green line with red handles.

  This also applies to parts of the line. If a line runs diagonally through the object, the upper part is shown as a dashed line, the lower part is shown as a dotted line, and the part in the current slice is shown as solid line.

Instrument Labels

You can specify the positioning of the instrument labels within the view. Move the mouse over the label and click the small button above the upper right corner of the label to switch between the following modes:

- **A** (automatic positioning mode)

  Places the label automatically, thereby avoiding intersections between the label line and the instrument line. This option is only available for the **Distance** and **Caliper** instruments.
- **F** (fixed positioning mode)

Places the label at a fixed position in the respective 2D window.

- **R** (relative positioning mode)
  Places the label at a position relative to the instrument.

Indicator

The **Indicator** instrument consists of 3D cross-hairs that point to a single voxel. Its label contains the gray value of the voxel and its x-/y-/z-coordinates in the units of the selected coordinate system. If the coordinate system is the voxel grid of the object, the position will be given in voxels. If the indicator lies within an ROI, the name of this ROI will also be displayed in the label.

Double-clicking the label in a 2D or 3D window opens a text field where you can enter customized text. Clicking the T button at the right border of the label opens the **Select Font** dialog for specifying font features (e.g., font style and font size) of this individual indicator.

If you want to apply the font changes to all indicators, change the preferences under **File > Preferences > Color & Styles > Annotation layout** (see section *Colors & Styles Preferences* on page 68 in chapter 3 *File Tab*).

The **Indicator** instrument can be positioned and modified in both the 2D and the 3D windows.

Distance

Measures the distance between two points. When you activate this instrument, the **Instrument** contextual tab for specifying the parameters will show up in the ribbon (for details, see section *Instrument Contextual Tab* on page 119).

The **Distance** instrument can be positioned and modified in the 2D windows only.

Tolerance values will be interpreted according to DIN EN ISO 8015 (see also section *Rounding Rules* on page 4 in chapter 1 *Welcome*).

Table 6-14: Controls for the **Distance** instrument

Control	Description
hold down LMB and draw	Draws a line for measuring the distance between the start and end points of the line. To measure another distance with the *same* **Distance** instrument, draw at a new position. To stop modifying a **Distance** instrument, select a different object or deselect the instrument in the Scene Tree. To measure another distance with an *additional* **Distance** instrument, select the **Distance** option again.
use LMB to click and drag handle	Modifies the position of the start or end point.

Control	Description
hold down **Ctrl** + **Shift** + use LMB to click and drag handle	Modifies the position of the start or end point, allowing the current direction of the **Distance** instrument to change only in steps of 45°.
hold down **Shift** + use LMB to click and drag handle	Modifies the position of the start or end point, restricting the measurement line to the horizontal or vertical direction in the respective 2D window.
use LMB to click and drag baseline between handles	Moves the entire **Distance** instrument.

If you want to measure a property (e.g., the material thickness), activate a snap mode (see section *Snap mode Drop-down List* on page 122) so that the handles of the **Distance** instrument will be automatically positioned on the material boundary.

In order to resnap the instrument handles to the surface, click **Resnap instrument handles** on the **Inspect** tab or on the **Instrument** contextual tab (see section *Resnap instrument handles* on page 123).

Apart from the **Distance** instrument, the **Caliper** instrument (see section *Caliper* on page 118) can also be used for measuring distances.

Angle (4 points)

Measures the angle between two edges. The **Angle (4 points)** instrument consists of two lines, each with two handles. When you activate this instrument, the **Instrument** contextual tab for specifying the parameters will show up in the ribbon (for details, see section *Instrument Contextual Tab* on page 119).

The **Angle** instrument can only be positioned and modified in the 2D windows.

Tolerance values will be interpreted according to DIN EN ISO 8015 (see also section *Rounding Rules* on page 4 in chapter 1 *Welcome*).

Table 6-15: Controls for the **Angle (4 points)** instrument

Control	Description
use LMB to click and drag handle	Defines the angle between the two lines, which is displayed in the label of the **Angle** instrument.
hold down **Ctrl** + **Shift** + use LMB to click and drag handle	Changes the current direction of the corresponding line only in steps of 45°.
hold down **Shift** + use LMB to click and drag handle	Modifies the position of the handle, restricting the movement to the horizontal or vertical direction in the respective 2D window.
use LMB to click and drag baseline between handles	Moves the entire **Angle** instrument.

You can activate a snap mode (see section *Snap mode Drop-down List* on page 122) so that the handles of the **Angle** instrument will be automatically positioned on the material boundary.

In order to resnap the instrument handles to the surface, click **Resnap instrument handles** on the **Inspect** tab or on the **Instrument** contextual tab (see section *Resnap instrument handles* on page 123).

Angle (3 points)

Measures the angle between two edges. The **Angle (3 points)** instrument consists of two lines—each with one handle—and a third handle at the intersection of the two lines. When you activate this instrument, the **Instrument** contextual tab for specifying the parameters will show up in the ribbon (for details, see section *Instrument Contextual Tab* on page 119).

The **Angle** instrument can be positioned and modified in the 2D windows only.

Tolerance values will be interpreted according to DIN EN ISO 8015 (see also section *Rounding Rules* on page 4 in chapter 1 *Welcome*).

Table 6-16: Controls for the **Angle (3 points)** instrument

Control	Description
use LMB to click and drag handle	Defines the angle between the two lines which is displayed in the label of the **Angle** instrument.
hold down **Ctrl** + **Shift** + use LMB to click and drag handle	Changes the current direction of the corresponding line only in steps of 45°.
hold down **Shift** + use LMB to click and drag handle	Modifies the position of the handle, restricting the movement to the horizontal or vertical direction in the respective 2D window.
use LMB to click and drag baseline between handles	Moves the entire **Angle** instrument.

You can activate a snap mode (see section *Snap mode Drop-down List* on page 122) so that the handles of the **Angle** instrument will be automatically positioned on the material boundary.

In order to resnap the instrument handles to the surface, click **Resnap instrument handles** on the **Inspect** tab or on the **Instrument** contextual tab (see section *Resnap instrument handles* on page 123).

Polyline length

Measures the outline of an arbitrary shape by fitting a polyline to that shape. The label shows the distance measured along the polyline. When you activate this instrument, the **Instrument** contextual tab for specifying the parameters will show up in the ribbon (for details, see section *Instrument Contextual Tab* on page 119).

The **Polyline length** instrument can be positioned and modified in both the 2D and the 3D windows.

Tolerance values will be interpreted according to DIN EN ISO 8015 (see also section *Rounding Rules* on page 4 in chapter 1 *Welcome*).

Table 6-17: Controls for the **Polyline length** instrument

Control	Description
2D window: click with LMB 3D window: hold down **Ctrl** + click with LMB	Creates control points for the **Polyline length** instrument. The new points are added to the start or end of the polyline, depending on whether the cursor is nearer to the current start or end point, respectively. The start and end points are distinguished from the other points by their different display. Each successive line segment adds to the total length.
2D window: click with MMB between existing points 3D window: hold down **Ctrl** + click with MMB between existing points	Adds a new point.
2D window: click with MMB on point 3D window: hold down **Ctrl** + click with MMB on point	Removes the point.
use LMB to click and drag point	Moves the point to a new position.
2D window: use LMB to click and drag baseline between handles	Moves the entire **Polyline length** instrument.
hold down **Alt** + scroll MW	Scales the polyline.
hold down **Alt** + **X** or **Y** + scroll MW	Scales the polyline only in the x- or y-direction.

You can activate a snap mode (see section *Snap mode Drop-down List* on page 122) so that the handles of the **Polyline length** instrument will be automatically positioned on the material boundary.

In order to resnap the instrument handles to the surface, click **Resnap instrument handles** on the **Inspect** tab or on the **Instrument** contextual tab (see section *Resnap instrument handles* on page 123).

Caliper

Measures the distance between two points. When you activate this instrument, the **Instrument** contextual tab for specifying the parameters will show up in the ribbon (for details, see section *Instrument Contextual Tab* on page 119).

The **Caliper** instrument can be regarded as a **Distance** instrument (see section *Distance* on page 115) that is enhanced by an additional line at each end. The additional lines are at right angles to the distance measurement line. Use the additional line to position one end of the

distance measurement line perpendicular to a surface. Move the other end of the distance measurement line to another position (e.g., onto the opposite surface) to measure the distance.

The **Caliper** instrument can only be positioned and modified in the 2D windows.

Tolerance values will be interpreted according to DIN EN ISO 8015 (see also section *Rounding Rules* on page 4 in chapter 1 *Welcome*).

Table 6-18: Controls for the **Caliper** instrument

Control	Description
hold down LMB and drag	Draws a line for measuring the distance between the start and end points of the line.
use LMB to click and drag middle handle	Modifies the position of the start or end point.
use LMB to click and drag handle of additional line	Modifies the position of the handle of the additional line, while the caliper instrument changes accordingly.
hold down **Ctrl** + **Shift** + use LMB to click and drag handle	Modifies the position of the handle, allowing the current direction of the measurement line to change only in steps of 45°. This key combination is also helpful if you want to adjust the measurement line or the additional line while keeping its direction.
hold down **Shift** + use LMB to click and drag handle	Modifies the position of the handle, restricting the measurement line to the horizontal or vertical direction in the respective 2D window.
use LMB to click and drag baseline between handles	Moves the entire **Caliper** instrument.

You can activate a snap mode (see section *Snap mode Drop-down List* on page 122) so that the handles of the **Caliper** instrument will be automatically positioned on the material boundary. First, have the handles of the additional line of one side of the **Caliper** instrument snap to the surface. Then, hold down **Ctrl** + **Shift** and have the middle handle of the other side of the **Caliper** instrument snap to the surface.

In order to resnap the instrument handles to the surface, click **Resnap instrument handles** on the **Inspect** tab or on the **Instrument** contextual tab (see section *Resnap instrument handles* on page 123).

If you change the coordinate system, the additional lines of the **Caliper** instrument will not be displayed. They will become visible again when you return to the coordinate system in which they have been created.

Instrument Contextual Tab

The **Instrument** contextual tab will be displayed in the ribbon when you create an instrument or an already created instrument is selected in the Scene Tree. It provides the following controls for specifying the settings for the instruments.

Table 6-19: Controls on the **Instrument** contextual tab

Control	Description
Cancel button	Closes the contextual tab.
<instrument type>	Indicates the currently selected instrument type.
Actual [<length unit>/<angle unit>]	Indicates the numerical value of the instrument.
status field	Provides status information on the instrument. For a list of possible status messages, see section *Status Messages* on page 121.
Use actual as nominal button	Clicking this button will set the actual value of the current measurement instrument as the nominal value.
Nominal [<length unit>/<angle unit>] spin box	Specifies the nominal value of the instrument.
Tolerance (lo)/Tolerance (hi) [<length unit>/<angle unit>] spin boxes	Specify the allowed tolerance of the actual value towards the given nominal value of the feature. If both values have not yet been set, you can create a symmetric tolerance range by entering a **Tolerance (hi)** value. **Tolerance (lo)** will automatically be set to the same value, but with a negative sign. Similarly, you can enter a negative **Tolerance (lo)** value; **Tolerance (hi)** will then automatically be set to the same value, but with a positive sign. You can also change both tolerances independently, such as when entering two negative or two positive tolerances, respectively).
Linear – Bent slider	For **Polyline length** instrument only: Adjusts the curvature of the polyline: • **Linear**: Connects the points with lines. • **Bent**: Connects the points with a spline.
Indicator	Activates the **Indicator** instrument (see section *Indicator* on page 115).
Distance	Activates the **Distance** instrument (see section *Distance* on page 115).
Angle (4 points)	Activates the **Angle (4 points)** instrument (see section *Angle (4 points)* on page 116).
Angle (3 points)	Activates the **Angle (3 points)** instrument (see section *Angle (3 points)* on page 117).
Polyline length	Activates the **Polyline length** instrument (see section *Polyline length* on page 117).
Caliper	Activates the **Caliper** instrument (see section *Caliper* on page 118).

Control	Description
Snap mode drop-down list	Opens the **Snap mode** drop-down list (see section *Snap mode Drop-down List* on page 122).
Resnap instrument handles	Opens the **Instrument handle adjustment** dialog (see section *Resnap instrument handles* on page 123).

Status Messages

The following table gives an overview of the possible status messages in the **Instrument** contextual tab:

Table 6-20: Status messages for instruments

Status	Description
OK	No errors or warnings. The instrument handles have snapped to the surface. A tolerance range has been defined and the measurement instrument meets the tolerance. The background of the field and the evaluation indicator in the Scene Tree are shown in green.
No tolerance	No errors or warnings. The instrument handles have snapped to the surface. No tolerance has been specified. The background of the field is shown in green and the evaluation indicator in the Scene Tree is shown in gray.
Out of tolerance	The instrument handles have snapped to the surface, but the actual value of the measurement instrument lies outside the specified tolerance range. The background of the field and the evaluation indicator in the Scene Tree are shown in red.
Invalid definition	The current definition of the instrument does not yield any values. The background of the field is shown in red.
Handles not snapped	One or more instrument handles have not snapped to the surface. No evaluation is possible. The background of the field is shown in orange and the evaluation indicator in the Scene Tree is shown in gray and has a warning sign.

Indicator template Drop-down List

Import indicator template

Imports a template of indicators (*.xvgt*) that contains information on their positions, names, and group affiliation.

In order to import an indicator template, you can also right-click a volume object, CAD model, or surface mesh in the Scene Tree and select **Import > Indicator(s)…** from the context menu.

By selecting the **Text/CSV files (*.*)** option in the **Import indicator template…** dialog, you can also import indicators from a CSV (comma-separated values) file of the structure "Position x;Position y;Position z." The global unit settings (see section *Units Drop-down List* on page 33 in chapter 2 *Workspace*) will be applied to the values. The values can be separated by semicolon, colon, space, or comma. If a value contains a comma, the comma can be interpreted as a decimal point. Lines that contain non-numeric characters will be disregarded during import.

Export indicator template

Exports a template (*.xvgt*) of the selected indicators that contains information on their positions, names, and group affiliation. You can use this template later on for similar objects.

In order to export an indicator template, you can also right-click one or more indicators in the Scene Tree and select **Export > Indicator(s)…** from the context menu.

To export indicators to a CSV (comma-separated values) file that you can import in myVGL, double-click the corresponding **Instruments** entry in the Scene Tree to open the **Object properties** dialog, hide all columns on the **Instruments** tab except for **Position x [<length unit>]**, **Position y [<length unit>]**, and **Position z [<length unit>]**, right-click the table, and select **Export as CSV** from the context menu.

Snap mode Drop-down List

Displays a square snap frame to automatically snap the points and handles set for an instrument within the frame. The snap works for volume objects, CAD models, and surface meshes in the 2D views. If the surface of a volume object has been determined, the surface can be used for snapping (for details on surface determination, see section *Surface determination* on page 949 in chapter 48 *Glossary*).

The default snap mode and the snap frame can be defined in the preferences under **File > Preferences > General > Snap frame** (see section *General Preferences* on page 57 in chapter 3 *File Tab*).

The color of an instrument handle that snapped to the surface will change to yellow, and a small line will indicate the surface normal vector.

If you want to set the points and handles exactly where you click, disable the snap mode.

Use one of the following snap modes for the instruments in the 2D view:

Table 6-21: **Snap mode** items

Icon	Item	Description
	Min	Snaps to the lowest gray value in the snap frame.
	Max	Snaps to the highest gray value in the snap frame.
	Gradient	Snaps to the position with the largest difference in gray value in the snap frame.
	Surface	Snaps to the nearest surface created by the surface determination in the snap frame. The color of an instrument handle that snapped to the surface will change to yellow, and a small line will indicate the surface normal vector. If there is no surface determination present, this mode will work like the **Local** snap mode.
	Local	Performs a temporary local surface determination within the snap frame and snaps to the resulting temporary surface.
	Off	Switches the snap mode off.

The different snap modes are only relevant for volume objects; for CAD models and surface meshes, the handles will always snap to the surface independently of the selected snap mode.

Resnap instrument handles

Opens the **Instrument handle adjustment** dialog for resnapping the handles of a **Distance**, **Angle**, **Polyline length**, or **Caliper** instrument to the nearest surface within the specified snapping distance, in the direction of either the surface normal (for the **Polyline length** and **Angle** instruments) or the distance line (for the **Distance** and **Caliper** instruments). Resnapping is performed in the slice where the instrument is located, except for the **Polyline length** instrument, which also works in the 3D window. The color of an instrument handle that snapped to the surface will change to yellow, and a small line will indicate the surface normal vector.

Resnapping will always work in **Surface** snap mode independently of the currently active snap mode.

Table 6-22: Controls in the **Instrument handle adjustment** dialog

Control	Description
Resnap handles to surface checkbox	When this option is checked, the handles will be resnapped to the surface by using the specified **Snapping distance**. When this option is unchecked, no resnapping will be performed.
Snapping distance spin box	Specifies the distance from the position of the handle in the direction of either the surface normal (for the **Polyline length** and **Angle** instruments) or the distance line (for the **Distance** and **Caliper** instruments) to search for the surface.

Annotation

Opens the **Annotation** contextual tab to create a new annotation for the analysis selected in the Scene Tree. An annotation can be used to show analysis results and data values at a specific location in the data set.

You can also access the **Annotation** contextual tab by right-clicking the desired analysis in the Scene Tree and selecting **Create >** **Analysis annotation** from the context menu.

Creating/moving annotations might be disallowed by the creator of the *.vgl* file.

The following controls are available on the **Annotation** contextual tab:

Table 6-23: Controls on the **Annotation** contextual tab

Control	Description
Cancel button	Closes the contextual tab.
Name template field	Allows you to enter a name for the annotations. If no name is provided, a name of the form *<annotation type> <id>* will automatically be generated.
Reset button	Resets the name template to the default entry.
Min. tolerance [<length unit>] spin box	If applicable: Allows you to manually specify the minimum tolerance of the selected parameter.
Max. tolerance [<length unit>] spin box	If applicable: Allows you to manually specify the maximum tolerance of the selected parameter.

Control	Description
Set from analysis button	If applicable: By default, the global tolerances specified on the **Settings** tab of the analysis are used for the annotation. Clicking the **Set from analysis** button toggles between manually specifying the tolerance band in the tolerance fields and using the global tolerances of the analysis.
Shape drop-down list	For P 202/P 201 analyses: Allows you to select an appropriate shape to define reference areas for which the porosity will be calculated: • **Square** • **Circle** • **Triangle** • **Rectangle**

To create an annotation, hold down the **Ctrl** key and click into any 2D window or the 3D window to position the annotation.

A movable label is attached to the annotation, which displays information on the current analysis. The values displayed in the annotation label depend on the selected analysis.

- An annotation label of a *porosity/inclusion analysis* includes the following information:
  - the name of the annotation
  - the position of the annotation
  - the volume of the indication
  - the probability of the indication
  - the diameter of the indication
  - if calculated, the porosity at the current position of the annotation
  - if available, the property selected in the **Active column** drop-down list
- An annotation label of a *nominal/actual analysis* includes the following information:
  - the name of the annotation
  - the position of the annotation
  - the deviation from the nominal object
  - if available, the specified tolerance values

  The deviation value is color coded according to the **Color mode** selected in the **Annotations** section on the **Colors** tab of the **Nominal/actual comparison** dialog (see section *Annotations Section* on page 422 in chapter 28 *Nominal/Actual Comparison*).
- An annotation label of a *wall thickness analysis* includes the following information:
  - the name of the annotation
  - the position of the annotation
  - the wall thickness
  - if available, the specified tolerance values

  The wall thickness value is color coded according to the **Color mode** selected in the **Annotations** section on the **Colors** tab of the **Wall thickness analysis** dialog (see section *Annotations Section* on page 459 in chapter 29 *Wall Thickness Analysis Module*).

- An annotation label of a *displacement analysis* includes the following information:
  - the name of the annotation
  - the position of the annotation on the actual object
  - the displacement, i.e., the distance between the current annotation position on the actual object and the corresponding point on the nominal object
  - the displacement vector at the position of the annotation
  - the position on the nominal object that corresponds to the position of the annotation on the actual object
- An annotation label of a *fiber composite material analysis* contains includes the following information:
  - the name of the annotation
  - the position of the annotation
  - if available, the specified tolerance values
  - if available, the fiber volume fraction
  - if available, the orientation (**Space orientation** mode), deviation angle (**Reference orientation** mode), or projected angle (**Plane projection** mode), respectively
  - if available, the property selected in the **Active column** drop-down list (**Integration mesh** mode and **Layered integration mesh** mode)
- An annotation label of a *foam/powder analysis* includes the following information:
  - the name of the annotation
  - the position of the annotation
  - the cell volume
  - if calculated, the cell surface, sphericity, and strut thickness at the current position of the annotation
  - if available, the property selected in the **Cell active column** drop-down list
- An annotation label of a *gray value analysis* includes the following information:
  - the name of the annotation
  - the position of the annotation
  - the gray value at the position of the annotation
  - if calculated, the local density at the current position of the annotation
  - if available, the specified tolerance values
- An annotation label of a *structural mechanics simulation* includes the following information:
  - the name of the annotation
  - the position of the annotation
  - the von Mises stress
  - if calculated, the von Mises strain, the maximum shear stress, the maximum principal stress, the magnitude of displacement as well as the displacement at the current position of the annotation
- An annotation label of a *digital volume correlation* includes the following information:
  - the name of the annotation
  - the position of the annotation
  - the displacement

- if calculated, the von Mises strain

An evaluation indicator is visible in front of the annotation name, indicating whether the tolerance at the position of the annotation is met (green) or not (red). For details on the color of the evaluation indicator, see section *Entries in the Scene Tree* on page 218 in chapter 21 *Scene Tree Tool*.

The following controls are available for annotation labels:

Table 6-24: Controls for annotation labels

Control	Description
use LMB to double-click anywhere within the annotation label	Minimizes/maximizes the annotation label.
use RMB to click anywhere within a window	Opens a context menu with the **Annotations** menu item, see the table below.
use RMB to click anywhere within the annotation label	Opens a context menu that additionally offers the **Annotation result** menu item where you can select the property to be displayed as default result for the annotation. The selected property is highlighted in bold in the annotation label and displayed in the Scene Tree next to the annotation name.
F button	Fixed positioning mode: Places the annotation label at a fixed position in the respective 2D window, for example when zooming in or out.
R button	Relative positioning mode: Places the annotation label at a position relative to the annotation in the respective 2D window, for example when zooming in or out.

A closed padlock symbol next to the annotation name in the annotation label indicates that this annotation was not created manually but by a rule (for example, defined on the **Rules** tab of the analysis dialog) or automatically (for example, by checking the corresponding option on the **Settings** tab of the analysis dialog). Rule-based and automatically created annotations can neither be moved nor deleted.

The **Annotations** menu item consists of the following submenu entries:

Table 6-25: Controls of the **Annotations** menu

Control	Description
Arrange	Automatically arranges the annotations in the current window according to the settings in the **Preferences** dialog.
Minimize	Minimizes all annotations.
Maximize	Maximizes all annotations.
Configure...	Opens the **Preferences** dialog where you can modify the properties for the annotations. For details, see section *Colors & Styles Preferences* on page 68 in chapter 3 *File Tab*.

Double-clicking an annotation in the Scene Tree will directly open the **Annotations** tab of the properties dialog of the corresponding analysis.

Live Value

Activates or deactivates the **Live value** label. When activated, hovering the mouse pointer over a color-coded area of an analysis will display the value corresponding to that color.

When you hover over multiple color overlays, the values for each overlay will be displayed.

When the **Live value** label is visible, pressing the left mouse button will open a pop-up dialog with annotation previews for each active color overlay and the option to create new annotations.

Table 6-26: Controls in the **Live value** pop-up dialog

Control	Description
Annotation preview(s)	Displays for each color overlay new annotations as preview.
Create button	Creates a new annotation according to the preview.
Open and select button	Opens the corresponding analysis and—if available—selects the corresponding entry in the table with the results of the analysis.

Select objects (3D)

Allows you to select objects directly in the 3D window by drawing a rectangle, ellipse, or lasso, respectively.

To enter the object selection mode, you can also use the default shortcut **Ctrl**+**Shift**+**D**.

The **Select objects (3D)** contextual tab will open, where you can specify the selection settings, such as the object type. See chapter 15 *Select objects (3D) Contextual Tab* on page 188.

As long as the **Select objects (3D)** mode is active, the center of mass of selectable objects will be represented by dots that change their color according to their status:

- gray: unselected
- blue: selected
- orange: highlighted

To improve the visibility of the objects, it is recommended that you increase the transparency of the render object.

The following controls are available in the 3D window:

Table 6-27: Controls in the 3D window

Control	Description
hover the mouse pointer over a center of mass	Shows a label that indicates the type and name of the corresponding object and changes the color of the center of mass to orange.
click and drag in 3D window	Draws a rectangle, ellipse, or lasso, respectively, to select the objects whose center of mass is within the shape. When the center of mass of an object is highlighted in blue, the object is selected. On releasing the mouse button, you will quit the object selection mode.
hold down **Ctrl** + click and drag in 3D window	Draws a rectangle, ellipse, or lasso, respectively, to select or add to the selection the objects whose center of mass is within the shape. On releasing the **Ctrl** key, you will quit the object selection mode.
hold down **Shift** + click and drag in 3D window	Draws a rectangle, ellipse, or lasso, respectively, to deselect the objects whose center of mass is within the shape. On releasing the **Shift** key, you will quit the object selection mode.
hold down **Ctrl** and click the center of mass of an object	Adds the corresponding object to the selection.
hold down **Shift** and click the center of mass of an object	Removes the corresponding object from the selection.
Esc key	Cancels object selection and quits the object selection mode.

CM results

Opens the **CM results** dialog, which allows you to view, edit, and print detailed information on the geometry elements and GD&T features connected to the volume object, CAD model, or surface mesh selected in the Scene Tree. The name of the selected volume object, CAD model, or surface mesh is shown in the caption of the dialog. For details, see section *CM results dialog* on page 264.

CM overview

Opens the **CM overview** dialog, which provides an overview of all GD&T features and geometry elements included in the currently open project. This dialog allows you to compare coordinate measurement results of multiple parts in a project. For details, see section *CM overview dialog* on page 276.

Reporting Tab

Introduction

The controls of the **Reporting** tab allow you to view, create, and edit one or more reports in the currently open project and export them as a *.pdf* file.

A report created using the **Create report** control of the **Reporting** tab initially contains all reportable content belonging to the analyses or objects that have been selected for reporting. You can easily select the objects to be reported by highlighting them in the Scene Tree or checking or unchecking the items in the tree view shown in the **Create report** dialog (for details, see section *Create report* on page 131). After the report has been created, it will be listed on the **Reporting** tab together with all reports that are available for the currently open project. You can click a report to select it and select **Open report** to open the **myVGL reporting** dialog where you can edit it.

The **Reporting** function currently does not support transport phenomena simulations and structural mechanics simulations. If a report is created that includes such an analysis, the analysis will be listed in the **Sections** section with the corresponding group header but without any sections.

All reported coordinates are scene coordinates.

Reports created with newer software versions can only be viewed in compatibility mode in the current software version and therefore cannot be edited.

You can find more information about integrated reporting in the Knowledge Base of the VG Community in Nexus.[1]

Create report

Opens the **Create report** dialog, where you can select the analyses and objects to be included in the report.

The following controls are available in the **Create report** dialog:

Table 7-1: Controls of the **Create report** dialog

Control	Description
Name field	Allows you to assign a name to the report.

[1] https://nexus.hexagon.com/

Control	Description
Advanced button	Expands or collapses the **Advanced** section, which provides access to the **Image settings** and the **Specific layout information** tabs: • On the **Image settings** tab, you can specify the image render settings of the selected report (for details, see section *Image settings section*). • The **Specific layout information** tab shows the objects referenced by the specific report layout and indicates whether the objects required for the references to be resolved are present. It also indicates if objects are selected that were not present in the original report. In this case, a specific report layout will not work.
Contents section	Shows a tree view of all objects of the currently open project that contain data for reporting, such as analysis results or object properties. The object currently highlighted in the Scene Tree and its associated child elements are preselected. Check the checkbox in front of a tree item to select or deselect the item (including its child items) in order to include it in or exclude it from the report. Note that if you want to select a **3D surface** item of a volume object, this object must have a surface determination.
3D surfaces and results section	Allows you to include 3D surfaces and 3D results for certain elements in the report. In the **myVGL reporting** dialog, you can view and interact with this content. • Click the **Check for all currently selected objects** button if you want to include 3D content for all objects currently selected for reporting. The amount of 3D content that will be created and included in the report will be displayed below the button. • Click the **Uncheck all** button if you do not want to include any 3D content in your report. Note that this content provides less detail than the original result data and is only intended for illustrative purposes. 3D content will automatically become static images when reports are exported as PDF.

Control	Description
Report layout field	If no user-defined layout is selected when you create a new report, a built-in default layout will be used for creating the report. Click the **Select** button below the **Report layout** field to select a previously saved layout from the drop-down list. The drop-down list contains the 10 previously used unique report layouts sorted by the time they were last used. Only applicable if a default report layout was used to create the original report: When an existing report is updated, the layout that was originally used to create the report will automatically be set as default in the **Report layout** field. If you want to change a selected layout, you can choose another default layout from the drop-down list. This will then be applied only to the newly added objects. Click the **Clear** button to remove the selected report layout from the field and return to the built-in default layout.
Open report after creation checkbox	This option is checked by default. Uncheck this option if you do not want the report to open immediately upon creation. All reports created in a project can be accessed on the **Reporting** tab. They can be opened for editing and viewing at any time.
Create button	Creates a report with the specified settings.
Cancel button	Closes the dialog without creating the report.

- **Image settings** section

  If an object for which images can be created is highlighted in the **Contents** section, you can specify individual image render settings that will be used for the images created for this object only. If **Scene** is highlighted in the **Contents** section, you can specify settings that will be used when generating images for objects for which no individual settings have been specified.

  The following options are available in the **Image settings** section:

  - **Use the image creation settings specified for the scene** checkbox: Check this option if you want to use the image render settings of the scene instead of the individual image render settings specified for the highlighted object.
  - **General render settings** section

    Allows you to customize the display of all automatically created images.

Table 7-2: Controls in the **General render settings** section

Control	Description
Image size spin box	Specifies the number of pixels for the larger side of the image. The other side is calculated to keep the aspect ratio. This option will not affect external custom images added to the report; however, all other images in the report will not exceed the specified value.
Visibility drop-down list	Available for analyses: • **Automatic**: Only the selected analysis and its parent objects are included in the images. All other Scene Tree items, such as geometry elements, GD&T features, and other analyses, will be hidden. • **From Scene Tree**: All objects currently set to visible in the Scene Tree are included in the images.

- **Content render settings** section

  Allows you to customize the display of all automatically created images.

This option does not affect the screenshots created using the **Capture from** button or the automatic 3D images.

Table 7-3: Controls in the **Content render settings** section

Control	Description
Display mode field	Specifies the coloring of the images (for details on the display modes, see section *Display mode Drop-down List* on page 168 in chapter 8 *Window Tab*).
Background color field	Double-clicking the field opens the **Select Color** dialog where you can set the background color of the images.
Text overlay, **Tripod**, **Scale bar** checkboxes	Check any of these options to include the corresponding information in the images.

- **Focused image** section

Table 7-4: Controls in the **Focused image** section

Control	Description
Zoom factor spin box	Sets the zoom level for the focused images you specified in the respective tables.

Report Selection Icon Group

Lists all reports that are available in the currently open project. An arrow in the icon of a report indicates that it contains at least one absolute reference.

Open report

Opens the **myVGL reporting** dialog, where you can view and edit the selected report.

myVGL reporting Dialog

The **myVGL reporting** dialog lists the reported objects and defines the layout of the reported content and background information. It consists of the **Sections** section on the left-hand side, the main area in the middle, the **Section properties**/**Element properties** section on the right-hand side (only visible in **Edit** mode), and several buttons at the top.

The following controls are available at the top of the **myVGL reporting** dialog:

Table 7-5: Controls at the top of the **myVGL reporting** dialog

Icon	Control	Description
	Save	Saves the current modifications applied to the layout.
	Export	• **Export as HTML document**: Opens the **Export as HTML** dialog, where you can select a path and a file name to save the report in the currently defined layout. The HTML report is intended for viewing only and cannot be edited. It provides the same content and interactive features as the integrated report and does not have any dependencies to other files or web resources. It can be viewed in any Chromium-based browser (such as Google Chrome or Microsoft Edge). • **Export as PDF document**: Opens the **Export as PDF** dialog, where you can select a path and a file name to save the report in the currently defined layout. When you export a report containing 3D elements from the editor, these elements are saved as 2D images showing the current state of the viewport.
	Undo	If available: Undoes the latest action.

Icon	Control	Description
	Redo	If available: Redoes the latest action.
	Snapping	Available only if **Edit** mode is selected. This button is enabled by default and allows you to align page elements on the content page or with each other, or to align background elements on the background of the report or with each other.
	View/Edit	Toggles between **View** and **Edit** mode.
	Content/Background	Available only if **Edit** mode is selected. Toggles between **Content** and **Background** for editing the reported content or the background information that will be displayed on each page of the report.
	Add info	Available only if **Edit** mode is selected. Opens a drop-down list, where you can select the information to be added to the current content section (if **Content** mode is selected) or the background of the report (if **Background** mode is selected).
	Add image	Available only if **Edit** mode is selected. • In **Content** mode: Opens a drop-down list, where you can select an image to be added to the current content section of the report. • In **Background** mode: Opens a file browser, where you can select an image to be added to the background of the report.
	Add text	Available only if **Edit** mode is selected. • In **Content** mode: Opens a drop-down list, where you can select an editable text box or a text label to be added to the current content section of the report. • In **Background** mode: Adds an editable text box to the background of the report.
	Add attributes	Available only if **Content** mode is selected for editing. Opens a drop-down list, where you can select attributes to be added to the current content section of the report.
	Add table	Available only if **Content** mode is selected for editing. Opens a drop-down list, where you can select a table to be added to the current content section of the report.
	Add 3D view	Available only if **Content** mode is selected for editing. Opens a drop-down list, where you can select a 3D view to be added to the current content section of the report.

Icon	Control	Description
	FAQ	Opens the FAQ page on reporting in the Knowledge Base of the VG Community in Nexus.
	Exit	Closes the report if no changes have been made. Otherwise, the **Save changes** message box will appear, where you can click **Yes** to save the report and close the editor, **No** to close the editor without saving the report, or **Cancel** to return to the editor without saving the report.

View Mode

- **Sections** section

  The reported data is listed in the **Sections** section and subdivided into section groups that consist of a headline that indicates the scene path of the reported object and the associated sections, such as object properties, analysis results, GD&T features, and images. Clicking on a section will highlight it and show the corresponding page in the main area. If a section consists of more than one page, the view in the main area will jump to the first page of the section.

The section **3D surface** exists only for CAD, mesh, and volume objects.

At the top of the section group list is the **Scene** section group, which does not contain sections by default (for information on how to add sections to this group, see the **Edit** mode described below).

- Main Area

  The main area shows the reported content according to the section that is currently highlighted in the **Sections** section. Each page is divided into content and background information. The background information, such as project name, date, and page number, will be displayed on each page of the report.

  The following buttons are available at the bottom of the main area:

  Zoom in/**Zoom out** buttons: Zoom the main area in/out.

A very fast and convenient method to zoom in or out is to position the mouse pointer over the main area and scroll the mouse wheel while holding down **Ctrl** (the zoom direction follows the setting specified in the **Reverse mouse wheel zoom** option in **File > Preferences > General > Window > 2D windows**).

Fit to screen button: Resets the zoom so that the report fits to the screen.

The report will remain fitted to the screen automatically as long as the zoom is not manually changed.

If the main area contains a 3D element, a light gray border and a 3D overlay will appear when you hover over it. Clicking the 3D overlay allows you to interact with the 3D content. Possible interactions include zooming and basic camera movements. To exit interaction mode, click in the main area outside the light gray border of the 3D element. Interactions in **View** mode will not be saved. When you switch to **Edit** mode, the original state of the 3D elements will be displayed.

Some 3D elements display indication information. The currently relevant indication will be marked by red cross-hairs in the 3D images, so you get a better idea of the position of the indications. You can toggle between two different view modes by clicking the small icon in the upper left corner of the viewport. The appearance of the icon depends on the selected view mode:

- Click the icon if you want to get full camera control and display the same image through all pages.
- Click the icon if you want the camera to rotate around the indication. The zoom factor will remain the same through all pages, but the image will change to focus the indication that is shown in the 2D view.

To exit interaction mode, click in the main area outside the light gray border of the 3D image.

Edit Mode

When you switch from **View** to **Edit** mode, the **Content**/**Background** buttons will become available and allow you to toggle between content and background editing. Depending on the selected mode, additional buttons will become available to add various information to the content or the background of the report. Dashed lines will appear in the main area to indicate the margins of content and background area and thus make it easier to position content and images more accurately.

When you click **Content** or **Background**, the following options will be available for editing the list of reported objects in the **Sections** section and the content or background displayed in the main area:

Table 7-6: Controls available in **Edit** mode

Control	Description

Add info button	• **Content** mode: Opens a drop-down list, where you can select the information to be shown in the current content section. The list is subdivided into the following sections:
	  • The first section includes the information types **Date/time**, **Project name**, **Page number**, **Section name**, and **Scene evaluation state**, which refer to the report in general.
	  • The second section includes the information types **Object type**, **Object name**, **Scene path**, and **Object evaluation state**, which refer to the section group the current content section belongs to, and which are available for all section groups of the report.

Control	Description
	• The third section is only available if the corresponding information types are applicable to the section group the current content section belongs to. In volume section groups, it includes **Component info**, **Manufacturer info**, and **Scan info**, in section groups that are children of a volume object, it includes **Component info of parent volume**, **Manufacturer info of parent volume**, and **Scan info of parent volume**, and in analysis and coordinate measurement section groups, it additionally includes **Analysis date/time**. • **Background** mode: Opens a drop-down list, where you can select the information to be shown in the background of the report. The list is subdivided into several sections which are described below. The information fields in the background get the information from the report itself and will adapt to the content section that is currently active in the main area. • The first section includes the information types **Date/time**, **Project name**, **Page number**, **Section name**, and **Scene evaluation state**, which refer to the report in general. • The second section includes the information types **Object type**, **Object name**, **Scene path**, and **Object evaluation state**, which will adapt to the current content section. • The third section includes the information types **Analysis date/time (if available)**, **Component info (if available)**, **Manufacturer info (if available)**, and **Scan info (if available)**. The corresponding information will be shown if available for the section group the current content section belongs to. Otherwise the information field will be empty, but the information type will be shown in the **Element data source** section of the **Element properties** section.

Control	Description

Add image button	• **Content** mode: Opens a drop-down list, where you can select the image(s) to be added to the current content section:
	  • **Custom image**: Opens the **Select image file** dialog, where you can select an image or an animated image to be added to the current content section.
	  Supported file formats are JPEG images (*.*jpg*), PNG images (*.*png*), SVG images (*.*svg*), and GIF animation (*.*gif*).
	  • **Dynamic from section group**: Opens a list of dynamic images belonging to the selected section group. Dynamic images can be present in an arbitrary number so that they will create multiple pages in the report, for example, indication images, bookmark snapshots, or annotation images.
	  • **Static from section group**: Opens a list of static images belonging to the selected section group, i.e., images that are fixed and will create a single page in the report, for example, feature plots or statistics.
	• **Background** mode: Opens the **Select image file** dialog, where you can select an image or a logo to be added to the background of the report.
	Tip: You can also add images directly from other applications, for example, Microsoft® PowerPoint, by using the copy and paste function.

Add text button	• **Content** mode: Opens a drop-down list, where you can select an editable text box or a fixed text label to be added to the current content section:
	  • **Custom text**: Adds a text box to the current content section, where you can edit text either by directly double-clicking into the box or by clicking the pencil icon in the left corner of the box.
	  You can resize the box by clicking and dragging the handles. The text will be wrapped according to the box. You can move the box to a different position by clicking and dragging its frame.

Control	Description
	• **Dynamic from section group**: Opens a list of dynamic text labels belonging to the selected section group that are associated with dynamic objects, for example, bookmark names. • **Static from section group**: Opens a list of static text labels belonging to the selected section group that are fixed, for example, analysis settings captions. • **Background** mode: Opens a text box, where you can edit text either by directly double-clicking into the box or by clicking the pencil icon in the left corner of the box. You can resize the box by clicking and dragging the handles. The text will be wrapped according to the box. You can move the box to a different position by clicking and dragging its frame. Tip: You can also add text directly from other applications, for example, PowerPoint, by using the copy and paste function.
Add attributes button	Available only in **Content** mode: Opens a drop-down list, where you can select the attributes to be added to the current content section: • **Dynamic from section group**: Opens a list of dynamic attributes belonging to the selected section group that are associated with dynamic objects such as indication images, for example, indication image info or annotation info. • **Static from section group**: Opens a list of attributes belonging to the selected section group that have a fixed size, for example, analysis parameters.
Add table button	Available only in **Content** mode: Opens a drop-down list, where you can select a table to be added to the current content section: • **Overview**: Opens a list of overview tables that can be used to compare all results of a kind in the report, for example, the coordinate measurement results for all volumes. • **Dynamic from section group**: Opens a list of tables belonging to the selected section group that can have an arbitrary number of rows, for example, indication tables. • **Static from section group**: Opens a list of tables belonging to the selected section group that have a fixed amount of rows, for example, the tables that show metainformation.

Control	Description
Add 3D view button	Available only in **Content** mode: Opens a drop-down list, where you can select a 3D view to be added to the current content section: • **Surface of parent object (volume/CAD/mesh)**: Available when you are in a section group of an analysis. Adds a 3D surface of the parent object of the selected analysis. • **Dynamic from section group > Indication info**: Available only when you are in a section group of a porosity/inclusion analysis: Adds the indication information, i.e., interactive 3D representations of the part showing the indications that are highlighted in the indication images. Note that rule-based images and 3D results have to be specified in the report. You can interact with the 3D image by clicking it and then clicking the pencil that will appear in the left corner of the box. As soon as you are in interaction mode, an icon will appear in the upper left corner that allows you to toggle between two different view modes. The appearance of the icon depends on the selected view mode: • Click the icon if you want to get full camera control and display the same image through all pages. • Click the icon if you want the camera to rotate around the indication. The zoom factor will remain the same through all pages, but the image will change to focus the indication that is shown in the 2D view. To exit interaction mode, click in the main area outside the light gray border of the 3D image.

Control	Description

	• **Static from section group >**
	  • **3D surface**: If you are in the section group of a CAD, mesh, or volume object: Adds the 3D surface of the selected object.
	  • **3D result**:
	  If you are in the section group of an analysis: Adds the 3D result of the analysis (currently available for nominal/actual comparison, wall thickness analysis, displacement analysis, and porosity/inclusion analysis).
	  If you are in a coordinate measurement section group: Adds a combined color overlay of all geometric tolerance features.
	  Note that the **Color-coding of deviations** option has to be activated in the **Geometric tolerancing** dialog for the 3D result to be available.
	  • **3D result – color bar**:
	  If you are in the section group of an analysis: Adds the color bar of the analysis result.
	  If you are in a coordinate measurement section group: Adds a global color bar for all geometric tolerance features in the report. Therefore, the deviation of the tolerance will be indicated as a relative deviation (**Relative tolerance**, in percent). If only a single tolerance feature is visible in the report or the same color range is applicable to all visible tolerances, the deviations will be indicated as absolute deviations (**Absolute tolerance**, in length unit).

Sections Section

- Clicking and dragging the headline of a section group allows you to move the entire section group up or down in order to change the sequence of the section groups, e.g., to have all analyses of the same type directly one below the other.
- Clicking and dragging a section of a section group allows you to move it up or down in order to change the sequence of the sections belonging to a section group.
- A minus sign to the right of a highlighted section allows you to remove the section from the report. If you want to (re-)add a section, you can click the **Undo** button or the plus sign next to the headline and select the desired section from the drop-down list.
- You can add a **Custom** section to the section group by clicking the plus sign next to the headline and selecting **Custom** from the drop-down list (for example, if you want to add a cover to the report). In **Content** mode, you can then edit the **Custom** section page in the main area, such as adding images or changing the section name.

  The **Custom** section is available for each section group.

- In **Content** mode, you can copy a page element, for example, an image, an info field, a table, or a 3D view from one section group and paste it to a different section group. The relative reference of the section where the element originally belongs to will then turn into an absolute reference. Absolute references indicate the type and position of the referenced object in the reported content and will be shown in the **Element properties** section (see section *Section properties/Element properties Section* on page 146).

  A reference icon to the right of a section indicates that this section references a page element from a different section group. The same icon will also be shown in the lower right corner of a page element that uses an absolute reference when you hover the mouse pointer over it in the main area.

  Absolute references can be very useful if, for example, you want to use elements from other section groups to compare results of different analyses on a custom section.

  In **Content** mode, you can also interact with the 3D element just like you would in **View** mode, but by double-clicking it. To exit interaction mode, click into the empty space of the main area. When you edit the 3D view layout element in **Content** mode, any changes to it will be saved to the layout, while interactions made in **View** mode will not be saved.

Main Area

The following controls are available in the main area:

Table 7-7: Controls in the main area

Control	Description
use drag-and-drop	Changes the position of page elements.
right-click a page element	Displays a context menu (see below).
click and drag the handles on the frame around a page element	Allows you to resize the page element. Note: If a dynamic table is changed in height, the amount of section pages might change.
For tables only: hover over a column header and drag the vertical line next to the header	Resizes the column in the direction you drag. The remaining space will be distributed evenly across the other columns. Note: If the table width is too small to display all the content, some content might be cut off.
For tables only: pin icon (only visible when the table is hovered)	Indicates that the size of a column has been adapted manually. The column will be locked and retain the size. When you click the pin icon, the column will be unlocked and the space will be distributed evenly across all columns with automatic sizing.
click and drag on a page	Draws a selection rectangle, starting from a corner. All page elements that are fully included when releasing the mouse button will be selected, e.g., for moving or removing all elements at once.
hold down **Ctrl** or **Shift** and click a selected page element	Removes the selected page element from the multi-selection.

Control	Description
hold down **Ctrl** or **Shift** and click an unselected page element	Adds the page element to the multi-selection.
press **Ctrl** + **A**	Selects all elements in the active section.
press **Ctrl** + **C**	Copies the selected page element to the system clipboard.
press **Ctrl** + **V**	For previously copied page elements: Pastes the page element(s) from the system clipboard to the active section. For content previously copied from other applications, e.g., PowerPoint: Pastes the content from the system clipboard to the active section: • If the system clipboard contains one or more images or shapes, they will be pasted as one image. • If the system clipboard contains text, it will be pasted in a text box. • If the system clipboard contains a combination of text and image, it will be pasted as image.

Context Menu of the Main Area

You can change the position of overlapping page elements via the context menu. The context menu contains the following items:

Table 7-8: Context menu items of the main area

Icon	Control	Description
	Bring to front	Moves the selected page element in front of all other elements.
	Bring forward	Moves the selected page element in front of its preceding element.
	Send backwards	Moves the selected page element behind its succeeding element.
	Send to back	Moves the selected page element behind all other elements.
	Remove	Deletes the selected page element.
	Cut	Copies the selected page element(s) to the system clipboard and removes them from the page.
	Copy	Copies the selected page element(s) to the system clipboard.
	Paste	Pastes the page element(s) from the system clipboard to the page.

Background page elements will always remain behind content page elements.

Section properties/**Element properties** Section

When you click the empty space in the main area, i.e., no page element is selected, the following options will be available for the currently active section in the **Section properties** section:

- **Current section** section:
  - **Section name**:

    Indicates the name of the section that is currently selected in the **Sections** section. You can edit the name by clicking into the **Section name** field. Pressing the **Esc** key allows you to discard the edit. Note: When the report is updated in the application in another language, the edited name will no longer be translated into other languages.
  - **Show background** checkbox:

    Allows you to show or hide the global background elements for the pages of each individual section.

When you click on a page element in the main area, some of the options that are listed below will be available in the **Element properties** section. Which of the options will be available depends on the type of the page element selected in the main area and on whether you are in **Content** or **Background** mode.

The type of the page element that is currently selected in the main area will be displayed directly below the **Element properties** caption, for example, **Custom image**, **Dynamic table**, or **Info field**.

If multiple page elements of different type are selected, no element type will be displayed.

If you scroll between sections in **Content** mode, the displayed element properties may no longer fit to the section currently shown in the main area. In this case, a triangle will appear at the upper right corner of the **Element properties** section. Clicking the triangle will take you back to the element the displayed properties belong to.

- **Element data source** section:
  - **Report**:

    Indicates that the selected page element, such as an image or an info field, is a relative reference that refers to the report in general, i.e., it gets the information from the report itself and adapts to the content section currently selected in the main area.
  - **Section group reference**:

    The section group reference is a relative reference that indicates the section group to which the page element currently selected in the main area belongs.

    When you select a page element in the main area that is an absolute reference to another element in the report, the information about the absolute reference will be displayed as follows:

    Absolute reference: Indicates the type and the fixed position of the selected element in the reported content (e.g., 1. Volume > 2. Nominal/actual comparison).

    Resolves to: Indicates the name of the selected element the absolute reference resolves to in the current report (e.g., Part 1 > Nominal/actual comparison > Analysis 2).
  - **Source name**:

For info fields: Indicates the name of the data source, i.e., the type of the information field that is currently selected in the main area, for example, **Object name**, **Manufacturer info of parent volume -> Homepage**.

For dynamic elements: Indicates the name of the data source of the dynamic element(s) that are currently selected in the main area. When you hover the mouse pointer over the source name, the page elements that display data from this source will be highlighted by an overlay of light-gray stripes. A label will additionally indicate the **Content group** and **Data row(s)** (if available) of each individual element.

- **Sort by column**:

  When a dynamic table element is selected in the main area, the corresponding columns will be listed in the **Sort by column** drop-down list, where you can select a column in order to sort the table in the main area according to the corresponding values. This option is disabled if at least one page element using a data source has the **Follow application layout** option checked.

☞ The specified sorting will apply to all elements that share the same data source.

- **Sort order**:

  You can use the radio buttons to choose an ascending or descending sorting order of the dynamic table element that is selected in the main area.

- **Available rows**:

  Display the number of rows contained in a dynamic table element when it is selected in the main area. When the **Limit displayed rows** checkbox is checked, you can use the spin box to restrict the number of rows to be displayed.

- **Element data assignment** section:

  If you want to add multiple dynamic images, attributes, or tables to one page of the report, you can use the **Content group** spin box to control the order in which the dynamic layout elements will be filled and which elements will display the same content. When you hover the mouse pointer over the **Content group** spin box or set a value in this spin box, the edited layout element and all elements that share its data source will be highlighted by an overlay of light-gray stripes. A label will additionally indicate the **Content group** and the **Data row(s)** of each individual element.

  If multiple objects share the same content group, you can use the multi-selection function to change the content group for all the selected objects at once.

- **Position and size** section:

  This section becomes available when you click on any content layout element of the report:

  - **Top [<unit>]** and **Left [<unit>]** spin boxes:

    Allow you to position the element precisely or to align it with other elements.

  - **Width [<unit>]** and **Height [<unit>]** spin boxes:

    Allow you to change the size of the element precisely.

- **Visualization settings** section:

  This section becomes available when you click a 3D element. You can use the **Transparency** spin box to specify a transparency level for the selected 3D element (0 = opaque…100 = transparent).

- **Text settings** section:

  This section becomes available when you edit a custom text field or when you select a layout element that displays text:

- When you edit a custom text field, you can use the **B Bold**, **/ Italic** and U **Underline** buttons to apply the corresponding font styles. You can use the **Font size** drop-down list and the **Font color** field to select a size or color for the text. The **Font color** field indicates the currently selected color. Clicking the **Font color** field will open a color picker where you can specify an RGB or Hex color.
- When you select a layout element that displays text, such as a table, text label, or settings list, only the **Font size** drop-down list and the **Font color** field will be available to change the size or the color of the font.

- **Text layout** section:

  This section becomes available when you edit an info field, such as **Object name** or **Object type**. You can uncheck the **Show name** option to hide the name of the info field and use the **Text alignment** radio buttons to align the info text to the right or left.
- **Cell display** section:

  This section becomes available when you click on a table element of the report.
  - **Maximum lines per cell** spin box:

    Allows you to change the maximum number of lines that a table cell can display.
  - **Always use full height** checkbox:

    When this option is checked, each table cell will display exactly the maximum number of lines that you set in the **Maximum lines per cell** spin box, regardless of the content.

    When this option is unchecked, depending on the content of the table cells, the number of lines displayed in the table cells can be less than (but not more than) the maximum number of lines that you set in the **Maximum lines per cell** spin box.
  - **Colorize cells according to their tolerance state** checkbox:

    Only available for overview tables: When this option is checked, the table cells showing the results will be colorized according to the tolerance state associated with them, if any.

- **Project name format** section:

  You can use the radio buttons to specify whether you want to display the full path, the file name only, or the file name and the extension.
- **Date and time format** section:

  You can use the **Select format** drop-down list to specify a date and time format.
- **Column display** section:
  - **Hide header if no data is available** checkbox: When you add an attribute without any data, you can check this option to hide the header of the info list. In **Edit** mode, the empty list will be grayed out and “No data available” will be displayed. In **View** mode, the attribute will be invisible.

  The following options become available when you click on a table element of the report:
  - **Follow application layout** checkbox:

    Check this option to apply the same layout to the currently selected table as the layout specified for the corresponding table in the application, for example, an **Indications** tab of a porosity/inclusion analysis. If this option is checked, the other **Column display** options will be disabled and columns will automatically be wrapped to additional pages, if necessary.
  - **Wrap columns** checkbox:

Allows you to wrap columns to the next page if the columns selected to be shown do not fit on a single page. Columns that would be cut off will be shown on the next pages where the same rows will be displayed. As soon as all columns for the current rows are shown, the next rows will be displayed on the following pages.

- **Show vertical grid lines** checkbox:

  Check this option to display the vertical grid lines in the selected table.

- **Minimum column width [cm]** spin box:

  Allows you to specify the minimum width of the columns of the currently selected table before they will be cut off or wrapped to the next page if the **Wrap columns** option is checked.

☞ The minimum column size settings will not be applied to manually sized columns.

- **Repeat name column on all pages** checkbox:

  Only available for overview tables and if the **Wrap columns** option is checked. When this option is checked, the **Name** column will be displayed on each page of the overview table.

- **Name column width [cm]** spin box:

  Only available for overview tables: Allows you to specify the width of the **Name** column.

- **Minimum data column width [cm]** spin box:

  Only available for overview tables: Allows you to specify the minimum width of the data columns before they will be cut off or wrapped to the next page if the **Wrap columns** option is checked.

When you click a table displayed in the main area, the names of the corresponding columns will be listed in the **Column display** section of the **Element properties** section. A checkbox in front of each name allows you to select or deselect the corresponding column in order to switch the visibility in the main area on or off. To select or deselect all available columns at a time, you can click **Show all** or **Hide all**.

You can use drag and drop to change the order of the columns. The table in the main area will be immediately updated accordingly.

Update Report

Opens the **Update report** dialog, where you can change the selection of analyses and objects to be included in the report and update the selected report accordingly by using a default report layout. Analyses that have been recalculated, such as after changing the settings, will be updated to show the current results. Clicking the **Update** button also changes the language of the selected report to the current application language. If the report was initially created in a different language, it can then be edited again. If an initially reported object has been removed from the scene in the meantime, a warning message will appear at the bottom of the **Update report** dialog. Note that the layout for existing elements in the report will remain the same after updating.

The following controls are available in the **Update report** dialog:

Table 7-9: Controls of the **Update report** dialog

Control	Description
Name field	Allows you to assign a name to the report.
Advanced button	Expands or collapses the **Advanced** section, which provides access to the **Image settings** and the **Specific layout information** tabs: • On the **Image settings** tab, you can specify the image render settings of the selected report (for details, see section *Image settings section* on page 133). • The **Specific layout information** tab shows the objects referenced by the specific report layout and indicates whether the objects required for the references to be resolved are present. It also indicates if objects are selected that were not present in the original report. In this case, a specific report layout will not work.
Contents section	Shows a tree view of all objects of the currently open project that contain data for reporting, such as analysis results or object properties. The object currently highlighted in the Scene Tree and its associated child elements are preselected. Check the checkbox in front of a tree item to select or deselect the item (including its child items) in order to include it in or exclude it from the report. Note that if you want to select a **3D surface** item of a volume object, this object must have a surface determination.
Report layout field	Click the **Select** button to the right of the **Report layout** field to select a previously saved layout from the drop-down list. The drop-down list contains the 10 previously used unique report layouts sorted by the time they were last used. Only applicable if a default report layout was used to create the original report: When an existing report is updated, the layout that was originally used to create the report will automatically be set as default in the **Report layout** field. If you want to change a selected layout, you can choose another default layout from the drop-down list. This will then be applied only to the newly added objects. Click the **Clear** button to remove the selected report layout from the field and return to the built-in default layout.

Control	Description
Update button	Updates the selected report with the specified settings. Note that it is not possible to update a report using a specific report layout. If a specific report layout is selected, the content configuration must be the same as in the original report, i.e., objects included in the current report must also be part of the original report. If you would like to add new objects to the report, a default report layout must be used.
Cancel button	Closes the dialog without creating or updating the report.

Delete report

Removes the selected report(s) from the report selection icon group.

Export PDF

Opens the **Export as PDF** dialog, where you can select a path and a file name to save the selected report(s). If multiple reports are selected, they will be saved in succession.

When you export a report containing 3D elements from the editor, these elements are saved as 2D images showing the current state of the viewport.

Export HTML

Opens the **Export as HTML** dialog, where you can specify a path and file name to export the selected report as self-contained HTML report. The HTML report is intended for viewing only and cannot be edited. It provides the same content and interactive features as the integrated report and does not have any dependencies to other files or web resources. It allows you to share reports with others without the need of using myVGL and can be viewed in any Chromium-based browser (such as Google Chrome or Microsoft Edge).

Clicking the **Show document information** button at the bottom left of the HTML report will open a pop-up window showing the name and version of the software the report was created with.

Export default layout

Allows you to save a reusable default layout as a *.vgrl* file based on a currently selected report (available only for reports that do not contain absolute references).

A default report layout defines the background information that will be displayed on each page of the report (such as logos, metainformation, or overall tolerance states).

It also defines the sections to be used for each reported content type (such as volume objects, CAD models, surface meshes, ROIs, analyses, geometry elements, and GD&T features) and what is to be included in each section when a report based on this layout is initially created. Settings specified for the default report layout will apply to each content of the same type. Using the default report layout, you will get the same set of sections for the same content type. If you want to get different sets of sections, you can use the specific report layout described below.

If you want to re-add sections that were available in your original report, you can click the plus sign next to the headline and select the desired section from the drop-down list.

The section will only be added to the created report if it has content. For example, if no images are configured, there will be no image section added to the initial report.

For objects that are not part of the currently selected report, the built-in defaults will be stored in the exported default report layout.

Export specific layout

Allows you to save a reusable specific layout as a *.vgrt* file based on a currently selected report.

A specific report layout defines the background information that will be displayed on each page of the report (such as logos, metainformation, or overall tolerance states).

It also defines the sections to be used for the reported content types (such as volume objects, CAD models, surface meshes, ROIs, analyses, geometry elements, and GD&T features) and what is to be included in each section when a report based on this layout is initially created.

You can use this option to save a report layout for reports that contain absolute references. Since report layouts that contain absolute references rely on a specific scene configuration, the referenced content types must also be present in the current report in order that the specific report layout can be reused.

You can also use specific report layouts for reports without absolute references if you want to define different sets of sections for the same content type. For example, the section group of “Volume 1” can contain different sections than the section group of “Volume 2,” provided that the content configuration in the current report is the same as in the specific report layout.

Create bookmark

Creates a new bookmark of the current scene. You can edit bookmarks in the **Bookmark editor** (see section *Bookmark editor* on page 153).

Bookmark editor

Allows you to save and switch between different visualization states of the current project. Properties stored in a bookmark include the workspace layout, render settings, camera settings, clipping settings, and the coordinate system.

Bookmarks can be exported from one project in order to apply them to another project. Apart from that, applying bookmarks can be recorded in a macro, which can be used in a batch processing setup.

In order to open the **Bookmark editor**, select **Bookmark editor** on the **Reporting** tab or **Create Bookmark > Bookmark editor** on the **Home** tab.

The **Bookmark editor** dialog consists of various sections:

- **Available bookmarks** section

  Lists all bookmarks available in the current project.

- **Bookmark image** section

  When you create a bookmark, a screenshot of all views currently visible in the scene will be automatically added to this section. If the bookmark image shows a warning triangle, the bookmark image is no longer in sync with the current scene. In this case, applying the bookmark may lead to a state other than shown by the bookmark image. To sync the bookmark image, click **Apply & replace**. Alternatively, you can first click **Apply** to see the changes and then click **Replace** to update the bookmark image.

  When you open a project with missing bookmark images, placeholders will be shown instead.

You can only capture one screenshot for each bookmark.

- **Title** section

  Shows the title of the selected bookmark. You can enter a customized name and press the **Enter** key to accept the changes.

- **Description** section

  You can enter a description for the selected bookmark.

- **Apply** button

  Applies the visualization settings of the selected bookmark to the scene. Volume objects, CAD models, and meshes that were added to the scene after creating the selected bookmark will be set to invisible.

- **New** button

  Creates a new bookmark.

In order to create a bookmark of the current scene, you can simply select **Create bookmark** on the **Reporting** tab.

- **Replace** button

  Replaces the visualization settings of the selected bookmark with the currently selected settings and updates the bookmark image accordingly.
- **Apply & replace** button

  Applies the selected bookmark to the scene, replaces the visualization settings of the selected bookmark accordingly, and updates the bookmark image.
- **Delete** button

  Deletes the selected bookmark.

In order to delete one or more bookmarks, you can also select them — either in the **Bookmark editor** or in the **Bookmarks and views** tool (see chapter 22 *Bookmarks and views Tool* on page 235) — and press the **Del** key.

- **Save images** button

  Opens the **Save bookmark images** dialog, where you can select a path and prefix for the file name for saving all bookmark images to image files (for supported file formats, see section *File Formats for Saving an Image, Image Stack, or Movie* on page 975 in chapter 50 *Appendix*). The file names for the images consist of the specified prefix and bookmark title separated by an underscore.

  The resolution of the images corresponds to the current screen resolution. For VGinLINE, the images are created in full HD quality.[1]
- **Close** button

  Closes the **Bookmark editor** dialog.

Create view

Creates a view with the current visualization and workspace settings beneath the selected Scene Tree object. Views can be transferred via copy and paste between top-level objects, such as volumes, CAD models, and meshes. In the case of other objects, such as ROIs or analyses, views can only be transferred between objects of the same type. For details, see chapter 22 *Bookmarks and views Tool* on page 235.

[1] VGinLINE is our software solution for fully automated analyses and evaluations.

Apply view

Applies the selected view, changing the current visualization and workspace settings. To apply a view, you can also double-click it in the Scene Tree. For details, see chapter 22 *Bookmarks and views Tool* on page 235.

Update view

Applies a view and then immediately replaces it. If any of the objects referenced by the view are no longer present, they will no longer be referenced by the updated view. This can be used to turn invalidated views into valid ones. For details, see chapter 22 *Bookmarks and views Tool* on page 235.

Replace view

Replaces the selected view with a new one that uses the current visualization and workspace settings. For details, see chapter 22 *Bookmarks and views Tool* on page 235.

Save image(s)

Captures the current workspace area into an image.

- **Preview** section

  Shows a preview of the image according to the current settings.
- **Views** section

  Allows you to choose whether you want to save screenshots of the view shown in the current workspace layout, in the currently selected window or in predefined windows.
  - **Current workspace layout** radio button

    When this option is selected, the saved image will be an exact representation of the current workspace layout, including all visible windows with their current visualization state.
  - **Currently active workspace window** radio button

    When this option is selected, only the window that is currently selected in the workspace will be taken into account for the final image.
  - **Defined windows** radio button

When this option is selected, the list of currently available windows will be enabled. To select the window to be taken into account for the final image, check the checkbox of the corresponding entry.

When opening the dialog again, the checked option will be remembered and the window(s) to be taken into account for the final image will be selected accordingly.

- **Custom image size** section

  Allows you to specify an image size different from the default size.

  Table 7-10: Controls in the **Custom image size** section

Control	Description
Width/Height spin boxes	Allow you to change the size of the image in pixels.
/ button	• Button is pressed : The image is scaled uniformly, i.e., the width/height ratio is maintained. • Button is released : The image width and height can be changed independently of each other.
R button	Resets the width/height values.

- **Overlays** section

  Allows you to enable/disable graphical overlays like analysis results, geometry elements and measurements for the image to be saved.

- **DPI/Font size** section

  Use the **Scale** spin box to control the size of handles, fonts and other display-relative elements. You can use it for saving images at higher resolution and still maintain the proportions of these elements. This will affect all overlays (e.g., the text overlay, the tripod, the surface, the ROI borders).

- **Slice position indicator** section

  When this option is checked, an additional 2D or 3D image is displayed either within the selected 2D view or next to it.

This function is available only for 2D and if exactly one 2D view is selected in the **Views** section.

Table 7-11: Controls in the **Slice position indicator** section

Control	Description
View drop-down list	Selects the additional 2D or 3D image.
Side by Side checkbox	Displays the selected 2D view and the additional image of the same size next to each other.
Picture in Picture checkbox	Displays the additional image within the selected 2D view. • **Position** checkboxes: Specify the position of the additional image within the selected view. • **Size** slider: Changes the size of the additional image (10 %…100 % of the slice image size).

Control	Description
As seen in 3D/2D view checkbox	When this option is checked, the additional image has the same aspect ratio and displays all overlays, analyses, annotations, etc. as seen in the original view.

- **Decorations** section

  Provides options for displaying additional information within the image.

  Table 7-12: Controls in the **Decorations** section

Control	Description
Show headline option	When you check this option, the text entered in the text field will appear above the image.
Show logo in headline option	Allows you to define a custom logo that will appear above the text specified in the headline text field if the **Show headline** option is checked.
Show legend option	When you check this option, the current slice position, the current coordinate system and the window type will be added below the image for the respective window.

- **Reset to default** button

  Clicking this button will reset all fields to their default values, except for the **Views** section.
- **Save...** button

  Opens a file browser where you can select a path and file name for saving the image(s). For the supported file formats, see section *File Formats* on page 975 in chapter 50 *Appendix*.
- **Cancel** button

  Discards all changes and closes the dialog.

In order to directly open the file browser and save the image(s) with the last saved settings, you can press the **Ctrl+Shift+G** keyboard shortcut.

Save movie/image stack

Saves the slices of one of the 2D views to a movie or image stack.

Creating movies is only possible on Microsoft Windows systems.

- **Preview** section

  The **Preview** section shows the slices according to the current settings.

If you do not want the movie/image stack to contain the complete data set, use the slice position spin box at the bottom left to navigate to the desired slice. The background color of the slice position spin box will change to red if the value lies outside the range specified in the **Slice range** section. Clicking the **s** or **e** button will define the **Start** or **End** slice, respectively, of the **Slice range** section.

- **2D view** section

  Allows you to select the 2D view for specifying the orientation. The images will be created parallel to this view.

- **Viewport** section

  Select the **As seen in 2D view** option to create a movie/image stack according to the display in the selected 2D view if you do not want the movie/image stack to show the complete object(s).

- **Display mode** section

  Allows you to specify the coloring of the resulting image (for details on display modes, see section *Display mode Drop-down List* on page 168 in chapter 8 *Window Tab*).

- **Image size** section

  Allows you to specify an image size different from the default size.

  Table 7-13: Controls in the **Image size** section

Control	Description
Width/Height spin boxes	Allow you to change the size of the images in pixels. If you want to save a movie in *.wmv* format, the width and height values have to be a multiple of four.
/ button	• Button is pressed : the image is scaled uniformly, i.e., the width/height ratio is maintained. • Button is released : the image width and height can be changed independently of each other.

- **Overlays** section

  Allows you to enable and disable graphical overlays (e.g., analysis results, geometry elements, and measurement) for the image stack or movie to be saved.

- **DPI/Font size** section

  Use the **Scale** spin box to control the size of handles, fonts, and other display-relative elements. You can use it for saving images at a higher resolution and still maintain the proportions of these elements. This will affect all overlays (e.g., the text overlay, the tripod, the surface, and the ROI borders).

- **Slice position indicator** section

  When this option is checked, an additional 2D or 3D image will be displayed either within the selected 2D view or next to it.

  Table 7-14: Controls in the **Slice position indicator** section

Control	Description
View drop-down list	Selects the additional 2D or 3D image.

Control	Description
Side by Side checkbox	Displays the selected 2D view and the additional image of the same size next to each other.
Picture in Picture checkbox	Displays the additional image within the selected 2D view. • **Position** checkboxes: Specify the position of the additional image within the selected 2D view. • **Size** slider: Changes the size of the additional image (0%…100% of the slice image size).
As seen in 3D/2D view checkbox	When this option is checked, the additional image will have the same aspect ratio and display all overlays, analyses, annotations, etc., as they are seen in the original view.

- **Boundary** option

  Allows you to apply an additional offset to the original image. It will not change the image size; instead it will allow you to zoom into or out of the current viewport.

- **Stack settings** section

  The stack settings apply to the complete data set in the current orientation.

  Table 7-15: Controls in the **Stack settings** section

Control	Description
Unit option	Specifies the unit for the **Dist** field.
No. of slices field	Specifies the number of slices for the movie or image stack. Modifying the number of slices will recalculate the slice distance and vice versa: distance x (number of slices – 1) = height of complete data set.
Dist field	Specifies the distance between the slices for the movie or image stack. Modifying the slice distance will recalculate the number of slices and vice versa: distance x (number of slices – 1) = height of complete data set. The unit for the distance can be defined in the **Unit** field.
POI wait field	Specifies the time (in seconds) during which the slice with the label of the **Indicator** instrument or analysis annotation selected in the Scene Tree will be shown in the movie. Make sure the **Indicator visible in all slices** or **Annotation visible in all slices** option is not checked in the preferences for the instrument or analysis annotation, respectively (see section *Coordinate measurement Settings* on page 71 and section *Analysis annotations Settings* on page 68 in chapter 3 *File Tab*).

- **Slice range** section

The slice range parameters specify the part of the slices to be exported. The slices will be resampled by applying the stack settings so that one of the slices will be positioned at the start value. The first slice to be exported will be defined by the **Start** value, and the second slice will be at position (start value + slice distance). The **End** value will specify the last slice.

You can change the direction of the movie/image stack by swapping the **Start** and **End** values.

You can also set the **Start** and **End** values by navigating to the desired position in the **Preview** and clicking the **s** button for **Start** or the **e** button for **End**.

Modifying the slice range will change the number of slices but not the slice distance. The **No. of slices** and **Dist** parameters specify how fine the data should be sampled within the given slice range.

If a rotation view is selected in the **2D view** field, you can define the angle range instead of the slice range.

- **Export queue** section

  Displays a list of the queued movies and image stacks with their respective paths and file names. Entries that have already been processed are marked with a green checkmark.

- **Reset to default** button

  Clicking this button will reset all fields to their default values except for the **2D view** field. The 2D view will be specified by the view currently selected in the 2D window. Entries in the **Export queue** section will remain unchanged.

- **Save...** button

  Opens the **Save image** dialog, where you can specify a path and file name for saving the movie or image stack. For the supported file formats, see section *File Formats* on page 975 in chapter 50 *Appendix*.

- **Queue...** button

  Opens the **Save image** dialog, where you can specify the path and file name for the movie or image stack to be added to the export queue for later saving.

- **Cancel** button

  Discards all changes and closes the dialog.

- **Process** button

  Saves all movies or image stacks listed in the export queue one after the other.

- **Remove** button

  Removes the selected and not yet saved movies or image stacks from the export queue.

Save view images

Opens the **Save view images** dialog, where you can specify a path and prefix for the file name for saving the selected view(s) to image files (for supported file formats, see section *File Formats for Saving an Image, Image Stack, or Movie* on page 975 in chapter 50 *Appendix*). The file names for the images consist of the specified prefix, scene path, and view title separated by an underscore.

Saving view images can be recorded in an macro, which can be used in a batch processing setup.

The resolution of the images corresponds to the current screen resolution. For VGinLINE[1], the images are created in full HD quality.

Export as Q-DAS file(s)

Opens the **Q-DAS export** dialog, where you can not only specify the path and file name for saving the evaluation results of the selected volume object, CAD model, or surface mesh in a file format that can be used in statistics software, but also specify a folder or optionally a subfolder for saving images that are exported along with the Q-DAS file. The items supported by Q-DAS export are GD&T features and the following analyses: fiber composite material analysis, porosity/inclusion analysis, wall thickness analysis, nominal/actual comparison, and battery anode overhang analysis. The images that can be exported are the images of the first bookmarks referenced by a top-level object (volume object, CAD model, or surface mesh), GD&T features, and analyses supported by Q-DAS export. For a list of Q-DAS export fields, see section *Q-DAS Export Fields* on page 977 in chapter 50 *Appendix*.

Table 7-16: Controls in the **Q-DAS export** dialog

Control	Description
Export folder field	Displays the path currently selected for exporting the file(s).
Browse... button	Opens the **Select Q-DAS export folder** dialog where you can select a folder in which to save the file(s).
File base name field	Allows you to enter a name for the file(s) to be exported.
Append incrementing index checkbox	Check this option to append an incrementing index to the file base name if the file base name is already being used by an existing file.
File type radio button	• **Shared file (*.DFQ)**: Values and descriptions of the evaluation results are exported in a single file. • **Value file and description file (*.DFX/DFD)**: Values and descriptions of the evaluation results are exported in separate files.
Character encoding radio buttons	Specify the character encoding to be used for the exported file(s): **ASCII**, **UTF-8**, **UTF-16 big endian**, **UTF-16 little endian**.
Coordinate measurement radio buttons	• **Sort features by ID**: Features will be sorted in the order of their creation. • **Sort features by name**: Features will be naturally sorted ascendingly, which is also the default in the Scene Tree.

[1] VGinLINE is our software solution developed to perform fully automated analyses and evaluations.

Control	Description
Use image of first referenced bookmark as drawing file checkbox	When this option is checked, the image of the first bookmark referenced by a volume object, CAD model, or surface mesh (part-level image), and images of the first bookmarks referenced by GD&T features, analyses supported by Q-DAS export (feature-level images) will also be exported along with the Q-DAS file. These exported images will be used as drawing files in the Q-DAS software.
Q-DAS images folder field	Displays the path currently selected for exporting the images when **Use image of first referenced bookmark as drawing file** checkbox is checked.
Browse... button	Opens the **Select Q-DAS base folder for images** dialog where you can select a base folder in which to save the image(s).
Optional subfolder field	Displays the subfolder name currently selected for saving the images when **Use image of first referenced bookmark as drawing file** checkbox is checked.
Clear button	Resets the subfolder selection and selects the **Q-DAS images folder**.
Browse... button	Opens the **Select image subfolder** dialog where you can optionally select a subfolder in which to save the image(s). The subfolder must be located in the **Q-DAS images folder**.
OK button	Exports the file(s) and image(s) to the specified location.
Cancel button	Closes the dialog.

Export VGRF

Opens a drop-down list where you can choose one of the following VGRF-based export options to create a report of the currently open project:

- **VGRF folder**
- **VGRF to XLSX via Excel**
- **VGRF to PDF via Excel**

The export formats **VGRF to XLSX via Excel** and **VGRF to PDF via Excel** require the Excel add-in to be enabled in the preferences. See section *Result data export Settings* on page 64 in chapter 3 *File Tab* on page 35.

Using the Excel add-in for VGRF-based exports is currently only supported for Windows.

The export formats **VGRF to XLSX via Excel** and **VGRF to PDF via Excel** currently do not support transport phenomena simulations and structural mechanics simulations.

An export dialog will open that shows a tree view of all objects of the currently open project that contain data for exporting, such as analysis results or object properties. Objects currently highlighted in the Scene Tree and their associated child elements will be preselected. Click the checkbox in front of a tree item to select or deselect the item (including its child items) in order to include it in or exclude it from the report.

- **Save** button: Opens the **Export results…** dialog, where you can save the report in the selected export format.
- **Close** button: Closes the export dialog.

Highlighting the object properties, analysis results, or coordinate measurement results in the tree view will show the corresponding export options in the panel to the right:

- **Exported sections** section

  Specifies the information to be included or excluded from the report by checking or unchecking the corresponding checkboxes.

  Object properties dialog only: When the **File list** on the **VGRF export** tab of the **Object properties** dialog is selected, the **Condense consecutive rows** checkbox will become available. When this option is checked, the report will only list the first three and the last file of the image stack.
- **General render settings** section

  Allows you to customize the display of all automatically created images.

  Table 7-17: Controls in the **General render settings** section

Control	Description
Image size spin box	Specifies the number of pixels for the larger side of the image. The other side is calculated to keep the aspect ratio. This option does not affect the screenshots created using the **Capture from** button.
Visibility drop-down list	Available for analyses: • **Automatic**: Only the selected analysis and its parent objects are included in the images. All other Scene Tree items, such as geometry elements, GD&T features, and other analyses, will be hidden. • **From Scene Tree**: All objects currently set to visible in the Scene Tree are included in the images.

- **Custom render settings** section

  Allows you to customize the display of all automatically created images.

This option does not affect the screenshots created using the **Capture from** button or the automatic 3D images.

Table 7-18: Controls in the **Custom render settings** section

Control	Description
Custom render settings checkbox	When this option is checked, the options in the **Custom render settings** section will be enabled and you can customize the display of all automatically created images. When this option is unchecked, the settings of the selected 2D window will be used for all automatically created images.
Display mode field	Specifies the coloring of the images (for details on the display modes, see section *Display mode Drop-down List* on page 168 in chapter 8 *Window Tab*).
Background color field	Double-clicking the field opens the **Select Color** dialog where you can set the background color of the images.
Text overlay, **Tripod**, **Scale bar** checkboxes	Check any of these options to include the corresponding information in the images.

- **Focused image** section

Table 7-19: Controls in the **Focused image** section

Control	Description
Zoom factor spin box	Sets the zoom level for the focused images you specified in the respective tables.
Grouping option	For the **Object properties** dialog only: When the option is set to **On**, all instruments with an image of the same view (e.g., **Top**) and in the same slice are displayed together in one screenshot.

Window Tab

Introduction

Allows you to choose and/or modify the overall layout of views in myVGL; this includes the 3D and 2D views to be displayed, their size and arrangement, and the display of rulers, text overlays, and tools.

Layout Selection Icon Group

The layout selection icon group provides the following preconfigured layouts for the arrangement of the 2D and 3D windows:

Quad

Applies a standard two by two layout with three 2D windows (**Top**, **Right**, **Front**) and a 3D window, where each window of the quad is of the same size.

Slices left

Applies a standard two-column layout with three 2D windows and a large 3D window. The 2D windows are arranged top to bottom in the left column.

Slices right

Applies a standard two-column layout with three 2D windows and a large 3D window. The 2D windows are arranged top to bottom in the right column.

Slices below

Applies a standard two-row layout with three 2D windows and a large 3D window. The 2D windows are arranged left to right below the 3D window.

Rotation

Applies the **Quad** layout and replaces the **Front** view with a **Rotation** view.

Quad profile

Applies the **Quad** layout and adds the gray value profile window below the quad.

Non-planar

Applies the **Quad** layout and adds a **Custom path** and a **Non-planar** window below the quad.

2D background

The **2D background** menu item consists of the following submenu entries:

Table 8-1: Controls of the **2D background** menu

Control	Description
Default	Applies the default 2D background setting.
Predefined colors	Applies the selected color to the 2D background setting.
Select color	Opens the **Select Color** dialog, where you can specify the settings for the background.
Save as default	Saves the current 2D background setting as default.

3D background

Only enabled when the 3D window is selected. Opens the **Background color** dialog where you can specify the settings for the background.

The **Background color** dialog provides the following options:

Table 8-2: Controls in the **Background color** dialog

Option	Description
drop-down field	• **Flat**: Fills the background with the color specified in the **Background color** field. • **Vertical gradient**: Applies a vertical color gradient, starting with the color specified in the **Background color** field and ending with the color specified in the **Blend color** field. • **Horizontal gradient**: Applies a horizontal color gradient, starting with the color specified in the **Background color** field and ending with the color specified in the **Blend color** field. • **Radial gradient**: Applies a radial color gradient, starting with the color specified in the **Background color** field and ending with the color specified in the **Blend color** field.
Background color field	Double-clicking the field opens the **Select Color** dialog, where you can specify the color for the flat background or the first color for the gradient.
Blend color field	Double-clicking the field opens the **Select Color** dialog, where you can specify the second color for the gradient.
	Swaps the background and the blend color.

Zoom Icon Group

The zoom icon group controls the zoom setting of the selected 2D window and consists of the controls listed below.

At a zoom factor of 100%, the physical size of the object on the monitor is identical to the dimension defined in the data set, given that the object fits adequately into the 2D window. If the object is considerably larger or smaller, the scale at zoom factor 100% will be adjusted in factors of 10. This refers to the largest visible object in the Scene Tree. The zoom behavior applies to monitors with physical PPI of 96.

Zoom in/Zoom out

Zooms into or out of the 2D window.

Voxel resolution

Adjusts the zoom so that each voxel of a volume object is displayed as one pixel in the 2D window. This refers to the object to which the currently selected coordinate system belongs. If no

object-dependent coordinate system is selected, the object with the smallest resolution will be referred to.

Set zoom factor

Opens a dialog where you can manually set the zoom factor of the slice view.

Fit object to window

Centers the slice view of the selected object in the 2D window.

Fit scene to window

Centers the slice view of the whole scene in the 2D window.

Reset zoom

Resets the zoom settings.

Display mode Drop-down List

The display mode determines the way the slice images are rendered in the 2D windows.

Original

Displays the slice images using their original color, brightness, and contrast.

Color

Displays the slice images using their original brightness and contrast but applies the color settings from the **Rendering** tool. This also displays the contour of the determined surface.

Color and opacity

Displays the slice images using the color, brightness, and contrast settings from the **Rendering** tool. This also displays the contour of the determined surface.

Thick slab

Only enabled when a 2D window is selected. Opens the **Thick slab settings** dialog.

In **Thick slab** mode, the 2D window shows an overlay of several slices instead of only one slice. The current slice position is the middle of the thick slab.

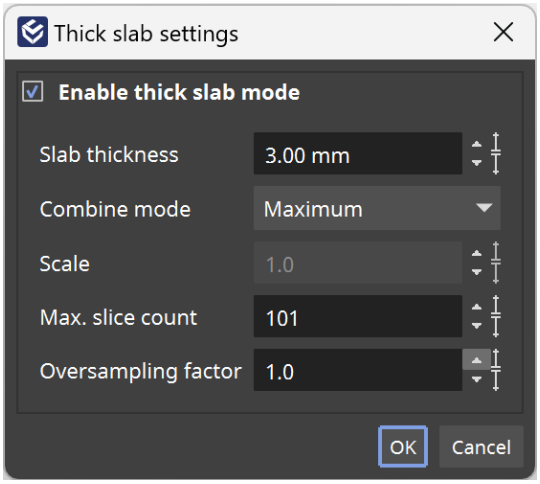


Figure 8-1: **Thick slab settings** dialog

The **Thick slab settings** dialog provides the following options:

Table 8-3: Controls in the **Thick slab settings** dialog

Control	Description
Enable thick slab mode	When you check this option, the thick slab parameter settings will be enabled.

Control	Description
Slab thickness spin box	Defines the height in which the slices are to be overlaid. The range of the thick slab is -1/2 thickness up to +1/2 thickness from the current slice. Clicking the arrow buttons of the spin box changes the slab thickness in steps of one voxel.
Combine mode drop-down list	• **Maximum**: Displays the highest gray value within the thick slab. • **Minimum**: Displays the lowest gray value within the thick slab. • **Average**: Displays the normalized average of the gray values of all slices within the thick slab. • **Standard deviation**: Displays the standard deviation of the gray values of all slices within the thick slab. The standard deviations are displayed as gray values; the higher the standard deviation, the brighter the corresponding pixel. When there is an ROI with activated visualization settings within the thick slab and the **Maximum** or **Minimum** combine mode is activated, only the slices that contain the ROI will be considered in the ROI area.
Scale spin box	Specifies the scale factor for the displayed gray value. Available for the **Average** mode and the **Standard deviation** mode.
Max. slice count spin box	Specifies the maximum number of slices taken into account to calculate the visualization of the thick slab. When a low **Max. slice count** and a high **Slab thickness** are specified, not every slice will be taken into account.
Oversampling factor spin box	As long as the **Max. slice count** is not reached, the object will be oversampled according to this value.

Slice step width

Only enabled when a 2D window is selected and when you are not in a grid coordinate system. Opens the **Set slice step width** dialog, where you can define the step width to be used for scrolling through the slices in the 2D windows. The default value is the resolution of the data set.

Level/Window mode

Only enabled when a 2D window is selected and the **Original** or the **Color** display mode is on.

Opens a dialog in which you can specify the brightness (**Level**) and contrast (**Window**) values for the 2D windows:

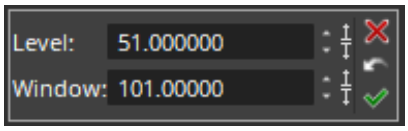


Figure 8-2: Brightness/contrast settings dialog

Table 8-4: Controls for setting the brightness/contrast values

Control	Description
	Accepts the values and closes the brightness/contrast settings dialog.
	Resets the values according to the gray value range of the selected object.
	Applies the values directly to the opacity curve(s) of the selected volume(s) in the rendering tool.
click and drag vertically in a 2D window	Modifies the brightness (**Level**) values.
click and drag horizontally in a 2D window	Modifies the contrast (**Window**) values.
hold down **Shift** key and click and drag	Selects a rectangular region on the volume object. When you release the **Shift** key, brightness and contrast are automatically optimized based on the gray values of the region.

Ruler

Switches the ruler at the top and left borders of the 2D windows on and off.

Annotations Drop-down List

Allows you to modify the display of the currently visible annotations. The **Annotations** drop-down list consists of the following entries:

Arrange

Automatically arranges the annotations in the current window based on the settings in the **Preferences** dialog.

Minimize

Minimizes all annotations.

Maximize

Maximizes all annotations.

Configure

Opens the **Preferences** dialog, where you can modify the properties for the annotations. For details, see section *Colors & Styles Preferences* on page 68 in chapter 3 *File Tab*.

Text overlay editor

Opens the **Configure text overlay** dialog where you can add customized text overlays to be displayed in the 2D windows and/or the 3D window. The text overlays allow you to provide additional information about the windows, for example, the current slice position, the window name, or even DICOM or DICONDE tags, or to add company logos. This feature is useful for reporting and documentation purposes (see also section *Save image(s)* on page 48 and section *Save movie/image stack* on page 50 in chapter 3 *File Tab*).

In order to open the **Text overlay editor**,

- select **Window > Text overlay editor** or
- right-click in the one of the 2D windows or the 3D window and select **Text overlay > Configure…** from the context menu.

The **Configure text overlay** dialog consists of two identical tabs:

- **2D windows** tab for configuring the text overlays for the 2D windows
- **3D window** tab for configuring the text overlays for the 3D window

2D Windows/3D Window Tabs

- **Preset selection** section

  Allows you to manage the text overlay presets.

  Table 8-5: Controls in the **Preset selection** section

Control	Description
drop-down list	Allows you to select a preset to be applied to the current text overlay settings.
Save button	Opens the **Preset name** dialog, where you can enter a name for the preset to be saved.
Remove button	Removes the currently selected preset from the drop-down list.
Reset button	Resets the currently selected preset to the last saved status.

- **Text labels** section

  Table 8-6: Controls in the **Text labels** section

Control	Description
use LMB to click on a text label	Selects the text label.
hold down **Ctrl** key + use LMB to click on several text labels	Selects the text labels.
hold down **Shift** key + use LMB to click on two separate text labels	Selects the two text labels, including all text labels between them.
use LMB to click on list header	Sorts the entries in ascending or descending order, respectively.
> button	Moves the text label highlighted in the **Available text labels** list to the **Selected text labels** list and adds it to the top left box in the **Preview** section.
< button	Moves the text label highlighted in the **Selected text labels** list to the **Available text labels** list and removes it from the **Preview** section.

- You can also drag and drop one or more selected text labels from the **Available text labels** or the **Selected text labels** list directly into the desired box in the **Preview** section.
- You can also drag and drop one or more selected text labels from the **Available text labels** to the **Selected text labels** list and vice versa.

- **Preview** section

Shows eight boxes in which you can place the selected text labels. The boxes indicate the positions of the text labels within the 2D windows or the 3D window, respectively. You can insert multiple text labels in each box.

Table 8-7: Controls in the **Preview** section

Control	Description
use LMB to click and drag text label to another box	Moves the text label to the new location within a box.
use RMB to click on a selected text label	Shows the **Remove** context menu item. Clicking it moves the text label to the **Available text labels** list and removes it from the **Preview** section.

- **Font settings** button

  Opens the **Preferences** dialog for the **Text overlay** settings.
- **OK** button

  Applies the current settings and closes the **Text Overlay Editor**.
- **Cancel** button

  Closes the **Text Overlay Editor** without applying any changes.
- **Apply** button

  Shows a preview of the current settings.

Default Text Labels

The following text labels are available by default:

Table 8-8: Default text labels

Text label	Description
<CoordinateSystem>	Displays the name of the currently active coordinate system for the respective window.
<SlicePosition/RotationAngle>	Only available for 2D windows: Displays the current slice position or—in the rotational view—the rotation angle. When the **Thick slab mode** is activated, the slab thickness will be additionally displayed.
<ViewZoom>	Only available for 2D windows: Displays the current zoom factor.
<WindowName>	Displays the name of the window (e.g., **Top**, **Front**, **Back**, or **3D**).
<PixelSize>	Displays the size of a pixel in the currently selected unit.
<CustomLogo>	When added to the **Selected text labels** list, this will open the **Select logo image...** dialog, which allows you to select an image file. You can use more than one **<CustomLogo>** entry.

Text label	Description
<CustomText>	When added to the **Selected text labels** list, this will allow you to enter an arbitrary text in the field highlighted in the **Selected text labels** list. You can use more than one **<CustomText>** entry.
<PatientID>, **<PatientName>**, **<SerialNumber>**, **<StudyDescrip-tion>**, **<StudyID>**, **<Study-Number>**	Placeholders for information provided by DICOM data sets.
<..._diconde>	Placeholders for information provided by DICONDE data sets.
<ComponentInfo_...>, **<Manufac-turerInfo_...>**, **<ScanInfo_...>**	Placeholders for the metainformation that is also displayed on the **Component**, **Scanner manufacturer**, and **Scan** tabs of the **Object properties** dialog.
<Object_Name>, **<Object_Full-Name>**	When added to the **Selected text labels** list, the name of the selected object in the Scene Tree will be displayed. If the object belongs to a group, **<Object_-FullName>** will also display the name of the group.

Tools Drop-down List

Allows you to activate and deactivate the various tools available in myVGL.

To activate a tool, click its entry in the **Tools** drop-down list. This will also activate the icon in front of the tool. An activated tool will be displayed either in one of the tool docks or as a floating tool. It may be minimized to its title bar or maximized. The position and size of the tool depends on its status before it was deactivated.

To deactivate a tool, click the highlighted icon in front of its entry in the **Tools** drop-down list. You can reactivate the tool at any time.

If you deactivate the **Light** tool or the **Clipping** tool and select a light or clipping object in the Scene Tree, a contextual tab with the major parameters of the **Light** or **Clipping** tool will appear in the ribbon.

For details on the individual tools, refer to the respective manual chapters.

The following tools can be activated or deactivated in the **Tools** drop-down list:

Rendering

Allows you to specify the rendering of volume objects, CAD models, meshes, and point clouds in the scene. See chapter 17 **Rendering *Tool* on page 192**.

Light

Allows you to access and control the properties of light sources in the scene, such as the type (e.g., spot light source), color, and shadow. See chapter 18 *Light Tool* on page 206.

Camera

Allows you to access and control the properties of the camera, such as its position, focal point, and rendering mode. See chapter 19 *Camera Tool* on page 212.

Clipping

Allows you to control the clipping plane. See chapter 20 *Clipping Tool* on page 215.

Scene Tree

Allows you to access and control objects (and their child objects) in the scene, such as volume objects, CAD models, meshes, point clouds, GD&T features, and clipping planes. See chapter 21 *Scene Tree Tool* on page 218.

Bookmarks and views

Allows you to access and apply existing bookmarks and views. See chapter 22 *Bookmarks and views Tool* on page 235.

Tool dock Drop-down List

Allows you to select the tool docks to be shown or hidden:

- **Show/hide right tool dock**
  Toggles the visibility of the right tool dock.
- **Show/hide left tool dock**
  Toggles the visibility of the left tool dock.
- **Show/hide lower tool dock**
  Toggles the visibility of the lower tool dock.
- **Show/hide upper tool dock**
  Toggles the visibility of the upper tool dock.

Reset tools

Resets all tool windows to the default settings.

Help Tab

Introduction

The **Help** tab provides information on the software and provides access to the manual and tutorials.

Show manual

Displays this Reference Manual.

Show tutorials

Opens a pdf file from which you can access the tutorials.

Product registration

Allows you to create and save a product registration form, which includes a system-specific hardware encryption key that is required for licensing purposes. To obtain either a temporary evaluation license or your final product license, fill in the missing information and e-mail the form (*register.txt*) as an attachment to sales@volumegraphics.com.

Update dongle license

Opens a file browser for selecting the updated license file (CodeMeter file, **.WibuCMRaU*) to be loaded onto the dongle.

For more information on dongle licenses, refer to the installation instructions available in your download account.

Website

Opens the VG website.

About

Opens the **About myVGL** dialog with product and system information.

- **About** tab
  Displays the product information.
- **Version information** tab
  Displays the version (release) and build number.
- **System information** tab
  Displays information on the hardware configuration of the computer.
- **Save information** button
  Creates a *.txt* file, which includes all information from the **About**, **Version information**, and **System information** tabs.
- **OK** button
  Closes the dialog.

Clipping Contextual Tab

The **Clipping** contextual tab will be displayed in the ribbon when you create a clipping object or when an existing clipping object is selected in the Scene Tree. It provides the following controls for editing the clipping object.

Table 10-1: Controls of the **Clipping** contextual tab

Control	Description
Invert clipping region	Inverts the region used for clipping. For clipping planes, inverting the clipping region will swap the sides used for clipping. For (aligned) clipping boxes, inverting the clipping region will render anything inside the clipping box transparent.
Transparency spin box	Specifies the transparency of the clipped region (0 = opaque…1 = transparent). The transparency setting is not available for clipped polygon objects.

The **Clipping** tool provides additional functions (see chapter 20 *Clipping Tool* on page 215).

Instrument Contextual Tab

The **Instrument** contextual tab will be displayed in the ribbon when you create an instrument or an already created instrument is selected in the Scene Tree. It provides the following controls for specifying the settings for the instruments.

Table 11-1: Controls on the **Instrument** contextual tab

Control	Description
Cancel button	Closes the contextual tab.
<instrument type>	Indicates the currently selected instrument type.
Actual [<length unit>/<angle unit>]	Indicates the numerical value of the instrument.
status field	Provides status information on the instrument. For a list of possible status messages, see section *Status Messages* on page 121 in chapter 6 *Inspect Tab*.
Use actual as nominal button	Clicking this button will set the actual value of the current measurement instrument as the nominal value.
Nominal [<length unit>/<angle unit>] spin box	Specifies the nominal value of the instrument.
Tolerance (lo)/Tolerance (hi) [<length unit>/<angle unit>] spin boxes	Specify the allowed tolerance of the actual value towards the given nominal value of the feature. If both values have not yet been set, you can create a symmetric tolerance range by entering a **Tolerance (hi)** value. **Tolerance (lo)** will automatically be set to the same value, but with a negative sign. Similarly, you can enter a negative **Tolerance (lo)** value; **Tolerance (hi)** will then automatically be set to the same value, but with a positive sign. You can also change both tolerances independently, such as when entering two negative or two positive tolerances, respectively).
Name field	If an instrument is selected in the Scene Tree, its name will be displayed and can be edited. Also allows you to edit the temporary name of the instrument to be created.
button	Opens the **Edit name template for instruments** dialog. For details, see section *Name Template Pop-up* on page 182. Note that the default name template for instruments is *<type> <id>*.
Linear – Bent slider	For **Polyline length** instrument only: Adjusts the curvature of the polyline: • **Linear**: Connects the points with lines. • **Bent**: Connects the points with a spline.

Control	Description
Indicator	Activates the **Indicator** instrument (see section *Indicator* on page 115 in chapter 6 *Inspect Tab*).
Distance	Activates the **Distance** instrument (see section *Distance* on page 115 in chapter 6 *Inspect Tab*).
Angle (4 points)	Activates the **Angle (4 points)** instrument (see section *Angle (4 points)* on page 116 in chapter 6 *Inspect Tab*).
Angle (3 points)	Activates the **Angle (3 points)** instrument (see section *Angle (3 points)* on page 117 in chapter 6 *Inspect Tab*).
Polyline length	Activates the **Polyline length** instrument (see section *Polyline length* on page 117 in chapter 6 *Inspect Tab*).
Caliper	Activates the **Caliper** instrument (see section *Caliper* on page 118 in chapter 6 *Inspect Tab*).
Snap mode drop-down list	Opens the **Snap mode** drop-down list (see section *Snap mode Drop-down List* on page 122 in chapter 6 *Inspect Tab*).
Resnap instrument handles	Opens the **Instrument handle adjustment** dialog (see section *Resnap instrument handles* on page 123 in chapter 6 *Inspect Tab*).

Name Template Pop-up

In order to edit the name template, you can click the button next to the **Name** field. The name template pop-up will open with the following options:

Table 11-2: Controls in the name template pop-up

Control	Description
Name template field	Allows you to edit the template for instrument names. Changes to this template will be applied to all instruments to be created. If no name is edited, a name of the form *<type> <id>* will automatically be generated by default.
Reset button	Resets the name template to its default setting.
Find lowest number radio button	When this option is selected, the lowest available ID number will be assigned to the <id>.
Find highest number radio button	When this option is selected, the <id> will be incremented starting from the highest existing ID number.
Start number spin box	Allows you to specify the start number for <id>.
Min. digits spin box	Allows you to specify the minimum number of digits for <id>.

Control	Description
OK button	Applies the changes and closes the dialog. You can also click anywhere outside the pop-up.
Cancel button	Discards the changes and closes the dialog. You can also press the **ESC** key.

Annotation Contextual Tab

The **Annotation** contextual tab opens when you create a new annotation for the analysis selected in the Scene Tree. It provides the following controls for editing the annotations:

Table 12-1: Controls on the **Annotation** contextual tab

Control	Description
Cancel button	Closes the contextual tab.
Name template field	Allows you to enter a name for the annotations. If no name is provided, a name of the form *<annotation type> <id>* will automatically be generated.
Reset button	Resets the name template to the default entry.
Min. tolerance [<length unit>] spin box	If applicable: Allows you to manually specify the minimum tolerance of the selected parameter.
Max. tolerance [<length unit>] spin box	If applicable: Allows you to manually specify the maximum tolerance of the selected parameter.
Set from analysis button	If applicable: By default, the global tolerances specified on the **Settings** tab of the analysis are used for the annotation. Clicking the **Set from analysis** button toggles between manually specifying the tolerance band in the tolerance fields and using the global tolerances of the analysis.
Shape drop-down list	For P 202/P 201 analyses: Allows you to select an appropriate shape to define reference areas for which the porosity will be calculated: • **Square** • **Circle** • **Triangle** • **Rectangle**

For details on how to create an annotation and the information included in the annotation labels, see section *Annotation* on page 124 in chapter 6 *Inspect Tab*.

Light Contextual Tab

The **Light** contextual tab will be displayed in the ribbon when you create a new light source or an already existing light source is selected in the Scene Tree. The following controls are available on the **Light** contextual tab for editing the light source:

Table 13-1: Controls of the **Light** contextual tab

Control	Description
Ambient color field	Specifies the light component for general illumination. It does not seem to come from any particular light source.
Diffuse color field	Specifies the light component that comes from the light source origin and scatters equally in all directions.
Enable shadow	Check this option to switch on shadows. Shadows are supported by the isosurface renderer, the Phong volume renderer, and the Scatter HQ volume renderer and need to be activated for each light source.
Overall intensity spin box	Specifies the light intensity globally and affects all three light components: ambient, diffuse, and specular. You can also modify the overall intensity of a selected light source by holding down the **Ctrl** key and scrolling the mouse wheel while the mouse pointer is in the 3D window.

For more advanced settings, you can use the **Light** tool, which is located in the tool dock (for details, see chapter 18 *Light Tool* on page 206).

Visualization Contextual Tab

The **Visualization** contextual tab will be displayed in the ribbon when a render object, i.e., CAD model, surface mesh, volume mesh, volume object, or ROI is selected in the Scene Tree. It allows you to easily change the color and transparency of the render object. For volume objects and ROIs on volume objects, the **Isosurface renderer** has to be selected on the **Voxel** tab of the **Rendering** tool. For more advanced settings, you can use the **Rendering** tool, which is located in the tool dock (for details, see chapter 17 **Rendering *Tool* on page 192**).

The **Visualization** tab provides the following controls:

Table 14-1: Controls on the **Visualization** tab

Control	Description
Transparency spin box	Specifies the transparency of the selected object (0 = opaque…100 = transparent).
Line/surface color drop-down list	The following option specifies the color to be used for 3D rendering: • **From histogram**: Available for a volume object with volume data loaded. Applies the color(s) assigned to the gray values in the gray value histogram of the **Voxel** tab. The following options specify the color to be used for 2D outline rendering and 3D surface rendering: • **From component**: For a volume object: Applies a gray value based on the mean gray value of the corresponding volume component. • **From CAD**: For a CAD model: Uses the color specified in the CAD file. • **From mesh**: For a surface mesh: Uses the color specified in the mesh or point cloud file. • **Red, ..., Black**: Allows you to select the color for the render object from a set of predefined colors. • **Custom color**: Opens the **Select Color** dialog, where you can set the color for the render object.

Control	Description
3D back color drop-down list	For a CAD model or surface mesh: • **Red, ..., Black**: Allows you to select the color for the rear side of the surface from a set of predefined colors. • **Custom color**: Opens the **Select Color** dialog, where you can set the color for the rear side of the surface. • **From CAD**: For a CAD model: Uses the color specified in the CAD file. • **From mesh**: For a surface mesh: Uses the color specified in the mesh or point cloud file. For a tetrahedral volume mesh, the **3D back color** will be the same as selected from the **Line/surface color** drop-down list.
ROI rendering	Available when an ROI is selected in the Scene Tree. Enables/disables rendering the selected ROI. When rendering is enabled, properties like color or transparency can be modified via the **Rendering** tool. The render settings of an ROI have a higher priority than the settings of the parent object, i.e., the render settings of the object to which the ROI is attached. Thus, it is possible to render an ROI differently than the parent object without having to extract the ROI first.

Select objects (3D) Contextual Tab

The **Select objects (3D)** contextual tab will open when you click the **Select objects (3D)** button on the **Inspect** tab (see section *Select objects (3D)* on page 128 in chapter 6 *Inspect Tab*). It allows you to specify the selection settings and quit the object selection mode.

Table 15-1: Controls of the **Select objects (3D)** contextual tab

Icon	Control	Description
	Cancel object selection button (or **Esc** key)	Cancels object selection and quits the object selection mode.
	Include invisible objects checkbox	When this option is activated, objects that are invisible in the Scene Tree will also be included in the selection.
	Shape drop-down list	Allows you to change the shape.
	Geometry elements, **Geometric tolerances**, **Regions of interest**, **CAD objects**, **Volume objects**, **Mesh objects** checkboxes	Allow you to specify the types of Scene Tree objects to be included in the selection.

Transform Contextual Tab

The **Transform** contextual tab allows you to modify the position and orientation of the selected object as well as its center of rotation. It will be displayed in the ribbon when the object selected in the Scene Tree was unlocked prior to saving the project.

The object can also be transformed using the active tripod; the translation and rotation values will be synchronized with the corresponding **X**, **Y**, and **Z** spin boxes on the **Transform** contextual tab accordingly. See also Table 16-2: *Controls of the active tripod*.

It is also possible to transform several objects or groups at a time.

Table 16-1: Controls of the **Transform** contextual tab

Icon	Control	Description
	Apply transformation button	Accepts the transformation and resets the spin boxes to zero. Note that when you change the selection in the Scene Tree, the transformations will be applied automatically.
	Cancel transformation button	Rejects the transformation and resets the spin boxes to zero.
	Reset position button	Resets the position of the object to the origin of the selected coordinate system.
	Reset rotation button	Resets the rotation of the object to the orientation of the selected coordinate system.
	X, **Y**, **Z** spin boxes for translation	• When the **Absolute** checkbox is unchecked: specify the translation of the object along the corresponding axis in the selected coordinate system. If the objects to be translated include at least one volume object whose voxel grid is aligned with the selected coordinate system, you can change the unit from **mm** to **voxel**. • When the **Absolute** checkbox is checked: specify the absolute position of the object in the selected coordinate system.
	X, **Y**, **Z** spin boxes for rotation	Available when the **Absolute** checkbox is unchecked. Specify the rotation of the object around the corresponding axis in the selected coordinate system.

Icon	Control	Description
	Absolute checkbox	Allows you to specify the absolute position/rotation in the selected coordinate system using the **Axis** and **Angle** spin boxes. Absolute rotation is defined by both a normalized vector in 3D space that serves as a rotational axis and a rotation angle around this axis. This checkbox is only enabled if exactly one object is selected and the object is independent of the selected coordinate system.
	Axis spin boxes	Available when the **Absolute** checkbox is checked: specify the x-, y-, and z-coordinates to define the rotational axis.
	Angle spin boxes	Available when the **Absolute** checkbox is checked: specify the angle around the rotational axis defined by the **Axis** spin boxes.
	Center of rotation drop-down list	Allows you to select the center of rotation to which the rotation specified on the **Transform** contextual tab and the active tripod will refer: • **Center of bounding box of individual object**: rotates around the individual bounding boxes of the selected objects. • **Center of current coordinate system**: rotates around the origin of the selected coordinate system. • **Navigation cursor**: rotates around the activated navigation cursor (to activate the navigation cursor, click in the quick access toolbar or **Inspect >** **Navigation cursor**). • **Bounding box**: rotates around the common bounding box of the selected objects.

Table 16-2: Controls of the active tripod

Control	Description
click and drag a tripod axis	Moves the object along the corresponding axis. A label that indicates the current translation distance will appear. During or after dragging, you can also enter a value into the label.
hold down **Shift** + click + drag a tripod axis	Moves the object along the corresponding axis in steps of 100 length units (e.g., mm).
hold down **Ctrl** + click + drag a tripod axis	Moves the object along the corresponding axis in steps of 10 length units (e.g., mm).
hold down **Ctrl**+**Shift** + click + drag a tripod axis	Moves the object along the corresponding axis in steps of 1 length unit (e.g., mm).

Control	Description
click and drag a tripod arc	Rotates the object around the corresponding axis. A label that indicates the current rotation angle will appear. During or after dragging, you can also enter a value into the label.
hold down **Shift** + click + drag a tripod arc	Rotates the object around the corresponding axis in steps of 45 degrees.
hold down **Ctrl** + click + drag a tripod arc	Rotates the object around the corresponding axis in steps of 5 degrees.
hold down **Ctrl**+**Shift** + click + drag a tripod arc	Rotates the object around the corresponding axis in steps of 1 degree.
click and drag a planar handle	Moves the object in the plane that is orthogonal to the corresponding axis.

Rendering Tool

Introduction

To have the **Rendering** tool displayed or hidden in the tool dock, activate or deactivate the corresponding entry in the **Tools** drop-down list on the **Window** tab in the ribbon. To collapse or expand the **Rendering** tool window in the tool dock, click the title bar of the **Rendering** tool window.

The **Rendering** tool allows you to specify the look of render objects, such as volume objects, CAD and mesh objects, and ROIs. Settings that are not applicable to the selected object will be grayed out.

When a rendering object is selected in the Scene Tree, the **Visualization** contextual tab, which provides a subset of functions, will be displayed in the ribbon (see chapter 14 **Visualization *Contextual Tab* on page 186**).

Modifying the render settings might be disallowed by the creator of the *.vgl* file.

Preset Selection

Table 17-1: Controls in the **Preset selection** section

Icon	Item	Description
	drop-down list	Specifies the preset to be applied, to be edited, or to be taken as a basis for a new preset. The presets are sorted according to the object types they belong to. The following icons are used in combination with the icon of the object type as shown in the Scene Tree: • default preset • customized preset • appears next to the icon of a preset that has been modified but not yet saved If a selected preset does not match the currently selected object, an error dialog will appear and the preset will not be applied.
	Save preset	Opens the **Save preset** dialog for saving the selected preset under the specified name. • **Absolute preset**: When this option is checked, the color and opacity settings of the preset will be mapped to the gray value range of the original data set. When this option is unchecked, the color and opacity settings of the preset will be mapped relative to the gray value range of the data set to which the preset is to be applied.

Icon	Item	Description
	Remove preset	Removes the selected preset from the preset drop-down list.
	Import preset	Opens the **Preset name** dialog for importing a preset from the specified location (see below).
	Export preset	Exports the selected preset to the specified location.

Preset name Dialog

Table 17-2: Controls of the **Preset name** dialog

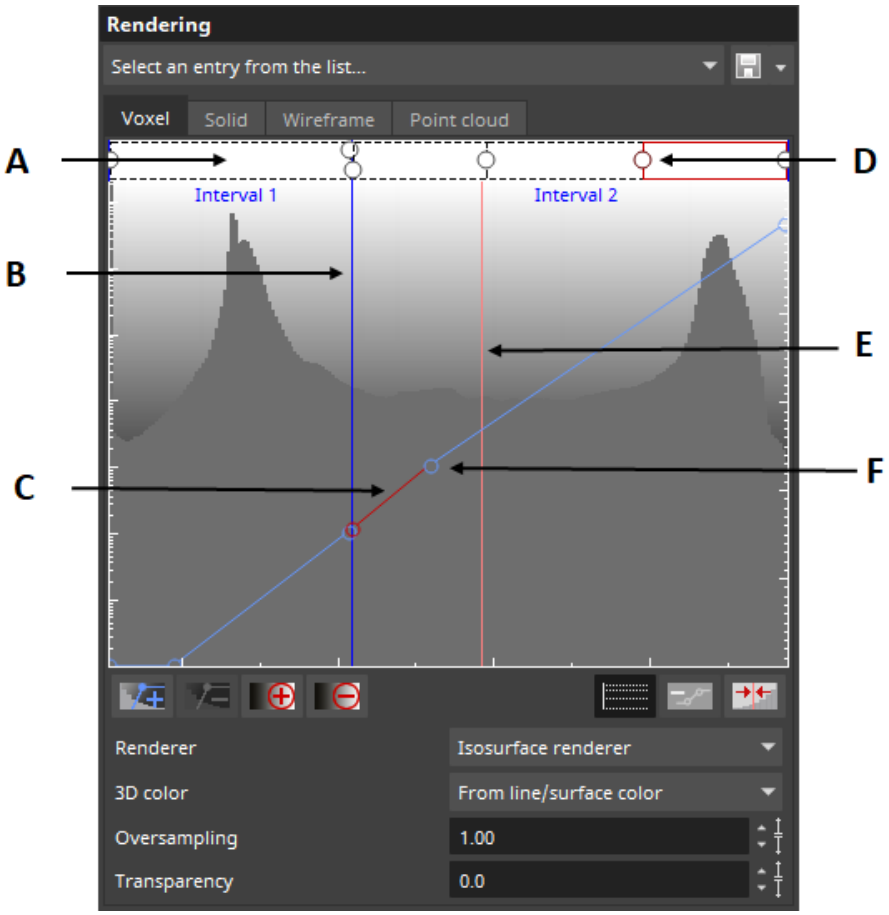
Controls	Description
Name field	Indicates the name of the preset. Clicking the button removes the original name and allows you to enter a new name.
Choose LUT application mode section	Specifies how the color lookup table (LUT) saved with the preset is to be applied to the gray value range of the currently loaded data set: • **As saved**: Uses the mode for applying the color and opacity settings that was selected when the preset was saved. • **Absolute**: Maps the color and opacity settings of the preset to the gray value range of the original data set. • **Relative**: Maps the color and opacity settings of the preset relative to the gray value range of the current data set.

Voxel Tab

Shows a histogram of the gray values of the selected volume object. A diagonal line in the histogram represents the linear mapping of gray values to opacities.

You can use the histogram for configuring the transparency and opacity for the gray value range by adding, deleting, and moving handles on the line. You can also use the histogram for assigning colors to specific gray value ranges.

If the voxel data has been unloaded for the selected volume object, the message “Voxel-based settings not available when gray values unloaded” will be displayed. In this case, you can use the **Solid** tab to adjust the render settings.



A:	Color segment	**D:**	Color handle
B:	Interval divider line	**E:**	Isosurface line
C:	Opacity line segment	**F:**	Opacity handle

Figure 17-1: Controls on the **Voxel** tab of the **Rendering** tool

Controls of the **Voxel** Tab

Table 17-3: Controls of the **Voxel** tab

Icon	Item	Description
	Add opacity handle	Inserts a handle in the middle of the selected line segment on the opacity curve. The new handle and the line segment to its right will be selected in red. Note: You can also automatically create opacity handles for optimizing the contrast by selecting **Smart contrast** from the preset drop-down list.

Icon	Item	Description
	Remove opacity handle	Removes the selected handle from the opacity curve and extends the selected line segment to the next handle to the left.
	Add color handle	Inserts a handle in the middle of the selected color segment in the color area. The new handle gets the current color for the exact gray value it was created for.
	Remove color handle	Removes the selected handle from the color area.
/	**Enable logarithmic scaling/Enable linear scaling**	Toggles between logarithmic and linear scale for the left y-axis, which represents the gray value histogram.
/	**Disable ROI rendering/Enable ROI rendering**	Disables/enables rendering the ROI selected in the Scene Tree. When rendering is enabled, ROIs can be rendered separately from the object to which they are attached.
/	**Disable surface determination render settings/Enable surface determination render settings**	For Isosurface renderer only: • **Enabled:** In the 3D view, the surface of the selected volume or ROI is rendered according to the determined surface. • **Disabled:** In the 3D view, the surface of the selected volume or ROI is rendered according to the position of the isosurface line. The isosurface line can be moved by clicking and dragging it. This will only affect the rendering and will not change the determined surface.
	Renderer drop-down list	Specifies the rendering algorithm to be used for displaying the volume object in the scene: • **Isosurface renderer** This algorithm displays the surface of the selected object as defined by the surface determination. It is the most suitable renderer for the visualization of typical industrial CT data sets: This algorithm yields high-quality, photorealistic images at interactive speeds almost independently of the size of the data set. • **Volume renderer (Phong)** This algorithm is a volume-rendering algorithm that emphasizes the local gradients within the voxel data. The full support of lighting sources and clipping objects makes it most suitable for animations.

Icon	Item	Description
		• **Volume renderer (Scatter HQ)** This algorithm is a volume-rendering algorithm. It is the “all-rounder” among the visualization algorithms of myVGL and is well suited for the visualization of faint gray value differences within the voxel data as well as for the visualization of surface structure details. • **Hardware renderer (Scatter HQ)** In contrast to all other renderers, which all use the CPU(s) for rendering, the hardware renderer uses the graphics card for direct volume rendering. This yields the best rendering performance on most systems, especially if all voxels of the data set have to be rendered, for example, because the entire volume is to be rendered transparently. However, the hardware renderer supports the least features of the light and clipping objects, as well as rendering functions. The clipping sphere, the clipping cylinder, and the clipping polyline 3D are not available. The **Invert clipping region** option is not available for the (aligned) clipping boxes, and no transparency and 3D clipping color is available for clipping objects. Apart from that, the hardware renderer does not support analysis and measurement color overlays. For data sets larger than the graphics card memory, the hardware renderer can be used as preview only, because the volume needs to be downsampled and loses detail. • **X-Ray** This algorithm casts one ray per display pixel into the data set. The higher the integrated opacity of voxels along a ray, the darker the corresponding pixel. • **Sum along Ray** This algorithm casts one ray per display pixel into the data set. The higher the integrated opacity of voxels along a ray, the brighter the corresponding pixel. • **Maximum Projection** This algorithm casts one ray per display pixel into the data set. The maximum intensity of the voxels along a ray determines the gray value of the corresponding pixel.

Icon	Item	Description
	3D color drop-down list	For isosurface renderer only: For a volume object. Specifies the color to be used for 3D rendering: • **From histogram**: Applies the color(s) assigned to the gray values in the gray value histogram of the **Voxel** tab. • **From line/surface color**: Applies the color specified in the **Line/surface color** drop-down list of the **Solid** tab. For an ROI, the color specified in the preferences (**Color & Styles > Region of interest > 3D color for newly created ROIs**) prior to creation of the ROI will be applied.
	Oversampling spin box	Sets the oversampling to a factor larger than 1.0 to sample the object more precisely. The higher the oversampling, the slower the rendering, but the better the image quality.
	Transparency spin box	For isosurface renderer only: Specifies the transparency of the selected volume object or ROI (0 = opaque…100 = transparent). Changing the transparency level in the **Voxel** tab also affects the **Transparency** spin box on the **Solid** tab.
	Density spin box	For renderers other than the isosurface renderer: Specifies a factor for the opacity values in the opacity curve of the gray value histogram (value range: 0.0…10.0; 0.0 = no opacity, i.e., fully transparent; 1.0 = opacity values from the opacity curve; 10.0 = 10 times the opacity values from the opacity curve).
	use LMB to click and drag red isosurface line	For isosurface renderer only: Moves the isosurface line and updates the 3D view accordingly. Dragging the isosurface line displays a tooltip that indicates the absolute isovalue. The isosurface line can be moved only if the selected object has no surface determination or if the surface determination render settings of the selected volume have been disabled by clicking the **Disable surface determination render settings** button.
	hover mouse pointer over one of the axes of the histogram	Highlights the axis and displays the respective label and ticks.
	click and hold LMB in the histogram area	Displays the minimum and maximum gray values of the selected volume. If available, the gray value at the current position of the isosurface line will also be displayed.

Icon	Item	Description
	use MMB to click the color area	Inserts a color handle at the exact position of the mouse pointer.
	use MMB to click a handle in the color area	Removes the selected color handle.
	use LMB to click and drag color handle	Moves the selected color handle. Moving the color handle displays the corresponding gray value.
	use LMB to click and drag a color segment	Moves the color segment. A color segment has a start and an end color handle and represents the color-to-gray-value assignment for an entire gray value range. The color assigned to each gray value of this range is an interpolation of the colors assigned to the start and end color handles. Moving the color segment displays the gray values of the involved color handles. Moving a color segment is only possible if the involved color handle is not associated with the start or end of an interval.
	use LMB to double-click a color handle	Opens the **Select Color** dialog, where you can select a color to be assigned to the gray value of the color handle.
	use LMB to double-click a color segment	Opens the **Select Color** dialog, where you can select a color to be assigned to all gray values in the color segment. This color is interpolated across the start and end handles of this segment, resulting in a color gradient with the colors of the neighboring color segments.
	use MMB to click the histogram area	Inserts an opacity handle at the exact position of the mouse pointer. The new handle and the line segment to its right will be selected and displayed in red.
	use MMB to click an opacity handle	Removes the selected opacity handle and extends the selected line segment to the next handle to the left.
	use LMB to click a blue line segment or a blue opacity handle	Selects the line segment with the opacity handle to its left and changes the color from blue (unselected) to red (selected).
	hover mouse pointer over interval divider line until mouse pointer changes to double-headed arrow	Click and drag the double-headed arrow to move the interval divider line to a new position.

Icon	Item	Description
	hover mouse pointer over interval divider line until triangular handles appear to the left and to the right of the interval divider line	Click and drag the right or left handle in the indicated direction to create a new interval from the interval divider line to where you release the mouse button. Creating an interval automatically creates a corresponding color handle in the color area. Note: You can also automatically create new intervals with two, three, four, or five predefined colors by selecting **Smart colors (2-5)** from the preset drop-down list.
	use LMB to click the interval label	Allows you to rename the interval label.
	scroll MW on left y-axis up/down	Zooms the y-axis of the gray value histogram out/in.
	scroll MW on right y-axis up/down	Zooms the opacity curve out/in.
	scroll MW in histogram area or x-axis up/down	Zooms the x-axis of the gray value histogram out/in.
	use RMB to click the histogram area or the color area	Opens a context menu (see below).

Context Menu of the **Voxel** Tab

Right-clicking the histogram area or the color area displays a context menu with the following options:

Table 17-4: Context menu items in the histogram area

Control	Description
Export histogram as CSV...	Opens the **Export histogram as CSV...** dialog for exporting the gray values as *.csv* file.
Copy to clipboard	Copies a screenshot of the chart to the system clipboard so that you can paste it into another application.
Add color handle	Inserts a color handle at the horizontal position of the mouse pointer.
Remove color handle	Removes the selected color handle.
Set handle color	• **Red, ..., Black**: Assigns a predefined color to the gray value of the selected color handle. • **Custom color**: Opens the **Select Color** dialog, where you can specify the color to be assigned to the gray value of the selected color handle.

Control	Description
Set color between handles	• **Red, ..., Black**: Assigns a predefined color to the gray values of the selected color segment. • **Custom color**: Opens the **Select Color** dialog, where you can specify the color to be assigned to the gray values of the selected color segment. This color selection overrides any color setting for the start and end color handles of this color segment.
Set interval color	• **Red, ..., Black**: Assigns a predefined color to the gray values of the selected interval. • **Custom color**: Opens the **Select Color** dialog, where you can specify the color to be assigned to the gray values of the selected interval. This color selection overrides any other color setting within this interval and removes all color handles and segments.
Copy interval color	Copies the color handles of the interval in which you opened the context menu.
Paste interval color	Pastes the color handles to the interval in which you opened the context menu.
Export interval color...	Opens the **Save color settings to...** dialog, where you can specify the path and file name for saving the colors and color handles of the interval in which you opened the context menu to a *.lut* or *.act* file.
Import interval color...	Opens the **Load color settings from...** dialog, where you can specify the path and file name for loading the colors and color handles from a *.lut* or *.act* file and apply them to the interval in which you opened the context menu.
Reset zoom	Fits the entire chart to the current window size.
Hide histogram/Show histogram	Toggles the visibility of the gray value histogram.
Split interval	Creates a new interval divider line at the position of the mouse pointer. Creating an interval automatically creates corresponding start and end color handles in the color area.
Merge interval	• **Merge left:** Merges the selected interval and the interval to the left without merging existing color segments within these intervals, so the color assignment will remain unchanged. • **Merge right:** Merges the selected interval and the interval to the right without merging existing color segments within these intervals, so the color assignment will remain unchanged.

Control	Description
Delete interval	• **Expand left neighbor:** Removes the selected interval as well as included color segments, which adds it to the interval to the left. • **Expand right neighbor:** Removes the selected interval as well as included color segments, which adds it to the interval to the right.
Disable interval/Enable interval	Hides or shows the gray values of the selected interval in the 2D and 3D windows.
Add opacity handle	Inserts a handle in the middle of the selected line segment. The new handle and the line segment to its right will be selected in red.
Remove opacity handle	Removes the selected handle and extends the selected line to the next handle on the left.
Copy opacity curve	Copies the opacity curve of the interval in which you opened the context menu.
Paste opacity curve	Pastes the opacity curve in the interval in which you opened the context menu.
Reset opacity curve	• **Default:** Sets the curve to its default. • **Fully opaque:** Sets the curve so that all voxels are displayed fully opaque. • **Fully transparent:** Sets the curve so that all voxels are displayed fully transparent.

Solid Tab

Table 17-5: Controls of the **Solid** tab

Control	Description
Render solid checkbox	For a CAD model or surface mesh: When this option is checked, the triangles of the CAD model or surface mesh will be rendered as a solid surface. For a tetrahedral mesh: When this option is checked, the surface triangles of the tetrahedral mesh will be rendered. To see the faces of inner tetrahedra in the 3D window, use a clipping plane.
ROI render settings checkbox	For an ROI: When this option is checked, the render settings for the selected ROI will be enabled so that you can render the ROI separately from the object to which it is attached.

Control	Description
3D color drop-down list	Available for a volume object with volume data loaded. Specifies the color to be used for 3D rendering: • **From histogram**: Applies the color(s) assigned to the gray values in the gray value histogram of the **Voxel** tab. • **From line/surface color**: Applies the color specified in the **Line/surface color** drop-down list.
Line/surface color drop-down list	Available for a volume object, CAD model, or mesh. Specifies the color to be used for 2D outline rendering and 3D surface rendering: • **From component**: For a volume object: Applies a gray value based on the mean gray value of the corresponding volume component. • **From CAD**: For a CAD model: Uses the color specified in the CAD file. • **From mesh**: For a surface mesh: Uses the color specified in the mesh or point cloud file. • **Red, ..., Black**: Allows you to select the color for the render object from a set of predefined colors. • **Custom color**: Opens the **Select Color** dialog, where you can set the color for the render object. The line color will have no effect if the surface lines are switched off in all 2D views.
2D fill color drop-down list	Available for a volume object if the link status is unlinked: • **From component**: Applies a gray value based on the mean gray value of the corresponding volume component. • **Red, ..., Black**: Allows you to select the color for the render object from a set of predefined colors. • **Custom color**: Opens the **Select Color** dialog, where you can set the color for the render object. The color is only used for the fill mode and will have no effect if the fill mode is switched off in all 2D views. Not applicable to CAD or mesh objects.
/ icon	Available for a volume object. Toggles the link status of the **Line/surface color** and the **2D fill color**. If both colors are linked, the **2D fill color** will just be a darker shade of the **Line/surface color**.
2D line width spin box	Specifies the line width for the object in the 2D windows.
Ambient intensity spin box	Specifies the intensity of the ambient component of light reflected from the selected object.

Control	Description
Diffuse intensity spin box	Specifies the intensity of the diffuse component of light reflected from the selected object.
Specular intensity spin box	Specifies the intensity of the specular component of light reflected from the selected object.
Shininess spin box	Specifies the size and brightness of the highlight of the specular component of light reflected from the selected object.
Transparency spin box	Specifies the transparency of the selected object (0 = opaque…100 = transparent). For volume objects, this will be available if the isosurface renderer is selected on the **Voxel** tab.
3D clipping color drop-down list	• **Color only:** For a volume object: Applies the user-defined color rendering settings to the clipped surface. • **Opacity only:** For a volume object: Applies the user-defined opacity rendering settings to the clipped surface. • **Color and opacity:** For a volume object: Applies the user-defined color and opacity rendering settings to the clipped surface. • **Red, ..., Black**: For a volume object or a volume mesh: Allows you to select the color for the clipped surface from a set of predefined colors. • **Custom color**: For a volume object or a volume mesh: Opens the **Select Color** dialog, where you can set the color for the clipped surface. • **From line/surface color**: For a volume mesh: Applies the color specified in the **Line/surface color** drop-down list in a lighter shade.
3D back color drop-down list	For a CAD model or surface mesh: • **Red, ..., Black**: Allows you to select the color for the rear side of the surface from a set of predefined colors. • **Custom color**: Opens the **Select Color** dialog, where you can set the color for the rear side of the surface. • **From CAD**: For a CAD model: Uses the color specified in the CAD file. • **From mesh**: For a surface mesh: Uses the color specified in the mesh or point cloud file. For a tetrahedral volume mesh, the **3D back color** will be the same as selected from the **Line/surface color** drop-down list.

Control	Description
Smooth shading checkbox	For a CAD model or mesh: When this option is checked, the color of the triangle vertices will be interpolated, which results in a much smoother object surface.
Render clip/segment surface checkbox	• For a volume object cut by a clipping object: When this option is checked, the clipped area of the volume object will be shown as a surface in the color specified in the **3D clipping color** option. When this option is unchecked, only the surface of the volume will be shown so that the interior of the volume is visible. • For an ROI for which render settings have been enabled: When this option is checked, the ROI will be shown as if it were a solid object. When this option is unchecked, the surface of the ROI that is common with the surface of the volume object will be shown.
Remove hidden surfaces checkbox	Disables the rendering of surfaces located inside the object or concealed by other surfaces. This will only have an effect if the surfaces are transparent.
Swap inner/outer areas checkbox	Interchanges the inner and outer areas of a volume object and vice versa.
Normalize gradients checkbox	Check this option to normalize the gradients for lighting calculations.

Wireframe Tab

Table 17-6: Controls of the **Wireframe** tab

Control	Description
Render wireframe checkbox	When this option is checked, the wireframe of the selected mesh or CAD object will be rendered. For mesh objects, this is the wireframe of the triangle mesh or tetrahedral mesh. For CAD objects, this is the wireframe of the CAD model.
Color drop-down list	• **Red, ..., Black**: Allows you to select the color for the wireframe from a set of predefined colors. • **Custom color**: Opens the **Select Color** dialog, where you can set the color for the wireframe.
Line width spin box	Specifies the line width (in pixels) of the wireframe in the 3D window.

Point cloud Tab

Table 17-7: Controls of the **Point cloud** tab

Control	Description
Render vertices/points checkbox	When this option is checked, all vertices/points of the selected surface mesh or the surface vertices/points of the tetrahedral mesh will be rendered as a point cloud.
Color drop-down list	• **Red, ..., Black**: Allows you to select the color for the point cloud from a set of predefined colors. • **Custom color**: Opens the **Select Color** dialog, where you can set the color for the point cloud.
Size spin box	Specifies the point size (in pixels) in the 3D window.

Light Tool

Introduction

To have the **Light** tool displayed or hidden in the tool dock, activate or deactivate the corresponding entry in the **Tools** drop-down list on the **Window** tab in the ribbon. To collapse or expand the **Light** tool window in the tool dock, click the title bar of the **Light** tool window.

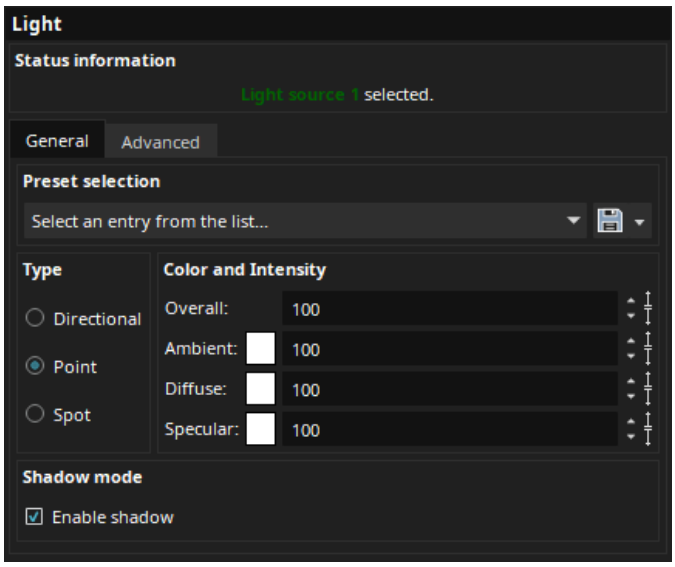


Figure 18-1: **Light** tool, **General** tab

When a light source is selected in the Scene Tree, the **Light** contextual tab, which provides a subset of functions, will be displayed in the ribbon (see chapter 13 **Light *Contextual Tab* on page 185**).

The following types of light sources are available in myVGL:

- Directional light
- Point light
- Spot light

A light source will only be visible in the 2D and 3D windows if it is selected in the Scene Tree; it can then be modified with the mouse in the following ways:

- In the 3D window, the light source can be rotated or moved, depending on whether the **Rotate** or **Move** mode is active (directional light sources can only be rotated).
- In the 2D windows, the origin and direction of the light source can be modified by clicking and dragging the handles.
- To initially place a light source, click somewhere in a 2D window and drag the mouse pointer in the direction of the light.

The position of a light source object can be modified only if its padlock icon in the Scene Tree is open.

Status information Section

Displays the name of the selected light source. If no light source is currently selected in the Scene Tree, the text “No light source selected” will be displayed in red and all controls will be disabled.

General Tab

- **Preset selection** section

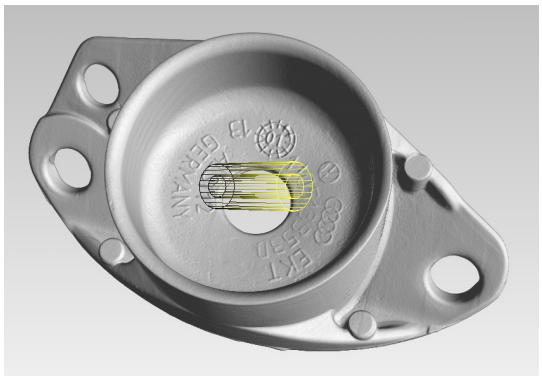
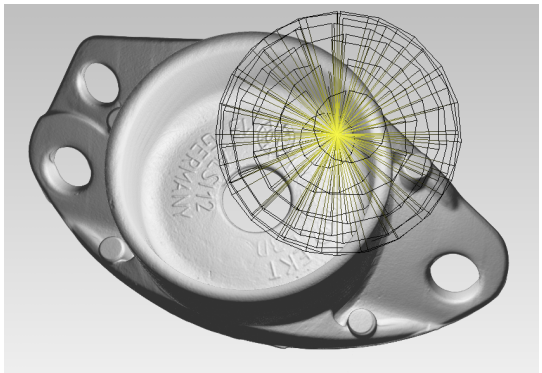
  Table 18-1: Controls in the **Preset selection** section

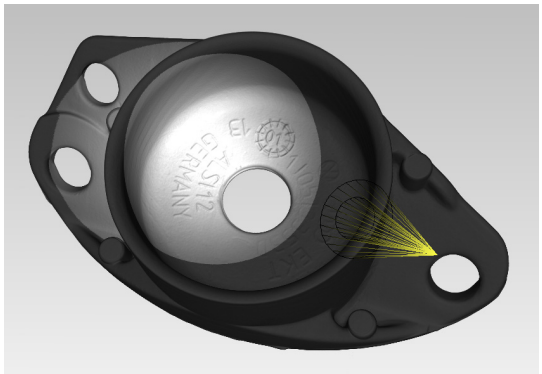
Icon	Item	Description
	drop-down list	Specifies the preset to be applied, to be edited, or to be taken as a basis for a new preset. The following icons are used: • default preset (if available) • customized preset • appears next to the icon of a preset that has been modified but not yet saved
	Save preset	Saves the selected preset under the specified name.
	Remove preset	Removes the selected preset from the preset drop-down list.
	Import preset	Imports a preset from the specified location.
	Export preset	Exports the selected preset to the specified location.

- **Type** section

  Specifies the type of the light source.

Table 18-2: Controls in the **Type** section

Control	Description
Directional	A light source that emits a parallel bundle of light rays in a particular direction. The light intensity does not drop with distance. The figure below shows an example of a directional light source.  Figure 18-2: Directional light source
Point	A single point in space that emits light equally in all directions. The intensity of the light decreases in proportion to the square of the distance to the light source. This is comparable to an infinitely small, unshaded light bulb. The figure below shows an example of a point light source.  Figure 18-3: Point light source

Control	Description
Spot	Similar to a point light, but the shape of the emitted light is limited to a cone, like the lamp shade of a regular desk lamp. Refer to the **Spot** section on the **Advanced** tab to change the settings for the spot light. The figure below shows an example of a spot light source.  Figure 18-4: Spot light source

- **Color and Intensity** section

  Specifies the color and intensity of the light components:

  - To specify the color of the respective light component, double-click the square box and select a color from the **Select Color** dialog.
  - To specify the intensity, use the corresponding spin box.

  See Figure 18-5: *Examples of light components* on page 210 for an illustration of the different light components.

  Table 18-3: Controls in the **Color and intensity** section

Control	Description
Overall	Specifies the light intensity globally and affects all three light components: ambient, diffuse, and specular. You can also modify the overall intensity of a selected light source by holding down the **Ctrl** key and scrolling the mouse wheel while the mouse pointer is in the 3D window. The **Overall intensity** option is also available on the **Light** contextual tab.
Ambient	Specifies the light component for general illumination. It does not seem to come from any particular light source. The **Ambient color** option is also available on the **Light** contextual tab.

Control	Description
Diffuse	Specifies the light component that comes from the light source origin and scatters equally in all directions. The **Diffuse color** option is also available on the **Light** contextual tab.
Specular	Specifies the light component that comes from the light source origin and bounces off into a preferred direction. It is responsible for the shininess of a lighted object.

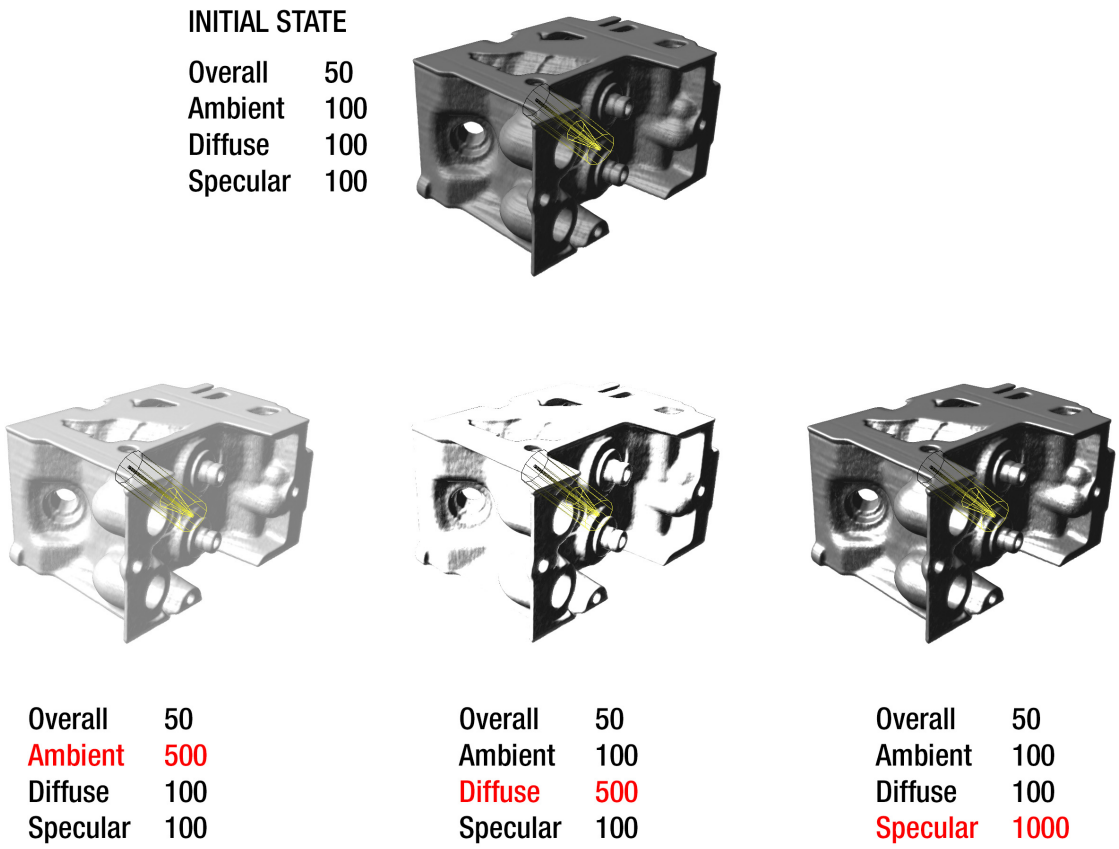


Figure 18-5: Examples of light components

- **Shadow mode** section

  Check the **Enable shadow** checkbox to switch on shadows for the selected light source. Shadows are supported by the isosurface renderer, the Phong volume renderer, and the Scatter HQ volume renderer and need to be activated for each light source.

  The **Enable shadow** option is also available on the **Light** contextual tab.

Using shadows slows down the rendering process.

Advanced Tab

- **Attenuation** section

  Available for point and spot light sources. This section specifies the decrease in light intensity as distance from the light source increases.

  Table 18-4: Controls in the **Attenuation** section

Control	Description
Constant	Applies a constant attenuation factor.
Linear	Applies a linear attenuation factor.
Quadratic	Applies a quadratic attenuation factor.
Constant button	Switches off the attenuation, setting the **Linear** and **Quadratic** attenuation factors to 0 and the **Constant** attenuation factor to 1. This is the default setting.
Gradient button	Sets the attenuation so that half of the decrease in light intensity lies within the 2D window. This intensity is shown by a dashed circle around the light source and can be modified with the mouse.

- **Spot** section

  Available for **Spot** light source.

  Table 18-5: Controls in the **Spot** section

Control	Description
Cutoff angle spin box	Specifies the opening angle of the cone of the spot light source. Value range (in degrees): 0 (closed)…90 (open). To open or close the cone, you can also hold down **Ctrl** and click and drag the cone in a 2D view.
Exponent spin box	Specifies the decrease in light intensity along the cone radius. The higher the value, the faster the decrease in light intensity and the smoother the light edges.

- **Shadow options** section

  Enabled only if the **Enable shadow** option on the **General** tab is checked.

  When the **Consider objects in view frustum only** option is checked, objects lying outside the viewing frustum will not cast a shadow.

Camera Tool

To have the **Camera** tool displayed or hidden in the tool dock, activate or deactivate the corresponding entry in the **Tools** drop-down list on the **Window** tab in the ribbon. To collapse or expand the **Camera** tool window in the tool dock, click the title bar of the **Camera** tool window.

The 3D view of myVGL is rendered using a virtual camera placed in the scene along with the volume, CAD, or mesh data. Various properties, such as camera position, viewing direction, and aperture angle, can be controlled using this tool.

☞ The camera will only be rotated/moved if the selected object (e.g., volume, ROI, light source, or clipping plane) is locked (padlock is closed); otherwise, the selected object will be rotated/moved.

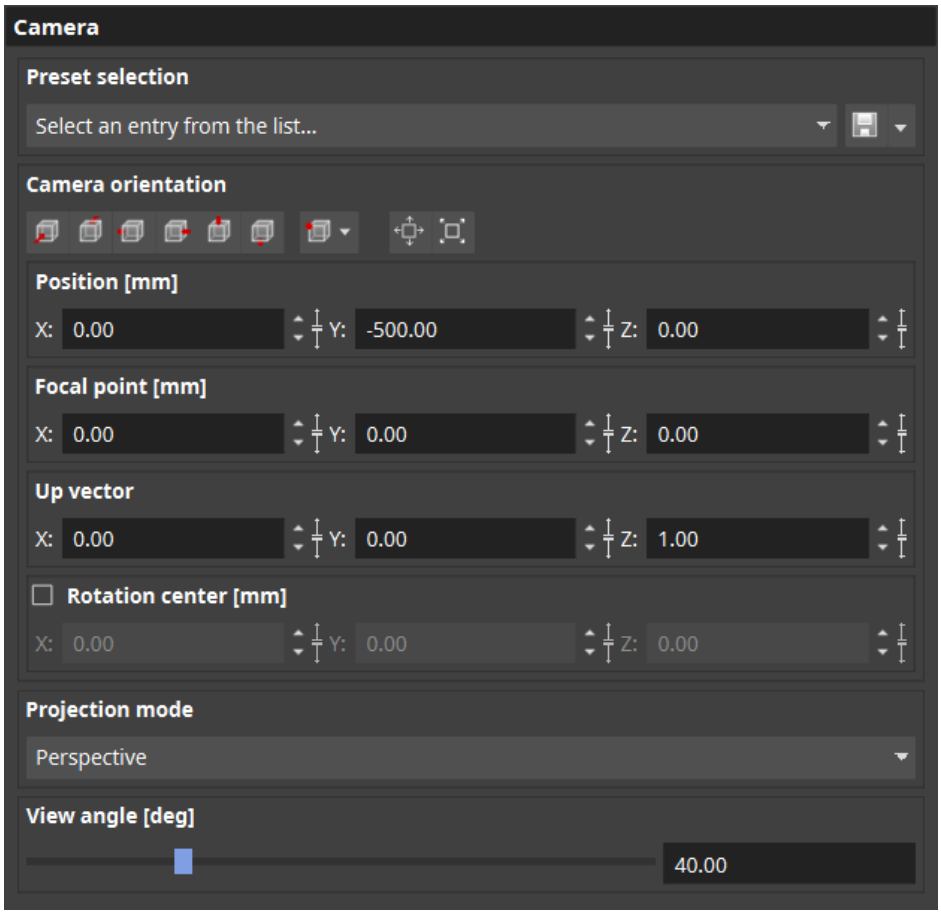


Figure 19-1: **Camera** tool

- **Preset selection** section

Table 19-1: Controls in the **Preset selection** section

Icon	Item	Description
	drop-down list	Specifies the preset to be applied, to be edited, or to be taken as a basis for a new preset. The following icons are used: • default preset (if available) • customized preset • appears next to the icon of a preset that has been modified but not yet saved
	Save preset	Saves the selected preset under the specified name.
	Remove preset	Removes the selected preset from the preset drop-down list.
	Import preset	Imports a preset from the specified location.
	Export preset	Exports the selected preset to the specified location.

- **Camera orientation** section

Table 19-2: Controls in the **Camera orientation** section

Icon	Control	Description
	default camera views	Provide shortcuts to various default camera views relative to the selected coordinate system. They can be used for quickly adjusting the camera point of view. These default views are shown along the three major axes (in both directions) as well as from positions along each of the four diagonals (one position for each corner).
	Center	Centers the selected object in the 3D view (via a translation along the screen plane).
	Focus	Focuses the selected object in the 3D view (via a translation along the viewing direction).
	Position X/Y/Z fields	Display and manipulate the position of the camera (in the current coordinate system).
	Focal point X/Y/Z fields	Display and manipulate the position to which the camera is focused. The view direction can be obtained by subtracting the position coordinates from the focal point coordinates and normalizing the result.
	Up vector X/Y/Z fields	Specify the vertical orientation (the roll) of the camera, i.e., implicitly set the axial rotation of the camera relative to the view direction.

Icon	Control	Description
	Rotation center X/Y/Z fields	Specify the camera rotation center. This option is available only if the default navigation mode is selected in the **Preferences** dialog under **General > Window > 3D window** (see section *General Preferences* in chapter 3 *File Tab*). You can also set the camera rotation center by right-clicking the 3D window and select **Set rotation center** from the context menu. The rotation center will be set to the position at which you right-clicked before the context menu is opened.

- **Projection mode** drop-down list

  Table 19-3: Options of the **Projection mode** drop-down list

Option	Description
Perspective	Renders the 3D models as seen by a single human eye: Spatial foreshortening and apparent size as a function of distance are taken into account. This means that objects look smaller when the distance from the observer increases, and parallel lines recede towards the vanishing point.
Parallel	Renders the 3D models without perspective correction so that parallel lines are maintained independently of distance.

  The projection mode used by default can be specified in the preferences under **General > Window > Camera** (see section *General Preferences* on page 57 in chapter 3 *File Tab*).

- **View angle** slider and input field

  For projection mode **Perspective**: Specifies the vertical viewing angle (in degrees) of the camera.

- **View height** spin box

  For projection mode **Parallel**: Specifies the height of the scene seen by the camera.

Clipping Tool

Introduction

To have the **Clipping** tool displayed or hidden in the tool dock, activate or deactivate the corresponding entry in the **Tools** drop-down list on the **Window** tab in the ribbon. To collapse or expand the **Clipping** tool window in the tool dock, click the title bar of the **Clipping** tool window.

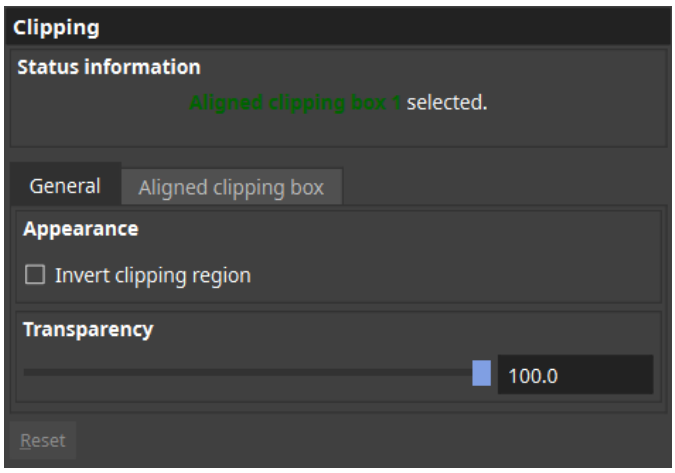


Figure 20-1: **Clipping** tool, **General** tab

When a clipping object is selected in the Scene Tree, the **Clipping** contextual tab, which provides a subset of functions, will be displayed in the ribbon (see section *Clipping Contextual Tab* on page 113).

Using clipping objects allows you to render parts of a volume object, CAD model, or mesh transparent, independently of the render settings of the object. This is done by cutting away parts of the object using a geometric object (e.g., plane or box).

In order to create a clipping object, select the type of clipping object from the **Create >** context menu in the **Scene Tree** tool or from the **Clipping** drop-down list on the **Select** tab in the ribbon.

For tetrahedral meshes, only clipping planes can be created.

In the 2D windows, a clipping plane can also be created by using the **Create/replace clipping plane using slice position** icon or the **Clipping > Create/replace clipping plane using slice position** context menu item. In this case, the plane is automatically located at the slice location shown in the 2D window in which the clipping plane has been created.

For details on the individual clipping objects, see section *Clipping Icon Group* on page 103 in chapter 6 *Inspect Tab*.

The transformation and scaling of a clipping object can be reset to its default values by using the **Reset transformation** context menu item.

Multiple clipping objects can be combined to achieve more complex clipping regions.

To share a clipping object between multiple volume, CAD, or surface mesh objects, group these objects and define the clipping object for the group. To clip all objects, create a clipping object for the scene.

Status information Section

Displays the name of the selected clipping object in green. If no clipping object is currently selected in the Scene Tree, the text “No clipping object selected” will be displayed in red and all controls will be disabled.

General Tab

This tab shows the controls applicable to all types of clipping objects:

Table 20-1: Controls of the **General** tab

Control	Description
Appearance section	Checking the **Invert clipping region** checkbox inverts the region used for clipping. For clipping planes, inverting the clipping region will swap the sides used for clipping. For (aligned) clipping boxes, inverting the clipping region will render anything inside the clipping box transparent. This option is also available on the **Clipping** contextual tab. This option is not available with the **Hardware renderer (Scatter HQ)**, for the (aligned) clipping boxes.
Transparency slider and input field	Controls the transparency value of the clipped region. Value range: 0…100. This option is also available on the **Clipping** contextual tab. This option is not available with the **Hardware renderer (Scatter HQ)**.
Reset button	Resets the rotation, translation, and scaling of the selected clipping object to the default values (transparency and inversion states remain unchanged).

Aligned clipping box Tab

Enabled only if an aligned clipping box is selected.

Table 20-2: Controls of the **Aligned clipping box** tab

Control	Description
Boundary X, **Y**, **Z** fields	Specify the minimum and maximum values (in voxels) of the clipping region in the x-, y-, and z-directions.
Reset button	Resets the boundary of the aligned clipping box to its default values, which correspond to the bounding box of the voxel grid of the volume.

Scene Tree Tool

Introduction

To have the **Scene Tree** tool displayed or hidden in the tool dock, activate or deactivate the corresponding entry in the **Tools** drop-down list on the **Window** tab in the ribbon. To collapse or expand the **Scene Tree** tool window in the tool dock, click the title bar of the **Scene Tree** tool window.

The scene in myVGL consists of all currently loaded elements, such as volume objects, CAD models, meshes, GD&T features, and analyses. The elements in the scene are structured hierarchically in the Scene Tree: For example, a volume object is at top level, and all measurements and analysis results that belong to this object are listed as child elements below it. The **Scene Tree** tool allows you to access the individual elements of the scene.

The entries in the Scene Tree are preceded by various icons and controls that will be explained in the following sections. More functions can be found in the context menu, which you can open by right-clicking the entry (or entries) in question.

Apart from the actual Scene Tree, the **Scene Tree** tool also provides a search function at the top of the tool window.

Entries in the Scene Tree

Controls in the Scene Tree

Table 21-1: Controls in the Scene Tree

Control	Description
use LMB to click an entry	Selects the object. A selected object is highlighted in the Scene Tree. Selecting an object in the Scene Tree is equivalent to selecting it in the 3D window. In the 3D window, its bounding box is displayed. Any object-related operation will refer to the selected object.
hold down **Ctrl** + use LMB to click several entries	Selects the objects.
hold down **Shift** + use LMB to click two separate entries	Selects the two objects, including all objects in between.
use LMB to click an entry, then hold down **Shift** + use up/down arrow keys	Selects the objects.
use LMB to click an entry and drag up/down	Selects multiple successive objects.
use RMB to click an entry	Displays a context menu for the corresponding object.

Control	Description
use LMB to double-click an entry	Opens the properties dialog for the corresponding object.
	Expands or collapses the entry.
select object + press **Del**	Deletes the selected object.
select object + press **F2**	Allows you to rename the selected object. Do not use the “/” character in an object name.
select several objects + press **F2**	Opens the **Rename objects** dialog in which you can systematically modify the names of several objects at a time. Do not use the “/” character in an object name.
use LMB to click a highlighted entry	Allows you to rename the selected object. Do not use the “/” character in an object name.
checkbox in front of an entry	When the checkbox is checked, the object will be displayed in the scene. When the checkbox is unchecked, the object will not be displayed. This will only change the visibility; all other settings will remain unchanged. To toggle the visibility of multiple objects at a time, select them and select the **Visibility on/off** item of the context menu.
use LMB to double-click evaluation indicator in front of volume object, CAD model, or surface mesh	Opens the **Evaluation** dialog for the corresponding object.

Icons in the Scene Tree

Table 21-2: Icons in the Scene Tree

Type	Icon	Description
Transformation status indicator (not applicable to all types of objects)		Closed padlock: The object is locked in the scene. This means that rotating the object with the mouse will actually rotate the camera, whereas the position of the object in the scene remains unchanged.
		Closed padlock with a black A: The object has been locked in the scene after alignment.
		Closed padlock with a green A: The object has been locked in the scene after alignment. The alignment has been toleranced and meets the tolerance.
		Closed padlock with a red A: The object has been locked in the scene after alignment. The alignment has been toleranced and does not meet the tolerance.

Type	Icon	Description
		Open padlock: The object is unlocked. This means that rotating the object will change the position of the object in the scene, whereas the camera will remain unchanged. Note: Newly created objects inherit the transformation status of their source object(s).
Warning indicator		There is something wrong with at least one of the child entries that is relevant for the evaluation of the object. Examples: An analysis must be recalculated, a geometry element could not be refitted, a feature is based on a geometry element with a warning. The warning triangle can be combined with all kinds of other indicators.
Evaluation indicator		Green: The object is valid, i.e., it meets the specified tolerances.
		Red: The object is invalid/out of tolerance.
		Gray: The object has no evaluation/no tolerance.
		Light green/red/gray: The overall status of this object is not used for the definition of a user-defined evaluation.
		Green/red/gray with outline: The user can define an evaluation for this object.
		Green/red/gray with outline and exclamation mark: The object has a user-defined evaluation.
View		Attached to a top-level object, an ROI, or an analysis.
Volume object		Top-level object.
		No surface determination has been performed for the object.
		An isosurface determination has been performed for the object.
		An advanced surface determination has been performed for the object (volume data loaded/unloaded).
Preview of the volume		Preview of the volume reconstructed with low resolution using the **CT Reconstruction** module.
		No surface determination has been performed for the preview volume.
		An isosurface determination has been performed for the preview volume.

Type	Icon	Description
		An advanced surface determination has been performed for the preview volume (volume data loaded/unloaded).
CAD object		Top-level object.
		CAD components
		CAD assembly
		CAD part
		Tool correction
Surface mesh		Top-level object.
Fixtured mesh		Top-level object, result of a fixture simulation.
GelSight mesh		Top-level object, result of a GelSight patch scan.
Camera		Top-level object, only one camera per scene.
Light source		Attached to top-level objects, the scene should have at least one light source.
Integration mesh		Top-level object.
Region of interest		Attached to a volume object, CAD model, or surface mesh.
		ROI with 1-bit mask precision
		ROI with 2-bit mask precision
		ROI with 4-bit mask precision
		ROI with 8-bit mask precision
Coordinate measurement		Attached to a volume object, CAD model, or surface mesh.
Dimensioning feature		Attached to a volume object, CAD model, or surface mesh. • No background: No tolerance has been defined for the feature. • Red background: The feature is out of tolerance. • Green background: The feature fulfills its tolerances.
		angle
		diameter
		distance

Type	Icon	Description
		position
		radius
Tolerance feature		Attached to a volume object, CAD model, or surface mesh. • Red background: The feature is out of tolerance. • Green background: The feature fulfills its tolerances.
		angularity
		coaxiality
		cylindricity
		flatness
		parallelism
		perpendicularity
		position
		roundness
		run-out
		straightness
		symmetry
		total run-out
		conicity
		line profile
		surface profile
		sphericity
		Next to a tolerance icon: indicates that the color-coding of tolerance deviations is active
Tolerancing annotation		Attached to a tolerance feature (created manually or automatically).

Type	Icon	Description
Geometry element		Attached to a volume object, CAD model, or surface mesh. Geometry elements created by fit points are shown in orange, while manually defined geometry elements are shown in blue. When the geometry element has been created by a manipulation operation, e.g., by intersection, a “c” will be displayed at the bottom left of the geometry element icon. When the geometry element has been created by tactile probing, a probe symbol will be displayed at the top left of the geometry element icon.
		point (fitted/defined)
		line (fitted/defined)
		circle (fitted/defined)
		corner circle (fitted/defined)
		plane (fitted/defined)
		sphere (fitted/defined)
		cylinder (fitted/defined)
		cone (fitted/defined)
		torus (fitted/defined)
		freeform line (fitted)
		freeform surface (fitted)
Coordinate system		Attached to a volume object, CAD model, or surface mesh. Lists the local coordinate systems available for the corresponding parent object.
Instrument		Attached to a volume object, CAD model, or surface mesh.
		distance
		4-point angle
		3-point angle
		polyline length
		min./max. distance

Type	Icon	Description
		caliper
Deep segmentation		Attached to a volume object or an ROI.
Porosity/inclusion analysis		Attached to a volume object or an ROI.
Porosity/inclusion analysis (VGDefX/Only threshold)		Legacy analysis. Attached to a volume object or an ROI.
Porosity/inclusion analysis (2.x compatibility)		Legacy analysis. Attached to a volume object or an ROI.
P 203 analysis		Attached to a volume object or an ROI.
P 202/P 201 analysis		Attached to a volume object or an ROI.
Nominal/actual comparison		Attached to a volume object, CAD model, or surface mesh or an ROI.
Wall thickness analysis (Ray method)		Attached to a volume object, CAD model, or surface mesh or an ROI.
Wall thickness analysis (Sphere method)		Attached to a volume object, CAD model, or surface mesh or an ROI.
Displacement analysis		Attached to a volume object, CAD model, or surface mesh or an ROI.
GelSight roughness analysis		Attached to a GelSight mesh.
Fiber composite material analysis		Attached to a volume object or an ROI.
Foam/powder analysis		Attached to a volume object or an ROI.
Digital volume correlation		Attached to a volume object or an ROI.
Gray value analysis		Attached to a volume object or an ROI.
Data quality analysis		Attached to a volume object.
Slice area analysis		Attached to a volume object or an ROI.
OCR analysis		Attached to a volume object or an ROI.
Fixture simulation		Attached to a volume object.
Structural mechanics simulation		Attached to a volume object, CAD model, or surface mesh or an ROI.

Type	Icon	Description
Absolute permeability experiment		Attached to a volume object or an ROI.
Absolute permeability tensor		Attached to a volume object or an ROI.
Molecular diffusivity experiment		Attached to a volume object or an ROI.
Molecular diffusivity tensor		Attached to a volume object or an ROI.
Thermal conductivity experiment		Attached to a volume object or an ROI.
Thermal conductivity tensor		Attached to a volume object or an ROI.
Electric conductivity experiment		Attached to a volume object or an ROI.
Electric conductivity tensor		Attached to a volume object or an ROI.
Capillary pressure curve		Attached to a volume object or an ROI.
Battery anode over-hang analysis		Attached to a volume object.
Analysis results		Attached to an analysis.
		color overlay for analysis result
		tensor
		needle visualizing orientation
		streamlines or force lines
Annotation		Attached to an analysis (manually defined/rule-based).
Deformation field		Attached to a volume object, CAD model, or surface mesh.
		deformation lines
		deformed source surface
		remaining distance lines
Clipping object		Attached to a volume object, CAD model, or mesh. For tetrahedral meshes, only clipping planes can be created.
		clipping plane

Type	Icon	Description
		clipping box
		clipping polyline 3D
		clipping sphere
		clipping cylinder
		aligned clipping box
Group		Top-level object, groups of top-level objects or of child objects.

Search Functions

Allows you to specify the items to be displayed in the Scene Tree. You can either search for a specific string in the object name or display objects with a specific evaluation state.

Table 21-3: Controls of the search function

Icon	Item	Description
	text input field	Allows you to enter a search string to show only objects that include the string. If you want to search for special characters, such as (,), *, ?, or +, you need to enter a backslash before the character (e.g., to search for `?`, type in `\?`).
	Reset search option	Resets all search options to the default settings.
	Expand all	Displays all objects, including child objects in the Scene Tree.
	Collapse all	Displays only the top-level objects in the Scene Tree. If one or more entries are selected, you can use this function to expand the selected entries and their child objects.
	Search options	Toggles the display of the additional search options.
	Undefined	Shows analyses with a warning sign, invalid geometry elements, invalid features, etc.
	Valid	Shows objects for which a tolerance can be defined and the specified tolerance is met.
	No tolerance	Shows objects for which no tolerance can be defined and which are valid (e.g., geometry elements) or objects for which a tolerance can be defined but has not yet been set (e.g., features without a specified tolerance or analyses without specified tolerance settings).

Icon	Item	Description
	Out of tolerance	Shows objects for which a tolerance can be defined and the specified tolerance is not met. If the **No tolerance** option is unchecked, the pertaining geometry element(s) will be displayed only for tolerances that are highlighted in the Scene Tree.
	Show children if text matches checkbox	When this option is checked, only child objects that include the specified string will be displayed.
	RegExp checkbox	This option allows you to search for a specific text pattern by using regular expressions (“RegExp” or “regex”). When this option is checked, only objects that match the regular expression specified in the text input field will be displayed. For details on regex, look up the relevant information.
	Hide inactive items checkbox	When this option is checked, only objects with a checked visibility checkbox will be displayed. Views belonging to objects with a checked visibility checkbox will also be displayed.

Context Menu

Right-clicking an entry in the **Scene Tree** tool displays a context menu that lists the available options for the selected object(s). The context menu will differ depending on the type of the object(s). Menu items available for the selected object type but currently not applicable will be disabled.

Create >

The options available in this submenu depend on the type of object selected.

Table 21-4: **Create** submenu items

Icon	Menu Item	Description
	Analysis annotation	Creates an annotation for the selected analysis. For details, see section *Annotation* on page 124 in chapter 6 *Inspect Tab*.
	Clipping plane, **Clipping box**, **Clipping polyline 3D**, **Clipping sphere**, **Clipping cylinder**, **Aligned clipping box**	Creates a clipping object of the selected type. The clipping will be applied to the objects selected in the Scene Tree. For details, see section *Clipping Icon Group* on page 103 in chapter 6 *Inspect Tab*.

Import >

Imports templates and applies them to the selected object.

Table 21-5: **Import** submenu items

Menu Item	Description
Indicator(s)…	Imports a template of indicators (*.xvgt*) containing information on their positions, names, and group affiliation. See section *Import indicator template* on page 122 in chapter 6 *Inspect Tab*.

Align slices to object

Aligns the axes of the slice views so that they are parallel to the axes of the selected geometry element, instrument, or clipping plane.

Visibility on/Visibility off

Switches the visibility of the selected object(s) on or off. This menu item corresponds to the visibility checkbox of each object but allows you to switch the visibility of multiple objects at a time on or off.

To toggle the visibility of one or multiple objects selected in the Scene Tree, you can also press the space bar.

Visibility toggle

Toggles the visibility of the objects selected in the Scene Tree. This is useful when the selected objects have different visibility settings.

Export as Q-DAS file(s)

Opens the **Q-DAS export** dialog, where you can not only specify the path and file name for saving the evaluation results of the selected volume object, CAD model, or surface mesh in a file format that can be used in statistics software, but also specify a folder or optionally a subfolder for saving images that are exported along with the Q-DAS file. The items supported by Q-DAS export are GD&T features and the following analyses: fiber composite material analysis, porosity/inclusion analysis, wall thickness analysis, nominal/actual comparison, and battery anode overhang analysis. The images that can be exported are the images of the first bookmarks referenced by a top-level object (volume object, CAD model, or surface mesh), GD&T features, and analyses supported by Q-DAS export. For a list of Q-DAS export fields, see section *Q-DAS Export Fields* on page 977 in chapter 50 *Appendix*.

Table 21-6: Controls in the **Q-DAS export** dialog

Control	Description
Export folder field	Displays the path currently selected for exporting the file(s).
Browse... button	Opens the **Select Q-DAS export folder** dialog where you can select a folder in which to save the file(s).
File base name field	Allows you to enter a name for the file(s) to be exported.
Append incrementing index checkbox	Check this option to append an incrementing index to the file base name if the file base name is already being used by an existing file.
File type radio button	• **Shared file (*.DFQ)**: Values and descriptions of the evaluation results are exported in a single file. • **Value file and description file (*.DFX/DFD)**: Values and descriptions of the evaluation results are exported in separate files.
Character encoding radio buttons	Specify the character encoding to be used for the exported file(s): **ASCII**, **UTF-8**, **UTF-16 big endian**, **UTF-16 little endian**.
Coordinate measurement radio buttons	• **Sort features by ID**: Features will be sorted in the order of their creation. • **Sort features by name**: Features will be naturally sorted ascendingly, which is also the default in the Scene Tree.
Use image of first referenced bookmark as drawing file checkbox	When this option is checked, the image of the first bookmark referenced by a volume object, CAD model, or surface mesh (part-level image), and images of the first bookmarks referenced by GD&T features, analyses supported by Q-DAS export (feature-level images) will also be exported along with the Q-DAS file. These exported images will be used as drawing files in the Q-DAS software.
Q-DAS images folder field	Displays the path currently selected for exporting the images when **Use image of first referenced bookmark as drawing file** checkbox is checked.
Browse... button	Opens the **Select Q-DAS base folder for images** dialog where you can select a base folder in which to save the image(s).
Optional subfolder field	Displays the subfolder name currently selected for saving the images when **Use image of first referenced bookmark as drawing file** checkbox is checked.
Clear button	Resets the subfolder selection and selects the **Q-DAS images folder**.

Control	Description
Browse... button	Opens the **Select image subfolder** dialog where you can optionally select a subfolder in which to save the image(s). The subfolder must be located in the **Q-DAS images folder**.
OK button	Exports the file(s) and image(s) to the specified location.
Cancel button	Closes the dialog.

ROI rendering

Enables/disables rendering the selected ROIs. When rendering is enabled, properties, such as color or transparency, can be modified via the **Rendering** tool (see chapter 17 *Rendering Tool* on page 192).

The render settings of an ROI have a higher priority than the settings of the parent object, i.e., the render settings of the object to which the ROI is attached. Thus, it is possible to render an ROI differently than the parent object without having to extract the ROI first.

Show fit points

Shows all fit points for the currently selected geometry elements. The fit points will be displayed in all 2D and 3D views using a color-coding scheme that indicates the fit point distance from the fitted geometry element.

Hide fit points

Hides all fit points for the currently selected geometry elements.

Toggle fit point visibility

Toggles the visibility of the fit points for the selected objects. This is useful when the selected objects have different fit point visibility settings.

Cut/Copy/Paste

These commands allow you to cut or copy the selected object(s) and then paste them to a new parent object in the Scene Tree (see chapter 21 *Scene Tree Tool* on page 218).

You can copy annotations between analyses. Note that this can only be performed between analyses of similar type.

To create new annotations based on annotations from an analysis of a different type, you can copy and paste the coordinates of the annotations. This is done by copying the **Annotations** table entries in the **Annotations** tab of one analysis into the **Annotations** table of another analysis.

In order to *cut* the selected object(s), you can also press the **Ctrl+X** keys.
In order to *copy* the selected object(s), you can also press the **Ctrl+C** keys.
In order to *paste* the selected object(s), you can also press the **Ctrl+V** keys.

Copy visual state/Paste visual state

These commands allow you to copy the visualization information (render settings, active column, visibility of child objects, etc.) of an object in the Scene Tree to one or more other objects in the Scene Tree.

The **Copy visual state**/**Paste visual state** function does not affect the common **Cut**/**Copy**/**Paste** function.

When copying and pasting the visual state between objects of the same type and structure in the Scene Tree, the entire visualization information will be transferred; in all other cases, only the minimal common set of visualization information will be transferred.

If the structure in the Scene Tree between the objects does not match, pasting may lead to minor side effects.

Create view

Creates a view with the current visualization and workspace settings beneath the selected Scene Tree object. Views can be transferred via copy and paste between top-level objects, such as volumes, CAD models, and meshes. In the case of other objects, such as ROIs or analyses, views can only be transferred between objects of the same type. For details, see chapter 22 *Bookmarks and views Tool* on page 235.

Apply view

Applies the selected view, changing the current visualization and workspace settings. To apply a view, you can also double-click it in the Scene Tree. For details, see chapter 22 *Bookmarks and views Tool* on page 235.

Update view

Applies a view and then immediately replaces it. If any of the objects referenced by the view are no longer present, they will no longer be referenced by the updated view. This can be used to turn invalidated views into valid ones. For details, see chapter 22 *Bookmarks and views Tool* on page 235.

Replace view

Replaces the selected view with a new one that uses the current visualization and workspace settings. For details, see chapter 22 *Bookmarks and views Tool* on page 235.

Unload volume data/Reload volume data

Unloads/reloads the voxel data of a volume object for which an advanced surface determination has been performed. This option is useful for reducing memory consumption.

Advanced surface determination is a feature of VGSTUDIO MAX. It is not available for myVGL. However, if an advanced surface determination was performed for an object, the results can be viewed in myVGL.

Align object

Allows you to align the selected object in the specified coordinate system. For details on the various alignment methods, see .

Lock/Unlock

Clicking **Lock** for a selected object locks the object in the scene, i.e., rotating the object will rotate the camera, while the relative position of the object in the scene will not be changed.

Clicking **Unlock** for a selected object unlocks the object in the scene, i.e., rotating the object will change the relative position of the object within the scene. If the object has been aligned (i.e., an A is visible in the padlock icon in front of the object in the Scene Tree), the alignment information will be deleted.

Analysis results based on the aligned position will become invalid after an object is unlocked.

You can also lock or unlock an object by clicking the padlock icon of its entry in the Scene Tree.

Delete

Deletes the selected object(s) from the scene. The object(s) can be (partially) restored using **Edit > Undo**. Analysis results (e.g., from a nominal/actual comparison) are not restored.

In order to delete the selected object(s) from the scene, you can also press the **Del** key.

Rename/Rename (multi)…

Renames the selected object. If multiple objects are selected, this menu item will change to **Rename (multi)…** and open the **Rename objects** dialog in which you can systematically modify the names of several objects at a time.

You can also select one or more objects in the Scene Tree and press the **F2** key to rename the object or open the **Rename objects** dialog, respectively.

Table 21-7: Controls of the **Rename objects** dialog

Control	Description
Object list	Here you can select the objects to which the renaming is to apply.
Prepend option	Check this option to enter a prefix to be appended to the object names.
Append option	Check this option to enter a suffix to be appended to the object names.
Search+replace option	Check this option to enter a search string in the top field and the string that is to replace the search string in the bottom field. If you want to search for some special characters such as (,), *, ?, +, you need to enter a backslash before the character (for example, to search for ?, type in \?). The search and replace function supports regular expressions (“RegExp” or “regex”). For details on regex, look up the relevant information.
Incremental (based on current final name) option	Check this option to apply the changes to the **Final name** displayed in the object list. By default, the changes are applied to the **Original name**.
Restore original button	Discards the modifications in the preview and shows the original file names in the object list.
Rename button	Provides a preview of the object names in the object list based on the current settings in the **Renaming** section.
OK button	Renames the objects and closes the dialog.
Cancel button	Closes the dialog without renaming the objects.

Do not use a slash (/) in the name of an object in the Scene Tree.

Group/Ungroup objects

Groups several top-level objects or several child objects of the same level of a top-level object.

You can group objects of the same type (e.g., two volume objects) or of a compatible type (e.g., a volume object and a surface mesh or a volume object and a clipping plane), or you can create groups of groups.

For transformation operations (i.e., move and rotate), a group behaves like a single object. The rotation center is the center of the group.

Reset transformation

Resets the position and orientation of unlocked objects to their initial state.

Evaluation properties…

Opens the **Evaluation** dialog (see section *Evaluation properties* on page 942 in chapter 46 *Evaluations*).

Properties

Displays information on the object selected in the Scene Tree.

Except for views, you can also open the **Properties** dialog by double-clicking the object in the Scene Tree.

The type of properties dialog depends on the type of object selected:

- If the selected object is a *geometry element*, the **Geometry element properties** dialog will open. For details, see section *Geometry element properties Dialog* on page 256 in chapter 24 *Coordinate Measurement*.
- If the selected object is a *dimensioning feature*, the **CM results** dialog will open. For details, see section *CM results dialog* on page 264 in chapter 6 *Inspect Tab*.
- If the selected object is a *tolerance feature*, the **CM results** dialog will open. For details, see section *CM results dialog* on page 264 in chapter 6 *Inspect Tab*.
- If the selected object is an *analysis*, the **Properties** dialog of the pertaining analysis will open. For details, see the chapter on the corresponding analysis.
- If the selected object is a *volume object*, a *CAD model,* a *surface mesh*, or an *ROI*, the **Object properties** dialog will open. For details, see section *Object properties Dialog* on page 79 in chapter 5 *Edit Tab*.
- If the selected object is a *tetrahedral mesh*, the **Tetrahedral mesh** dialog will open. For details, see section *Tetrahedral mesh Dialog* on page 97 in chapter 5 *Edit Tab*.

Bookmarks and views Tool

Introduction

To have the **Bookmarks and views** tool displayed or hidden in the tool dock, activate or deactivate the corresponding entry in the **Tools** drop-down list on the **Window** tab in the ribbon. To collapse or expand the **Bookmarks and views** tool window in the tool dock, click the title bar of the **Bookmarks and views** tool window.

The **Bookmarks and views** tool lists all existing bookmarks and views and allows you to apply them.

Bookmarks

Bookmarks enable you to quickly switch between different visualization settings.

A bookmark consists of an image (a screenshot of the windows) and a title. Hovering the mouse pointer over the image shows a tooltip with the title and, if available, a description of the bookmark.

To apply the visualization settings of a bookmark, double-click a bookmark image.

When you open a project with missing bookmark images, placeholders will be shown instead.

Bookmarks can be created and edited in VGSTUDIO MAX, VGMETROLOGY, and VGSTUDIO.

You can change the order of the existing bookmarks via drag-and-drop.

You can change the title of an existing bookmark by clicking it twice or pressing the **F2** key.

When you apply a bookmark, all objects that were not included in the scene when the bookmark was created will be set to invisible (this also applies to objects that were deleted and recreated with the same name after the bookmark was created). These objects will keep all changes you made after adding them to the scene (e.g., creating geometry elements, moving/rotating the object, and running analyses).

Bookmarks store information on the padlock state of an object (locked, unlocked, aligned) and on the transformation of the object in the scene. However, this information is only applied to objects that do not have the padlock state (aligned), i.e., after an object has been aligned, neither its padlock state nor its transformation will be changed by applying a bookmark with a different padlock state and/or transformation.

Views

Views can be used to store visualization and workspace settings for particular objects and then return to them later. They can be transferred via copy and paste between top-level objects, such as volume objects, CAD models, and meshes. For other objects, such as ROIs and analyses, views can only be transferred between objects of the same type. Applying views can be recorded in a macro, which can be used in a batch processing setup or in VGinLINE.

Views are object-related. In the Scene Tree, they are listed below the object to which they belong. When you hover over a view in the Scene Tree, a preview of the view and the referenced objects will be displayed.

In the **Bookmarks and views** tool, views are grouped according to the object they belong to.

A view references the following objects:

- the object to which the view belongs
- the parent objects of the object to which the view belongs and all its visible child objects
- objects that are referenced by child objects, such as nominal meshes or analysis results that are used by other analyses

A view stores the following information:

- the visibility settings, i.e., objects that were set to invisible when the view was created will not be included in the view
- the workspace settings, such as size and arrangement of the 2D and 3D windows, except for **Rotation**, **Quad profile**, and **Non-planar** windows, which are currently not supported
- the active coordinate system
- the render settings

It is not possible to create views on an object if a coordinate system belonging to another object is currently active.

It is not possible to create views on an invisible object.

A view consists of an image (a snapshot of the visualization and workspace state when the view was created or last updated, or replaced) and a title. Hovering the mouse pointer over the image shows a tooltip with the title.

To apply a view, double-click a view image in the **Bookmarks and views** tool, double-click the view item in the Scene Tree, right-click the view and select **Apply view** from the context menu, or click **Apply view** on the **Reporting** tab.

In order to delete one or more views, select them — either in the **Bookmarks and views** tool or in the Scene Tree — and press the **Del** key.

To update a view that is no longer valid because referenced objects are no longer present or have been invalidated, right-click the view in the Scene Tree and select **Update view** from the context menu, or click **Update view** on the **Reporting** tab (for details, see section *Properties of view Dialog* on page 97 in chapter 5 *Edit Tab*).

When you create a report that includes views or when you save views via the **Save view images** function on the **Reporting** tab, all view images will be updated on the fly.

You can integrate views you created and edited in myVGL into reports and export the reports. However, be aware that views created in myVGL will not be saved.

You can change the title of an existing view by clicking it twice or pressing the **F2** key.

When you apply a view, all objects that were not included in the scene when the view was created will be set to invisible. These objects will keep all changes you made after adding them to the scene (e.g., creating geometry elements, moving/rotating the object, and running analyses).

- If you rename objects referenced by a view, they will still be recognized.
- If you remove objects and re-create them later under the same name, they will still be recognized, and the view will be applied to the newly created objects.

Views do not store information on the padlock state of an object (locked, unlocked, aligned) and on the transformation of the object in the scene.

Deep Segmentation Module

Introduction

Deep Segmentation is an advanced segmentation method for VGSTUDIO MAX based on modern machine-learning algorithms, in particular deep learning. The segmentation results will be added as ROIs to the Scene Tree under the analyzed volume object or ROI. The number of ROIs created depends on the specifications in the deep learning model.

License Information

This module is an optional add-on module for VGSTUDIO MAX. It is not available for myVGL. However, if a project loaded in myVGL contains results obtained with this module, they can be viewed and reported in myVGL.

If you are interested in a more comprehensive functionality than the one offered by myVGL, you have the chance to evaluate VGSTUDIO MAX. You can request an evaluation license of VGSTUDIO MAX on our website:

https://volumegraphics.hexagon.com/en/products/evaluation

If you have further questions about our product portfolio, please contact us:

- For Europe, Middle East, and Africa:
  Write an e-mail to sales@volumegraphics.com or call +49 6221 73920 744.
- For Japan:
  Write an e-mail to sales@volumegraphics.jp or call +81 52 508 9682.
- For the Americas:
  Write an e-mail to sales-us@volumegraphics.com or call +1 704 248 7736.
- For China, including Mainland China, Hong Kong, Macao, and Taiwan:
  Write an e-mail to sales@volumegraphics.cn or call +86 10 8532 6305.
- For Singapore and other parts of Asia (except China and Japan), Australia, and parts of Oceania:
  Write an e-mail to sales@volumegraphics.sg or call +65 6665 0310.

Opening the Dialog

In order to open the **Deep segmentation** dialog,

- right-click the corresponding entry in the Scene Tree and select **Properties** from the context menu or
- double-click the corresponding entry in the Scene Tree.

The **Deep segmentation** dialog consists of several tabs on which you can view the parameters.

To close the dialog, click the **Close** button at the bottom of the dialog.

Deep segmentation applies binary classification to each voxel, i.e., it determines whether or not a voxel belongs to a class. For this, 1-bit precision is sufficient, and increasing it would have no effect on the results. Despite the ROI precision in the preferences (by default 4 bit), deep segmentation will yield 1-bit results.

A status bar at the bottom of the dialog indicates the current status of the segmentation. The status can be one of the following:

Table 23-1: Messages in the status bar

Status	Description	Possible solutions
Calculation required	All required parameters have been specified and are consistent. You can click **Calculate** to start a new segmentation or recalculate an existing segmentation that has been invalidated by some user action.	
Result is up to date	The current segmentation result is valid and does not need recalculation.	
Cannot find any compatible deep learning model	No segmentation model files are available on this computer.	Import a deep learning model.
Could not load the external plugin		Run the Deep Learning Plugin to install the inference environment.
The version of the loaded plugin does not match		• Run the Deep Learning Plugin to install the appropriate inference environment. • If required, contact us to obtain the corresponding file.
The loaded plugin is not compatible		• Run the Deep Learning Plugin to install the appropriate inference environment. • If required, contact us to obtain the corresponding file.

Status	Description	Possible solutions
Out of memory	Unable to allocate memory.	• Try to close other applications. • Check the minimum system requirements needed to run the application and **Deep segmentation**. • Check the minimum system requirements of the deep learning model you are using. • Run **Deep segmentation** on a smaller ROI and not on the entire volume.
Out of GPU memory	Unable to allocate memory on the graphics card.	• Try to close other applications that might consume GPU memory excessively. • Check the minimum system requirements needed to run the application and **Deep segmentation**. • Check the minimum system requirements of the deep learning model you are using. • In case of 3rd party ONNX models, try specifying a smaller inference block size in the model metainfo when importing the model.
No machine learning model has been specified	No deep learning model has been selected in the **Deep segmentation** dialog.	• Select one of the imported models shown in the **Deep segmentation** dialog. • If the list of deep learning models is empty, import a deep learning model using **File > Import**.
Deep learning model file does not exist	The specified deep learning model is missing.	• Reimport the missing deep learning model using **File > Import**. • Choose another deep learning model from the list.

Status	Description	Possible solutions
Unsupported or corrupted deep learning model	The deep learning model you are trying to use is either not supported or corrupted.	• Reimport the model. • In case of 3rd party ONNX models, make sure to follow the guidelines and syntax for the metainformation file format. • Check for updates of myVGL as the model might not yet be supported with the software version you are using. • Contact the provider of the deep learning model or Hexagon for further support.
Failed to set up data preprocessing	Unable to set up data normalization. The data normalization method required by the model is either not supported or its definition is corrupted.	• In case of peak normalization, make sure you have two distinct background and material peaks set. Enter values manually if automatic peak detection fails. • In case of 3rd party ONNX models, make sure to follow the guidelines and syntax for the metainformation file format. Reimport the model after correction. • Check for updates of myVGL as the required data preprocessing might not yet be supported with the current software version. • Contact the provider of the deep learning model or Hexagon for further support.
Failed to set up output pipeline	Unable to set up the pipeline for postprocessing the results. The features required by the model are either not supported or their definition is corrupted.	• In case of 3rd party ONNX models, make sure to follow the guidelines and syntax for the metainformation file format. Reimport the model after correction. • Check for updates of myVGL as the model might not yet be supported with the current software version. • Contact the provider of the deep learning model or Hexagon for further support.

Status	Description	Possible solutions
Failed to initialize TensorRT plugins	Some of the required software components are missing.	• Install the deep learning components. • Check for updates of myVGL and the **Deep segmentation** module. • Contact us for further support.
CUDA compute capability check failed	The required NVIDIA CUDA compute capabilities are not met by your graphics hardware and/or driver.	• Check for graphics card driver updates. • Check the minimum system requirements needed to run the application and **Deep segmentation**.
CUDA GPU memory check failed	The minimum memory requirements are not met by your graphics hardware.	• Try to close other applications that might consume GPU memory excessively. • Check the minimum system requirements needed to run the application and **Deep segmentation**.
Generic error	An unexpected error has occurred.	Contact us for further support.
Unspecified error	An unexpected error has occurred.	Contact us for further support.
License missing	The add-on module is not licensed.	

☞ An invalid or outdated status of the segmentation is indicated in the Scene Tree by a warning sign. Double-click the segmentation to open it and check the status bar for messages.

Settings Tab

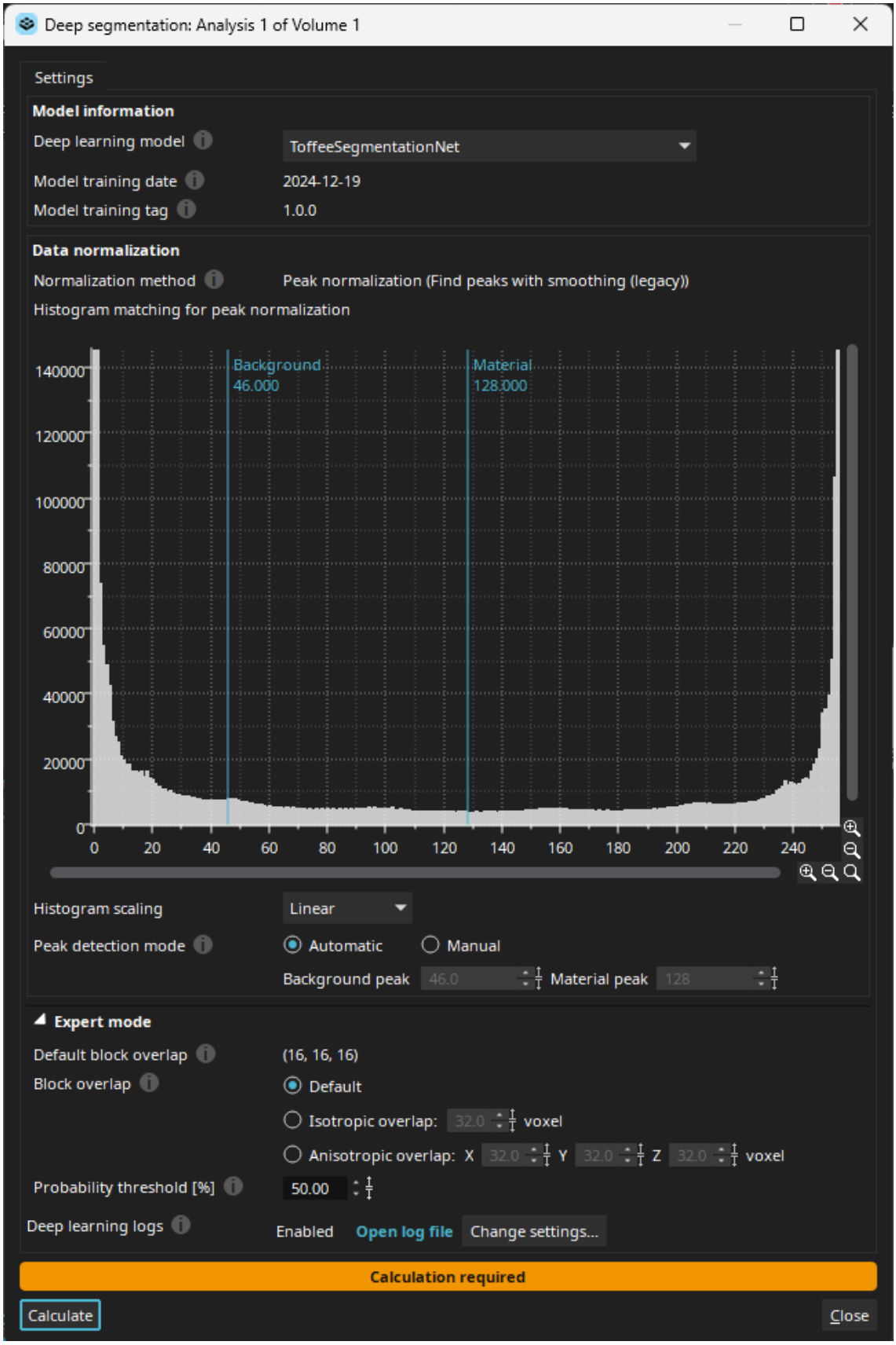

Deep segmentation: Analysis 1 of Volume 1
Settings
Model information
Deep learning model
ToffeeSegmentationNet
Model training date
2024-12-19
Model training tag
1.0.0
Data normalization
Normalization method
Peak normalization (Find peaks with smoothing (legacy))
Histogram matching for peak normalization
Background
46.000
Material
128.000
140000
120000
100000
80000
60000
40000
20000
0
0 20 40 60 80 100 120 140 160 180 200 220 240
Histogram scaling
Linear
Peak detection mode
Automatic
Manual
Background peak
46.0
Material peak
128
Expert mode
Default block overlap
(16, 16, 16)
Block overlap
Default
Isotropic overlap:
32.0
voxel
Anisotropic overlap: X
32.0
Y
32.0
Z
32.0
voxel
Probability threshold [%]
50.00
Deep learning logs
Enabled
Open log file
Change settings...
Calculation required
Calculate
Close

Figure 23-1: **Deep segmentation** dialog, **Settings** tab

In myVGL, all parameter settings are displayed. Most of these parameters are read-only in myVGL. The complete functional range is available with VGSTUDIO MAX and the respective add-on module(s).

The **Settings** tab consists of the following sections:

- **Model information** section

  Table 23-2: Controls in the **Model information** section

Control	Description
Deep learning model drop-down list	Indicates the deep learning model used for segmentation.
Model training date field	If available: Indicates the date when the model was trained.
Model training tag field	If available: Indicates the version information added when the model was trained.

- **Data normalization** section

  Table 23-3: Controls in the **Data normalization** section

Control	Description
Normalization method field	Indicates the method used for normalizing the gray values in the data set as specified by the model. Common normalization methods are: • Peak normalization: Uses the air and material peaks to normalize the histogram. • Zero mean and unit variance: Subtracts the mean and rescales the histogram by standard deviation.
Histogram area	Shows the gray value distribution in the data set.
Histogram matching for peak normalization area	Only available if provided by the model: Shows the gray value distribution in the data set with vertical lines indicating the automatically detected values for the background and material peaks.
Peak detection mode radio buttons	If available: If you are not satisfied with automatic normalization, you can either switch to **Manual** mode and enter the required values in the **Background peak** and **Material peak** spin boxes or drag the vertical lines in the histogram to adjust the peaks.
Background peak spin box	Enabled in **Manual** mode: Allows you to manually specify the background peak for normalizing the data.

Control	Description
Material peak spin box	Enabled in **Manual** mode: Allows you to manually specify the material peak for normalizing the data.
Histogram scaling drop-down list	• **Linear**: Applies a linear scale to the histogram. • **Logarithmic**: Applies a logarithmic scale to the histogram.

- **Expert mode** section

  Table 23-4: Controls in the **Expert mode** section

Control	Description
Expert mode button	Toggles the visibility of additional options.
Default block overlap field	Indicates the default block overlap as specified by the model.
Block overlap radio buttons	Large volumes that wouldn't fit into the GPU memory will be predicted on block by block. In order for the model to see sufficient context in each block, these blocks will overlap slightly. Reducing the overlap will speed up the inference, but at the expense of accuracy. It is recommended that you use the default provided by the model whenever possible. • **Default**: Applies the default overlap specified by the model. • **Isotropic overlap**: Use the spin box to specify the number of voxels to overlap in each direction. • **Anisotropic overlap**: Use the spin boxes to specify the number of voxels to overlap separately in the x-, y-, and z-directions.
Probability threshold spin box	The model indicates the probability of whether the voxel belongs to a certain class (such as indication ROI or background) or not. • When the probability threshold is set to 0%, all voxels will belong to the ROI, except for those where the model is 100% sure that the voxel belongs to the background. • When the probability threshold is set to 100%, no voxel will belong to the ROI, since in this case, the model would have to be 100% sure that the voxel is an indication.

- **Deep learning logs** section

  Indicates if deep-learning-related log files will be written.

If you want to enable logging, click the **Change settings…** button. The **Preferences** dialog will open on the **Expert** page, where you can change the **User log settings** (for details, see section *User log settings section* on page 67 in chapter 3 *File Tab*).

The log will be written and stored in the path specified in the preferences (see section *Directory settings section* on page 66 in chapter 3 *File Tab*).

If logging is enabled, clicking the **Open log file** link will directly open the log file.

The **Deep segmentation** analysis makes heavy use of your machine's GPU for faster calculations. Sometimes, the wrong GPU driver version, the GPU type, the amount of RAM, or concurrent GPU utilization by other applications can cause issues. In that case, you could share the log file with VG Support to get help solving the issues.

Coordinate Measurement

Introduction

In myVGL, you can view the coordinate measurement results—such as geometry elements and dimensioning and tolerance features—created with VGSTUDIO MAX or VGMETROLOGY.

License Information

This module is an optional add-on module for VGSTUDIO MAX. It is not available for myVGL. However, if a project loaded in myVGL contains results obtained with this module, they can be viewed and reported in myVGL.

If you are interested in a more comprehensive functionality than the one offered by myVGL, you have the chance to evaluate VGSTUDIO MAX. You can request an evaluation license of VGSTUDIO MAX on our website:

https://volumegraphics.hexagon.com/en/products/evaluation

If you have further questions about our product portfolio, please contact us:

- For Europe, Middle East, and Africa:
  Write an e-mail to sales@volumegraphics.com or call +49 6221 73920 744.
- For Japan:
  Write an e-mail to sales@volumegraphics.jp or call +81 52 508 9682.
- For the Americas:
  Write an e-mail to sales-us@volumegraphics.com or call +1 704 248 7736.
- For China, including Mainland China, Hong Kong, Macao, and Taiwan:
  Write an e-mail to sales@volumegraphics.cn or call +86 10 8532 6305.
- For Singapore and other parts of Asia (except China and Japan), Australia, and parts of Oceania:
  Write an e-mail to sales@volumegraphics.sg or call +65 6665 0310.

Types of Geometry Elements

There are various types of geometry elements (see description below), an arbitrary number of which can be created for surface meshes, CAD models, and volume objects with a determined surface. In the Scene Tree, the geometry elements are listed in the **Coordinate Measurement > Geometry elements** section.

Clicking a geometry element in a 2D window or double-clicking it in the 3D window will highlight the corresponding entry in the Scene Tree.

Based on existing geometry elements, features show measured positions, distances, angles, radii, and tolerances. Features rely on the definition of distinct coordinate systems.

The following list gives an overview of the types of geometry elements:

- **Point**
  A geometry element of type point was fitted to the object based on one or more fit points. The only geometric property of a point is its position.
- **Line**
  A line geometry element was fitted to the object based on two or more fit points. The geometric properties of a line are its position and direction.
- **Circle**
  A geometry element of type circle was fitted to the object based on three or more fit points. The geometric properties of a circle are its center position, its orientation normal, and its radius.
- **Corner circle**
  A geometry element of type corner circle was fitted to the object based on five or more fit points. The geometric properties of a corner circle are its center position, its orientation normal, and its radius.
- **Plane**
  A geometry element of type plane was fitted to the object based on three or more fit points. The geometric properties of a plane are its center position and orientation normal.
- **Sphere**
  A geometry element of type sphere was fitted to the object based on four or more fit points. The geometric properties of a sphere are its center position and radius.
- **Cylinder**
  A geometry element of type cylinder was fitted to the object based on three or more fit points. The geometric properties of a cylinder are its center position, its direction, and its radius.
- **Cone**
  A geometry element of type cone was fitted to the object based on three or more fit points. The geometric properties of a cone are its center position, its direction, its center radius, and its conicity angle.
- **Torus**
  A geometry element of type torus was fitted to the object based on four or more fit points. The geometric properties of a torus are its center position, the direction of its rotational axis, and its major and minor radii.
- **Freeform line**
  A geometry element of type freeform line was fitted to the object based on an arbitrary number of fit points.
- **Freeform surface**
  A geometry element of type freeform surface was fitted to the object based on an arbitrary number of fit points.

Types of Features

There are two basic types of GD&T features that can be created on the basis of existing geometry elements:

- dimensioning features
- tolerance features

Types of Dimensioning Features

There are various types of dimensioning features (see description below), an arbitrary number of which can be created on the basis of existing geometry elements for surface meshes, CAD models, and volume objects that have a determined surface. In the Scene Tree, the dimensioning features are listed in the **Coordinate Measurement > Features** section. All **Distance** types are first created in the 3-dimensional space before **Projection** will be applied, if specified.

The following list gives an overview of the types of dimensioning features:

- **Distance**

  Default distance measuring method. The distance line between the center positions of the two geometry elements is calculated.
- **Angle**

  Angle between two geometry elements. Angles can be measured between a pair of geometry elements that have a direction or an orientation normal.
- **Distance (mid perpendicular)**

  Geometry element A is considered as finite, while geometry element B is considered as infinitely extended. The mean between minimum and maximum distance (orthogonal to geometry element A) between the two geometry elements is determined.
- **Distance (min perpendicular)**

  Geometry element A is considered as finite, while geometry element B is considered as infinitely extended. The minimum distance (orthogonal to geometry element A) between the two geometry elements is determined.
- **Distance (max perpendicular)**

  Geometry element A is considered as finite, while geometry element B is considered as infinitely extended. The maximum distance (orthogonal to geometry element A) between the two geometry elements is determined.
- **Distance (min finite)**

  Both geometry elements are considered as finite. The minimum distance between the two geometry elements is determined.
- **Distance (max finite)**

  Both geometry elements are considered as finite. The maximum distance between the two geometry elements is determined.
- **Distance (min infinite)**

  Both geometry elements are considered as infinitely extended. The minimum distance between the infinite geometry elements is determined if they are not intersecting.
- **Distance (min)**

  Geometry element A is considered as finite, while geometry element B is considered as infinitely extended. The minimum distance (orthogonal to geometry element B) between the two geometry elements is determined.
- **Distance (centroid)**

  The distance between the geometrical center of all fit points used to fit geometry element A and geometry element B is determined. Note that the geometrical center of a geometry element is calculated with respect to the fit point coordinates only. It is not calculated as the geometrical center of the fitted geometry element A or B.
- **Position**

  Determines the position of a single geometry element in the current coordinate system, i.e., its distance to the origin.

- **Radius**
  Radius of a single geometry element. Radii can be measured for circles, corner circles, spheres, cylinders, cones, and tori (major radius).
- **Diameter**
  Diameter of a single geometry element. This equals twice the radius.
- **Minor radius**
  Minor radius of a torus.
- **Minor diameter**
  Minor diameter of a torus. This equals twice the minor radius.
- **Opening angle**
  Opening angle of a cone. This can be either a half or full angle.

Types of Tolerance Features

There are various types of tolerance features (see description below), an arbitrary number of which can be created on the basis of existing geometry elements for surface meshes, CAD models, and volume objects with a determined surface. In the Scene Tree, the tolerance features are listed in the **Coordinate measurement > Features** section.

The following list gives an overview of the types of tolerance features:

- **Angularity**
  Available for cones, cylinders, lines, freeform lines, and planes.
  The **Tolerance zone** can be planar or cylindrical. The **Tolerance** defines the distance between the planes or the diameter of the cylinder, respectively. Depending on the **Toleranced element**, the **Tolerance target** can be selected automatically (**Auto**) or manually set to **Actual element** (plane), **Fitted element** (line, plane), **Fitted axis** (cone, cylinder, line), or **Fitted position** (cone, cylinder, line, plane).
- **Coaxiality**
  Available for circles, cones, cylinders, lines, freeform lines, and points.
  The **Tolerance zone** can be cylindrical or circular. The **Tolerance** defines the diameter of the cylinder or circle. Depending on the **Toleranced element**, the **Tolerance target** can be selected automatically (**Auto**) or manually set to **Actual element** (line), **Fitted element** (line), **Fitted axis** (cone, cylinder, line), or **Fitted position** (cone, cylinder, line, point).

This option also includes the **Concentricity** tolerance for circles and points. The **Tolerance zone** is circular. The **Tolerance** defines the diameter of the tolerance circle. The **Tolerance target** can be selected automatically (**Auto**) or manually set to **Actual element**, **Fitted element**, or **Fitted position**.

- **Cylindricity**
  Available for cylinders.
  The **Tolerance zone** is cylindrical, i.e., all points of the cylindrical surface must lie between two coaxial cylinders. The **Tolerance** defines the distance between the two coaxial cylinders. The **Tolerance target** are the actual fit points of the cylinder.
  To tolerance several cylinders in one tolerance zone, you can add more cylinders to the **Additional toleranced elements (CZ)** field (CZ = combined zone).

The axis orientation of the two coaxial cylinders is not specified.

- **Flatness**

  Available for planes.

  The **Tolerance zone** is planar and is limited by two parallel planes. The **Tolerance** defines the distance between the two parallel planes. The **Tolerance target** are the actual fit points of the plane.

  In order to tolerance several planes in one tolerance zone, you can add more planes to the **Additional toleranced elements (CZ)** field (CZ = combined zone).

The direction of the parallel planes is not specified.

- **Parallelism**

  Available for cones, cylinders, lines, freeform lines, and planes.

  The **Tolerance zone** can be planar or cylindrical. The **Tolerance** defines the distance between the planes or the diameter of the cylinder, respectively. Depending on the **Toleranced element**, the **Tolerance target** can be selected automatically (**Auto**) or manually set to **Actual element** (plane, line), **Fitted element** (line, plane), **Fitted axis** (cone, cylinder, line), or **Fitted position** (cone, cylinder, line, plane).

  To define the orientation of the tolerance zone relative to the secondary datum element, you can set the **Zone options** to **Auto/Default** or **Orthogonal**.

- **Perpendicularity**

  Available for cones, cylinders, lines, freeform lines, and planes.

  The **Tolerance zone** can be planar or cylindrical. The **Tolerance** defines the distance between the planes or the diameter of the cylinder, respectively. Depending on the **Toleranced element**, the **Tolerance target** can be selected automatically (**Auto**) or manually set to **Actual element** (plane), **Fitted element** (line, plane), **Fitted axis** (cone, cylinder, line), or **Fitted position** (cone, cylinder, line, plane).

  To define the orientation of the tolerance zone relative to the secondary datum element, you can set the **Zone options** to **Auto/Default** or **Orthogonal**.

- **Position**

  Available for circles, cones, cylinders, lines, freeform lines, planes, points, spheres, and tori.

  The **Tolerance zone** can be spherical (i.e., the geometry element's position is toleranced in three spatial directions), cylindrical (i.e., the geometry element's position is toleranced in two spatial directions), or planar (i.e., the geometry element's position is toleranced in one spatial direction). Depending on the **Toleranced element**, the **Tolerance target** can be selected automatically (**Auto**) or manually set to **Actual element** (circle, line, plane, point), **Fitted element** (circle, line, plane, point), **Fitted axis** (cone, cylinder, line), or **Fitted position** (circle, cone, cylinder, line, plane, point, sphere, torus).

  If two **Positions** are considered in the **Nominal values** section, the tolerance zone can be cylindrical (**Zone options: Auto/Default**) or square (**Zone options: Square/Box**). If three **Positions** are considered in the **Nominal values** section, the tolerance zone can be spherical (**Zone options: Auto/Default**) or a box (**Zone options: Square/Box**).

- **Roundness**

  Available for circles and corner circles.

  The **Tolerance zone** is circular, i.e., all points of the circle must lie between two concentric circles. The **Tolerance** defines the difference between the two circle radii. The **Tolerance target** are the actual fit points of the circle.

To tolerance several circles at a time (but independently of each other), you can add more circles to the **Additional toleranced elements** field.

The roundness of a cylinder or cone is toleranced by creating cross-sections and tolerancing these circles. Note that the center of the two concentric circles is not specified.

- **Run-out**

  Available for circles.

  The **Tolerance zone** is cylindrical for a radial run-out (**Zone options: Radial**) or planar for an axial run-out (**Zone options: Axial**). The **Tolerance** defines the difference between the two cylinder radii or the distance between the two planes, respectively. The **Tolerance target** can be selected automatically (**Auto**) or manually set to **Actual element** or **Fitted element**.

  To tolerance several circles at a time (but independently of each other), you can add more circles to the **Additional toleranced elements** field.

- **Straightness**

  Available for lines and freeform lines.

  The **Tolerance zone** consists of two parallel lines (displayed as two thin parallel planes) if the **Toleranced element** was created in a 2D view. Otherwise, the **Tolerance zone** is cylindrical. The **Tolerance** is either the distance between the two parallel lines or the cylinder diameter. The **Tolerance target** are the actual fit points of the line. For defined lines, the **Tolerance target** are the end points of the line.

  Several lines, freeform lines, cylinders, or cones can be toleranced simultaneously in a combined zone by selecting **Additional toleranced elements (CZ)**.

- **Symmetry**

  Available for cones, cylinders, lines, freeform lines, points, and planes.

  The **Tolerance zone** can be planar (**Zone options: Auto/Default**, **Planar UZ (ISO)** or **Planar Ⓤ (ASME)**) or cylindrical (**Zone options: Cylindrical**). The **Tolerance** defines the distance between the planes which are symmetrically arranged with respect to the datum plane or the diameter of the cylinder, respectively. Depending on the **Toleranced element**, the **Tolerance target** can be selected automatically (**Auto**) or manually set to **Actual element** (plane), **Fitted element** (line, plane), **Fitted axis** (cone, cylinder, line), or **Fitted position** (cone, cylinder, line, point, plane).

- **Total run-out**

  Available for cylinders and planes.

  The **Tolerance zone** can be planar or cylindrical. The **Tolerance** defines the distance between the planes or the difference between the radii of the cylinders, respectively. The **Tolerance target** can be selected automatically (**Auto**) or manually set to **Actual element** or **Fitted element**.

- **Conicity**

  Available for cones.

  The **Tolerance zone** is conical, i.e., all points of the conical surface must lie between two coaxial cones. The **Tolerance** defines the perpendicular distance between the lateral surfaces of two coaxial cones with identical opening angles. The **Tolerance target** are the actual fit points of the cone.

- **Line profile**

  Available for freeform lines.

  The **Tolerance zone** can be:

- **Minimal**: Difference between the points with the largest deviation in both directions.
- **Symmetric**: Twice the largest absolute deviation of the points from the nominal curve in either direction.
- **Symmetric UZ (ISO)**: Twice the largest absolute deviation of the points from the nominal curve in either direction. The nominal curve will be moved by the specified offset.
- **Symmetric Ⓤ (ASME)**: Twice the largest absolute deviation of the points from the nominal surface in either direction. The upper limit of the tolerance zone will be offset from the nominal surface by the specified offset.
- **Positive**: Distance between the nominal curve and the point with the largest deviation in the positive direction; negative deviations will be ignored.
- **Negative**: Distance between the nominal curve and the point with the largest deviation in the negative direction; positive deviations will be ignored.
- **Positive minimal**: Difference between largest and smallest deviation in the positive direction; if there are also negative deviations, they will be set to the nominal curve so that the tolerance zone corresponds to **Positive**.
- **Negative minimal**: Difference between largest and smallest deviation in the negative direction; if there are also positive deviations, they will be set to the nominal curve so that the tolerance zone corresponds to **Negative**.

!

Create profile tolerances with datums on the nominal object and apply them to the actual object.

Note that changing the base system, the toleranced element, or the datum elements of profile tolerances on the actual object may lead to unreliable results.

- **Surface profile**

  Available for freeform surfaces.

  The **Tolerance zone** can be:
  - **Minimal**: Difference between the points with the largest deviation in both directions.
  - **Symmetric**: Twice the largest absolute deviation of the points from the nominal curve in either direction.
  - **Symmetric UZ (ISO)**: Twice the largest absolute deviation of the points from the nominal curve in either direction. The nominal curve will be moved by the specified offset.
  - **Symmetric Ⓤ (ASME)**: Twice the largest absolute deviation of the points from the nominal surface in either direction. The upper limit of the tolerance zone will be offset from the nominal surface by the specified offset.
  - **Positive**: Distance between the nominal curve and the point with the largest deviation in the positive direction; negative deviations will be ignored.
  - **Negative**: Distance between the nominal curve and the point with the largest deviation in the negative direction; positive deviations will be ignored.
  - **Positive minimal**: Difference between largest and smallest deviation in the positive direction; if there are also negative deviations, they will be set to the nominal curve so that the tolerance zone corresponds to **Positive**.
  - **Negative minimal**: Difference between largest and smallest deviation in the negative direction; if there are also positive deviations, they will be set to the nominal curve so that the tolerance zone corresponds to **Negative**.

Create profile tolerances with datums on the nominal object and apply them to the actual object. Note that changing the base system, the toleranced element, or the datum elements of profile tolerances on the actual object may lead to unreliable results.

- **Sphericity**
  Available for spheres.
  The **Tolerance zone** is spherical, i.e., all points of the spherical surface must lie between two concentric spheres. The **Tolerance** defines the difference between the radii of the two concentric spheres. The **Tolerance target** are the actual fit points of the sphere.

Geometry element properties Dialog

To show the properties of a geometry element,

- double-click the geometry element in the Scene Tree,
- highlight the geometry element in the Scene Tree and select the **Properties** item from the context menu of the Scene Tree, or
- highlight the geometry element in the Scene Tree, go to the **Edit** tab, and click **Properties**.

Be aware that all geometric properties (e.g., positions and directions) will be displayed with respect to the currently selected coordinate system.

Although all parameter settings are displayed in myVGL, most of them are read-only. The complete functionality is available with VGSTUDIO MAX and the respective add-on module(s).

Properties Tab

Shows geometric and status properties of the geometry element.

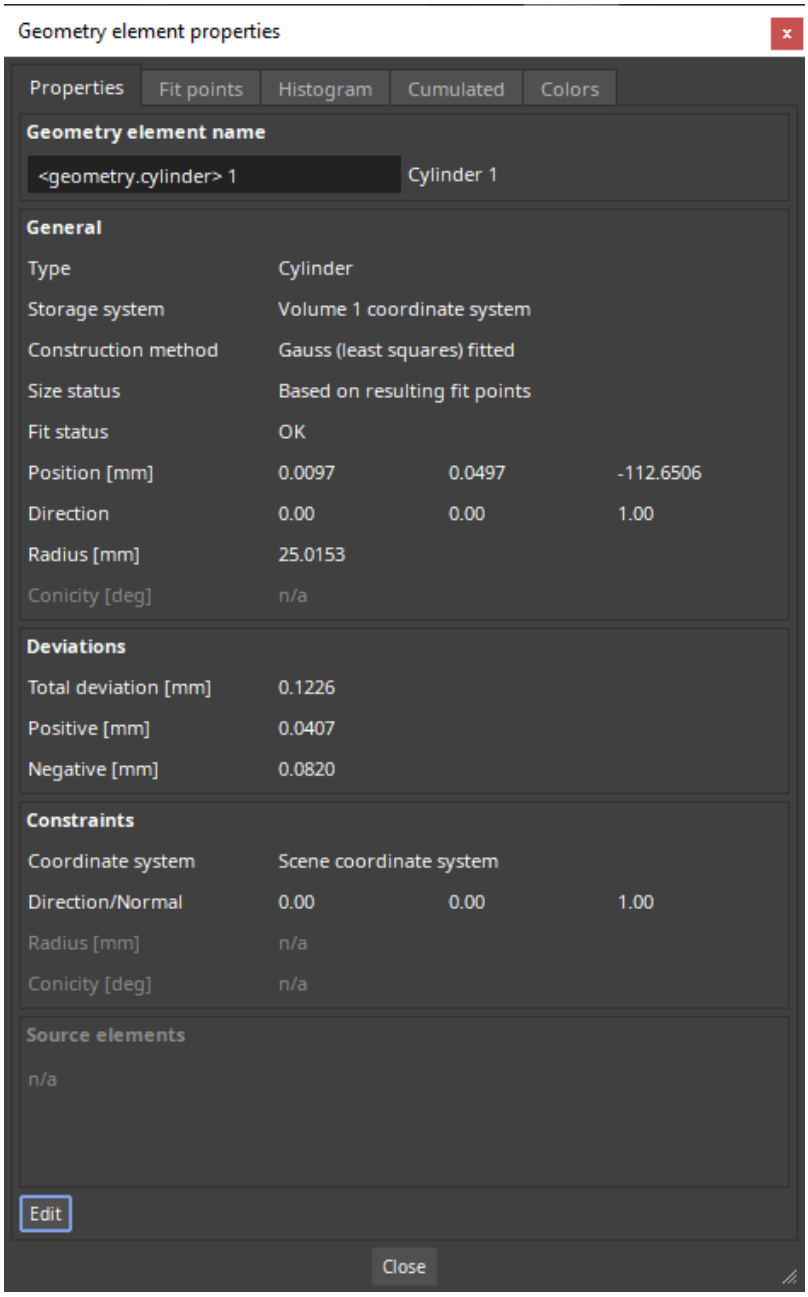


Figure 24-1: **Geometry element properties** dialog, **Properties** tab

- **Geometry element name** section
  Indicates the name of the geometry element. The name can be edited.
- **General** section
  Provides general information on this geometry element:
  - **Type**
    Indicates the type of the geometry element.
  - **Storage system**
    Indicates the coordinate system in which the geometry element is stored.

- **Construction method**

  Indicates how this geometry element was created:

  - [Gauss (least squares)/Minimum zone/...] fitted
  - Result of [intersection/combination/projection/...]
  - Manually defined geometry element

- **Size status**

  Provides status information on how the actual size of the geometry element is determined. In most cases, the size of a fitted geometry element depends on all its fit points, and the size of an intersected/combined geometry element depends on its source elements. Other sizing methods can be selected via the **Resize** option on the **Geometry** tab in the ribbon and the **Resize to selected fit points** context menu item on the **Fit points** tab of the **Geometry element properties** dialog.

Table 24-1: Size status

Status	Description
Based on original fit points	The size of the geometry element is based on the fit points actually set with the mouse.
Based on resulting fit points	The size of the geometry element is based on the fit points resulting from the **Auto fit points** and **Auto expand** options.
Based on source element extent	The size of the combined geometry element is based on the size of its source elements.
Based on subset of fit points	The size of the geometry element is based on a subset of the fit points defined, for example, through the **Resize to selected fit points** option on the **Fit points** tab of the **Geometry element properties** dialog.
Fixed	The size of the geometry element is fixed. This applies to points, circles, spheres, freeform lines freeform surfaces, etc.
Modified	The size of the geometry element has been modified, for example, through the **Resize** function (**Measurements > Geometry element manipulation > Resize**).

- **Fit status**

  Provides status information on the last fitting process of the geometry element.

- **Position/Radius/Major Radius/Minor Radius/Conicity/Direction/Normal**

  Geometric parameters. The position is defined by the center of the geometry element. Direction and normal vectors are normalized to unit length. For cones, the radius at the center position is given.

- **Deviations** section

  Statistic measures of the fit point distribution. Positive and negative deviations denote the maximum positive and negative distances of any fit point to the surface of the geometry element. The total deviation equals the sum of positive and negative.

For circles, the deviation is the distance to the actual circle outline, not just the plane of the circle.

For lines that were initially specified in a 2D window, the 2D orientation at the time of fitting is stored and used to provide a “left of line/right of line” distinction for signed distances (e.g., for all other geometry element types except the point). If a line has no orientation information, all distances will be positive (valley deviation zero per definition).

The deviation signs are chosen so that positive deviations indicate points where the resulting geometry element is located within the determined surface (i.e., in the material area).

- **Constraints** section

  Provides information regarding the constraints on the geometry element as defined in the **Fit geometry element** dialog.
- **Source elements** field

  If the selected geometry element was created by geometry element manipulation (e.g. **Intersect**, **Combine**, etc.), this field will list the original geometry elements.

Fit points Tab

Shows a list of the fit points used for calculating the properties of the geometry element. In case of a regular element from two parallel planes or lines, individual points on either side of the regular element will be listed and the deviation of each point will refer to the corresponding side of the regular element.The coordinates will be represented by x, y, and z, which is the default Cartesian mode.

Columns of the **Fit points** Table

Table 24-2: Columns of the **Fit points** table

Column	description
x/y/z	Indicates the x-, y-, and z-coordinates of the fit point.
Deviation	Indicates the distance of the fit point from the fitted geometry element.
Sign	Indicates the direction of the deviation of the fit point from the geometry element.
Value	Indicates the (interpolated) gray value at the position of the fit point.

Controls of the **Fit points** Tab

Table 24-3: Controls of the **Fit points** tab

Control	Description
use LMB to click on a table row	Selects the fit point and makes it visible in the 2D and 3D views.
hold down **Ctrl** key + use LMB to click on several table rows	Selects the fit points and makes them visible in the 2D and 3D views.

Control	Description
hold down **Shift** key + use LMB to click on two separate table rows	Selects the two fit points, including all fit points between them, and makes them visible in the 2D and 3D views.
use RMB to click into the fit points table	Displays a context menu (see below).
use LMB to click a column heading	Sorts the table according to the values of the column. Clicking subsequently toggles between ascending and descending order.
use LMB to click and drag column heading to new position, then release LMB	Inserts the column at the new position.

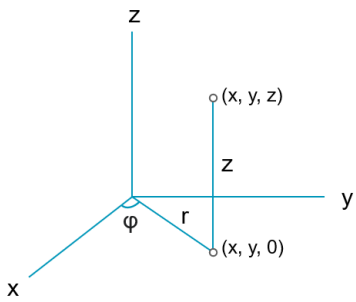
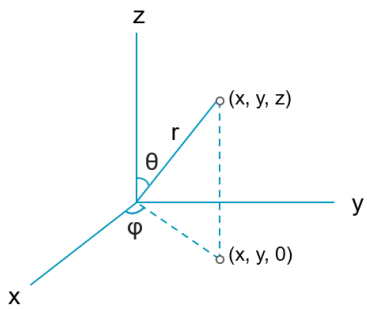
When you edit a geometry element using the **Remove and fit** option, the remaining fit points will immediately be shown in the 2D and 3D views.

Context Menu of the **Fit points** Tab

Right-click anywhere in the **Fit points** table to open its context menu. The menu contains the following items:

Table 24-4: Context menu items of the **Fit points** tab

Control	Description
Columns	• **x, y, z, Deviation, Sign, Value**: Allows you to toggle the visibility of each column by checking and unchecking the respective checkbox. • **Show all**: Checks all columns to set them to visible. • **Hide all**: Unchecks all columns to set them to invisible.
Trim columns	Resizes all columns to their smallest possible size.
Apply default column layout	Applies the default column layout previously saved by the user to the current table. If no default column layout has been saved, the original column layout will be applied.
Save as default column layout	Saves modifications applied to the table—e.g., the visibility of a column, the order in which the columns appear, the column width—as default column layout. This layout will be applied when you create a new project.
Apply original column layout	Restores the original table layout and discards any modifications applied by the user. The original table layout is predefined and cannot be modified by the user.

Control	Description
Coordinate mode	Allows you to select the display mode for the coordinates of the fit points. Cylindrical and spherical coordinates will be converted from the Cartesian coordinates, according to the ISO 80000-2 standard. • **Cartesian**: Displays the **x [<length unit>]**, **y [<length unit>]**, and **z [<length unit>]** coordinates. This is the default mode. • **Cylindrical**: Displays the radial distance **r [<length unit>]** (the distance from (0, 0, 0) to (x, y, 0)), the angular coordinate **φ [<angle unit>]** (the angle between the x-axis and the line joining (x, y, 0) to (0, 0, 0)), and the height **z [<length unit>]** (the signed distance from (x, y, z) to the xy-plane).  Figure 24-2: Cylindrical coordinate system • **Spherical**: Displays the radial distance **r [<length unit>]** (the distance from (0, 0, 0) to (x, y, z)), the polar angle **θ [<angle unit>]** (the angle between the z-axis and the line joining (x, y, z) to (0, 0, 0)), and the azimuthal angle **φ [<angle unit>]** (the angle between the x-axis and the line joining (x, y, 0) to (0, 0, 0)).  Figure 24-3: Spherical coordinate system
Export as CSV…	Opens the **Export as CSV…** dialog for exporting the table values as *.csv* file.

Control	Description
Copy to clipboard	Copies the selected rows as well as the column heading into the system clipboard. The clipboard information is provided both as plain text and rich-text table, so when pasting into a rich-text-capable application like a word processor, you will see a proper table with cell borders and bold headings.

Histogram Tab

Shows the histogram plot of the fit point count against the deviation of the fit points from the geometry element. The coloring is determined by the **Reference deviation** field of the **Colors** tab.

In contrast to other tabs of the **Geometry element properties** dialog, the **Histogram** tab is also available when multiple geometry elements are selected. It will then reflect the union of the fit points of the selected geometry elements.

Controls of the **Histogram** Tab

The following controls are available for the **Histogram** tab:

Table 24-5: Controls of the **Histogram** tab

Control	Description
Binning field	• **Off**: No binning is applied to the values shown in the histogram. • **From color bar**: Replaces the original values in the histogram by a value representative for the corre-sponding interval (“bin”) of the color bar.
button	Zooms the corresponding axis in.
button	Zooms the corresponding axis out.
use RMB to click into the chart area	Displays a context menu (see below).

Cumulated Tab

Shows the accumulated percentile of the fit points against the deviation of the fit points from the geometry element.

In contrast to other tabs of the **Geometry element properties** dialog, the **Cumulated** tab is also available when multiple geometry elements are selected. It will then reflect the union of the fit points of the selected geometry elements.

Controls of the **Cumulated** Tab

The following controls are available for the **Cumulated** tab:

Table 24-6: Controls of the **Cumulated** tab

Control	Description
Cumulation field	• **Absolute**: Shows the statistics for all fit points as a function of their absolute numerical deviation. • **Only positive**: Shows the statistics for fit points with a positive deviation. • **Only negative**: Shows the statistics for fit points with a negative deviation.
Abs. deviation/Pos. deviation/ Neg. deviation spin box	Allows you to specify a deviation value to obtain the cumulated percentage of fit points within this deviation. This control is synchronized with the green cross-hairs that indicate the corresponding position on the curve.
Percentage spin box	Allows you to specify a percentage for which you want to obtain the maximum deviation. This control is synchronized with the green cross-hairs that indicate the corresponding position on the curve.
use LMB to click and drag green cross-hairs lines	Moves the green cross-hairs along the curve, which indicates the percentage of fit points within a given deviation (or, alternatively, the maximum deviation for a given percentage).
use RMB to click into the chart area	Displays a context menu (see below).

Colors Tab

Sets the interval width and colors used in the histogram plot and for the color-coded fit points visible in the 2D and 3D windows as well as the settings for the fit point color bar.

In contrast to other tabs of the **Geometry element properties** dialog, the **Colors** tab is also available when multiple geometry elements are selected. It will then reflect the union of the fit points of the selected geometry elements.

- **Reference deviation** section

  When the **automatic** option is checked (default), the interval width is in units of the automatically determined standard deviation. This is the standard deviation of all selected geometry elements or—if no geometry elements are selected—all geometry elements found in the scene.

  When this option is unchecked, you can specify a custom value.
- **Colors** section

  Shows the intervals for the fit point deviations and the corresponding colors. Double-clicking a color bar opens the **Select Color** dialog, where you can set the color for the corresponding interval.
- **Color bar** section

Specifies the settings for the fit point color bar.

Table 24-7: Settings for the color bar

Control	Description
Visibility drop-down list	Switches the color bar on and off.
Positioning drop-down list	Specifies the location of the color bar within the 2D and 3D windows: **Left, Right, Top, Bottom, All - automatic, Left or right - automatic, Top or bottom - automatic**.
Caption field	Specifies the color bar headline by using place-holders.
Reset button	Resets the **Caption** field to the default entry.
Caption preview field	Displays the preview of the color bar headline defined in the **Caption** field.

Viewing the Coordinate Measurement Results

CM results dialog

Clicking the **CM results** button on the **Inspect** tab or double-clicking a feature in the Scene Tree will open the **CM results** dialog, which allows you to view, edit, and print detailed information on the geometry elements and GD&T features connected to the volume object, CAD model, or surface mesh selected in the Scene Tree. The name of the selected volume object, CAD model, or surface mesh is shown in the caption of the dialog.

Features Tab

The **Features** tab consists of the following sections:

- **Feature list** section: Lists all existing dimensioning, tolerance and/or linear size features and their properties. For details, see below.
- **Annotation list** section: Lists all existing tolerancing annotations that belong to the feature selected in the feature list. The annotations will be listed only if only one feature is selected in the feature list. For details on the columns of the table, see section *Annotations Tab* on page 269.
- **Screenshots** section: Allows you to capture images from one of the 2D windows, the 3D window, or the current window layout for the item currently selected in the table. For details, see section *General Table Controls* on page 283.

Double-clicking the **Features** entry in the Scene Tree directly opens the **Features** tab of the **CM results** dialog.

Columns of the Feature List

As each feature is defined in a distinct coordinate system, lengths and positions displayed in the table do not refer to the currently selected coordinate system, but to the coordinate system of the feature itself.

Table 24-8: Columns of the feature list

Column	Description
Group	Indicates the name of the group the feature belongs to.
Name	Indicates the name of the feature and the icon for the feature type. This column can be edited.
Comment	Allows you to enter a comment about the feature by double-clicking the respective cell.
Type	Indicates the feature type. For details on the feature types, see section *Types of Features* on page 250.
Projection	Indicates the spatial projection of the feature. Available for the feature types **Distance**, **Position**, and **Angle**. These can be projected along one or two spatial dimensions: • A **dx** (or **dy** or **dz**) **Distance/Position** feature refers to the x (or y or z) component of the measured distance line only. • A **dxy** (or **dxz** or **dyz**) **Distance/Position** feature refers to the distance line projected onto the corresponding plane. • If no projection is desired, a **dxyz** feature will be used. • For the feature type **Angle**, only **dxy, dxz, dyz**, and **dxyz** projections are available, since angles cannot be projected onto a single axis. • Projection directions always refer to the axes of the feature coordinate system.
View	Indicates the view to be included in the report. • For **dxyz** features, **All views** will always be included in the report. • **Distance** or **Position** features with **dx**, **dy** or **dz** projection can exist in two possible orientations (a **dx** feature can show up in a top/bottom (xy) slice or a front/back (xz) slice). The **View** determines the orientation. • For tolerance features, either manually select the view of the image included in the report (**Left, Right, Front, Back, Top, Bottom**) or select **Auto** to automatically select the optimal view.
Source A/B	Indicates the geometry element(s) used for defining this feature. • For **Position**, **Radius** and **Diameter** features, only **Source A** is available. For **Distance** and **Angle** features, both **Source A** and **Source B** objects are available. • For tolerance features, only **Source A** (the toleranced geometry element) is available. Additional toleranced geometry elements (CZ) are also listed here.

Column	Description
Coordinate system	Indicates the coordinate system in which the feature is defined.
Datum P./S./T.	Tolerances often need one or more datum object(s). • **Datum P.**: The primary datum object can be a base plane defined by the axes of the coordinate system (usually the scene coordinate system) or a suitable geometry element. This option is available for the following tolerance types: **Angularity**, **Coaxiality**, **Line profile**, **Parallelism**, **Perpendicularity**, **Position**, **Run-out**, **Surface profile**, **Symmetry**, and **Total run-out**. • **Datum S.**: The secondary datum object can be a base plane defined by the axes of the coordinate system (usually the scene coordinate system) or a suitable geometry element. This option is available for the following tolerance types: **Angularity**, **Coaxiality**, **Line profile**, **Parallelism**, **Perpendicularity**, **Position**, **Run-out**, **Surface profile**, and **Total run-out**. • **Datum T.**: The tertiary datum object can be a base plane defined by the axes of the coordinate system (usually the scene coordinate system) or a suitable geometry element. This option is available for the following tolerance types: **Line profile**, **Position**, and **Surface profile**.
Tolerance zone	Indicates the shape of the tolerance zone. The tolerance zone can be **Planar**, **Planar UZ**, **Planar U**, **Circular**, **Conical**, **Cylindrical**, **Spherical**, **Square**, **Box**, **Minimal**, **Symmetric**, **Symmetric UZ**, **Symmetric U**, **Positive**, **Negative**, **Positive minimal**, or **Negative minimal**.
Tolerance target	Indicates the target object of the toleranced geometry element. • **Actual element**: Tolerances all fit points. • **Fitted element**: Tolerances the geometry element (e.g., the plane). • **Fitted axis**: Tolerances the axis of the geometry element (e.g., the axis of a cylinder). • **Fitted position**: Tolerances the position of the geometry element. • **Extracted median element (Line)** or **(Plane)**: Tolerances all calculated fit points of the median element (e.g., the extracted median axis of a cylinder or a cone, or the extracted median plane from two planes).
Actual [<length unit>/<angle unit>]	Indicates the numerical value of the feature. For tolerance features, the actual value corresponds to the actual deviation calculated for the selected tolerance type. For angle features, the value is displayed in the current angle unit; for all other types of features, it is displayed in the current length unit.
Actual pos. x/y/z [<length unit>]	For **Position** tolerance features: Indicates the actual position of the toleranced geometry element with respect to the base coordinate system.

Column	Description
Nominal [<length unit>/<angle unit>]	• For dimensioning and linear size features: Indicates the nominal value for the feature. Based on the **Tolerance (lo)/(hi)** settings, the software will determine whether the feature meets the specified tolerance and set the feature status accordingly. The evaluation will be performed only if both the nominal value and the tolerance values are set. • For tolerance features: This value is always 0.
Nominal pos. x/y/z [<length unit>]	For **Position** tolerance features: Indicates the nominal position of the feature along the x-axis, y-axis, or z-axis, respectively. Based on the **Tolerance** settings, the software will determine whether the feature is within the specified tolerance and set the feature status accordingly.
Tolerance (lo)/(hi) [<length unit>/<angle unit>]	• For dimensioning and linear size features: Specifies the allowed tolerance of the actual value towards the given nominal value. • For tolerance features: The **Tolerance (hi)** column corresponds to the selected **Tolerance** in the **Geometric tolerancing** dialog.
Status	Provides status information on the feature. For a list of possible status messages, see section *Status Messages for Dimensioning Features* on page 289, section *Status Messages for Tolerance Features* on page 290 or section *Status Messages for Linear Size Features* on page 293.
Depth [<length unit>]	Available and relevant for projected (non-dxyz) dimensioning features only. Determines the position in which the projected feature is visualized in 3D. The feature orientation is determined by its **Projection** and **View**, but there will still be one degree of freedom when it is displayed in a 3D view. When a feature is dragged into a 2D window, the initial depth will be determined from the slice position from which the feature was dragged out. The depth can later be changed freely.

Column	Description
Image	Allows you to add a detailed 2D image and feature description on a separate page of the report. • **Off**: No image is created (default). • **On**: Creates a suitable slice image and feature description. • **If not OK**: Automatically includes an image if the tolerance status is **Out of tolerance**. The generated image will only contain the reported feature, its source geometry elements, and its parent volume object or surface mesh. All other geometry elements, GD&T features, analyses, etc., will be hidden. The 2D slice position used for taking the image is determined by the position of the feature. The zoom factor of the image is chosen so that the entire parent volume object or surface mesh is visible. For all features with a preferred orientation (i.e., all features except dxyz-positions and distances), a single image in this orientation will be created. Otherwise, an orthographic projection with three orthogonal views relative to the coordinate system of the feature will be generated.
Captures	Indicates the number of images captured for this feature using the **Capture from** button in the **Screenshots** section.
Tolerance (excess) [%]	Specifies an additional allowed excess of the tolerance in percent of the tolerance range, in order to account for deviations caused by digits after the decimal point. This column can be edited. The value is applied to **Tolerance (lo)** and **Tolerance (hi)** separately.
Visual tolerance	Visually displays the actual tolerance range and the position of the feature within or outside the tolerance range. The allowed excess is not considered.
Deviation [<length unit>/<angle unit>]	Indicates the difference between actual and nominal value.
Rel. deviation [%]	Indicates the percentage difference between actual and nominal value, i.e., the **Deviation** (the difference between actual and nominal value) divided by the **Tolerance** or **Tolerance (hi)**, respectively.
MR type	Indicates the type of material requirement of a tolerance feature. This can be one of the following: • **Least material (LMR)** • **Least material (LMR) reciprocal** • **Maximum material (MMR)** • **Maximum material (MMR) reciprocal**
MR main feature	Indicates the main toleranced dimensioning or linear size feature used for defining the material requirement.
MR datum feature 1	Indicates feature 1 used for defining the material requirement.
MR datum feature 2	Indicates feature 2 used for defining the material requirement.

Column	Description
Nominal distance [<length unit>]	For cylindrical and spherical **Position** tolerances: Indicates the nominal distance of the toleranced geometry element from the nominal position. The tolerance zone is a double cylinder or sphere around the perfect cylinder or sphere.
Final tolerance (hi) [<length unit>]	Indicates the final tolerance including the tolerances defined by the material requirement, if applicable.
Unique ID	Relevant when exporting the results for use in statistics software via the **Q-DAS export** function. Specifies a unique identifier for the corresponding feature. This field may be used for matching the corresponding features across multiple results.
Severity	Relevant when you export the results for use in statistics software via the **Q-DAS export** function. This allows you to specify a severity level: **Unimportant**, **Of secondary importance**, **Important**, **Significant**, **Critical**. This field may be used for filtering the results in the statistics software.

Controls of the Feature List

Table 24-9: Controls of the feature list

Control	Description
use RMB to click anywhere in the list	Opens the context menu (see section *Table Context Menu* on page 285).

Annotations Tab

Lists all existing tolerancing annotations and their properties.

All properties (e.g., positions) will be displayed and reported with respect to the currently selected coordinate system as well as the currently selected display unit.

Double-clicking a tolerancing annotation attached to a tolerance feature in the Scene Tree will directly open the **Annotations** tab of the **CM results** dialog.

Tolerance values will be interpreted according to DIN EN ISO 8015 (see also section *Rounding Rules* on page 4 in chapter 1 *Welcome*).

Columns of the Annotation List

Table 24-10: Columns of the annotation list

Column	Description
Group	Indicates the name of the group the annotation belongs to.

Column	Description
Feature	Indicates the name of the tolerance feature the annotation belongs to.
Name	Indicates the name of the tolerancing annotation. For automatically generated minimum or maximum tolerancing annotations, the name cannot be edited, while for manually created tolerancing annotations, the name can be edited.
Type	Indicates if the tolerancing annotation was created automatically (**Automatic**) or manually (**Manually defined**).
Position x/y/z	Indicates the coordinates of the annotation in the current coordinate system.
Deviation	Indicates the deviation of the toleranced geometry element from the specified tolerance at the indicated position.
Status	Provides status information on the tolerancing annotation. For a list of possible status messages, see section *Status Messages for Tolerancing Annotations* on page 293.

Controls of the Annotation List

Table 24-11: Controls of the annotation list

Control	Description
F2 key	Allows you to rename the selected manual tolerancing annotation.
Ctrl+C	Copies the selected rows as well as the column heading into the system clipboard.
Ctrl+V	Pastes previously copied coordinates into the **Annotations** table. If the format of the clipboard content is not recognized unequivocally, the **Specify file format** dialog will open (for details on this dialog, see below). The information will be interpreted in the currently selected coordinate system. The parameters can be separated by space, tab, semicolon, or comma (if a comma is already used as a decimal mark or digit grouping symbol, the values must be enclosed in double quotation marks). Example: annotation name;8.89;25.82;-0.55 You can also copy the information directly from a text file or the cells of a spreadsheet.
use RMB to click anywhere in the list	Opens the context menu (see section *Table Context Menu* on page 285).

Specify file format Dialog

Pressing the **Ctrl+V** keyboard shortcut on the **Annotations** tab will open the **Specify file format** dialog if the format of the clipboard content is not recognized unequivocally. In the **Specify file format** dialog, you can manually adapt the automatically detected file format.

- File preview

  Displays how the import wizard interprets the information (i.e., name and coordinates) of the annotations in the clipboard. The import wizard will try to automatically assign a meaning to the columns. Clicking a column header opens a drop-down list, which allows you to assign a different meaning to the column. Cells that cannot be parsed will be shown in red.

- Selecting **Position** from the column header drop-down list assigns all three coordinates to the current and the next two columns.
- An assignment can be cleared by again assigning the same meaning to the column (for example, clear **Position** by again selecting **Position**).

- **Preset selection** section

  Table 24-12: Controls in the **Preset selection** section

Icon	Item	Description
	drop-down list	Specifies the preset to be applied, to be edited, or to be taken as a basis for a new preset. The following icons are used: • default preset (if available) • customized preset • appears next to the icon of a preset that has been modified but not yet saved
	Save preset	Saves the selected preset under the specified name.
	Remove preset	Removes the selected preset from the preset drop-down list.
	Import preset	Imports a preset from the specified location.
	Export preset	Exports the selected preset to the specified location.

- **File format** section

  Table 24-13: Controls in the **File format** section

Control	Description
Start in line spin box	Specifies the first line of the text file to be used for import. The lines above this line will be grayed out in the file preview and not be considered for import.
Comments begin with drop-down list	Allows you to specify a text string used for preceding comments in the text file. The field can be edited.

Control	Description
Columns drop-down list	Allows you to transpose the column and row data. • **Vertical**: Shows the column data in columns. • **Horizontal**: Shows the column data in rows.
Encoding drop-down list	Specifies the character encoding of the text file: • **Auto**: If the file starts with UTF-8 byte order mark, it will be interpreted as **UTF-8**, otherwise as **Local**. • **Local**: Uses the 8-bit encoding specified in the operating system settings. • **UTF-8**: Uses the UTF-8 encoding.
List separator drop-down list	Specifies the character used as a separator. The field can be edited.
Decimal symbol drop-down list	Specifies the decimal mark, e.g., period or comma. The field can be edited.
Digit grouping symbol drop-down list	Specifies the separator for digit grouping, e.g., period or comma. The field can be edited.

- **Units** section

Table 24-14: Controls in the **Units** section

Control	Description
Length drop-down list	Specifies the unit for the annotation coordinates.

- Status line

Green: All settings are valid and the annotations can be pasted.

Yellow: The status line shows at least one warning and pasting the annotations might fail.

Red: The settings are invalid and the annotations cannot be pasted.

The following table gives an overview of the possible status messages in the status line:

Table 24-15: Status messages for importing annotations

Status	Description
At least one of the columns in the input cannot be imported	The meaning of at least one column provided in the input data is not supported in this software version.
Column "<column header>" is assigned to more than one column in the input	A meaning can be assigned to one column only.
No columns are selected for import	Click the column header drop-down lists to assign meanings to the columns.
Some fields in the column "<column header>" cannot be parsed	At least one field of the column contains an empty or an invalid value (for example, a digit is expected, but the field contains a different character).

Status	Description
Some fields in the set of columns of "<column group>" cannot be parsed	At least one field of the column group contains an empty or an invalid value (for example, a digit is expected, but the field contains a different character).
The <symbol 1> cannot be the same as the <symbol 2>	Make sure not to use the same symbol for different purposes (for example, the decimal symbol and the digit grouping symbol must be different).
The column "<column header>" is required but not selected for import	Click the column header drop-down list to assign a meaning to the column.
The set of columns "<column group>" is incomplete, the column "<column header>" is not selected for import	Click the column header drop-down list to assign a meaning to the column.
Unable to read from the input file	An error occurred while reading the data.
Valid setup	The current settings are valid and the annotations can be imported.

- **Import** button
  Accepts the settings and imports the annotations.
- **Cancel** button
  Closes the dialog and aborts the import wizard.

Geometry elements Tab

Lists all existing geometry elements and their properties.

All geometric properties (e.g., positions and directions) will be displayed and reported with respect to the currently selected coordinate system as well as the currently selected display unit.

Double-clicking the **Geometry elements** entry in the Scene Tree directly opens the **Geometry elements** tab of the **CM results** dialog.

Columns of the Geometry Element List

Table 24-16: Columns of the geometry element list

Column	Description
Group	Indicates the name of the group the geometry element belongs to.

Column	Description
Name	Indicates the name of the geometry element and the icon for the geometry element type. This column can be edited.
Status	Provides status information on the geometry element. For a list of possible status messages, see section *Status Messages for Geometry Elements* on page 288.
Type	Indicates the geometry element type: point, line, circle, corner circle, plane, sphere, cylinder, cone, torus, freeform line, or freeform surface. For details on the geometry element types, see section *Types of Geometry Elements* on page 249.
Coordinate system	Indicates the coordinate system that was selected when the report was opened. The coordinates, directions, and normals of the geometry elements are specified in this coordinate system.
Storage system	Indicates the storage system of the geometry element.
Position X/Y/Z	Indicates the coordinates of the center of the geometry element in the current coordinate system.
Direction x/y/z	Available for lines, cylinders, cones, and tori. Indicates the normalized direction vector of the geometry element.
Normal x/y/z	Available for circles, corner circles, and planes. Indicates the normalized normal vector of the geometry element.
Radius	Available for circles, corner circles, spheres, cylinders, cones, and tori. Indicates the radius of the geometry element (major radius for tori).
Minor radius	Available for tori. Indicates the minor radius of the geometry element.
Conicity	Available for cones. Indicates the conicity of the geometry element in angle units.
Total deviation/Positive/Negative	Available for fitted geometry elements only. Indicates the maximum deviation of the fit points from the fitted geometry element (see also section *Fit points Tab* on page 259). • Total deviation: The total of **Positive** and **Negative**. • **Positive**: The maximum positive deviation of a fit point from the fitted geometry element. • **Negative**: The maximum negative deviation of a fit point from the fitted geometry element.

Column	Description
Construction method	Indicates the method used for defining the geometry element (see section *Properties Tab* on page 256).
Image	Allows you to add a detailed 2D image and geometry element description on a separate page of the report. • **Off**: No image is created (default). • **Orthographic projection**: Creates three orthogonal views. • **Top/Bottom/Left/Right/Front/Back**: Creates a single 2D view in the specified orientation. The image orientation corresponds to the currently selected coordinate system. The generated image will only contain the reported geometry element and its parent volume object or surface mesh. All other geometry elements, GD&T features, analyses, etc., will be hidden. The geometry element is always shown without visible fit points and in a “highlighted” visual state. The 2D slice position used for taking the image is determined by the position of the geometry element. The zoom factor of the image is chosen so that the entire parent volume object or surface mesh is visible.
Focused image	This option is almost identical to the **Image** option but will generate an image that focuses on the respective item and is zoomed in by the **Zoom factor** specified during report creation or VGRF-based export.
Histogram image	Available for fitted geometry elements only. Allows you to choose whether to include the fit point histogram and/or the cumulated histogram in the reporting details for this geometry element.
Captures	Indicates the number of images captured for this geometry element using the **Capture from** button in the **Screenshots** section.
Centroid x/y/z	Indicates the centroid defined by the actual fit points. The centroid coordinates are calculated by adding up the values of all fit points for each spatial direction and dividing them by the number of fit points.

Controls of the Geometry Element List

Table 24-17: Controls of the Geometry Element list

Control	Description
Delete button	Deletes the selected geometry element from the Scene Tree.

Control	Description
use RMB to click anywhere in the list	Opens the context menu (see section *Table Context Menu* on page 285).

CM overview dialog

Clicking the **CM overview** button on the **Inspect** tab will open the **CM overview** dialog, which provides an overview of all GD&T features and geometry elements included in the currently open project. This dialog allows you to compare coordinate measurement results of multiple parts in a project.

Geometric tolerancing is based on DIN EN ISO 1101 and ASME Y14.5-2018.

The **CM overview** dialog consists of the following tabs:

- **Features** tab

  Lists all existing dimensioning and tolerance features. Clicking a feature on the **Features** tab will display all features of the same type and name available in the Scene Tree as well as their properties in the table area.
- **Geometry elements** tab

  Lists all existing geometry elements. Clicking a geometry element on the **Geometry elements** tab will display all geometry elements of the same type and name available in the Scene Tree as well as their properties in the table area.

Clicking an entry in the table area directly selects the corresponding feature or geometry element in the Scene Tree and shows it in the 2D and 3D windows.

Features and **Geometry elements** Tabs

The following columns are available on the **Features** and **Geometry elements** tabs:

Table 24-18: Columns of the **Features** and **Geometry elements** tabs

Column	Description
Feature set/Geometry element set	Lists the name of each feature or geometry element, respectively, that is common to all occurrences in the scene. A small warning triangle indicates different settings for this CM object across scene objects.

Column	Description
Box plot	If a feature set is selected: Shows a box plot of the statistical distribution of actual values for objects in this group, relative to the tolerance range. Figure 24-4: Example of a box plot • Dark gray area = tolerance range • Vertical white line = nominal value • White bar = range in which most of the values lie • Red dot = outliers
μ	If a feature set is selected: Shows the statistical mean of actual values for objects in this group.
σ	If a feature set is selected: Shows the statistical standard deviation of actual values for objects in this group.
C_{pk}	If a feature set is selected: Process capability index, for distributions not centered around the nominal value.The C_{pk} value is calculated from the mean μ, the corresponding standard deviation σ, and the upper (USL) or lower (LSL) specification limit: $$C_{pk} = \frac{\min(\mu - LSL, ULS - \mu)}{3\sigma}$$ While the C_p value only indicates the ratio of the given tolerance to the process variation, the C_{pk} value also takes into account the position of the mean relative to the center of the given tolerance. Higher values indicate a more reliable production process.
C_p	If a feature set is selected: Process capability index. The C_p value indicates the ratio of the given tolerance to the process variation. The C_p value is defined as: $$C_p = \frac{USL - LSL}{6\sigma}$$ Higher values indicate a more reliable production process.
Object count	Indicates the number of objects belonging to the selected feature set or geometry element set.

Features Table

The following columns are available for the GD&T feature selected on the **Features** tab:

Table 24-19: Columns of the feature table

Column	Description
Name	Indicates the icon for the feature type, the name of the object the feature belongs to, and the name of the feature.
Entry state	Indicates the current state of the entry. The following states are possible: • **Consistent**: A feature of the same name and type is present on this object. • **Name conflict**: A feature of the same name but different type is present on this object. • **Not present**: The feature is not present on this object.
Comment	Allows you to enter a comment about the feature by double-clicking the respective cell.
Modifiers	Indicates the modifiers applied to a linear size feature.
Projection	Indicates the spatial projection of the feature. Available for the feature types **Distance**, **Position**, and **Angle**. These can be projected along one or two spatial dimensions: • A **dx** (or **dy** or **dz**) **Distance/Position** feature refers to the x (or y or z) component of the measured distance line only. • A **dxy** (or **dxz** or **dyz**) **Distance/Position** feature refers to the distance line projected onto the corresponding plane. • If no projection is desired, a **dxyz** feature will be used. • For the feature type **Angle**, only **dxy, dxz, dyz**, and **dxyz** projections are available, since angles cannot be projected onto a single axis. • Projection directions always refer to the axes of the feature coordinate system.
View	Indicates the view to be included in the report. • For **dxyz** features, **All views** will always be included in the report. • **Distance** or **Position** features with **dx**, **dy** or **dz** projection can exist in two possible orientations (a **dx** feature can show up in a top/bottom (xy) slice or a front/back (xz) slice). The **View** determines the orientation. • For tolerance features, either manually select the view of the image included in the report (**Left, Right, Front, Back, Top, Bottom**) or select **Auto** to automatically select the optimal view.

Column	Description
Depth	Available and relevant for projected (non-dxyz) dimensioning features only. Determines the position in which the projected feature is visualized in 3D. The feature orientation is determined by its Projection and View, but there will still be one degree of freedom when it is displayed in a 3D view. When a feature is dragged into a 2D window, the initial depth will be determined from the slice position from which the feature was dragged out. The depth can later be changed freely.
Source A/B	Indicates the geometry element(s) used for defining this feature. • For **Position**, **Radius** and **Diameter** features, only **Source A** is available. For **Distance** and **Angle** features, both **Source A** and **Source B** objects are available. • For tolerance features, only **Source A** (the toleranced geometry element) is available. Additional toleranced geometry elements (CZ) are also listed here.
Coordinate system	Indicates the coordinate system in which the feature is defined.
Datum P./S./T.	Tolerances often need one or more datum object(s). • **Datum P.**: The primary datum object can be a base plane defined by the axes of the coordinate system (usually the scene coordinate system) or a suitable geometry element. This option is available for the following tolerance types: **Angularity**, **Coaxiality**, **Line profile**, **Parallelism**, **Perpendicularity**, **Position**, **Run-out**, **Surface profile**, **Symmetry**, and **Total run-out**. • **Datum S.**: The secondary datum object can be a base plane defined by the axes of the coordinate system (usually the scene coordinate system) or a suitable geometry element. This option is available for the following tolerance types: **Angularity**, **Coaxiality**, **Line profile**, **Parallelism**, **Perpendicularity**, **Position**, **Run-out**, **Surface profile**, and **Total run-out**. • **Datum T.**: The tertiary datum object can be a base plane defined by the axes of the coordinate system (usually the scene coordinate system) or a suitable geometry element. This option is available for the following tolerance types: **Line profile**, **Position**, and **Surface profile**.
Tolerance zone	Indicates the shape of the tolerance zone. The tolerance zone can be **Planar**, **Planar UZ**, **Planar U**, **Circular**, **Conical**, **Cylindrical**, **Spherical**, **Square**, **Box**, **Minimal**, **Symmetric**, **Symmetric UZ**, **Symmetric U**, **Positive**, **Negative**, **Positive minimal**, or **Negative minimal**.

Column	Description
Tolerance target	Indicates the target object of the toleranced geometry element. • **Actual element**: Tolerances all fit points. • **Fitted element**: Tolerances the geometry element (e.g., the plane). • **Fitted axis**: Tolerances the axis of the geometry element (e.g., the axis of a cylinder). • **Fitted position**: Tolerances the position of the geometry element. • **Extracted median element (Line)** or **(Plane)**: Tolerances all calculated fit points of the median element (e.g., the extracted median axis of a cylinder or a cone, or the extracted median plane from two planes).
Actual	Indicates the numerical value of the feature. For tolerance features, the actual value corresponds to the actual deviation calculated for the selected tolerance type. For angle features, the value is displayed in the current angle unit; for all other types of features, it is displayed in the current length unit.
Actual pos. x/y/z	For **Position** tolerance features: Indicates the actual position of the toleranced geometry element with respect to the base coordinate system.
Nominal	• For dimensioning and linear size features: Indicates the nominal value for the feature. Based on the **Tolerance (lo)**/**(hi)** settings, the software will determine whether the feature meets the specified tolerance and set the feature status accordingly. The evaluation will be performed only if both the nominal value and the tolerance values are set. • For tolerance features: This value is always 0.
Nominal pos. x/y/z	For **Position** tolerance features: Indicates the nominal position of the feature along the x-axis, y-axis, or z-axis, respectively. Based on the **Tolerance** settings, the software will determine whether the feature is within the specified tolerance and set the feature status accordingly.
Nominal distance	For cylindrical and spherical position tolerances: Indicates the nominal distance of the toleranced geometry element from the nominal position. The tolerance zone is a double cylinder or sphere around the perfect cylinder or sphere.
Tolerance (lo)/(hi)	• For dimensioning and linear size features: Specifies the allowed tolerance of the actual value towards the given nominal value. • For tolerance features: The **Tolerance (hi)** column corresponds to the selected **Tolerance** in the **Geometric tolerancing** dialog.

Column	Description
Status	Provides status information on the feature. For a list of possible status messages, see section *Status Messages for Dimensioning Features* on page 289, section *Status Messages for Tolerance Features* on page 290 or section *Status Messages for Linear Size Features* on page 293.
Tolerance (excess)	Specifies an additional allowed excess of the tolerance in percent of the tolerance range, in order to account for deviations caused by digits after the decimal point. This column can be edited. The value is applied to **Tolerance (lo)** and **Tolerance (hi)** separately.
Visual tolerance	Visually displays the actual tolerance range and the position of the feature within or outside the tolerance range. The allowed excess is not considered.
Deviation	Indicates the difference between actual and nominal value.
Rel. deviation	Indicates the percentage difference between actual and nominal value, i.e., the **Deviation** (the difference between actual and nominal value) divided by the **Tolerance** or **Tolerance (hi)**, respectively.
MR type	Indicates the type of material requirement of a tolerance feature. This can be one of the following: • **Least material (LMR)** • **Least material (LMR) reciprocal** • **Maximum material (MMR)** • **Maximum material (MMR) reciprocal**
MR main feature	Indicates the main toleranced dimensioning or linear size feature used for defining the material requirement.
MR datum feature 1	Indicates feature 1 used for defining the material requirement.
MR datum feature 2	Indicates feature 2 used for defining the material requirement.
Final tolerance (hi)	Indicates the final tolerance including the tolerances defined by the material requirement, if applicable.
Out of tolerance value	Indicates the value by which the feature exceeds the specified tolerance range.
Unique ID	Relevant when exporting the results for use in statistics software via the **Q-DAS export** function. Specifies a unique identifier for the corresponding feature. This field may be used for matching the corresponding features across multiple results.
Severity	Relevant when you export the results for use in statistics software via the **Q-DAS export** function. This allows you to specify a severity level: **Unimportant**, **Of secondary importance**, **Important**, **Significant**, **Critical**. This field may be used for filtering the results in the statistics software.

Geometry element table

The following columns are available for the geometry element selected on the **Geometry elements** tab:

Table 24-20: Columns of the geometry element table

Column	Description
Name	Indicates the icon for the geometry element type, the name of the object the geometry element belongs to, and the name of the geometry element.
Entry state	Indicates the current state of the entry. The following states are possible: • **Consistent**: A geometry element of the same name and type is present on this object. • **Name conflict**: A geometry element of the same name but different type is present on this object. • **Not present**: The geometry element is not present on this object.
Status	Provides status information on the geometry element. For a list of possible status messages, see section *Status Messages for Geometry Elements* on page 288.
Position x/y/z	Indicates the coordinates of the center of the geometry element in the current coordinate system.
Radius	Available for circles, corner circles, spheres, cylinders, cones, and tori. Indicates the radius of the geometry element (major radius for tori).
Minor radius	Available for tori. Indicates the minor radius of the geometry element.
Conicity	Available for cones. Indicates the conicity of the geometry element in angle units.
Total deviation/Positive/Negative	Available for fitted geometry elements only. Indicates the maximum deviation of the fit points from the fitted geometry element (see also section *Fit points Tab* on page 259). • Total deviation: The total of **Positive** and **Negative**. • **Positive**: The maximum positive deviation of a fit point from the fitted geometry element. • **Negative**: The maximum negative deviation of a fit point from the fitted geometry element.
Construction method	Indicates the method used for defining the geometry element (see section *Properties Tab* on page 256).

Column	Description
Centroid x/y/z	Indicates the centroid defined by the actual fit points. The centroid coordinates are calculated by adding up the values of all fit points for each spatial direction and dividing them by the number of fit points.
Orientation	Indicates either the direction (line, cylinder, cone, torus) or the normal vector (plane, circle) of the geometry element. Not relevant for points and spheres.

Controls of the Feature and Geometry Element Tables

The following buttons are available at the bottom of the tables:

Table 24-21: Buttons of the feature and geometry element tables

Column	Description
Delete button	Removes the selected items from the scene.
Show placeholder objects checkbox	Uncheck this option to hide placeholder objects, i.e., objects with the entry state **Name conflict** or **Not present**.

Chart Area

The chart area shows a graph that can be used to draw conclusions about the production process. The graph shows how the parameter selected from the drop-down list changes from object to object. On the x-axis, the objects currently available in the table are plotted. On the y-axis, the parameter selected from the drop-down list is displayed. In the graph, the objects are represented by points connected with a line. Clicking a point on the line will highlight the corresponding object in the table.

For features, **Quality control chart** can be selected from the drop-down list. In the quality control chart, the gray area indicates the tolerance band and the dotted line indicates the nominal value.

General Table Controls

- List section

  The following table provides an overview of the general controls available in the various list views:

  Table 24-22: Controls in the list section

Control	Description
button	Opens a submenu for selecting the filter/search mode.

Control	Description
Filter	Clicking the **Click to add a filter or search criterion** field to the right of the icon opens a series of drop-down lists from which you can select a table column, an operator, and—depending on the column—a value. If a column does not offer a value drop-down list, you can type in a value. When the selection is complete, the table shows the rows matching the filter criterion. Clicking the **+** button or the **Click to add a filter or search criterion** field allows you to specify more filter criteria. Clicking the **x** button removes the filter.
Search	Clicking the **Click to add a filter or search criterion** field to the right of the icon opens a series of drop-down lists from which you can select a table column, an operator, and—depending on the column—a value. If a column does not offer a value drop-down list, you can type in a value. When the selection is complete, the table rows matching the search criterion are highlighted. Clicking the **+** button or the **Click to add a filter or search criterion** field allows you to specify more search criteria. Pressing **F3** jumps to the next search result in the list. Clicking the **x** button removes the search.
Full-text filter	Entering a value or text string into the input field to the right of the icon filters the table accordingly and shows the rows that match the filter criterion.
Full-text search	Entering a value or text string into the input field to the right of the icon searches the table accordingly and highlights the rows that match the search criterion.
use LMB to click on a table row	Selects the row and the corresponding object in the Scene Tree. In analysis result lists, the result, e.g., the component, is marked by a cross-hairs cursor in each of the 2D views.
hold **Ctrl** key + use LMB to click on several table rows	Selects the rows and the corresponding objects in the Scene Tree.
hold **Shift** key + use LMB to click on two separate table rows	Selects the two rows, including all rows between the two as well as the corresponding objects in the Scene Tree.
hold **Shift** key + use up/down arrow keys	Selects the rows and the corresponding objects in the Scene Tree.

Control	Description
press **Ctrl+A**	Selects all table rows.
use up and down arrow keys	Steps up and down through the table rows.
use RMB to click into the table area	Displays a context menu. See below.
use LMB to click a column heading	Sorts the table according to the values of the column. Clicking subsequently toggles between ascending and descending.
use LMB to click and drag column heading to new position, then release LMB	Inserts the column at the new position.
use LMB to double-click cell highlighted in white (light theme) or medium gray (dark theme)	If applicable: Allows you to edit the contents of the cell.

- **Screenshots** section (if available)

  The **Screenshots** section below the list section allows you to capture images from one of the 2D windows, the 3D window, or the current window layout for the item currently selected in the table. Only available if exactly one row is selected.

  Table 24-23: Controls in the **Screenshots** section

Control	Description
Capture from button	Adds the image of the view selected from the drop-down list to the preview area above.
use LMB to click and drag one or more images, then release LMB	Moves the image(s) to the new position.
double-click the image	Opens the **Snapshot display** window showing the image: • **Zoom in**/**Zoom out** button: Zooms the image in/out. You can also move the mouse pointer in the image area and turn the mouse wheel. • **Fit to window** button: Resets the zoom so that the image fits into the window.
click the **<no description>** placeholder twice (first click to select, second click to enable renaming)	Allows you to label the image.
Delete selected button	Deletes the selected image from the preview area.

Table Context Menu

Right-clicking anywhere in the table area shows a context menu with the following options:

Table 24-24: Context menu items

Control	Description
Columns	Allows you to toggle the visibility of each column by checking/unchecking the respective item. • **Show all**: Checks all columns to set them to visible. • **Hide all**: Unchecks all columns to set them to invisible. • **Hide empty**: Unchecks all not editable columns which are empty or **n/a** to set them to invisible.
Trim columns	Resizes all columns to their smallest possible size.
Apply default column layout	Applies the default column layout previously saved by the user to the current table. If no default column layout has been saved, the original column layout will be applied.
Save as default column layout	Saves modifications applied to the table—e.g., the visibility of a column, the order in which the columns appear, the column width—as default column layout. This layout will be applied when you create a new project.
Apply original column layout	Restores the original table layout and discards any modifications applied by the user. The original table layout is predefined and cannot be modified by the user.
Remove entries	If applicable: Deletes the selected row(s) from the table.
Create annotations	If applicable: Creates annotations for the selected items.
Export as CSV...	Opens the **Export as CSV...** dialog for exporting the table values as **.csv* file. This option always exports the complete table even if a filter was applied. In order to export only the filtered rows, press **Ctrl** + **A** to highlight all filtered rows and use the **Copy to clipboard** menu item.
Copy to clipboard	Copies the selected rows as well as the column heading into the system clipboard. The clipboard information is provided both as plain text and rich-text table, so when pasting into a rich-text-capable application like a word processor, you will see a proper table with cell borders and bold headings.

Control	Description
Paste	For annotation tables: Pastes previously copied coordinates and—optionally—snap directions to create new annotations in the table. For annotations of a nominal/actual comparison, the search distance specified on the **Settings** tab of the analysis will be considered. Note: Pasted annotations will be interpreted in the selected coordinate system at the time of pasting. The information in the clipboard must have the following structure: • x-, y-, and z-coordinate of the annotation or • x-, y-, and z-coordinate of the annotation as well as x-, y-, and z-component of the vector for the snap direction The parameters can be separated by space, tab, semicolon, or comma (if a comma is already used as a decimal mark or digit grouping symbol, the values must be enclosed in double quotation marks). Example: 8.89;25.82;-0.55;1;0;0 You can also copy the information directly from the cells of a spreadsheet. In order to paste the annotation information, you can also press the **Ctrl** + **V** keyboard shortcut.
Set as active column	If applicable: Makes the current column the active column, i.e., the results of this column are color-coded according to their values as defined by the color lookup table and the colors specified in the **Sections** section of the **Colors** tab.
Unset active column	If applicable: Deselects the currently active column and sets the **Active column** drop-down list on the corresponding **Settings** tab to **Uncoded**, i.e., removes any color coding.
Enter/change value (all items)	If applicable: Opens the **Enter value** dialog (see below) where you can enter the desired value for the selected parameter. This value will be applied to all entries in the table.
Enter/change value (selected items)	If applicable: Opens the **Enter value** dialog (see below) where you can enter the desired value for the selected parameter. This value will be applied to the selected entries in the table.
Delete selected items	If applicable: Removes the selected items from the scene.

The **Enter value** dialog includes the following controls:

Table 24-25: Controls in the **Enter value** dialog

Control	Description
Enter value field	Allows you to enter the desired value.
OK button	Sets the selected parameter to the specified value.
Reset button	For analyses only: Resets the selected parameter to undefined.
Set from tolerance settings button	For analyses only: Enters the value specified in the tolerance settings of the analysis for the selected parameter.
Cancel button	Discards the changes and closes the dialog.

Status Messages

The following tables give an overview of the possible status messages for geometry elements, dimensioning features, and tolerance features.

Status Messages for Geometry Elements

The following table gives an overview of the possible status messages for geometry elements.

Table 24-26: Status messages for geometry elements

Status	Description
Definition incorrect	For geometry elements created by geometry element manipulation: The specified manipulation parameters do not yield any valid result for this geometry element.
Invalid: Automatic refit failed	For fitted geometry elements: The last refitting process (due to resolution adjustment or measurement template import) failed, most likely because an insufficient number of fit points could be fit to the new underlying surface.
Invalid: Automatic refit failed for some source objects	For geometry elements created by geometry element manipulation: The fit status of at least one of the source elements has changed to **Invalid: Automatic refit failed**.
Invalid: Element needs to be reprobed	For geometry elements copied on scan objects: The points must be reprobed with **Update probed element(s)**.
Invalid: Not synchronized with current situation (surface determination change?)	For fitted geometry elements: The underlying data (voxel data, surface determination, mesh data) has changed since the last fitting process.

Status	Description
Invalid: Some source objects not synchronized	For geometry elements created by geometry element manipulation: The fit status of at least one of the source elements has changed to **Invalid: Not synchronized with current situation (surface determination change?)**.
Invalid: Source objects are no longer present	For geometry elements created by geometry element manipulation: At least one of the source elements has been deleted.
Isosurface not found for iteration > 0, but previous result could be taken	The last (iterative) (re-)fitting process was only partially successful—an intermediate valid result will be taken.
OK	The last fitting or refitting process succeeded with no problems. The geometry element is synchronized with the current situation.
Source element(s) in inconsistent state	For geometry elements created by geometry element manipulation: At least one of the source elements indicates a warning status. It is likely that the source element needs to be refitted, or that the last refit succeeded only partially.
Source element(s) in undefined state	For geometry elements created by geometry element manipulation: At least one of the source elements indicates a warning status. It is likely that the refit of the source element failed.
Source coordinate system is invalid	For fitted geometry elements: The storage coordinate system or the constraint coordinate system is invalid or in the inconsistent state. For defined geometry elements: The storage coordinate system is invalid or in the inconsistent state. For geometry elements created by geometry element manipulation: The coordinate system used for creating the geometry element is invalid or in the inconsistent state.

Status Messages for Dimensioning Features

The following table gives an overview of the possible status messages for dimensioning features.

Table 24-27: Status messages for dimensioning features

Status	Description
Invalid measurement	Although the source elements are valid, the desired feature cannot be measured. This may occur in case of undefined measurement modes (e.g., a centroid distance between objects without fit points).

Status	Description
Material condition error	An error occurred in connection with the reciprocal material requirement for the associated tolerance feature.
OK	No errors or warnings. Feature and source elements are well defined. A tolerance (range) is present and the feature meets the tolerance.
OK, but no tolerance settings	Dimensioning feature and source elements are well defined, but no tolerance range is given. The feature value is not tested against any allowed range.
OK (with MR)	No errors or warnings. Feature and source elements are well defined. A tolerance feature with a material requirement with a reciprocity requirement has been defined and the feature meets the tolerance—however, this is only due to the material requirement.
Out of tolerance band	Dimensioning feature and source elements are well defined, but the actual value of the feature lies outside the specified tolerance range.
Material requirement in undefined state	At least one geometric tolerance that makes use of this feature as reciprocity requirement in the **Material requirement** section is invalid. The geometric tolerance features are listed under **Related objects** in the context menu of the dimensioning feature.
Source element(s) in inconsistent state	The feature could be measured, but at least one source element indicates a warning status. Probably the source element needs to be refitted, or the last refit succeeded only partially.
Source element(s) in undefined state	The feature could be measured, but at least one source element indicates an error status. Probably the refit of the source element failed.
Source elements are not fitted, but defined	The element to be toleranced is not a fitted but a manually defined element and the **Allow defined elements** option is set to **No**.
Source coordinate system is invalid	The feature could be measured, but the coordinate system in which the feature is defined is invalid or in the inconsistent state.

Status Messages for Tolerance Features

The following table gives an overview of the possible status messages for tolerance features.

Table 24-28: Status messages for tolerance features

Status	Description
Select element to be toleranced	No geometry element is selected in the **Toleranced element** field.
Element fitted with “Adjust shape” cannot be toleranced	The toleranced freeform element was fitted with the **Adjust shape** option in the **Refit options** section on the **Refit** tab of the **Fit geometry element** dialog. Only freeform elements fitted with the **Keep original shape** option can be toleranced.
Configuration not supported	The selected object types do not match to each other.
Specify the tolerance type	A tolerance type is required but has not yet been specified.
Specify one or more datum elements	Depending on the tolerance type, one or more datum elements are required but have not yet been specified.
Invalid	A suitable datum element is required but has not been specified.
Datum element(s) not suited for zone type	The tolerance zone specified in the **Zone options** field is not suitable for the specified datum elements.
UZ applies to planar tolerance zones only/U applies to planar tolerance zones only	The **Planar UZ (ISO)** or **Planar Ⓤ (ASME)** option is selected in the **Zone options** field, but more than one nominal position is checked in the **Nominal values** section. Only one nominal position should be checked for a planar tolerance zone.
Invalid datum element(s)	At least one selected datum element is not suitable for the geometry element and tolerance type.
Specify an MMR/LMR related feature	A feature is required for the material requirement but has not yet been specified.
Invalid MMR/LMR configuration	An unsuitable feature (e.g., a feature without tolerance) has been selected for the material requirement, or a feature has been selected more than once.
Material requirement in undefined state	At least one of the selected features in the **Material requirement** section is invalid. The features in the **Material requirement** section are listed under **Related objects** in the context menu of the tolerance feature.
Invalid: No axis toleranced	For **Position** tolerances: No nominal position values have been specified.
OK	No errors or warnings. Feature and source elements are well defined. A tolerance (range) has been defined and the feature meets the tolerance.

Status	Description
OK (with MR)	No errors or warnings. Feature and source elements are well defined. A tolerance (range) with a material requirement has been defined and the feature meets the tolerance—however, this is only due to the material requirement.
Out of sync	The feature needs to be recalculated.
Out of tolerance	Feature and source elements are well defined, but the actual value of the feature lies outside the specified tolerance range.
Geometry element(s) unsuited for tolerance type	The geometry element cannot be toleranced with the selected settings, e.g., the selected target.
No fit points to tolerance	The tolerance target does not provide enough valid points to evaluate the geometric tolerance. This can happen when the selected source element is in an invalid state or — depending on the selected tolerance target — not enough valid points could be derived.
Refit search distance smaller than tolerance	For freeform elements: Refit the element with a suitable search distance. To do so, you can click the **Recreate** button on the **Fit points** tab of the **Geometry element properties** dialog and adjust the **Search distance** in the **Refit options** section on the **Refit** tab of the **Fit geometry element** dialog. Alternatively, you can paste the existing feature and adjust the **Search distance** in the **Refit options** section on the **Geometry element** tab of the **CM template import** dialog. In this case, the **Replace (overwrite existing element in scene if present)** option in the **Import options** section must be selected.
Source element(s) in inconsistent state	The tolerance could be measured, but at least one source element indicates a warning status. It is likely that the source element needs to be refitted, or that the last refit succeeded only partially.
Source element(s) in undefined state	The tolerance could be measured, but at least one source element indicates an error status. It is likely that the refit of the source element failed.
Source elements are not fitted, but defined	The element to be toleranced is not a fitted, but a manually defined element and the **Allow defined elements** option is set to **No**.
Specify the coordinate system	A coordinate system is required but has not yet been specified.

Status	Description
Source coordinate system is invalid	The tolerance could be measured, but the coordinate system in which the tolerance feature is defined is invalid or in an inconsistent state.

Status Messages for Linear Size Features

Status Messages for Tolerancing Annotations

The following table gives an overview of the possible status messages for tolerancing annotations:

Table 24-29: Status messages for tolerancing annotations

Status	Description
OK	No errors or warnings. The feature is valid. The deviation at the annotation position meets the tolerance.
OK (with MR)	No errors or warnings. The feature is valid. The deviation at the annotation position meets the tolerance—however, this is only due to the material requirement of the feature.
Out of tolerance	No errors or warnings. The feature is valid, but the deviation at the annotation position lies outside the specified tolerance range.
Feature is invalid	The feature is not valid. The status column of the feature can be checked for further information.
Outside the color overlay	The annotation position is outside the color overlay of the feature.
Color-coding disabled	Color-coding of deviations is not activated for the feature.
Color-coding not supported	Color-coding of deviations is not supported by this feature.
Color overlay not supported	Color-coding of deviations is supported by this feature but color overlay is not. An example of such a feature is a position tolerance with the tolerance target “Fitted element.”
Annotations not supported	This feature does not support tolerancing annotations.

Porosity/Inclusion Analysis Module

Introduction

The **Porosity/Inclusion Analysis** module has been designed to investigate voxel data sets for internal discontinuities, such as voids and inclusions, and to provide detailed analysis results with information on each individual indication as well as overall statistical information. An analysis report will be generated, which contains information such as position, size, surface, and volume of each individual indication.

License Information

This module is an optional add-on module for VGSTUDIO MAX. It is not available for myVGL. However, if a project loaded in myVGL contains results obtained with this module, they can be viewed and reported in myVGL.

If you are interested in a more comprehensive functionality than the one offered by myVGL, you have the chance to evaluate VGSTUDIO MAX. You can request an evaluation license of VGSTUDIO MAX on our website:

https://volumegraphics.hexagon.com/en/products/evaluation

If you have further questions about our product portfolio, please contact us:

- For Europe, Middle East, and Africa:
  Write an e-mail to sales@volumegraphics.com or call +49 6221 73920 744.
- For Japan:
  Write an e-mail to sales@volumegraphics.jp or call +81 52 508 9682.
- For the Americas:
  Write an e-mail to sales-us@volumegraphics.com or call +1 704 248 7736.
- For China, including Mainland China, Hong Kong, Macao, and Taiwan:
  Write an e-mail to sales@volumegraphics.cn or call +86 10 8532 6305.
- For Singapore and other parts of Asia (except China and Japan), Australia, and parts of Oceania:
  Write an e-mail to sales@volumegraphics.sg or call +65 6665 0310.

Opening the Dialog

In order to open the **Porosity/inclusion analysis** dialog,

- right-click the corresponding entry in the Scene Tree and select **Properties** from the context menu or
- double-click the corresponding entry in the Scene Tree.

The **Porosity/inclusion analysis** dialog consists of several pages and tabs on which you can view the results of the porosity/inclusion analysis.

To close the dialog, click the **Close** button at the bottom of the dialog.

A status bar at the bottom of the dialog indicates the current status of the analysis. The status can be one of the following:

Table 25-1: Messages in the status bar

Status	Description
Result is up to date	The current analysis result is valid.
Calculation required	All required parameters have been specified and are consistent, but the analysis was not calculated or was invalidated by some user action before the project was saved.
Volume has no surface determination	No surface determination information is available for the selected volume object. See also section *Surface determination* on page 949 in chapter 48 *Glossary*.
Invalid configuration	Input data is missing to run the analysis. The tab with the missing information is highlighted in red, and a message is displayed in red below the corresponding option.
License missing	The add-on module is not licensed.

An invalid or outdated status of an analysis is indicated in the Scene Tree by a warning sign. Double-click this analysis to open it and check the status bar for messages.

The units of the dialog are set according to the global unit settings (see section *Units Drop-down List* on page 33 in chapter 2 *Workspace*).

Settings page

Allows you to specify the settings to perform the porosity/inclusion analysis.

In myVGL, all parameter settings are displayed. Most of these parameters are read-only in myVGL. The complete functional range is available with VGSTUDIO MAX and the respective add-on module(s).

Basic tab

Displays the key settings required to perform the analysis.

The adjustments made on the **Basic** tab will be immediately reflected in the preview.

- **Detection method** section

Table 25-2: Controls in the **Detection method** section

Control	Description
VGEasyPore (recommended)	Is a locally adaptive detection technique that works well for most use cases. It is especially suitable for handling gray value deviations across the part, as caused, for example, by beam hardening.
Global threshold	Is a simple threshold technique. For pore/inclusion detection, gray values below/above the threshold will be considered part of an indication. This mode is suited for data sets with good material-to-indication contrast and provides fast results.
Indication ROI	Is an advanced technique that allows you to use an ROI representing the indications. Using this mode with ROIs created by tools like **Paint & Segment** or **Deep segmentation** helps tackle particularly complex tasks

- **Analysis parameters** section

Table 25-3: Controls in the **Analysis parameters** section

Control	Description
Indication type drop-down list	Specifies the type of indication the algorithm is to detect: • **Voids**: Detects voxels with gray values *lower* than those of the surrounding material (pores, cracks, etc.). • **Inclusions**: Detects voxels with gray values *higher* than those of the surrounding material.
Contrast spin box	For **VGEasyPore**: Specifies the threshold for detecting indications. Indications are detected only if their gray values differ from the gray values of the surrounding material by at least the value set for **Contrast**. For the default value of 20%, a *void* has to be at least 20% *darker* than the surrounding material, while an *inclusion* has to be at least 20% *brighter* than the surrounding material.
Threshold spin box/slider	For **Global threshold**: Specifies the threshold for detecting indications. Voids will be detected only if their gray values are lower than this value, while inclusions will be detected only if their gray values are higher than this value. To specify the threshold, you can use the slider or enter the value directly in the spin box.

Control	Description
Indication ROI drop-down list	For **Indication ROI**: Allows you to select an existing ROI that represents your indications. You can use this mode to analyze ROIs created with segmentation tools such as **Paint & Segment** or **Deep segmentation**.

- **Presets** button

Table 25-4: Controls in the **Presets** section

Icon	Item	Description
	Presets list	Allows you to select a recently saved preset.
	Import button	Allows you to use an existing preset.
	Create new button	Saves the current settings in a preset.
	Analysis factory settings	Resets the analysis parameters to their default values.
	Set as default preset	Sets the selected preset as default. The default preset will be applied when creating a new analysis of the same type.
	Update with current settings	Overwrites the selected preset with the current settings.
	Rename	Allows you to change the name of the selected preset.
	Export preset	Exports the selected preset to the specified location.
	Delete	Removes the selected preset from the **Presets** drop-down list. If the removed preset is the default preset, the next time an analysis of the same type is created, the factory settings will be used.

Advanced tab (**VGEasyPore**)

Provides additional options for the respective detection method to refine and improve indication detection.

The adjustments made on the **Advanced** tab will be immediately reflected in the preview.

- **Analysis parameters** section

Table 25-5: Controls of the **Analysis parameters** section

Control	Description
Noise reduction drop-down list	Applies a denoising filter to reduce the number of falsely detected indications due to image noise. The following options for the noise reduction filter are available: • **Off**: No filtering is applied. • **Low**: Use this setting for data sets with little noise. • **High**: Use this setting for data sets with a lot of noise. Activate **Noise reduction** when your scan contains noise and adjusting the value for **Contrast** or **Threshold** does not lead to satisfactory results. Note that activating this option increases the amount of memory required during calculation.
Local area size spin box	Specifies the diameter of the search area around each voxel for determining the **Contrast**.
Air gray value mode drop-down list	Allows you to choose the mode in which you want the **Air gray value** to be specified: • **Automatic**: Automatically detects the left-most peak, which represents the air gray value, based on the gray value histogram and enters the value to the field. • **Custom**: Allows you to specify the air gray value manually by entering a value in the spin box.
Air gray value spin box	Enabled if the **Air gray value mode** is set to **Custom**: Allows you to specify the air gray value manually by entering a value in the spin box.

- **Analysis area** section

Table 25-6: Controls of the **Analysis area** section

Control	Description
Surface treatment drop-down list	Specifies the area of the selected volume/ROI on which the algorithm will be performed. The analysis area is based on the surface determination of the volume. This option does not change the actual surface determination. This is an internal representation used for porosity/inclusion analysis only.

Control	Description

	• **Automatic**: Automatically selects the appropriate setting based on the part's surface determination and on the **Indication type** (**Voids**/**Inclusions**).
	  • **Indication type > Voids**
	  If you selected **Voids** as **Indication type** and the voids have not been filtered in the advanced surface determination with the **Filter voids** option, this option will remove all voids.
	  • **Indication type > Inclusions**
	  In **Inclusions** mode, no voids will be filtered. The basis for the calculation will be the determined surface (**Surface as seen**).
	• **Surface as seen**: Uses the area within the original surface determination.
	• **Include voids/surface voids**: All voids within the determined surface will be closed, allowing them to be detected as indications. It also enables the closing of open pores.

Surface void closing radius spin box	When **Include voids/surface voids** is selected: Allows you to specify a radius to seal the opening that links the void to the background.
Surface margin spin box	Specifies how close to the edge of the determined surface indications can be detected.

Advanced tab (**Global threshold**)

Provides additional options for the respective detection method to refine and improve indication detection.

The adjustments on the **Advanced** tab will be immediately reflected in the preview.

- **Analysis parameters** section

Table 25-7: Controls of the **Analysis parameters** section

Control	Description
Noise reduction drop-down list	Applies a denoising filter to reduce the number of falsely detected indications due to image noise. The following options for the noise reduction filter are available: • **Off**: No filtering is applied. • **Low**: Use this setting for data sets with little noise. • **High**: Use this setting for data sets with a lot of noise. Activate **Noise reduction** when your scan contains noise and adjusting the value for **Contrast** or **Threshold** does not lead to satisfactory results. Note that activating this option increases the amount of memory required during calculation.

- **Analysis area** section

Table 25-8: Controls of the **Analysis area** section

Control	Description
Use surface determination checkbox	When checked, indications will be detected only within the determined surface. When unchecked, indications will be detected across the entire volume.
Surface treatment drop-down list	Specifies the area of the selected volume/ROI on which the algorithm will be performed. The analysis area is based on the surface determination of the volume. This option does not change the actual surface determination. This is an internal representation used for porosity/inclusion analysis only.

Control	Description

	• **Automatic**: Automatically selects the appropriate setting based on the part's surface determination and on the **Indication type** (**Voids**/**Inclusions**).
	  • **Indication type > Voids**
	  If you selected **Voids** as **Indication type** and the voids have not been filtered in the advanced surface determination with the **Filter voids** option, this option will remove all voids.
	  • **Indication type > Inclusions**
	  In **Inclusions** mode, no voids will be filtered. The basis for the calculation will be the determined surface (**Surface as seen**).
	• **Surface as seen**: Uses the area within the original surface determination.
	• **Include voids/surface voids**: All voids within the determined surface will be closed, allowing them to be detected as indications. It also enables the closing of open pores.

Surface void closing radius spin box	When **Include voids/surface voids** is selected: Allows you to specify a radius to seal the opening that links the void to the background.
Surface margin spin box	Specifies how close to the edge of the determined surface indications can be detected.

Advanced tab (**Indication ROI**)

Provides additional options for the respective detection method to refine and improve indication detection.

The adjustments made in the **Advanced** tab will be immediately reflected in the preview.

- **Analysis area** section

  Table 25-9: Controls of the **Analysis area** section

Control	Description
Use surface determination checkbox	When checked, indications will be detected only within the determined surface. When unchecked, indications will be detected across the entire volume.

Control	Description

Surface treatment drop-down list	Specifies the area of the selected volume/ROI on which the algorithm will be performed. The analysis area is based on the surface determination of the volume.
	This option does not change the actual surface determination. This is an internal representation used for porosity/inclusion analysis only.
	• **Automatic**: Automatically selects the appropriate setting based on the part's surface determination and on the **Indication type** (**Voids**/**Inclusions**).
	  • **Indication type > Voids**
	  If you selected **Voids** as **Indication type** and the voids have not been filtered in the advanced surface determination with the **Filter voids** option, this option will remove all voids.
	  • **Indication type > Inclusions**
	  In **Inclusions** mode, no voids will be filtered. The basis for the calculation will be the determined surface (**Surface as seen**).
	• **Surface as seen**: Uses the area within the original surface determination.
	• **Include voids/surface voids**: All voids within the determined surface will be closed, allowing them to be detected as indications. It also enables the closing of open pores.

Surface void closing radius spin box	When **Include voids/surface voids** is selected: Allows you to specify a radius to seal the opening that links the void to the background.

Filters tab

Allows you to automatically filter out indications outside specified ranges from the analysis results.

The adjustments made on the **Filter** tab will not be reflected in the preview.

- **General filters** section

Table 25-10: Controls of the **General filters** section

Control	Description
Probability threshold spin box	All potential indication areas that pass the size check will be further processed by several analysis stages. These stages try to differentiate between real indications and artifacts by utilizing sophisticated image processing algorithms. Each detected indication is tagged with a value indicating the probability that it is a real indication.
Reduce probability for indications in noisy regions checkbox	Compares the potential indications with their local neighborhood. If the gray value distribution of a potential indication is very similar to that of the surrounding material, its probability will be reduced.
Minimum voxel count spin box	Filters out indications with a voxel count smaller than the value specified in this spin box.
Diameter range spin boxes	Filters out indications with a diameter outside the specified range.
Volume range spin boxes	Filters out indications with a volume outside the specified range.
Compactness range spin boxes	Specifies the range for the compactness of the indication, i.e., the ratio between the volume of the indication and the volume of the circumscribed sphere. $$\text{Compactness} = \frac{V_{indication}}{V_{sphere}}$$
Sphericity range spin boxes	Specifies the range for the sphericity of the indication, i.e., the ratio between the surface of a sphere with the same volume as the indication and the surface of the indication. $$\text{Sphericity} = \frac{A_{sphere}}{A_{indication}}$$

- **Distance-to-surface filters** section

Table 25-11: Controls of the **Distance-to-surface filters** section

Control	Description
Classification drop-down list	Specifies the position of the indication relative to the object selected from the **Distance to surface** drop-down list on the **Additional features** tab: **All**, **Cut**, **Inside**, **Outside**, and all combinations of these classes.
Distance-to-surface range spin boxes	Specifies the range for the distance between the surface of the indication and the surface of the object selected from the **Distance to surface** drop-down list on the **Additional features** tab.

Control	Description
Cut surface range [<length unit>²] spin boxes	Specifies the range for the surface area where the indication intersects the surface of the object selected from the **Distance to surface** drop-down list on the **Additional features** tab.

Additional features tab

Allows you to apply additional quantification options, which will be displayed in the analysis results.

The adjustments made on the **Additional features** tab will not be reflected in the preview.

Indication features section

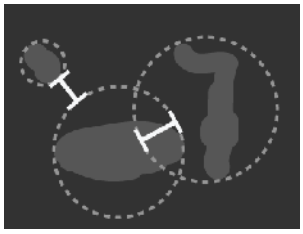
This section allows you to calculate the following additional properties for each indication:

- **Gap**: the closest distance of an indication to its neighboring indication
- **Distance to surface**: the distance to the surface of a specified reference object
- **Wall thickness evaluation**: properties related to the results of a wall thickness analysis

The results will be shown on the **Indications** tab of the **Results** page.

***Gap** section*

Table 25-12: Controls in the **Gap** section

Control	Description
Gap checkbox	Calculates the distance of an indication to the closest neighboring indication. The following calculation methods are available: • **Voxel-based** Calculates the closest distance based on the actual voxel boundaries of the indications. • **Sphere-based (legacy)** Approximates the closest distance by finding the circumscribed sphere of each indication and calculating the distance to the closest neighboring sphere. If the spheres intersect, the distance will be negative.  • **Voxel-based and sphere-based** Calculates the gap according to both calculation methods.

***Distance to surface** section*

This function is highly important for virtual machining. For example, prior to actually eroding a sealing surface or cutting a screw thread, this analysis parameter delivers the information if indications will be cut open by the machining process. This information can be significant when you are interested in the sealing or crack opening properties of an object area.

Table 25-13: Controls in the **Distance to surface** section

Control	Description
Distance to surface checkbox	When this option is checked, the distance of each indication to the object selected as reference object will be calculated. The distance to surface will be calculated relative to the nearest surface of the reference object. If you use a surface determination as reference, make sure it does not include areas within the material (e.g., indications).
Drop-down list	Specifies the object to which the distance-to-surface calculation refers. Note: If a CAD model or a surface mesh is referenced, it should be a solid object with a closed surface.
Components... button	This button is enabled when you select an object with components as reference object. Clicking it opens a dialog box where you can specify the components to be used as reference for the distance-to-surface calculation: • Checkbox of component: Clicking it checks/unchecks the component, including all child components. • **Select all** button: Selects all components of the object. • **Deselect all** button: Deselects all components of the object. • **Apply visibility** button: Selects all components which are set to visible in the Scene Tree.

Wall thickness evaluation *section*

This option allows you to use an existing wall thickness analysis for combined analysis: The detected indications will then not only be analyzed with respect to their size but also with respect to their relative size referring to the smallest local wall thickness.

Performing a wall thickness analysis may require additional licensing. Contact us for details.

Table 25-14: Controls of the **Wall thickness evaluation** section

Control	Description
Wall thickness evaluation checkbox	Enables a drop-down list where you can select a wall thickness analysis for combined analysis.

Local averaging section

This section allows you to calculate the average porosity:

- **Local porosity**: at a specific location
- **Directional variability**: per slice in a defined direction

- **Integration mesh**: within each individual cell of an integration mesh

Local porosity *section*

Table 25-15: Controls in the **Local porosity** section

Control	Description
Local porosity checkbox	Enables the corresponding controls for calculating areas of particularly high porosity.
Smoothing window size spin box	Specifies the radius of the window that is considered at each location within the object. This window is Gaussian weighted. The **Smoothing window size** corresponds to the sigma (σ) of the Gaussian distribution.
Hot spot threshold [<ratio unit>] spin box	Specifies a threshold to be applied to the porosity of the analyzed areas. The areas where the porosity is larger than the threshold will be regarded as hot spots.

Directional variability *section*

Allows you to calculate the per-slice porosity in a defined direction.

Table 25-16: Controls of the **Directional variability** section

Control	Description
Directional variability checkbox	Enables the corresponding controls for calculating the porosity per slice in a defined direction.
Direction fields	Specify the direction (in the currently selected coordinate system) in which the porosity is to be analyzed. The specified vector is normalized to unit length before it is taken into account in the calculation. When you change the coordinate system, the specified vector will automatically be recalculated accordingly.
Choose... button	Opens a drop-down list that shows the windows currently available in the workspace for specifying the direction in which the analysis is to be performed. The direction is the normal of the selected 2D window or the current direction of view of the 3D window.
Slice thickness spin boxes	Specify the thickness (in physical units (e.g., mm) or voxels) of the individual slices to be analyzed.

Integration mesh *section*

Allows you to calculate the porosity within each individual cell of an integration mesh.

Table 25-17: Controls of the **Integration mesh** section

Control	Description
Integration mesh checkbox	Enables the corresponding controls for using an integration mesh.
Integration mesh drop-down list	Allows you to select an existing integration mesh.
Create… button	Creates an integration mesh and opens the **Mesh** dialog for specifying the mesh parameters.

Preview panel

The preview panel allows you to easily configure the analysis and instantly view the analysis results.

Unlike the standard workspace, in which you can see the 2D windows and the 3D window, the preview panel always shows one view.

If you want to use the standard window layout instead of the preview panel, you can either hide the preview panel by clicking the **Hide preview panel** button or minimize it.

Table 25-18: Controls of the preview panel

Icon	Item	Description
	Show preview panel/Hide preview panel button	Shows/hides the preview panel.
	Slider	Allows you to scroll through the slices of the selected view.
	Show visualization options button	• Allows you to visualize the analysis area, indications, ROIs, and crosshairs. • Double-clicking the color squares allows you to change the default color of the respective items. • button: Resets all visualization options to default. • **Interpolate gray values** checkbox: When this option is checked, the gray values between the voxels will be interpolated, thus providing “soft” transitions between neighboring voxels. When this option is unchecked, the individual voxels will be clearly discernible.
	Show minimap button	Opens a minimap that serves as an interactive orientation helping you to identify the preview's location within the object. You can also use the minimap to move your preview by dragging the line or box.

Icon	Item	Description
	+Z/**-Y**/**+X** views	Show the respective view of the object in the preview with respect to the coordinate system axis. The coordinate system selected in the main window will always be used.
	Fit to window button	Resets the zoom so that the image fits into the window.
	Reset view button	Moves the preview to the center plane.

Summary panel

When the analysis has been calculated, the preview panel will close and the summary panel will open.

The **Summary of results** section in the summary panel provides you with an overview of the most important analysis results:

- **Tolerance status**
- **Maximum diameter**
- **Porosity**
- **Indication count**

Table 25-19: Controls of the summary panel

Icon	Item	Description
	Show summary panel/**Hide summary panel** button	Shows/hides the summary panel.
	Show results button	Redirects you to the **Indications** tab of the **Results** page.

Tolerances page

Allows you to specify tolerances.

Tolerances tab

- **Global tolerances** section

Table 25-20: Controls of the **Global tolerances** section

Control	Description
Porosity [<ratio unit>] field	Specifies the maximum permissible ratio between the total indication volume and the total material volume.
Indication count field	Specifies the maximum permissible number of pores.
Total indication volume [<length unit³>] field	Specifies the maximum permissible volume of indications.
Directional variability (Porosity) [<ratio unit>] field	Specifies the maximum porosity with respect to the direction specified in the **Direction** fields of the **Directional variability** section on the **Additional features** tab of the **Settings** page.

- **Indication tolerances** section

Table 25-21: Controls of the **Indication tolerances** section

Control	Description
Diameter [<length unit>] field	Specifies the maximum permissible diameter of an indication.
Equivalent diameter [<length unit>] field	Specifies the diameter of a sphere with the same maximum permissible volume as the indication.
Volume [<length unit>³] field	Specifies the maximum permissible volume of an individual indication.
Projected area (yz-plane)/(xz-plane)/ (xy-plane) [<length unit>²] fields	Specifies the maximum permissible projected surface of an indication.
Cut surface [<length unit>²] field	Specifies the maximum permissible surface area where the indication intersects the surface of the object selected from the **Distance to surface** drop-down list on the **Additional features** tab.
Max. distance to surface (cut) [<length unit>] field	For an indication classified as **Cut**: Specifies the maximum permissible maximum distance between the surface of the indication in the material and the surface of the object selected from the **Distance to surface** drop-down list on the **Additional features** tab.
Min. distance to surface (inside) [<length unit>] field	For an indication classified as **Inside**: Specifies the minimum permissible minimum distance between the surface of the indication and the surface of the object selected from the **Distance to surface** drop-down list on the **Additional features** tab.

Control	Description
Min. distance to surface (outside) [<length unit>] field	For an indication classified as **Outside**: Specifies the minimum permissible minimum distance between the surface of the indication and the surface of the object selected from the **Distance to surface** drop-down list on the **Additional features** tab.
Gap (voxel) [<length unit>] field	Specifies the minimum permissible distance between the surfaces of two indications.

Visuals page

Allows you to specify the visualization settings.

Indication visualization tab

Visualization options section

- **Visualized property** drop-down list (if available)

  Allows you to select the property of the indication that is to be shown according to the color-coding settings.

  The visualized property selected by default is **Diameter**: The indications will be color-coded according to their diameter as defined by the color lookup table and the colors specified in the **Sections** section of the **Indication visualization** tab.

  You can also select the visualized property on the **Indications** tab of the **Results** page by right-clicking the column and choosing the **Set as visualized property** item from the context menu.
- **Share color bar** checkbox

  When checked, the color bar settings will apply to all analyses of the same type. When unchecked, the color bar settings will apply to the selected analysis only.
- **LUT** – Color Lookup Table

  The color lookup table (LUT) shows the partitioning into color sections.
- **Sections** section

  Defines the appearance of each color section.

Table 25-22: Controls in the **Sections** section

Control	Description
From/To fields	Specify the start and end values of the color sections. The first color section represents all values above the upper limit, i.e., the value in the **From** field (**+inf** signifies positive infinity), while the last color section represents all values below the lower limit, i.e., the value in the **To** field (**-inf** signifies negative infinity). The default limits are calculated from the results of the analysis (for an analysis color bar) or taken from the **Default** preset (for a tolerance deviation color bar).
Type field	Switches between the color schemes **Continue**, **Constant**, **Gradient**, **Rainbow**, **Reverse rainbow**, **Hue cycle**, **Green to red**, and **Red to green**.
Color/transparency field	Double-clicking the field for the **Continue**, **Constant**, and **Gradient** color schemes opens the **Select Color** dialog where you can modify the appearance of the selected color scheme. For the **Gradient** color scheme, you can specify the start and end colors by double-clicking the left or right side of the field, respectively. Double-clicking the field for the **Rainbow**, **Reverse rainbow**, **Green to red**, **Red to green**, and **Hue cycle** color schemes opens the **Transparency** dialog, where you can set the transparency for the selected color scheme.
use RMB to click a color section	Opens a context menu with the following items: • **Split**: Subdivides the color section into two new color sections where each represents half of the original section. • **Merge**: Combines several color sections to a single color section. Only consecutive intervals can be merged.
Create smooth button	Opens the **Create smooth table** dialog to generate one color section. • **Type** drop-down list: Allows you to select the type of coloring scheme. • **From/To** spin boxes: Specify the value range covered by the color section.

Control	Description
Create stepped button	Opens the **Create stepped table** dialog to generate a set of color sections. • **Type** drop-down list: Allows you to select the type of coloring scheme. • **From/To** spin boxes: Specify the value range covered by the color sections. • **Step** spin box: Specifies the step size of the individual color sections.
Auto scale button	Fits the color LUT to the range of the results of all available analyses. For example, if you have a minimal porosity of 2% and maximal porosity of 10%, these values will be your minimum and maximum on your color LUT. The gradient changing from green to red will be used. Note that if you load an old project, you may have to manually click the **Auto scale** button to rescale the color LUT, because the relevant settings in the old project remain unchanged in the current version.

Settings side panel

Color bar settings *section*

Table 25-23: Controls of the **Color bar settings** section

Control	Description
Show color bar toggle button	Shows/hides the color bar.
Positioning drop-down list	Specifies the location of the color bar within the 2D and 3D windows: **Left, Right, Top, Bottom, All - automatic, Left or right - automatic, Top or bottom - automatic**
Caption field	Specifies the color bar headline by using placeholders.
button	Resets the **Caption** field to the default entry.
Auto scale color bar range on calculate checkbox	Fits the color LUT automatically to the range of the results of all available analyses. The gradient changing from green to red will be used.

***Rendering settings** section*

Table 25-24: Controls of the **Rendering settings** section

Control	Description
Outline rendering checkbox	Shows the outline of the color-coded indications such that the indications will not be covered by the color-coding.
Uncoded indications color field	Depending on the analysis type, this option is only available when **Uncoded** is selected from the **Visualized property** drop-down list. Double-clicking the color field opens the **Select Color** dialog, where you can set the color for the detected indications. All indications will be shown in this color.

Porosity visualization tab

Visualization options section

- **Visualized property** drop-down list (if available)

  Allows you to select the property of the indication that is to be shown according to the color-coding settings.

  The visualized property selected by default is **Diameter**: The indications will be color-coded according to their diameter as defined by the color lookup table and the colors specified in the **Sections** section of the **Indication visualization** tab.

  You can also select the visualized property on the **Indications** tab of the **Results** page by right-clicking the column and choosing the **Set as visualized property** item from the context menu.
- **Share color bar** checkbox

  When checked, the color bar settings will apply to all analyses of the same type. When unchecked, the color bar settings will apply to the selected analysis only.
- **LUT** – Color Lookup Table

  The color lookup table (LUT) shows the partitioning into color sections.
- **Sections** section

  Defines the appearance of each color section.

Table 25-25: Controls in the **Sections** section

Control	Description
From/To fields	Specify the start and end values of the color sections. The first color section represents all values above the upper limit, i.e., the value in the **From** field (**+inf** signifies positive infinity), while the last color section represents all values below the lower limit, i.e., the value in the **To** field (**-inf** signifies negative infinity). The default limits are calculated from the results of the analysis (for an analysis color bar) or taken from the **Default** preset (for a tolerance deviation color bar).
Type field	Switches between the color schemes **Continue**, **Constant**, **Gradient**, **Rainbow**, **Reverse rainbow**, **Hue cycle**, **Green to red**, and **Red to green**.
Color/transparency field	Double-clicking the field for the **Continue**, **Constant**, and **Gradient** color schemes opens the **Select Color** dialog where you can modify the appearance of the selected color scheme. For the **Gradient** color scheme, you can specify the start and end colors by double-clicking the left or right side of the field, respectively. Double-clicking the field for the **Rainbow**, **Reverse rainbow**, **Green to red**, **Red to green**, and **Hue cycle** color schemes opens the **Transparency** dialog, where you can set the transparency for the selected color scheme.
use RMB to click a color section	Opens a context menu with the following items: • **Split**: Subdivides the color section into two new color sections where each represents half of the original section. • **Merge**: Combines several color sections to a single color section. Only consecutive intervals can be merged.
Create smooth button	Opens the **Create smooth table** dialog to generate one color section. • **Type** drop-down list: Allows you to select the type of coloring scheme. • **From/To** spin boxes: Specify the value range covered by the color section.

Control	Description
Create stepped button	Opens the **Create stepped table** dialog to generate a set of color sections. • **Type** drop-down list: Allows you to select the type of coloring scheme. • **From/To** spin boxes: Specify the value range covered by the color sections. • **Step** spin box: Specifies the step size of the individual color sections.
Auto scale button	Fits the color LUT to the range of the results of all available analyses. For example, if you have a minimal porosity of 2% and maximal porosity of 10%, these values will be your minimum and maximum on your color LUT. The gradient changing from green to red will be used. Note that if you load an old project, you may have to manually click the **Auto scale** button to rescale the color LUT, because the relevant settings in the old project remain unchanged in the current version.

Settings side panel

Color bar settings *section*

Table 25-26: Controls of the **Color bar settings** section

Control	Description
Show color bar toggle button	Shows/hides the color bar.
Positioning drop-down list	Specifies the location of the color bar within the 2D and 3D windows: **Left, Right, Top, Bottom, All - automatic, Left or right - automatic, Top or bottom - automatic**
Caption field	Specifies the color bar headline by using placeholders.
button	Resets the **Caption** field to the default entry.
Auto scale color bar range on calculate checkbox	Fits the color LUT automatically to the range of the results of all available analyses. The gradient changing from green to red will be used.

Results page

Allows you to view the results.

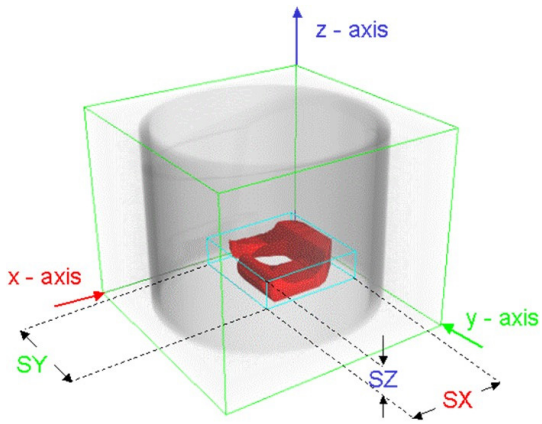
Indications tab

Lists all indications detected by the analysis.

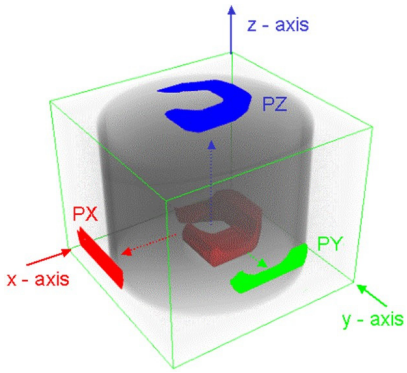
The **Indications** table consists of the following columns:

Table 25-27: Columns of the **Indications** table

Column	Description
Probability	Indicates the probability that the discontinuity is an indication.
Radius [<length unit>]	Indicates the radius of the circumscribed sphere of the indication.
Diameter [<length unit>]	Indicates the diameter of the circumscribed sphere of the indication.
Equivalent diameter [<length unit>]	Indicates the diameter of a sphere that has the same volume as the indication.
Center x/y/z [<length unit>]	Indicates the center position of the circumscribed sphere of the indication.
Volume [<length unit>³]	Indicates the volume of the indication.
Voxel	Indicates the number of voxels the indication consists of.
Surface [<length unit>²]	Indicates the surface area of the indication.
Classification	Indicates the position of the indication relative to the object selected from the **Distance to surface** drop-down list on the **Additional features** tab: **Cut**, **Inside**, or **Outside**, or a combination of these classes.
Gap (sphere) [<length unit>]	Indicates the minimum distance between the surfaces of the circumscribed spheres of two indications. Note that this value may also be negative.
Gap (voxel) [<length unit>]	Indicates the minimum distance between two pores based on the actual voxel boundaries of the indications.
Compactness	Indicates the ratio between the volume of the indication and the volume of the circumscribed sphere. $$\text{Compactness} = \frac{V_{indication}}{V_{sphere}}$$
Sphericity	Indicates the ratio between the surface of a sphere with the same volume as the indication and the surface of the indication. $$\text{Sphericity} = \frac{A_{sphere}}{A_{indication}}$$

Column	Description
Pos. x/y/z [<length unit>]	Analysis mode **Void**: Indicates the position of the darkest voxel of the indication. Analysis mode **Inclusion**: Indicates the position of the brightest voxel of the indication.
Projected size x/y/z [<length unit>]	Indicates the size of the bounding box surrounding the indication in the scene coordinate system. See the following figure for an illustration:  Figure 25-1: Projected size
PCA deviation 1/2/3 [<length unit>]	Indicate the standard deviations along each of the three mutually orthogonal axes calculated, from a Principal Component Analysis (PCA), with **PCA deviation 1** corresponding to the standard deviation along the most pronounced axis of the indication. The standard deviations are the square root of the eigenvalues.
PCA max. deviation ratio [<ratio unit>]	Indicates the ratio between **PCA deviation 1** and the radius of the circumscribed sphere of the indication. $\text{Max. relative PCA deviation} = \frac{\text{PCA deviation 1}}{r_{sphere}}$
PCA min. deviation ratio [<ratio unit>]	Indicates the ratio between **PCA deviation 3** and the radius of the circumscribed sphere of the indication. $\text{Min. relative PCA deviation} = \frac{\text{PCA deviation 3}}{r_{sphere}}$
Min. gray value	Indicates the minimum gray value within the indication.
Max. gray value	Indicates the maximum gray value within the indication.
Mean gray value	Indicates the mean gray value within the indication.
Deviation of gray values	Indicates the standard deviation of the gray values within the indication.
Label	Indicates the consecutive number of the indication.

Column	Description
Min. thickness [<length unit>]	Indicates the minimum wall thickness within the region of the indication.
Max. thickness [<length unit>]	Indicates the maximum wall thickness within the region of the indication.
Mean thickness [<length unit>]	Indicates the mean wall thickness within the region of the indication.
Relative diameter	Indicates a measurement for the diameter of the circumscribed sphere of the indication with respect to the minimum wall thickness within the region of the indication. $$\text{Relative diameter} = \frac{Ø_{sphere}}{t_{min}}$$
Cut surface [<length unit>²]	Indicates the surface area where the indication intersects the surface of the object selected from the **Distance to surface** drop-down list on the **Additional features** tab of the **Settings** page.
Distance to surface [<length unit>]	Indicates the closest distance of an indication to the surface of the object selected from the **Distance to surface** drop-down list on the **Additional features** tab of the **Settings** page.
Min. distance to surface (inside) [<length unit>]	For an indication classified as **Inside**: Indicates the smallest distance between the surface of the indication and the surface of the object selected from the **Distance to surface** drop-down list on the **Additional features** tab of the **Settings** page.
Min. distance to surface (outside) [<length unit>]	For an indication classified as **Outside**: Indicates the smallest distance between the surface of the indication and the surface of the object selected from the **Distance to surface** drop-down list on the **Additional features** tab of the **Settings** page.
Max. distance to surface (cut) [<length unit>]	For an indication classified as **Cut**: Indicates the largest distance between the surface of the indication in the material and the surface of the object selected from the **Distance to surface** drop-down list on the **Additional features** tab of the **Settings** page.

Column	Description
Projected area (yz-plane)/(xz-plane)/ (xy-plane) [<length unit>²]	Indicates the surface area of the indication shape projected along each of the axes of the scene coordinate system. See the following figure for an illustration:  Figure 25-2: Projected area
Description	Allows you to enter a description for the component used for reporting.
Tolerance status	Indicates the tolerance status of the indication depending on the tolerances specified for the indications on the **Tolerances** tab: **Valid** (green), **Out of tolerance** (red), or **No tolerance** (white).

If a column shows a parameter for which a tolerance has been specified (see chapter 25 *Tolerances tab* on page 309), each entry will be evaluated separately according to the specified tolerance and highlighted in the following colors:

- Green: The tolerance is met.
- Red: The tolerance is not met.

Statistics tab

Displays the global results of the analysis.

- **Material** section

  Table 25-28: Controls of the **Material** section

Control	Description
Porosity or inclusion percentage [<ratio unit>] field	Indicates the total volume of all voids or inclusions in relation to the **Material volume** plus the **Total indication volume**.
Indication count	Indicates the total number of voids or inclusions found.
Total indication volume [<length unit>³] field	Indicates the total volume of all voids or inclusions.

Control	Description
Material volume [<length unit>³] field	Indicates the volume enclosed by the determined surface minus the volume of the voids or inclusions inside this volume.

Some indications may cover a region that includes a determined surface (see figure below). If you remove such an indication from the indication table, the decrease in indication volume and the increase in material volume will not correspond with each other. While the complete indication volume will be subtracted from **Total indication volume**, only the volume of the indication that lies within the determined surface will be added to **Material volume**.

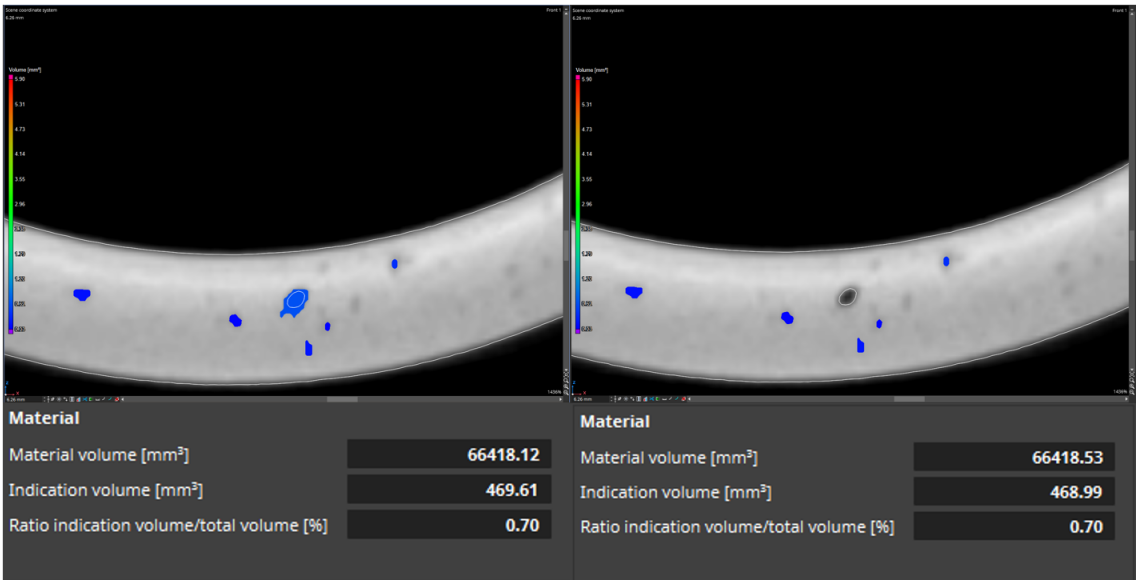


Figure 25-3: Left: initial situation; right: indication removed

- **Voids/Inclusions** section

  Table 25-29: Controls of the **Voids/Inclusions** section

Control	Description
Σ **Voxel**	Indicates the total number of voxels in all voids/inclusions.
Σ **Volume [<length unit>³]**	Indicates the total volume of all voids/inclusions.
Σ **Surface [<length unit>²]**	Indicates the total surface of all voids/inclusions.
Σ **Proj. area (yz)/(xz)/(xy) [<length unit>²]**	Indicates the total surface of all projected voids/inclusions. The projection of the indications refers to the scene coordinate system.

Histogram tab

Shows a histogram of the indication distribution according to the selected **Visualized property**. The histogram bars are colored according to the settings in the **Visualization options** section on the **Visuals** page.

Configure side panel

- **Visualized property** drop-down list

  Allows you to select the property of the indication that is to be shown according to the settings on the **Visuals** page.
- **Options** section

  Table 25-30: Controls of the **Options** section

Control	Description
Color drop-down list	• **From color bar**: The values in the histogram are shown according to the color bar. • **Gray**: All values in the histogram are shown in gray.
Ordinate scale drop-down list	• **Linear**: Applies a linear scale to the y-axis of the histogram. • **Logarithmic**: Applies a logarithmic scale to the y-axis of the histogram.
Binning drop-down list	• **Off**: No binning is applied to the values shown in the histogram. • **From color bar**: The original values in the histogram are replaced by a value representative for the corresponding interval (“bin”) of the color bar. The “bins” become visible when “stepped” sections on the **Colors** tab are created. • **Manual number of bins**: Enables the **Bin count** spin box, where you can enter the required number of “bins.” • **Manual bin width**: Enables the **Bin width** spin box, where you can specify the width of the bins.

- **Intervals** section

  Table 25-31: Controls of the **Intervals** section

Control	Description
Left/**Right** spin box	Only enabled when an interval has been created: Moves the left or right interval border to the specified value. You can also click and drag the interval borders by using the left mouse button.

Control	Description
Create button	Creates a new interval. On the right-hand side of a selected interval, statistical information is displayed: • **Left**: Indicates the minimum value of the parameter selected as **Visualized property** on the **Visuals** page within the interval, i.e., the left interval border. • **Right**: Indicates the maximum value of the parameter selected as **Visualized property** on the **Visuals** page within the interval, i.e., the right interval border. • **Mean**: Indicates the mean value of the parameter selected as **Visualized property** on the **Visuals** page within the interval. • **Dev**: Indicates the standard deviation of the values of the parameter selected as **Visualized property** on the **Visuals** page within the interval. • **Sum:** Indicates the number of indications within the interval. • **Percentage**: Indicates the percentage of the parameter selected as **Visualized property** on the **Visuals** page within the interval. Note that the statistical information may change with the number of bins specified in the **Options** section.
Remove button	Removes the selected interval.

Controls of the **Histogram** Tab

Table 25-32: General controls of the **Histogram** tab

Control	Description
use RMB to click the chart area	Displays a context menu (see below).
scroll MW in chart area or x-axis up/down	Zooms the x-axis of the chart out/in.
scroll MW in y-axis up/down	Zooms the y-axis of the chart out/in.
use LMB to click and drag the x-axis	Scrolls the x-axis.
use LMB to click and drag the y-axis	Scrolls the y-axis.
Reset zoom	Fits the entire chart to the current window size.

Context menu of the **Histogram** tab

Right-clicking anywhere in the chart area opens a context menu with the following options:

Table 25-33: Context menu items

Control	Description
Export as CSV...	Opens a dialog for saving the chart values to a *.csv* file.
Copy to clipboard	Copies a screenshot of the chart to the system clipboard so that you can paste it into another application.
Show/Hide x/y grid	Toggles the visibility of the grid lines for the corresponding axis.
Reset zoom	Fits the entire chart to the current window size.
Create interval	Creates a new interval.
Remove interval	Removes the selected interval.

Directional variability plot tab

This curve shows how the porosity changes with respect to the direction specified in the **Directional variability** section on the **Additional features** tab of the **Settings** page. If a tolerance has been specified for the directional variability, the tolerance status will be indicated by a horizontal line. A red line indicates that the porosity of at least one slice exceeds the specified tolerance. A green line indicates that the porosity of all slices is within the specified tolerance. You can use the **Directional variability** curve to answer questions such as “How high is the porosity at a specific slice position?”

Table 25-34: Controls of the **Directional variability plot** tab

Control	Description
hover the mouse pointer over the curve	Displays the legend of the function as well as its values at the specified location.
use LMB to click and drag the vertical line in the histogram	Indicates the function values at the specified location and updates the slice views accordingly. Hold down the **Ctrl** key while left-clicking in the chart area to display the vertical line in case you dragged it out of the chart area.
use RMB to click the chart area	Displays a context menu, see below.
scroll MW in chart area or x-axis up/down	Zooms the x-axis of the chart out/in.
scroll MW in y-axis up/down	Zooms the y-axis of the chart out/in.
use LMB to click and drag the x-axis	Scrolls the x-axis.
use LMB to click and drag the y-axis	Scrolls the y-axis.

Right-clicking anywhere in the chart area shows a context menu with the following options:

Table 25-35: Context menu items

Control	Description
Export as CSV...	Opens a dialog for saving the chart values to a *.csv* file.
Copy to clipboard	Copies a screenshot of the chart to the system clipboard so you can paste it in another application.
Show/Hide x/y grid	Toggles the visibility of the grid lines for the corresponding axis.
Reset zoom	Fits the entire chart to the current window size.
Show/Hide legend	Displays or hides the legend for the plotted curves.

Directional variability values tab

Lists the individual slices that have been analyzed including their positions, the calculated values, and the tolerance states.

The **Directional variability values** tab is available only if the **Directional variability** option has been checked (**Settings > Additional features > Directional variability**).

Table 25-36: Controls of the **Directional variability values** tab

Control	Description
Slice center x/y/z [<length unit>]	Indicates the x-, y-, and z-coordinates of the center of the slice.
Directional variability (Porosity) [<ratio unit>]	Indicates the porosity with respect to the direction specified in the **Directional variability** section on the **Additional features** tab of the **Settings** page.
Description	Allows you to enter a description for the slice used for reporting.
Image	Allows you to add a detailed 2D image and object description on a separate page of the report. • **Off**: No image is created (default). • **On**: Creates a 2D view in the direction specified in the **Directional variability** section on the **Additional features** tab of the **Settings** page. The image will be generated according to the render settings specified during report creation or VGRF-based export. The zoom factor of the image is chosen so that the entire parent volume is visible.
Focused image	This option is almost identical to the **Image** option but will generate an image that focuses on the respective item and is zoomed in by the **Zoom factor** specified during report creation or VGRF-based export.

Control	Description
Tolerance status	Indicates the tolerance status of the slice depending on the tolerances specified for the slices on the **Tolerances** tab: **Valid** (green), **Out of tolerance** (red), or **No tolerance** (white).

If a column shows a parameter for which a tolerance has been specified (see section *Tolerances tab* on page 309), each entry will be evaluated separately according to the specified tolerance and highlighted in the following colors:

- Green: The tolerance is met.
- Red: The tolerance is not met.

Hot spots of porosity tab

Displays the hot spots resulting from the local porosity calculation.

The **Hot spots of porosity** tab is available only if the **Local porosity** option has been checked (**Settings > Additional features > Local porosity**).

Table 25-37: Columns of the **Hot spots of porosity** table

Column	Description
Position x/y/z [<length unit>]	Indicates the x-, y-, and z-position of the hot spot.
Volume [<length unit>³]	Indicates the volume of the hot spot.
Surface [<length unit>²]	Indicates the surface area of the hot spot.
Mean porosity [<ratio unit>]	Indicates the mean porosity value of the hot spot.
Porosity deviation [<ratio unit>]	Indicates the standard deviation of the porosity value of the hot spot.
Maximum porosity [<ratio unit>]	Indicates the maximum porosity within the hot spot.
Description	Allows you to enter a description for the hot spot used for reporting.

Column	Description
Image	Allows you to add a detailed 2D image and object description on a separate page of the report. • **Off**: No image is created (default). • **Orthographic projection**: Creates three orthogonal views. • **Top/Bottom/Left/Right/Front/Back**: Creates a single 2D view in the specified orientation. The image orientation is relative to the currently selected coordinate system. The image will be generated according to the render settings specified during report creation or VGRF-based export. The 2D slice position used for taking the image is determined by the position of the hot spot. The zoom factor of the image is chosen so that the entire parent volume is visible.
Focused image	This option is almost identical to the **Image** option but will generate an image that focuses on the respective item and is zoomed in by the **Zoom factor** specified during report creation or VGRF-based export.

Mesh cells tab

Displays the results of the porosity/inclusion analysis for each cell of the integration mesh.

The **Mesh cells** tab is available only if an integration mesh has been specified (**Settings > Additional features > Integration mesh**).

You can export the results from the **Mesh cells** tab and use them for comparing real part properties with simulations of manufacturing processes or improving FE simulations for testing the stability of objects (e.g., of injection-molded parts).

Table 25-38: Columns of the **Mesh cells** table

Column	Description
Element ID	If available, indicates the ID of the mesh cell for imported integration mesh files.
Position x/y/z [<length unit>]	Indicates the x-, y-, and z-position of the mesh cell.
Porosity [<ratio unit>]	Indicates the porosity within the mesh cell.
Description	Allows you to enter a description for the cell used for reporting.

Column	Description
Image	Allows you to add a detailed 2D image and object description on a separate page of the report. • **Off**: No image is created (default). • **Orthographic projection**: Creates three orthogonal views. • **Top/Bottom/Left/Right/Front/Back**: Creates a single 2D view in the specified orientation. The image orientation is relative to the currently selected coordinate system. The image will be generated according to the render settings specified during report creation or VGRF-based export. The 2D slice position used for taking the image is determined by the position of the cell. The zoom factor of the image is chosen so that the entire parent volume is visible.
Focused image	This option is almost identical to the **Image** option but will generate an image that focuses on the respective item and is zoomed in by the **Zoom factor** specified during report creation or VGRF-based export.

Annotations page

Allows you to inspect analysis results at specific locations by creating annotations.

For details on how to create an annotation, see section *Annotation* on page 124 in chapter 6 *Inspect Tab*.

Annotations tab

Lists all annotations created for the selected analysis. You can view the information supplied by the annotations or edit the annotation properties.

To create new annotations in the table, it is also possible to paste previously copied coordinates by right-clicking the table and selecting **Paste** from the context menu or by pressing the **Ctrl** + **V** keyboard shortcut. For details, see the **Paste** menu item in section *Table context menu*.

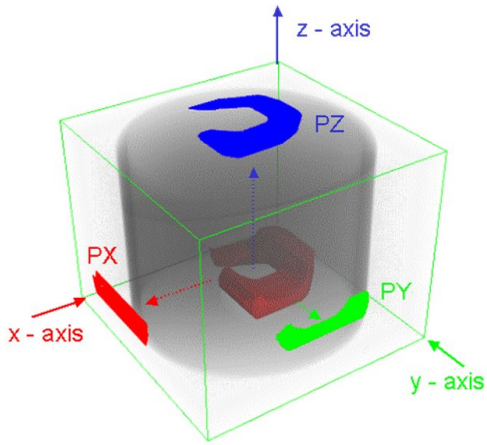
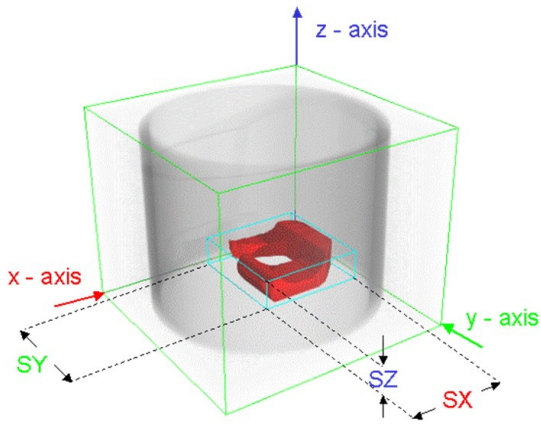
Double-clicking an analysis annotation in the Scene Tree will directly open the **Annotations** tab.

Tolerance values will be interpreted according to DIN EN ISO 8015 (see also section *Rounding Rules* on page 4 in chapter 1 *Welcome*).

The **Annotations** table consists of the following columns:

Table 25-39: Columns of the **Annotations** table

Column	Description
Name	Indicates the name of the annotation.
Pos. x/y/z [<length unit>]	Indicates the position of the annotation.
Probability	Indicates the probability that the discontinuity is an indication.
Volume [<length unit>³]	Indicates the volume of the indication at the current annotation position.
Radius [<length unit>]	Indicates the radius of the circumscribed sphere of the indication.
Diameter [<length unit>]	Indicates the diameter of the circumscribed sphere of the indication.
Equivalent diameter [<length unit>]	Indicates the diameter of a sphere that has the same volume as the indication.
Classification	Indicates the position of the indication relative to the object selected from the **Distance to surface** drop-down list on the **Additional features** tab of the **Settings** page: **Inside**, **Outside**, **Cut**, or a combination of these classes.
Min. distance to surface (inside) [<length unit>]	For an indication classified as **Inside**: Indicates the smallest distance between the surface of the indication and the surface of the object selected from the **Distance to surface** drop-down list on the **Additional features** tab of the **Settings** page.
Min. distance to surface (outside) [<length unit>]	For an indication classified as **Outside**: Indicates the smallest distance between the surface of the indication and the surface of the object selected from the **Distance to surface** drop-down list on the **Additional features** tab of the **Settings** page.
Max. distance to surface (cut) [<length unit>]	For an indication classified as **Cut**: Indicates the largest distance between the surface of the indication and the surface of the object selected from the **Distance to surface** drop-down list on the **Additional features** tab of the **Settings** page.
Cut surface [<length unit>²]	Indicates the surface area where the indication intersects the surface of the object selected from the **Distance to surface** drop-down list on the **Additional features** tab of the **Settings** page.
Gap (sphere) [<length unit>]	Indicates the minimum distance between the surfaces of the circumscribed spheres of two indications. Note that this value may also be negative.

Column	Description
Gap (voxel) [<length unit>]	Indicates the minimum distance between two pores based on the actual voxel boundaries of the indications.
Projected area x/y/z [<length unit>²]	The surface area of the indication shape projected along each of the axes of the scene coordinate system. See the following figure for an illustration:  Figure 25-4: Projected area
Projected size x/y/z [<length unit>]	Indicates the size of the bounding box surrounding the indication in the scene coordinate system. See the following figure for an illustration:  Figure 25-5: Projected size
Surface [<length unit>²]	Indicates the surface area of the indication.
Compactness	Indicates the ratio between the volume of the indication and the volume of the circumscribed sphere. $\text{Compactness} = \frac{V_{indication}}{V_{sphere}}$

Column	Description
Sphericity	Indicates the ratio between the surface of a sphere with the same volume as the indication and the surface of the indication. $$\text{Sphericity} = \frac{A_{sphere}}{A_{indication}}$$
Min. gray value	Indicates the minimum gray value within the indication.
Max. gray value	Indicates the maximum gray value within the indication.
Mean gray value	Indicates the mean gray value within the indication.
Deviation of gray values	Indicates the standard deviation of the gray values within the indication.
PCA deviation 1/2/3 [<length unit>]	Indicate the standard deviations along each of the three mutually orthogonal axes calculated from a Principal Component Analysis (PCA), with **PCA deviation 1** corresponding to the standard deviation along the most pronounced axis of the indication. The standard deviations are the square root of the eigenvalues.
PCA min. deviation ratio [<ratio unit>]	A measure for the ratio between **PCA deviation 3** and the radius of the circumscribed sphere of the indication. $$\text{Min. relative PCA deviation} = \frac{\text{PCA deviation 3}}{r_{sphere}}$$
PCA max. deviation ratio [<ratio unit>]	A measure for the ratio between **PCA deviation 1** and the radius of the circumscribed sphere of the indication. $$\text{Max. relative PCA deviation} = \frac{\text{PCA deviation 1}}{r_{sphere}}$$
Min. thickness [<length unit>]	Indicates the minimum wall thickness within the indication.
Max. thickness [<length unit>]	Indicates the maximum wall thickness within the indication.
Mean thickness [<length unit>]	Indicates the mean wall thickness within the indication.
Relative diameter [<ratio unit>]	Indicates a measure for the diameter of the circumscribed sphere of the indication with respect to the minimum wall thickness covered by the indication. $$\text{Relative diameter} = \frac{\varnothing_{sphere}}{t_{min}}$$
Porosity [<ratio unit>]	Indicates the porosity in percent at the current annotation position.
Nom. porosity [<ratio unit>]	Allows you to specify the nominal value for tolerancing the porosity at the current annotation position. Double-click the cell to edit it.

Column	Description
Min. porosity [<ratio unit>]	Allows you to specify the minimum value for tolerancing the porosity at the current annotation position. Double-click the cell to edit it. If the value for **Nom. porosity** is specified, **Min. porosity** will refer to this value. If the value for **Nom. porosity** is not specified, the value for **Min. porosity** will be considered as an absolute value.
Max. porosity [<ratio unit>]	Allows you to specify the maximum value for tolerancing the porosity at the current annotation position. Double-click the cell to edit it. If the value for **Nom. porosity** is specified, **Max. porosity** will refer to this value. If the value for **Nom. porosity** is not specified, the value for **Max. porosity** will be considered as an absolute value.
Description	Allows you to enter a description of the annotation used for reporting.
Image	Allows you to add a detailed 2D image and object description on a separate page of the report. • **Off**: No image is created (default). • **Orthographic projection**: Creates three orthogonal views. • **Top/Bottom/Left/Right/Front/Back**: Creates a single 2D view in the specified orientation. • **... - If not OK**: Automatically creates the image if the tolerance status is **Out of tolerance**. The image orientation corresponds to the currently selected coordinate system. The image will be generated according to the render settings specified during report creation or VGRF-based export. The 2D slice position used for taking the image is determined by the position of the indication. The zoom factor of the image is selected so that the entire parent volume is visible.
Focused image	This option is almost identical to the **Image** option but will generate an image that focuses on the respective item and is zoomed in by the **Zoom factor** specified during report creation or VGRF-based export.
Captures	Indicates the number of images captured for this object using the **Capture from** button in the **Screenshots** section.
Tolerance status	Indicates the tolerance status of the indication depending on the tolerances specified for the indications on the **Tolerances** tab: **Valid** (green), **Out of tolerance** (red), or **No tolerance** (white).

Column	Description
Type	Indicates how the annotation has been created: • **Rule based**: The annotation has been created by a report rule. • **Manually defined**: The annotation has been defined by the user.

If a column shows a parameter for which a tolerance has been specified (see section *Tolerances tab* on page 309), each entry will be evaluated separately according to the specified tolerance and highlighted in the following colors:

- Green: The tolerance is met.
- Red: The tolerance is not met.

Rules tab

Shows the existing rules for selecting features (e.g., probability, diameter) with defined properties to be included in the final report.

With the default rule **Big five**, images of the five indications with the largest diameters will automatically be created and included in your standard report.

The following buttons are available at the bottom of the **Rules** tab:

Table 25-40: Controls of the **Rules** tab

Icon	Control	Description
	New rule button	Opens the **New rule** section which allows you to create a new rule.
	Edit rule button	Opens the **Edit rule** section which allows you to edit an existing rule
	Delete rule button	Deletes the selected rule from the table.

New rule/**Edit rule** section

Allows you to define or edit a new rule for annotations.

- **Name** input field

  Allows you to enter a name for the new rule. This name has to be unique.
- **Condition** section

  Table 25-41: Controls in the **Condition** section

Control	Description
Column drop-down list	Selects the property of the feature (e.g., probability, radius, diameter) that defines the rule.
Comparator drop-down list	Specifies the comparator to be applied to the selected property.

Control	Description
Value [<unit>] spin box or drop-down list	Specifies the reference value or status of the selected property for comparison.
Result count field	Indicates the number of results that meet the specified condition.

- **Annotation settings** section

  Table 25-42: Controls in the **Annotation settings** section

Control	Description
Name template field	Allows you to enter a name for the annotations. If this is not done, a name of the form *<annotation type>* *<id>* will automatically be generated.
Image drop-down list	Allows you to add a detailed 2D image and object description on a separate page of the report. • **Off**: No image is created (default). • **Orthographic projection**: Creates three orthogonal views. • **Top/Bottom/Left/Right/Front/Back**: Creates a single 2D view in the specified orientation. • If applicable: **... - If not OK**: Automatically creates the image if the tolerance status is **Out of tolerance**.
Focused image drop-down list	This option is almost identical to the **Image** option but will generate an image that focuses on the respective item and is zoomed in by the **Zoom factor** specified during report creation or VGRF-based export.
Max. annotations checkbox and spin box	Allows you to specify the maximum number of annotations that will be generated.

In contrast to manually created annotations, rule-based annotations can neither be moved nor deleted. This is indicated by a closed padlock symbol next to the annotation name in the annotation label.

- **Create** button

  Creates the new rule, adds it to the list in the **Rules** tab and updates the annotations.
- **Cancel** button

  Discards the settings and closes the section.

Directional variability rules tab

Shows the existing rules for selecting porosities with defined directional variability or tolerance status to be included in the final report.

The following buttons are available at the bottom of the tab:

Table 25-43: Controls of the **Directional variability rules** tab

Icon	Control	Description
+	**New rule** button	Opens the **New rule** section which allows you to create a new rule.
	Edit rule button	Opens the **Edit rule** section which allows you to edit an existing rule
	Delete rule button	Deletes the selected rule from the table.

New rule/**Edit rule** section

- **Name** input field
  Allows you to enter a name for the new rule. This name has to be unique.
- **Condition** section

  Table 25-44: Controls in the **Condition** section

Control	Description
Column drop-down list	Selects the property of the feature (**Directional variability (Porosity)**, **Tolerance status**) that defines the rule.
Comparator drop-down list	Specifies the comparator to be applied to the selected property.
Value [<unit>] spin box or drop-down list	Specifies the reference value or status of the selected property for comparison.
Result count field	Indicates the number of results that meet the specified condition.

- **Create images** section

  Table 25-45: Controls in the **Create images** section

Control	Description
Image drop-down list	Allows you to add a detailed 2D image and object description on a separate page of the report. • **Off**: No image is created (default). • **Orthographic projection**: Creates three orthogonal views. • **Top/Bottom/Left/Right/Front/Back**: Creates a single 2D view in the specified orientation. • If applicable: **... - If not OK**: Automatically creates the image if the tolerance status is **Out of tolerance**.
Focused image drop-down list	This option is almost identical to the **Image** option, but will generate an image that focuses on the respective item and is zoomed in by the **Zoom factor** specified during report creation or VGRF-based export.

Control	Description
Max. images checkbox and spin box	Allows you to specify the maximum number of images to be included in the report.

- **Apply** button

  Closes the dialog, adds the new rule to the list in the **Directional variability rules** tab, and updates the images.
- **Cancel** button

  Discards the settings and closes the section.

General Table Controls

- List section

  The following table provides an overview of the general controls available in the various list views:

  Table 25-46: Controls in the list section

Control	Description
button	Opens a submenu for selecting the filter/search mode.
Filter	Clicking the **Click to add a filter or search criterion** field to the right of the icon opens a series of drop-down lists from which you can select a table column, an operator, and—depending on the column—a value. If a column does not offer a value drop-down list, you can type in a value. When the selection is complete, the table shows the rows matching the filter criterion. Clicking the **+** button or the **Click to add a filter or search criterion** field allows you to specify more filter criteria. Clicking the **x** button removes the filter.

Control	Description
Search	Clicking the **Click to add a filter or search criterion** field to the right of the icon opens a series of drop-down lists from which you can select a table column, an operator, and—depending on the column—a value. If a column does not offer a value drop-down list, you can type in a value. When the selection is complete, the table rows matching the search criterion are highlighted. Clicking the **+** button or the **Click to add a filter or search criterion** field allows you to specify more search criteria. Pressing **F3** jumps to the next search result in the list. Clicking the **x** button removes the search.
Full-text filter	Entering a value or text string into the input field to the right of the icon filters the table accordingly and shows the rows that match the filter criterion.
Full-text search	Entering a value or text string into the input field to the right of the icon searches the table accordingly and highlights the rows that match the search criterion.
use LMB to click on a table row	Selects the row and the corresponding object in the Scene Tree. In analysis result lists, the result, e.g., the component, is marked by a cross-hairs cursor in each of the 2D views.
hold **Ctrl** key + use LMB to click on several table rows	Selects the rows and the corresponding objects in the Scene Tree.
hold **Shift** key + use LMB to click on two separate table rows	Selects the two rows, including all rows between the two as well as the corresponding objects in the Scene Tree.
hold **Shift** key + use up/down arrow keys	Selects the rows and the corresponding objects in the Scene Tree.
press **Ctrl+A**	Selects all table rows.
use up and down arrow keys	Steps up and down through the table rows.
use RMB to click into the table area	Displays a context menu. See below.
use LMB to click a column heading	Sorts the table according to the values of the column. Clicking subsequently toggles between ascending and descending.
use LMB to click and drag column heading to new position, then release LMB	Inserts the column at the new position.

Control	Description
use LMB to double-click cell highlighted in white (light theme) or medium gray (dark theme)	If applicable: Allows you to edit the contents of the cell.

- **Screenshots** section (if available)

  The **Screenshots** section below the list section allows you to capture images from one of the 2D windows, the 3D window, or the current window layout for the item currently selected in the table. Only available if exactly one row is selected.

  Table 25-47: Controls in the **Screenshots** section

Control	Description
Capture from button	Adds the image of the view selected from the drop-down list to the preview area above.
use LMB to click and drag one or more images, then release LMB	Moves the image(s) to the new position.
double-click the image	Opens the **Snapshot display** window showing the image: • **Zoom in**/**Zoom out** button: Zooms the image in/out. You can also move the mouse pointer in the image area and turn the mouse wheel. • **Fit to window** button: Resets the zoom so that the image fits into the window.
click the **<no description>** placeholder twice (first click to select, second click to enable renaming)	Allows you to label the image.
Delete selected button	Deletes the selected image from the preview area.

Table context menu

Right-clicking anywhere in the table area shows a context menu with the following options:

Table 25-48: Context menu items

Control	Description
Columns	Allows you to toggle the visibility of each column by checking/unchecking the respective item. • **Show all**: Checks all columns to set them to visible. • **Hide all**: Unchecks all columns to set them to invisible. • **Hide empty**: Unchecks all not editable columns which are empty or **n/a** to set them to invisible.

Control	Description
Trim columns	Resizes all columns to their smallest possible size.
Apply default column layout	Applies the default column layout previously saved by the user to the current table. If no default column layout has been saved, the original column layout will be applied.
Save as default column layout	Saves modifications applied to the table—e.g., the visibility of a column, the order in which the columns appear, the column width—as default column layout. This layout will be applied when you create a new project.
Apply original column layout	Restores the original table layout and discards any modifications applied by the user. The original table layout is predefined and cannot be modified by the user.
Remove entries	If applicable: Deletes the selected row(s) from the table.
Create annotations	If applicable: Creates annotations for the selected items.
Create annotations with images	If applicable: Allows you to add a detailed 2D image (**Image**, **Focused image**, or **Both**) and object description on a separate page of the report. • **Off**: No image is created. • **Orthographic projection**: Creates three orthogonal views. • **Top**/**Bottom**/**Left**/**Right**/**Front**/**Back**: Creates a single 2D view in the specified orientation. • If applicable: **... - If not OK**: Automatically creates the image if the tolerance status is **Out of tolerance**.
Export as CSV...	Opens the **Export as CSV...** dialog for exporting the table values as **.csv* file. This option always exports the complete table even if a filter was applied. In order to export only the filtered rows, press **Ctrl** + **A** to highlight all filtered rows and use the **Copy to clipboard** menu item.
Copy to clipboard	Copies the selected rows as well as the column heading into the system clipboard. The clipboard information is provided both as plain text and rich-text table, so when pasting into a rich-text-capable application like a word processor, you will see a proper table with cell borders and bold headings.

Control	Description
Paste	For annotation tables: Pastes previously copied coordinates and—optionally—snap directions to create new annotations in the table. For annotations of a nominal/actual comparison, the search distance specified on the **Settings** tab of the analysis will be considered. Note: Pasted annotations will be interpreted in the selected coordinate system at the time of pasting. The information in the clipboard must have the following structure: • x-, y-, and z-coordinate of the annotation or • x-, y-, and z-coordinate of the annotation as well as x-, y-, and z-component of the vector for the snap direction The parameters can be separated by space, tab, semicolon, or comma (if a comma is already used as a decimal mark or digit grouping symbol, the values must be enclosed in double quotation marks). Example: 8.89;25.82;-0.55;1;0;0 You can also copy the information directly from the cells of a spreadsheet. In order to paste the annotation information, you can also press the **Ctrl** + **V** keyboard shortcut.
Set as visualized property	If applicable: Makes the current column the visualized property, i.e., the results of this column are color-coded according to their values as defined by the color lookup table and the colors specified in the **Visualization options** section on the **Visuals** page.
Unset visualized property	If applicable: Deselects the currently visualized property and sets the **Visualized property** drop-down list on the **Indication visualization** tab to **Uncoded**, i.e., removes any color coding.

Tutorial button

Provides direct access to our tutorials on porosity/inclusion analysis on our website.

Porosity/Inclusion Analysis Module: P 203

Introduction

The **P 203 analysis** function is part of the **Porosity/Inclusion Analysis** module of VGSTUDIO MAX and is designed to analyze a volume object or specified freeform regions on a volume object for pores in 3D based on the BDG Reference Sheet P 203. It provides detailed analysis results with information on individual pores, individual regions of inspection, or porosity hot spots, as well as overall statistical information.

License Information

This module is an optional add-on module for VGSTUDIO MAX. It is not available for myVGL. However, if a project loaded in myVGL contains results obtained with this module, they can be viewed and reported in myVGL.

If you are interested in a more comprehensive functionality than the one offered by myVGL, you have the chance to evaluate VGSTUDIO MAX. You can request an evaluation license of VGSTUDIO MAX on our website:

https://volumegraphics.hexagon.com/en/products/evaluation

If you have further questions about our product portfolio, please contact us:

- For Europe, Middle East, and Africa:
  Write an e-mail to sales@volumegraphics.com or call +49 6221 73920 744.
- For Japan:
  Write an e-mail to sales@volumegraphics.jp or call +81 52 508 9682.
- For the Americas:
  Write an e-mail to sales-us@volumegraphics.com or call +1 704 248 7736.
- For China, including Mainland China, Hong Kong, Macao, and Taiwan:
  Write an e-mail to sales@volumegraphics.cn or call +86 10 8532 6305.
- For Singapore and other parts of Asia (except China and Japan), Australia, and parts of Oceania:
  Write an e-mail to sales@volumegraphics.sg or call +65 6665 0310.

Opening the Dialog

In order to open the **P 203 analysis** dialog,

- right-click the corresponding entry in the Scene Tree and select **Properties** from the context menu or
- double-click the corresponding entry in the Scene Tree.

The **P 203 analysis** dialog consists of several tabs on which you can view the results of the P 203 analysis.

To close the dialog, click the **Close** button at the bottom of the dialog.

A status bar at the bottom of the dialog indicates the current status of the analysis. The status can be one of the following:

Table 26-1: Messages in the status bar

Status	Description
Result is up to date	The current analysis result is valid.
Calculation required	All required parameters have been specified and are consistent, but the analysis was not calculated or was invalidated by some user action before the project was saved.
Object has no surface determination	No surface determination information is available for the selected volume object. See also section *Surface determination* on page 949 in chapter 48 *Glossary*.
Select a reference object for edge distance calculation	The reference object selected in the **Edge distance calculation** section of the **Settings** tab is not available.
Edge distance reference has no surface determination	From the **Reference** drop-down list in the **Edge distance calculation** section, a volume object was selected for which no surface determination information is available. See also section *Surface determination* on page 949 in chapter 48 *Glossary*.
Size range: Max. value must be larger than min. value	The specified minimum value is larger than the maximum value.
Compactness range: Max. value must be larger than min. value	The minimum value specified in the **Compactness range** fields is larger than the maximum value.
Sphericity range: Max. value must be larger than min. value	The minimum value specified in the **Sphericity range** fields is larger than the maximum value.
Manual changes to result	Some indications have been manually deleted.
License missing	The add-on module is not licensed.

An invalid or outdated status of an analysis is indicated in the Scene Tree by a warning sign. Double-click this analysis to open it and check the status bar for messages.

The units of the dialog are set according to the global unit settings (see section *Units Drop-down List* on page 33 in chapter 2 *Workspace*).

However, due to the definition of the porosity key in the BDG Reference Sheet P 203 (see section “Porosity Key”), the parameters of the porosity key are always displayed in mm, mm³, and %.

Settings Tab

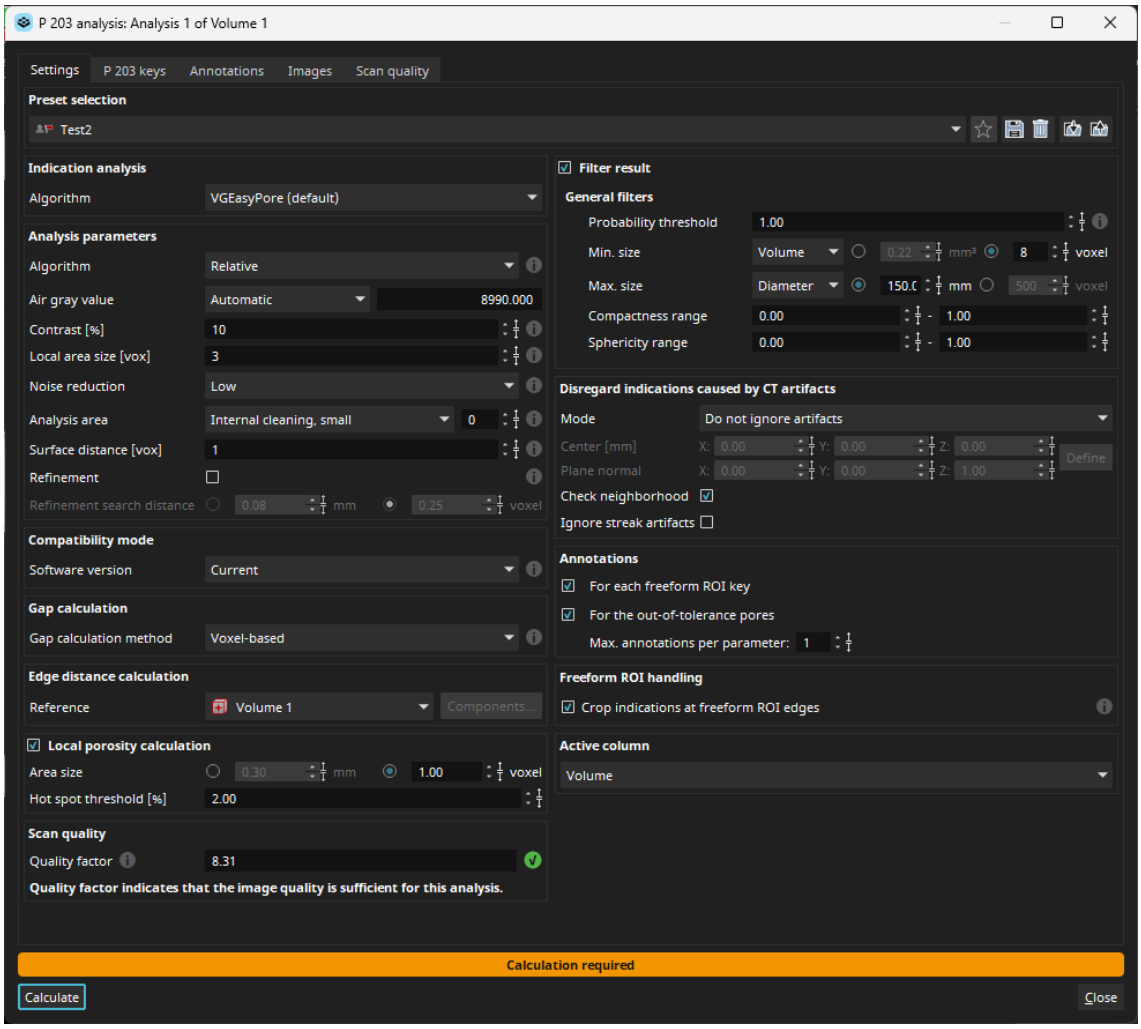


Figure 26-1: **P 203 analysis** dialog, **Settings** tab

In myVGL, all parameter settings are displayed. Most of these parameters are read-only in myVGL. The complete functional range is available with VGSTUDIO MAX and the respective add-on module(s).

Preset selection Section

Table 26-2: Controls in the **Preset selection** section

Icon	Item	Description
	drop-down list	Specifies the preset to be applied, to be edited, or to be taken as a basis for a new preset. The following icons are used: • analysis factory settings • customized preset • appears next to the icon of a preset that has been modified but not yet saved
	Set this preset as default	Sets the selected preset as default. The default preset will be applied when creating a new analysis of the same type. If the selected preset is already set as default, the button is disabled.
	Save preset	Saves the selected preset. When saving a preset, the **Save preset** dialog will open, which allows you to set the new preset as default by checking the **Set as default for new analyses** checkbox.
	Remove preset	Removes the selected preset from the preset drop-down list. If the removed preset is the default preset, the next time an analysis of the same type is created, the factory settings will be used.
	Import preset	Imports a preset from the specified location.
	Export preset	Exports the selected preset to the specified location.

Indication analysis Section

Table 26-3: Controls in the **Indication analysis** section

Control	Description
Algorithm drop-down list	• **VGEasyPore**: This subvoxel-accurate approach identifies voxels as indications based on the actual local gray value of the material in relation to a specified local contrast threshold and can detect indications that are connected to the surrounding air. • **Global threshold**: With this subvoxel-accurate algorithm, each group of indication candidates is considered an indication if the gray value is below the specified threshold. • **From indication ROI**: With this subvoxel-accurate algorithm, an indication mask from any ROI can be used for the P 203 analysis.

Analysis parameters Section

Table 26-4: Controls in the **Analysis parameters** section

Control	Description
Algorithm drop-down list	Available for the **VGEasyPore** algorithm: • **Absolute**: This algorithm determines the voxels that belong to an indication on the basis of an absolute contrast threshold. Voxels with a gray value difference compared to the surrounding (material) voxels larger than the absolute contrast threshold will be marked as indications. • **Relative**: This algorithm determines the voxels that belong to an indication on the basis of a relative contrast threshold (percentage of the material gray value). The standard value is 20%, which means that all voxels with a contrast difference greater than 20% compared to their surrounding voxels will be marked as indications.
Contrast spin box	Available for the **Absolute** algorithm of the **VGEasyPore** algorithm: Specifies the absolute contrast threshold. Each voxel with a local contrast that is higher than the absolute contrast threshold is considered part of an indication if the surrounding voxels in the search area are brighter than this voxel.
Estimate button	Available for the **Absolute** algorithm of the **VGEasyPore** algorithm: Automatically detects the absolute contrast threshold based on the gray value histogram and enters the value into the **Contrast** spin box, where it can be adapted manually.
Air gray value drop-down list	Available for the **Relative** algorithm of the **VGEasyPore** algorithm: • **Automatic**: Automatically detects the left-most peak, which represents the air gray value, based on the gray value histogram and enters the value to the field. • **Manual**: Manually defines an air gray value by specifying a value in the spin box.

Control	Description
Contrast [%] spin box	Available for the **Relative** algorithm of the **VGEasyPore** algorithm: Specifies the relative contrast threshold, i.e., the percentage of (material gray value – air gray value). Every voxel with a gray value smaller than or equal to the gray value derived from the relative contrast threshold is considered part of an indication.
Local area size [vox] spin box	Available for the **VGEasyPore** algorithm: Specifies the diameter of the search area around each voxel for determining the contrast.
Threshold spin box	Available for the **Global threshold** algorithm: Specifies the maximum gray value for determining the indication candidates.
Estimate button	Available for the **Global threshold** algorithm: Automatically detects the gray value threshold based on the gray value histogram and enters the value into the **Threshold** spin box, where it can be adapted manually.
Analysis area drop-down list	Specifies the area of the selected volume/ROI on which the algorithm will be performed. The analysis area is based on the surface determination of the volume. This option does not change the actual surface determination. This is an internal representation used for porosity/inclusion analysis only. • **Automatic**: Automatically selects the appropriate setting based on the part's surface determination. If voids have been filtered in the surface determination, no further filtering will take place. Otherwise, this option will remove all voids. • **From surface (as seen)**: Uses the area within the original surface determination. • **Internal cleaning, small**: Also includes small indications that are separated by the determined surface from the material. • **Internal cleaning, all**: Also includes larger indications that are separated by the determined surface from the material. This will use the entire area enclosed by the outermost defined surface. • **Overall closing**: Also includes indications that are separated by the determined surface from the material. This is achieved by performing a closing with the specified number of voxels. When you specify a number of voxels after having selected **Internal cleaning, small** or **Internal cleaning, all**, **Overall closing** is done additionally.

Control	Description
Surface distance [vox] spin box	Restrains the indication detection to the analysis area. To avoid detecting “false” indications along the surface caused by the partial voxel effect, you can reduce the area by the selected number of voxels.
Refinement checkbox	When this option is checked, the borders of the initially detected indications will be adjusted by using the local gray value gradients within the search distance. This local refinement reduces the effect of the **Contrast** parameter (for the **VGEasyPore** algorithm) or the **Threshold** parameter (for the **Global threshold** algorithm) on the size of the detected indications. Indications will not extend outside the **Analysis area**.
Refinement search distance spin box	Specifies the area (in physical units (e.g., mm) or in voxels) around the indication border to be considered for refinement.
Indication ROI drop-down list	Available for the **From indication ROI** algorithm: Specifies the ROI that will serve as indication mask for the P 203 analysis.

Compatibility mode Section

For the **VGEasyPore** algorithm:

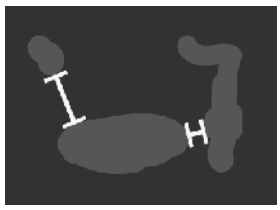
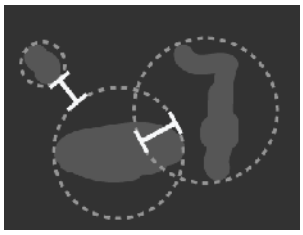
Compatibility mode can be used to reproduce the detection procedure of an earlier version of VGEasyPore by selecting the corresponding software version. This makes it possible to reproduce old analysis results, for example, for automated setups. Indication filtering is not affected by the compatibility mode.

Table 26-5: Options of the **Compatibility mode** drop-down list

Option	Description
Software version	The **Software version** drop-down list allows you to reproduce the detection procedure using earlier versions of VGEasyPore.

Gap calculation Section

Table 26-6: Controls in the **Gap calculation** section

Control	Description
Gap calculation checkbox	Calculates the closest distance to the nearest neighbor of each pore. There are two calculation methods: **Voxel-based** Calculates the closest distance based on the actual voxel boundaries of the indications.  **Sphere-based (legacy)** Approximates the closest distance by finding the circumscribed sphere of each indication and calculating the distance to the closest neighboring sphere. If the spheres intersect, the distance will be negative. 

Edge distance calculation Section

The distance of each indication to the object selected in the **Reference** field will be calculated. The edge distance will be calculated relative to the nearest surface of the reference object. If you use a surface determination as reference, make sure it does not include areas within the material (e.g., indications). This function is essential for the **Distance to surface** parameter in the **Add global key** and **Add freeform ROI key** dialogs.

This function is highly important for virtual machining. For example, prior to actually eroding a sealing surface or cutting a screw thread, this analysis parameter delivers the information if indications will be cut open by the machining process. This information can be significant when you are interested in the sealing or crack opening properties of an object area.

Table 26-7: Controls in the **Edge distance calculation** section

Control	Description
Reference drop-down list	Specifies the object to which the edge distance calculation refers.

Control	Description
Components... button	This button is enabled when you select an object with components from the **Reference** drop-down list. Clicking it opens a dialog box where you can specify the components to be used as reference for the edge distance calculation: • Checkbox of component: Clicking it checks/unchecks the component, including all child components. • **Select all** button: Selects all components of the object. • **Deselect all** button: Deselects all components of the object. • **Apply visibility** button: Selects all components which are set to visible in the Scene Tree.

Local porosity calculation Section

This option is very useful especially when the P 203 analysis is used for identifying reference volumes within the part that have a very high local porosity. After the hot spots have been identified, ROIs can be generated in these areas and evaluated with the corresponding P 203 key.

Table 26-8: Controls in the **Local porosity calculation** section

Control	Description
Local porosity calculation checkbox	When this option is checked, the corresponding controls for calculating areas of particularly high porosity will be enabled.
Area size spin box	Specifies the standard deviation of a normal distribution (in physical units (e.g., mm) or in voxels)—starting from the center of each voxel—of the area considered for calculating the ratio of pore voxels to material voxels. The resulting 3-dimensional normal distribution function will be used as a weight function for the calculation of porosity.
Hot spot threshold [<ratio unit>] spin box	Specifies a threshold to be applied to the porosity of the analyzed areas. The areas where the porosity is larger than the threshold are regarded as hot spots.

Scan Quality Section

The quality factor Q indicates if the image quality is sufficient for a P 203 analysis. The quality factor is calculated based on the current gray value histogram. It is a measure of the degree of separation between the material peak and the air peak in the analyzed histogram.

Data sets with clearly separated gray value peaks for material and air will result in a higher quality factor than noisy data sets with numerous artifacts and poorly separated gray value peaks.

See also section *Scan quality Tab* on page 387.

Table 26-9: Controls in the **Scan quality** section

Control	Description
Quality factor field	Indicates if the image quality is sufficient for the analysis. A Q factor below 3.0 (three-sigma limit) may indicate inadequate image quality. The quality factor provides a visual indicator: • Green: OK • Yellow: Possibly insufficient

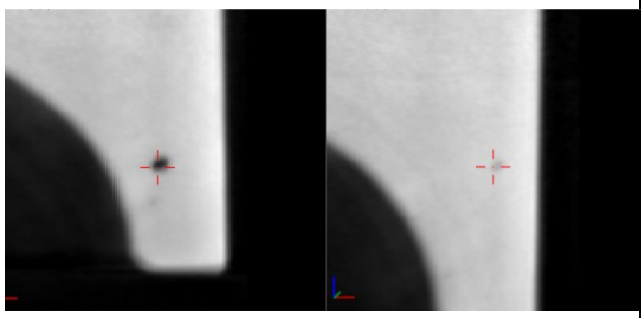
Filter result Section

When the **Filter result** checkbox is checked, only indications that meet the specified filter criteria will be included in the results, e.g., the indication list and statistics.

- **General filters** section

  Table 26-10: Controls in the **General filters** section

Control	Description
Probability threshold spin box	All potential indication areas that pass the size check will be further processed by several analysis stages. These stages try to differentiate between real indications and artifacts by utilizing sophisticated image processing algorithms. Each detected indication is tagged with a value indicating the probability that it is a real indication. Specify the **Probability threshold** so that only indications with a probability above the threshold will be included in the list. Start with a **Probability threshold** of zero if you are running the indication detection on a new data set for the first time to make sure you do not filter real indications from the list. There is no absolute value for the threshold applicable to all data sets.

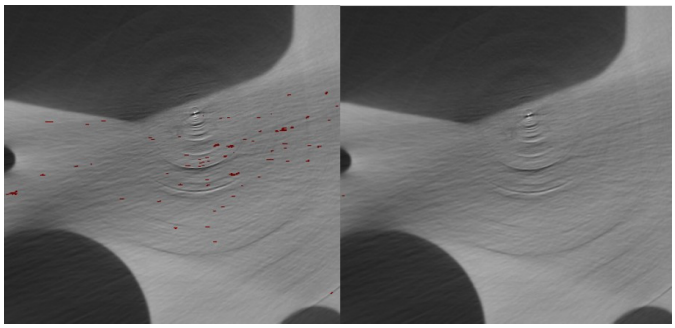
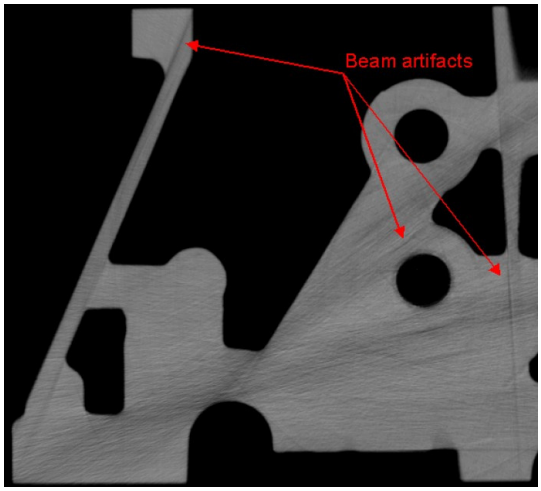
Control	Description
	The following figure shows two indications with different probabilities, where the indication on the left-hand side has a probability that is ten times higher than the indication on the right-hand side:  Figure 26-2: Probability threshold
Min. size spin boxes	Indicates the minimum indication size. Due to the nature of CT data, the value for **Min. size** should be no less than 8 voxels in edge length (i.e., an area of 2x2x2 voxels). Increase the value when data quality decreases.
Max. size spin boxes	Indicates the maximum indication size. When specifying the **Max. size** of the indication, consider that longish cracks have a rather large volume and that an accumulation of nearby small indications might be interpreted as one large indication. Specify the **Max. size** generously.
Compactness range spin boxes	Specifies the range for the compactness of the indication, i.e., the ratio between the volume of the indication and the volume of the circumscribed sphere. $\text{Compactness} = \frac{V_{indication}}{V_{sphere}}$
Sphericity range spin boxes	Specifies the range for the sphericity of the indication, i.e., the ratio between the surface of a sphere with the same volume as the indication and the surface of the indication. $\text{Sphericity} = \frac{A_{sphere}}{A_{indication}}$

Disregard indications caused by CT artifacts Section

Ring artifacts may appear within (industrial) CT data as dark circles or arcs. The voxel in the rotation center may also appear as a dark area. Depending on the selected mode, the circular structures around the specified center and/or the center itself will be considered ring artifacts and/or center artifacts, respectively, and will not be included in the indication list.

Table 26-11: Controls in the **Disregard indications caused by CT artifacts** section

Control	Description
Mode drop-down list	• **Do not ignore artifacts**: If present, center and ring artifacts will possibly be detected as indications. • **Center artifacts**: The center voxel will not be detected as indication. • **Ring artifacts**: Circular structures around the center voxel will less likely be detected as indications. • **Center and ring artifacts**: Both the center voxel and circular structures around the center voxel will less likely be detected as indications. Important: • If **Ring artifacts** is activated, a real indication connected to a *ring artifact* might not be detected. • If **Center artifacts** is activated, a real indication connected to a *center artifact* might not be detected. • If **Center and ring artifacts** is activated, a real indication connected to a *center or ring artifact* might not be detected. Note that the **Ring artifacts** and **Center and ring artifacts** modes will change the probability of the indications. With a **Probability threshold** > 0, result filtering and thus the number of indications in the **Indications** table will also be affected.
Define button	Opens a dialog that prompts you to specify the position of the (rotation) center by holding down the left mouse button and dragging a circle in the corresponding 2D view. The center of the circle must coincide with the center of the ring artifact. When you release the left mouse button, the position of the center of the circle will be adopted as center and the direction of the 2D view will be adopted as plane normal. When you do not drag a circle, the old position and normal will be maintained.
Center X/Y/Z [<length unit>] spin boxes	Indicate the position of the rotation center of the specified artifact area.
Plane normal X/Y/Z spin boxes	Indicate the plane normal of the specified artifact area.
Check neighborhood checkbox	When this option is checked, the indication detection algorithm will compare the potential indication with its local neighborhood. If the appearance of a potential indication is very similar to the surrounding structure, its probability will be reduced. This option is useful for reducing the number of erroneously detected artifacts.

Control	Description
	The following figure illustrates the effect of this option: The image on the left has been obtained without using neighborhood check; the right image with neighborhood check.  Figure 26-3: check neighborhood
Ignore streak artifacts checkbox	Beam artifacts may appear in (industrial) CT data as linear dark streaks. When this option is checked, these structures will be detected and assigned a low indication probability value. The following figure shows an example of beam artifacts:  Figure 26-4: Beam artifacts A real indication might not be detected when **Ignore streak artifacts** is activated if it is connected to and/or fits into the shape of a beam artifact. A beam artifact might not be removed by the ignore streak artifacts algorithm in cases where a beam artifact is connected to another indication (i.e., resulting shape is no longer a straight, line-like structure).

Annotations Section

Table 26-12: Controls in the **Annotations** section

Control	Description
For each freeform ROI key checkbox	When this option is checked, an annotation will automatically be created for each freeform ROI key and shown at the corresponding position in the 3D window and the 2D windows as well as in the Scene Tree. An annotation label of a freeform ROI key in the 3D window and the 2D windows indicates the sequential number of the freeform ROI key, the nominal freeform ROI key, and—if available—the name of the key in parentheses. Apart from that, it shows the toleranced parameters and their “worst” values. If the tolerance is met, the value will be highlighted in green. If the tolerance is not met, it will be highlighted in red. If the tolerance cannot be calculated, it will be highlighted in yellow. An evaluation indicator is visible in front of the annotation name, indicating whether the overall tolerance for the freeform ROI key is met (green) or not (red). In the Scene Tree, the freeform ROI key annotations will be listed under the **Freeform ROI key annotations** entry and indicate the sequential number of the freeform ROI key, the nominal freeform ROI key, the name of the key—if available—in parentheses, and the position of the freeform ROI.
For the out-of-tolerance pores checkbox	When this option is checked, annotations will automatically be created for the pores that are out of tolerance and shown at the corresponding positions in the 3D window and the 2D windows as well as in the Scene Tree. Apart from that, they will be listed on the **Annotations** tab. The **Max. annotations per parameter** spin box allows you to specify the maximum number of annotations created for each parameter that has out-of-tolerance values. If more than one parameter of a pore is out of tolerance, only one annotation will be created for that pore.

Adding, removing, or editing the P 203 porosity keys will automatically update the automatic annotations.

For details on annotations in general, see section *Annotation* on page 124 in chapter 6 *Inspect Tab*.

Freeform ROI handling Section

Table 26-13: Controls in the **Freeform ROI handling** section

Control	Description
Crop indications at freeform ROI edges checkbox	When cropping is activated, indications will be cropped at the ROI boundary. Metrics like sphericity or volume will be evaluated on the resulting fragments of the indication. This option can also affect the topology of the indications, as cropping may split indications into multiple smaller ones, thus having an effect on the number of indications within the corresponding ROI. When cropping is deactivated, statistics like sphericity or volume will be calculated on the original indications even if the indications are only partially contained in the corresponding ROI. The calculation of the ROI's porosity will still be voxel-precise and only consider indication voxels within the ROI.

Active column Section

This drop-down list allows you to select the property of the indication that is to be shown according to the settings on the **Colors** tab.

When you select an indication property, e.g., **Surface**, from the **Active column** drop-down list, the indications will be color-coded according to their surface area as defined by the color lookup table and the colors specified in the **Sections** section of the **Colors** tab. In the indication list on the **Indications** tab, the column of the selected property becomes the "active" column, and its values are highlighted in bold and italic font.

When you select **Uncoded** from the **Active column** drop-down list, all indications will be shown in the same color regardless of their properties, e.g., radius and volume. The color can be specified in the **Uncoded indications** field of the **Other colors** section on the **Colors** tab.

The property selected in the **Active column** drop-down list will be added to the information provided in the annotation labels.

☞ The **Active column** section is also available on the **Colors** tab. The changes made on the **Settings** tab will also affect the **Colors** tab and vice versa.

☞ You can also select the active column on the **Indications** tab by right-clicking the column and choosing the **Set as active column** item from the context menu.

P 203 keys Tab

The **P 203 keys** tab is always available, even if the analysis has not been calculated or is invalid. This allows you to define the porosity keys prior to the indication calculation, thus offering a more comfortable workflow.

Applying a preset on the **Settings** tab will override any keys specified on the **P 203 keys** tab.

Tolerance values will be interpreted according to DIN EN ISO 8015 (see also section *Rounding Rules* on page 4 in chapter 1 *Welcome*).

Columns of the **P 203 keys** Table

The **P 203 keys** table consists of the following columns:

Table 26-14: Columns of the **P 203 keys** table

Column	Description
Key	Indicates the porosity key, which may consist of several parameters. For details, see section *Add key Dialog* on page 359. When you delete indications from the indication table, the P 203 keys will be automatically updated. Note that the units of the key parameters are fixed and will not be affected by the settings in the **Units** drop-down list in the ribbon.
Out-of-tolerance values	Indicates the parameters that are out of tolerance, the most critical value of each parameter that is out of tolerance, and—in square brackets—the number of discontinuities that are out of tolerance for this parameter. Hovering the mouse pointer over the **Out-of-tolerance values** field will open a tooltip that lists the individual parameters, the **Worst actual value**, the **Tolerance limit**, and the **NOK count** (NOK = not OK) in the form of a table. The first number of the **NOK count** indicates the number of pores that are out of tolerance for this parameter, while the second number indicates the total number of pores evaluated for this porosity key. Note that the total number of pores evaluated for this porosity key may change when the **Disregarded pores** criterion is used for one of the parameters.
Name	Indicates the name of the key that was specified in the **Name** field of the **Add key** dialog.
ROI	Indicates the name of the ROI to which the freeform ROI key will be applied.

Column	Description
Key type	Indicates the region to which the porosity key will be applied: • **Global**: The porosity key will be applied to the entire parent object (volume or ROI). A porosity key for the entire parent object can be specified via the **Global key** segment of the **Add key** dialog. • **Freeform**: The porosity key will be applied to the specified freeform ROI. A porosity key for an existing ROI can be specified via the **Freeform ROI key** segment of the **Add key** dialog.
Porosity [<ratio unit>]	Indicates the porosity calculated for the specified region.
Pore count	Indicates the number of pores detected in the specified region.
Max. pore volume [<length unit>³]	Indicates the largest volume of a single pore detected in the specified region.
Max. diameter [<length unit>]	Indicates the largest diameter of the circumscribed sphere of a pore detected in the specified region.
Max. equivalent diameter [<length unit>]	Indicates the largest equivalent diameter of a pore detected in the specified region. For a description of this parameter, see section *Indications Tab* on page 366.
Min. sphericity	Indicates the smallest sphericity of a pore detected in the specified region. For a description of this parameter, see section *Indications Tab* on page 366.
Min. compactness	Indicates the smallest compactness of a pore detected in the specified region. For a description of this parameter, see section *Indications Tab* on page 366.
Min. gap [<length unit>]	Indicates the smallest gap between two pores detected in the specified region. For a description of this parameter, see section *Indications Tab* on page 366.
Min. distance to surface [<length unit>]	Indicates the smallest distance of a pore to the surface of the reference object detected in the specified region. See section *Edge distance calculation Section* on page 348. In contrast to the edge distance calculation on the **Indications** tab, which differentiates the individual indications into inside, outside, and cut, the **Distance to surface** value is described by the absolute value of the minimum distance between the reference surface and the surface of the pore. If the pore is cut open by the reference surface, the value will be zero.

If a cell shows a parameter for which a tolerance has been specified via the porosity key (see section *Add key Dialog* on page 359), each entry will be evaluated separately according to the specified tolerance and highlighted in the following colors:

- Green: The tolerance is met.
- Red: The tolerance is not met.
- Yellow: No tolerance can be calculated.

  This can occur, for example, if the reference volume (ROI) for which the P 203 key has been defined is outside the object surface (the ROI does not cover the part).

The color of the **Key** field will be red if at least one of the toleranced parameters is red.

If no indication was detected, the values of all parameters—except for **Porosity** and **Pore count**—will read **n/a**. In addition, if only one indication was detected in the analyzed area, the value of **Gap** will read **n/a**.

If tolerances were applied to these parameters, **n/a** will be highlighted in green ("in tolerance"), since no problematic indications are present.

Controls of the **P 203 keys** Tab

Table 26-15: Controls of the **P 203 keys** tab

Control	Description
Add key… button	Opens the **Add key** dialog, where you can generate the porosity key for the entire parent object (volume object or ROI) or for a previously created region of interest. See section *Add key Dialog* on page 359.
Edit… button	Enabled when exactly one table row is selected: Opens the **Add key** dialog for editing the selected porosity key. You can also double-click a table row to edit the porosity key.
Duplicate button	Duplicates the selected porosity key(s) in the table. This allows you to create copies of existing porosity keys in the table and modify them by using the **Edit** context menu item.
Remove button (or **Del** key)	Deletes the selected porosity key(s) from the table.

Context Menu of the **P 203 keys** Tab

Right-clicking anywhere in the table area shows a context menu with the following options:

Table 26-16: Context menu of the **P 203** tab

Control	Description
Columns	Allows you to toggle the visibility of each column by checking/unchecking the respective item. • **Show all**: Checks all columns to set them to visible. • **Hide all**: Unchecks all columns to set them to invisible. • **Hide empty**: Unchecks all not editable columns which are empty or **n/a** to set them to invisible.
Trim columns	Resizes all columns to their smallest possible size.
Apply default column layout	Applies the default column layout previously saved by the user to the current table. If no default column layout has been saved, the original column layout will be applied.
Save as default column layout	Saves modifications applied to the table—e.g., the visibility of a column, the order in which the columns appear, the column width—as default column layout. This layout will be applied when you create a new project.
Apply original column layout	Restores the original table layout and discards any modifications applied by the user. The original table layout is predefined and cannot be modified by the user.
Edit	Enabled when exactly one table row is selected: Opens the **Add key** dialog for editing the selected porosity key. You can also double-click a table row to edit the porosity key.
Duplicate	Duplicates the selected porosity key(s) in the table. This allows you to create copies of existing porosity keys in the table and modify them by using the **Edit** context menu item.
Remove (or **Del** key)	Deletes the selected porosity key(s) from the table.

Add key Dialog

Allows you to specify a porosity key for the entire parent object or for a region of interest by clicking the corresponding option of the segmented button:

- **Global key**: Allows you to specify a porosity key for the entire parent object (volume object or ROI).
- **Freeform ROI key**: Allows you to specify a porosity key for a selected region of interest.

Table 26-17: Fields of the **Add key** dialog

Control	Description
Freeform ROI drop-down list	For a freeform ROI key: Specifies the ROI to which the porosity key will be applied.
Name field	Allows you to enter a name for the key. This name will be displayed in the **Name** cell of the **P 203 keys** table and—for a freeform ROI key—in the annotation label in the 3D window and the 2D windows and in the annotation name in the Scene Tree.
ROI porosity P_{ROI}	For a freeform ROI key: **Tolerance value** field: Specifies the maximum permissible porosity, i.e., the volume of the pores with respect to the volume of the ROI, in percent. The volume of the ROI is defined by the intersection of the ROI with the surface of the volume object.
Global porosity P_G [%]	For a global key: **Tolerance value** field: Specifies the maximum permissible porosity, i.e., the volume of the pores with respect to the entire volume of the part, in percent.
Number of pores Z	**Tolerance value** field: Specifies the maximum permissible number of pores.
Single pore volume V_P [mm³]	• **Tolerance value** field: Specifies the maximum permissible volume of an individual pore. • **Disregarded pores** field: Pores with a volume smaller than this value will not be considered by the current porosity key.
Pore diameter $\varnothing_P$ [mm]	• **Tolerance value** field: Specifies the maximum permissible diameter of the circumscribed sphere of an individual pore. • **Disregarded pores** field: Pores with a diameter of the circumscribed sphere smaller than this value will not be considered by the current porosity key.
Equivalent diameter $\varnothing_{aq}$ [mm]	• **Tolerance value** field: Specifies the maximum permissible equivalent diameter of an individual pore. • **Disregarded pores** field: Pores with an equivalent diameter smaller than this value will not be considered by the current porosity key. For a description of this parameter, see section *Indications Tab* on page 366.

Control	Description
Sphericity Ψ	• **Tolerance value** field: Specifies the minimum permissible sphericity of an individual pore. • **Disregarded pores** field: Pores with a sphericity larger than this value will not be considered by the current porosity key. For a description of this parameter, see section *Indications Tab* on page 366.
Compactness C	• **Tolerance value** field: Specifies the minimum permissible compactness of an individual pore. • **Disregarded pores** field: Pores with a compactness larger than this value will not be considered by the current porosity key. For a description of this parameter, see section *Indications Tab* on page 366.
Gap [mm]	• **Tolerance value** field: Specifies the minimum permissible gap between two pores. • **Disregarded pores** field: Pores with a gap larger than this value will not be considered by the current porosity key. For a description of this parameter, see section *Indications Tab* on page 366.
Distance to surface d_a [mm]	• **Tolerance value** field: Specifies the minimum permissible distance of an individual pore to the surface of the reference object selected in the **Reference** drop-down list of the **Edge distance calculation** section on the **Settings** tab. • **Disregarded pores** field: Pores with a distance to surface larger than this value will not be considered by the current porosity key. In contrast to the edge distance calculation on the **Indications** tab, which differentiates the individual indications into inside, outside, and cut, the **Distance to surface** value is described by the absolute value of the minimum distance between the reference surface and the surface of the pore. If the pore is cut open by the reference surface, the value will be zero.
Resulting key field	Indicates the porosity key that results from the specified parameters (for this reference volume).
Recent keys button	Allows you to select a key from a list of previously defined keys. The **Recent keys** function saves the five last unique keys. They can be used for both the **Global key** option and the **Freeform ROI key** option. Recent keys are not project-specific but will be saved in the application settings of myVGL.

☞ The values for the disregarded pores need to match the corresponding tolerance values, otherwise the porosity key cannot be generated.

☞ The units in this dialog are fixed to mm, mm³, and % and will not be affected by the settings in the **Units** drop-down list in the ribbon.

Colors/Porosity colors Tab

Here you can specify the color-coding scheme used for the representation of the general analysis results for the property selected in the **Active column** drop-down list.

Caption Section

Table 26-18: Controls of the **Caption** section

Control	Description
Caption field	Indicates the color bar headline as specified in the **Caption** field of the **Color bar** section.
Share color bar checkbox	When this option is checked, all analyses of the same type (and—if applicable—of the same algorithm) will use the same color bar. When this option is unchecked, the color bar settings will apply to the selected analysis only.

LUT – Color Lookup Table

The color lookup table (LUT) shows the partitioning into color sections.

Sections Section

Defines the appearance of each color section.

Table 26-19: Controls in the **Sections** section

Control	Description
From/To fields	Specify the start and end values of the color sections. The first color section represents all values above the upper limit, i.e., the value in the **From** field (**+inf** signifies positive infinity), while the last color section represents all values below the lower limit, i.e., the value in the **To** field (**-inf** signifies negative infinity). The default limits are calculated from the results of the analysis (for an analysis color bar) or taken from the **Default** preset (for a tolerance deviation color bar).

Control	Description
Type field	Switches between the color schemes **Continue**, **Constant**, **Gradient**, **Rainbow**, **Reverse rainbow**, and **Hue cycle**.
Color/transparency field	Double-clicking the field for the **Continue**, **Constant**, and **Gradient** color schemes opens the **Select Color** dialog where you can modify the appearance of the selected color scheme. For the **Gradient** color scheme, you can specify the start and end colors by double-clicking the left or right side of the field, respectively. Double-clicking the field for the **Rainbow**, **Reverse rainbow**, **Green to red**, **Red to green**, and **Hue cycle** color schemes opens the **Transparency** dialog, where you can set the transparency for the selected color scheme.
use RMB to click a color section	Opens a context menu with the following items: • **Split**: Subdivides the color section into two new color sections where each represents half of the original section. • **Merge**: Combines several color sections to a single color section. Only consecutive intervals can be merged.
Create smooth button	Opens the **Create smooth table** dialog to generate one color section. • **Type** drop-down list: Allows you to select the type of coloring scheme. • **From/To** spin boxes: Specify the value range covered by the color section.
Create stepped button	Opens the **Create stepped table** dialog to generate a set of color sections. • **Type** drop-down list: Allows you to select the type of coloring scheme. • **From/To** spin boxes: Specify the value range covered by the color sections. • **Step** spin box: Specifies the step size of the individual color sections.
Auto scale button	Fits the color LUT to the range of the results of all available analyses. For example, if you have a minimal porosity of 2% and maximal porosity of 10%, these values will be your minimum and maximum on your color LUT. The gradient changing from green to red will be used. Note that if you load an old project, you may have to manually click the **Auto scale** button to rescale the color LUT, because the relevant settings in the old project remain unchanged in the current version.

Active column Section

This drop-down list allows you to select the property of the indication that is to be shown according to the specified color-coding.

The **Active column** section is also available on the **Settings** tab. The changes made on the **Colors** tab will also affect the **Settings** tab and vice versa. For details, see the “**Settings** tab” chapter of the corresponding analysis.

Preset selection Section

Table 26-20: Controls in the **Preset selection** section

Icon	Item	Description
	drop-down list	Specifies the preset to be applied, to be edited, or to be taken as a basis for a new preset. The following icons are used: • default preset • customized preset • appears next to the icon of a preset that has been modified but not yet saved
	Save preset	Opens the **Save preset** dialog for saving the color LUT of the current data set under the specified name. • **Absolute preset**: When this option is checked and the preset applied, the settings of the original data set, including the LUT range, will be applied. When this option is unchecked, the color settings of the preset will be mapped relatively to the actual range of results of the analysis to which the preset will be applied.
	Remove preset	Removes the selected preset from the preset drop-down list.
	Import preset	Imports a preset from the specified location.
	Export preset	Exports the selected preset to the specified location.

Outline rendering Section

Specifies the rendering of the results of a porosity/inclusion analysis.

Table 26-21: Settings in the **Outline rendering** section

Control	Description
Outline rendering checkbox	When this option is checked, only the outline of the color-coded indications is shown such that the indications will not be covered by the color-coding.

Control	Description
Outline width spin box	Specifies the outline width for the color-coded indications. Note that when increasing the outline width, the outline will grow equally inward and outward. The real outline of the indication lies in the middle of the line.

To visualize the outline of the indications, you can also create a colored mesh by right-clicking the analysis in the Scene Tree and selecting **Convert to > Colored surface mesh from analysis result(s)** from the context menu. The color of the mesh corresponds to the color-coding of the analysis results.

Display mode in 3D Section

Table 26-22: Controls in the **Display mode in 3D** section

Control	description
Opacity mode drop-down list	Specifies the visual representation of the analysis results. The following modes are available: • **Constant**: Each indication is fully opaque independently of its gray value. • **Ramp**: The lower the gray value of the respective indication, the lower its opacity value. The higher the gray value of the respective indication, the higher its opacity value. Available only if the volume data of the object is loaded. • **Inverse ramp**: The lower the gray value of the respective indication, the higher its opacity value. The higher the gray value of the respective indication, the lower its opacity value. Available only if the volume data of the object is loaded. This option allows you to see through the indications that lie on top and discover indications that may lie behind them.

Other Colors Section

Depending on the analysis type, this option is only available when **Uncoded** is selected in the **Active column** field on the **Settings** tab. Double-clicking the **Uncoded indications** field opens the **Select Color** dialog, where you can set the color for the detected indications. All indications will be shown in this color.

Color LUT Settings Section

Specifies the appearance of the color lookup table.

Table 26-23: Options for the appearance of the color lookup table

Control	Description
Auto tick marks checkbox	When this option is checked, equidistant tick marks will be produced for the color bars. When this option is unchecked, tick marks will appear only at the color section boundaries of the color lookup table.
Auto scale color bar range on calculate checkbox	When this option is checked, the color LUT will be automatically fitted to the range of the results of all available analyses. The gradient changing from green to red will be used.

Color bar Section

Specifies the settings for the color bar.

Table 26-24: Settings for the color bar

Control	Description
Visibility drop-down list	Switches the color bar on/off.
Positioning drop-down list	Specifies the location of the color bar within the 2D and 3D windows: **Left, Right, Top, Bottom, All - automatic, Left or right - automatic, Top or bottom - automatic**.
Caption field	Specifies the color bar headline by using placeholders.
Reset button	Resets the **Caption** field to the default entry.

Indications Tab

Lists all indications detected by the P 203 analysis.

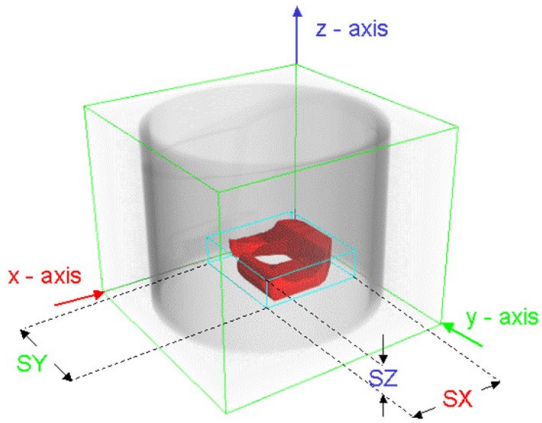
When you delete indications from the indication table, the P 203 keys will be automatically updated.

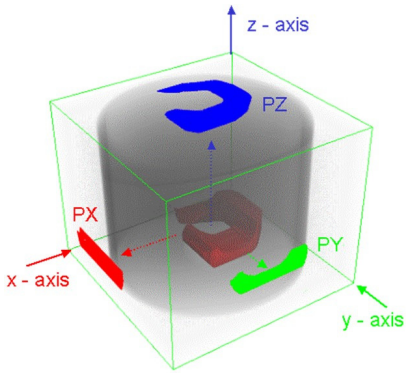
The **Indications** table consists of the following columns:

Table 26-25: Columns of the **Indications** table

Column	Description
Probability	Indicates the probability that the discontinuity is an indication.
Radius [<length unit>]	Indicates the radius of the circumscribed sphere of the indication.

Column	Description
Diameter [<length unit>]	Indicates the diameter of the circumscribed sphere of the indication.
Equivalent diameter [<length unit>]	Indicates the diameter of a sphere that has the same volume as the indication.
Center x/y/z [<length unit>]	Indicates the center position of the circumscribed sphere of the indication.
Volume [<length unit>³]	Indicates the volume of the indication.
Voxel	Indicates the number of voxels the indication consists of.
Surface [<length unit>²]	Indicates the surface area of the indication.
Classification	Indicates the position of the indication relative to the object selected in the **Reference** field of the **Edge distance calculation** section: **Cut**, **Inside**, or **Outside**.
Gap [<length unit>]	Indicates the minimum distance between the surfaces of the circumscribed spheres of two indications. Note that this value may also be negative.
Compactness	Indicates the ratio between the volume of the indication and the volume of the circumscribed sphere. $\text{Compactness} = \frac{V_{indication}}{V_{sphere}}$
Sphericity	Indicates the ratio between the surface of a sphere with the same volume as the indication and the surface of the indication. $\text{Sphericity} = \frac{A_{sphere}}{A_{indication}}$
Pos. x/y/z [<length unit>]	Indicates the position of the darkest voxel of the indication.

Column	Description
Projected size x/y/z [<length unit>]	Indicates the size of the bounding box surrounding the indication in the scene coordinate system. See the following figure for an illustration:  Figure 26-5: Projected size
PCA deviation 1/2/3 [<length unit>]	Indicate the standard deviations along each of the three mutually orthogonal axes calculated, from a Principal Component Analysis (PCA), with **PCA deviation 1** corresponding to the standard deviation along the most pronounced axis of the indication. The standard deviations are the square root of the eigenvalues.
PCA max. deviation ratio [<ratio unit>]	Indicates the ratio between **PCA deviation 1** and the radius of the circumscribed sphere of the indication. $\text{Max. relative PCA deviation} = \frac{\text{PCA deviation 1}}{r_{sphere}}$
PCA min. deviation ratio [<ratio unit>]	Indicates the ratio between **PCA deviation 3** and the radius of the circumscribed sphere of the indication. $\text{Min. relative PCA deviation} = \frac{\text{PCA deviation 3}}{r_{sphere}}$
Min. gray value	Indicates the minimum gray value within the indication.
Max. gray value	Indicates the maximum gray value within the indication.
Mean gray value	Indicates the mean gray value within the indication.
Deviation of gray values	Indicates the standard deviation of the gray values within the indication.
Label	Indicates the consecutive number of the indication.
Cut surface [<length unit>²]	Indicates the surface area where the indication intersects the surface of the object selected in the **Reference** field of the **Edge distance calculation** section.

Column	Description
Min. edge distance (inside) [<length unit>]	For an indication classified as **Inside**: Indicates the smallest distance between the surface of the indication and the surface of the object selected in the **Reference** field of the **Edge distance calculation** section.
Min. edge distance (outside) [<length unit>]	For an indication classified as **Outside**: Indicates the smallest distance between the surface of the indication and the surface of the object selected in the **Reference** field of the **Edge distance calculation** section.
Max. edge distance (cut) [<length unit>]	For an indication classified as **Cut**: Indicates the largest distance between the surface of the indication in the material and the surface of the object selected in the **Reference** field of the **Edge distance calculation** section.
Projected area (yz-plane)/(xz-plane)/ (xy-plane) [<length unit>²]	Indicates the surface area of the indication shape projected along each of the axes of the scene coordinate system. See the following figure for an illustration:  Figure 26-6: Projected area
Description	Allows you to enter a description for the component used for reporting.

Column	Description
Image	Allows you to add a detailed 2D image and object description on a separate page of the report. • **Off**: No image is created (default). • **Orthographic projection**: Creates three orthogonal views. • **Top/Bottom/Left/Right/Front/Back**: Creates a single 2D view in the specified orientation. The image orientation corresponds to the currently selected coordinate system. The image will be generated according to the render settings specified during report creation or VGRF-based export. The 2D slice position used for taking the image is determined by the position of the indication. The zoom factor of the image is selected so that the entire parent volume is visible.
Focused image	This option is almost identical to the **Image** option but will generate an image that focuses on the respective item and is zoomed in by the **Zoom factor** specified during report creation or VGRF-based export.
Captures	Indicates the number of images captured for this object using the **Capture from** button in the **Screenshots** section.

Porosity statistics Tab

Shows a histogram of the calculated porosity for the entire analyzed object (number of voxels versus the percentage of the porosity). The histogram bars are colored according to the settings on the **Porosity colors** tab. You can use the **Porosity statistics** tab to answer questions such as “How many voxels have a porosity of 4%?”

Controls of the **Porosity statistics** Tab

- **Options** section

  Table 26-26: Controls of the **Porosity statistics** tab, **Options** section

Control	Description
Color drop-down list	• **From color bar**: The values in the histogram are shown according to the color bar. • **Gray**: All values in the histogram are shown in gray.

Control	Description
Ordinate scaling drop-down list	• **Linear**: Applies a linear scale to the y-axis of the histogram. • **Logarithmic**: Applies a logarithmic scale to the y-axis of the histogram.
Binning drop-down list	• **Off**: No binning is applied to the values shown in the histogram. • **From color bar**: The original values in the histogram are replaced by a value representative for the corresponding interval (“bin”) of the color bar. The “bins” become visible when creating “stepped” sections on the **Colors** tab. • **Manual number of bins**: Enables the **Bin count** spin box, where you can enter the required number of “bins.” • **Manual bin width**: Enables the **Bin width** spin box, where you can specify the width of the bins.

- **Intervals** section

Table 26-27: Controls of the **Porosity statistics** tab, **Intervals** section

Control	Description
Left/**Right** spin box	Only enabled when an interval has been created: Moves the left or right interval border to the specified value. You can also click and drag the interval borders by using the left mouse button.

Control	Description
Create button	Creates a new interval. On the right hand side of a selected interval, statistical information is displayed: • **Left**: Indicates the minimum value of the parameter selected in the **Active column** field of the **Settings** tab within the interval, i.e., the left interval border. • **Right**: Indicates the maximum value of the parameter selected in the **Active column** field of the **Settings** tab within the interval, i.e., the right interval border. • **Mean**: Indicates the mean value of the parameter selected in the **Active column** field of the **Settings** tab within the interval. • **Dev**: Indicates the standard deviation of the values of the parameter selected in the **Active column** field of the **Settings** tab within the interval. • **Percentage**: Indicates the percentage of the parameter selected in the **Active column** field of the **Settings** tab within the interval. Note that the statistical information may change with the number of bins specified in the **Options** section.
Remove button	Removes the selected interval.

- General controls

Table 26-28: General controls of the **Porosity statistics** tab

Control	Description
use RMB to click the chart area	Displays a context menu (see below).
scroll MW in chart area or x-axis up/down	Zooms the x-axis of the chart out/in.
scroll MW in y-axis up/down	Zooms the y-axis of the chart out/in.
use LMB to click and drag the x-axis	Scrolls the x-axis.
use LMB to click and drag the y-axis	Scrolls the y-axis.
Zoom in/out	Zooms the corresponding axis in/out.
Reset zoom	Fits the entire chart to the current window size.

Context Menu of the **Porosity statistics** Tab

Right-clicking anywhere in the chart area shows a context menu with the following options:

Table 26-29: Context menu items

Control	Description
Export as CSV...	Opens a dialog for saving the chart values to a *.csv* file.
Copy to clipboard	Copies a screenshot of the chart to the system clipboard so you can paste it in another application.
Hide/Show x/y grid	Toggles the visibility of the grid lines for the corresponding axis.
Reset zoom	Fits the entire chart to the current window size.
Create interval	Creates a new interval. For details on the statistical information, see section *Controls of the Porosity statistics Tab* on page 370.
Remove interval	Removes the selected interval.

Hot spots of porosity Tab

Displays the hot spots resulting from the porosity calculation.

☞ The **Hot spots of porosity** tab is available only if the **Porosity calculation** option has been checked on the **Settings** tab.

Table 26-30: Columns of the **Hot spots of porosity** list

Column	Description
Position x/y/z [<length unit>]	Indicates the x-, y-, and z-position of the hot spot.
Volume [<length unit>^{3}]	Indicates the volume of the hot spot.
Surface [<length unit>^{2}]	Indicates the surface area of the hot spot.
Mean porosity [<ratio unit>]	Indicates the mean porosity value of the hot spot.
Porosity deviation [<ratio unit>]	Indicates the standard deviation of the porosity value of the hot spot.
Maximum porosity [<ratio unit>]	Indicates the maximum porosity within the hot spot.
Description	Allows you to enter a description for the hot spot used for reporting.

Column	Description
Image	Allows you to add a detailed 2D image and object description on a separate page of the report. • **Off**: No image is created (default). • **Orthographic projection**: Creates three orthogonal views. • **Top/Bottom/Left/Right/Front/Back**: Creates a single 2D view in the specified orientation. The image orientation is relative to the currently selected coordinate system. The image will be generated according to the render settings specified during report creation or VGRF-based export. The 2D slice position used for taking the image is determined by the position of the hot spot. The zoom factor of the image is chosen so that the entire parent volume is visible.
Focused image	This option is almost identical to the **Image** option but will generate an image that focuses on the respective item and is zoomed in by the **Zoom factor** specified during report creation or VGRF-based export.
Captures	Indicates the number of images captured for this hot spot by using the **Capture from** button in the **Screen-shots** section.

Annotations Tab

Lists all annotations created for the selected P 203 analysis. You can view the information supplied by the annotations or edit the annotation properties.

For details on how to create an annotation, see section *Annotation* on page 124 in chapter 6 *Inspect Tab*.

To create new annotations in the table, it is also possible to paste previously copied coordinates by right-clicking the table and selecting **Paste** from the context menu or by pressing the **Ctrl** + **V** keyboard shortcut. For details, see the **Paste** menu item in section *Table Context Menu*.

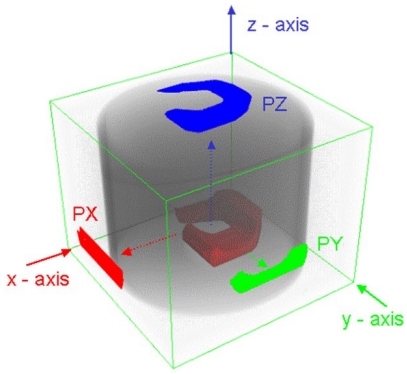
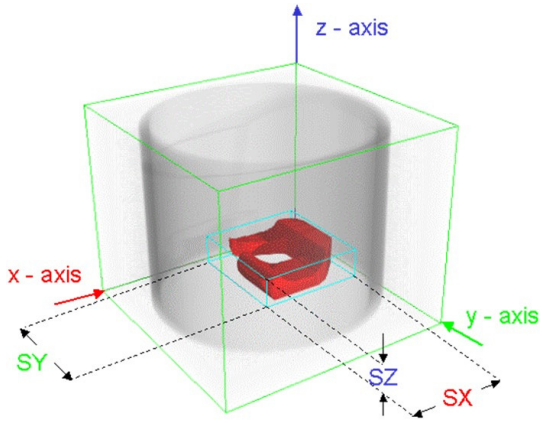
Double-clicking an analysis annotation in the Scene Tree will directly open the **Annotations** tab of the properties dialog of the corresponding analysis.

The **Annotations** table consists of the following columns:

Table 26-31: Columns of the **Annotations** table

Column	Description
Name	Indicates the name of the annotation.

Column	Description
Pos. x/y/z [<length unit>]	Indicates the position of the annotation.
Probability	Indicates the probability that the discontinuity is an indication.
Volume [<length unit>³]	Indicates the volume of the indication at the current annotation position.
Radius [<length unit>]	Indicates the radius of the circumscribed sphere of the indication.
Diameter [<length unit>]	Indicates the diameter of the circumscribed sphere of the indication.
Equivalent diameter [<length unit>]	Indicates the diameter of a sphere that has the same volume as the indication.
Classification	Indicates the position of the indication relative to the object selected in the **Reference** field of the **Edge distance calculation** section: **Inside**, **Outside**, or **Cut**.
Edge distance (inside) [<length unit>]	For an indication classified as **Inside**: Indicates the smallest distance between the surface of the indication and the surface of the object selected in the **Reference** field of the **Edge distance calculation** section.
Edge distance (outside) [<length unit>]	For an indication classified as **Outside**: Indicates the smallest distance between the surface of the indication and the surface of the object selected in the **Reference** field of the **Edge distance calculation** section.
Edge distance (cut) [<length unit>]	For an indication classified as **Cut**: Indicates the largest distance between the surface of the indication and the surface of the object selected in the **Reference** field of the **Edge distance calculation** section.
Cut surface [<length unit>²]	Indicates the surface area where the indication intersects the surface of the object selected in the **Reference** field of the **Edge distance calculation** section.
Gap [<length unit>]	Indicates the minimum distance between the surfaces of the circumscribed spheres of two indications.

Column	Description
Projected area x/y/z [<length unit>²]	The surface area of the indication shape projected along each of the axes of the scene coordinate system. See the following figure for an illustration:  Figure 26-7: Projected area
Projected size x/y/z [<length unit>]	Indicates the size of the bounding box surrounding the indication in the scene coordinate system. See the following figure for an illustration:  Figure 26-8: Projected size
Surface [<length unit>²]	Indicates the surface area of the indication.
Compactness	Indicates the ratio between the volume of the indication and the volume of the circumscribed sphere. $\text{Compactness} = \frac{V_{indication}}{V_{sphere}}$
Sphericity	Indicates the ratio between the surface of a sphere with the same volume as the indication and the surface of the indication. $\text{Sphericity} = \frac{A_{sphere}}{A_{indication}}$
Min. gray value	Indicates the minimum gray value within the indication.

Column	Description
Max. gray value	Indicates the maximum gray value within the indication.
Mean gray value	Indicates the mean gray value within the indication.
Deviation of gray values	Indicates the standard deviation of the gray values within the indication.
PCA deviation 1/2/3 [<length unit>]	Indicate the standard deviations along each of the three mutually orthogonal axes calculated from a Principal Component Analysis (PCA), with **PCA deviation 1** corresponding to the standard deviation along the most pronounced axis of the indication. The standard deviations are the square root of the eigenvalues.
PCA min. deviation ratio [<ratio unit>]	A measure for the ratio between **PCA deviation 3** and the radius of the circumscribed sphere of the indication. $\text{Min. relative PCA deviation} = \frac{\text{PCA deviation 3}}{r_{sphere}}$
PCA max. deviation ratio [<ratio unit>]	A measure for the ratio between **PCA deviation 1** and the radius of the circumscribed sphere of the indication. $\text{Max. relative PCA deviation} = \frac{\text{PCA deviation 1}}{r_{sphere}}$
Porosity [<ratio unit>]	Indicates the porosity in percent at the current annotation position.
Description	Allows you to enter a description of the annotation used for reporting.
Image	Allows you to add a detailed 2D image and object description on a separate page of the report. • **Off**: No image is created (default). • **Orthographic projection**: Creates three orthogonal views. • **Top/Bottom/Left/Right/Front/Back**: Creates a single 2D view in the specified orientation. The image orientation corresponds to the currently selected coordinate system. The image will be generated according to the render settings specified during report creation or VGRF-based export. The 2D slice position used for taking the image is determined by the position of the indication. The zoom factor of the image is selected so that the entire parent volume is visible.
Focused image	This option is almost identical to the **Image** option but will generate an image that focuses on the respective item and is zoomed in by the **Zoom factor** specified during report creation or VGRF-based export.

Column	Description
Captures	Indicates the number of images captured for this object using the **Capture from** button in the **Screenshots** section.
Type	Indicates how the annotation has been created: • **Automatic**: The annotation has been automatically created via the **For the out-of-tolerance pores** option in the **Annotations** section on the **Settings** tab. • **Manually defined**: The annotation has been defined by the user. • **Rule based**: The annotation has been created by a report rule.

General Table Controls

- List section

  The following table provides an overview of the general controls available in the various list views:

  Table 26-32: Controls in the list section

Control	Description
button	Opens a submenu for selecting the filter/search mode.
Filter	Clicking the **Click to add a filter or search criterion** field to the right of the icon opens a series of drop-down lists from which you can select a table column, an operator, and—depending on the column—a value. If a column does not offer a value drop-down list, you can type in a value. When the selection is complete, the table shows the rows matching the filter criterion. Clicking the **+** button or the **Click to add a filter or search criterion** field allows you to specify more filter criteria. Clicking the **x** button removes the filter.

Control	Description
Search	Clicking the **Click to add a filter or search criterion** field to the right of the icon opens a series of drop-down lists from which you can select a table column, an operator, and—depending on the column—a value. If a column does not offer a value drop-down list, you can type in a value. When the selection is complete, the table rows matching the search criterion are highlighted. Clicking the **+** button or the **Click to add a filter or search criterion** field allows you to specify more search criteria. Pressing **F3** jumps to the next search result in the list. Clicking the **x** button removes the search.
Full-text filter	Entering a value or text string into the input field to the right of the icon filters the table accordingly and shows the rows that match the filter criterion.
Full-text search	Entering a value or text string into the input field to the right of the icon searches the table accordingly and highlights the rows that match the search criterion.
use LMB to click on a table row	Selects the row and the corresponding object in the Scene Tree. In analysis result lists, the result, e.g., the component, is marked by a cross-hairs cursor in each of the 2D views.
hold **Ctrl** key + use LMB to click on several table rows	Selects the rows and the corresponding objects in the Scene Tree.
hold **Shift** key + use LMB to click on two separate table rows	Selects the two rows, including all rows between the two as well as the corresponding objects in the Scene Tree.
hold **Shift** key + use up/down arrow keys	Selects the rows and the corresponding objects in the Scene Tree.
press **Ctrl+A**	Selects all table rows.
use up and down arrow keys	Steps up and down through the table rows.
use RMB to click into the table area	Displays a context menu. See below.
use LMB to click a column heading	Sorts the table according to the values of the column. Clicking subsequently toggles between ascending and descending.
use LMB to click and drag column heading to new position, then release LMB	Inserts the column at the new position.

Control	Description
use LMB to double-click cell highlighted in white (light theme) or medium gray (dark theme)	If applicable: Allows you to edit the contents of the cell.

- **Screenshots** section (if available)

  The **Screenshots** section below the list section allows you to capture images from one of the 2D windows, the 3D window, or the current window layout for the item currently selected in the table. Only available if exactly one row is selected.

  Table 26-33: Controls in the **Screenshots** section

Control	Description
Capture from button	Adds the image of the view selected from the drop-down list to the preview area above.
use LMB to click and drag one or more images, then release LMB	Moves the image(s) to the new position.
double-click the image	Opens the **Snapshot display** window showing the image: • **Zoom in**/**Zoom out** button: Zooms the image in/out. You can also move the mouse pointer in the image area and turn the mouse wheel. • **Fit to window** button: Resets the zoom so that the image fits into the window.
click the **<no description>** placeholder twice (first click to select, second click to enable renaming)	Allows you to label the image.
Delete selected button	Deletes the selected image from the preview area.

Table Context Menu

Right-clicking anywhere in the table area shows a context menu with the following options:

Table 26-34: Context menu items

Control	Description
Columns	Allows you to toggle the visibility of each column by checking/unchecking the respective item. • **Show all**: Checks all columns to set them to visible. • **Hide all**: Unchecks all columns to set them to invisible. • **Hide empty**: Unchecks all not editable columns which are empty or **n/a** to set them to invisible.

Control	Description
Trim columns	Resizes all columns to their smallest possible size.
Apply default column layout	Applies the default column layout previously saved by the user to the current table. If no default column layout has been saved, the original column layout will be applied.
Save as default column layout	Saves modifications applied to the table—e.g., the visibility of a column, the order in which the columns appear, the column width—as default column layout. This layout will be applied when you create a new project.
Apply original column layout	Restores the original table layout and discards any modifications applied by the user. The original table layout is predefined and cannot be modified by the user.
Remove entries	If applicable: Deletes the selected row(s) from the table.
Create annotations	If applicable: Creates annotations for the selected items.
Export as CSV...	Opens the **Export as CSV...** dialog for exporting the table values as **.csv* file. This option always exports the complete table even if a filter was applied. In order to export only the filtered rows, press **Ctrl** + **A** to highlight all filtered rows and use the **Copy to clipboard** menu item.
Copy to clipboard	Copies the selected rows as well as the column heading into the system clipboard. The clipboard information is provided both as plain text and rich-text table, so when pasting into a rich-text-capable application like a word processor, you will see a proper table with cell borders and bold headings.
Paste	For annotation tables: Pastes previously copied coordinates and—optionally—snap directions to create new annotations in the table. For annotations of a nominal/actual comparison, the search distance specified on the **Settings** tab of the analysis will be considered. Note: Pasted annotations will be interpreted in the selected coordinate system at the time of pasting.

Control	Description
	The information in the clipboard must have the following structure: • x-, y-, and z-coordinate of the annotation or • x-, y-, and z-coordinate of the annotation as well as x-, y-, and z-component of the vector for the snap direction The parameters can be separated by space, tab, semi-colon, or comma (if a comma is already used as a decimal mark or digit grouping symbol, the values must be enclosed in double quotation marks). Example: 8.89;25.82;-0.55;1;0;0 You can also copy the information directly from the cells of a spreadsheet. In order to paste the annotation information, you can also press the **Ctrl** + **V** keyboard shortcut.
Set as active column	If applicable: Makes the current column the active column, i.e., the results of this column are color-coded according to their values as defined by the color lookup table and the colors specified in the **Sections** section of the **Colors** tab.
Unset active column	If applicable: Deselects the currently active column and sets the **Active column** drop-down list on the corre-sponding **Settings** tab to **Uncoded**, i.e., removes any color coding.
Enter/change value (all items)	If applicable: Opens the **Enter value** dialog (see below) where you can enter the desired value for the selected parameter. This value will be applied to all entries in the table.
Enter/change value (selected items)	If applicable: Opens the **Enter value** dialog (see below) where you can enter the desired value for the selected parameter. This value will be applied to the selected entries in the table.
Delete selected items	If applicable: Removes the selected items from the scene.

The **Enter value** dialog includes the following controls:

Table 26-35: Controls in the **Enter value** dialog

Control	Description
Enter value field	Allows you to enter the desired value.
OK button	Sets the selected parameter to the specified value.

Control	Description
Reset button	For analyses only: Resets the selected parameter to undefined.
Set from tolerance settings button	For analyses only: Enters the value specified in the tolerance settings of the analysis for the selected parameter.
Cancel button	Discards the changes and closes the dialog.

Rules Tab

Shows existing rules for selecting features (e.g., probability, radius) with defined properties to be included in the final report. Apart from that, the **Rule** dialog allows you to create new rules and edit or delete existing rules.

With the default rule **Big five**, images of the five indications with the largest diameters will automatically be created and included in your standard report.

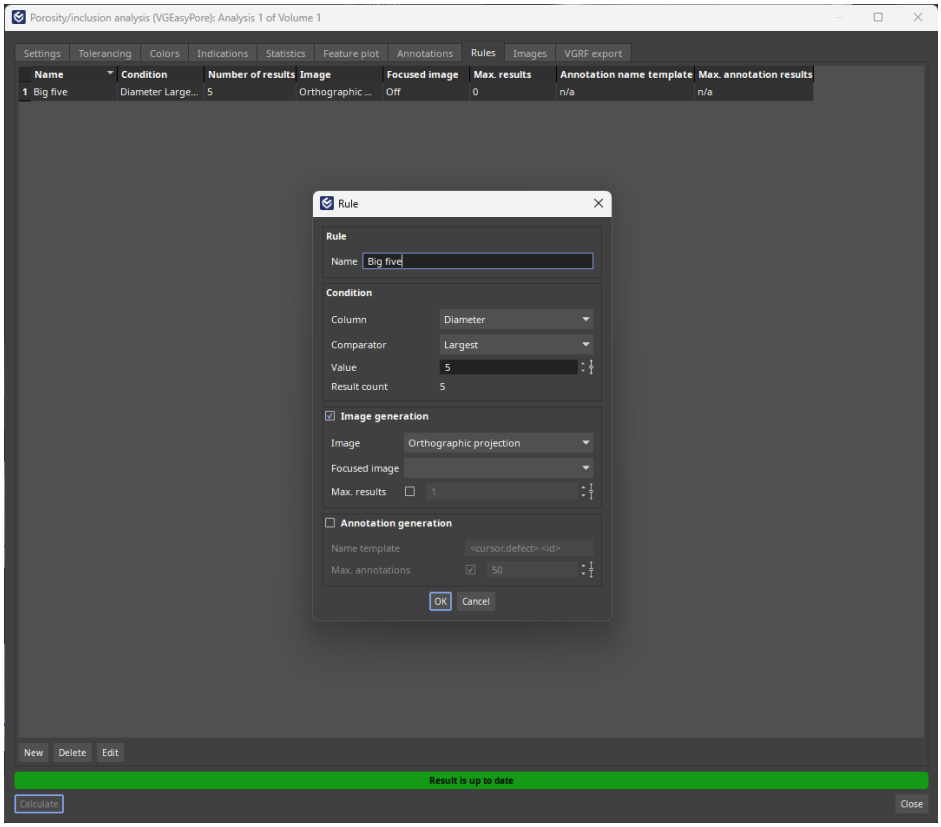


Figure 26-9: **Rules** tab with **Rule** dialog

- **New** button

  Opens the **Rule** dialog for creating a new rule.
- **Delete** button

Deletes a selected rule.

- **Edit** button

  Opens the **Rule** dialog for editing a selected rule.

You can also double-click a rule to open the **Rule** dialog for editing a selected rule.

Rule Dialog

- **Rule** section

  The **Name** field allows you to enter a name for the new rule. This name has to be unique.
- **Condition** section

  Table 26-36: Controls in the **Condition** section

Control	Description
Column drop-down list	Selects the property of the feature (e.g., probability, radius, diameter) that defines the rule.
Comparator drop-down list	Specifies the comparator to be applied to the selected property.
Value [<unit>] spin box or drop-down list	Specifies the reference value or status of the selected property for comparison.
Result count field	Indicates the number of results that meet the specified condition.

- **Image generation** section

  Table 26-37: Controls in the **Image generation** section

Control	Description
Image drop-down list	Allows you to add a detailed 2D image and object description on a separate page of the report. • **Off**: No image is created (default). • **Orthographic projection**: Creates three orthogonal views. • **Top/Bottom/Left/Right/Front/Back**: Creates a single 2D view in the specified orientation. • If applicable: **... - If not OK**: Automatically creates the image if the tolerance status is **Out of tolerance**.
Focused image drop-down list	This option is almost identical to the **Image** option, but will generate an image that focuses on the respective item and is zoomed in by the **Zoom factor** specified during report creation or VGRF-based export.
Max. results checkbox and spin box	When this option is checked, you will be able to use the corresponding spin box to specify the maximum number of results to be included in the report.

- **Annotation generation** section

  Table 26-38: Controls in the **Annotation generation** section

Control	Description
Name template field	Allows you to enter a name for the annotations. If this is not done, a name of the form *<annotation type> <id>* will automatically be generated.
Max. annotations checkbox and spin box	When this option is checked, you will be able to use the corresponding spin box to specify the maximum number of annotations to be generated.

In contrast to manually created annotations, rule-based annotations can neither be moved nor deleted. This is indicated by a closed padlock symbol next to the annotation name in the annotation label.

Rule-based annotations that are based on components are created at the position of the component that fulfills the condition. For wall thickness analyses performed with the **Sphere method** algorithm and nominal/actual comparisons, the position of the component is always the spatial center (or—if the spatial center lies outside the component—a position within the component that is closest to the spatial center), while for wall thickness analyses performed with the **Ray method** algorithm, the position is defined by the **Position property** option on the **Settings** tab of the properties dialog.

- **OK** button

  Closes the dialog, adds the new rule to the list in the **Rules** tab and updates the annotations.
- **Cancel** button

  Discards the settings and closes the dialog.

Images Tab

Allows you to take screenshots of the selected workspace views and/or add bookmark references to the report. In the final report, the captured images will be listed separately from the screenshots created on other tabs.

- **Snapshots** section

  Table 26-39: Controls in the **Snapshots** section

Control	Description
Capture from button	Adds the image of the view selected from the drop-down list to the preview area above.
Delete selected button	Deletes the selected image(s) from the preview area.
use LMB to click and drag one or more images, then release LMB	Moves the image(s) to the new position.

Control	Description
double-click the image	Opens the **Snapshot display** window showing the image: • **Zoom in**/**Zoom out** button: Zooms the image in/out. You can also move the mouse pointer on the image area and turn the mouse wheel. • **Fit to window** button: Resets the zoom so that the image fits into the window.
click the **<no description>** placeholder twice (first click to select, second click to enable renaming)	Allows you to label the image.

- **Automatic 3D images** section (if available)

  Check the corresponding checkbox to include the desired 3D view (e.g., **Top**, **Front**, **Top-left-front**, and **Current camera settings**) in the report without changing the 3D view.

- **Bookmark references** section

  Allows you to add bookmark references via drag and drop from the **Bookmarks and views** tool or the **Bookmark editor** to the preview area. The images of the referenced bookmarks will then be included in VGRF-based reports.

  When you open a project with missing bookmark images, placeholders will be shown instead.

  Bookmark references are stored in evaluations and can be used in automation scenarios.

☞ You will still need to import a bookmark template containing the actual bookmarks in these cases, as evaluations store only references to them.

Table 26-40: Controls in the **Bookmark references** section

Control	Description
New bookmark button	Adds a bookmark of the current view to the preview area.
Remove button	Removes the bookmark currently selected in the preview area.
click the bookmark title twice (first click to select, second click to enable renaming) or press the **F2** key	Allows you to rename the bookmark. The changes made on the **Images** tab will also affect the **Bookmark editor** and the **Bookmarks and views** tool. If the renamed bookmark is referenced by one or more objects for reporting, a warning message will be displayed indicating that the referenced bookmark will also be renamed for all these objects in the report.

The global concept of bookmark references allows for multiple objects to reference the same bookmark and for objects to reference bookmarks that show arbitrary information, e.g., other analyses or objects.

Scan quality Tab

Shows a histogram of the gray value distribution in the data set and provides the quality factor calculated according to the BDG Reference Sheet P 203.

- The quality factor calculation is currently only supported for single-material data sets.
- Filtering or altering the gray values in any way will also affect the quality factor.

The histogram is calculated for the entire volume object and does not consider any ROIs. If you would like to exclude certain areas (e.g., the rotation table of the CT scanner) from the quality evaluation, it is recommended that you use the **Extract ROI(s)** function to generate a new volume object that only consists of the object of interest and the surrounding air.

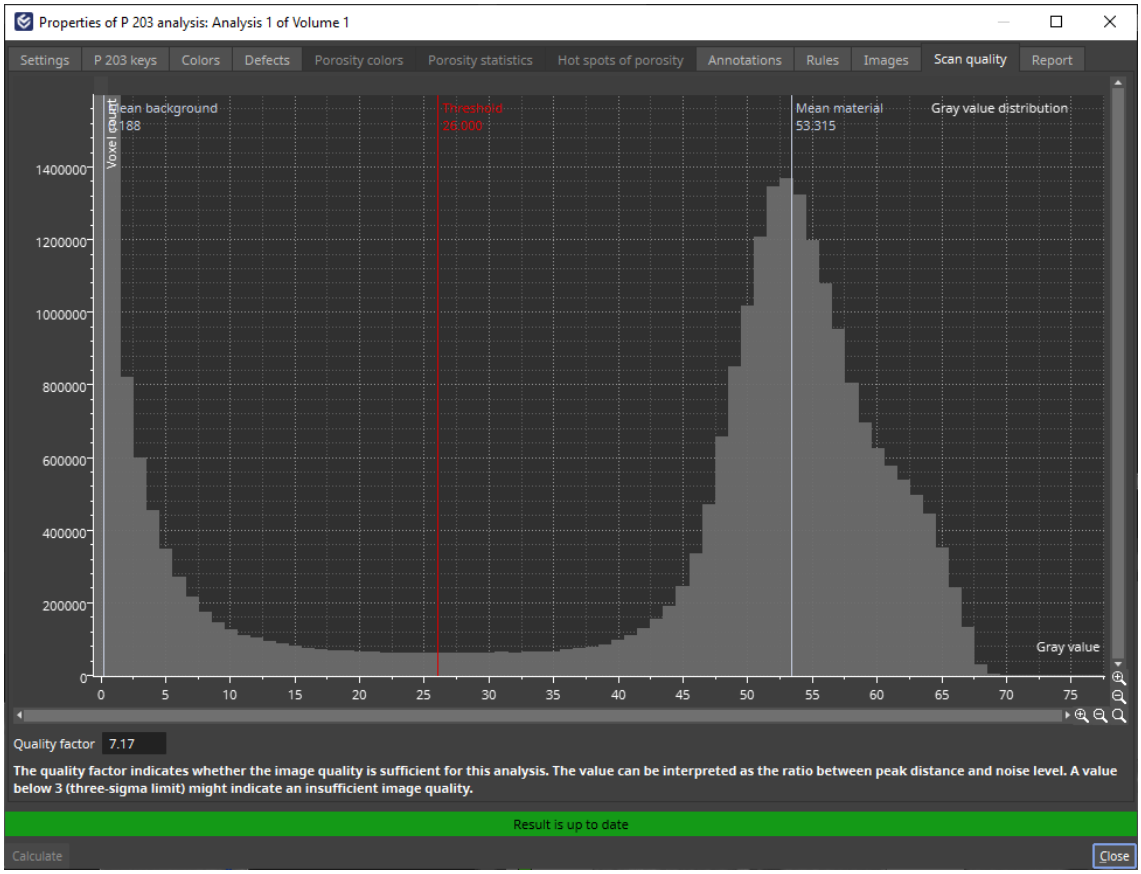


Figure 26-10: **Scan quality** tab

The histogram shows the gray values of the voxels of the CT data set on the x-axis and the number of voxels on the y-axis. Two vertical white lines indicate the **Mean background** and

Mean material gray values. A red vertical line indicates the **Threshold**, which separates the background interval from the material interval and which is automatically calculated using Otsu's method for thresholding.

The quality factor, which is displayed below the histogram in the **Quality factor** field, is automatically calculated according to the following formula:

$$Q = \frac{|\mu_1 - \mu_2|}{\sqrt{\sigma_1^2 + \sigma_2^2}}$$

with μ_1 = mean value of background interval, ${\sigma_1}^2$ = variance of background interval, μ_2 = mean value of material interval, and ${\sigma_2}^2$ = variance of material interval.

The quality factor indicates whether the image quality is sufficient for the P 203 analysis. The value can be interpreted as the ratio between peak distance and noise level. A value below 3 (three-sigma limit) might indicate an insufficient image quality. For detailed information about the quality factor, please refer to the BDG Reference Sheet P 203.

Controls of the **Scan quality** Tab

Table 26-41: Controls of the **Scan quality** tab

Control	Description
use RMB to click the chart area	Displays a context menu (see below).
scroll MW in chart area or x-axis up/down	Zooms the x-axis of the chart out/in.
scroll MW in y-axis up/down	Zooms the y-axis of the chart out/in.
use LMB to click and drag the x-axis	Scrolls the x-axis.
use LMB to click and drag the y-axis	Scrolls the y-axis.
Zoom in/Zoom out	Zooms the corresponding axis in/out.
Reset zoom	Fits the entire chart to the current window size.

Context Menu of the **Scan quality** Tab

Right-clicking the chart area displays a context menu with the following options:

Table 26-42: Context menu of the **Scan quality** tab

Control	Description
Copy to clipboard	Copies a screenshot of the chart to the system clipboard so you can paste it into another application.
Show x grid/Hide x grid **Show y grid/Hide y grid**	Toggles the display of dashed indicator lines for the respective axis.
Reset zoom	Fits the entire chart to the current window size.

Porosity/Inclusion Analysis Module: P 202/P 201

Introduction

The **P 202/P 201 analysis** function is part of the **Porosity/Inclusion Analysis** module of VGSTUDIO MAX and is designed to analyze a volume object for pores in a specified 2D slice based on the BDG Reference Sheet P 202 (VW 50093) and VDG Specification P 201 (VW 50097). It provides detailed analysis results with information on individual pores and reference faces as well as overall statistical information.

License Information

This module is an optional add-on module for VGSTUDIO MAX. It is not available for myVGL. However, if a project loaded in myVGL contains results obtained with this module, they can be viewed and reported in myVGL.

If you are interested in a more comprehensive functionality than the one offered by myVGL, you have the chance to evaluate VGSTUDIO MAX. You can request an evaluation license of VGSTUDIO MAX on our website:

https://volumegraphics.hexagon.com/en/products/evaluation

If you have further questions about our product portfolio, please contact us:

- For Europe, Middle East, and Africa:
  Write an e-mail to sales@volumegraphics.com or call +49 6221 73920 744.
- For Japan:
  Write an e-mail to sales@volumegraphics.jp or call +81 52 508 9682.
- For the Americas:
  Write an e-mail to sales-us@volumegraphics.com or call +1 704 248 7736.
- For China, including Mainland China, Hong Kong, Macao, and Taiwan:
  Write an e-mail to sales@volumegraphics.cn or call +86 10 8532 6305.
- For Singapore and other parts of Asia (except China and Japan), Australia, and parts of Oceania:
  Write an e-mail to sales@volumegraphics.sg or call +65 6665 0310.

Opening the Dialog

In order to open the **P 202/P 201 analysis** dialog,

- right-click the corresponding entry in the Scene Tree and select **Properties** from the context menu or
- double-click the corresponding entry in the Scene Tree.

The **P 202/P 201 analysis** dialog consists of several tabs on which you can view the results of the P 202/P 201 analysis.

To close the dialog, click the **Close** button at the bottom of the dialog.

A status bar at the bottom of the dialog indicates the current status of the analysis. The status can be one of the following:

Table 27-1: Messages in the status bar

Status	Description
Result is up to date	The current analysis result is valid.
Calculation required	All required parameters have been specified and are consistent, but the analysis was not calculated or was invalidated by some user action before the project was saved.
Diameter range: Max. value must be larger than min. value	The minimum value of the diameter range specified in the **Filter** section is larger than the maximum value.
Invalid P201/P202 code	The code specified in the **Code** section is invalid. For details on allowed values, refer to section *Settings Tab* on page 391.
Manual changes to result	Some voids or inclusions have been manually deleted.
License missing	The add-on module is not licensed.

☞ An invalid or outdated status of an analysis is indicated in the Scene Tree by a warning sign. Double-click this analysis to open it and check the status bar for messages.

☞ The units of the dialog are set according to the global unit settings (see section *Units Drop-down List* on page 33 in chapter 2 *Workspace*).

Settings Tab

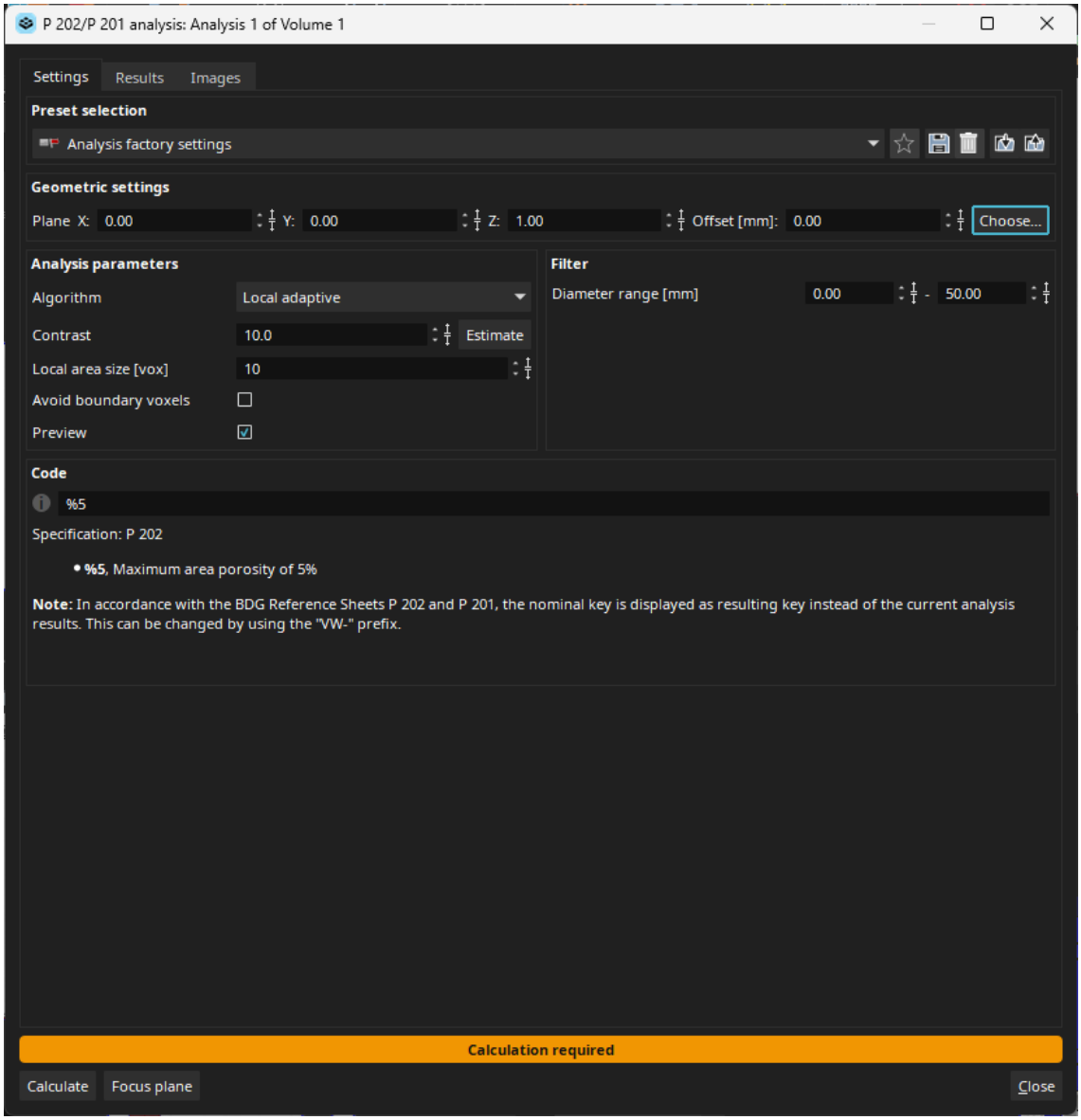


Figure 27-1: **P 202/P 201 analysis** dialog, **Settings** tab

☞ In myVGL, all parameter settings are displayed. Most of these parameters are read-only in myVGL. The complete functional range is available with VGSTUDIO MAX and the respective add-on module(s).

Preset selection Section

Table 27-2: Controls in the **Preset selection** section

Icon	Item	Description
	drop-down list	Specifies the preset to be applied, to be edited, or to be taken as a basis for a new preset. The following icons are used: • analysis factory settings • customized preset • appears next to the icon of a preset that has been modified but not yet saved
	Set this preset as default	Sets the selected preset as default. The default preset will be applied when creating a new analysis of the same type. If the selected preset is already set as default, the button is disabled.
	Save preset	Saves the selected preset. When saving a preset, the **Save preset** dialog will open, which allows you to set the new preset as default by checking the **Set as default for new analyses** checkbox.
	Remove preset	Removes the selected preset from the preset drop-down list. If the removed preset is the default preset, the next time an analysis of the same type is created, the factory settings will be used.
	Import preset	Imports a preset from the specified location.
	Export preset	Exports the selected preset to the specified location.

Geometric settings Section

In the **Geometric settings** section, you can select the plane and the slice position to be analyzed by scrolling to the desired slice in a 2D window and selecting the respective 2D view by clicking the **Choose** button. Apart from that, you can also specify the plane by entering an arbitrary normal vector.

Table 27-3: Controls in the **Geometric settings** section

Control	Description
Plane X/Y/Z fields	Specify the normal of the plane in which the P 202/P 201 analysis will be calculated. The specified vector is normalized to unit length before it is taken into account in the calculation.
Offset [<length unit>] spin box	Specifies the distance of the plane to be analyzed to the origin of the currently selected coordinate system.

Control	Description
Choose button	Opens a drop-down list that shows the 2D windows currently available in the workspace for specifying the plane to be analyzed.

Analysis parameters Section

Table 27-4: Controls in the **Analysis parameters** section

Control	Description
Algorithm drop-down list	• **Local adaptive**: This algorithm determines the voxels that belong to an indication on the basis of a local contrast threshold. • **Only threshold**: This algorithm determines the voxels that belong to an indication on the basis of a global gray value threshold.
Contrast spin box	**Local adaptive** algorithm: Specifies the local contrast threshold. Every voxel with a local contrast higher than the contrast threshold is considered part of an indication.
Threshold spin box	**Only threshold** algorithm: Specifies the maximum indication gray value. Every voxel with a gray value smaller than or equal to the gray value threshold is considered part of an indication.
Estimate button	Automatically detects the contrast or gray value threshold based on the gray value histogram and enters the value into the **Contrast** or **Threshold** spin box, respectively, where it can be adapted manually.
Local area size spin box	**Local adaptive** algorithm: Specifies the diameter of the search area around each voxel for determining the contrast.
Avoid boundary voxels checkbox	**Local adaptive** algorithm: When this option is checked, voxels located close to the material boundary will not be considered indications.
Preview checkbox	When this option is checked, a preview of the indications will be displayed.

☞ The preview is calculated according to the parameters of the **Analysis parameters** section only. All other parameters will not influence the preview.

Filter Section

The **Diameter range [<length unit>]** spin boxes allow you to define the minimum and maximum permissible diameter for the circumscribed circle of an indication. All indications smaller than or larger than these limits will be disregarded.

Code Section

In the **Code** section, you can define a nominal code as specified by P 202 (VDG P 202, BDG P 202, VW 50093) or P 201 (VDG P 201, BDG P 201, VW 50097).

- Supported P 202 porosity key parameters

  In VGSTUDIO MAX, P 202 codes may start with an optional prefix that is followed by a series of parameters that each start with a symbol and are separated by a “/” (slash).

  - Possible prefixes: no prefix, VDG P 202-, BDG P 202-, VW 50093-, VW-

When the prefix “VW-” or “VW 50093” is used, the parameters of the **Result porosity key** displayed on the **Results** tab will be rounded as specified in the VW test specification PV 6093.

According to PV 6093, rectangular faces larger than 3 x 4 mm² with a tolerance specification for porosity smaller than or equal to 4% are to be handled in a special way. This is not implemented here.

When no prefix is specified, the type of code (P 201 or P 202) will be determined automatically by the syntax of the code, however, error messages may be more helpful if the type of code is explicitly specified.

- **Maximum area porosity**: The character % followed by a digit specifies the maximum permissible porosity in percent for the classes G, S, and D.
- **Maximum diameter**: The diameter character Ø (or alternatively, the letters O, OL, or OI) followed by a digit specifies the maximum diameter defined as the Feret diameter.

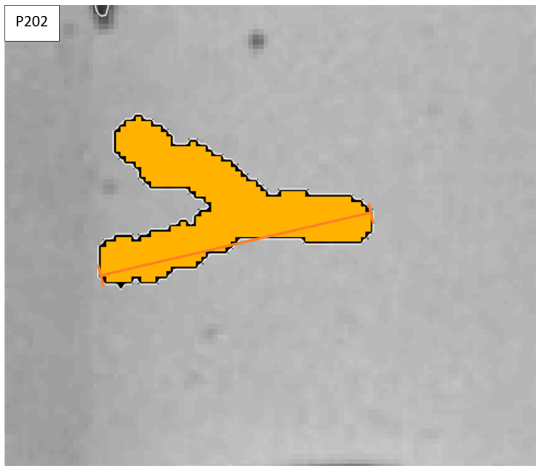


Figure 27-2: Maximum diameter as the Feret diameter

- **Minimum normalized distance between pores**: The letter A followed by a digit specifies the minimum normalized distance between two adjacent pores, just as with P 201.

- **Maximum pore count**: The letter Z followed by a digit specifies the maximum permissible number of defined pores related to a reference surface for the class F.

The following examples show valid P 202 codes:

- BDG P202-%5/Z10/O2: maximum area porosity of 5%, maximum pore count of 10, maximum diameter (Feret diameter) of 2 mm
- BDG P202-Z2/A2: maximum pore count of 2, minimum normalized distance between pores: 2x
- VW-%5/Ø2: maximum area porosity of 5%, maximum diameter (Feret diameter) of 2 mm

- Supported P 201 porosity key parameters

  In VGSTUDIO MAX, P 201 codes may start with an optional prefix and may consist of up to three parts—separated by a “/” (slash)—that specify porosity, diameter, and minimum normalized distances.

  - Possible prefixes: no prefix, VDG P 201-, BDG P 201-, VW 50097-, VW-

When the prefix “VW-” or “VW 50097” is used, the parameters of the **Result porosity key** displayed on the **Results** tab will be rounded as specified in the VW test specification PV 6097.

According to PV 6097, rectangular faces larger than 3 x 4 mm² with a tolerance specification for porosity smaller than or equal to 4% are to be handled in a special way. This is not implemented here.

When no prefix is specified, the type of code (P 201 or P 202) will be determined automatically by the syntax of the code, however, error messages may be more helpful if the type of code is explicitly specified.

- **Maximum area porosity**: The code begins with a letter that specifies the class, followed by a digit that indicates the maximum permissible porosity in percent for the classes G, S, and D and the maximum permissible number of defined pores related to a reference surface for the class F (e.g., F1).

  The classes pose the following restrictions on which digits are allowed: For D, the digits 1, 2, 3, 4 and all multiples of 5 are allowed; for S, only multiples of 5 are allowed; for F and G, all integers are allowed.

These values are evaluated only for each reference face.

- **Maximum diameter**: This optional part of the code specifies the maximum permissible diameter of single pores in mm (e.g.,12). The values can be set in 0.5 steps, starting from the smallest value of 0.5. VGSTUDIO MAX calculates the diameter of a pore by using the minimal enclosing circle around a pore.

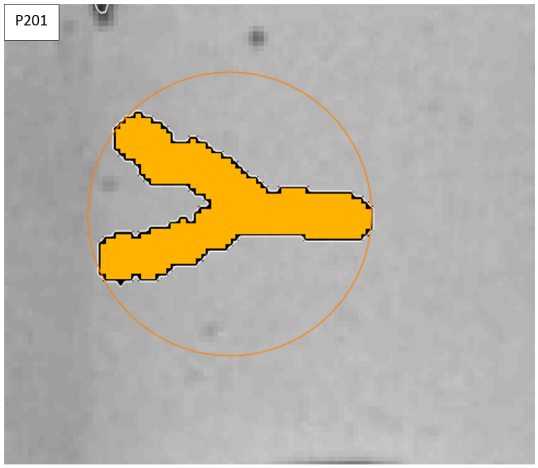


Figure 27-3: Maximum diameter taken from the minimal enclosing circle around a pore

This value is evaluated for the entire analyzed slice.

- **Minimum normalized distance between pores**: This optional part of the code consists of the letter A followed by a digit and specifies the minimum normalized distance between two adjacent pores (e.g., A3). The digit can be any integer starting with 0.

  The distance is the length of the smallest line segment that connects the borders of two adjacent pores. The normalized distance is this value divided by the diameter of the smaller pore. The minimum normalized distance is the smallest of these values in an analyzed slice.

This value is evaluated for the entire analyzed slice.

The following examples show valid codes:

- G3/A1: class G, maximum area porosity of 3%, minimum normalized distance between pores: 1x (i.e., each pore must be at least its own diameter away from a larger pore)
- D5/3.5/A2: class D, maximum area porosity of 5%, maximum diameter (smallest enclosing circle) of 3.5 mm, minimum normalized distance between pores: 2x
- BDG P201-F11/0.5: class F, maximum pore count of 11, maximum diameter (smallest enclosing circle) of 0.5 mm
- VW-S5/2: class S, maximum area porosity of 5%, maximum diameter (smallest enclosing circle) of 2 mm

Results Tab

Result porosity key Section

Displays the code resulting from the current analysis. The displayed result porosity key depends on the prefix of the code:

- **VW-**, **VW 50093-**, **VW 50097-**: The actual values of the code parameters specified in the **Code** field on the **Settings** tab will be rounded as specified in PV 6093 and PV 6097 and displayed as result porosity key. For details on and examples of the rounding policy, see section *Rounding Policy according to the VW Test Specifications PV 6097 and PV 6093* on page 397.

According to PV 6093 and PV 6097, rectangular faces larger than 3 x 4 mm² with a tolerance specification for porosity smaller than or equal to 4% are to be handled in a special way. This is not implemented here.

- For all other prefixes, the nominal key specified in the **Code** field on the **Settings** tab will be displayed as result porosity key.

For details on the code structure, see section *Code Section* on page 394.

The result porosity key will be indicated in the Scene Tree and included in the report for the P 202/P 201 analysis.

If any of the actual values has not yet been calculated (for example, no reference face has been generated), the **Result porosity key** field will show **n/a** and the result porosity key will neither be visible in the Scene Tree nor included in the report.

If more than one P 202/P 201 analysis is performed, the resulting code displayed in the Scene Tree will be subject to the following rules:

- P 201 and P 202 keys cannot be combined.
- Keys with different rounding rules cannot be combined, i.e., only analyses without prefix or with the code prefixes BDG- and VDG- as well as analyses with the code prefixes VW- and VW-xxxxx can be combined.
- The prefix of the combined result key will be determined as follows:
  - BDG, VDG, no prefix: The combined key will always have the BDG prefix.
  - VW, VW-xxxxx: The combined key will always have the complete VW prefix, i.e., VW-xxxxx.
- If the keys of the individual analyses cannot be combined, **n/a** will be displayed as result key.

Rounding Policy according to the VW Test Specifications PV 6097 and PV 6093

- Porosity

  For this parameter, the rounding policy also depends on the nominal key.
  - Nominal key ≤ 4% (1%, 2%, 3%, 4%): round up in steps of 1%; if the actual value is > 5%, round up in steps of 5%

    Examples: 2.1% → 3%; 4.4% → 5%; 6.7% → 10%

According to PV 6093 and PV 6097, rectangular faces larger than 3 x 4 mm² with a tolerance specification for porosity smaller than or equal to 4% are to be handled in a special way. This is not implemented here.

  - Nominal key ≥ 5% (5%, 10%, 15%, 20%): round up in steps of 5%

Examples: 2.1% → 5%; 6.7% →10%

- P 201 only: Porosity that is normally indicated by D can also be described by S → the rounding rules are the same for D and S.
- Nominal key G (equal to D) (G1, G2, …, G9, G10): round up in steps of 1%
  Example: 2.1% → G3; 6,7% → G7

- Diameter (Ø values)
  For this parameter, rounding is only based on the actual value.
  Always round up in steps of 0.5 mm.
  Example: 7.3 mm → 7.5 mm
- Nominal distance (A values)
  For this parameter, rounding is only based on the actual value.
  Always round down to next integer.
  Examples: 1.649 → 1; 1.11 → 1
- Number of pores (F values)
  For this parameter, no rounding is performed but the actual value is shown.
  Example: 11 pores → F11
- Number of pores (Z values)
  For this parameter, no rounding is performed but the actual value is shown.
  Example: 11 pores → Z11

The following examples illustrate the rounding policy for the individual parameters following the VW test specifications PV 6093 and PV 6097:

- For P 202:

  Table 27-5: Examples of the rounding policy according to PV 6093

Nominal porosity key	Porosity analysis result	Result porosity key
VW-%5/Ø2	2.37%, Ø 0.74 mm	VW 50093-%5/Ø1.0
VW-%5/Ø2	2.37%, Ø 1.49 mm	VW 50093-%5/Ø1.5
VW-%4/Ø10	4.61%, Ø 1.49 mm	VW 50093-%5/Ø1.5
VW-%4/Ø10	6.01%, Ø 1.49 mm	VW 50093-%10/Ø1.5
VW-%5/Ø10	6.01%, Ø 1.49 mm	VW 50093-%10/Ø1.5
VW-%4/Ø10	3.99%, Ø 1.49 mm	VW 50093-%4/Ø1.5
VW-%4/A5	3.99%, normalized distance 1.67	VW 50093-%4/A1
VW-%4/A5	3.99%, normalized distance 6.67	VW 50093-%4/A6
VW-Z5	7 pores	VW 50093-Z7

- For P 201:

Table 27-6: Examples of the rounding policy according to PV 6097

Nominal porosity key	Porosity analysis result	Result porosity key
VW-D5/2	2.37%, Ø 0.74 mm	VW 50097-D5/1.0
VW-G5/2	2.37%, Ø 0.74 mm	VW 50097-G3/1.0
VW-S5/2	2.37%, Ø 0.74 mm	VW 50097-S5/1.0
VW-D5/2	2.37%, Ø 1.49 mm	VW 50097-D5/1.5
VW-D5/10	6.01%, Ø 1.49 mm	VW 50097-D10/1.5
VW-D4/10	4.61%, Ø 1.49 mm	VW 50097-D5/1.5
VW-D4/10	6.01%, Ø 1.49 mm	VW 50097-D10/1.5
VW-D4/10	3.99%, Ø 1.49 mm	VW 50097-D4/1.5
VW-D4/A5	3.99%, normalized distance 1.67	VW 50097-D4/A1 (relative diameter is rounded down)
VW-D4/A5	3.99%, normalized distance 6.67	VW 50097-D4/A6 (relative diameter is rounded down)
VW-D10/10	4.01%, Ø 1.49 mm	VW 50097-D5/1.5
VW-F11	12 pores	VW 50097-F12
VW-F11	9 pores	VW 50097-F9

Global parameters Section

If the specified code includes a value for the maximum indication size or the smallest normalized distance, the result of the current analysis will be evaluated accordingly and compared with the values of the specified code. The result is highlighted in the following colors:

- Green: The tolerance is met.
- Red: The tolerance is not met.
- Yellow: A tolerance has been specified but the analysis has to be (re-)calculated. Note that this color will also be used if the entered code is invalid.

The result of the evaluation is also displayed graphically in the Scene Tree. For more information on evaluations, see chapter 46 *Evaluations*.

Table 27-7: Controls of the **Global parameters** section

Control	Description
Diameter [<length unit>] field	Displays the diameter of all pores.
Smallest normalized distance field	Displays the smallest distance between the borders of two adjacent pores.

Both the smallest normalized distance and the largest pore are also shown in the 2D view of the analyzed slice. The smallest normalized distance is displayed as a blue line, while the circumscribed circle of the largest pore (P 201) and the Feret diameter (P 202) are displayed in red.

Reference faces Section

Allows you to create new reference faces for the selected analysis and lists every created reference face in a table.

In order to create a new reference face,

- go to the **Analysis** tab and click **Annotation** or
- click the **Create reference faces** button in the **Reference faces** section.

The **Annotation** contextual tab for creating a new reference face will show up in the ribbon. After the new reference face has been created, a corresponding annotation will be displayed in each 2D window and in the 3D window.

The following controls are available on the contextual tab:

Table 27-8: Controls on the **Annotation** contextual tab

Control	Description
button	Closes the contextual tab.
Name template field	Specifies the template for the annotation name.
Reset button	Resets the name template to the default entry.
Shape drop-down list	Allows you to select an appropriate shape to define reference areas for which the porosity will be calculated: • Square • Circle • Triangle • Rectangle
2D window: hold down **Ctrl** key and use LMB to click and drag, then release LMB	Creates a shape at the desired position in the selected slice.
2D window: use LMB to click and drag the shape	Repositions the shape.
2D window: use LMB to click and drag cyan handle in corner (square or triangle)	Resizes and rotates the shape with respect to corner.
2D window: use LMB to click and drag cyan handle in corner (rectangle)	Resizes the shape.
2D window: hold down **Shift** key and click and drag cyan handle in corner (square or triangle)	Resizes and rotates the shape with respect to center.
2D window: hold down **Shift** key and click and drag cyan handle in corner (rectangle)	Rotates the shape with respect to center.

Control	Description
2D window: use LMB to click and drag highlighted border (circle)	Resizes the shape.

If the **Surface** snap mode is activated, the corners of the square or rectangle will snap to the nearest surface. For more information on snap modes, see section *Snap mode Drop-down List* on page 122 in chapter 6 *Inspect Tab*.

An annotation label of a reference face contains the annotation name, the size of the area covered by the selected shape, the porosity inside the reference face, and the specified maximum tolerance value. If the tolerance is met, the porosity will be highlighted in green. If the tolerance is not met, it will be highlighted in red.

For details on annotations in general, see section *Annotation* on page 124 in chapter 6 *Inspect Tab*.

The **Reference faces** table lists all reference faces created for the selected P 202/P 201 analysis and their properties.The **Reference faces** list consists of the following columns:

Table 27-9: Columns of the **Reference faces** table

Column	Description
Name	Indicates the name of the reference face.
Shape type	Indicates the shape of the reference face.
Pos. x/y/z [<length unit>]	Indicates the center position of the reference face.
Area [<length unit>²]	Indicates the size of the area covered by the selected shape.
Porosity [<ratio unit>]	Indicates the ratio between the area of the pores and the area of the selected reference face.
Pore count	Indicates the number of pores in the selected reference face.
Description	Allows you to enter a description of the reference face used for reporting.
Image	Allows you to add a detailed 2D image and description on a separate page of the report. • **Off**: No image is created (default). • **On**: Creates a detailed 2D image and feature description. • **If not OK**: Automatically includes an image if the tolerance status is **Out of tolerance**.
Focused image	This option is almost identical to the **Image** option but will generate an image that focuses on the respective item and is zoomed in by the **Zoom factor** specified during report creation or VGRF-based export.

Column	Description
Captures	Indicates the number of images captured for this reference face using the **Capture from** button in the **Screenshots** section.
Tolerance status	Indicates the **Tolerance status** of the analysis based on the tolerances specified for the reference faces in the **Code** field of the **Settings** tab: **Valid** (green), **Out of tolerance** (red), or **No tolerance** (gray).

Make sure not to include surrounding air when you define a reference face. This would falsify the results of the analysis.

Colors/Porosity colors Tab

Here you can specify the color-coding scheme used for the representation of the analysis results.

Outline rendering Section

Specifies the rendering of the results of a porosity/inclusion analysis.

Table 27-10: Settings in the **Outline rendering** section

Control	Description
Outline rendering checkbox	When this option is checked, only the outline of the color-coded indications is shown such that the indications will not be covered by the color-coding.
Outline width spin box	Specifies the outline width for the color-coded indications. Note that when increasing the outline width, the outline will grow equally inward and outward. The real outline of the indication lies in the middle of the line.

To visualize the outline of the indications, you can also create a colored mesh by right-clicking the analysis in the Scene Tree and selecting **Convert to > Colored surface mesh from analysis result(s)** from the context menu. The color of the mesh corresponds to the color-coding of the analysis results.

Other Colors Section

Depending on the analysis type, this option is only available when **Uncoded** is selected in the **Active column** field on the **Settings** tab. Double-clicking the **Uncoded indications** field opens the **Select Color** dialog, where you can set the color for the detected indications. All indications will be shown in this color.

Pores Tab

The **Pores** table lists all pores detected by the selected P 202/P 201 analysis. Each pore selected in the table is marked with red cross-hairs in each of the slice views.

You can also access any pore within the table by clicking it.

The **Pores** table consists of the following columns:

Table 27-11: Columns of the **Pores** table

Column	Description
Center x/y/z [<length unit>]	Indicates the center position of the circumscribed circle around the pore.
Diameter [<length unit>]	For P 201: Displays the diameter of the circumscribed circle around the pore. For P 202: Displays the maximum diameter as the Feret diameter.
Equivalent diameter [<length unit>]	For P 202: Displays the diameter of a circle of equal area of the corresponding pore.
Description	Allows you to enter a description of the pore used for reporting.
Image	Allows you to add a detailed 2D image and feature description on a separate page of the report. • **Off**: No image is created (default). • **On**: Creates a detailed 2D image and feature description. • **If not OK**: Automatically includes an image if the tolerance status is **Out of tolerance**.
Focused image	This option is almost identical to the **Image** option but will generate an image that focuses on the respective item and is zoomed in by the **Zoom factor** specified during report creation or VGRF-based export.
Captures	Indicates the number of images captured using the **Capture from** button in the **Screenshot** section.

General Table Controls

- List section

  The following table provides an overview of the general controls available in the various list views:

Table 27-12: Controls in the list section

Control	Description
button	Opens a submenu for selecting the filter/search mode.
Filter	Clicking the **Click to add a filter or search criterion** field to the right of the icon opens a series of drop-down lists from which you can select a table column, an operator, and—depending on the column—a value. If a column does not offer a value drop-down list, you can type in a value. When the selection is complete, the table shows the rows matching the filter criterion. Clicking the **+** button or the **Click to add a filter or search criterion** field allows you to specify more filter criteria. Clicking the **x** button removes the filter.
Search	Clicking the **Click to add a filter or search criterion** field to the right of the icon opens a series of drop-down lists from which you can select a table column, an operator, and—depending on the column—a value. If a column does not offer a value drop-down list, you can type in a value. When the selection is complete, the table rows matching the search criterion are highlighted. Clicking the **+** button or the **Click to add a filter or search criterion** field allows you to specify more search criteria. Pressing **F3** jumps to the next search result in the list. Clicking the **x** button removes the search.
Full-text filter	Entering a value or text string into the input field to the right of the icon filters the table accordingly and shows the rows that match the filter criterion.
Full-text search	Entering a value or text string into the input field to the right of the icon searches the table accordingly and highlights the rows that match the search criterion.
use LMB to click on a table row	Selects the row and the corresponding object in the Scene Tree. In analysis result lists, the result, e.g., the component, is marked by a cross-hairs cursor in each of the 2D views.
hold **Ctrl** key + use LMB to click on several table rows	Selects the rows and the corresponding objects in the Scene Tree.

Control	Description
hold **Shift** key + use LMB to click on two separate table rows	Selects the two rows, including all rows between the two as well as the corresponding objects in the Scene Tree.
hold **Shift** key + use up/down arrow keys	Selects the rows and the corresponding objects in the Scene Tree.
press **Ctrl+A**	Selects all table rows.
use up and down arrow keys	Steps up and down through the table rows.
use RMB to click into the table area	Displays a context menu. See below.
use LMB to click a column heading	Sorts the table according to the values of the column. Clicking subsequently toggles between ascending and descending.
use LMB to click and drag column heading to new position, then release LMB	Inserts the column at the new position.
use LMB to double-click cell highlighted in white (light theme) or medium gray (dark theme)	If applicable: Allows you to edit the contents of the cell.

- **Screenshots** section (if available)

  The **Screenshots** section below the list section allows you to capture images from one of the 2D windows, the 3D window, or the current window layout for the item currently selected in the table. Only available if exactly one row is selected.

  Table 27-13: Controls in the **Screenshots** section

Control	Description
Capture from button	Adds the image of the view selected from the drop-down list to the preview area above.
use LMB to click and drag one or more images, then release LMB	Moves the image(s) to the new position.
double-click the image	Opens the **Snapshot display** window showing the image: • **Zoom in**/**Zoom out** button: Zooms the image in/out. You can also move the mouse pointer in the image area and turn the mouse wheel. • **Fit to window** button: Resets the zoom so that the image fits into the window.
click the **<no description>** placeholder twice (first click to select, second click to enable renaming)	Allows you to label the image.

Control	Description
Delete selected button	Deletes the selected image from the preview area.

Table Context Menu

Right-clicking anywhere in the table area shows a context menu with the following options:

Table 27-14: Context menu items

Control	Description
Columns	Allows you to toggle the visibility of each column by checking/unchecking the respective item. • **Show all**: Checks all columns to set them to visible. • **Hide all**: Unchecks all columns to set them to invisible. • **Hide empty**: Unchecks all not editable columns which are empty or **n/a** to set them to invisible.
Trim columns	Resizes all columns to their smallest possible size.
Apply default column layout	Applies the default column layout previously saved by the user to the current table. If no default column layout has been saved, the original column layout will be applied.
Save as default column layout	Saves modifications applied to the table—e.g., the visibility of a column, the order in which the columns appear, the column width—as default column layout. This layout will be applied when you create a new project.
Apply original column layout	Restores the original table layout and discards any modifications applied by the user. The original table layout is predefined and cannot be modified by the user.
Remove entries	If applicable: Deletes the selected row(s) from the table.
Create annotations	If applicable: Creates annotations for the selected items.
Export as CSV...	Opens the **Export as CSV...** dialog for exporting the table values as **.csv* file. This option always exports the complete table even if a filter was applied. In order to export only the filtered rows, press **Ctrl** + **A** to highlight all filtered rows and use the **Copy to clipboard** menu item.

Control	Description
Copy to clipboard	Copies the selected rows as well as the column heading into the system clipboard. The clipboard information is provided both as plain text and rich-text table, so when pasting into a rich-text-capable application like a word processor, you will see a proper table with cell borders and bold headings.
Paste	For annotation tables: Pastes previously copied coordinates and—optionally—snap directions to create new annotations in the table. For annotations of a nominal/actual comparison, the search distance specified on the **Settings** tab of the analysis will be considered. Note: Pasted annotations will be interpreted in the selected coordinate system at the time of pasting. The information in the clipboard must have the following structure: • x-, y-, and z-coordinate of the annotation or • x-, y-, and z-coordinate of the annotation as well as x-, y-, and z-component of the vector for the snap direction The parameters can be separated by space, tab, semicolon, or comma (if a comma is already used as a decimal mark or digit grouping symbol, the values must be enclosed in double quotation marks). Example: 8.89;25.82;-0.55;1;0;0 You can also copy the information directly from the cells of a spreadsheet. In order to paste the annotation information, you can also press the **Ctrl** + **V** keyboard shortcut.
Set as active column	If applicable: Makes the current column the active column, i.e., the results of this column are color-coded according to their values as defined by the color lookup table and the colors specified in the **Sections** section of the **Colors** tab.
Unset active column	If applicable: Deselects the currently active column and sets the **Active column** drop-down list on the corresponding **Settings** tab to **Uncoded**, i.e., removes any color coding.
Enter/change value (all items)	If applicable: Opens the **Enter value** dialog (see below) where you can enter the desired value for the selected parameter. This value will be applied to all entries in the table.

Control	Description
Enter/change value (selected items)	If applicable: Opens the **Enter value** dialog (see below) where you can enter the desired value for the selected parameter. This value will be applied to the selected entries in the table.
Delete selected items	If applicable: Removes the selected items from the scene.

The **Enter value** dialog includes the following controls:

Table 27-15: Controls in the **Enter value** dialog

Control	Description
Enter value field	Allows you to enter the desired value.
OK button	Sets the selected parameter to the specified value.
Reset button	For analyses only: Resets the selected parameter to undefined.
Set from tolerance settings button	For analyses only: Enters the value specified in the tolerance settings of the analysis for the selected parameter.
Cancel button	Discards the changes and closes the dialog.

Images Tab

Allows you to take screenshots of the selected workspace views and/or add bookmark references to the report. In the final report, the captured images will be listed separately from the screenshots created on other tabs.

- **Snapshots** section

  Table 27-16: Controls in the **Snapshots** section

Control	Description
Capture from button	Adds the image of the view selected from the drop-down list to the preview area above.
Delete selected button	Deletes the selected image(s) from the preview area.
use LMB to click and drag one or more images, then release LMB	Moves the image(s) to the new position.

Control	Description
double-click the image	Opens the **Snapshot display** window showing the image: • **Zoom in**/**Zoom out** button: Zooms the image in/out. You can also move the mouse pointer on the image area and turn the mouse wheel. • **Fit to window** button: Resets the zoom so that the image fits into the window.
click the **<no description>** placeholder twice (first click to select, second click to enable renaming)	Allows you to label the image.

- **Automatic 3D images** section (if available)

  Check the corresponding checkbox to include the desired 3D view (e.g., **Top**, **Front**, **Top-left-front**, and **Current camera settings**) in the report without changing the 3D view.

- **Bookmark references** section

  Allows you to add bookmark references via drag and drop from the **Bookmarks and views** tool or the **Bookmark editor** to the preview area. The images of the referenced bookmarks will then be included in VGRF-based reports.

  When you open a project with missing bookmark images, placeholders will be shown instead.

  Bookmark references are stored in evaluations and can be used in automation scenarios.

☞ You will still need to import a bookmark template containing the actual bookmarks in these cases, as evaluations store only references to them.

Table 27-17: Controls in the **Bookmark references** section

Control	Description
New bookmark button	Adds a bookmark of the current view to the preview area.
Remove button	Removes the bookmark currently selected in the preview area.
click the bookmark title twice (first click to select, second click to enable renaming) or press the **F2** key	Allows you to rename the bookmark. The changes made on the **Images** tab will also affect the **Bookmark editor** and the **Bookmarks and views** tool. If the renamed bookmark is referenced by one or more objects for reporting, a warning message will be displayed indicating that the referenced bookmark will also be renamed for all these objects in the report.

The global concept of bookmark references allows for multiple objects to reference the same bookmark and for objects to reference bookmarks that show arbitrary information, e.g., other analyses or objects.

Nominal/Actual Comparison

Introduction

The **Nominal/actual comparison** is designed for comparing volume data sets, CAD models, and surface meshes to each other. As a result of this analysis, the user will get a detailed report on the detected deviations as well as a false-color coded data set for documentation purposes.

License Information

This analysis is part of an optional add-on module for VGSTUDIO MAX. It is not available for myVGL. However, if a project loaded in myVGL contains an analysis, its results can be viewed and reported in myVGL.

If you are interested in a more comprehensive functionality than the one offered by myVGL, you have the chance to evaluate VGSTUDIO MAX. You can request an evaluation license of VGSTUDIO MAX on our website:

https://volumegraphics.hexagon.com/en/products/evaluation

For further questions about our product portfolio, please contact us:

- For Europe, Middle East, and Africa:
  Write an e-mail to sales@volumegraphics.com or call +49 6221 73920 744.
- For Japan:
  Write an e-mail to sales@volumegraphics.jp or call +81 52 508 9682.
- For the Americas:
  Write an e-mail to sales-us@volumegraphics.com or call +1 704 248 7736.
- For China, including Mainland China, Hong Kong, Macao, and Taiwan:
  Write an e-mail to sales@volumegraphics.cn or call +86 10 8532 6305.
- For Singapore and other parts of Asia (except China and Japan), Australia, and parts of Oceania:
  Write an e-mail to sales@volumegraphics.sg or call +65 6665 0310.

Opening the Dialog

In order to open the **Nominal/actual comparison** dialog,

- right-click the corresponding entry in the Scene Tree and select **Properties** from the context menu or
- double-click the corresponding entry in the Scene Tree.

The **Nominal/actual comparison** dialog consists of several tabs on which you can view the results of the nominal/actual analysis.

To close the dialog, click the **Close** button at the bottom of the dialog.

A status bar at the bottom of the dialog indicates the current status of the analysis. The status can be one of the following:

Table 28-1: Messages in the status bar

Status	Description
Result is up to date	The current analysis result is valid.
Calculation required	All required parameters have been specified and are consistent, but the analysis was not calculated or was invalidated by some user action before the project was saved.
Actual object has no surface determination	No surface determination information is available for the actual object. See also section *Surface determination* on page 949 in chapter 48 *Glossary*.
Nominal object has no surface determination	No surface determination information is available for the nominal object. See also section *Surface determination* on page 949 in chapter 48 *Glossary*.
Deviation interval: Max. value must be larger than min. value	The **Calculate components** option has been checked, but the maximum value of the **Deviation interval** is smaller than the minimum value. Specify a larger maximum value (or a smaller minimum value) or uncheck the **Calculate components** option.
Deviation interval: Max. value must be larger than min. value	The **Calculate components** option has been checked, but the maximum value of the **Deviation interval** is smaller than the minimum value.
Manual changes to result	One or more components have been manually deleted.
License missing	The add-on module is not licensed.

An invalid or outdated status of an analysis will be indicated in the Scene Tree by a warning sign. Double-click the analysis to open it and check the status bar for messages.

The units of the dialog depend on the global unit settings (see section *Units Drop-down List* on page 33 in chapter 2 *Workspace*).

Settings Tab

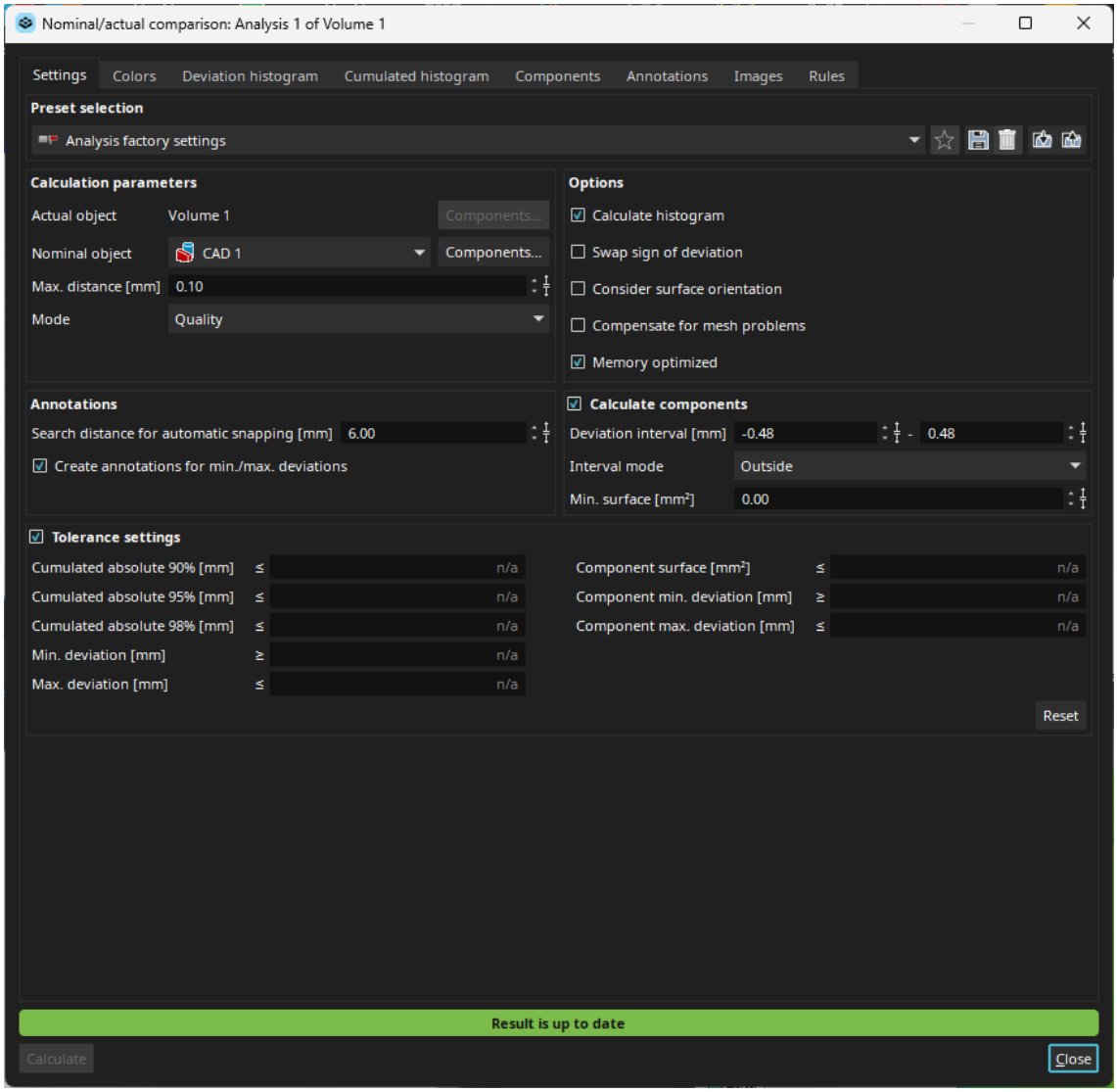


Figure 28-1: **Nominal/actual comparison** dialog, **Settings** tab

☞ In myVGL, all parameter settings are displayed. Most of these parameters are read-only in myVGL. The complete functional range is available with VGSTUDIO MAX and the respective add-on module(s).

Preset selection Section

Table 28-2: Controls in the **Preset selection** section

Icon	Item	Description
	drop-down list	Specifies the preset to be applied, to be edited, or to be taken as a basis for a new preset. The following icons are used: • analysis factory settings • customized preset • appears next to the icon of a preset that has been modified but not yet saved
	Set this preset as default	Sets the selected preset as default. The default preset will be applied when creating a new analysis of the same type. If the selected preset is already set as default, the button is disabled.
	Save preset	Saves the selected preset. When saving a preset, the **Save preset** dialog will open, which allows you to set the new preset as default by checking the **Set as default for new analyses** checkbox.
	Remove preset	Removes the selected preset from the preset drop-down list. If the removed preset is the default preset, the next time an analysis of the same type is created, the factory settings will be used.
	Import preset	Imports a preset from the specified location.
	Export preset	Exports the selected preset to the specified location.

The **Nominal object** parameter is not included in the preset.

Calculation parameters Section

Table 28-3: Controls in the **Calculation parameters** section

Control	Description
Actual object field	Indicates the object for which the nominal/actual comparison is to be performed.
Nominal object drop-down list	Specifies the object against which the actual object will be compared.

Control	Description
Components... buttons	These buttons are enabled when the **Actual object** or the **Nominal object**, respectively, is an object with components. Clicking them opens a dialog box where you can specify the components to be used for the comparison: • Checkbox of component: Clicking it checks/unchecks the component, including all child components. • **Select all** button: Selects all components of the object. • **Deselect all** button: Deselects all components of the object. • **Apply visibility** button: Selects all components that are set to visible in the Scene Tree. For volume objects that consist of several volume components, the analysis will be based on the outer surface of all united components unless otherwise specified in the **Components** option.
Max. distance [<length unit>] spin box	The surface of the nominal object can be either above or below the surface of the actual object within a certain distance. This field determines the distance for searching for the surface of the nominal object. For color-coding, deviations above **+Max. distance** or below **-Max. distance** are represented by the entry **+inf** or **-inf** in the **Colors** tab. In the tables and annotations, this is indicated by “>= <**Max. distance** value>” or “<= -<**Max. distance** value>,” e.g., “>= 0.40 mm” or “<= -0.40 mm.”
Mode drop-down list	Specifies the resolution for the comparison: • **Oversampling**: The resolution is higher than the resolution of the data set. • **Quality**: The resolution is the same as the data set resolution. • **Performance**: The resolution is lower than the resolution of the data set. • **Preview**: A fixed resolution will be used, independently of the data set resolution. This mode is meant to obtain a quick visual impression of the nominal/actual comparison. Therefore, no histograms, no components, and no minimum or maximum deviations will be calculated. This setting affects the time and system memory required for performing the analysis.

Annotations Section

Table 28-4: Controls in the **Annotations** section

Control	Description
Search distance for automatic snapping spin box	Specifies the distance from the position of the annotation for searching for the surface in the snap direction when pasting or importing annotations in the Scene Tree or in the **Annotations** table or when importing an evaluation template.
Create annotations for min./max. deviations checkbox	When this option is checked, the minimum and maximum signed deviations of the actual object from the nominal object as well as the positions where the deviations occur will be calculated and shown as annotations at the corresponding positions in the 3D window, the 2D windows, and the Scene Tree.

Options Section

Table 28-5: Controls in the **Options** section

Control	Description
Calculate histogram checkbox	When this option is unchecked, no histograms, no minimum or maximum deviations, and no annotations for min./max. deviations will be calculated.
Swap sign of deviation checkbox	If the surface of the nominal object is below the surface of the actual object, the deviation between the two surfaces is positive. If the surface of the nominal object is above the surface of the actual object, the deviation is negative. If both surfaces match, the deviation is zero. Checking this option inverts the deviation value. The deviation must be between ± **Max. distance**. Deviations above or below ± **Max. distance** are represented by the entry **±inf** in the **Colors** tab.
Consider surface orientation checkbox	Ensures that the nominal/actual comparison is only performed between surfaces that have a similar surface orientation.
Compensate for mesh problems checkbox	Relevant if the nominal object is a CAD model or surface mesh: When this option is checked, the inner/outer discrimination will be improved to compensate for flaws, e.g., incorrect or missing normal information, holes in the mesh, or parts with adjacent surfaces.
Memory optimized checkbox	If this option is unchecked, the deviation values will be stored more precisely, which will produce more precise results at the cost of higher memory consumption.

Calculate components Section

Table 28-6: Controls in the **Calculate components** section

Control	Description
Calculate components checkbox	When this option is checked, components will be calculated and the corresponding controls will be enabled.
Deviation interval [<length unit>] spin boxes	Define the lower and upper limit of the permissible deviation of the components from the nominal object.
Interval mode drop-down list	Allows you to further specify the permissible values for the components: • **Outside**: Either below the lower or above the upper limit. • **Inside**: Between lower and upper limit. • **Left**: Below the lower limit. • **Right**: Above the upper limit.
Min. surface [<length unit>²] spin box	Discounts all components with surfaces smaller than this value.

Tolerance settings Section

Tolerance values will be interpreted according to DIN EN ISO 8015 (see also section *Rounding Rules* on page 4 in chapter 1 *Welcome*).

Table 28-7: Controls in the **Tolerance settings** section

Control	Description
Tolerance settings checkbox	Checking this option allows you to define and apply the corresponding tolerance settings.
Cumulated absolute 90% [<length unit>] ≤ field	Specifies the maximum permissible absolute deviation for 90% of the analyzed surface.
Cumulated absolute 95% [<length unit>] ≤ field	Specifies the maximum permissible absolute deviation for 95% of the analyzed surface.
Cumulated absolute 98% [<length unit>] ≤ field	Specifies the maximum permissible absolute deviation for 98% of the analyzed surface.
Min. deviation [<length unit>] ≥ field	Specifies the minimum permissible deviation of the actual object from the nominal object.
Max. deviation [<length unit>] ≤ field	Specifies the maximum permissible deviation of the actual object from the nominal object.
Component surface [<length unit>²] ≤ field	Specifies the maximum permissible value for the area of the components.

Control	Description
Component min. deviation [<length unit>] ≥ field	Specifies the minimum permissible deviation of the components from the nominal object.
Component max. deviation [<length unit>] ≤ field	Specifies the maximum permissible deviation of the components from the nominal object.
Reset button	Deletes all tolerance settings.

Depending on the results of this evaluation, the tolerances on the **Settings** tab will be highlighted in the following colors:

- Green: The tolerance is met.
- Red: The tolerance is not met.
- White (light theme)/black (dark theme): No tolerance settings have been specified or they are deactivated.
- Yellow: A tolerance has been specified but the analysis has to be (re-)calculated. Note that this color will also be used if the entered tolerance value is invalid.

The result of the evaluation is also displayed graphically in the Scene Tree. For more information on evaluations, see chapter 46 *Evaluations*.

Colors Tab

Here you can specify the color-coding scheme used for the representation of the analysis results.

Caption Section

Table 28-8: Controls of the **Caption** section

Control	Description
Caption field	Indicates the color bar headline as specified in the **Caption** field of the **Color bar** section.
Share color bar checkbox	When this option is checked, all analyses of the same type (and—if applicable—of the same algorithm) will use the same color bar. When this option is unchecked, the color bar settings will apply to the selected analysis only.

LUT – Color Lookup Table

The color lookup table (LUT) shows the partitioning into color sections.

Sections Section

Defines the appearance of each color section.

Table 28-9: Controls in the **Sections** section

Control	Description
From/To fields	Specify the start and end values of the color sections. The first color section represents all values above the upper limit, i.e., the value in the **From** field (**+inf** signifies positive infinity), while the last color section represents all values below the lower limit, i.e., the value in the **To** field (**-inf** signifies negative infinity). The default limits are calculated from the results of the analysis (for an analysis color bar) or taken from the **Default** preset (for a tolerance deviation color bar).
Type field	Switches between the color schemes **Continue**, **Constant**, **Gradient**, **Rainbow**, **Reverse rainbow**, **Hue cycle**, **Green to red**, and **Red to green**.
Color/transparency field	Double-clicking the field for the **Continue**, **Constant**, and **Gradient** color schemes opens the **Select Color** dialog where you can modify the appearance of the selected color scheme. For the **Gradient** color scheme, you can specify the start and end colors by double-clicking the left or right side of the field, respectively. Double-clicking the field for the **Rainbow**, **Reverse rainbow**, **Hue cycle**, **Green to red**, and **Red to green** color schemes opens the **Transparency** dialog, where you can set the transparency for the selected color scheme.
use RMB to click a color section	Opens a context menu with the following items: • **Split**: Subdivides the color section into two new color sections where each represents half of the original section. • **Merge**: Combines several color sections to a single color section. Only consecutive intervals can be merged.
Create smooth button	Opens the **Create smooth table** dialog to generate one color section. • **Type** drop-down list: Allows you to select the type of coloring scheme. • **From/To** spin boxes: Specify the value range covered by the color section.

Control	Description
Create stepped button	Opens the **Create stepped table** dialog to generate a set of color sections. • **Type** drop-down list: Allows you to select the type of coloring scheme. • **From/To** spin boxes: Specify the value range covered by the color sections. • **Step** spin box: Specifies the step size of the individual color sections.
Auto scale button	If available: Fits the color LUT to the range of the results of all available analyses.
Auto scale color bar range on calculate checkbox	If available: When this option is checked, the color LUT will be automatically fitted to the range of the results of all available analyses.
Default button	If available: Resets any changes made to the **Sections** table.

Preset selection Section

Table 28-10: Controls in the **Preset selection** section

Icon	Item	Description
	drop-down list	Specifies the preset to be applied, to be edited, or to be taken as a basis for a new preset. The following icons are used: • default preset • customized preset • appears next to the icon of a preset that has been modified but not yet saved
	Save preset	Opens the **Save preset** dialog for saving the color LUT of the current data set under the specified name. • **Absolute preset**: When this option is checked and the preset applied, the settings of the original data set, including the LUT range, will be applied. When this option is unchecked, the color settings of the preset will be mapped relatively to the actual range of results of the analysis to which the preset will be applied.
	Remove preset	Removes the selected preset from the preset drop-down list.
	Import preset	Imports a preset from the specified location.
	Export preset	Exports the selected preset to the specified location.

Render hairlines Section

Defines the appearance of the deviation hairlines.

Table 28-11: Controls in the **Render hairlines** section

Control	Description
Length scale spin box	Defines the length of the hairlines.
Distance mode drop-down list	Defines the mode for specifying the distance between the hairlines: • **Display relative**: The distance (in pixels) between the hairlines is relative to the screen, i.e., the distance remains the same when you zoom in or out. • **Scene relative**: The distance (in physical units, e.g., mm) between the hairlines is relative to the scene, i.e., the distance changes when you zoom in or out.
Distance spin box	Allows you to specify the distance between the hairlines.

Color LUT Settings Section

Specifies the appearance of the color lookup table.

Table 28-12: Options for the appearance of the color lookup table

Control	Description
Auto tick marks checkbox	When this option is checked, equidistant tick marks will be produced for the color bars. When this option is unchecked, tick marks will appear only at the color section boundaries of the color lookup table.
Auto scale color bar range on calculate checkbox	When this option is checked, the color LUT will be automatically fitted to the range of the results of all available analyses.

Color bar Section

Specifies the settings for the color bar.

Table 28-13: Settings for the color bar

Control	Description
Visibility drop-down list	Switches the color bar on/off.
Positioning drop-down list	Specifies the location of the color bar within the 2D and 3D windows: **Left, Right, Top, Bottom, All - automatic, Left or right - automatic, Top or bottom - automatic**.

Control	Description
Caption field	Specifies the color bar headline by using placeholders.
Reset button	Resets the **Caption** field to the default entry.

Visualization options Section

When the **Show components only** option is checked, the color-coded results will only be displayed for the components. Results that are not included in a component will not be displayed.

If all or no components are selected, their color overlays will be shown with the transparency level of the parent object and no hairlines will be shown. If only some components are selected, their color overlays will be shown with the transparency level of the parent object and the hairlines will be shown, while those of components that are not selected will be shown more transparently and their hairlines will not be shown.

Annotations Section

The **Color mode** drop-down list specifies the color of the analysis annotation:

- **Tolerance status**: Colors the annotations according to the tolerance status at this position.
- **As lookup table**: Colors the annotations according to their values (e.g., indication volume, deviation, wall thickness) at this position.

Deviation histogram Tab

Shows a histogram of the calculated deviations for the entire analyzed surface of the selected object. The histogram bars can be colored according to the settings on the **Colors** tab. A bin at the minimum or maximum deviation indicates the surface areas for which the deviations fall below or exceed the **Max. distance** value.

Controls of the **Deviation histogram** Tab

Table 28-14: Controls of the **Deviation histogram** tab

Control	Description
Color drop-down field	• **From color bar**: The values in the histogram are shown according to the color bar. • **Gray**: All values in the histogram are shown in gray.
Normalization drop-down field	• **Absolute**: Displays the surface in absolute values. • **Relative**: Displays the surface in relative values with respect to the entire analyzed surface.

Control	Description
Binning drop-down field	• **Off**: No binning is applied to the values shown in the histogram. • **From color bar**: The original values in the histogram are replaced by a value that represents the corre-sponding interval (“bin”) of the color bar. The “bins” become visible when “stepped” sections are created on the **Colors** tab. • **Manual number of bins**: Enables the **Bin count** spin box, where you can enter the required number of “bins.” • **Manual bin width**: Enables the **Bin width** spin box, where you can specify the width of the bins.
Left/**Right** spin box	Only enabled when an interval has been created: Moves the left or right interval border to the specified value. You can also click and drag the interval borders by using the left mouse button.
Create button	Creates a new interval. On the right hand side of a selected interval, statistical information is displayed: • **Left**: Indicates the minimum deviation within the interval, i.e., the value of the left interval border. • **Right**: Indicates the maximum deviation within the interval, i.e., the value of the right interval border. • **Mean**: Indicates the mean value of the deviations within the interval. • **Dev**: Indicates the standard deviation of the devia-tions within the interval. • **Sum**: Indicates the surface area within the interval. • **Percentage**: Indicates the percentage of the surface area within the interval. Note that the statistical information may change with the number of bins.
Remove button	Removes the selected interval.
Min./Max. deviation [<length unit>] fields	Indicate the minimum and maximum deviations between actual object and reference object.
use RMB to click the chart area	Displays a context menu (see below).
scroll MW in chart area or x-axis up/down	Zooms the x-axis of the chart out/in.
scroll MW in y-axis up/down	Zooms the y-axis of the chart out/in.
use LMB to click and drag the x-axis	Scrolls the x-axis.
use LMB to click and drag the y-axis	Scrolls the y-axis.

Control	Description
Zoom in/out	Zooms the corresponding axis in/out.
Reset zoom	Fits the entire chart to the current window size.

Context Menu of the **Deviation histogram** Tab

Right-clicking anywhere in the chart area opens a context menu with the following options:

Table 28-15: Context menu items

Control	Description
Export as CSV...	Opens a dialog for saving the chart values to a *.csv* file.
Copy to clipboard	Copies a screenshot of the chart to the system clipboard so that you can paste it into another application.
Show/Hide x/y grid	Toggles the visibility of the grid lines for the corresponding axis.
Reset zoom	Fits the entire chart to the current window size.
Create interval	Creates a new interval. For details on the statistical information, see section *Controls of the Deviation histogram Tab* on page 422.
Remove interval	Removes the selected interval.

Cumulated histogram Tab

Displays the cumulated surface area (in absolute or relative values) for a certain deviation value. The value is derived from the histogram data. You can use the **Cumulated deviation distribution** curve to answer questions like “What percentage of the analyzed surface differs less than x mm from the nominal value?” or, conversely, “What is the smallest deviation that ninety percent of the analyzed surface does not exceed?”

Controls of the **Cumulated histogram** Tab

Table 28-16: Controls of the **Cumulated histogram** tab

Control	Description
Cumulation drop-down field	• **Absolute**: Shows the statistics for all deviations as a function of their absolute numerical deviation. • **Only positive**: Shows the statistics for positive deviations. • **Only negative**: Shows the statistics for negative deviations.

Control	Description
Normalization drop-down field	• **Absolute**: Displays the surface in absolute values. • **Relative**: Displays the surface in relative values with respect to the entire analyzed surface.
Abs. deviation/Pos. deviation/Neg. deviation [<length unit>] spin box	Indicates the deviation value that corresponds to the cumulated surface area with the deviation indicated in the **Surface** field. You can also specify a deviation value for which you want to obtain the corresponding surface area. This control is synchronized with the green cross-hairs that indicate the corresponding position on the curve.
Surface/Normalized surface [<ratio unit>] spin box	Indicates the cumulated surface area that corresponds to the deviation value indicated in the **Abs. deviation/Pos. deviation/Neg. deviation** field. When the value for **Abs. deviation** has been set to **Max. distance**, the entire surface area of the object will be indicated in the **Surface** field. You can also specify a surface area value for which you want to obtain the maximum deviation value. This control is synchronized with the green cross-hairs that indicate the corresponding position on the curve.
Cumulated absolute 90%/95%/98% [<length unit>] fields	Indicate the maximum absolute deviation values for 90%, 95%, or 98% of the analyzed surface, respectively.
use LMB to click and drag green cross-hairs lines	Moves the green cross-hairs along the curve, which indicates the percentage of the analyzed surface within a given deviation (or, alternatively, the maximum deviation for a given percentage).
use RMB to click the chart area	Displays a context menu (see below).
scroll MW in chart area or x-axis up/down	Zooms the x-axis of the chart out/in.
scroll MW in y-axis up/down	Zooms the y-axis of the chart out/in.
use LMB to click and drag the x-axis	Scrolls the x-axis.
use LMB to click and drag the y-axis	Scrolls the y-axis.
Zoom in/out	Zooms the corresponding axis in/out.
Reset zoom	Fits the entire chart to the current window size.

Context Menu of the **Cumulated histogram** Tab

Right-clicking anywhere in the chart area opens a context menu with the following options:

Table 28-17: Context menu items

Control	Description
Export as CSV…	Opens a dialog for saving the chart values to a *.csv* file.
Copy to clipboard	Copies a screenshot of the chart to the system clipboard so that you can paste it into another application.
Show/Hide x/y grid	Toggles the visibility of the grid lines for the corresponding axis.
Reset zoom	Fits the entire chart to the current window size.

Components Tab

Lists all existing components and their properties.

The **Components** table consists of the following columns:

Table 28-18: Columns of the **Components** table

Column	Description
Pos. x/y/z [<length unit>]	Indicates the position of the largest deviation of the component.
Component surface [<length unit>²]	Indicates the total surface of the component.
Component min./max. deviation [<length unit>]	Indicates the minimum/maximum deviation calculated for the component.
Description	Allows you to enter a description for the component used for reporting.

Column	Description
Image	Allows you to add a detailed 2D image and object description on a separate page of the report. • **Off**: No image is created (default). • **Orthographic projection**: Creates three orthogonal views. • **Top/Bottom/Left/Right/Front/Back**: Creates a single 2D view in the specified orientation. • **... - If not OK**: Automatically creates the image if the tolerance status is **Out of tolerance**. The image orientation corresponds to the currently selected coordinate system. The image will be generated according to the render settings specified during report creation or VGRF-based export. The 2D slice position used for taking the image is determined by the position of the component. The zoom factor of the image is chosen so that the entire parent volume object, CAD model, or surface mesh is visible.
Focused image	This option is almost identical to the **Image** option but will generate an image that focuses on the respective item and is zoomed in by the **Zoom factor** specified during report creation or VGRF-based export.
Captures	Indicates the number of images that were captured for this component with the **Capture from** button in the **Screenshots** section.
Tolerance status	Indicates the tolerance status of the component depending on the tolerances specified for the components in the **Tolerance settings** section of the **Settings** tab: **Valid** (green), **Out of tolerance** (red), or **No tolerance** (gray).

If a column shows a parameter for which a tolerance has been specified (see section *Tolerance settings Section* on page 417), each entry will be evaluated separately according to the specified tolerance and highlighted in the following colors:

- Green: The tolerance is met.
- Red: The tolerance is not met.

Annotations Tab

Lists all annotations created for the selected nominal/actual analysis. You can view the information supplied by the annotations or edit the annotation properties.

For details on how to create an annotation, see section *Annotation* on page 124 in chapter 6 *Inspect Tab*.

To create new annotations in the table, it is also possible to paste previously copied coordinates and (optionally) snap directions by right-clicking the table and selecting **Paste** from the context menu or pressing the **Ctrl** + **V** keyboard shortcut. For details, see the **Paste** menu item in section *Table Context Menu*.

Double-clicking an analysis annotation in the Scene Tree will directly open the **Annotations** tab of the properties dialog of the corresponding analysis.

Tolerance values will be interpreted according to DIN EN ISO 8015 (see also section *Rounding Rules* on page 4 in chapter 1 *Welcome*).

The **Annotations** table consists of the following columns:

Table 28-19: Columns of the **Annotations** table

Column	Description
Name	Indicates the name of the annotation.
Pos. x/y/z [<length unit>]	Indicates the position of the annotation.
Deviation [<length unit>]	Indicates the deviation of the actual object from the nominal object at the current annotation position. If an individual tolerance has been specified in the **Min./Max. deviation** fields of the **Annotations** table, the annotation will be evaluated accordingly, and the **Deviation** field will be highlighted in the following colors: • Green: The tolerance is met. • Red: The tolerance is not met.
Min./Max. deviation [<length unit>]	Allows you to specify individual tolerance values (i.e., the minimum/maximum permissible deviations between the actual and nominal object) for the corresponding annotation. This setting is independent of the **Min./Max. deviation** settings specified in the **Tolerance settings** section of the **Settings** tab.
Description	Allows you to enter a description of the annotation used for reporting.

Column	Description
Image	Allows you to add a detailed 2D image and object description on a separate page of the report. • **Off**: No image is created (default). • **Orthographic projection**: Creates three orthogonal views. • **Top/Bottom/Left/Right/Front/Back**: Creates a single 2D view in the specified orientation. • **... - If not OK**: Automatically creates the image if the tolerance status is **Out of tolerance**. The image orientation corresponds to the currently selected coordinate system. The image will be generated according to the render settings specified during report creation or VGRF-based export. The 2D slice position used for taking the image is determined by the position of the annotation. The zoom factor of the image is chosen so that the entire parent volume object, CAD model, or surface mesh is visible.
Focused image	This option is almost identical to the **Image** option but will generate an image that focuses on the respective item and is zoomed in by the **Zoom factor** specified during report creation or VGRF-based export.
Captures	Indicates the number of images that were captured for this object with the **Capture from** button in the **Screen-shots** section.
Tolerance status	Indicates the tolerance status at the position of the annotation if an individual tolerance has been specified in the **Min./Max. deviation** fields of the **Annotations** table: **Valid** (green), **Out of tolerance** (red), or **No tolerance** (gray).
Type	Indicates how the annotation has been created: • **Automatic**: The annotation has been automatically created via the **Create annotations for min./max. deviations** option on the **Settings** tab. • **Manually defined**: The annotation has been defined by the user. • **Rule based**: The annotation has been created by a report rule.

General Table Controls

- List section

The following table provides an overview of the general controls available in the various list views:

Table 28-20: Controls in the list section

Control	Description
button	Opens a submenu for selecting the filter/search mode.
Filter	Clicking the **Click to add a filter or search criterion** field to the right of the icon opens a series of drop-down lists from which you can select a table column, an operator, and—depending on the column—a value. If a column does not offer a value drop-down list, you can type in a value. When the selection is complete, the table shows the rows matching the filter criterion. Clicking the **+** button or the **Click to add a filter or search criterion** field allows you to specify more filter criteria. Clicking the **x** button removes the filter.
Search	Clicking the **Click to add a filter or search criterion** field to the right of the icon opens a series of drop-down lists from which you can select a table column, an operator, and—depending on the column—a value. If a column does not offer a value drop-down list, you can type in a value. When the selection is complete, the table rows matching the search criterion are highlighted. Clicking the **+** button or the **Click to add a filter or search criterion** field allows you to specify more search criteria. Pressing **F3** jumps to the next search result in the list. Clicking the **x** button removes the search.
Full-text filter	Entering a value or text string into the input field to the right of the icon filters the table accordingly and shows the rows that match the filter criterion.
Full-text search	Entering a value or text string into the input field to the right of the icon searches the table accordingly and highlights the rows that match the search criterion.
use LMB to click on a table row	Selects the row and the corresponding object in the Scene Tree. In analysis result lists, the result, e.g., the component, is marked by a cross-hairs cursor in each of the 2D views.
hold **Ctrl** key + use LMB to click on several table rows	Selects the rows and the corresponding objects in the Scene Tree.

Control	Description
hold **Shift** key + use LMB to click on two separate table rows	Selects the two rows, including all rows between the two as well as the corresponding objects in the Scene Tree.
hold **Shift** key + use up/down arrow keys	Selects the rows and the corresponding objects in the Scene Tree.
press **Ctrl+A**	Selects all table rows.
use up and down arrow keys	Steps up and down through the table rows.
use RMB to click into the table area	Displays a context menu. See below.
use LMB to click a column heading	Sorts the table according to the values of the column. Clicking subsequently toggles between ascending and descending.
use LMB to click and drag column heading to new position, then release LMB	Inserts the column at the new position.
use LMB to double-click cell highlighted in white (light theme) or medium gray (dark theme)	If applicable: Allows you to edit the contents of the cell.

- **Screenshots** section (if available)

  The **Screenshots** section below the list section allows you to capture images from one of the 2D windows, the 3D window, or the current window layout for the item currently selected in the table. Only available if exactly one row is selected.

  Table 28-21: Controls in the **Screenshots** section

Control	Description
Capture from button	Adds the image of the view selected from the drop-down list to the preview area above.
use LMB to click and drag one or more images, then release LMB	Moves the image(s) to the new position.
double-click the image	Opens the **Snapshot display** window showing the image: • **Zoom in**/**Zoom out** button: Zooms the image in/out. You can also move the mouse pointer in the image area and turn the mouse wheel. • **Fit to window** button: Resets the zoom so that the image fits into the window.
click the **<no description>** placeholder twice (first click to select, second click to enable renaming)	Allows you to label the image.

Control	Description
Delete selected button	Deletes the selected image from the preview area.

Table Context Menu

Right-clicking anywhere in the table area shows a context menu with the following options:

Table 28-22: Context menu items

Control	Description
Columns	Allows you to toggle the visibility of each column by checking/unchecking the respective item. • **Show all**: Checks all columns to set them to visible. • **Hide all**: Unchecks all columns to set them to invisible. • **Hide empty**: Unchecks all not editable columns which are empty or **n/a** to set them to invisible.
Trim columns	Resizes all columns to their smallest possible size.
Apply default column layout	Applies the default column layout previously saved by the user to the current table. If no default column layout has been saved, the original column layout will be applied.
Save as default column layout	Saves modifications applied to the table—e.g., the visibility of a column, the order in which the columns appear, the column width—as default column layout. This layout will be applied when you create a new project.
Apply original column layout	Restores the original table layout and discards any modifications applied by the user. The original table layout is predefined and cannot be modified by the user.
Remove entries	If applicable: Deletes the selected row(s) from the table.
Create annotations	If applicable: Creates annotations for the selected items.
Export as CSV...	Opens the **Export as CSV...** dialog for exporting the table values as **.csv* file. This option always exports the complete table even if a filter was applied. In order to export only the filtered rows, press **Ctrl** + **A** to highlight all filtered rows and use the **Copy to clipboard** menu item.

Control	Description
Copy to clipboard	Copies the selected rows as well as the column heading into the system clipboard. The clipboard information is provided both as plain text and rich-text table, so when pasting into a rich-text-capable application like a word processor, you will see a proper table with cell borders and bold headings.
Paste	For annotation tables: Pastes previously copied coordinates and—optionally—snap directions to create new annotations in the table. For annotations of a nominal/actual comparison, the search distance specified on the **Settings** tab of the analysis will be considered. Note: Pasted annotations will be interpreted in the selected coordinate system at the time of pasting. The information in the clipboard must have the following structure: • x-, y-, and z-coordinate of the annotation or • x-, y-, and z-coordinate of the annotation as well as x-, y-, and z-component of the vector for the snap direction The parameters can be separated by space, tab, semicolon, or comma (if a comma is already used as a decimal mark or digit grouping symbol, the values must be enclosed in double quotation marks). Example: 8.89;25.82;-0.55;1;0;0 You can also copy the information directly from the cells of a spreadsheet. In order to paste the annotation information, you can also press the **Ctrl** + **V** keyboard shortcut.
Set as active column	If applicable: Makes the current column the active column, i.e., the results of this column are color-coded according to their values as defined by the color lookup table and the colors specified in the **Sections** section of the **Colors** tab.
Unset active column	If applicable: Deselects the currently active column and sets the **Active column** drop-down list on the corresponding **Settings** tab to **Uncoded**, i.e., removes any color coding.
Enter/change value (all items)	If applicable: Opens the **Enter value** dialog (see below) where you can enter the desired value for the selected parameter. This value will be applied to all entries in the table.

Control	Description
Enter/change value (selected items)	If applicable: Opens the **Enter value** dialog (see below) where you can enter the desired value for the selected parameter. This value will be applied to the selected entries in the table.
Delete selected items	If applicable: Removes the selected items from the scene.

The **Enter value** dialog includes the following controls:

Table 28-23: Controls in the **Enter value** dialog

Control	Description
Enter value field	Allows you to enter the desired value.
OK button	Sets the selected parameter to the specified value.
Reset button	For analyses only: Resets the selected parameter to undefined.
Set from tolerance settings button	For analyses only: Enters the value specified in the tolerance settings of the analysis for the selected parameter.
Cancel button	Discards the changes and closes the dialog.

Images Tab

Allows you to take screenshots of the selected workspace views and/or add bookmark references to the report. In the final report, the captured images will be listed separately from the screenshots created on other tabs.

- **Snapshots** section

  Table 28-24: Controls in the **Snapshots** section

Control	Description
Capture from button	Adds the image of the view selected from the drop-down list to the preview area above.
Delete selected button	Deletes the selected image(s) from the preview area.
use LMB to click and drag one or more images, then release LMB	Moves the image(s) to the new position.

Control	Description
double-click the image	Opens the **Snapshot display** window showing the image: • **Zoom in**/**Zoom out** button: Zooms the image in/out. You can also move the mouse pointer on the image area and turn the mouse wheel. • **Fit to window** button: Resets the zoom so that the image fits into the window.
click the **<no description>** placeholder twice (first click to select, second click to enable renaming)	Allows you to label the image.

- **Automatic 3D images** section (if available)

  Check the corresponding checkbox to include the desired 3D view (e.g., **Top**, **Front**, **Top-left-front**, and **Current camera settings**) in the report without changing the 3D view.

- **Bookmark references** section

  Allows you to add bookmark references via drag and drop from the **Bookmarks and views** tool or the **Bookmark editor** to the preview area. The images of the referenced bookmarks will then be included in VGRF-based reports.

  When you open a project with missing bookmark images, placeholders will be shown instead.

  Bookmark references are stored in evaluations and can be used in automation scenarios.

You will still need to import a bookmark template containing the actual bookmarks in these cases, as evaluations store only references to them.

Table 28-25: Controls in the **Bookmark references** section

Control	Description
New bookmark button	Adds a bookmark of the current view to the preview area.
Remove button	Removes the bookmark currently selected in the preview area.
click the bookmark title twice (first click to select, second click to enable renaming) or press the **F2** key	Allows you to rename the bookmark. The changes made on the **Images** tab will also affect the **Bookmark editor** and the **Bookmarks and views** tool. If the renamed bookmark is referenced by one or more objects for reporting, a warning message will be displayed indicating that the referenced bookmark will also be renamed for all these objects in the report.

The global concept of bookmark references allows for multiple objects to reference the same bookmark and for objects to reference bookmarks that show arbitrary information, e.g., other analyses or objects.

Rules Tab

Shows existing rules for selecting features (e.g., probability, radius) with defined properties to be included in the final report. Apart from that, the **Rule** dialog allows you to create new rules and edit or delete existing rules.

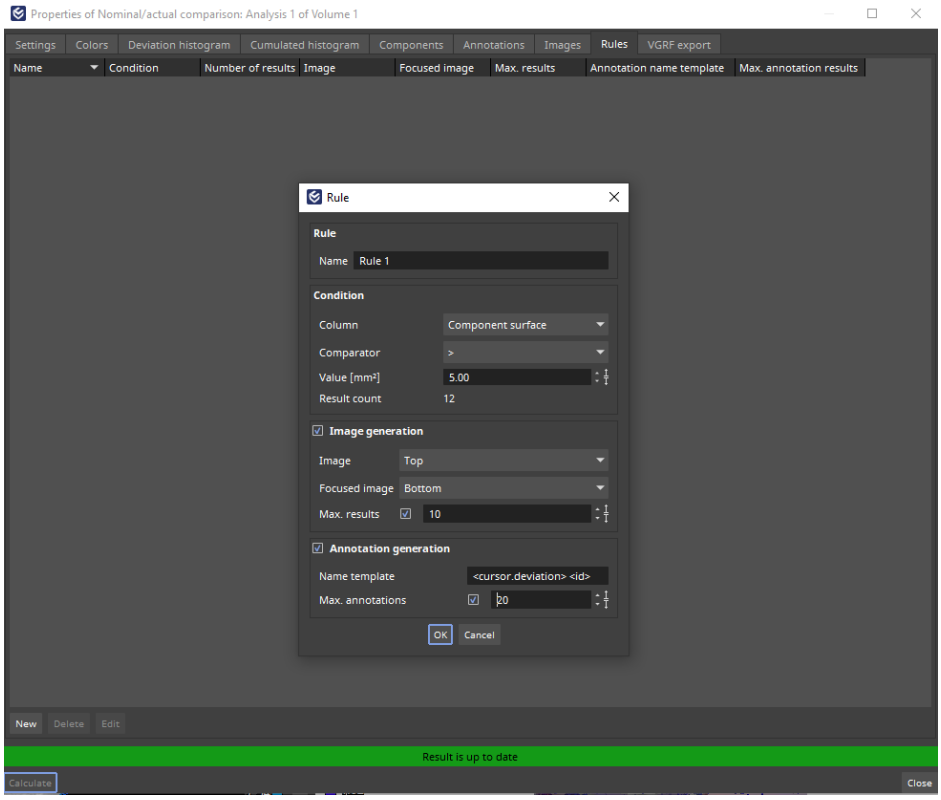


Figure 28-2: **Rules** tab with **Rule** dialog

- **New** button
  Opens the **Rule** dialog for creating a new rule.
- **Delete** button
  Deletes a selected rule.
- **Edit** button
  Opens the **Rule** dialog for editing a selected rule.

You can also double-click a rule to open the **Rule** dialog for editing a selected rule.

Rule Dialog

- **Rule** section

  The **Name** field allows you to enter a name for the new rule. This name has to be unique.
- **Condition** section

  Table 28-26: Controls in the **Condition** section

Control	Description
Column drop-down list	Selects the property of the feature (e.g., probability, radius, diameter) that defines the rule.
Comparator drop-down list	Specifies the comparator to be applied to the selected property.
Value [<unit>] spin box or drop-down list	Specifies the reference value or status of the selected property for comparison.
Result count field	Indicates the number of results that meet the specified condition.

- **Image generation** section

  Table 28-27: Controls in the **Image generation** section

Control	Description
Image drop-down list	Allows you to add a detailed 2D image and object description on a separate page of the report. • **Off**: No image is created (default). • **Orthographic projection**: Creates three orthogonal views. • **Top/Bottom/Left/Right/Front/Back**: Creates a single 2D view in the specified orientation. • If applicable: **... - If not OK**: Automatically creates the image if the tolerance status is **Out of tolerance**.
Focused image drop-down list	This option is almost identical to the **Image** option, but will generate an image that focuses on the respective item and is zoomed in by the **Zoom factor** specified during report creation or VGRF-based export.
Max. results checkbox and spin box	When this option is checked, you will be able to use the corresponding spin box to specify the maximum number of results to be included in the report.

- **Annotation generation** section

  Table 28-28: Controls in the **Annotation generation** section

Control	Description
Name template field	Allows you to enter a name for the annotations. If this is not done, a name of the form *<annotation type> <id>* will automatically be generated.

Control	Description
Max. annotations checkbox and spin box	When this option is checked, you will be able to use the corresponding spin box to specify the maximum number of annotations to be generated.

In contrast to manually created annotations, rule-based annotations can neither be moved nor deleted. This is indicated by a closed padlock symbol next to the annotation name in the annotation label.

Rule-based annotations that are based on components are created at the position of the component that fulfills the condition. For wall thickness analyses performed with the **Sphere method** algorithm and nominal/actual comparisons, the position of the component is always the spatial center (or—if the spatial center lies outside the component—a position within the component that is closest to the spatial center), while for wall thickness analyses performed with the **Ray method** algorithm, the position is defined by the **Position property** option on the **Settings** tab of the properties dialog.

- **OK** button

  Closes the dialog, adds the new rule to the list in the **Rules** tab and updates the annotations.
- **Cancel** button

  Discards the settings and closes the dialog.

Wall Thickness Analysis Module

Introduction

The **Wall Thickness Analysis** module examines a voxel, CAD, or surface mesh data set for the occurring wall thicknesses (or, inversely, gap widths). As a result of this analysis, you will get a detailed report on the detected wall thicknesses and a false-color coded data set for documentation purposes.

The following analysis types are provided:

- **Wall thickness analysis (Ray method)**

  Calculates the wall thicknesses for a specified thickness range by searching for the opposite surface for each point on the surface. The resulting thicknesses will be the shortest distances between the surfaces.

- **Wall thickness analysis (Sphere method)**

  For each voxel, the algorithm searches for the largest inscribed sphere, which may be located anywhere within the surface but must also include the center position of the voxel.

  Since this approach yields a result for each voxel—whether or not the analyzed part includes an indication—it is particularly suitable as a combined analysis in connection with a porosity/inclusion analysis.

  The **Sphere method** mode provides two algorithms, **Absolute**, which calculates absolute wall thicknesses, and **Deviation**, which additionally calculates the deviations of wall thicknesses with respect to a nominal object, for example, a CAD model.

License Information

This module is an optional add-on module for VGSTUDIO MAX. It is not available for myVGL. However, if a project loaded in myVGL contains results obtained with this module, they can be viewed and reported in myVGL.

If you are interested in a more comprehensive functionality than the one offered by myVGL, you have the chance to evaluate VGSTUDIO MAX. You can request an evaluation license of VGSTUDIO MAX on our website:

https://volumegraphics.hexagon.com/en/products/evaluation

If you have further questions about our product portfolio, please contact us:

- For Europe, Middle East, and Africa:

  Write an e-mail to sales@volumegraphics.com or call +49 6221 73920 744.

- For Japan:

  Write an e-mail to sales@volumegraphics.jp or call +81 52 508 9682.

- For the Americas:

  Write an e-mail to sales-us@volumegraphics.com or call +1 704 248 7736.

- For China, including Mainland China, Hong Kong, Macao, and Taiwan:

  Write an e-mail to sales@volumegraphics.cn or call +86 10 8532 6305.

- For Singapore and other parts of Asia (except China and Japan), Australia, and parts of Oceania:

Write an e-mail to sales@volumegraphics.sg or call +65 6665 0310.

Opening the Dialog

In order to open the **Wall thickness analysis** dialog,

- right-click the corresponding entry in the Scene Tree and select **Properties** from the context menu or
- double-click the corresponding entry in the Scene Tree.

The **Wall thickness analysis** dialog consists of several tabs on which you can view the results of the wall thickness analysis.

To close the dialog, click the **Close** button at the bottom of the dialog.

A status bar at the bottom of the dialog indicates the current status of the analysis. The status can be one of the following:

Table 29-1: Messages in the status bar

Status	Description
Result is up to date	The current analysis result is valid.
Calculation required	All required parameters have been specified and are consistent, but the analysis was not calculated or was invalidated by some user action before the project was saved.
Object has no surface determination	No surface determination information is available for the selected object. See also section *Surface determination* on page 949 in chapter 48 *Glossary*.
Thickness range: Max. value must be larger than min. value	The minimum value of the thickness range specified in the **Wall thickness** section is larger than the maximum value.
Manual changes to result	Some components have been manually deleted.
License missing	The add-on module is not licensed.

☞ The result of a wall thickness analysis of type **Ray method** refers to the specified wall thickness interval, i.e., only the wall thickness within this interval is analyzed.

For example, if an analysis is performed for a wall thickness of 2.5 mm to 5 mm and the thickest result is 4.6 mm, this does not mean that the whole part does not contain a wall thicker than 4.6 mm. Instead, there might be a wall thickness larger than 5 mm.

☞ An invalid or outdated status of an analysis is indicated in the Scene Tree by a warning sign. Double-click this analysis to open it and check the status bar for messages.

The units of the dialog are set according to the global unit settings (see section *Units Drop-down List* on page 33 in chapter 2 *Workspace*).

Settings Tab for the Ray method Algorithm

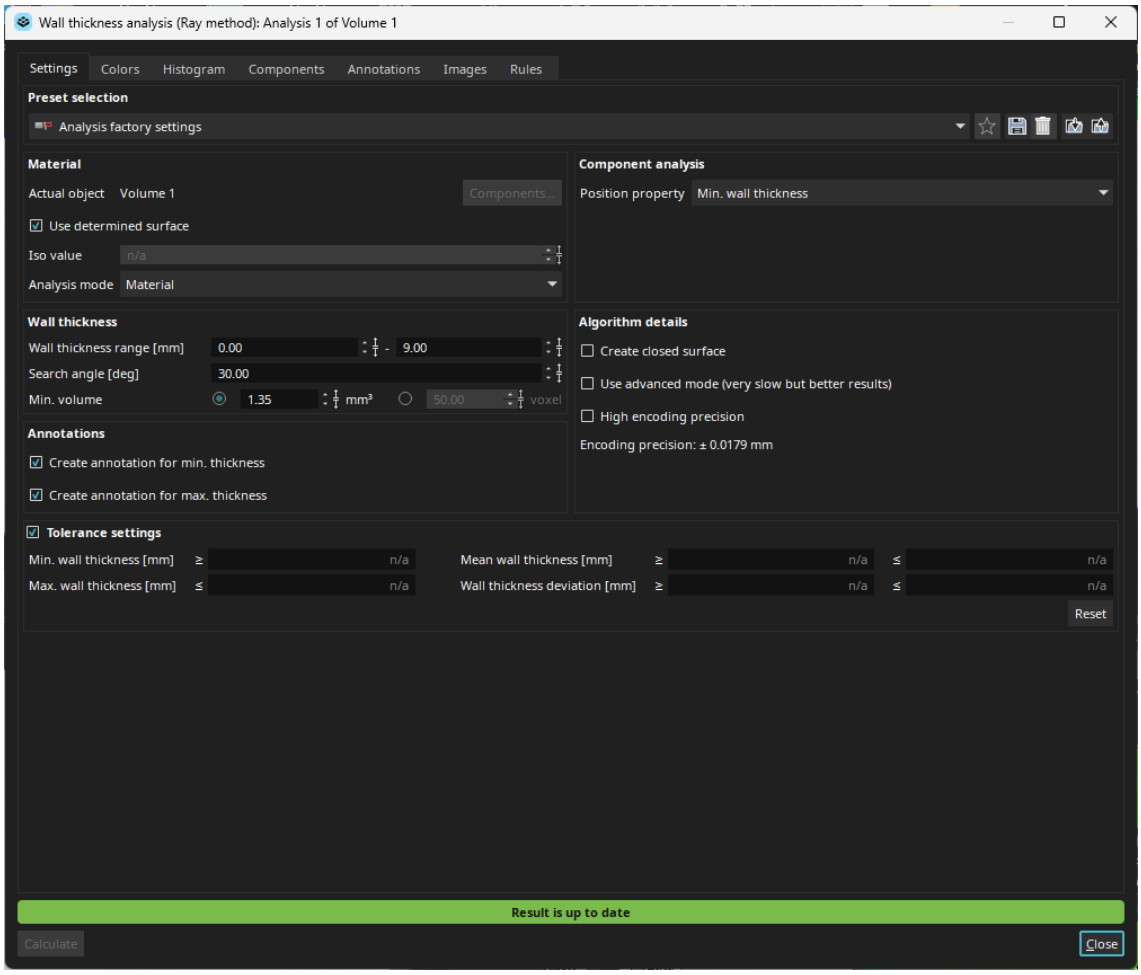


Figure 29-1: **Wall thickness analysis (Ray method)** dialog, **Settings** tab

In myVGL, all parameter settings are displayed. Most of these parameters are read-only in myVGL. The complete functional range is available with VGSTUDIO MAX and the respective add-on module(s).

Preset selection Section

Table 29-2: Controls in the **Preset selection** section

Icon	Item	Description
	drop-down list	Specifies the preset to be applied, to be edited, or to be taken as a basis for a new preset. The following icons are used: • analysis factory settings • customized preset • appears next to the icon of a preset that has been modified but not yet saved
	Set this preset as default	Sets the selected preset as default. The default preset will be applied when creating a new analysis of the same type. If the selected preset is already set as default, the button is disabled.
	Save preset	Saves the selected preset. When saving a preset, the **Save preset** dialog will open, which allows you to set the new preset as default by checking the **Set as default for new analyses** checkbox.
	Remove preset	Removes the selected preset from the preset drop-down list. If the removed preset is the default preset, the next time an analysis of the same type is created, the factory settings will be used.
	Import preset	Imports a preset from the specified location.
	Export preset	Exports the selected preset to the specified location.

Material Section

Table 29-3: Controls in the **Material** section

Control	Description
Actual object field	Indicates the object for which the wall thickness analysis is to be performed.

Control	Description
Components... button	This button is enabled when the **Actual object** is an object with components. Clicking it opens a dialog box where you can specify the components for which the wall thickness analysis is to be performed: • Checkbox of component: Clicking it checks/unchecks the component including all child components. • **Select all** button: Selects all components of the object. • **Deselect all** button: Deselects all components of the object. • **Apply visibility** button: Selects all components which are set visible in the Scene Tree. For volume objects consisting of several volume components, the analysis is based on the outer surface of all united components, unless differently specified using the **Components** option.
Use determined surface checkbox	For volume objects only. When this checkbox is checked, the analysis uses the surface determination information for determining the transition between background and material. For this purpose, a surface determination must have been performed prior to the wall thickness analysis. For details on surface determination, see section *Surface determination* on page 949 in chapter 48 *Glossary*.
Iso value spin box	For volume objects only. When the **Use determined surface** checkbox is unchecked, the analysis uses the gray value of the isosurface specified in the **Iso value** field as transition between background and material.
Analysis mode drop-down list	• **Material**: The analysis is performed on the material. • **Background**: The analysis is performed on the background. This option can be used for determining the gap width of an object.

Wall thickness Section

Table 29-4: Controls in the **Wall thickness** section

Control	Description
Wall thickness range [<length unit>] spin boxes	Specify the wall thickness interval you are interested in. Only wall thicknesses within this interval are calculated and displayed.

Control	Description
Search angle [<angle unit>] field	At each point on the object surface, the software searches for the nearest point on the opposite surface within a search cone with the surface normal of the start point as centerline. This procedure is repeated for the end point of the shortest distance line on the opposite surface. If the start point lies within the search cone of the end point, the distance between the two points is taken as wall thickness; otherwise, no wall thickness will be available at this location. The **Search angle** specifies the aperture angle of the search cone. See Figure 29-2 below for an illustration of this principle.
Min. volume spin boxes	Specify the minimum size for a component to be listed as a result either as a volumetric dimension or as a number of voxels. Components smaller than the specified minimum size are not included in the results.

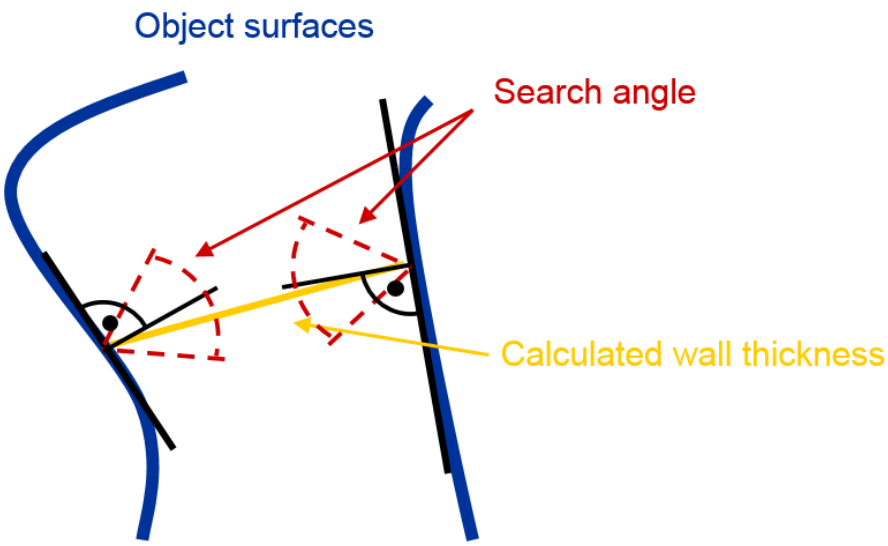


Figure 29-2: Search angle

For a search angle larger than 45°, the adjoining surface instead of the opposite surface might be taken into account.

Annotations Section

Table 29-5: Controls in the **Annotations** section

Control	Description
Create annotation for min. thickness checkbox	When this option is checked, the minimum thickness as well as the position where it occurs will be calculated and shown as annotation at the corresponding position in the 3D window, the 2D windows, and the Scene Tree.

Control	Description
Create annotation for max. thickness checkbox	When this option is checked, the maximum thickness as well as the position where it occurs will be calculated and shown as annotation at the corresponding position in the 3D window, the 2D windows, and the Scene Tree.

Component analysis Section

Table 29-6: Controls in the **Component analysis** section

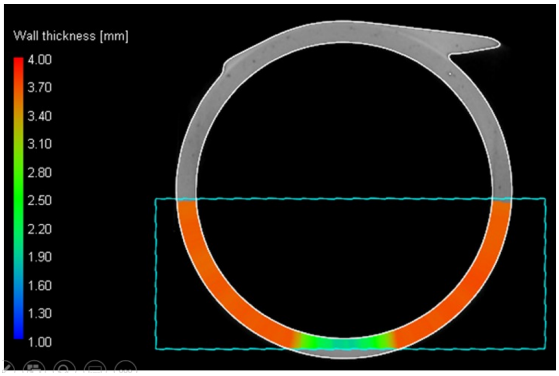
Control	Description
Position property drop-down list	Specifies the part of a component to be recognized as its position: the point of its **Min. wall thickness**, **Max. wall thickness** or its **Spatial center**. This affects, for example, the values in the **Pos. x/y/z** columns of the **Components** table. Note that for performance reasons, the **Spatial center** value may vary from run to run.

Algorithm details Section

Table 29-7: Controls in the **Algorithm details** section

Control	Description
Create closed surface checkbox	When this option is checked, additional boundaries will be introduced. For example, if the analysis is performed within a region of interest (ROI) and **Create closed surface** is activated, the ROI boundaries can be interpreted as opposite surface. See Figure 29-3 for an illustration of this principle:

Create closed surface option activated



Create closed surface option deactivated

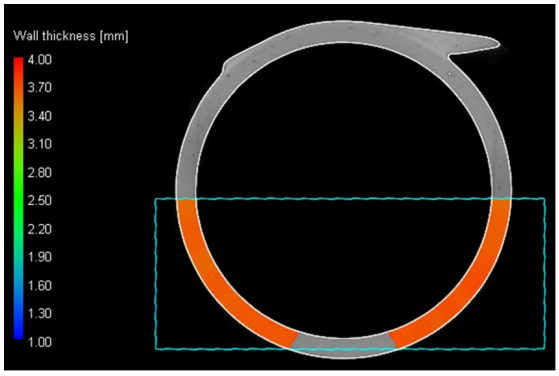


Figure 29-3: Effect of the **Create closed surface** option—left: activated, right: deactivated

Control	Description
Use advanced mode checkbox	When this option is checked, the risk to get gaps in the analysis is reduced—at the cost of significantly longer computing time.
High encoding precision checkbox	When this option is checked, the wall thickness values will be stored more precisely, which will produce more precise results at the cost of significantly higher computing time and memory consumption. The resulting precision is displayed below this option.

Tolerance settings Section

Table 29-8: Controls in the **Tolerance settings** section

Control	Description
Min. wall thickness [<length unit>] >= field	Specifies the minimum permissible thickness of a component.
Max. wall thickness [<length unit>] <= field	Specifies the maximum permissible thickness of a component.
Mean wall thickness [<length unit>] >=/<= field	Specifies a permissible range for the mean value of the wall thickness values. When you specify the upper limit only, the actual value will be within the tolerance (shown in green) if it is below the upper limit. When you specify the lower limit only, the actual value will be within the tolerance (shown in green) if it is above the lower limit.
Wall thickness deviation [<length unit>] >=/<= field	Specifies a permissible range for the standard deviation of the wall thickness values. When you specify the upper limit only, the actual value will be within the tolerance (shown in green) if it is below the upper limit. When you specify the lower limit only, the actual value will be within the tolerance (shown in green) if it is above the lower limit.
Reset button	Deletes all tolerance settings.

Depending on the results of this evaluation, the tolerances on the **Settings** tab are highlighted in the following colors:

- Green: The tolerance is met for all components.
- Red: The tolerance is not met for one or more components.
- White (light theme)/black (dark theme): No tolerance settings have been specified or they are deactivated.
- Yellow: A tolerance has been specified but the analysis has to be (re-)calculated. Note that this color will also be used if the entered tolerance value is invalid.

The result of the evaluation is also displayed graphically in the Scene Tree. For more information on evaluations, see chapter 46 *Evaluations*.

Settings Tab for the Sphere method Algorithm

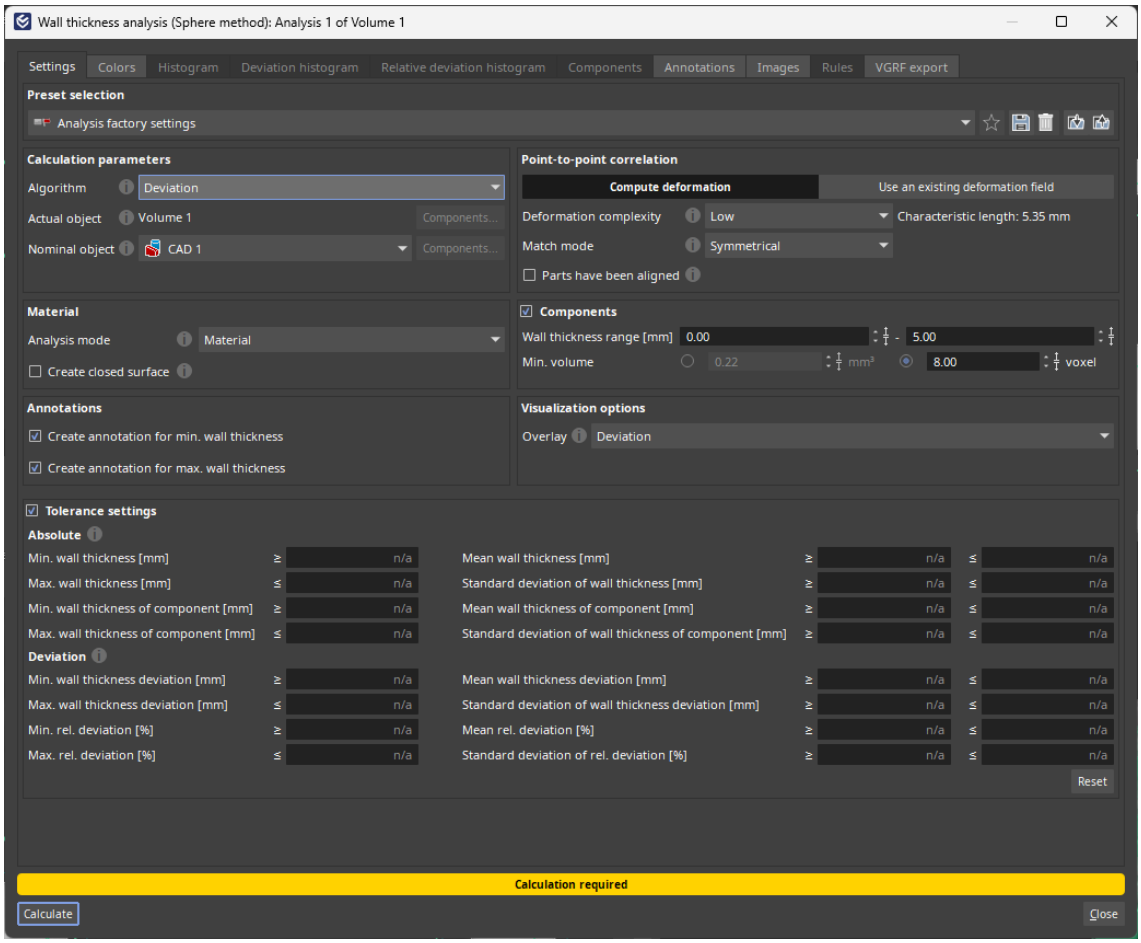


Figure 29-4: **Wall thickness analysis (Sphere method)** dialog, **Settings** tab

In myVGL, all parameter settings are displayed. Most of these parameters are read-only in myVGL. The complete functional range is available with VGSTUDIO MAX and the respective add-on module(s).

Preset selection Section

Table 29-9: Controls in the **Preset selection** section

Icon	Item	Description
	drop-down list	Specifies the preset to be applied, to be edited, or to be taken as a basis for a new preset. The following icons are used: • analysis factory settings • customized preset • appears next to the icon of a preset that has been modified but not yet saved
	Set this preset as default	Sets the selected preset as default. The default preset will be applied when creating a new analysis of the same type. If the selected preset is already set as default, the button is disabled.
	Save preset	Saves the selected preset. When saving a preset, the **Save preset** dialog will open, which allows you to set the new preset as default by checking the **Set as default for new analyses** checkbox.
	Remove preset	Removes the selected preset from the preset drop-down list. If the removed preset is the default preset, the next time an analysis of the same type is created, the factory settings will be used.
	Import preset	Imports a preset from the specified location.
	Export preset	Exports the selected preset to the specified location.

Calculation parameters Section

Table 29-10: Controls in the **Calculation parameters** section

Control	Description
Algorithm drop-down list	• **Absolute**: Calculates absolute wall thicknesses. • **Deviation**: Calculates wall thickness deviations with respect to a nominal object.
Actual object field	Indicates the object for which the wall thickness analysis is to be performed. Usually, this is the scanned surface of a manufactured part.
Nominal object drop-down list	Specifies the object against which the wall thicknesses of the actual object will be compared. Usually, this is a CAD model.

Control	Description
Components... buttons	These buttons are enabled when the **Actual object** or the **Nominal object**, respectively, is an object with components. Clicking them opens a dialog box where you can specify the components for which the wall thickness analysis is to be performed: • Checkbox of component: Clicking it checks/unchecks the component including all child components. • **Select all** button: Selects all components of the object. • **Deselect all** button: Deselects all components of the object. • **Apply visibility** button: Selects all components which are set to visible in the Scene Tree. For volume objects that consist of several volume components, the analysis will be based on the outer surface of all united components unless otherwise specified in the **Components** option.

Material Section

Table 29-11: Controls in the **Material** section

Control	Description
Analysis mode drop-down list	• **Material**: The analysis is performed on the material. • **Background**: The analysis is performed on the background. This option can be used for determining the gap width of an object.
Create closed surface checkbox	When this option is checked, additional boundaries will be introduced. For example, if the analysis is performed within a region of interest (ROI) and **Create closed surface** is activated, the ROI boundaries can be interpreted as surface. See Figure 29-5 for an illustration of this principle:

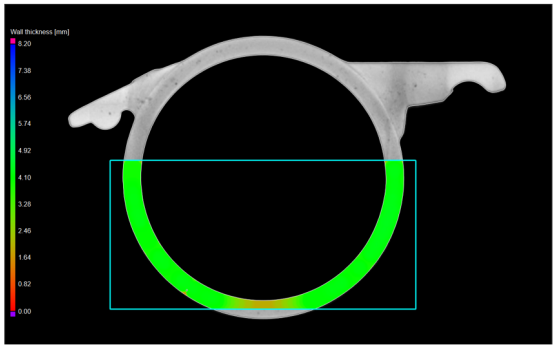
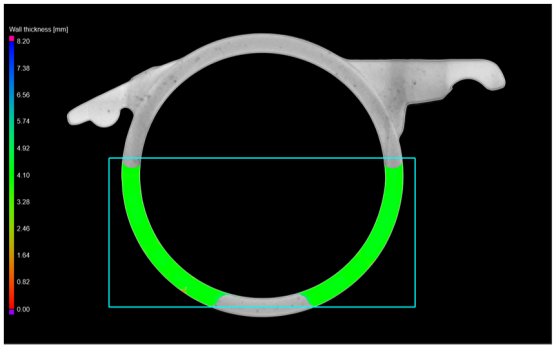
Control	Description
Create closed surface option activated	**Create closed surface** option deactivated
	

Figure 29-5: Effect of the **Create closed surface** option—left: activated, right: deactivated

Annotations Section

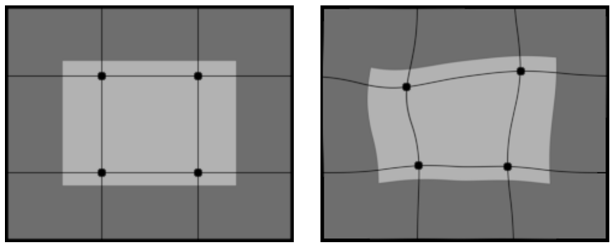
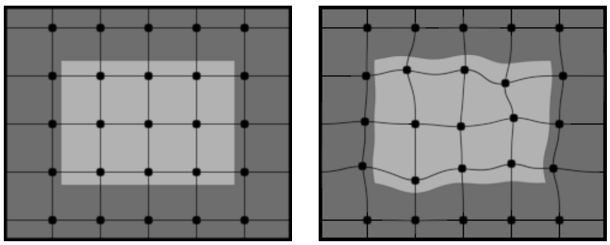
Table 29-12: Controls in the **Annotations** section

Control	Description
Create annotation for min. thickness checkbox	When this option is checked, the minimum thickness as well as the position where it occurs will be calculated and shown as annotation at the corresponding position in the 3D window, the 2D windows, and the Scene Tree.
Create annotation for max. thickness checkbox	When this option is checked, the maximum thickness as well as the position where it occurs will be calculated and shown as annotation at the corresponding position in the 3D window, the 2D windows, and the Scene Tree.

Point-to-point correlation Section

Table 29-13: Controls in the **Point-to-point correlation** section

Control	Description
Compute deformation segmented button	Analyses the difference between actual object and nominal object.

Control	Description
Deformation complexity drop-down list	A higher deformation complexity is suited for complex deformations between actual object and nominal object, at the cost of longer calculation time. Low deformation complexity corresponds to a long characteristic length and is thus suitable for coarse deformations.  High deformation complexity corresponds to a short characteristic length and is thus suitable for complex deformations.  **Very low**, **Low**, **Medium**, **High**: Allows you to select a predefined characteristic length.
Characteristic length field	Indicates the scale at which significant variations in deformation are still handled accurately.
Match mode drop-down list	• **Symmetrical**: The algorithm tries to match the actual object to the nominal object and vice versa, thus finding the best match that satisfies both directions. For this mode, the topology of the two objects must be identical. This is the recommended scenario as it yields the best results. • **Incomplete nominal object**: The nominal object will only be fitted to the actual object. This setting is recommended if the nominal object is a subset of the actual object. • **Incomplete actual object**: The actual object will only be fitted to the nominal object. This setting is recommended if the actual object is a subset of the nominal object.
Parts have been aligned checkbox	When this option is checked, the current orientation of the actual and nominal objects will be considered for calculating the deformation field.

Control	Description
Use an existing deformation field segmented button	Allows you to select a previously calculated deformation field from the **Deformation field** drop-down list. If a small warning triangle appears in the icon of the deformation field, this indicates that the surfaces could not be properly matched everywhere.

Components Section

Table 29-14: Controls in the **Components** section

Control	Description
Wall thickness range [<length unit>] spin boxes	Specify an interval for the wall thickness of the components you are interested in. All the wall thicknesses are calculated and displayed, but only components with wall thicknesses within this interval are listed on the **Components** tab.
Min. volume spin boxes	Specify the minimum size for a component to be listed as a result either as a volumetric dimension or as a number of voxels. Components smaller than the specified minimum size are not included in the results.

Visualization options Section

Table 29-15: Controls in the **Visualization options** section

Control	Description
Overlay drop-down list	• **Absolute**: Shows the color overlay of the absolute wall thicknesses. • **Deviation**: Shows the color overlay of the wall thickness deviations in absolute values. • **Relative deviation**: Shows the color overlay of the wall thickness deviations in relative values with respect to the nominal wall thickness.

Tolerance settings Section

Table 29-16: Controls in the **Tolerance settings** section

Control	Description
Min. wall thickness [<length unit>] >= field	Specifies the minimum permissible wall thickness.
Max. wall thickness [<length unit>] <= field	Specifies the maximum permissible wall thickness.

Control	Description
Min. wall thickness of component [<length unit>] >= field	Specifies the minimum permissible thickness of a component.
Max. wall thickness of component [<length unit>] <= field	Specifies the maximum permissible thickness of a component.
Mean wall thickness [<length unit>] >=/<= fields	Specify a permissible range for the mean value of the wall thickness values. When you specify the upper limit only, the actual value will be within the tolerance (shown in green) if it is below the upper limit. When you specify the lower limit only, the actual value will be within the tolerance (shown in green) if it is above the lower limit.
Standard deviation of wall thickness [<length unit>] >=/<= fields	Specify a permissible range for the standard deviation of the wall thickness values. When you specify the upper limit only, the actual value will be within the tolerance (shown in green) if it is below the upper limit. When you specify the lower limit only, the actual value will be within the tolerance (shown in green) if it is above the lower limit.
Mean wall thickness of component [<length unit>] >=/<= field	Specifies a permissible range for the mean value of the wall thickness value of the components. When you specify the upper limit only, the actual value will be within the tolerance (shown in green) if it is below the upper limit. When you specify the lower limit only, the actual value will be within the tolerance (shown in green) if it is above the lower limit.
Standard deviation of wall thickness of component [<length unit>] >=/<= fields	Specify a permissible range for the standard deviation of the wall thickness values of the components. When you specify the upper limit only, the actual value will be within the tolerance (shown in green) if it is below the upper limit. When you specify the lower limit only, the actual value will be within the tolerance (shown in green) if it is above the lower limit.
Min. wall thickness deviation [<length unit>] >= field	Specifies the minimum permissible wall thickness deviation.
Max. wall thickness deviation [<length unit>] <= field	Specifies the maximum permissible wall thickness deviation.
Min. rel. deviation [<ratio unit>] >= field	Specifies the minimum permissible relative wall thickness deviation.

Control	Description
Max. rel. deviation [<ratio unit>] <= field	Specifies the maximum permissible relative wall thickness deviation.
Mean wall thickness deviation [<length unit>] >=/<= fields	Specify a permissible range for the mean value of the wall thickness deviations. When you specify the upper limit only, the actual value will be within the tolerance (shown in green) if it is below the upper limit. When you specify the lower limit only, the actual value will be within the tolerance (shown in green) if it is above the lower limit.
Standard deviation of wall thickness deviation [<length unit>] >=/<= fields	Specify a permissible range for the standard deviation of the wall thickness deviations. When you specify the upper limit only, the actual value will be within the tolerance (shown in green) if it is below the upper limit. When you specify the lower limit only, the actual value will be within the tolerance (shown in green) if it is above the lower limit.
Mean rel. deviation [<ratio unit>] >=/<= fields	Specify a permissible range for the mean value of the relative wall thickness deviations. When you specify the upper limit only, the actual value will be within the tolerance (shown in green) if it is below the upper limit. When you specify the lower limit only, the actual value will be within the tolerance (shown in green) if it is above the lower limit.
Standard deviation of rel. deviation [<ratio unit>] >=/<= fields	Specify a permissible range for the standard deviation of the relative wall thickness deviations. When you specify the upper limit only, the actual value will be within the tolerance (shown in green) if it is below the upper limit. When you specify the lower limit only, the actual value will be within the tolerance (shown in green) if it is above the lower limit.
Reset button	Deletes all tolerance settings.

Depending on the results of this evaluation, the tolerances on the **Settings** tab are highlighted in the following colors:

- Green: The tolerance is met for all components.
- Red: The tolerance is not met for one or more components.
- White (light theme)/black (dark theme): No tolerance settings have been specified or they are deactivated.
- Yellow: A tolerance has been specified but the analysis has to be (re-)calculated. Note that this color will also be used if the entered tolerance value is invalid.

The result of the evaluation is also displayed graphically in the Scene Tree. For more information on evaluations, see chapter 46 *Evaluations*.

Colors Tab

Here you can specify the color-coding scheme used for the representation of the analysis results.

Caption Section

Table 29-17: Controls of the **Caption** section

Control	Description
Caption field	Indicates the color bar headline as specified in the **Caption** field of the **Color bar** section.
Share color bar checkbox	When this option is checked, all analyses of the same type (and—if applicable—of the same algorithm) will use the same color bar. When this option is unchecked, the color bar settings will apply to the selected analysis only.

LUT – Color Lookup Table

The color lookup table (LUT) shows the partitioning into color sections.

Sections Section

Defines the appearance of each color section.

Table 29-18: Controls in the **Sections** section

Control	Description
From/To fields	Specify the start and end values of the color sections. The first color section represents all values above the upper limit, i.e., the value in the **From** field (**+inf** signifies positive infinity), while the last color section represents all values below the lower limit, i.e., the value in the **To** field (**-inf** signifies negative infinity). The default limits are calculated from the results of the analysis (for an analysis color bar) or taken from the **Default** preset (for a tolerance deviation color bar).
Type field	Switches between the color schemes **Continue**, **Constant**, **Gradient**, **Rainbow**, **Reverse rainbow**, **Hue cycle**, **Green to red**, and **Red to green**.

Control	Description
Color/transparency field	Double-clicking the field for the **Continue**, **Constant**, and **Gradient** color schemes opens the **Select Color** dialog where you can modify the appearance of the selected color scheme. For the **Gradient** color scheme, you can specify the start and end colors by double-clicking the left or right side of the field, respectively. Double-clicking the field for the **Rainbow**, **Reverse rainbow**, **Hue cycle**, **Green to red**, and **Red to green** color schemes opens the **Transparency** dialog, where you can set the transparency for the selected color scheme.
use RMB to click a color section	Opens a context menu with the following items: • **Split**: Subdivides the color section into two new color sections where each represents half of the original section. • **Merge**: Combines several color sections to a single color section. Only consecutive intervals can be merged.
Create smooth button	Opens the **Create smooth table** dialog to generate one color section. • **Type** drop-down list: Allows you to select the type of coloring scheme. • **From/To** spin boxes: Specify the value range covered by the color section.
Create stepped button	Opens the **Create stepped table** dialog to generate a set of color sections. • **Type** drop-down list: Allows you to select the type of coloring scheme. • **From/To** spin boxes: Specify the value range covered by the color sections. • **Step** spin box: Specifies the step size of the individual color sections.
Auto scale button	If available: Fits the color LUT to the range of the results of all available analyses.
Auto scale color bar range on calculate checkbox	If available: When this option is checked, the color LUT will be automatically fitted to the range of the results of all available analyses.
Default button	If available: Resets any changes made to the **Sections** table.

Preset selection Section

Table 29-19: Controls in the **Preset selection** section

Icon	Item	Description
	drop-down list	Specifies the preset to be applied, to be edited, or to be taken as a basis for a new preset. The following icons are used: • default preset • customized preset • appears next to the icon of a preset that has been modified but not yet saved
	Save preset	Opens the **Save preset** dialog for saving the color LUT of the current data set under the specified name. • **Absolute preset**: When this option is checked and the preset applied, the settings of the original data set, including the LUT range, will be applied. When this option is unchecked, the color settings of the preset will be mapped relatively to the actual range of results of the analysis to which the preset will be applied.
	Remove preset	Removes the selected preset from the preset drop-down list.
	Import preset	Imports a preset from the specified location.
	Export preset	Exports the selected preset to the specified location.

Display mode in 3D Section

Table 29-20: Controls in the **Display mode in 3D** section

Control	Description
Opacity mode drop-down list	Specifies the visual representation of the analysis results. The following modes are available: • **Overlay**: The color of the analyzed object will be set according to its local wall thickness. • **Constant**: Every component is fully opaque independently of its gray value. • **Ramp**: The lower the gray value of the respective component, the lower its opacity value. The higher the gray value of the respective component, the higher its opacity value. Available only if the analysis was performed on the material of the object and the volume data of the object is loaded. • **Inverse ramp**: The lower the gray value of the respective component, the higher its opacity value. The higher the gray value of the respective component, the lower its opacity value. Available only if the analysis was performed on the background of the object and the volume data of the object is loaded.

Color LUT Settings Section

Specifies the appearance of the color lookup table.

Table 29-21: Options for the appearance of the color lookup table

Control	Description
Auto tick marks checkbox	When this option is checked, equidistant tick marks will be produced for the color bars. When this option is unchecked, tick marks will appear only at the color section boundaries of the color lookup table.
Auto scale color bar range on calculate checkbox	When this option is checked, the color LUT will be automatically fitted to the range of the results of all available analyses.

Color bar Section

Specifies the settings for the color bar.

Table 29-22: Settings for the color bar

Control	Description
Visibility drop-down list	Switches the color bar on/off.

Control	Description
Positioning drop-down list	Specifies the location of the color bar within the 2D and 3D windows: **Left, Right, Top, Bottom, All - automatic, Left or right - automatic, Top or bottom - automatic**.
Caption field	Specifies the color bar headline by using placeholders.
Reset button	Resets the **Caption** field to the default entry.

Visualization options Section

Available for **Wall thickness analysis (Sphere method)**.

Table 29-23: Controls in the **Tolerance settings** section

Control	Description
Overlay drop-down list	• **Absolute**: Shows the color overlay of the absolute wall thicknesses. • **Deviation**: Shows the color overlay of the wall thickness deviations in absolute values. • **Relative deviation**: Shows the color overlay of the wall thickness deviations in relative values with respect to the nominal wall thickness.

Annotations Section

The **Color mode** drop-down list specifies the color of the analysis annotation:

- **Tolerance status**: Colors the annotations according to the tolerance status at this position.
- **As lookup table**: Colors the annotations according to their values (e.g., indication volume, deviation, and wall thickness) at this position.

Histogram Tab for the Ray method Algorithm

Shows a histogram of the calculated wall thicknesses for the entire analyzed surface of the selected object. The histogram bars are colored based on the settings on the **Colors** tab.

Controls of the **Histogram** Tab

Table 29-24: Controls of the **Histogram** tab

Control	Description
Color drop-down field	• **From color bar**: The values in the histogram are shown according to the color bar. • **Gray**: All values in the histogram are shown in gray.

Control	Description
Normalization drop-down field	• **Absolute**: Displays the surface in absolute values. • **Relative**: Displays the surface in relative values with respect to the entire analyzed surface.
Binning drop-down field	• **Off**: No binning is applied to the values shown in the histogram. • **From color bar**: The original values in the histogram are replaced by a value representative for the corresponding interval (“bin”) of the color bar. The “bins” become visible when “stepped” sections are created on the **Colors** tab. • **Manual number of bins**: Enables the **Bin count** spin box, where you can enter the required number of “bins.” • **Manual bin width**: Enables the **Bin width** spin box, where you can specify the width of the bins.
Left/**Right** spin box	Only enabled when an interval has been created: Moves the left or right interval border to the specified value. You can also click and drag the interval borders using the left mouse button.
Create button	Creates a new interval. On the right hand side of a selected interval, statistical information is displayed: • **Left**: Indicates the minimum deviation within the interval, i.e., the value of the left interval border. • **Right**: Indicates the maximum deviation within the interval, i.e., the value of the right interval border. • **Mean**: Indicates the mean value of the wall thicknesses within the interval. • **Dev**: Indicates the standard deviation of the wall thicknesses within the interval. • **Sum**: Indicates the surface area within the interval. • **Percentage**: Indicates the percentage of the surface area within the interval. Note that the statistical information may change with the number of bins.
Remove button	Removes the selected interval.
Create ROI button	Generates a new ROI that contains all voxels that have wall thickness values that lie within the range of the selected interval.
Min./Max. wall thickness [<length unit>] fields	Indicate the minimum and maximum wall thicknesses detected.

Control	Description
Mean wall thickness [<length unit>] field	Indicates the mean value of the wall thicknesses.
Wall thickness deviation [<length unit>] field	Indicates the standard deviation of the wall thicknesses.
Analyzed volume [<length unit>³] field	Indicates the sum of the volumes of all components.
use RMB to click the chart area	Displays a context menu (see below).
scroll MW in chart area or x-axis up/down	Zooms the x-axis of the chart out/in.
scroll MW in y-axis up/down	Zooms the y-axis of the chart out/in.
use LMB to click and drag the x-axis	Scrolls the x-axis.
use LMB to click and drag the y-axis	Scrolls the y-axis.
Zoom in/out	Zooms the corresponding axis in/out.
Reset zoom	Fits the entire chart to the current window size.

Context Menu of the **Histogram** Tab

Right-clicking anywhere in the chart area shows a context menu with the following options:

Table 29-25: Context menu items

Control	Description
Export as CSV...	Opens a dialog for saving the chart values to a *.csv* file.
Copy to clipboard	Copies a screenshot of the chart to the system clipboard so you can paste it in another application.
Show/Hide x/y grid	Toggles the visibility of the grid lines for the corresponding axis.
Reset zoom	Fits the entire chart to the current window size.
Create interval	Creates a new interval. For details on the statistical information, see section *Controls of the Histogram Tab* on page 459.
Remove interval	Removes the selected interval.
Create ROI	Generates a new ROI that contains all voxels that have wall thickness values that lie within the range of the selected interval.

Histogram Tab for the Sphere method Algorithm

Shows the wall thickness distribution in a histogram using the color coding defined on the **Colors** tab. The x-axis shows the wall thickness, and the y-axis shows the number of voxels.

Controls of the **Histogram** Tab

Table 29-26: Controls of the **Histogram** tab

Control	Description
Color drop-down field	• **From color bar**: The values in the histogram are shown according to the color bar. • **Gray**: All values in the histogram are shown in gray.
Normalization drop-down field	• **Absolute**: Displays the number of voxels in absolute values. • **Relative**: Displays the number of voxels in relative values with respect to the entire analyzed volume.
Binning drop-down field	• **Off**: No binning is applied to the values shown in the histogram. • **From color bar**: The original values in the histogram are replaced by a value representative for the corresponding interval (“bin”) of the color bar. The “bins” become visible when “stepped” sections are created on the **Colors** tab. • **Manual number of bins**: Enables the **Bin count** spin box, where you can enter the required number of “bins.” • **Manual bin width**: Enables the **Bin width** spin box, where you can specify the width of the bins.
Left/**Right** spin box	Only enabled when an interval has been created: Moves the left or right interval border to the specified value. You can also click and drag the interval borders.
Create button	Creates a new interval. On the right hand side of a selected interval, statistical information is displayed: • **Left**: Indicates the minimum wall thickness within the interval, i.e., the value of the left interval border. • **Right**: Indicates the maximum wall thickness within the interval, i.e., the value of the right interval border. • **Mean**: Indicates the mean value of the wall thicknesses within the interval. • **Dev**: Indicates the standard deviation of the wall thicknesses within the interval.

Control	Description
	• **Sum**: Indicates the number of voxels within the interval. • **Percentage**: Indicates the number of voxels within the interval in relation to the total number of voxels. Note that the statistical information may change with the number of bins.
Remove button	Removes the selected interval.
Create ROI button	Generates a new ROI that contains all voxels that have wall thickness values that lie within the range of the selected interval.
Min. wall thickness/Max. wall thickness [<length unit>] fields	Indicate the minimum and maximum wall thicknesses detected.
Mean wall thickness [<length unit>] field	Indicates the mean value of the wall thicknesses.
Standard deviation [<length unit>] field	Indicates the standard deviation of the wall thicknesses.
use RMB to click the chart area	Displays a context menu (see below).
scroll MW in chart area or x-axis up/down	Zooms the x-axis of the chart out/in.
scroll MW in y-axis up/down	Zooms the y-axis of the chart out/in.
use LMB to click and drag the x-axis	Scrolls the x-axis.
use LMB to click and drag the y-axis	Scrolls the y-axis.
Zoom in/Zoom out	Zooms the corresponding axis in/out.
Reset zoom	Fits the entire chart to the current window size.

Context Menu of the **Histogram** Tab

Right-clicking anywhere in the chart area shows a context menu with the following options:

Table 29-27: Context menu items

Control	Description
Export as CSV...	Opens a dialog for saving the chart values to a *.csv* file.
Copy to clipboard	Copies a screenshot of the chart to the system clipboard so you can paste it into another application.
Show/Hide x/y grid	Toggles the visibility of the grid lines for the corresponding axis.
Reset zoom	Fits the entire chart to the current window size.

Control	Description
Create interval	Creates a new interval. For details on the statistical information, see section *Controls of the Histogram Tab* on page 462.
Remove interval	Removes the selected interval.
Create ROI	Generates a new ROI that contains all voxels that have wall thickness values that lie within the range of the selected interval.

Deviation histogram Tab

Available for **Wall thickness analysis (Sphere method)** calculated with the **Deviation** algorithm.

Shows a histogram of the calculated absolute deviations for the entire analyzed surface of the selected object. The histogram bars can be colored according to the settings on the **Colors** tab.

Controls of the **Deviation histogram** Tab

Table 29-28: Controls of the **Deviation histogram** tab

Control	Description
Color drop-down field	• **From color bar**: The values in the histogram are shown according to the color bar. • **Gray**: All values in the histogram are shown in gray.
Normalization drop-down field	• **Absolute**: Displays the number of voxels in absolute values. • **Relative**: Displays the number of voxels in relative values with respect to the entire analyzed surface.
Binning drop-down field	• **Off**: No binning is applied to the values shown in the histogram. • **From color bar**: The original values in the histogram are replaced by a value that represents the corre-sponding interval (“bin”) of the color bar. The “bins” become visible when “stepped” sections are created on the **Colors** tab. • **Manual number of bins**: Enables the **Bin count** spin box, where you can enter the required number of “bins.” • **Manual bin width**: Enables the **Bin width** spin box, where you can specify the width of the individual bins.

Control	Description
Left/**Right** spin box	Only enabled when an interval has been created: Moves the left or right interval border to the specified value. You can also click and drag the interval borders by using the left mouse button.
Create button	Creates a new interval. On the right hand side of a selected interval, statistical information is displayed: • **Left**: Indicates the minimum deviation within the interval, i.e., the value of the left interval border. • **Right**: Indicates the maximum deviation within the interval, i.e., the value of the right interval border. • **Mean**: Indicates the mean value of the deviations within the interval. • **Dev**: Indicates the standard deviation of the deviations within the interval. • **Sum**: Indicates the surface area within the interval. • **Percentage**: Indicates the percentage of the surface area within the interval. Note that the statistical information may change with the number of bins.
Remove button	Removes the selected interval.
Min. wall thickness deviation/**Max. wall thickness deviation [<length unit>]** fields	Indicate the minimum and maximum deviations between actual and nominal object.
Mean wall thickness deviation [<length unit>] field	Indicates the mean deviation between actual and nominal object.
Standard deviation of wall thickness deviation [<length unit>] field	Indicates the standard deviation of the deviations between actual and nominal object.
use RMB to click the chart area	Displays a context menu (see below).
scroll MW in chart area or x-axis up/down	Zooms the x-axis of the chart out/in.
scroll MW in y-axis up/down	Zooms the y-axis of the chart out/in.
use LMB to click and drag the x-axis	Scrolls the x-axis.
use LMB to click and drag the y-axis	Scrolls the y-axis.
Zoom in/**Zoom out**	Zooms the corresponding axis in/out.
Reset zoom	Fits the entire chart to the current window size.

Context Menu of the **Deviation histogram** Tab

Right-clicking anywhere in the chart area opens a context menu with the following options:

Table 29-29: Context menu items

Control	Description
Export as CSV...	Opens a dialog for saving the chart values to a *.csv* file.
Copy to clipboard	Copies a screenshot of the chart to the system clipboard so that you can paste it into another application.
Show/Hide x/y grid	Toggles the visibility of the grid lines for the corresponding axis.
Reset zoom	Fits the entire chart to the current window size.
Create interval	Creates a new interval. For details on the statistical information, see section *Controls of the Deviation histogram Tab* on page 464.
Remove interval	Removes the selected interval.

Relative deviation histogram Tab

Available for **Wall thickness analysis (Sphere method)** calculated with the **Deviation** algorithm.

Shows a histogram of the calculated relative deviations for the entire analyzed surface of the selected object. The histogram bars can be colored according to the settings on the **Colors** tab.

Controls of the **Relative deviation histogram** Tab

Table 29-30: Controls of the **Relative deviation histogram** tab

Control	Description
Color drop-down field	• **From color bar**: The values in the histogram are shown according to the color bar. • **Gray**: All values in the histogram are shown in gray.
Normalization drop-down field	• **Absolute**: Displays the number of voxels in absolute values. • **Relative**: Displays the number of voxels in relative values with respect to the entire analyzed surface.

Control	Description
Binning drop-down field	• **Off**: No binning is applied to the values shown in the histogram. • **From color bar**: The original values in the histogram are replaced by a value that represents the corresponding interval (“bin”) of the color bar. The “bins” become visible when “stepped” sections are created on the **Colors** tab. • **Manual number of bins**: Enables the **Bin count** spin box, where you can enter the required number of “bins.” • **Manual bin width**: Enables the **Bin width** spin box, where you can specify the width of the individual bins.
Left/**Right** spin box	Only enabled when an interval has been created: Moves the left or right interval border to the specified value. You can also click and drag the interval borders by using the left mouse button.
Create button	Creates a new interval. On the right hand side of a selected interval, statistical information is displayed: • **Left**: Indicates the minimum relative deviation within the interval, i.e., the value of the left interval border. • **Right**: Indicates the maximum relative deviation within the interval, i.e., the value of the right interval border. • **Mean**: Indicates the mean value of the relative deviations within the interval. • **Dev**: Indicates the standard deviation of the relative deviations within the interval. • **Sum**: Indicates the surface area within the interval. • **Percentage**: Indicates the percentage of the surface area within the interval. Note that the statistical information may change with the number of bins.
Remove button	Removes the selected interval.
Min. rel. wall thickness deviation/**Max. rel. wall thickness deviation [<ratio unit>]** fields	Indicate the minimum and maximum relative deviations between actual and nominal object.
Mean rel. wall thickness deviation [<ratio unit>] field	Indicates the mean relative deviation between actual and nominal object.
Standard deviation of rel. wall thickness deviation [<ratio unit>] field	Indicates the standard deviation of the relative deviations between actual and nominal object.

Control	Description
use RMB to click the chart area	Displays a context menu (see below).
scroll MW in chart area or x-axis up/down	Zooms the x-axis of the chart out/in.
scroll MW in y-axis up/down	Zooms the y-axis of the chart out/in.
use LMB to click and drag the x-axis	Scrolls the x-axis.
use LMB to click and drag the y-axis	Scrolls the y-axis.
Zoom in/**Zoom out**	Zooms the corresponding axis in/out.
Reset zoom	Fits the entire chart to the current window size.

Context Menu of the **Relative deviation histogram** Tab

Right-clicking anywhere in the chart area opens a context menu with the following options:

Table 29-31: Context menu items

Control	Description
Export as CSV...	Opens a dialog for saving the chart values to a *.csv* file.
Copy to clipboard	Copies a screenshot of the chart to the system clipboard so that you can paste it into another application.
Show/Hide x/y grid	Toggles the visibility of the grid lines for the corresponding axis.
Reset zoom	Fits the entire chart to the current window size.
Create interval	Creates a new interval. For details on the statistical information, see section *Controls of the Relative deviation histogram Tab* on page 466.
Remove interval	Removes the selected interval.

Components Tab

For **Ray method** algorithm: Lists all connected regions detected by the wall thickness analysis according to the parameters specified in the **Wall thickness** section of the **Settings** tab.

For **Sphere method** algorithm: Only available when the **Components** checkbox is activated on the **Settings** tab. Lists all connected regions detected within the specified **Wall thickness range**.

The **Components** table consists of the following columns:

Table 29-32: Columns of the **Components** table

Column	Description
Position x/y/z [<length unit>]	For **Sphere method** algorithm: Indicates the position of the corresponding component area. For **Ray method** algorithm: Indicates the position of the minimum thickness, maximum thickness, or spatial center of the corresponding component, depending on what has been selected from the **Position property** drop-down list (see section *Component analysis Section* on page 445).
Volume [<length unit>^{3}]	Indicates the volume of the component.
Surface [<length unit>^{2}]	Available for **Sphere method** algorithm only: Indicates the surface area of the component.
Mean wall thickness [<length unit>]	Available for **Sphere method** algorithm only: Indicates the mean wall thickness of the component.
Standard deviation of wall thickness (<length unit>]	Available for **Sphere method** algorithm only: Indicates the standard deviation of the wall thicknesses within the component.
Min. wall thickness [<length unit>]	Indicates the minimum wall thickness detected within the component.
Max. wall thickness [<length unit>]	Indicates the maximum wall thickness detected within the component.
Voxel count	Available for **Sphere method** algorithm only: Indicates the number of voxels the component consists of.
Description	Allows you to enter a description for the component used for reporting.

Column	Description
Image	Allows you to add a detailed 2D image and object description on a separate page of the report. • **Off**: No image is created (default). • **Orthographic projection**: Creates three orthogonal views. • **Top/Bottom/Left/Right/Front/Back**: Creates a single 2D view in the specified orientation. • **... - If not OK**: Automatically creates the image if the tolerance status is **Out of tolerance**. The image orientation is relative to the currently selected coordinate system. The image will be generated according to the render settings specified during report creation or VGRF-based export. The 2D slice position used for taking the image is determined by the position of the component. The zoom factor of the image is chosen so that the entire parent volume object, CAD model, or surface mesh is visible.
Focused image	This option is almost identical to the **Image** option but will generate an image that focuses on the respective item and is zoomed in by the **Zoom factor** specified during report creation or VGRF-based export.
Captures	Indicates the number of images captured for this object using the **Capture from** button in the **Screenshots** section.
Tolerance status	Indicates the tolerance status of the component depending on the tolerances specified for the components in the **Tolerance settings** section of the **Settings** tab: **Valid** (green), **Out of tolerance** (red), or **No tolerance** (gray).

If a column shows a parameter for which a tolerance has been specified (see section *Tolerance settings Section* on page 452 and section *Tolerance settings Section* on page 452), each entry will be evaluated separately according to the specified tolerance and highlighted in the following colors:

- Green: The tolerance is met.
- Red: The tolerance is not met.

Annotations Tab

Lists all annotations created for the selected wall thickness analysis. You can view the information supplied by the annotations or edit the annotation properties.

For details on how to create an annotation, see section *Annotation* on page 124 in chapter 6 *Inspect Tab*.

To create new annotations in the table, it is also possible to paste previously copied coordinates by right-clicking the table and selecting **Paste** from the context menu or by pressing the **Ctrl** + **V** keyboard shortcut. For details, see the **Paste** menu item in section *Table Context Menu*.

Double-clicking an analysis annotation in the Scene Tree will directly open the **Annotations** tab of the properties dialog of the corresponding analysis.

Tolerance values will be interpreted according to DIN EN ISO 8015 (see also section *Rounding Rules* on page 4 in chapter 1 *Welcome*).

The **Annotations** table consists of the following columns:

Table 29-33: Columns of the **Annotations** table

Column	Description
Name	Indicates the name of the annotation.
Pos. x/y/z [<length unit>]	Indicates the position of the annotation.
Wall thickness [<length unit>]	Indicates the wall thickness of the analyzed data set at the current annotation position. If an individual tolerance has been specified in the **Min./Max. wall thickness** fields of the **Annotations** table, the annotation will be evaluated accordingly and the **Wall thickness** field will be highlighted in the following colors: • Green: The tolerance is met. • Red: The tolerance is not met.
Min./Max. wall thickness [<length unit>]	Allows you to specify individual tolerance values, i.e., the minimum/maximum permissible wall thickness for the corresponding annotation. This setting is independent of the **Min./Max. wall thickness** settings specified in the **Tolerance settings** section of the **Settings** tab.
Deviation [<length unit>]	Available for **Wall thickness analysis (Sphere method)** calculated with the **Deviation** algorithm. Indicates the wall thickness deviation of the actual object with respect to the nominal object at the current annotation position. If an individual tolerance has been specified in the **Min. deviation**/**Max. deviation** fields of the **Annotations** table, the annotation will be evaluated accordingly and the **Deviation** field will be highlighted in the following colors: • Green: The tolerance is met. • Red: The tolerance is not met.

Column	Description
Min. deviation/Max. deviation [<length unit>]	Available for **Wall thickness analysis (Sphere method)** calculated with the **Deviation** algorithm. Allows you to specify individual tolerance values, i.e., the minimum/maximum permissible wall thickness deviation for the corresponding annotation. This setting is independent of the **Min. wall thickness deviation/ Max. wall thickness deviation** settings specified in the **Tolerance settings** section of the **Settings** tab.
Rel. deviation [<ratio unit>]	Available for **Wall thickness analysis (Sphere method)** calculated with the **Deviation** algorithm. Indicates the relative wall thickness deviation of the actual object with respect to the nominal object at the current annotation position. If an individual tolerance has been specified in the **Min. rel. deviation/Max. rel. deviation** fields of the **Annotations** table, the annotation will be evaluated accordingly and the **Rel. deviation** field will be highlighted in the following colors: • Green: The tolerance is met. • Red: The tolerance is not met.
Min. rel. deviation/Max. rel. deviation [<ratio unit>]	Available for **Wall thickness analysis (Sphere method)** calculated with the **Deviation** algorithm. Allows you to specify individual tolerance values, i.e., the minimum/maximum permissible relative wall thickness deviation for the corresponding annotation. This setting is independent of the **Min. rel. deviation/Max. rel. deviation** settings specified in the **Tolerance settings** section of the **Settings** tab.
Description	Allows you to enter a description of the annotation used for reporting.

Column	Description
Image	Allows you to add a detailed 2D image and object description on a separate page of the report. • **Off**: No image is created (default). • **Orthographic projection**: Creates three orthogonal views. • **Top/Bottom/Left/Right/Front/Back**: Creates a single 2D view in the specified orientation. • **... - If not OK**: Automatically creates the image if the tolerance status is **Out of tolerance**. The image orientation corresponds to the currently selected coordinate system. The image will be generated according to the render settings specified during report creation or VGRF-based export. The 2D slice position used for taking the image is determined by the position of the annotation. The zoom factor of the image is chosen so that the entire parent volume object, CAD model, or surface mesh is visible.
Focused image	This option is almost identical to the **Image** option but will generate an image that focuses on the respective item and is zoomed in by the **Zoom factor** specified during report creation or VGRF-based export.
Captures	Indicates the number of images captured for this object using the **Capture from** button in the **Screenshots** section.
Tolerance status	Indicates the tolerance status at the position of the annotation if an individual tolerance has been specified in the **Min. wall thickness**/**Max. wall thickness**, **Min. deviation**/**Max. deviation**, or **Min. rel. deviation**/**Max. rel. deviation** fields of the **Annotations** table: **Valid** (green), **Out of tolerance** (red), or **No tolerance** (gray).
Type	Indicates how the annotation has been created: • **Automatic**: The annotation has been automatically created via the **Create annotation for min. thickness** or **Create annotation for max. thickness** option on the **Settings** tab. • **Manually defined**: The annotation has been defined by the user. • **Rule based**: The annotation has been created by a report rule.

General Table Controls

- List section

  The following table provides an overview of the general controls available in the various list views:

  Table 29-34: Controls in the list section

Control	Description
button	Opens a submenu for selecting the filter/search mode.
Filter	Clicking the **Click to add a filter or search criterion** field to the right of the icon opens a series of drop-down lists from which you can select a table column, an operator, and—depending on the column—a value. If a column does not offer a value drop-down list, you can type in a value. When the selection is complete, the table shows the rows matching the filter criterion. Clicking the **+** button or the **Click to add a filter or search criterion** field allows you to specify more filter criteria. Clicking the **x** button removes the filter.
Search	Clicking the **Click to add a filter or search criterion** field to the right of the icon opens a series of drop-down lists from which you can select a table column, an operator, and—depending on the column—a value. If a column does not offer a value drop-down list, you can type in a value. When the selection is complete, the table rows matching the search criterion are highlighted. Clicking the **+** button or the **Click to add a filter or search criterion** field allows you to specify more search criteria. Pressing **F3** jumps to the next search result in the list. Clicking the **x** button removes the search.
Full-text filter	Entering a value or text string into the input field to the right of the icon filters the table accordingly and shows the rows that match the filter criterion.
Full-text search	Entering a value or text string into the input field to the right of the icon searches the table accordingly and highlights the rows that match the search criterion.

Control	Description
use LMB to click on a table row	Selects the row and the corresponding object in the Scene Tree. In analysis result lists, the result, e.g., the component, is marked by a cross-hairs cursor in each of the 2D views.
hold **Ctrl** key + use LMB to click on several table rows	Selects the rows and the corresponding objects in the Scene Tree.
hold **Shift** key + use LMB to click on two separate table rows	Selects the two rows, including all rows between the two as well as the corresponding objects in the Scene Tree.
hold **Shift** key + use up/down arrow keys	Selects the rows and the corresponding objects in the Scene Tree.
press **Ctrl+A**	Selects all table rows.
use up and down arrow keys	Steps up and down through the table rows.
use RMB to click into the table area	Displays a context menu. See below.
use LMB to click a column heading	Sorts the table according to the values of the column. Clicking subsequently toggles between ascending and descending.
use LMB to click and drag column heading to new position, then release LMB	Inserts the column at the new position.
use LMB to double-click cell highlighted in white (light theme) or medium gray (dark theme)	If applicable: Allows you to edit the contents of the cell.

- **Screenshots** section (if available)

  The **Screenshots** section below the list section allows you to capture images from one of the 2D windows, the 3D window, or the current window layout for the item currently selected in the table. Only available if exactly one row is selected.

  Table 29-35: Controls in the **Screenshots** section

Control	Description
Capture from button	Adds the image of the view selected from the drop-down list to the preview area above.
use LMB to click and drag one or more images, then release LMB	Moves the image(s) to the new position.

Control	Description
double-click the image	Opens the **Snapshot display** window showing the image: • **Zoom in**/**Zoom out** button: Zooms the image in/out. You can also move the mouse pointer in the image area and turn the mouse wheel. • **Fit to window** button: Resets the zoom so that the image fits into the window.
click the **<no description>** place-holder twice (first click to select, second click to enable renaming)	Allows you to label the image.
Delete selected button	Deletes the selected image from the preview area.

Table Context Menu

Right-clicking anywhere in the table area shows a context menu with the following options:

Table 29-36: Context menu items

Control	Description
Columns	Allows you to toggle the visibility of each column by checking/unchecking the respective item. • **Show all**: Checks all columns to set them to visible. • **Hide all**: Unchecks all columns to set them to invis-ible. • **Hide empty**: Unchecks all not editable columns which are empty or **n/a** to set them to invisible.
Trim columns	Resizes all columns to their smallest possible size.
Apply default column layout	Applies the default column layout previously saved by the user to the current table. If no default column layout has been saved, the original column layout will be applied.
Save as default column layout	Saves modifications applied to the table—e.g., the visi-bility of a column, the order in which the columns appear, the column width—as default column layout. This layout will be applied when you create a new project.
Apply original column layout	Restores the original table layout and discards any modifications applied by the user. The original table layout is predefined and cannot be modified by the user.
Remove entries	If applicable: Deletes the selected row(s) from the table.

Control	Description
Create annotations	If applicable: Creates annotations for the selected items.
Export as CSV...	Opens the **Export as CSV...** dialog for exporting the table values as **.csv* file. This option always exports the complete table even if a filter was applied. In order to export only the filtered rows, press **Ctrl** + **A** to highlight all filtered rows and use the **Copy to clipboard** menu item.
Copy to clipboard	Copies the selected rows as well as the column heading into the system clipboard. The clipboard information is provided both as plain text and rich-text table, so when pasting into a rich-text-capable application like a word processor, you will see a proper table with cell borders and bold headings.
Paste	For annotation tables: Pastes previously copied coordinates and—optionally—snap directions to create new annotations in the table. For annotations of a nominal/actual comparison, the search distance specified on the **Settings** tab of the analysis will be considered. Note: Pasted annotations will be interpreted in the selected coordinate system at the time of pasting. The information in the clipboard must have the following structure: • x-, y-, and z-coordinate of the annotation or • x-, y-, and z-coordinate of the annotation as well as x-, y-, and z-component of the vector for the snap direction The parameters can be separated by space, tab, semicolon, or comma (if a comma is already used as a decimal mark or digit grouping symbol, the values must be enclosed in double quotation marks). Example: 8.89;25.82;-0.55;1;0;0 You can also copy the information directly from the cells of a spreadsheet. In order to paste the annotation information, you can also press the **Ctrl** + **V** keyboard shortcut.
Set as active column	If applicable: Makes the current column the active column, i.e., the results of this column are color-coded according to their values as defined by the color lookup table and the colors specified in the **Sections** section of the **Colors** tab.

Control	Description
Unset active column	If applicable: Deselects the currently active column and sets the **Active column** drop-down list on the corresponding **Settings** tab to **Uncoded**, i.e., removes any color coding.
Enter/change value (all items)	If applicable: Opens the **Enter value** dialog (see below) where you can enter the desired value for the selected parameter. This value will be applied to all entries in the table.
Enter/change value (selected items)	If applicable: Opens the **Enter value** dialog (see below) where you can enter the desired value for the selected parameter. This value will be applied to the selected entries in the table.
Delete selected items	If applicable: Removes the selected items from the scene.

The **Enter value** dialog includes the following controls:

Table 29-37: Controls in the **Enter value** dialog

Control	Description
Enter value field	Allows you to enter the desired value.
OK button	Sets the selected parameter to the specified value.
Reset button	For analyses only: Resets the selected parameter to undefined.
Set from tolerance settings button	For analyses only: Enters the value specified in the tolerance settings of the analysis for the selected parameter.
Cancel button	Discards the changes and closes the dialog.

Images Tab

Allows you to take screenshots of the selected workspace views and/or add bookmark references to the report. In the final report, the captured images will be listed separately from the screenshots created on other tabs.

- **Snapshots** section

  Table 29-38: Controls in the **Snapshots** section

Control	Description
Capture from button	Adds the image of the view selected from the drop-down list to the preview area above.

Control	Description
Delete selected button	Deletes the selected image(s) from the preview area.
use LMB to click and drag one or more images, then release LMB	Moves the image(s) to the new position.
double-click the image	Opens the **Snapshot display** window showing the image: • **Zoom in**/**Zoom out** button: Zooms the image in/out. You can also move the mouse pointer on the image area and turn the mouse wheel. • **Fit to window** button: Resets the zoom so that the image fits into the window.
click the **<no description>** place-holder twice (first click to select, second click to enable renaming)	Allows you to label the image.

- **Automatic 3D images** section (if available)

  Check the corresponding checkbox to include the desired 3D view (e.g., **Top**, **Front**, **Top-left-front**, and **Current camera settings**) in the report without changing the 3D view.

- **Bookmark references** section

  Allows you to add bookmark references via drag and drop from the **Bookmarks and views** tool or the **Bookmark editor** to the preview area. The images of the referenced bookmarks will then be included in VGRF-based reports.

  When you open a project with missing bookmark images, placeholders will be shown instead.

  Bookmark references are stored in evaluations and can be used in automation scenarios.

You will still need to import a bookmark template containing the actual bookmarks in these cases, as evaluations store only references to them.

Table 29-39: Controls in the **Bookmark references** section

Control	Description
New bookmark button	Adds a bookmark of the current view to the preview area.
Remove button	Removes the bookmark currently selected in the preview area.

Control	Description
click the bookmark title twice (first click to select, second click to enable renaming) or press the **F2** key	Allows you to rename the bookmark. The changes made on the **Images** tab will also affect the **Bookmark editor** and the **Bookmarks and views** tool. If the renamed bookmark is referenced by one or more objects for reporting, a warning message will be displayed indicating that the referenced bookmark will also be renamed for all these objects in the report.

The global concept of bookmark references allows for multiple objects to reference the same bookmark and for objects to reference bookmarks that show arbitrary information, e.g., other analyses or objects.

Rules Tab

Shows existing rules for selecting features (e.g., probability, radius) with defined properties to be included in the final report. Apart from that, the **Rule** dialog allows you to create new rules and edit or delete existing rules.

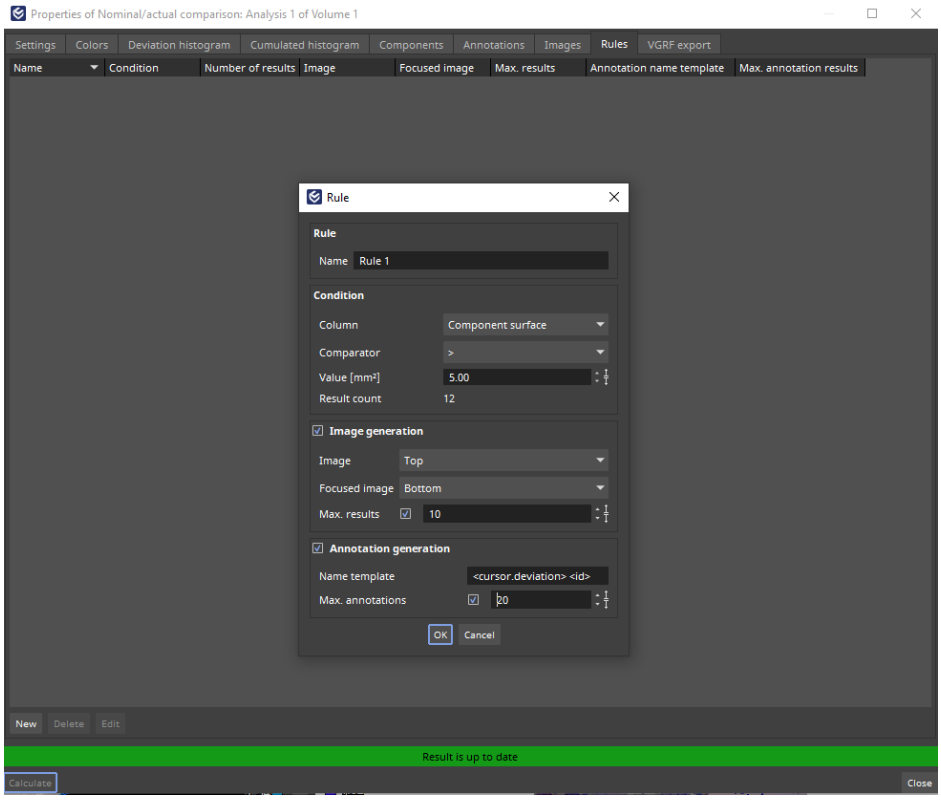


Figure 29-6: **Rules** tab with **Rule** dialog

- **New** button

Opens the **Rule** dialog for creating a new rule.

- **Delete** button

  Deletes a selected rule.

- **Edit** button

  Opens the **Rule** dialog for editing a selected rule.

You can also double-click a rule to open the **Rule** dialog for editing a selected rule.

Rule Dialog

- **Rule** section

  The **Name** field allows you to enter a name for the new rule. This name has to be unique.

- **Condition** section

  Table 29-40: Controls in the **Condition** section

Control	Description
Column drop-down list	Selects the property of the feature (e.g., probability, radius, diameter) that defines the rule.
Comparator drop-down list	Specifies the comparator to be applied to the selected property.
Value [<unit>] spin box or drop-down list	Specifies the reference value or status of the selected property for comparison.
Result count field	Indicates the number of results that meet the specified condition.

- **Image generation** section

  Table 29-41: Controls in the **Image generation** section

Control	Description
Image drop-down list	Allows you to add a detailed 2D image and object description on a separate page of the report. • **Off**: No image is created (default). • **Orthographic projection**: Creates three orthogonal views. • **Top/Bottom/Left/Right/Front/Back**: Creates a single 2D view in the specified orientation. • If applicable: **... - If not OK**: Automatically creates the image if the tolerance status is **Out of tolerance**.
Focused image drop-down list	This option is almost identical to the **Image** option, but will generate an image that focuses on the respective item and is zoomed in by the **Zoom factor** specified during report creation or VGRF-based export.

Control	Description
Max. results checkbox and spin box	When this option is checked, you will be able to use the corresponding spin box to specify the maximum number of results to be included in the report.

- **Annotation generation** section

  Table 29-42: Controls in the **Annotation generation** section

Control	Description
Name template field	Allows you to enter a name for the annotations. If this is not done, a name of the form <*annotation type*> <*id*> will automatically be generated.
Max. annotations checkbox and spin box	When this option is checked, you will be able to use the corresponding spin box to specify the maximum number of annotations to be generated.

In contrast to manually created annotations, rule-based annotations can neither be moved nor deleted. This is indicated by a closed padlock symbol next to the annotation name in the annotation label.

Rule-based annotations that are based on components are created at the position of the component that fulfills the condition. For wall thickness analyses performed with the **Sphere method** algorithm and nominal/actual comparisons, the position of the component is always the spatial center (or—if the spatial center lies outside the component—a position within the component that is closest to the spatial center), while for wall thickness analyses performed with the **Ray method** algorithm, the position is defined by the **Position property** option on the **Settings** tab of the properties dialog.

- **OK** button

  Closes the dialog, adds the new rule to the list in the **Rules** tab and updates the annotations.
- **Cancel** button

  Discards the settings and closes the dialog.

Manufacturing Geometry Correction Module

Introduction

The optional **Manufacturing Geometry Correction** module includes the following functions:

- **Tool correction** (see section *Tool Correction* on page 483)
- **Compensation mesh** (see section *Compensation Mesh* on page 487)
- **Iterative compensation mesh** (see section *Iterative Compensation Mesh* on page 487)
- **Morph mesh** (see section *Morph mesh* on page 487)

License Information

This module is an optional add-on module for VGSTUDIO MAX and VGMETROLOGY. It is not available for myVGL. However, if a project loaded in myVGL contains results obtained with this module, they can be viewed and reported in myVGL.

If you are interested in a more comprehensive functionality than the one offered by myVGL, you have the chance to evaluate VGSTUDIO MAX. You can request an evaluation license of VGSTUDIO MAX on our website:

https://volumegraphics.hexagon.com/en/products/evaluation

For further questions about our product portfolio, please contact us:

- For Europe, Middle East, and Africa:

  Write an e-mail to sales@volumegraphics.com or call +49 6221 73920 744.
- For Japan:

  Write an e-mail to sales@volumegraphics.jp or call +81 52 508 9682.
- For the Americas:

  Write an e-mail to sales-us@volumegraphics.com or call +1 704 248 7736.
- For China, including Mainland China, Hong Kong, Macao, and Taiwan:

  Write an e-mail to sales@volumegraphics.cn or call +86 10 8532 6305.
- For Singapore and other parts of Asia (except China and Japan), Australia, and parts of Oceania:

  Write an e-mail to sales@volumegraphics.sg or call +65 6665 0310.

Tool Correction

The **Tool correction** function is part of the **Manufacturing Geometry Correction** module of VGSTUDIO MAX and VGMETROLOGY and is designed for the following purposes:

- Part reconstruction: reconstructing areas of the actual surface of a scanned part for diverse applications (e.g., as a basis for reverse engineering).

- Part correction: correcting the geometry of the part based on the deviation between the actual and the nominal part for diverse applications (e.g., correcting the CAD model for 3D printing).
- Tool correction: correcting the geometry of the tool based on a part correction and the deviation between the CAD models of the nominal part and the current tool.

The data for the actual part can be available as the surface of a volume object from a CT scan.

As a result of the tool correction, the user will get new CAD components and, optionally, a color-coded visualization that shows where and how the manufactured part deviates from the nominal part, including curvatures and undercuts.

Opening the Dialog

In order to open the **Tool correction** dialog to view the components and their settings, double-click the corresponding entry in the Scene Tree.

The **Tool correction** dialog will open, which consists of the **Components** section to the left and the main section to the right.

The following controls are available for a new tool correction:

Table 30-1: Controls for a new tool correction

Control	Description
>> Components/<< Components button	Hides or shows the **Components** section on the left-hand side of the dialog. For details, see section *Components Section* on page 484.

Components Section

The components created for the tool correction will be listed in the **Components** section on the left-hand side of the dialog with respect to the workflow they were created for. A color field in front of each component indicates the color used for displaying the points of the component in the 3D window and the 2D windows.

Clicking the triangle in front of a workflow entry collapses or expands the entry.

Checking or unchecking the checkbox in front of a component shows or hides the component in the 3D window and the 2D windows.

Once you highlight a component in the **Components** section, the corresponding **Sampling**, **Adjustment**, and **Reconstruction** tabs will be displayed on the right-hand side of the window.

Sampling Tab

The **Sampling** tab allows you to view the settings for the initial points of the component.

Adjustment Tab

The **Adjustment** tab allows you to view all functions that were used to filter, compensate, and visualize the points.

Reconstruction Tab

The **Reconstruction** tab allows you to create a CAD face or wire from the compensated points calculated on the **Adjustment** tab for the selected component.

In myVGL, all parameter settings are displayed. Most of these parameters are read-only in myVGL. The complete functional range is available with VGSTUDIO MAX or VGMETROLOGY and the respective add-on module(s).

General Controls on the **Reconstruction** Tab

Table 30-2: General controls on the **Reconstruction** tab

Control	Description
Perform reconstruction checkbox	When this option is checked, the CAD reconstruction will be performed based on the points from the **Adjustment** tab.
drop-down list	Specifies the mode for the reconstruction. • **3D surface**: See section *3D surface Option* on page 486. • **2D section**: See section *2D section Option* on page 486. • **Re-align CAD geometry**: See section *Re-align CAD geometry Option* on page 486. • **Geometric primitive**: See section *Geometric primitive Option* on page 487.

Table 30-3: Controls in the **Result visualization** section

Control	Description
Result drop-down list	Allows you to specify the visualization options for the reconstructed CAD face or wire. • **Not visible** • **Grid**: Visualizes the UV grid of the reconstructed CAD face. • **Surface**: Visualizes the surface of the reconstructed CAD face. • **Grid and surface**: Visualizes the UV grid and the surface of the reconstructed CAD face.

Control	Description
Hairlines option	• **Visible** checkbox: When this option is checked, the shortest distance between the points from the **Adjustment** tab and the reconstructed CAD face or wire will be displayed by hairlines. • **Length** spin box: Allows you to apply a factor to the length of the hairlines. • **Tolerance** spin box: Allows you to specify a tolerance value for the length of the hairlines. If the tolerance is met, the color of the hairlines will be green. If the tolerance is not met, the color of the hairlines will be red.
Surface color drop-down list	• **Uniform** • **Gauss curvature (kU * kV)** • **Mean curvature (kU + kV)** • **Draft angle**
Draft angle option	Displays the components color-coded according to the draft angle as defined by the **Visualization axis** and **Min. required angle** options. Undercuts will be displayed in red.
Convert result to CAD radio buttons	• **New CAD object** option: Creates a new CAD object in the Scene Tree that will contain the reconstructed CAD face or wire. • **Add to** option: Appends the reconstructed CAD face or wire to an existing CAD object in the Scene Tree.
Convert button	Executes the conversion according to the settings.

3D surface Option

The controls points of the initial CAD face specified in this section (plane, cylinder, or face from the nominal CAD model) will be manipulated in order to minimize the deviations between the CAD face and the compensated points from the **Adjustment** tab.

2D section Option

This option allows you to fit a wire to the compensated points in a 2D slice. This approach may be useful when a geometry can be created in the CAD system by using the “sweep” or “loft” command on 2D sections.

Re-align CAD geometry Option

Allows you to rigidly move selected sets of CAD faces of the nominal mold to their compensated position, based on the compensated points.

Geometric primitive Option

When this option is checked, the resulting CAD face will be a geometric primitive adjusted to the position of the compensated points.

Compensation Mesh

The **Compensation mesh** function is part of the **Manufacturing Geometry Correction** module of VGSTUDIO MAX and VGMETROLOGY.

The **Compensation mesh** function creates a surface mesh that uses a deformation field to compensate for the difference between the source object (usually a nominal CAD model or STL mesh) and a target object (usually a scan of the actual object, i.e., a volume object or an STL mesh), for example, for distorted 3D-printed parts.

Iterative Compensation Mesh

The **Iterative compensation mesh** function is part of the **Manufacturing Geometry Correction** module of VGSTUDIO MAX and VGMETROLOGY.

The **Iterative compensation mesh** function creates a surface mesh that uses a deformation field to compensate for the difference between the source object (usually a nominal CAD model or STL mesh) and a target object (usually a scan of the actual object, i.e., a volume object or an STL mesh) in up to three iterations, for example, for distorted 3D-printed parts.

Morph mesh

The **Morph mesh** function is part of the **Manufacturing Geometry Correction** module of VGSTUDIO MAX and VGMETROLOGY.

The **Morph mesh** function creates a morphed mesh that uses a deformation field to adjust the positions of the triangle vertices on the source object (usually a nominal CAD model or STL mesh) to those of the corresponding vertices on the target object (usually a scan of the actual object, i.e., a volume object or an STL mesh).

Displacement Analysis

Introduction

The **Displacement analysis** shows how each surface point on the actual object is displaced compared to the corresponding point on the nominal object. As a result of this analysis, the user will get detailed information on and a color overlay of the displacements.

License Information

This analysis is part of an optional add-on module for VGSTUDIO MAX. It is not available for myVGL. However, if a project loaded in myVGL contains an analysis, its results can be viewed and reported in myVGL.

If you are interested in a more comprehensive functionality than the one offered by myVGL, you have the chance to evaluate VGSTUDIO MAX. You can request an evaluation license of VGSTUDIO MAX on our website:

https://volumegraphics.hexagon.com/en/products/evaluation

For further questions about our product portfolio, please contact us:

- For Europe, Middle East, and Africa:

  Write an e-mail to sales@volumegraphics.com or call +49 6221 73920 744.
- For Japan:

  Write an e-mail to sales@volumegraphics.jp or call +81 52 508 9682.
- For the Americas:

  Write an e-mail to sales-us@volumegraphics.com or call +1 704 248 7736.
- For China, including Mainland China, Hong Kong, Macao, and Taiwan:

  Write an e-mail to sales@volumegraphics.cn or call +86 10 8532 6305.
- For Singapore and other parts of Asia (except China and Japan), Australia, and parts of Oceania:

  Write an e-mail to sales@volumegraphics.sg or call +65 6665 0310.

Opening the Dialog

In order to open the **Displacement analysis** dialog,

- right-click the corresponding entry in the Scene Tree and select **Properties** from the context menu or
- double-click the corresponding entry in the Scene Tree.

The **Displacement analysis** dialog consists of several tabs on which you can view the results of the displacement analysis.

To close the dialog, click the **Close** button at the bottom of the dialog.

A status bar at the bottom of the dialog indicates the current status of the analysis. The status can be one of the following:

Table 31-1: Messages in the status bar

Status	Description
Result is up to date	The current analysis result is valid.
Calculation required	All required parameters have been specified and are consistent, but the analysis was not calculated or was invalidated by some user action before the project was saved.
Nominal object has no surface determination	No surface determination information is available for the nominal object. See also section *Surface determination* on page 949 in chapter 48 *Glossary*.
Actual object has no surface determination	No surface determination information is available for the actual object. See also section *Surface determination* on page 949 in chapter 48 *Glossary*.
License missing	The add-on module is not licensed.

An invalid or outdated status of an analysis will be indicated in the Scene Tree by a warning sign. Double-click the analysis to open it and check the status bar for messages.

The units of the dialog depend on the global unit settings (see section *Units Drop-down List* on page 33 in chapter 2 *Workspace*).

Settings Tab

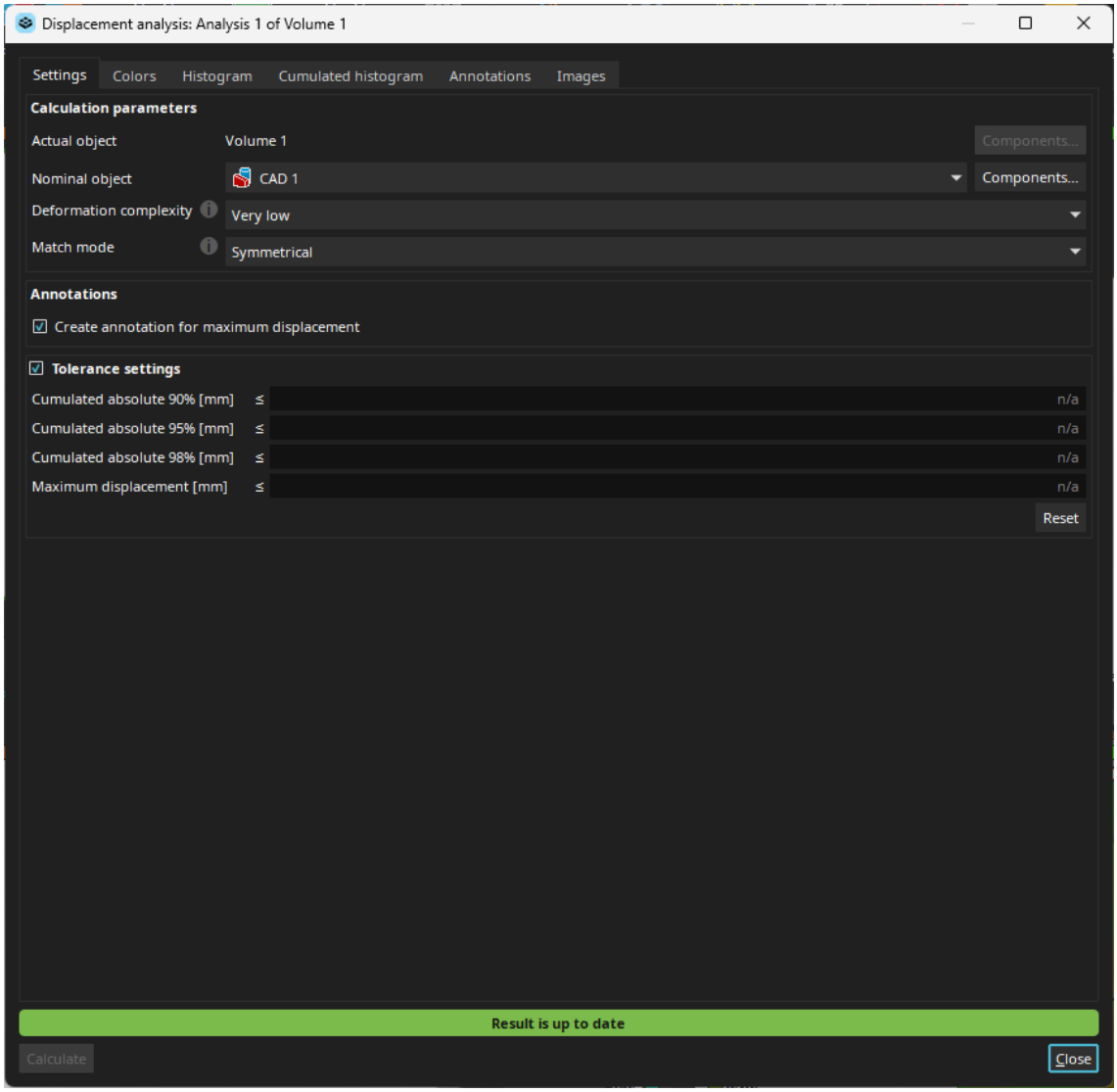
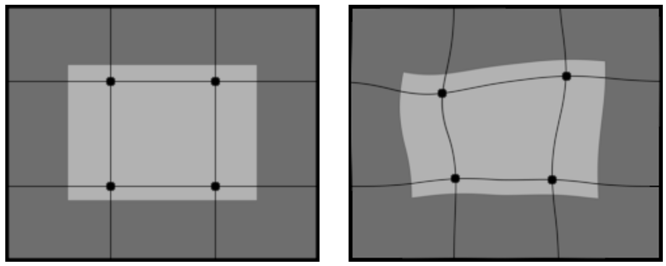
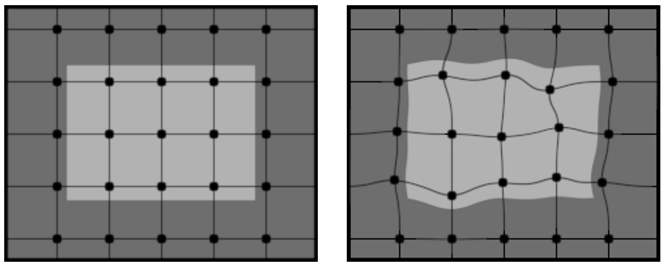


Figure 31-1: **Displacement analysis** dialog, **Settings** tab

In myVGL, all parameter settings are displayed. Most of these parameters are read-only in myVGL. The complete functional range is available with VGMETROLOGY or VGSTUDIO MAX and the respective add-on module(s).

Calculation parameters Section

Table 31-2: Controls in the **Calculation parameters** section

Control	Description
Actual object field	Indicates the object for which the displacement analysis is to be performed.
Nominal object drop-down list	Specifies the object (volume object, CAD model, or surface mesh) against which the displacements will be calculated.
Components... buttons	These buttons are enabled when the **Actual object** or the **Nominal object**, respectively, is an object with components. Clicking them opens a dialog box where you can specify the components to be used for calculation: • Checkbox of component: Clicking it checks/unchecks the component, including all child components. • **Select all** button: Selects all components of the object. • **Deselect all** button: Deselects all components of the object. • **Apply visibility** button: Selects all components which are set to visible in the Scene Tree.
Deformation complexity drop-down list	**Very low**, **Low**, **Medium**, **High**: A lower deformation complexity is suitable for smooth deformations between actual object and nominal object.  A higher deformation complexity is suited for complex deformations, at the cost of longer calculation time and increased memory requirements. 

Control	Description
Match mode drop-down list	• **Symmetrical**: The algorithm tries to match the actual object to the nominal object and vice versa, thus finding the best match that satisfies both directions. • **Incomplete nominal object**: The nominal object will only be fitted to the actual object. This setting is recommended if the nominal object is a subset of the actual object. • **Incomplete actual object**: The actual object will only be fitted to the nominal object. This setting is recommended if the actual object is a subset of the nominal object.

Annotations Section

Table 31-3: Controls in the **Annotations** section

Control	Description
Create annotation for maximum displacement checkbox	When this option is checked, the point where the maximum displacement between actual object and nominal object occurs will be calculated and shown as annotation at the corresponding position in the 3D window, the 2D windows, and the Scene Tree.

Tolerance settings Section

Tolerance values will be interpreted according to DIN EN ISO 8015 (see also section *Rounding Rules* on page 4 in chapter 1 *Welcome*).

Table 31-4: Controls in the **Tolerance settings** section

Control	Description
Tolerance settings checkbox	Checking this option allows you to define and apply the corresponding tolerance settings.
Maximum displacement [<length unit>] ≤ field	Specifies the maximum permissible displacement of the actual object from the nominal object.
Cumulated absolute 90% [<length unit>] ≤ field	Specifies the maximum permissible absolute displacement for 90% of the analyzed surface.
Cumulated absolute 95% [<length unit>] ≤ field	Specifies the maximum permissible absolute displacement for 95% of the analyzed surface.
Cumulated absolute 98% [<length unit>] ≤ field	Specifies the maximum permissible absolute displacement for 98% of the analyzed surface.
Reset button	Deletes all tolerance settings.

Depending on the results of this evaluation, the tolerances on the **Settings** tab will be highlighted in the following colors:

- Green: The tolerance is met.
- Red: The tolerance is not met.
- White (light theme)/black (dark theme): No tolerance settings have been specified or they are deactivated.
- Yellow: A tolerance has been specified but the analysis has to be (re-)calculated. Note that this color will also be used if the entered tolerance value is invalid.

The result of the evaluation is also displayed graphically in the Scene Tree. For more information on evaluations, see chapter 46 *Evaluations*.

Colors Tab

Here you can specify the color-coding scheme used for the representation of the analysis results.

Caption Section

Table 31-5: Controls of the **Caption** section

Control	Description
Caption field	Indicates the color bar headline as specified in the **Caption** field of the **Color bar** section.
Share color bar checkbox	When this option is checked, all analyses of the same type (and—if applicable—of the same algorithm) will use the same color bar. When this option is unchecked, the color bar settings will apply to the selected analysis only.

LUT – Color Lookup Table

The color lookup table (LUT) shows the partitioning into color sections.

Sections Section

Defines the appearance of each color section.

Table 31-6: Controls in the **Sections** section

Control	Description
From/To fields	Specify the start and end values of the color sections. The first color section represents all values above the upper limit, i.e., the value in the **From** field (**+inf** signifies positive infinity), while the last color section represents all values below the lower limit, i.e., the value in the **To** field (**-inf** signifies negative infinity). The default limits are calculated from the results of the analysis (for an analysis color bar) or taken from the **Default** preset (for a tolerance deviation color bar).
Type field	Switches between the color schemes **Continue**, **Constant**, **Gradient**, **Rainbow**, **Reverse rainbow**, **Hue cycle**, **Green to red**, and **Red to green**.
Color/transparency field	Double-clicking the field for the **Continue**, **Constant**, and **Gradient** color schemes opens the **Select Color** dialog where you can modify the appearance of the selected color scheme. For the **Gradient** color scheme, you can specify the start and end colors by double-clicking the left or right side of the field, respectively. Double-clicking the field for the **Rainbow**, **Reverse rainbow**, **Hue cycle**, **Green to red**, and **Red to green** color schemes opens the **Transparency** dialog, where you can set the transparency for the selected color scheme.
use RMB to click a color section	Opens a context menu with the following items: • **Split**: Subdivides the color section into two new color sections where each represents half of the original section. • **Merge**: Combines several color sections to a single color section. Only consecutive intervals can be merged.
Create smooth button	Opens the **Create smooth table** dialog to generate one color section. • **Type** drop-down list: Allows you to select the type of coloring scheme. • **From/To** spin boxes: Specify the value range covered by the color section.

Control	Description
Create stepped button	Opens the **Create stepped table** dialog to generate a set of color sections. • **Type** drop-down list: Allows you to select the type of coloring scheme. • **From/To** spin boxes: Specify the value range covered by the color sections. • **Step** spin box: Specifies the step size of the individual color sections.
Auto scale button	If available: Fits the color LUT to the range of the results of all available analyses.
Auto scale color bar range on calculate checkbox	If available: When this option is checked, the color LUT will be automatically fitted to the range of the results of all available analyses.
Default button	If available: Resets any changes made to the **Sections** table.

Preset selection Section

Table 31-7: Controls in the **Preset selection** section

Icon	Item	Description
	drop-down list	Specifies the preset to be applied, to be edited, or to be taken as a basis for a new preset. The following icons are used: • default preset • customized preset • appears next to the icon of a preset that has been modified but not yet saved
	Save preset	Opens the **Save preset** dialog for saving the color LUT of the current data set under the specified name. • **Absolute preset**: When this option is checked and the preset applied, the settings of the original data set, including the LUT range, will be applied. When this option is unchecked, the color settings of the preset will be mapped relatively to the actual range of results of the analysis to which the preset will be applied.
	Remove preset	Removes the selected preset from the preset drop-down list.
	Import preset	Imports a preset from the specified location.
	Export preset	Exports the selected preset to the specified location.

Displacement lines Section

Specifies the appearance of the displacement lines, which start on the actual object and go towards the nominal object.

Table 31-8: Controls in the **Displacement lines** section

Control	Description
Length factor spin box	Specifies a factor by which the length of the displacement lines is to be multiplied. A factor of 1 means that the lines indicate the actual distance between a point on the actual object and the corresponding point on the nominal object. With a factor of 2, the start point will remain on the actual object and the length of the line will be multiplied by 2.
Density drop-down list	Specifies the density and thus the number of displacement lines in the 3D view: **Sparse**, **Medium**, or **Dense**.

Histogram Tab

Shows a histogram of the calculated displacements for the entire analyzed surface of the selected object.

Controls of the **Histogram** Tab

Table 31-9: Controls of the **Histogram** tab

Control	Description
Color drop-down field	• **From color bar**: The values in the histogram are shown according to the color bar. • **Gray**: All values in the histogram are shown in gray.
Normalization drop-down field	• **Absolute**: Displays the surface in absolute values. • **Relative**: Displays the surface in relative values with respect to the entire analyzed surface.

Control	Description
Binning drop-down field	• **Off**: No binning is applied to the values shown in the histogram. • **From color bar**: The original values in the histogram are replaced by a value that represents the corre-sponding interval (“bin”) of the color bar. The “bins” become visible when “stepped” sections are created on the **Colors** tab. • **Manual number of bins**: Enables the **Bin count** spin box, where you can enter the required number of “bins.” • **Manual bin width**: Enables the **Bin width** spin box, where you can specify the width of the individual bins.
Left/**Right** spin box	Only enabled when an interval has been created: Moves the left or right interval border to the specified value. You can also click and drag the interval borders by using the left mouse button.
Create button	Creates a new interval. On the right hand side of a selected interval, statistical information is displayed: • **Left**: Indicates the minimum displacement within the interval, i.e., the value of the left interval border. • **Right**: Indicates the maximum displacement within the interval, i.e., the value of the right interval border. • **Mean**: Indicates the mean value of the displace-ments within the interval. • **Dev**: Indicates the standard deviation of the displacements within the interval. • **Sum**: Indicates the surface area within the interval. • **Percentage**: Indicates the percentage of the surface area within the interval. Note that the statistical information may change with the number of bins.
Remove button	Removes the selected interval.
Maximum displacement [<length unit>] field	Indicates the maximum displacement between actual object and nominal object.
use RMB to click the chart area	Displays a context menu (see below).
scroll MW in chart area or x-axis up/down	Zooms the x-axis of the chart out/in.
scroll MW in y-axis up/down	Zooms the y-axis of the chart out/in.
use LMB to click and drag the x-axis	Scrolls the x-axis.

Control	Description
use LMB to click and drag the y-axis	Scrolls the y-axis.
Zoom in/out	Zooms the corresponding axis in/out.
Reset zoom	Fits the entire chart to the current window size.

Context Menu of the **Histogram** Tab

Right-clicking anywhere in the chart area opens a context menu with the following options:

Table 31-10: Context menu items

Control	Description
Export as CSV...	Opens a dialog for saving the chart values to a *.csv* file.
Copy to clipboard	Copies a screenshot of the chart to the system clipboard so that you can paste it into another application.
Show/Hide x/y grid	Toggles the visibility of the grid lines for the corresponding axis.
Reset zoom	Fits the entire chart to the current window size.
Create interval	Creates a new interval. For details on the statistical information, see section *Controls of the Histogram Tab* on page 496.
Remove interval	Removes the selected interval.

Cumulated histogram Tab

Displays the cumulated surface area for a certain displacement value. The value is derived from the histogram data. You can use the curve to answer questions like “What percentage of the analyzed surface differs less than x mm from the nominal value?” or, conversely, “What is the smallest displacement that ninety percent of the analyzed surface does not exceed?”

Controls of the **Cumulated histogram** Tab

Table 31-11: Controls of the **Cumulated histogram** tab

Control	Description
Normalization drop-down field	• **Absolute**: Displays the surface in absolute values. • **Relative**: Displays the surface in relative values with respect to the entire analyzed surface.

Control	Description
Displacement [<length unit>] spin box	Indicates the displacement value that corresponds to the cumulated surface area with this displacement indicated in the **Surface** or **Normalized surface** field. You can also specify a displacement value for which you want to obtain the corresponding surface area. This control is synchronized with the green cross-hairs that indicate the corresponding position on the curve.
Surface/Normalized surface [<ratio unit>] spin box	Indicates the cumulated surface area that corresponds to the displacement value indicated in the **Displacement** field. You can also specify a surface area value for which you want to obtain the maximum displacement value. This control is synchronized with the green cross-hairs that indicate the corresponding position on the curve.
Cumulated absolute 90%/95%/98% [<length unit>] fields	Indicate the maximum absolute displacement values for 90%, 95%, or 98% of the analyzed surface, respectively.
use LMB to click and drag green cross-hairs lines	Moves the green cross-hairs along the curve, which indicates the percentage of the analyzed surface within a given displacement (or, alternatively, the maximum displacement for a given percentage).
use RMB to click the chart area	Displays a context menu (see below).
scroll MW in chart area or x-axis up/down	Zooms the x-axis of the chart out/in.
scroll MW in y-axis up/down	Zooms the y-axis of the chart out/in.
use LMB to click and drag the x-axis	Scrolls the x-axis.
use LMB to click and drag the y-axis	Scrolls the y-axis.
Zoom in/out	Zooms the corresponding axis in/out.
Reset zoom	Fits the entire chart to the current window size.

Context Menu of the **Cumulated histogram** Tab

Right-clicking anywhere in the chart area opens a context menu with the following options:

Table 31-12: Context menu items

Control	Description
Export as CSV…	Opens a dialog for saving the chart values to a *.csv* file.
Copy to clipboard	Copies a screenshot of the chart to the system clipboard so that you can paste it into another application.

Control	Description
Show/Hide x/y grid	Toggles the visibility of the grid lines for the corresponding axis.
Reset zoom	Fits the entire chart to the current window size.

Annotations Tab

Lists all annotations created for the selected displacement analysis. You can view the information supplied by the annotations or edit the annotation properties.

For details on how to create an annotation, see section *Annotation* on page 124 in chapter 6 *Inspect Tab*.

To create new annotations in the table, it is also possible to paste previously copied coordinates and (optionally) snap directions by right-clicking the table and selecting **Paste** from the context menu or pressing the **Ctrl** + **V** keyboard shortcut. For details, see the **Paste** menu item in section *Table Context Menu*.

Double-clicking an analysis annotation in the Scene Tree will directly open the **Annotations** tab of the properties dialog of the corresponding analysis.

Tolerance values will be interpreted according to DIN EN ISO 8015 (see also section *Rounding Rules* on page 4 in chapter 1 *Welcome*).

The **Annotations** table consists of the following columns:

Table 31-13: Columns of the **Annotations** table

Column	Description
Name	Indicates the name of the annotation.
Pos. x, y, z [<length unit>]	Indicates the position of the annotation on the actual object.
Displacement [<length unit>]	Indicates the distance between the current annotation position on the actual object and the corresponding point on the nominal object. If an individual tolerance has been specified in the **Max. Displacement** field of the **Annotations** table, the annotation will be evaluated accordingly, and the **Displacement** field will be highlighted in the following colors: • Green: The tolerance is met. • Red: The tolerance is not met.

Column	Description
Max. Displacement [<length unit>]	Allows you to specify an individual tolerance value (i.e., the maximum permissible displacement between actual and nominal object) for the corresponding annotation position.
Displacement vector x, **y**, **z** [<length unit>]	Indicate the x-, y-, and z-components of the displacement vector at the position of the annotation.
Pos. on nominal x, **y**, **z** [<length unit>]	Indicates the position on the nominal object that corresponds to the position of the annotation on the actual object.
Description	Allows you to enter a description of the annotation used for reporting.
Image	Allows you to add a detailed 2D image and object description on a separate page of the report. • **Off**: No image is created (default). • **Orthographic projection**: Creates three orthogonal views. • **Top/Bottom/Left/Right/Front/Back**: Creates a single 2D view in the specified orientation. • **... - If not OK**: Automatically creates the image if the tolerance status is **Out of tolerance**. The image orientation corresponds to the currently selected coordinate system. The image will be generated according to the render settings specified during report creation or VGRF-based export. The 2D slice position used for taking the image is determined by the position of the annotation. The zoom factor of the image is chosen so that the entire parent object is visible.
Focused image	This option is almost identical to the **Image** option but will generate an image that focuses on the respective item and is zoomed in by the **Zoom factor** specified during report creation or VGRF-based export.
Captures	Indicates the number of images that were captured for this object with the **Capture from** button in the **Screenshots** section.
Tolerance status	Indicates the tolerance status at the position of the annotation if an individual tolerance has been specified in the **Max. Displacement** field of the **Annotations** table: **Valid** (green), **Out of tolerance** (red), or **No tolerance** (gray).

Column	Description
Type	Indicates how the annotation has been created: • **Automatic**: The annotation has been automatically created via the **Create annotation for maximum displacement** option on the **Settings** tab. • **Manually defined**: The annotation has been defined by the user.

General Table Controls

- List section

  The following table provides an overview of the general controls available in the various list views:

  Table 31-14: Controls in the list section

Control	Description
button	Opens a submenu for selecting the filter/search mode.
Filter	Clicking the **Click to add a filter or search criterion** field to the right of the icon opens a series of drop-down lists from which you can select a table column, an operator, and—depending on the column—a value. If a column does not offer a value drop-down list, you can type in a value. When the selection is complete, the table shows the rows matching the filter criterion. Clicking the **+** button or the **Click to add a filter or search criterion** field allows you to specify more filter criteria. Clicking the **x** button removes the filter.
Search	Clicking the **Click to add a filter or search criterion** field to the right of the icon opens a series of drop-down lists from which you can select a table column, an operator, and—depending on the column—a value. If a column does not offer a value drop-down list, you can type in a value. When the selection is complete, the table rows matching the search criterion are highlighted. Clicking the **+** button or the **Click to add a filter or search criterion** field allows you to specify more search criteria. Pressing **F3** jumps to the next search result in the list. Clicking the **x** button removes the search.

Control	Description
Full-text filter	Entering a value or text string into the input field to the right of the icon filters the table accordingly and shows the rows that match the filter criterion.
Full-text search	Entering a value or text string into the input field to the right of the icon searches the table accordingly and highlights the rows that match the search criterion.
use LMB to click on a table row	Selects the row and the corresponding object in the Scene Tree. In analysis result lists, the result, e.g., the component, is marked by a cross-hairs cursor in each of the 2D views.
hold **Ctrl** key + use LMB to click on several table rows	Selects the rows and the corresponding objects in the Scene Tree.
hold **Shift** key + use LMB to click on two separate table rows	Selects the two rows, including all rows between the two as well as the corresponding objects in the Scene Tree.
hold **Shift** key + use up/down arrow keys	Selects the rows and the corresponding objects in the Scene Tree.
press **Ctrl+A**	Selects all table rows.
use up and down arrow keys	Steps up and down through the table rows.
use RMB to click into the table area	Displays a context menu. See below.
use LMB to click a column heading	Sorts the table according to the values of the column. Clicking subsequently toggles between ascending and descending.
use LMB to click and drag column heading to new position, then release LMB	Inserts the column at the new position.
use LMB to double-click cell highlighted in white (light theme) or medium gray (dark theme)	If applicable: Allows you to edit the contents of the cell.

- **Screenshots** section (if available)

  The **Screenshots** section below the list section allows you to capture images from one of the 2D windows, the 3D window, or the current window layout for the item currently selected in the table. Only available if exactly one row is selected.

  Table 31-15: Controls in the **Screenshots** section

Control	Description
Capture from button	Adds the image of the view selected from the drop-down list to the preview area above.

Control	Description
use LMB to click and drag one or more images, then release LMB	Moves the image(s) to the new position.
double-click the image	Opens the **Snapshot display** window showing the image: • **Zoom in**/**Zoom out** button: Zooms the image in/out. You can also move the mouse pointer in the image area and turn the mouse wheel. • **Fit to window** button: Resets the zoom so that the image fits into the window.
click the **<no description>** place-holder twice (first click to select, second click to enable renaming)	Allows you to label the image.
Delete selected button	Deletes the selected image from the preview area.

Table Context Menu

Right-clicking anywhere in the table area shows a context menu with the following options:

Table 31-16: Context menu items

Control	Description
Columns	Allows you to toggle the visibility of each column by checking/unchecking the respective item. • **Show all**: Checks all columns to set them to visible. • **Hide all**: Unchecks all columns to set them to invis-ible. • **Hide empty**: Unchecks all not editable columns which are empty or **n/a** to set them to invisible.
Trim columns	Resizes all columns to their smallest possible size.
Apply default column layout	Applies the default column layout previously saved by the user to the current table. If no default column layout has been saved, the original column layout will be applied.
Save as default column layout	Saves modifications applied to the table—e.g., the visi-bility of a column, the order in which the columns appear, the column width—as default column layout. This layout will be applied when you create a new project.
Apply original column layout	Restores the original table layout and discards any modifications applied by the user. The original table layout is predefined and cannot be modified by the user.

Control	Description
Remove entries	If applicable: Deletes the selected row(s) from the table.
Create annotations	If applicable: Creates annotations for the selected items.
Export as CSV...	Opens the **Export as CSV...** dialog for exporting the table values as **.csv* file. This option always exports the complete table even if a filter was applied. In order to export only the filtered rows, press **Ctrl** + **A** to highlight all filtered rows and use the **Copy to clipboard** menu item.
Copy to clipboard	Copies the selected rows as well as the column heading into the system clipboard. The clipboard information is provided both as plain text and rich-text table, so when pasting into a rich-text-capable application like a word processor, you will see a proper table with cell borders and bold headings.
Paste	For annotation tables: Pastes previously copied coordinates and—optionally—snap directions to create new annotations in the table. For annotations of a nominal/actual comparison, the search distance specified on the **Settings** tab of the analysis will be considered. Note: Pasted annotations will be interpreted in the selected coordinate system at the time of pasting. The information in the clipboard must have the following structure: • x-, y-, and z-coordinate of the annotation or • x-, y-, and z-coordinate of the annotation as well as x-, y-, and z-component of the vector for the snap direction The parameters can be separated by space, tab, semicolon, or comma (if a comma is already used as a decimal mark or digit grouping symbol, the values must be enclosed in double quotation marks). Example: 8.89;25.82;-0.55;1;0;0 You can also copy the information directly from the cells of a spreadsheet. In order to paste the annotation information, you can also press the **Ctrl** + **V** keyboard shortcut.
Set as active column	If applicable: Makes the current column the active column, i.e., the results of this column are color-coded according to their values as defined by the color lookup table and the colors specified in the **Sections** section of the **Colors** tab.

Control	Description
Unset active column	If applicable: Deselects the currently active column and sets the **Active column** drop-down list on the corresponding **Settings** tab to **Uncoded**, i.e., removes any color coding.
Enter/change value (all items)	If applicable: Opens the **Enter value** dialog (see below) where you can enter the desired value for the selected parameter. This value will be applied to all entries in the table.
Enter/change value (selected items)	If applicable: Opens the **Enter value** dialog (see below) where you can enter the desired value for the selected parameter. This value will be applied to the selected entries in the table.
Delete selected items	If applicable: Removes the selected items from the scene.

The **Enter value** dialog includes the following controls:

Table 31-17: Controls in the **Enter value** dialog

Control	Description
Enter value field	Allows you to enter the desired value.
OK button	Sets the selected parameter to the specified value.
Reset button	For analyses only: Resets the selected parameter to undefined.
Set from tolerance settings button	For analyses only: Enters the value specified in the tolerance settings of the analysis for the selected parameter.
Cancel button	Discards the changes and closes the dialog.

Images Tab

Allows you to take screenshots of the selected workspace views and/or add bookmark references to the report. In the final report, the captured images will be listed separately from the screenshots created on other tabs.

- **Snapshots** section

  Table 31-18: Controls in the **Snapshots** section

Control	Description
Capture from button	Adds the image of the view selected from the drop-down list to the preview area above.

Control	Description
Delete selected button	Deletes the selected image(s) from the preview area.
use LMB to click and drag one or more images, then release LMB	Moves the image(s) to the new position.
double-click the image	Opens the **Snapshot display** window showing the image: • **Zoom in**/**Zoom out** button: Zooms the image in/out. You can also move the mouse pointer on the image area and turn the mouse wheel. • **Fit to window** button: Resets the zoom so that the image fits into the window.
click the **<no description>** place-holder twice (first click to select, second click to enable renaming)	Allows you to label the image.

- **Automatic 3D images** section (if available)

  Check the corresponding checkbox to include the desired 3D view (e.g., **Top**, **Front**, **Top-left-front**, and **Current camera settings**) in the report without changing the 3D view.

- **Bookmark references** section

  Allows you to add bookmark references via drag and drop from the **Bookmarks and views** tool or the **Bookmark editor** to the preview area. The images of the referenced bookmarks will then be included in VGRF-based reports.

  When you open a project with missing bookmark images, placeholders will be shown instead.

  Bookmark references are stored in evaluations and can be used in automation scenarios.

You will still need to import a bookmark template containing the actual bookmarks in these cases, as evaluations store only references to them.

Table 31-19: Controls in the **Bookmark references** section

Control	Description
New bookmark button	Adds a bookmark of the current view to the preview area.
Remove button	Removes the bookmark currently selected in the preview area.

Control	Description
click the bookmark title twice (first click to select, second click to enable renaming) or press the **F2** key	Allows you to rename the bookmark. The changes made on the **Images** tab will also affect the **Bookmark editor** and the **Bookmarks and views** tool. If the renamed bookmark is referenced by one or more objects for reporting, a warning message will be displayed indicating that the referenced bookmark will also be renamed for all these objects in the report.

☞ The global concept of bookmark references allows for multiple objects to reference the same bookmark and for objects to reference bookmarks that show arbitrary information, e.g., other analyses or objects.

Visualization of the Analysis Results

Various overlays are provided for the visualization of the analysis results in the 2D and 3D windows. These overlays can be switched on or off in the Scene Tree below the analysis node by checking or unchecking the corresponding checkboxes.

- **Displacement** overlay

  The displacement is shown color-coded (according to the settings on the **Colors** tab of the **Displacement analysis** dialog) at each point in the object.

- **Displacement lines** overlay

  The distance between actual object and nominal object is shown in the form of displacement lines, which start on the actual object and go towards the nominal object. In the 2D views, the displacement lines start on the actual object and are projected to the slice plane before being drawn.

  The color of the lines is the same as the color of the starting point on the actual object (i.e., for a red-to-green color gradient, lines for small displacements will be green and lines for large displacements will be red).

  The appearance of the displacement lines can be tuned by setting their length factor and density in the **Displacement lines** section on the **Colors** tab.

GelSight Roughness Analysis

Introduction

The GelSight roughness analysis is part of the **GelSight Integration** module of VGSTUDIO MAX and VGMETROLOGY. It allows you to calculate the surface roughness of patch scans via the GelSight Mobile software and view the analysis results in myVGL.

License Information

This analysis is part of an optional add-on module for VGSTUDIO MAX. It is not available for myVGL. However, if a project loaded in myVGL contains an analysis, its results can be viewed and reported in myVGL.

If you are interested in a more comprehensive functionality than the one offered by myVGL, you have the chance to evaluate VGSTUDIO MAX. You can request an evaluation license of VGSTUDIO MAX on our website:

https://volumegraphics.hexagon.com/en/products/evaluation

For further questions about our product portfolio, please contact us:

- For Europe, Middle East, and Africa:

  Write an e-mail to sales@volumegraphics.com or call +49 6221 73920 744.
- For Japan:

  Write an e-mail to sales@volumegraphics.jp or call +81 52 508 9682.
- For the Americas:

  Write an e-mail to sales-us@volumegraphics.com or call +1 704 248 7736.
- For China, including Mainland China, Hong Kong, Macao, and Taiwan:

  Write an e-mail to sales@volumegraphics.cn or call +86 10 8532 6305.
- For Singapore and other parts of Asia (except China and Japan), Australia, and parts of Oceania:

  Write an e-mail to sales@volumegraphics.sg or call +65 6665 0310.

Opening the Dialog

In order to open the **GelSight roughness analysis** dialog,

- right-click the corresponding entry in the Scene Tree and select **Properties** from the context menu or
- double-click the corresponding entry in the Scene Tree.

The **GelSight roughness analysis** dialog consists of several tabs on which you can view the results of the **GelSight roughness** analysis.

To close the dialog, click the **Close** button at the bottom of the dialog.

Settings Tab

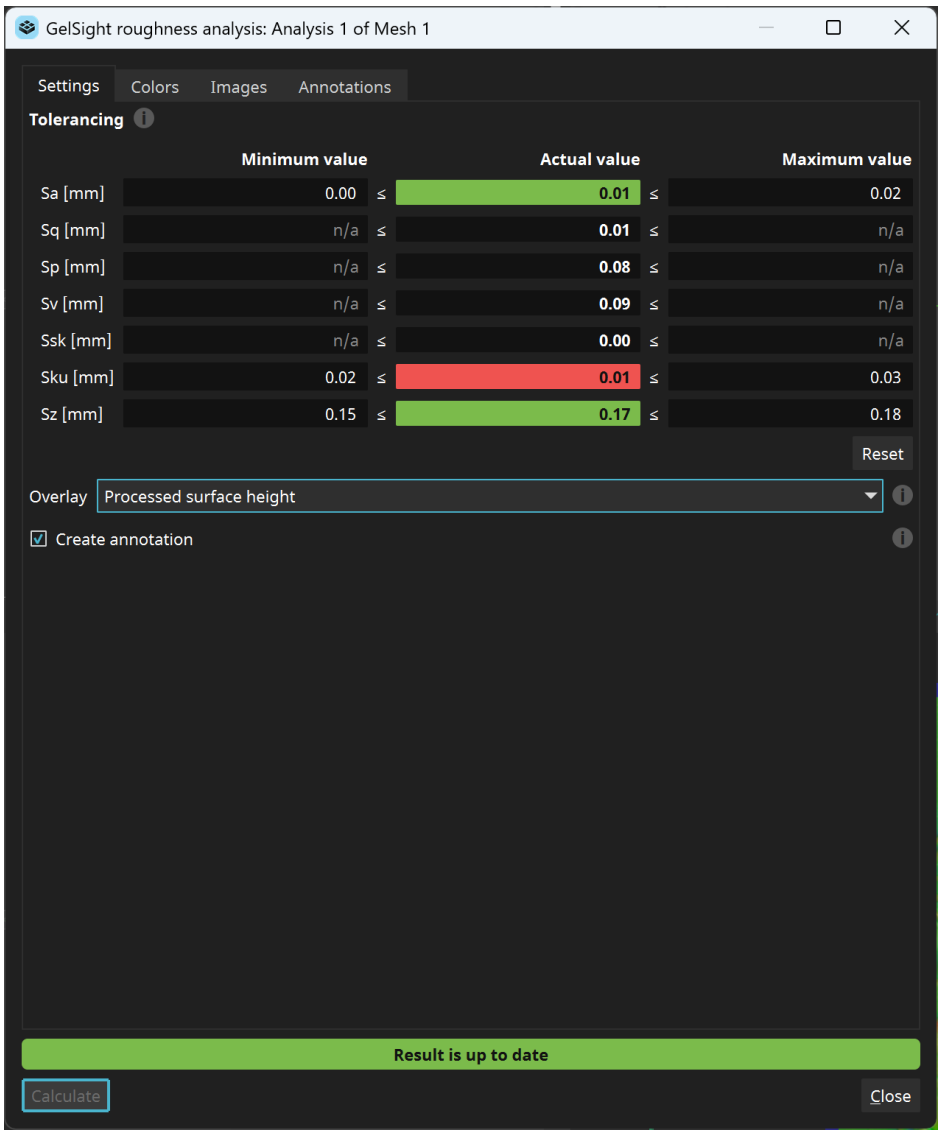


Figure 32-1: **GelSight roughness analysis** dialog, **Settings** tab

Tolerancing Section

The description of the following parameters refers to the GelSight specification. For details, please refer to the GelSight documentation.

Table 32-1: Controls in the **Tolerancing** section

Control	Description
Sa [<length unit>] (Minimum value/Actual value/ Maximum value) <= fields	Indicate the actual value of the *Average Roughness* and allow you to specify the minimum and maximum permissible values. **Sa** is the root mean square average of the ordinate values Z(x,y) within the evaluation area. Standards: • ASME B46.1-2019 — The parameter is computed over the evaluation area. • ISO 25178-2:2021 — In the ISO standard, Sa is referred to as “Arithmetical mean height.”
Sq [<length unit>] (Minimum value/Actual value/ Maximum value) <= fields	Indicate the actual value of the *Root Mean Square Roughness* and allow you to specify the minimum and maximum permissible values. **Sq** is the root mean square average of the ordinate values Z(x,y) within the evaluation area. Standards: • ASME B46.1-2019 — The parameter is computed over the evaluation area. • ISO 25178-2:2021 — In the ISO standard, Sq is referred to as “Root mean square height.”
Sp [<length unit>] (Minimum value/Actual value/ Maximum value) <= fields	Indicate the actual value of the *Maximum Peak Height* and allow you to specify the minimum and maximum permissible values. **Sp** is the maximum height of the ordinate values Z(x,y) with respect to the mean plane within the evaluation area. Standards: • ASME B46.1-2019 — The parameter is computed over the evaluation area. • ISO 25178-2:2021 — In the ISO standard, Sp is referred to as “Maximum peak height.”
Sv [<length unit>] (Minimum value/Actual value/ Maximum value) <= fields	Indicate the actual value of the *Maximum Pit Height* and allow you to specify the minimum and maximum permissible values. **Sv** is the absolute value of the minimum height of the ordinate values Z(x,y) with respect to the mean plane within the evaluation area. Standards: • ASME B46.1-2019 — The parameter is computed over the evaluation area. • ISO 25178-2:2021 — In the ISO standard, Sv is referred to as “Maximum pit depth.”

Control	Description
Ssk [<length unit>] (Minimum value/Actual value/ Maximum value) <= fields	Indicate the actual value of the *Skewness* and allow you to specify the minimum and maximum permissible values. **Ssk** is a measure of the asymmetry of the ordinate values Z(x,y) about the mean plane. The parameter is computed over the evaluation area. Standards: • ASME B46.1-2019 • ISO 25178-2:2021
Sku [<length unit>] (Minimum value/Actual value/ Maximum value) <= fields	Indicate the actual value of the *Kurtosis* and allow you to specify the minimum and maximum permissible values. **Sku** is a measure of the “peakedness” of the ordinate values Z(x,y) about the mean plane. The parameter is computed over the evaluation area. Standards: • ASME B46.1-2019
Sz [<length unit>] (Minimum value/Actual value/ Maximum value) <= fields	Indicate the actual value of the *Area Peak-to-Valley Height* and allow you to specify the minimum and maximum permissible values. **Sz** is computed as the vertical distance between maximum height and the maximum depth within the evaluation area. Standards: • ASME B46.1-2019 — Note: The ASME standard refers to this parameter as “St”. • ISO 25178-2:2021 — Sz = Sp + Sv. In the ISO standard, **Sz** is referred to as “Maximum Height.”
Reset button	Deletes all tolerance settings.

Overlay Section

Table 32-2: Controls in the **Overlay** section

Control	Description
Overlay drop-down list	Selects the visualized color overlay: • **Processed surface height**: Shows the filtered patch for roughness calculation (after “Form Removal” and “Filter Cutoff”; for details on the filter options, refer to the GelSight documentation). • **Original surface height**: Shows the original height map.
Create annotation checkbox	Creates an annotation that shows the global roughness parameters. The annotation points to the center of the patch.

Colors Tab

Here you can specify the color-coding scheme used for the representation of the analysis results.

Caption Section

Table 32-3: Controls of the **Caption** section

Control	Description
Caption field	Indicates the color bar headline as specified in the **Caption** field of the **Color bar** section.
Share color bar checkbox	When this option is checked, all analyses of the same type (and—if applicable—of the same algorithm) will use the same color bar. When this option is unchecked, the color bar settings will apply to the selected analysis only.

LUT – Color Lookup Table

The color lookup table (LUT) shows the partitioning into color sections.

Sections Section

Defines the appearance of each color section.

Table 32-4: Controls in the **Sections** section

Control	Description
From/To fields	Specify the start and end values of the color sections. The first color section represents all values above the upper limit, i.e., the value in the **From** field (**+inf** signifies positive infinity), while the last color section represents all values below the lower limit, i.e., the value in the **To** field (**-inf** signifies negative infinity). The default limits are calculated from the results of the analysis (for an analysis color bar) or taken from the **Default** preset (for a tolerance deviation color bar).
Type field	Switches between the color schemes **Continue**, **Constant**, **Gradient**, **Rainbow**, **Reverse rainbow**, **Hue cycle**, **Green to red**, and **Red to green**.

Control	Description
Color/transparency field	Double-clicking the field for the **Continue**, **Constant**, and **Gradient** color schemes opens the **Select Color** dialog where you can modify the appearance of the selected color scheme. For the **Gradient** color scheme, you can specify the start and end colors by double-clicking the left or right side of the field, respectively. Double-clicking the field for the **Rainbow**, **Reverse rainbow**, **Hue cycle**, **Green to red**, and **Red to green** color schemes opens the **Transparency** dialog, where you can set the transparency for the selected color scheme.
use RMB to click a color section	Opens a context menu with the following items: • **Split**: Subdivides the color section into two new color sections where each represents half of the original section. • **Merge**: Combines several color sections to a single color section. Only consecutive intervals can be merged.
Create smooth button	Opens the **Create smooth table** dialog to generate one color section. • **Type** drop-down list: Allows you to select the type of coloring scheme. • **From/To** spin boxes: Specify the value range covered by the color section.
Create stepped button	Opens the **Create stepped table** dialog to generate a set of color sections. • **Type** drop-down list: Allows you to select the type of coloring scheme. • **From/To** spin boxes: Specify the value range covered by the color sections. • **Step** spin box: Specifies the step size of the individual color sections.
Auto scale button	If available: Fits the color LUT to the range of the results of all available analyses.
Auto scale color bar range on calculate checkbox	If available: When this option is checked, the color LUT will be automatically fitted to the range of the results of all available analyses.
Default button	If available: Resets any changes made to the **Sections** table.

Images Tab

Allows you to take screenshots of the selected workspace views and/or add bookmark references to the report. In the final report, the captured images will be listed separately from the screenshots created on other tabs.

- **Snapshots** section

  Table 32-5: Controls in the **Snapshots** section

Control	Description
Capture from button	Adds the image of the view selected from the drop-down list to the preview area above.
Delete selected button	Deletes the selected image(s) from the preview area.
use LMB to click and drag one or more images, then release LMB	Moves the image(s) to the new position.
double-click the image	Opens the **Snapshot display** window showing the image: • **Zoom in**/**Zoom out** button: Zooms the image in/out. You can also move the mouse pointer on the image area and turn the mouse wheel. • **Fit to window** button: Resets the zoom so that the image fits into the window.
click the **<no description>** placeholder twice (first click to select, second click to enable renaming)	Allows you to label the image.

- **Automatic 3D images** section (if available)

  Check the corresponding checkbox to include the desired 3D view (e.g., **Top**, **Front**, **Top-left-front**, and **Current camera settings**) in the report without changing the 3D view.

- **Bookmark references** section

  Allows you to add bookmark references via drag and drop from the **Bookmarks and views** tool or the **Bookmark editor** to the preview area. The images of the referenced bookmarks will then be included in VGRF-based reports.

  When you open a project with missing bookmark images, placeholders will be shown instead.

  Bookmark references are stored in evaluations and can be used in automation scenarios.

☞ You will still need to import a bookmark template containing the actual bookmarks in these cases, as evaluations store only references to them.

Table 32-6: Controls in the **Bookmark references** section

Control	Description
New bookmark button	Adds a bookmark of the current view to the preview area.
Remove button	Removes the bookmark currently selected in the preview area.
click the bookmark title twice (first click to select, second click to enable renaming) or press the **F2** key	Allows you to rename the bookmark. The changes made on the **Images** tab will also affect the **Bookmark editor** and the **Bookmarks and views** tool. If the renamed bookmark is referenced by one or more objects for reporting, a warning message will be displayed indicating that the referenced bookmark will also be renamed for all these objects in the report.

The global concept of bookmark references allows for multiple objects to reference the same bookmark and for objects to reference bookmarks that show arbitrary information, e.g., other analyses or objects.

Annotations Tab

Lists all annotations created for the selected GelSight roughness analysis. You can view the information supplied by the annotations or edit the annotation properties.

Annotations created for GelSight patches are valid for the entire patch, regardless of their position.

For details on how to create an annotation, see section *Annotation* on page 124 in chapter 6 *Inspect Tab*.

To create new annotations in the table, it is also possible to paste previously copied coordinates by right-clicking the table and selecting **Paste** from the context menu or by pressing the **Ctrl** + **V** keyboard shortcut. For details, see the **Paste** menu item in section *Table Context Menu*.

Double-clicking an analysis annotation in the Scene Tree will directly open the **Annotations** tab of the properties dialog of the corresponding analysis.

The **Annotations** table consists of the following columns:

Table 32-7: Columns of the **Annotations** table

Column	Description
Name	Indicates the name of the annotation.
Pos. x/y/z [<length unit>]	Indicates the position of the annotation.

Column	Description
Sa [<length unit>]	Indicates the actual value of the *Average roughness* at the current annotation position. If an individual tolerance has been specified in the **Nom./Min./Max. Sa** fields of the **Annotations** table, the annotation will be evaluated accordingly, and the **Sa** field will be highlighted in the following colors: • Green: The tolerance is met. • Red: The tolerance is not met.
Nom./Min./Max. Sa [<length unit>]	Allows you to specify individual tolerance values, i.e., the nominal/minimum/maximum permissible “average roughness” for the corresponding annotation. This setting is independent of the **Minimum value/Maximum value** settings specified in the **Tolerance settings** section of the **Settings** tab.
Sq [<length unit>]	Indicates the actual value of the *Root mean square roughness* at the current annotation position. If an individual tolerance has been specified in the **Nom./Min./Max. Sq** fields of the **Annotations** table, the annotation will be evaluated accordingly, and the **Sq** field will be highlighted in the following colors: • Green: The tolerance is met. • Red: The tolerance is not met.
Nom./Min./Max. Sq [<length unit>]	Allows you to specify individual tolerance values, i.e., the nominal/minimum/maximum permissible “root mean square roughness” for the corresponding annotation. This setting is independent of the **Minimum value/Maximum value** settings specified in the **Tolerance settings** section of the **Settings** tab.
Sp [<length unit>]	Indicates the actual value of the *Maximum peak height* at the current annotation position. If an individual tolerance has been specified in the **Nom./Min./Max. Sp** fields of the **Annotations** table, the annotation will be evaluated accordingly, and the **Sp** field will be highlighted in the following colors: • Green: The tolerance is met. • Red: The tolerance is not met.
Nom./Min./Max. Sp [<length unit>]	Allows you to specify individual tolerance values, i.e., the nominal/minimum/maximum permissible “maximum peak height” for the corresponding annotation. This setting is independent of the **Minimum value/Maximum value** settings specified in the **Tolerance settings** section of the **Settings** tab.

Column	Description
Sv [<length unit>]	Indicates the actual value of the *Maximum pit height* at the current annotation position. If an individual tolerance has been specified in the **Nom./Min./Max. Sv** fields of the **Annotations** table, the annotation will be evaluated accordingly, and the **Sv** field will be highlighted in the following colors: • Green: The tolerance is met. • Red: The tolerance is not met.
Nom./Min./Max. Sv [<length unit>]	Allows you to specify individual tolerance values, i.e., the nominal/minimum/maximum permissible “maximum pit height” for the corresponding annotation. This setting is independent of the **Minimum value**/**Maximum value** settings specified in the **Tolerance settings** section of the **Settings** tab.
Ssk [<length unit>]	Indicates the actual value of the *Skewness* at the current annotation position. If an individual tolerance has been specified in the **Nom./Min./Max. Ssk** fields of the **Annotations** table, the annotation will be evaluated accordingly, and the **Ssk** field will be highlighted in the following colors: • Green: The tolerance is met. • Red: The tolerance is not met.
Nom./Min./Max. Ssk [<length unit>]	Allows you to specify individual tolerance values, i.e., the nominal/minimum/maximum permissible “skewness” for the corresponding annotation. This setting is independent of the **Minimum value**/**Maximum value** settings specified in the **Tolerance settings** section of the **Settings** tab.
Sku [<length unit>]	Indicates the actual value of the *Kurtosis* at the current annotation position. If an individual tolerance has been specified in the **Nom./Min./Max. Sku** fields of the **Annotations** table, the annotation will be evaluated accordingly, and the **Sku** field will be highlighted in the following colors: • Green: The tolerance is met. • Red: The tolerance is not met.
Nom./Min./Max. Sku [<length unit>]	Allows you to specify individual tolerance values, i.e., the nominal/minimum/maximum permissible “kurtosis” for the corresponding annotation. This setting is independent of the **Minimum value**/**Maximum value** settings specified in the **Tolerance settings** section of the **Settings** tab.

Column	Description
Sz [<length unit>]	Indicates the actual value of the *Area peak-to-valley height* at the current annotation position. If an individual tolerance has been specified in the **Nom./Min./Max. Sz** fields of the **Annotations** table, the annotation will be evaluated accordingly, and the **Sz** field will be highlighted in the following colors: • Green: The tolerance is met. • Red: The tolerance is not met.
Nom./Min./Max. Sz [<length unit>]	Allows you to specify individual tolerance values, i.e., the nominal/minimum/maximum permissible “area peak-to-valley height” for the corresponding annotation. This setting is independent of the **Minimum value**/**Maximum value** settings specified in the **Tolerance settings** section of the **Settings** tab.
Description	Allows you to enter a description of the annotation used for reporting.
Image	Allows you to add a detailed 2D image and object description on a separate page of the report. • **Off**: No image is created (default). • **Orthographic projection**: Creates three orthogonal views. • **Top/Bottom/Left/Right/Front/Back**: Creates a single 2D view in the specified orientation. • **... - If not OK**: Automatically creates the image if the tolerance status is **Out of tolerance**. (Currently not implemented.) The image orientation corresponds to the currently selected coordinate system. The image will be generated according to the render settings specified during report creation or VGRF-based export.
Focused image	This option is almost identical to the **Image** option but will generate an image that focuses on the respective item and is zoomed in by the **Zoom factor** specified during report creation or VGRF-based export.
Captures	Indicates the number of images captured for this object using the **Capture from** button in the **Screenshots** section.
Tolerance status	Indicates the tolerance status at the position of the annotation if an individual tolerance has been specified in the **Nom./Min./Max.** fields of the **Annotations** table: **Valid** (green), **Out of tolerance** (red), or **No tolerance** (gray).

Column	Description
Type	Indicates how the annotation has been created: • **Rule based**: The annotation has been created by a report rule. (Currently not implemented.) • **Manually defined**: The annotation has been defined by the user.

General Table Controls

- List section

  The following table provides an overview of the general controls available in the various list views:

  Table 32-8: Controls in the list section

Control	Description
button	Opens a submenu for selecting the filter/search mode.
Filter	Clicking the **Click to add a filter or search criterion** field to the right of the icon opens a series of drop-down lists from which you can select a table column, an operator, and—depending on the column—a value. If a column does not offer a value drop-down list, you can type in a value. When the selection is complete, the table shows the rows matching the filter criterion. Clicking the **+** button or the **Click to add a filter or search criterion** field allows you to specify more filter criteria. Clicking the **x** button removes the filter.
Search	Clicking the **Click to add a filter or search criterion** field to the right of the icon opens a series of drop-down lists from which you can select a table column, an operator, and—depending on the column—a value. If a column does not offer a value drop-down list, you can type in a value. When the selection is complete, the table rows matching the search criterion are highlighted. Clicking the **+** button or the **Click to add a filter or search criterion** field allows you to specify more search criteria. Pressing **F3** jumps to the next search result in the list. Clicking the **x** button removes the search.

Control	Description
Full-text filter	Entering a value or text string into the input field to the right of the icon filters the table accordingly and shows the rows that match the filter criterion.
Full-text search	Entering a value or text string into the input field to the right of the icon searches the table accordingly and highlights the rows that match the search criterion.
use LMB to click on a table row	Selects the row and the corresponding object in the Scene Tree. In analysis result lists, the result, e.g., the component, is marked by a cross-hairs cursor in each of the 2D views.
hold **Ctrl** key + use LMB to click on several table rows	Selects the rows and the corresponding objects in the Scene Tree.
hold **Shift** key + use LMB to click on two separate table rows	Selects the two rows, including all rows between the two as well as the corresponding objects in the Scene Tree.
hold **Shift** key + use up/down arrow keys	Selects the rows and the corresponding objects in the Scene Tree.
press **Ctrl+A**	Selects all table rows.
use up and down arrow keys	Steps up and down through the table rows.
use RMB to click into the table area	Displays a context menu. See below.
use LMB to click a column heading	Sorts the table according to the values of the column. Clicking subsequently toggles between ascending and descending.
use LMB to click and drag column heading to new position, then release LMB	Inserts the column at the new position.
use LMB to double-click cell highlighted in white (light theme) or medium gray (dark theme)	If applicable: Allows you to edit the contents of the cell.

- **Screenshots** section (if available)

  The **Screenshots** section below the list section allows you to capture images from one of the 2D windows, the 3D window, or the current window layout for the item currently selected in the table. Only available if exactly one row is selected.

  Table 32-9: Controls in the **Screenshots** section

Control	Description
Capture from button	Adds the image of the view selected from the drop-down list to the preview area above.

Control	Description
use LMB to click and drag one or more images, then release LMB	Moves the image(s) to the new position.
double-click the image	Opens the **Snapshot display** window showing the image: • **Zoom in**/**Zoom out** button: Zooms the image in/out. You can also move the mouse pointer in the image area and turn the mouse wheel. • **Fit to window** button: Resets the zoom so that the image fits into the window.
click the **<no description>** place-holder twice (first click to select, second click to enable renaming)	Allows you to label the image.
Delete selected button	Deletes the selected image from the preview area.

Table Context Menu

Right-clicking anywhere in the table area shows a context menu with the following options:

Table 32-10: Context menu items

Control	Description
Columns	Allows you to toggle the visibility of each column by checking/unchecking the respective item. • **Show all**: Checks all columns to set them to visible. • **Hide all**: Unchecks all columns to set them to invis-ible. • **Hide empty**: Unchecks all not editable columns which are empty or **n/a** to set them to invisible.
Trim columns	Resizes all columns to their smallest possible size.
Apply default column layout	Applies the default column layout previously saved by the user to the current table. If no default column layout has been saved, the original column layout will be applied.
Save as default column layout	Saves modifications applied to the table—e.g., the visi-bility of a column, the order in which the columns appear, the column width—as default column layout. This layout will be applied when you create a new project.
Apply original column layout	Restores the original table layout and discards any modifications applied by the user. The original table layout is predefined and cannot be modified by the user.
Remove entries	If applicable: Deletes the selected row(s) from the table.

Control	Description
Create annotations	If applicable: Creates annotations for the selected items.
Export as CSV...	Opens the **Export as CSV...** dialog for exporting the table values as **.csv* file. This option always exports the complete table even if a filter was applied. In order to export only the filtered rows, press **Ctrl** + **A** to highlight all filtered rows and use the **Copy to clipboard** menu item.
Copy to clipboard	Copies the selected rows as well as the column heading into the system clipboard. The clipboard information is provided both as plain text and rich-text table, so when pasting into a rich-text-capable application like a word processor, you will see a proper table with cell borders and bold headings.
Paste	For annotation tables: Pastes previously copied coordinates and—optionally—snap directions to create new annotations in the table. For annotations of a nominal/actual comparison, the search distance specified on the **Settings** tab of the analysis will be considered. Note: Pasted annotations will be interpreted in the selected coordinate system at the time of pasting. The information in the clipboard must have the following structure: • x-, y-, and z-coordinate of the annotation or • x-, y-, and z-coordinate of the annotation as well as x-, y-, and z-component of the vector for the snap direction The parameters can be separated by space, tab, semicolon, or comma (if a comma is already used as a decimal mark or digit grouping symbol, the values must be enclosed in double quotation marks). Example: 8.89;25.82;-0.55;1;0;0 You can also copy the information directly from the cells of a spreadsheet. In order to paste the annotation information, you can also press the **Ctrl** + **V** keyboard shortcut.
Set as active column	If applicable: Makes the current column the active column, i.e., the results of this column are color-coded according to their values as defined by the color lookup table and the colors specified in the **Sections** section of the **Colors** tab.

Control	Description
Unset active column	If applicable: Deselects the currently active column and sets the **Active column** drop-down list on the corresponding **Settings** tab to **Uncoded**, i.e., removes any color coding.
Enter/change value (all items)	If applicable: Opens the **Enter value** dialog (see below) where you can enter the desired value for the selected parameter. This value will be applied to all entries in the table.
Enter/change value (selected items)	If applicable: Opens the **Enter value** dialog (see below) where you can enter the desired value for the selected parameter. This value will be applied to the selected entries in the table.
Delete selected items	If applicable: Removes the selected items from the scene.

The **Enter value** dialog includes the following controls:

Table 32-11: Controls in the **Enter value** dialog

Control	Description
Enter value field	Allows you to enter the desired value.
OK button	Sets the selected parameter to the specified value.
Reset button	For analyses only: Resets the selected parameter to undefined.
Set from tolerance settings button	For analyses only: Enters the value specified in the tolerance settings of the analysis for the selected parameter.
Cancel button	Discards the changes and closes the dialog.

Fiber Composite Material Analysis (FCMA) Module

Introduction

The **Fiber Composite Material Analysis (FCMA)** module has been designed to calculate and visualize local and global fiber orientations and fiber volume fractions in composite materials. It offers analysis modes for any type of fiber composite material and manufacturing process, no matter if you work with short fiber-reinforced materials in an injection molding process, long fiber compression-molded parts, or even with woven fabrics of unidirectional fibers. It allows you to derive fiber orientation tensors of injection-molded parts, for example, to validate flow simulations, to determine the principal orientations of woven fabrics or lay-up materials, or to investigate the orientation of plate-like structures. Detailed analysis results with information on local and global fiber statistics can be displayed in the form of fiber orientation tensors or histograms. Fiber and matrix statistics can be mapped to volume meshes and exported for use in your simulation software.

☞ The fiber orientation is calculated on the gray values and does not rely on the surface determination or the gray value threshold.

License Information

This module is an optional add-on module for VGSTUDIO MAX. It is not available for myVGL. However, if a project loaded in myVGL contains results obtained with this module, they can be viewed and reported in myVGL.

If you are interested in a more comprehensive functionality than the one offered by myVGL, you have the chance to evaluate VGSTUDIO MAX. You can request an evaluation license of VGSTUDIO MAX on our website:

https://volumegraphics.hexagon.com/en/products/evaluation

If you have further questions about our product portfolio, please contact us:

- For Europe, Middle East, and Africa:
  Write an e-mail to sales@volumegraphics.com or call +49 6221 73920 744.
- For Japan:
  Write an e-mail to sales@volumegraphics.jp or call +81 52 508 9682.
- For the Americas:
  Write an e-mail to sales-us@volumegraphics.com or call +1 704 248 7736.
- For China, including Mainland China, Hong Kong, Macao, and Taiwan:
  Write an e-mail to sales@volumegraphics.cn or call +86 10 8532 6305.
- For Singapore and other parts of Asia (except China and Japan), Australia, and parts of Oceania:
  Write an e-mail to sales@volumegraphics.sg or call +65 6665 0310.

Opening the Dialog

In order to open the **Fiber composite material analysis** dialog,

- right-click the corresponding entry in the Scene Tree and select **Properties** from the context menu or
- double-click the corresponding entry in the Scene Tree.

The **Fiber composite material analysis** dialog consists of several tabs on which you can view the results of the fiber composite material analysis.

To close the dialog, click the **Close** button at the bottom of the dialog.

A status bar at the bottom of the dialog indicates the current status of the analysis. The status can be one of the following:

Table 33-1: Messages in the status bar

Status	Description
Result is up to date	The current analysis result is valid.
Calculation required	All required parameters have been specified and are consistent, but the analysis was not calculated or was invalidated by some user action before the project was saved.
Object has no surface determination	**Use surface determination** is selected in the **Fiber material definition** section, but the parent object has no surface determination. See also section *Surface determination* on page 949 in chapter 48 *Glossary*.
Selected porosity/inclusion analysis has no results	The selected porosity/inclusion analysis is invalid.
License missing	The add-on module is not licensed.

An invalid or outdated status of an analysis is indicated in the Scene Tree by a warning sign. Double-click this analysis to open it and check the status bar for messages.

The units of the dialog depend on the global unit settings (see section *Units Drop-down List* on page 33 in chapter 2 *Workspace*).

Settings Tab

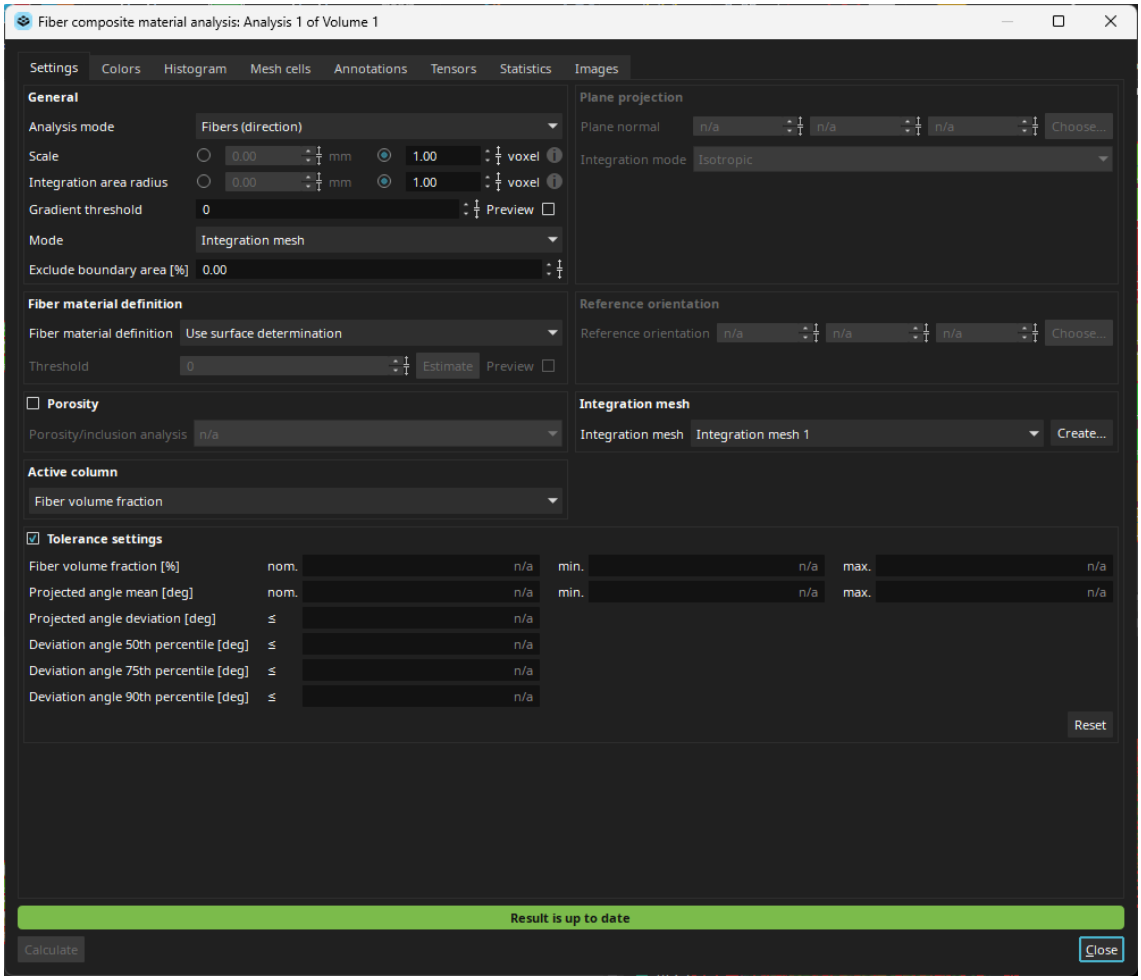


Figure 33-1: **Fiber composite material analysis** dialog, **Settings** tab

In myVGL, all parameter settings are displayed. Most of these parameters are read-only in myVGL. The complete functional range is available with VGSTUDIO MAX and the respective add-on module(s).

General Section

Table 33-2: Controls of the **General** section

Control	Description
Analysis mode drop-down list	Specifies the structure to be analyzed: • **Fibers (direction)**: Calculates the orientation along elongated narrow structures (e.g., fibers). • **Flakes (surface normal)**: Calculates the orientation of the normal of flat structures that extend in two directions.
Scale spin box	Specifies the resolution of the analysis. It is recommended that you set the scale to a value of 1 voxel. For high-resolution data sets, you can increase the value to reduce memory consumption. You can specify the resolution either in physical units or voxels.
Integration area radius spin box	Defines the radius of the volume around each grid point that will be used to analyze the local gray values and calculate the orientation. For separated fibers, it is recommended that you set this value to the fiber radius. When you investigate fiber bundles (for example, woven fabrics or lay-ups), you can increase the integration area radius up to half of the fiber bundle height which will make the result more robust against noise. You can specify the radius either in physical units or voxels.
Gradient threshold spin box	Specifies the local gray value gradient for differentiating between real structures in the data set, which are to be analyzed, and the noise within the data set. If the local gradient is smaller than the threshold, this area will not be analyzed. It is recommended that you specify 5% to 15% (starting with 10%) of the gray value difference between the fiber material and the matrix material as the start value. Note that the fiber orientation is calculated on the gray values and does not rely on the surface determination or the gray value threshold.
Preview checkbox	Check this option to display a preview of the areas where the orientation is calculated based on the specified values for **Scale**, **Integration area radius**, **Gradient threshold**, and **Exclude boundary area**.

Control	Description
Mode drop-down list	Specifies the analysis mode: • **Plane projection:** Calculates the orientation projected to the specified projection plane. This mode is useful for objects with a preferred plane or surface on which you want to analyze the fibers (e.g., woven or multiaxial fabrics and injection molding parts). This mode calculates the 3D orientations of the fibers, projects them to a user-defined plane, and calculates the projected angle from the reference axis within that plane. The automatically specified reference axis can be deduced from the color disk at the right edge of the 2D and the 3D views, where it is indicated by a small red line (for details, see section *Visualization of the Analysis Results* on page 534). If your parts are deformed or the preferred surface is non-planar, you can use the non-planar view to create a resampled volume with the preferred surface projected to a plane. • **Reference orientation:** Calculates the deviation of the orientation from the specified reference orientation. This mode is useful if you want to analyze the deviations of the fibers from a reference orientation, e.g., if you want to ensure that the fibers can sustain a tensile force. • **Space orientation:** Calculates the orientation in 3D. This mode is typically used for complicated injection molding parts. These parts do not have a preferred surface, so you cannot use the features of the non-planar view. They also do not have a preferred fiber orientation. This mode displays the calculated orientations completely in 3D. It is also a good starting point if you want to get a first impression of the fiber orientations within the volume. Based on the results of the **Space orientation** analysis, you can decide which other analysis mode may be useful. • **Integration mesh:** Calculates the mean orientation for each cell of the specified integration mesh. This mode is useful if you want to compare actual orientations with your simulations or use results as input for your simulations.

Control	Description
	• **Layered integration mesh:** Calculates the mean orientation for each cell of the specified integration mesh as well as the orientations projected to the plane specified in the **Mesh** dialog. Note: If the integration mesh is created from a cylinder or a freeform surface, the direction in which the fiber orientations are projected is the normal at the position of the corresponding cell. This mode is useful if you want to analyze materials structured in layers, such as woven or multiaxial fabrics.
Exclude boundary area spin box	Allows you to reduce the influence of structures outside the ROI on which the analysis is calculated. You can specify a value between 0% and 100%. Depending on the **Exclude boundary area** parameter and additionally depending on the **Scale** and **Integration area radius** parameters, the distance is calculated up to which the structures outside the ROI are considered. When **Exclude boundary area** is set to 100%, the distance will be 0 and the structures outside the ROI will not be considered at all. The more boundary area is excluded, the larger the area at the ROI border where the orientation cannot be calculated.

Fiber material definition Section

Table 33-3: Controls of the **Fiber material definition** section

Control	Description
Fiber material definition drop-down list	Specifies the method to define the fiber material: • **Use surface determination**: All areas within the surface determination are considered fiber material. • **Define manually**: All voxels with a gray value above the **Threshold** value are considered fiber material.
Threshold spin box	Specifies the gray value threshold for the manually defined fiber material (all voxels with a higher gray value are taken as fibers).
Estimate button	Click the **Estimate** button to have the gray value threshold deduced from the data set if you are not sure about the value.
Preview checkbox	Check this option to display a preview of the areas that will be considered as fiber material according to the manually specified gray value threshold.

Porosity Section

Available when **Integration mesh** or **Layered integration mesh** is selected in the **Mode** field of the **General** section.

When the **Porosity** checkbox is checked, the **Porosity/inclusion analysis** drop-down list, where you can select the porosity/inclusion analysis to be used for combined analysis, will be enabled. For each analyzed mesh cell, both the fiber orientation and the porosity will be calculated. The results will be shown on the **Mesh cells** tab.

Performing a porosity/inclusion analysis may require additional licensing. Contact us for details.

Active column Section

Only enabled when the analysis is performed on an integration mesh.

This drop-down list allows you to select the property that is to be shown according to the settings on the **Colors** tab.

When you select a mesh cell property (e.g., **1st eigenvalue**) from the **Active column** drop-down list, the mesh cells will be color-coded according to their first eigenvalue as defined by the color lookup table and the colors specified in the **Sections** section of the **Colors** tab. In the list on the **Mesh cells** tab, the column of the selected property will become the “active” column, and its values will be highlighted in bold and italic font.

When you select **Uncoded** from the **Active column** drop-down list, all mesh cells will be shown in gray, independently of their values. The **Colors** tab and the **Histogram** tab will not be visible in this case.

The property selected in the **Active column** drop-down list will be added to the information provided in the annotation labels.

You can also select the active column on the **Mesh cells** tab by right-clicking the column and selecting the **Set as active column** item from the context menu.

Plane projection Section

Available when **Plane projection** is selected in the **Mode** field of the **General** section. Allows you to calculate the projected angles within a selected plane.

Table 33-4: Controls of the **Plane projection** section

Control	Description
Plane normal fields	Specify the normal of the projection plane. The specified vector is normalized to unit length before it is taken into account in the calculation.
Choose... button	Opens a drop-down list showing the windows currently available in the workspace for specifying the normal of the projection plane. The normal is the normal of the selected 2D window or the current direction of view of the 3D window.

Control	Description
Integration mode drop-down list	Specifies whether the integration area shall be 2D or 3D: • **Isotropic**: The average value is calculated from the 3D integration area (e.g., for injection molding). • **Planar**: The average value is calculated from the 2D integration area parallel to the projection plane (e.g., for filaments).

Reference orientation Section

Available when **Reference orientation** is selected in the **Mode** field of the **General** section. Allows you to visualize the deviations of the fiber orientation from a defined orientation.

Table 33-5: Controls of the **Reference orientation** section

Control	Description
Reference orientation fields	Specify the orientation relative to which the local fiber orientation will be calculated. The specified vector is normalized to unit length before it is taken into account in the calculation.
Choose... button	Opens a drop-down list that shows the windows currently available in the workspace for specifying the reference orientation. The reference orientation is the normal of the selected 2D window or the current direction of view of the 3D window.

Integration mesh Section

Available when **Integration mesh** or **Layered integration mesh** is selected in the **Mode** field of the **General** section. Allows you to obtain information about the orientations in a user-defined integration mesh. The information can then be exported and be used to run simulations of the processing and behavior of fiber composite material parts.

Table 33-6: Controls of the **Integration mesh** Section

Control	Description
Integration mesh drop-down list	Allows you to specify an integration mesh by selecting an existing mesh from the drop-down list.
Create… button	Creates an integration mesh and opens the **Mesh** dialog for adjusting the parameters manually.

Tolerance settings Section

Tolerance values will be interpreted according to DIN EN ISO 8015 (see also section *Rounding Rules* on page 4 in chapter 1 *Welcome*).

Table 33-7: Controls of the **Tolerance settings** section

control	description
Tolerance settings checkbox	Checking this option allows you to define and apply the corresponding tolerance settings.
Fiber volume fraction [<ratio unit>] (nom./min./max.) fields	Specify a nominal value and the tolerance range for the fiber volume fraction in the analyzed data. When no nominal value is specified, the **min.** and **max.** fields will specify the minimum and maximum permissible values for the fiber volume fraction. When nominal value is specified, the values in the **min.** and **max.** fields will refer to this value. Note that the tolerance settings for the fiber volume fraction will always refer to the whole part, not to individual cells of an integration mesh.
Projected angle mean [<angle unit>] (nom./min./max.) fields	For **Plane projection** mode: Specify a nominal value and the tolerance range for the mean value of the projected angles in the analyzed data. When no nominal value is specified, the **min.** and **max.** fields will specify the minimum and maximum permissible values for the mean value of the projected angles. When nominal value is specified, the values in the **min.** and **max.** fields will refer to this value.
Projected angle deviation [<angle unit>] < field	For **Plane projection** mode: Specifies the maximum permissible standard deviation of the projected angles.
Deviation angle 50th percentile [<angle unit>] < field	For **Reference orientation** mode: Specifies the maximum permissible deviation angle for 50% of the analyzed data.
Deviation angle 75th percentile [<angle unit>] < field	For **Reference orientation** mode: Specifies the maximum permissible deviation angle for 75% of the analyzed data.
Deviation angle 90th percentile [<angle unit>] field	For **Reference orientation** mode: Specifies the maximum permissible deviation angle for 90% of the analyzed data.
Reset button	Deletes all tolerance settings.

Depending on the results of this evaluation, the tolerances on the **Settings** tab are highlighted in the following colors:

- Green: The tolerance is met.
- Red: The tolerance is not met.

- White (light theme)/black (dark theme): No tolerance settings have been specified or they are deactivated.
- Yellow: A tolerance has been specified but the analysis has to be (re-)calculated. Note that this color will also be used if the entered tolerance value is invalid.

The result of the evaluation is also displayed graphically in the Scene Tree. For more information on evaluations, see chapter 46 *Evaluations*.

Visualization of the Analysis Results

When the projected angle of an orientation analysis of type **Plane projection** is displayed, the color coding is visualized on a color disk at the right edge of the 2D views and the 3D view. The color disk displays both the color coding and the orientation of the projection plane. When the object is rotated in 3D, the orientation of the color disk in the 3D view will be updated according to the new orientation of the projection plane in 3D.

When the orientations of an orientation analysis of type **Space orientation** are displayed, the color coding is visualized on a color sphere at the right edge of the 2D views and the 3D view. When the object is rotated in 3D, the orientation of the color sphere in the 3D view will be updated according to the new orientation of the analyzed object in 3D.

When the projected angles or the orientations of several orientation analyses are displayed, the color disks and color spheres will be displayed underneath each other.

The color disks or color spheres of orientation analyses that are selected in the Scene Tree are displayed in a larger size and have brighter colors than the color disks or color spheres of deselected analyses.

When the orientations of an orientation analysis of type **Layered integration mesh** are displayed, a small histogram in the 2D and 3D views indicates the distribution of orientations orthogonal to the specified direction within each mesh cell.

Colors Tab

The results of a fiber composite material analysis are displayed in the 2D and 3D views by a color-coded scheme. After an analysis has been calculated, the color settings are displayed on the **Colors** tab and can be changed.

All orientation analyses of the **Plane projection** and **Reference orientation** mode share the same color lookup table. Orientation analyses of the **Space orientation** mode have individual color lookup tables.

Plane projection and **Reference orientation** Modes

Caption Section

Table 33-8: Controls of the **Caption** section

Control	Description
Caption field	Indicates the color bar headline as specified in the **Caption** field of the **Color bar** section.
Share color bar checkbox	When this option is checked, all analyses of the same type (and—if applicable—of the same algorithm) will use the same color bar. When this option is unchecked, the color bar settings will apply to the selected analysis only.

LUT – Color Lookup Table

The color lookup table (LUT) shows the partitioning into color sections.

Sections Section

Defines the appearance of each color section.

Table 33-9: Controls in the **Sections** section

Control	Description
From/To fields	Specify the start and end values of the color sections. The first color section represents all values above the upper limit, i.e., the value in the **From** field (**+inf** signifies positive infinity), while the last color section represents all values below the lower limit, i.e., the value in the **To** field (**-inf** signifies negative infinity). The default limits are calculated from the results of the analysis (for an analysis color bar) or taken from the **Default** preset (for a tolerance deviation color bar).
Type field	Switches between the color schemes **Continue**, **Constant**, **Gradient**, **Rainbow**, **Reverse rainbow**, **Hue cycle**, **Green to red**, and **Red to green**.

Control	Description
Color/transparency field	Double-clicking the field for the **Continue**, **Constant**, and **Gradient** color schemes opens the **Select Color** dialog where you can modify the appearance of the selected color scheme. For the **Gradient** color scheme, you can specify the start and end colors by double-clicking the left or right side of the field, respectively. Double-clicking the field for the **Rainbow**, **Reverse rainbow**, **Hue cycle**, **Green to red**, and **Red to green** color schemes opens the **Transparency** dialog, where you can set the transparency for the selected color scheme.
use RMB to click a color section	Opens a context menu with the following items: • **Split**: Subdivides the color section into two new color sections where each represents half of the original section. • **Merge**: Combines several color sections to a single color section. Only consecutive intervals can be merged.
Create smooth button	Opens the **Create smooth table** dialog to generate one color section. • **Type** drop-down list: Allows you to select the type of coloring scheme. • **From/To** spin boxes: Specify the value range covered by the color section.
Create stepped button	Opens the **Create stepped table** dialog to generate a set of color sections. • **Type** drop-down list: Allows you to select the type of coloring scheme. • **From/To** spin boxes: Specify the value range covered by the color sections. • **Step** spin box: Specifies the step size of the individual color sections.
Auto scale button	If available: Fits the color LUT to the range of the results of all available analyses.
Auto scale color bar range on calculate checkbox	If available: When this option is checked, the color LUT will be automatically fitted to the range of the results of all available analyses.
Default button	If available: Resets any changes made to the **Sections** table.

Color bar Section

Specifies the settings for the color bar.

Table 33-10: Settings for the color bar

Control	Description
Visibility drop-down list	Switches the color bar on/off.
Positioning drop-down list	Specifies the location of the color bar within the 2D and 3D windows: **Left, Right, Top, Bottom, All - automatic, Left or right - automatic, Top or bottom - automatic**.
Caption field	Specifies the color bar headline by using placeholders.
Reset button	Resets the **Caption** field to the default entry.

Space orientation Mode

The **Colors** tab defines the color coding in the 2D and 3D windows. For **Space orientation** mode, the results can be displayed by using a color-coded scheme in two different ways according to the **Mode** specified in the **Settings** section. You can view the results in a polar color plot as well as in a spherical color plot.

Polar color plot Section

Visualizes the color coding in 2D on a polar color plot. The orientations calculated in the data set are color-coded according to their deviation from the orientation with the highest frequency, which is indicated by a white cross-hair cursor. You can specify a different orientation as reference by moving the cursor to a new position.

Table 33-11: Controls of the **Polar color plot** section

Control	Description
use LMB to click and drag the white cross-hairs	Moves the white cross-hairs to a new position.
hold down **Ctrl** key + click	Sets the white cross-hairs to the desired position.

Spherical color plot Section

Visualizes the color coding on a sphere in 3D in the scene coordinate system. The orientations are color-coded according to their deviation from the orientation with the highest frequency, which is indicated by the cursor (yellow point) on the sphere. You can specify another orientation as reference by moving the cursor to a new position.

Table 33-12: Controls of the **Spherical color plot** section

Control	Description
use LMB to click and drag	Rotates the sphere.
hold down **Ctrl** key + scroll MW	Zooms the plot in or out.

Settings Section

Table 33-13: Controls of the **Settings** section

Control	Description
Mode drop-down list	Allows you to choose a particular mode for the color coding: • **Deviation angle - rainbow:** The deviation angle of the orientation relative to a reference orientation is coded in rainbow colors. • **Deviation angle - gradient:** The deviation angle of the orientation relative to a reference orientation is color-coded as a gradient. • **Projected angle - hue cycle:** The orientation is projected to a plane. The resulting projected angle of the orientation is color-coded according to a hue cycle. The reference orientation and the normal of the projected plane are initially set to the most frequent orientation in the analyzed volume. It is displayed as a cursor in the **Polar color plot** and the **Spherical color plot** and can be changed by moving the cursor.
Topography spin box	Visualizes the frequency of the different orientations as the height of the surface of the sphere. The higher the frequency of an orientation, the higher the surface will be at this position. You can specify the topography value either via its input field or by positioning the cursor on the **Spherical color plot** and turning the mouse wheel while holding down the **Shift** key.
Interval [<angle unit>] spin boxes	Specify the angles for the color definition. You can also manually specify the angles by dragging the white lines in the **Color definition** section.
Cursor position [<angle unit>] spin boxes	Specify the values for azimuth φ and polar angle ϑ for the cursor position. You can also manually specify these values by moving the cursor on the **Polar color plot**.
Set cursor to histogram peak button	Sets the cursor to the most frequent orientation.

Color definition Section

- If the **Deviation angle - rainbow** mode is selected in the **Mode** drop-down list of the **Settings** section, the result will be coded in rainbow colors.

Table 33-14: Controls for the **Deviation angle - rainbow** mode

Control	Description
click and drag the left white line	Specifies the range of deviation angles that will be displayed in blue.
click and drag the middle white line	Moves the rainbow-colored range.
click and drag the right white line	Specifies the range of deviation angles that will be displayed in red.

- If the **Deviation angle - gradient** mode is selected in the **Mode** drop-down list of the **Settings** section, the orientations will be color-coded as a color gradient.

  Table 33-15: Controls for the **Deviation Angle - gradient** mode

Control	Description
click and drag the left white line	Specifies the range of deviation angles that will be displayed in red.
click and drag the middle white line	Moves the gradient-colored range.
click and drag the right white line	Specifies the range of deviation angles that will be displayed in green.

- If the **Projected angle - hue cycle** mode is selected in the **Mode** drop-down list of the **Settings** section, the resulting projected angle of the orientation will be color-coded according to a hue cycle. You can modify the transparency for the deviation angle of the orientation relative to the plane normal. This way, you can specify that only orientations that deviate more than the specified value from the plane normal will be color-coded.

  Table 33-16: Controls for the **Projected angle - hue cycle** mode

Control	Description
click and drag the left white line	Specifies the deviation range that will be displayed transparently.
click and drag the middle white line	Moves the transparency range, with the transparency ranging from transparent to opaque.
click and drag the right white line	Specifies the deviation range that will be displayed opaquely.

The lines on the left, in the middle, and on the right correspond to the **Interval** spin boxes in the **Settings** section.

Histogram Tab

The **Histogram** tab displays a color-coded histogram of the results of the fiber composite material analysis. The frequency is visualized according to this color code. The content differs depending on the selected analysis mode.

Plane projection and **Reference orientation** Modes

The **Histogram** tab for the **Plane projection** and the **Reference orientation** modes shows the projected angle distribution or deviation angle distribution, respectively, in a histogram according to the color coding defined on the **Colors** tab. The x-axis shows the angle, and the y-axis shows the number of voxels.

Controls of the **Histogram** Tab

Table 33-17: Controls of the **Histogram** tab

Control	Description
Color drop-down list	• **From color bar**: The values in the histogram are shown according to the color bar. • **Gray**: All values in the histogram are shown in gray.
Normalization drop-down list	• **Absolute:** Displays the number of voxels versus the analyzed orientation or deviation, respectively. • **Relative:** Displays the percentage of voxels versus the analyzed orientation or deviation, respectively.
Binning drop-down list	• **Off:** No binning is applied to the values shown in the histogram. • **From color bar:** The original values in the histogram are replaced by a value representative for the corresponding interval (“bin”) of the color bar. The “bins” become visible when creating “stepped” sections on the **Colors** tab. • **Manual number of bins**: Enables the **Bin count** spin box, where you can enter the required number of “bins.” • **Manual bin width**: Enables the **Bin width** spin box, where you can specify the width of the individual bins.
Left/Right spin box	Only enabled when an interval has been created: Moves the left or right interval border to the specified value. You can also click and drag the interval borders with the left mouse button.

Control	Description
Create button	Creates a new interval in the histogram with a default range. On the right hand side of the selected interval, statistical information is displayed: • **Left:** Indicates the minimum projected angle or deviation angle, respectively, within the interval, i.e., the value of the left interval border. • **Right:** Indicates the maximum projected angle or deviation angle, respectively, within the interval, i.e., the value of the right interval border. • **Mean:** Indicates the mean value of the projected angle or deviation angle, respectively, within the interval. • **Dev:** Indicates the standard deviation of the mean projected angle or deviation angle, respectively, within the interval. • **Sum:** Indicates the number of voxels within the interval. • **Percentage:** Indicates the ratio between all analyzed voxels and the voxels within the interval. Note that the statistical information may change with the number of bins.
Remove button	Removes the selected interval.
Create ROI button	Generates a new ROI that contains all voxels whose projected angle or deviation angle, respectively, lies within the range of the selected interval.
Projected angle mean [<angle unit>] field	For **Plane projection** analysis: Indicates the mean value of the selected angles.
Projected angle deviation [<angle unit>] field	For **Plane projection** analysis: Indicates the standard deviation of the selected angles.
Deviation angle 50th percentile field	For **Reference orientation** analysis: The deviation angles of 50% of the analyzed voxels fall into the interval between 0° and this angle.
Deviation angle 75th percentile field	For **Reference orientation** analysis: The deviation angles of 75% of the analyzed voxels fall into the interval between 0° and this angle.
Deviation angle 90th percentile field	For **Reference orientation** analysis: The deviation angles of 90% of the analyzed voxels fall into the interval between 0° and this angle.
use RMB to click the chart area	Displays a context menu (see below).

Control	Description
scroll MW in chart area or x-axis up/down	Zooms the x-axis of the chart out/in.
scroll MW in y-axis up/down	Zooms the y-axis of the chart out/in.
use LMB to click and drag the x-axis	Scrolls the x-axis.
use LMB to click and drag the y-axis	Scrolls the y-axis.
Zoom in/out	Zooms the corresponding axis in/out.
Reset zoom	Fits the entire chart to the current window size.

Context Menu of the **Histogram** Tab

Right-clicking anywhere in the chart area shows a context menu with the following options:

Table 33-18: Context menu items

Control	Description
Export as CSV...	Opens a dialog for saving the chart values to a *.csv* file.
Copy to clipboard	Copies a screenshot of the chart to the system clipboard so you can paste it in another application.
Show/Hide x/y grid	Toggles the visibility of the grid lines for the corresponding axis.
Reset zoom	Fits the entire chart to the current window size.
Create interval	Creates a new interval. For details on the statistical information, see section *Controls of the Histogram Tab* on page 540.
Remove interval	Removes the selected interval.
Create ROI	Generates a new ROI that contains all voxels whose projected angle or deviation angle, respectively, lies within the range of the selected interval.

Integration mesh, **Layered integration mesh** Modes

The **Histogram** tab for the **Integration mesh** and the **Layered integration mesh** modes shows the property selected in the **Active column** field of the **Settings** tab in a histogram according to the color coding defined on the **Colors** tab. The x-axis shows the property, and the y-axis shows the number of mesh cells.

If **Uncoded** is selected in the **Active column** section of the **Settings** tab, the **Colors** tab and the **Histogram** tab will not be visible.

Controls of the **Histogram** Tab

Table 33-19: Controls of the **Histogram** tab

Control	Description
Left/Right spin box	Only enabled when an interval has been created: Moves the left or right interval border to the specified value. You can also click and drag the interval borders with the left mouse button.
Create button	Creates a new interval in the histogram with a default range. On the right hand side of the selected interval, statistical information is displayed: • **Left:** Indicates the minimum value of the parameter selected in the **Active column** field of the **Settings** tab within the interval, i.e., the left interval border. • **Right:** Indicates the maximum value of the parameter selected in the **Active column** field of the **Settings** tab within the interval, i.e., the right interval border. • **Mean:** Indicates the mean value of the parameter selected in the **Active column** field of the **Settings** tab within the interval. • **Dev:** Indicates the standard deviation of the values of the parameter selected in the **Active column** field of the **Settings** tab within the interval. • **Sum:** Indicates the number of voxels of the parameter selected in the **Active column** field of the **Settings** tab within the interval. • **Percentage:** Indicates the percentage of the parameter selected in the **Active column** field of the **Settings** tab within the interval.
Remove button	Removes the selected interval.
use RMB to click the chart area	Displays a context menu (see below).
scroll MW in chart area or x-axis up/down	Zooms the x-axis of the chart out/in.
scroll MW in y-axis up/down	Zooms the y-axis of the chart out/in.
use LMB to click and drag the x-axis	Scrolls the x-axis.
use LMB to click and drag the y-axis	Scrolls the y-axis.
Zoom in/out	Zooms the corresponding axis in/out.
Reset zoom	Fits the entire chart to the current window size.

Context Menu of the **Histogram** Tab

Right-clicking anywhere in the chart area shows a context menu with the following options:

Table 33-20: Context menu items

Control	Description
Export as CSV...	Opens a dialog for saving the chart values to a *.csv* file.
Copy to clipboard	Copies a screenshot of the chart to the system clipboard so you can paste it in another application.
Show/Hide x/y grid	Toggles the visibility of the grid lines for the corresponding axis.
Reset zoom	Fits the entire chart to the current window size.
Create interval	Creates a new interval. For details on the statistical information, see section *Controls of the Histogram Tab* on page 543.
Remove interval	Removes the selected interval.

Space orientation Mode

The **Histogram** tab for the **Space orientation** analysis displays the frequency of each orientation according to the color code in the **Orientation histogram** section and the **Settings** section. The three visualization options **Equatorial plot**, **Spherical plot**, and **Polar plot** are available as buttons at the bottom of the **Orientation histogram** section.

!

The color coding for the frequency is different from the color coding for the visualization of the measured orientation in 2D and 3D.

Orientation histogram Section

The **Orientation histogram** displays the frequencies of the orientations on a sphere according to the selected plot:

- **Equatorial plot** button

  Shows the surface of the sphere unrolled into 2D with values with the same azimuth displayed on a horizontal line.

- **Spherical plot** button

  Shows a sphere in 3D. The tripod shows the axes of the current coordinate system. The following options for moving the sphere are available:

  Table 33-21: Controls for the **Spherical plot**

Control	Description
use LMB to click and drag	Rotates the sphere.
keep MMB pressed and move the cursor up and down	Rotates the sphere around the middle axis.
hold down **Ctrl** key + scroll MW	Zooms the plot in and out.

Control	Description
hold down **Shift** key + scroll MW	Visualizes the frequency of the different orientations as the height of the surface of the sphere. The higher the frequency of an orientation, the higher the surface at this position.

Right-clicking the **Orientation histogram** area displays a context menu with the following options:

Table 33-22: Context menu of the **Spherical plot**

Control	Description
Reset	Resets the sphere to its initial orientation and resets the zoom level.
Orbiting	Rotates the sphere around fixed axes (following the longitude and the latitude).

- **Polar plot** button

  Shows the surface of half the sphere in 2D (projected to the xy-plane of the current coordinate system); values with the same polar angle displayed on a line. The tripod shows the axes of the current coordinate system.

Settings Section

The **Settings** section displays the color coding of the results. The default color coding uses a rainbow spectrum from blue (low frequencies) to red (high frequencies). The color coding can be changed by moving the vertical white lines. The values of the axis express the voxel count per steradian.

Cumulated histogram Tab

For **Reference orientation** mode: Displays the cumulated percentage of the deviation angle. The rate is given in proportion to the total analyzed volume. It is derived from the histogram data.

You can use the deviation angle distribution curve to answer questions like “What percentage of the analyzed volume has a deviation angle less than 30°?” or, conversely, “What is the smallest deviation angle that ninety percent of the analyzed volume do not exceed?”

Controls of the **Cumulated histogram** Tab

Table 33-23: Controls of the **Cumulated histogram** tab

Control	Description
Deviation angle [<angle unit>] spin box	This control is synchronized with the green cross-hairs, which indicate the corresponding position on the curve.
Count [<ratio unit>] spin box	This control is synchronized with the green cross-hairs, which indicate the corresponding position on the curve.

Control	Description
use LMB to click and drag green cross-hairs lines	Moves the green cross-hairs along the curve, which indicates the percentage of the analyzed volume with a given deviation angle (or, alternatively, the deviation angle for a given percentage).
use RMB to click the chart area	Displays a context menu (see below).
scroll MW in chart area or x-axis up/down	Zooms the x-axis of the chart out/in.
scroll MW in y-axis up/down	Zooms the y-axis of the chart out/in.
use LMB to click and drag the x-axis	Scrolls the x-axis.
use LMB to click and drag the y-axis	Scrolls the y-axis.
Zoom in/out	Zooms the corresponding axis in and out.
Reset zoom	Fits the entire chart to the current window size.

Context Menu of the **Cumulated histogram** Tab

Right-clicking anywhere in the chart area shows a context menu with the following options:

Table 33-24: Context menu items

Control	Description
Export as CSV...	Opens a dialog for saving the chart values to a *.csv* file.
Copy to clipboard	Copies a screenshot of the chart to the system clipboard so you can paste it in another application.
Show/Hide x/y grid	Toggles the visibility of the grid lines for the corresponding axis.
Reset zoom	Fits the entire chart to the current window size.

Plot Tab

For **Plane projection** mode: Displays the results of the fiber composite material analysis per plane perpendicular to the specified plane normal. On the x-axis, the distance of the plane from the origin of the current coordinate system is displayed. On the y-axis, the selected orientation tensor is displayed. If the fiber volume fraction has been calculated, it will be displayed on an additional y-axis.

Controls of the **Plot** Tab

The following options are available for the **Plot** tab:

Table 33-25: Controls of the **Plot** tab

Control	Description
Orientation tensor xx/xy/xz/yy/yz/zz	When this curve is selected, the xx-/xy-/xz-/yy-/yz-/zz-component of the mean orientation tensor per plane in the current coordinate system will be displayed.
Fiber volume fraction	When this curve is selected, the ratio between fiber volume and total volume will be displayed.
use LMB to click an option of the list	Toggles the visibility of the corresponding curve.
hover the mouse pointer over one of the curves	Displays the legend of the selected function along with its values at the specified location and highlights the curve of the selected function.
use LMB to click and drag the vertical line in the histogram	Indicates the function values at the specified location and updates the slice views accordingly. Press the **Ctrl** key while left-clicking in the chart area to display the vertical line in case you dragged it out of the chart area.
use RMB to click the chart area	Displays a context menu (see below).
scroll MW in chart area or x-axis up/down	Zooms the x-axis of the chart out/in.
scroll MW in y-axis up/down	Zooms the y-axis of the chart out/in.
use LMB to click and drag the x-axis	Scrolls the x-axis.
use LMB to click and drag the y-axis	Scrolls the y-axis.
Zoom in/out	Zooms the corresponding axis in/out.
Reset zoom	Fits the entire chart to the current window size.

Context Menu of the **Plot** Tab

Right-clicking anywhere in the chart area shows a context menu with the following options:

Table 33-26: Context menu items

Control	Description
Export as CSV...	Opens a dialog for saving the chart values to a *.csv* file.
Copy to clipboard	Copies a screenshot of the chart to the system clipboard so you can paste it in another application.
Show/Hide x/y grid	Toggles the visibility of the grid lines for the corresponding axis.
Reset zoom	Fits the entire chart to the current window size.
Show/Hide legend	Displays or hides the legend for the plotted curves.

Mesh cells Tab

For **Integration mesh** and **Layered integration mesh** modes: Displays the results of the fiber composite material analysis for each cell of the integration mesh. The **Mesh cells** list consists of the following columns:

Table 33-27: Columns of the **Mesh cells** list

Column	Description
Element ID	If available, indicates the ID of the mesh cell for imported integration mesh files.
Pos. x/y/z [<length unit>]	Indicates the x-, y-, and z-position of the mesh cell center.
Orientation tensor xx/xy/xz/yy/yz/zz	Indicates the xx-/xy-/xz-/yy-/yz-/zz-component of the mean orientation tensor of the mesh cell in the current coordinate system.
1st eigenvector x/y/z	Indicates the x-/y-/z-component of the first eigenvector of the mesh cell in the current coordinate system.
2nd eigenvector x/y/z	Indicates the x-/y-/z-component of the second eigen-vector of the mesh cell in the current coordinate system.
3rd eigenvector x/y/z	Indicates the x-/y-/z-component of the third eigenvector of the mesh cell in the current coordinate system.
1st eigenvalue	Indicates the eigenvalue of the first eigenvector.
2nd eigenvalue	Indicates the eigenvalue of the second eigenvector.
3rd eigenvalue	Indicates the eigenvalue of the third eigenvector.
Analyzed voxels	Indicates the number of voxels in the mesh cell that have been analyzed.
Fiber volume fraction [<ratio unit>]	Indicates the ratio between fiber volume and total volume.
1st main direction x/y/z [<length unit>]	For **Layered integration mesh** mode only: Indicates the x-/y-/z-component of the first main direction of the projected orientation within a mesh cell.
2nd main direction x/y/z [<length unit>]	For **Layered integration mesh** mode only: Indicates the x-/y-/z-component of the second main direction of the projected orientation within a mesh cell.
3rd main direction x/y/z [<length unit>]	For **Layered integration mesh** mode only: Indicates the x-/y-/z-component of the third main direction of the projected orientation within a mesh cell.
Angular difference [<angle unit>]	For **Layered integration mesh** mode only: Indicates the size of the angle between the first and the second main direction within a mesh cell.

Column	Description
Porosity [<ratio unit>]	Indicates the porosity of the cell if an existing porosity/inclusion analysis has been selected on the **Settings** tab.
Description	Allows you to enter a description for the cell used for reporting.
Image	Allows you to add a detailed 2D image and object description on a separate page of the report. • **Off**: No image is created (default). • **Orthographic projection**: Creates three orthogonal views. • **Top/Bottom/Left/Right/Front/Back**: Creates a single 2D view in the specified orientation. The image orientation is relative to the currently selected coordinate system. The image will be generated according to the render settings specified during report creation or VGRF-based export. The 2D slice position used for taking the image is determined by the position of the cell. The zoom factor of the image is chosen so that the entire parent volume is visible.
Focused image	This option is almost identical to the **Image** option, but will generate an image that focuses on the respective item and is zoomed in by the **Zoom factor** specified during report creation or VGRF-based export.
Captures	Indicates the number of images captured for this component via the **Capture from** button in the **Screen-shots** section.

Annotations Tab

Lists all annotations created for the selected fiber composite material analysis. You can view the information supplied by the annotations or edit the annotation properties.

For details on how to create an annotation, see section *Annotation* on page 124 in chapter 6 *Inspect Tab*.

To create new annotations in the table, it is also possible to paste previously copied coordinates by right-clicking the table and selecting **Paste** from the context menu or by pressing the **Ctrl** + **V** keyboard shortcut. For details, see the **Paste** menu item in section *Table Context Menu*.

Double-clicking an analysis annotation in the Scene Tree will directly open the **Annotations** tab of the properties dialog of the corresponding analysis.

Tolerance values will be interpreted according to DIN EN ISO 8015 (see also section *Rounding Rules* on page 4 in chapter 1 *Welcome*).

The **Annotations** list consists of the following columns. The values displayed depend on the analysis mode:

Table 33-28: Columns of the **Annotations** list

Column	Description
Name	Indicates the name of the annotation.
Pos. x/y/z [<length unit>]	Indicates the position of the annotation.
Projected angle [<angle unit>]	For **Plane projection** mode: Indicates the projected angle at the position of the annotation.
Nom. projected angle [<angle unit>]	For **Plane projection** mode: Allows you to specify the nominal value for tolerancing the projected angle for the current annotation. Double-click the cell to edit it.
Min. projected angle [<angle unit>]	For **Plane projection** mode: Allows you to specify the minimum value for tolerancing the projected angle for the current annotation. Double-click the cell to edit it. If the value for **Nom. projected angle** is specified, the value for **Min. projected angle** will refer to this value. If the value for **Nom. projected angle** is not specified, the value for **Min. projected angle** will be considered as an absolute value.
Max. projected angle [<angle unit>]	For **Plane projection** mode: Allows you to specify the maximum value for tolerancing the projected angle for the current annotation. Double-click the cell to edit it. If the value for **Nom. projected angle** is specified, the value for **Max. projected angle** will refer to this value. If the value for **Nom. projected angle** is not specified, the value for **Max. projected angle** will be considered as an absolute value.
Orientation x/y/z	For **Space orientation** mode: Indicates the orientation at the position of the annotation.
Deviation angle [<angle unit>]	For **Reference orientation** mode: Indicates the deviation angle at the position of the annotation.
Max. deviation angle [<angle unit>]	For **Reference orientation** mode: Indicates the maximum value for tolerancing the deviation angle.
Fiber volume fraction [<ratio unit>]	Indicates the ratio between fiber volume and the total volume of the ROI or volume object.
Nom. fiber volume fraction [<ratio unit>]	Indicates the nominal value for tolerancing the fiber volume fraction.
Min. fiber volume fraction [<ratio unit>]	Indicates the minimal value for tolerancing the fiber volume fraction.

Column	Description
Max. fiber volume fraction [<ratio unit>]	Indicates the maximum value for tolerancing the fiber volume fraction.
1st eigenvalue	Indicates the eigenvalue of the first eigenvector.
2nd eigenvalue	Indicates the eigenvalue of the second eigenvector.
3rd eigenvalue	Indicates the eigenvalue of the third eigenvector.
Analyzed voxels	For **Layered integration mesh** mode: Indicates the number of voxels in the mesh cell that have been analyzed.
Angular difference [<angle unit>]	For **Layered integration mesh** mode: Indicates the size of the angle between the first and the second main direction within a mesh cell.
Porosity [<ratio unit>]	Indicates the porosity of the cell if an existing porosity/inclusion analysis has been selected on the **Settings** tab.
Description	Allows you to enter a description of the annotation used for reporting.
Image	Allows you to add a detailed 2D image and object description on a separate page of the report. • **Off**: No image is created (default). • **Orthographic projection**: Creates three orthogonal views. • **Top/Bottom/Left/Right/Front/Back**: Creates a single 2D view in the specified orientation. • **... - If not OK**: Automatically creates the image if the tolerance status is **Out of tolerance**. The image orientation is relative to the currently selected coordinate system. The image will be generated according to the render settings specified during report creation or VGRF-based export. The 2D slice position used for taking the image is determined by the position of the annotation. The zoom factor of the image is chosen so that the entire parent volume is visible.
Focused image	This option is almost identical to the **Image** option, but will generate an image that focuses on the respective item and is zoomed in by the **Zoom factor** specified during report creation or VGRF-based export.
Captures	Indicates the number of images captured for this object using the **Capture from** button in the **Screenshots** section.

Column	Description
Tolerance status	Indicates the overall tolerance status of all parameters at the position of the annotation: **Valid** (green), **Out of tolerance** (red), or **No tolerance** (gray).
Type	Indicates how the annotation has been created: • **Rule based**: The annotation has been created by a report rule. • **Manually defined**: The annotation has been defined by the user.

General Table Controls

- List section

  The following table provides an overview of the general controls available in the various list views:

  Table 33-29: Controls in the list section

Control	Description
button	Opens a submenu for selecting the filter/search mode.
Filter	Clicking the **Click to add a filter or search criterion** field to the right of the icon opens a series of drop-down lists from which you can select a table column, an operator, and—depending on the column—a value. If a column does not offer a value drop-down list, you can type in a value. When the selection is complete, the table shows the rows matching the filter criterion. Clicking the **+** button or the **Click to add a filter or search criterion** field allows you to specify more filter criteria. Clicking the **x** button removes the filter.

Control	Description
Search	Clicking the **Click to add a filter or search criterion** field to the right of the icon opens a series of drop-down lists from which you can select a table column, an operator, and—depending on the column—a value. If a column does not offer a value drop-down list, you can type in a value. When the selection is complete, the table rows matching the search criterion are highlighted. Clicking the **+** button or the **Click to add a filter or search criterion** field allows you to specify more search criteria. Pressing **F3** jumps to the next search result in the list. Clicking the **x** button removes the search.
Full-text filter	Entering a value or text string into the input field to the right of the icon filters the table accordingly and shows the rows that match the filter criterion.
Full-text search	Entering a value or text string into the input field to the right of the icon searches the table accordingly and highlights the rows that match the search criterion.
use LMB to click on a table row	Selects the row and the corresponding object in the Scene Tree. In analysis result lists, the result, e.g., the component, is marked by a cross-hairs cursor in each of the 2D views.
hold **Ctrl** key + use LMB to click on several table rows	Selects the rows and the corresponding objects in the Scene Tree.
hold **Shift** key + use LMB to click on two separate table rows	Selects the two rows, including all rows between the two as well as the corresponding objects in the Scene Tree.
hold **Shift** key + use up/down arrow keys	Selects the rows and the corresponding objects in the Scene Tree.
press **Ctrl+A**	Selects all table rows.
use up and down arrow keys	Steps up and down through the table rows.
use RMB to click into the table area	Displays a context menu. See below.
use LMB to click a column heading	Sorts the table according to the values of the column. Clicking subsequently toggles between ascending and descending.
use LMB to click and drag column heading to new position, then release LMB	Inserts the column at the new position.

Control	Description
use LMB to double-click cell highlighted in white (light theme) or medium gray (dark theme)	If applicable: Allows you to edit the contents of the cell.

- **Screenshots** section (if available)

  The **Screenshots** section below the list section allows you to capture images from one of the 2D windows, the 3D window, or the current window layout for the item currently selected in the table. Only available if exactly one row is selected.

  Table 33-30: Controls in the **Screenshots** section

Control	Description
Capture from button	Adds the image of the view selected from the drop-down list to the preview area above.
use LMB to click and drag one or more images, then release LMB	Moves the image(s) to the new position.
double-click the image	Opens the **Snapshot display** window showing the image: • **Zoom in**/**Zoom out** button: Zooms the image in/out. You can also move the mouse pointer in the image area and turn the mouse wheel. • **Fit to window** button: Resets the zoom so that the image fits into the window.
click the **<no description>** placeholder twice (first click to select, second click to enable renaming)	Allows you to label the image.
Delete selected button	Deletes the selected image from the preview area.

Table Context Menu

Right-clicking anywhere in the table area shows a context menu with the following options:

Table 33-31: Context menu items

Control	Description
Columns	Allows you to toggle the visibility of each column by checking/unchecking the respective item. • **Show all**: Checks all columns to set them to visible. • **Hide all**: Unchecks all columns to set them to invisible. • **Hide empty**: Unchecks all not editable columns which are empty or **n/a** to set them to invisible.

Control	Description
Trim columns	Resizes all columns to their smallest possible size.
Apply default column layout	Applies the default column layout previously saved by the user to the current table. If no default column layout has been saved, the original column layout will be applied.
Save as default column layout	Saves modifications applied to the table—e.g., the visibility of a column, the order in which the columns appear, the column width—as default column layout. This layout will be applied when you create a new project.
Apply original column layout	Restores the original table layout and discards any modifications applied by the user. The original table layout is predefined and cannot be modified by the user.
Remove entries	If applicable: Deletes the selected row(s) from the table.
Create annotations	If applicable: Creates annotations for the selected items.
Export as CSV...	Opens the **Export as CSV...** dialog for exporting the table values as **.csv* file. This option always exports the complete table even if a filter was applied. In order to export only the filtered rows, press **Ctrl** + **A** to highlight all filtered rows and use the **Copy to clipboard** menu item.
Copy to clipboard	Copies the selected rows as well as the column heading into the system clipboard. The clipboard information is provided both as plain text and rich-text table, so when pasting into a rich-text-capable application like a word processor, you will see a proper table with cell borders and bold headings.
Paste	For annotation tables: Pastes previously copied coordinates and—optionally—snap directions to create new annotations in the table. For annotations of a nominal/actual comparison, the search distance specified on the **Settings** tab of the analysis will be considered. Note: Pasted annotations will be interpreted in the selected coordinate system at the time of pasting.

Control	Description
	The information in the clipboard must have the following structure: • x-, y-, and z-coordinate of the annotation or • x-, y-, and z-coordinate of the annotation as well as x-, y-, and z-component of the vector for the snap direction The parameters can be separated by space, tab, semi-colon, or comma (if a comma is already used as a decimal mark or digit grouping symbol, the values must be enclosed in double quotation marks). Example: 8.89;25.82;-0.55;1;0;0 You can also copy the information directly from the cells of a spreadsheet. In order to paste the annotation information, you can also press the **Ctrl** + **V** keyboard shortcut.
Set as active column	If applicable: Makes the current column the active column, i.e., the results of this column are color-coded according to their values as defined by the color lookup table and the colors specified in the **Sections** section of the **Colors** tab.
Unset active column	If applicable: Deselects the currently active column and sets the **Active column** drop-down list on the corresponding **Settings** tab to **Uncoded**, i.e., removes any color coding.
Enter/change value (all items)	If applicable: Opens the **Enter value** dialog (see below) where you can enter the desired value for the selected parameter. This value will be applied to all entries in the table.
Enter/change value (selected items)	If applicable: Opens the **Enter value** dialog (see below) where you can enter the desired value for the selected parameter. This value will be applied to the selected entries in the table.
Delete selected items	If applicable: Removes the selected items from the scene.

The **Enter value** dialog includes the following controls:

Table 33-32: Controls in the **Enter value** dialog

Control	Description
Enter value field	Allows you to enter the desired value.
OK button	Sets the selected parameter to the specified value.

Control	Description
Reset button	For analyses only: Resets the selected parameter to undefined.
Set from tolerance settings button	For analyses only: Enters the value specified in the tolerance settings of the analysis for the selected parameter.
Cancel button	Discards the changes and closes the dialog.

Orientations Tab

For **Space orientation** mode: Displays the settings for the visualization of the calculated orientations as needles.

Table 33-33: Controls of the **Orientations** tab

Control	Description
Scale spin box	Specifies a scale factor for the length of the needles.
2D sample step spin box	Specifies the spacing of the needles in 2D.
3D sample step spin box	Specifies the spacing of the needles in 3D.
3D rendering checkbox	When this option is checked, the needles will be displayed in 3D.
3D slice view checkbox	When this option is checked, the needles will be displayed in 3D only in the planes selected by the current slice views.
Thickness spin box	Specifies the thickness of the needles.
Color field	Double-clicking the field opens the **Select Color** dialog, where you can specify a color for the needles.

Since it may be time-consuming, 3D rendering of the needles is deactivated by default.

Tensors Tab

For **Integration mesh** and **Layered integration mesh** modes: Displays the settings for the visualization of the mean calculated orientation tensors as well as for the first, second, and third eigenvectors in a cell. The orientation tensors are visualized as ellipsoids. The eigenvectors are visualized as needles.

- **Render settings** section

Table 33-34: Controls in the **Render settings** section

Control	Description
Scale spin box	Specifies the size of the ellipsoids that represent the tensors.
3D rendering checkbox	When this option is checked, the ellipsoids that represent the tensors will be displayed in the 3D window.
Linear, **Planar**, **Spherical** fields	Double-clicking a color box opens the **Select Color** dialog, where you can set the color of the linear, planar, or spherical components, respectively, of the ellipsoids that represent the tensors.

- **1st/2nd/3rd eigenvector** section

  Table 33-35: Controls in the **1st/2nd/3rd eigenvectors** section

Control	Description
Scale spin box	Specifies the length of the needles that represent the eigenvectors.
3D rendering checkbox	When this option is checked, the needles that represent the eigenvectors will be displayed in the 3D window.
Thickness spin box	Specifies the thickness of the needles that represent the eigenvectors.
Color field	Double-clicking a color box opens the **Select Color** dialog, where you can set the color of needles representing the 1st, 2nd, and/or 3rd eigenvectors.

Main directions Tab

For **Layered integration mesh** mode only: Displays the settings for the visualization of the local histograms and of the first and second main directions of the orientations in a mesh cell. The first and second main directions are visualized as arrows.

- **1st/2nd main direction** section

  Specifies the shape and the color for the visualization of the first and second main directions calculated within a cell.

  Table 33-36: Controls of the **1st/2nd main direction** section

Control	description
Scale spin box	Specifies a scale factor for the length of the arrows.
3D rendering checkbox	When this option is checked, the arrows will be displayed in 3D.
Thickness spin box	Defines the thickness of the arrows.

Control	description
Color field	Double-clicking the field opens the **Select Color** dialog, where you can set the color for the visualization of the first and second main directions.

- **Local histogram** section

  Table 33-37: Controls of the **Local histogram** section

Control	Description
Scale factor spin box	Specifies a scale factor for the local histogram.
Tripod checkbox	When this option is checked, the tripod for the cell coordinate system will be shown in the local histogram.
Reference circles checkbox	When this option is checked, reference circles will be displayed in the local histogram.

Statistics Tab

Displays various statistical information on the analyzed volume object or ROI, which is grouped in the sections **Mean orientation tensor** and **Other global results**. Depending on the selected analysis mode, only a subset of the statistical data can be calculated.

On this tab, the values for tolerancing the analysis results are only displayed. You can specify them on the **Settings** tab.

- **Mean orientation tensor** section

  Indicates the components of the mean orientation tensor in the current coordinate system.
- **Other global results** section

  Table 33-38: Controls in the **Other global results** section

Control	Description
Projected angle mean [<angle unit>]	For **Plane projection** mode: Indicates the mean value of the projected angles.
Projected angle deviation [<angle unit>]	For **Plane projection** mode: Indicates the standard deviation of the mean of the projected angles.
Fiber volume fraction [<ratio unit>]	Indicates the ratio between fiber volume and total volume. This parameter is only available when the surface of the volume object is determined or a threshold value is specified manually.
Deviation angle 50th percentile [<angle unit>]	For **Reference orientation** mode: The deviation angles of 50% of the analyzed voxels fall into the interval between 0° and this angle.

Control	Description
Deviation angle 75th percentile [<angle unit>]	For **Reference orientation** mode: The deviation angles of 75% of the analyzed voxels fall into the interval between 0° and this angle.
Deviation angle 90th percentile [<angle unit>]	For **Reference orientation** mode: The deviation angles of 90% of the analyzed voxels fall into the interval between 0° and this angle.

Images Tab

Allows you to take screenshots of the selected workspace views and/or add bookmark references to the report. In the final report, the captured images will be listed separately from the screenshots created on other tabs.

- **Snapshots** section

  Table 33-39: Controls in the **Snapshots** section

Control	Description
Capture from button	Adds the image of the view selected from the drop-down list to the preview area above.
Delete selected button	Deletes the selected image(s) from the preview area.
use LMB to click and drag one or more images, then release LMB	Moves the image(s) to the new position.
double-click the image	Opens the **Snapshot display** window showing the image: • **Zoom in**/**Zoom out** button: Zooms the image in/out. You can also move the mouse pointer on the image area and turn the mouse wheel. • **Fit to window** button: Resets the zoom so that the image fits into the window.
click the **<no description>** placeholder twice (first click to select, second click to enable renaming)	Allows you to label the image.

- **Automatic 3D images** section (if available)

  Check the corresponding checkbox to include the desired 3D view (e.g., **Top**, **Front**, **Top-left-front**, and **Current camera settings**) in the report without changing the 3D view.

- **Bookmark references** section

  Allows you to add bookmark references via drag and drop from the **Bookmarks and views** tool or the **Bookmark editor** to the preview area. The images of the referenced bookmarks will then be included in VGRF-based reports.

When you open a project with missing bookmark images, placeholders will be shown instead.

Bookmark references are stored in evaluations and can be used in automation scenarios.

You will still need to import a bookmark template containing the actual bookmarks in these cases, as evaluations store only references to them.

Table 33-40: Controls in the **Bookmark references** section

Control	Description
New bookmark button	Adds a bookmark of the current view to the preview area.
Remove button	Removes the bookmark currently selected in the preview area.
click the bookmark title twice (first click to select, second click to enable renaming) or press the **F2** key	Allows you to rename the bookmark. The changes made on the **Images** tab will also affect the **Bookmark editor** and the **Bookmarks and views** tool. If the renamed bookmark is referenced by one or more objects for reporting, a warning message will be displayed indicating that the referenced bookmark will also be renamed for all these objects in the report.

The global concept of bookmark references allows for multiple objects to reference the same bookmark and for objects to reference bookmarks that show arbitrary information, e.g., other analyses or objects.

Foam/Powder Analysis Module

Introduction

The **Foam/Powder Analysis** module of VGSTUDIO MAX allows for the segmentation of CT data into topologically disconnected components that can be visualized and statistically analyzed. A significant application for this kind of analysis is the structural analysis of foams. All foams have a cellular structure that arises from a solid or liquid medium that is embedded with gas-filled cavities. These cavities typically occupy a large volume fraction of the foam and may either be completely surrounded by material or—as in the case of open-cell foams—be linked to adjacent cells. Another type of cellular structure that may also be analyzed with the foam/powder analysis consists of densely packed objects (comprised of solid material) that are immersed in a background medium, such as air. Real-world examples of these structures are fill materials, loose sediments, and drill samples.

License Information

This module is an optional add-on module for VGSTUDIO MAX. It is not available for myVGL. However, if a project loaded in myVGL contains results obtained with this module, they can be viewed and reported in myVGL.

If you are interested in a more comprehensive functionality than the one offered by myVGL, you have the chance to evaluate VGSTUDIO MAX. You can request an evaluation license of VGSTUDIO MAX on our website:

https://volumegraphics.hexagon.com/en/products/evaluation

If you have further questions about our product portfolio, please contact us:

- For Europe, Middle East, and Africa:

  Write an e-mail to sales@volumegraphics.com or call +49 6221 73920 744.
- For Japan:

  Write an e-mail to sales@volumegraphics.jp or call +81 52 508 9682.
- For the Americas:

  Write an e-mail to sales-us@volumegraphics.com or call +1 704 248 7736.
- For China, including Mainland China, Hong Kong, Macao, and Taiwan:

  Write an e-mail to sales@volumegraphics.cn or call +86 10 8532 6305.
- For Singapore and other parts of Asia (except China and Japan), Australia, and parts of Oceania:

  Write an e-mail to sales@volumegraphics.sg or call +65 6665 0310.

Opening the Dialog

In order to open the **Foam/powder analysis** dialog,

- right-click the corresponding entry in the Scene Tree and select **Properties** from the context menu or

- double-click the corresponding entry in the Scene Tree.

The **Foam/powder analysis** dialog consists of several tabs on which you can view the results of the analysis.

To close the dialog, click the **Close** button at the bottom of the dialog.

A status bar at the bottom of the dialog indicates the current status of the analysis. The status can be one of the following:

Table 34-1: Messages in the status bar

Status	Description
Result is up to date	The current analysis result is valid.
Object has no surface determination	No surface determination information is available for the object. See also section *Surface determination* on page 949 in chapter 48 *Glossary*.
License missing	The add-on module is not licensed.

An invalid or outdated status of an analysis is indicated in the Scene Tree by a warning sign. Double-click this analysis to open it and check the status bar for messages.

The units of the dialog depend on the global unit settings (see section *Units Drop-down List* on page 33 in chapter 2 *Workspace*).

Settings Tab

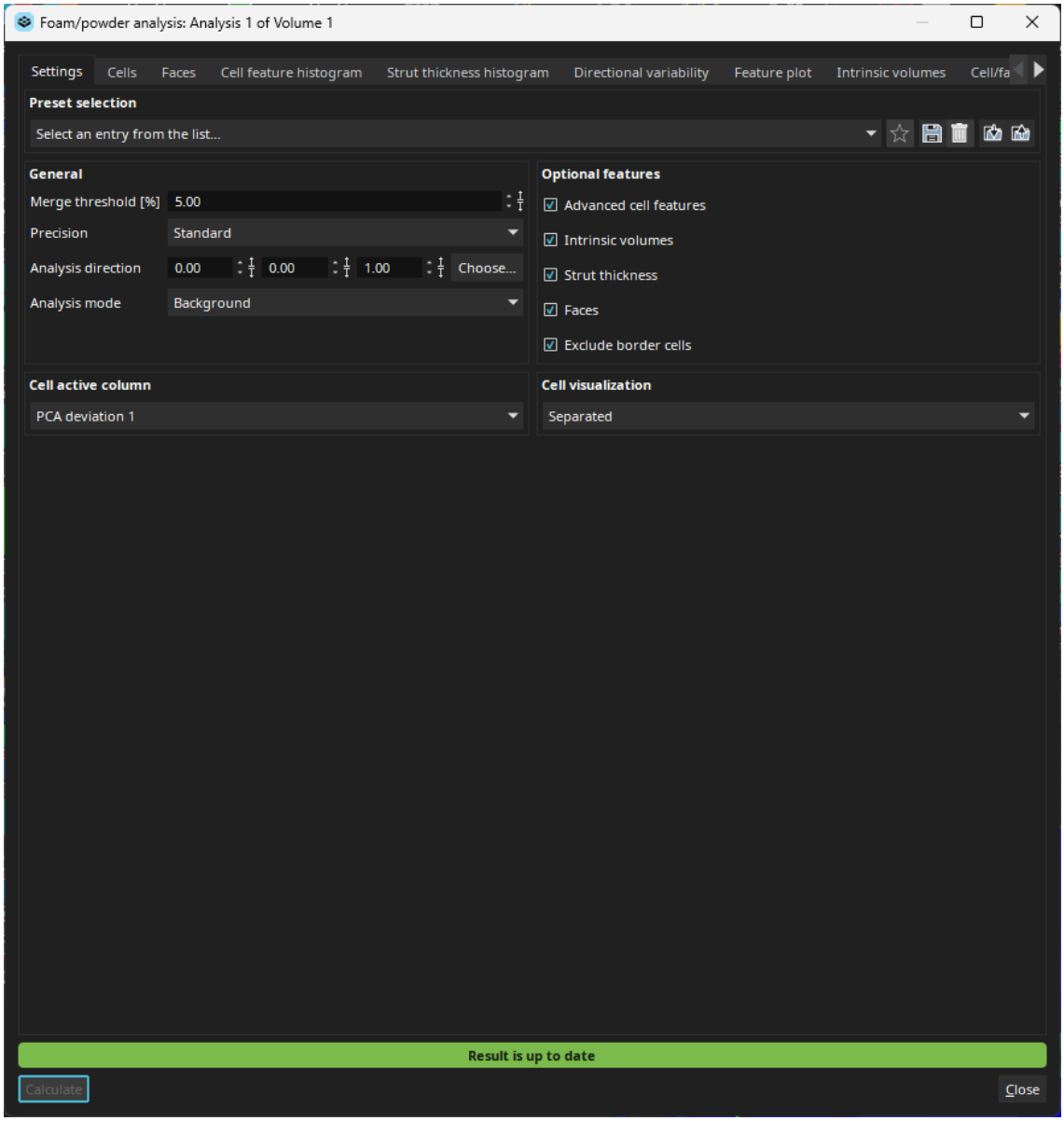


Figure 34-1: **Foam/powder analysis** dialog, **Settings** tab

In myVGL, all parameter settings are displayed. Most of these parameters are read-only in myVGL. The complete functional range is available with VGSTUDIO MAX and the respective add-on module(s).

Preset selection Section

Table 34-2: Controls in the **Preset selection** section

Icon	Item	Description
	drop-down list	Specifies the preset to be applied, to be edited, or to be taken as a basis for a new preset. The following icons are used: • analysis factory settings • customized preset • appears next to the icon of a preset that has been modified but not yet saved
	Set this preset as default	Sets the selected preset as default. The default preset will be applied when creating a new analysis of the same type. If the selected preset is already set as default, the button is disabled.
	Save preset	Saves the selected preset. When saving a preset, the **Save preset** dialog will open, which allows you to set the new preset as default by checking the **Set as default for new analyses** checkbox.
	Remove preset	Removes the selected preset from the preset drop-down list. If the removed preset is the default preset, the next time an analysis of the same type is created, the factory settings will be used.
	Import preset	Imports a preset from the specified location.
	Export preset	Exports the selected preset to the specified location.

General Section

Table 34-3: Controls of the **General** section

Control	Description
Merge threshold spin box	Specifies a tolerance for local fluctuations in the definition of material boundaries. This parameter is intended to prevent the over-segmentation of cells. A larger value increases the likelihood for small segments to be joined with an adjacent larger segment to form a larger cell. For example, a value of 100% means that all cells will be merged.

Control	Description
Precision drop-down list	Specifies the resolution of the analysis: • **Standard**: The analysis will be performed more slowly, but with a higher resolution. • **Fast**: The analysis will be performed faster, but with a lower resolution.
Analysis direction fields	Specify the direction (in the currently selected coordinate system) in which the **Directional variability** of the cell property specified in the **Cell active column** field is to be analyzed. The specified vector is normalized to unit length before it is taken into account in the calculation. When you change the coordinate system, the specified vector will automatically be recalculated accordingly.
Choose... button	Opens a drop-down list that shows the windows currently available in the workspace for specifying the direction in which the analysis is to be performed. The direction is the normal of the selected 2D window or the current direction of view of the 3D window.
Analysis mode drop-down list	• **Material**: The cellular structure to be analyzed is composed of material (e.g., solid material, like grains). • **Background**: The cellular structure to be analyzed is composed of background (e.g., pores in a medium). This is the default setting.

Optional features Section

Table 34-4: Controls of the **Optional features** section

Control	Description
Advanced cell features checkbox	When this option is checked, the following features will be calculated: • Surface • PCA deviation ratios • Sphericity • Compactness
Intrinsic volumes checkbox	When this option is checked, a number of integral geometric and topological quantities derived from the Minkowski functionals will be calculated.

Control	Description
Strut thickness checkbox	When this option is checked, the thicknesses of the struts will be calculated. The strut thickness is determined by calculating the maximum inscribed sphere. When the analysis mode **Background** is selected, the strut thickness will be the thickness of the material between the pores. When the analysis mode **Material** is selected, the strut thickness will be the thickness of the gaps (i.e., the background) between the material. Tip: In order to visualize the strut thickness for analysis mode **Material** in the 3D window, set the transparency of the object to a value (e.g., 50%) and check the **Swap inner/outer areas** checkbox in the **Rendering** tool.
Faces checkbox	When this option is checked, the topological boundary between neighboring cells will be calculated.
Exclude border cells checkbox	When this option is checked, cells touching the boundary of the data set or the selected ROI will be ignored. Otherwise, these cells would lead to unexpected results in the statistics.

Cell active column Section

This drop-down list allows you to select the property that is to be shown according to the settings on the **Cell/face colors** tab. The default setting is **Uncoded**, i.e., all cells are shown in an arbitrary color, independently of their values. The **Cell/face colors** tab is not active in this case. When you select a cell property, e.g., **Volume**, from the **Cell active column** drop-down list, the cells will be color-coded according to their volume value as defined by the color lookup table and the colors specified in the **Sections** section of the **Cell/face colors** tab. In the list on the **Cells** tab, the column of the selected cell property will become the “active” column and its values will be highlighted in bold and italic font.

The property selected in the **Cell active column** drop-down list will be added to the information provided in the annotation labels.

You can also select the active column on the **Cells** tab by right-clicking the column and selecting the **Set as active column** item from the context menu.

Cell visualization Section

Table 34-5: Controls of the **Cell visualization** section

Control	Description
drop-down list	• **Separated**: Shows a divider between the individual cells. • **Connected**: Removes the divider between the individual cells.

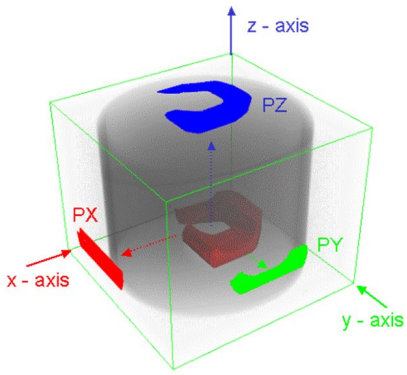
Cells Tab

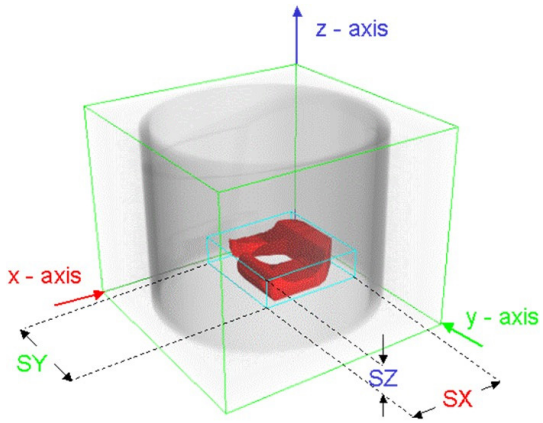
Lists all cells detected by the foam/powder analysis.

The **Cells** table consists of the following columns:

Table 34-6: Columns of the **Cells** table

Column	Description
Pos. x/y/z [<length unit>]	Indicates the position of the center of gravity of the cell.
Volume [<length unit>³]	Indicates the volume of the cell.
Equivalent diameter [<length unit>]	Indicates the diameter of a sphere that has the same volume as the cell.
Surface [<length unit>²]	Indicates the surface area of the cell.
Mean gray value	Indicates the mean gray value within the cell.
Voxel count	Indicates the number of voxels the cell consists of.
Sphericity	Indicates the ratio between the surface of a sphere with the same volume as the cell and the surface of the cell. $\text{Sphericity} = \frac{A_{sphere}}{A_{cell}}$
Compactness	Indicates the ratio between the volume of the cell and the volume of the circumscribed sphere. $\text{Compactness} = \frac{V_{cell}}{V_{sphere}}$
PCA 1 x/y/z [<length unit>]	Indicate the x-, y-, or z-component, respectively, of the most pronounced axis of the cell calculated from a Principal Component Analysis (PCA).
PCA 2 x/y/z [<length unit>]	Indicate the x-, y-, or z-component, respectively, of the medium axis of the cell calculated from a Principal Component Analysis (PCA).

Column	Description
PCA 3 x/y/z [<length unit>]	Indicate the x-, y-, or z-component, respectively, of the least pronounced axis of the cell calculated from a Principal Component Analysis (PCA).
PCA deviation 1/2/3 [<length unit>]	Indicate the standard deviations along each of the three mutually orthogonal axes calculated from a Principal Component Analysis (PCA), with **PCA deviation 1** corresponding to the standard deviation along the most pronounced axis of the cell. The standard deviations are the square root of the eigenvalues.
PCA min. deviation ratio [<ratio unit>]	Indicates the ratio between **PCA deviation 3** and the radius of the circumscribed sphere of the cell. $$\text{Min. relative PCA deviation} = \frac{\text{PCA deviation 3}}{r_{sphere}}$$
PCA max. deviation ratio [<ratio unit>]	Indicates the ratio between **PCA deviation 1** and the radius of the circumscribed sphere of the cell. $$\text{Max. relative PCA deviation} = \frac{\text{PCA deviation 1}}{r_{sphere}}$$
Projected area x/y/z [<length unit>²]	Indicates the surface area of the cell shape projected along each of the axes of the scene coordinate system. See the following figure for an illustration:  Figure 34-2: Projected area

Column	Description
Projected size x/y/z [<length unit>]	Indicates the size of the bounding box surrounding the cell in the scene coordinate system. See the following figure for an illustration:  Figure 34-3: Projected size
Type	• **Connected**: The cell contacts neighboring cells. • **Border**: The cell is located at the border of the analyzed region. • **Isolated**: The cell is completely surrounded by material.
Description	Allows you to enter a description of the cell used for reporting.
Image	Allows you to add a detailed 2D image and object description on a separate page of the report. • **Off**: No image is created (default). • **Orthographic projection**: Creates three orthogonal views. • **Top/Bottom/Left/Right/Front/Back**: Creates a single 2D view in the specified orientation. • **... - If not OK**: Automatically creates the image if the tolerance status is **Out of tolerance**. The image orientation corresponds to the currently selected coordinate system. The image will be generated according to the render settings specified during report creation or VGRF-based export. If **Automatic** is selected from the **Visibility** drop-down list in the **General render settings** section, only the cells will be shown. The 2D slice position used for taking the image is determined by the position of the cell. The zoom factor of the image is chosen so that the entire parent volume is visible.

Column	Description
Focused image	This option is almost identical to the **Image** option but will generate an image that focuses on the respective item and is zoomed in by the **Zoom factor** specified during report creation or VGRF-based export.
Captures	Indicates the number of images captured for this object using the **Capture from** button in the **Screenshots** section.

Faces Tab

Lists all faces—the contact areas between neighboring cells—detected by the foam/powder analysis.

This information will only be calculated if the **Faces** option has been checked in the **Optional features** section on the **Settings** tab.

The **Faces** table consists of the following columns:

Table 34-7: Columns of the **Faces** table

Column	Description
Pos. x/y/z [<length unit>]	Indicates the position of the center of gravity of the face.
Normal x/y/z [length unit]	Indicates the normal of the face.
Area [<length unit>²]	Indicates the surface area of the face.
Description	Allows you to enter a description of the face used for reporting.

Column	Description
Image	Allows you to add a detailed 2D image and object description on a separate page of the report. • **Off**: No image is created (default). • **Orthographic projection**: Creates three orthogonal views. • **Top/Bottom/Left/Right/Front/Back**: Creates a single 2D view in the specified orientation. • **... - If not OK**: Automatically creates the image if the tolerance status is **Out of tolerance**. The image orientation corresponds to the currently selected coordinate system. The image will be generated according to the render settings specified during report creation or VGRF-based export. If **Automatic** is selected from the **Visibility** drop-down list in the **General render settings** section, only the faces will be shown. The 2D slice position used for taking the image is determined by the position of the face. The zoom factor of the image is chosen so that the entire parent volume is visible.
Focused image	This option is almost identical to the **Image** option but will generate an image that focuses on the respective item and is zoomed in by the **Zoom factor** specified during report creation or VGRF-based export.
Captures	Indicates the number of images captured for this object using the **Capture from** button in the **Screenshots** section.

Cell feature histogram Tab

Shows the number of occurrences of the cell feature selected from the **Cell active column** drop-down list on the **Settings** tab. The histogram bars can be colored according to the settings on the **Cell/face colors** tab.

This histogram is available only if a feature has been selected from the **Cell active column** drop-down list on the **Settings** tab.

Controls of the **Cell feature histogram** Tab

Table 34-8: Controls of the **Cell feature histogram** tab

Control	Description
Color drop-down list	• **From color bar**: The values in the histogram are shown according to the color bar. • **Gray**: All values in the histogram are shown in gray.
Normalization drop-down list	• **Absolute**: Displays the count of cells with the property selected in the **Cell active column** field of the **Settings** tab in absolute values. • **Relative**: Displays the count of cells with the property selected in the **Cell active column** field of the **Settings** tab in relative values with respect to the total cell count.
Binning drop-down list	• **Off**: No binning is applied to the values shown in the histogram. • **From color bar**: The original values in the histogram are replaced by a value representative for the corresponding interval (“bin”) of the color bar. The “bins” will become visible when “stepped” sections are created on the **Cell/face colors** tab. • **Manual number of bins**: Enables the **Bin count** spin box, where you can enter the required number of “bins.” • **Manual bin width**: Enables the **Bin width** spin box, where you can specify the width of the individual bins.
Left/**Right** spin box	Only enabled when an interval has been created: Moves the left or right interval border to the specified value. You can also click and drag the interval borders using the left mouse button.
Create button	Creates a new interval. On the right hand side of a selected interval, statistical information is displayed: • **Left**: Indicates the minimum value of the selected cell feature within the interval, i.e., the left interval border. • **Right**: Indicates the maximum value of the selected cell feature within the interval, i.e., the right interval border. • **Mean**: Indicates the mean value of the values of selected cell feature within the interval. • **Dev**: Indicates the standard deviation of the values of the selected cell feature within the interval.

Control	Description
	• **Sum**: Indicates the number of cells within the interval. • **Percentage**: Indicates the number of cells within the interval (**Sum**) in relation to the total number of cells. Note that the statistical information may change with the number of bins.
Remove button	Removes the selected interval.
Min./Max./Mean [<unit>] fields	Indicate the minimum, maximum, and mean values of the selected cell feature.
Standard deviation [<unit>] field	Indicates the standard deviation of the values of the selected cell feature.
use RMB to click the chart area	Displays a context menu (see below).
scroll MW in chart area or x-axis up/down	Zooms the x-axis of the chart out/in.
scroll MW in y-axis up/down	Zooms the y-axis of the chart out/in.
use LMB to click and drag the x-axis	Scrolls the x-axis.
use LMB to click and drag the y-axis	Scrolls the y-axis.
Zoom in/out	Zooms the corresponding axis in/out.
Reset zoom	Fits the entire chart to the current window size.

Context Menu of the **Cell feature histogram** Tab

Right-clicking the chart area displays a context menu with the following options:

Table 34-9: Context menu items

Control	Description
Export as CSV...	Opens a dialog for saving the chart values to a *.csv* file.
Copy to clipboard	Copies a screenshot of the chart to the system clipboard so you can paste it into another application.
Show/Hide x/y grid	Toggles the display of dashed indicator lines for the respective axis.
Reset zoom	Fits the entire chart to the current window size.
Create interval	Creates a new interval. For details on the statistical information, see section *Controls of the Cell feature histogram Tab* on page 573.
Remove interval	Removes the selected interval.

Strut thickness histogram Tab

Shows the number of voxels of the struts for the calculated strut thicknesses. The histogram bars can be colored according to the settings on the **Strut thickness colors** tab.

This histogram is available only if the **Strut thickness** option has been checked in the **Optional features** section on the **Settings** tab.

Controls of the **Strut thickness histogram** Tab

Table 34-10: Controls of the **Strut thickness histogram** tab

Control	Description
Color drop-down list	• **From color bar**: The values in the histogram are shown according to the color bar. • **Gray**: All values in the histogram are shown in gray.
Normalization drop-down list	• **Absolute**: Displays the number of voxels in absolute values. • **Relative**: Displays the number of voxels in relative values with respect to the number of analyzed voxels.
Binning drop-down list	• **Off**: No binning is applied to the values shown in the histogram. • **From color bar**: The original values in the histogram are replaced by a value representative for the corresponding interval (“bin”) of the color bar. The “bins” will become visible when “stepped” sections are created on the **Strut thickness colors** tab. • **Manual number of bins**: Enables the **Bin count** spin box, where you can enter the required number of “bins.” • **Manual bin width**: Enables the **Bin width** spin box, where you can specify the width of the individual bins.
Left/**Right** spin box	Only enabled when an interval has been created: Moves the left or right interval border to the specified value. You can also click and drag the interval borders using the left mouse button.
Create button	Creates a new interval. On the right hand side of a selected interval, statistical information is displayed: • **Left**: Indicates the minimum strut thickness within the interval, i.e., the value of the left interval border. • **Right**: Indicates the maximum strut thickness within the interval, i.e., the value of the right interval border.

Control	Description
	• **Mean**: Indicates the mean value of the strut thicknesses within the interval. • **Dev**: Indicates the standard deviation of the strut thicknesses within the interval. • **Sum**: Indicates the number of voxels of the struts within the interval. • **Percentage**: Indicates the number of strut voxels within the interval (**Sum**) in relation to the total number of strut voxels. Note that the statistical information may change with the number of bins.
Remove button	Removes the selected interval.
Min./Max./Mean thickness [<unit>] fields	Indicate the minimum, maximum, and mean strut thickness.
Standard deviation [<unit>] field	Indicates the standard deviation of the strut thicknesses.
use RMB to click the chart area	Displays a context menu (see below).
scroll MW in chart area or x-axis up/down	Zooms the x-axis of the chart out/in.
scroll MW in y-axis up/down	Zooms the y-axis of the chart out/in.
use LMB to click and drag the x-axis	Scrolls the x-axis.
use LMB to click and drag the y-axis	Scrolls the y-axis.
Zoom in/out	Zooms the corresponding axis in/out.
Reset zoom	Fits the entire chart to the current window size.

Context Menu of the **Strut thickness histogram** Tab

Right-clicking the chart area displays a context menu with the following options:

Table 34-11: Context menu items

Control	Description
Export as CSV...	Opens a dialog for saving the chart values to a *.csv* file.
Copy to clipboard	Copies a screenshot of the chart to the system clipboard so you can paste it into another application.
Show/Hide x/y grid	Toggles the display of dashed indicator lines for the respective axis.
Reset zoom	Fits the entire chart to the current window size.

Control	Description
Create interval	Creates a new interval. For details on the statistical information, see section *Controls of the Strut thickness histogram Tab* on page 575.
Remove interval	Removes the selected interval.

Directional variability Tab

This curve shows how the parameter selected in the **Active column** field changes with respect to the direction specified in the **Analysis direction** field of the **Settings** tab. You can use the **Directional variability** curve to answer questions like “How do the pore sizes decrease from the top to the bottom of the foam?” The actual curve indicates the mean value of the parameter. The light gray area around the curve indicates the standard deviation of the values of the parameter.

Controls of the **Directional variability** Tab

Table 34-12: Controls of the **Directional variability** Tab

Control	Description
hover the mouse pointer over the curve	Displays the legend of the function along with its values at the specified location.
use LMB to click and drag the vertical line in the histogram	Indicates the function values at the specified location and updates the slice views accordingly. Press the **Ctrl** key while left-clicking in the chart area to display the vertical line in case you dragged it out of the chart area.
use RMB to click the chart area	Displays a context menu (see below).
scroll MW in chart area or x-axis up/down	Zooms the x-axis of the chart out/in.
scroll MW in y-axis up/down	Zooms the y-axis of the chart out/in.
use LMB to click and drag the x-axis	Scrolls the x-axis.
use LMB to click and drag the y-axis	Scrolls the y-axis.
Zoom in/out	Zooms the corresponding axis in/out.
Reset zoom	Fits the entire chart to the current window size.

Context Menu

Right-clicking anywhere in the chart area shows a context menu with the following options:

Table 34-13: Context menu items

Control	Description
Export as CSV...	Opens a dialog for saving the chart values to a *.csv* file.
Copy to clipboard	Copies a screenshot of the chart to the system clipboard so you can paste it into another application.
Show/Hide x/y grid	Toggles the visibility of the grid lines for the corresponding axis.
Reset zoom	Fits the entire chart to the current window size.

Feature plot Tab

Allows you to plot a cell property (e.g., the volume) against another property (e.g., the PCA deviation). This allows you to draw certain conclusions about the characteristics of the cells in the scanned object.

Intrinsic volumes Tab

Table 34-14: Fields of the **Intrinsic volumes** tab

Field	Description
Euler characteristic	In convex geometry, the Euler characteristic may be defined as the unique valuation on the convex ring that yields $\chi(\mathrm{K})=1$ for every convex body K. It contains information on the connectivity of the analyzed structure and is related to its number of disconnected components and the n-dimensional holes contained inside. It is given by the alternating sum $\chi=\#(\mathrm{components})-\#(\mathrm{tunnels})+\#(\mathrm{cavities})$.
Integral over mean curvature [length unit]	The mean curvature of a surface is a local property that is defined as half of the sum of the two principal curvatures at a point on the surface $\mathrm{H}=\frac{1}{2}(\kappa_1+\kappa_2)$. It contains information on how an embedded surface is twisted inside the surrounding space without regard to its internal geometry. The integral mean curvature is related to the mean width via the following equation: $$2\pi b = \int_{surface} H d^2x$$

Field	Description
Total Gaussian curvature	The Gaussian curvature is the product of both principal curvatures $K=\kappa_1\kappa_2$ of the surface. In contrast to the mean curvature, the Gaussian curvature depends solely on the inner geometry of the surface. It is connected to the Euler characteristic via the Gauss-Bonnet theorem: $$2\pi\chi = \int_{surface} K d^2x$$

Cell/face colors/Strut thickness colors Tabs

Caption Section

Table 34-15: Controls of the **Caption** section

Control	Description
Caption field	Indicates the color bar headline as specified in the **Caption** field of the **Color bar** section.
Share color bar checkbox	When this option is checked, all analyses of the same type (and—if applicable—of the same algorithm) will use the same color bar. When this option is unchecked, the color bar settings will apply to the selected analysis only.

LUT – Color Lookup Table

The color lookup table (LUT) shows the partitioning into color sections.

Sections Section

Defines the appearance of each color section.

Table 34-16: Controls in the **Sections** section

Control	Description
From/To fields	Specify the start and end values of the color sections. The first color section represents all values above the upper limit, i.e., the value in the **From** field (**+inf** signifies positive infinity), while the last color section represents all values below the lower limit, i.e., the value in the **To** field (**-inf** signifies negative infinity). The default limits are calculated from the results of the analysis (for an analysis color bar) or taken from the **Default** preset (for a tolerance deviation color bar).
Type field	Switches between the color schemes **Continue**, **Constant**, **Gradient**, **Rainbow**, **Reverse rainbow**, **Hue cycle**, **Green to red**, and **Red to green**.
Color/transparency field	Double-clicking the field for the **Continue**, **Constant**, and **Gradient** color schemes opens the **Select Color** dialog where you can modify the appearance of the selected color scheme. For the **Gradient** color scheme, you can specify the start and end colors by double-clicking the left or right side of the field, respectively. Double-clicking the field for the **Rainbow**, **Reverse rainbow**, **Hue cycle**, **Green to red**, and **Red to green** color schemes opens the **Transparency** dialog, where you can set the transparency for the selected color scheme.
use RMB to click a color section	Opens a context menu with the following items: • **Split**: Subdivides the color section into two new color sections where each represents half of the original section. • **Merge**: Combines several color sections to a single color section. Only consecutive intervals can be merged.
Create smooth button	Opens the **Create smooth table** dialog to generate one color section. • **Type** drop-down list: Allows you to select the type of coloring scheme. • **From/To** spin boxes: Specify the value range covered by the color section.

Control	Description
Create stepped button	Opens the **Create stepped table** dialog to generate a set of color sections. • **Type** drop-down list: Allows you to select the type of coloring scheme. • **From/To** spin boxes: Specify the value range covered by the color sections. • **Step** spin box: Specifies the step size of the individual color sections.
Auto scale button	If available: Fits the color LUT to the range of the results of all available analyses.
Auto scale color bar range on calculate checkbox	If available: When this option is checked, the color LUT will be automatically fitted to the range of the results of all available analyses.
Default button	If available: Resets any changes made to the **Sections** table.

Preset selection Section

Table 34-17: Controls in the **Preset selection** section

Icon	Item	Description
	drop-down list	Specifies the preset to be applied, to be edited, or to be taken as a basis for a new preset. The following icons are used: • default preset • customized preset • appears next to the icon of a preset that has been modified but not yet saved
	Save preset	Opens the **Save preset** dialog for saving the color LUT of the current data set under the specified name. • **Absolute preset**: When this option is checked and the preset applied, the settings of the original data set, including the LUT range, will be applied. When this option is unchecked, the color settings of the preset will be mapped relatively to the actual range of results of the analysis to which the preset will be applied.
	Remove preset	Removes the selected preset from the preset drop-down list.
	Import preset	Imports a preset from the specified location.
	Export preset	Exports the selected preset to the specified location.

Color LUT Settings Section

Specifies the appearance of the color lookup table.

Table 34-18: Options for the appearance of the color lookup table

Control	Description
Auto tick marks checkbox	When this option is checked, equidistant tick marks will be produced for the color bars. When this option is unchecked, tick marks will appear only at the color section boundaries of the color lookup table.
Auto scale color bar range on calculate checkbox	When this option is checked, the color LUT will be automatically fitted to the range of the results of all available analyses.

Color bar Section

Specifies the settings for the color bar.

Table 34-19: Settings for the color bar

Control	Description
Visibility drop-down list	Switches the color bar on/off.
Positioning drop-down list	Specifies the location of the color bar within the 2D and 3D windows: **Left, Right, Top, Bottom, All - automatic, Left or right - automatic, Top or bottom - automatic**.
Caption field	Specifies the color bar headline by using placeholders.
Reset button	Resets the **Caption** field to the default entry.

Faces Section

Specifies the visualization of the faces.

Table 34-20: Controls in the **faces** section

Control	Description
Faces field	Double-clicking the field opens the **Select Color** dialog, where you can set the color for the unselected faces.
Selected faces field	Double-clicking the field opens the **Select Color** dialog, where you can set the color for the selected faces.
Opacity spin box	Specifies the opacity of the faces.

Annotations Tab

Lists all annotations created for the selected foam/powder analysis. You can view the information supplied by the annotations or edit the annotation properties.

For details on how to create an annotation, see section *Annotation* on page 124 in chapter 6 *Inspect Tab*.

To create new annotations in the table, it is also possible to paste previously copied coordinates by right-clicking the table and selecting **Paste** from the context menu or by pressing the **Ctrl** + **V** keyboard shortcut. For details, see the **Paste** menu item in section *Table Context Menu*.

Double-clicking an analysis annotation in the Scene Tree will directly open the **Annotations** tab of the properties dialog of the corresponding analysis.

The **Annotations** table consists of the following columns:

Table 34-21: Columns of the **Annotations** table

Column	Description
Name	Indicates the name of the annotation.
Pos. x/y/z [<length unit>]	Indicates the position of the annotation.
Cell volume [<length unit>³]	Indicates the volume of the cell at the current annotation position.
Equivalent diameter [<length unit>]	Indicates the diameter of a sphere that has the same volume as the cell.
Cell surface [<length unit>³]	Indicates the surface area of the cell at the current annotation position.
Cell mean gray value	Indicates the mean gray value within the cell.
Cell sphericity	Indicates the ratio between the surface of a sphere with the same volume as the cell and the surface of the cell. $\text{Sphericity} = \frac{A_{sphere}}{A_{cell}}$
Cell compactness	Indicates the ratio between the volume of the cell and the volume of the circumscribed sphere. $\text{Compactness} = \frac{V_{cell}}{V_{sphere}}$
PCA deviation 1/2/3 [<length unit>]	Indicate the standard deviations along each of the three mutually orthogonal axes calculated from a Principal Component Analysis (PCA), with **PCA deviation 1** corresponding to the standard deviation along the most pronounced axis of the cell. The standard deviations are the square root of the eigenvalues.

Column	Description
PCA minimum deviation ratio [<ratio unit>]	Indicates the ratio between **PCA deviation 3** and the radius of the circumscribed sphere of the cell. $\text{Min. relative PCA deviation} = \frac{\text{PCA deviation 3}}{r_{sphere}}$
PCA maximum deviation ratio [<ratio unit>]	Indicates the ratio between **PCA deviation 1** and the radius of the circumscribed sphere of the cell. $\text{Max. relative PCA deviation} = \frac{\text{PCA deviation 1}}{r_{sphere}}$
Strut thickness [<length unit>]	Indicates the strut thickness at the current annotation position.
Description	Allows you to enter a description of the annotation used for reporting.
Image	Allows you to add a detailed 2D image and object description on a separate page of the report. • **Off**: No image is created (default). • **Orthographic projection**: Creates three orthogonal views. • **Top/Bottom/Left/Right/Front/Back**: Creates a single 2D view in the specified orientation. • **... - If not OK**: Automatically creates the image if the tolerance status is **Out of tolerance**. (Currently not implemented.) The image orientation corresponds to the currently selected coordinate system. The image will be generated according to the render settings specified during report creation or VGRF-based export. If **Automatic** is selected from the **Visibility** drop-down list in the **General rendering settings** section, only the cells will be shown. The 2D slice position used for taking the image is determined by the position of the cell. The zoom factor of the image is chosen so that the entire parent volume is visible.
Focused image	This option is almost identical to the **Image** option but will generate an image that focuses on the respective item and is zoomed in by the **Zoom factor** specified during report creation or VGRF-based export.
Captures	Indicates the number of images captured for this object using the **Capture from** button in the **Screenshots** section.
Tolerance status	Currently not implemented.

Column	Description
Type	Indicates how the annotation has been created: • **Rule based**: The annotation has been created by a report rule. (Currently not implemented.) • **Manually defined**: The annotation has been defined by the user.

General Table Controls

- List section

  The following table provides an overview of the general controls available in the various list views:

  Table 34-22: Controls in the list section

Control	Description
button	Opens a submenu for selecting the filter/search mode.
Filter	Clicking the **Click to add a filter or search criterion** field to the right of the icon opens a series of drop-down lists from which you can select a table column, an operator, and—depending on the column—a value. If a column does not offer a value drop-down list, you can type in a value. When the selection is complete, the table shows the rows matching the filter criterion. Clicking the **+** button or the **Click to add a filter or search criterion** field allows you to specify more filter criteria. Clicking the **x** button removes the filter.
Search	Clicking the **Click to add a filter or search criterion** field to the right of the icon opens a series of drop-down lists from which you can select a table column, an operator, and—depending on the column—a value. If a column does not offer a value drop-down list, you can type in a value. When the selection is complete, the table rows matching the search criterion are highlighted. Clicking the **+** button or the **Click to add a filter or search criterion** field allows you to specify more search criteria. Pressing **F3** jumps to the next search result in the list. Clicking the **x** button removes the search.

Control	Description
Full-text filter	Entering a value or text string into the input field to the right of the icon filters the table accordingly and shows the rows that match the filter criterion.
Full-text search	Entering a value or text string into the input field to the right of the icon searches the table accordingly and highlights the rows that match the search criterion.
use LMB to click on a table row	Selects the row and the corresponding object in the Scene Tree. In analysis result lists, the result, e.g., the component, is marked by a cross-hairs cursor in each of the 2D views.
hold **Ctrl** key + use LMB to click on several table rows	Selects the rows and the corresponding objects in the Scene Tree.
hold **Shift** key + use LMB to click on two separate table rows	Selects the two rows, including all rows between the two as well as the corresponding objects in the Scene Tree.
hold **Shift** key + use up/down arrow keys	Selects the rows and the corresponding objects in the Scene Tree.
press **Ctrl+A**	Selects all table rows.
use up and down arrow keys	Steps up and down through the table rows.
use RMB to click into the table area	Displays a context menu. See below.
use LMB to click a column heading	Sorts the table according to the values of the column. Clicking subsequently toggles between ascending and descending.
use LMB to click and drag column heading to new position, then release LMB	Inserts the column at the new position.
use LMB to double-click cell highlighted in white (light theme) or medium gray (dark theme)	If applicable: Allows you to edit the contents of the cell.

- **Screenshots** section (if available)

  The **Screenshots** section below the list section allows you to capture images from one of the 2D windows, the 3D window, or the current window layout for the item currently selected in the table. Only available if exactly one row is selected.

  Table 34-23: Controls in the **Screenshots** section

Control	Description
Capture from button	Adds the image of the view selected from the drop-down list to the preview area above.

Control	Description
use LMB to click and drag one or more images, then release LMB	Moves the image(s) to the new position.
double-click the image	Opens the **Snapshot display** window showing the image: • **Zoom in**/**Zoom out** button: Zooms the image in/out. You can also move the mouse pointer in the image area and turn the mouse wheel. • **Fit to window** button: Resets the zoom so that the image fits into the window.
click the **<no description>** place-holder twice (first click to select, second click to enable renaming)	Allows you to label the image.
Delete selected button	Deletes the selected image from the preview area.

Table Context Menu

Right-clicking anywhere in the table area shows a context menu with the following options:

Table 34-24: Context menu items

Control	Description
Columns	Allows you to toggle the visibility of each column by checking/unchecking the respective item. • **Show all**: Checks all columns to set them to visible. • **Hide all**: Unchecks all columns to set them to invisible. • **Hide empty**: Unchecks all not editable columns which are empty or **n/a** to set them to invisible.
Trim columns	Resizes all columns to their smallest possible size.
Apply default column layout	Applies the default column layout previously saved by the user to the current table. If no default column layout has been saved, the original column layout will be applied.
Save as default column layout	Saves modifications applied to the table—e.g., the visibility of a column, the order in which the columns appear, the column width—as default column layout. This layout will be applied when you create a new project.
Apply original column layout	Restores the original table layout and discards any modifications applied by the user. The original table layout is predefined and cannot be modified by the user.

Control	Description
Remove entries	If applicable: Deletes the selected row(s) from the table.
Create annotations	If applicable: Creates annotations for the selected items.
Export as CSV...	Opens the **Export as CSV...** dialog for exporting the table values as **.csv* file. This option always exports the complete table even if a filter was applied. In order to export only the filtered rows, press **Ctrl** + **A** to highlight all filtered rows and use the **Copy to clipboard** menu item.
Copy to clipboard	Copies the selected rows as well as the column heading into the system clipboard. The clipboard information is provided both as plain text and rich-text table, so when pasting into a rich-text-capable application like a word processor, you will see a proper table with cell borders and bold headings.
Paste	For annotation tables: Pastes previously copied coordinates and—optionally—snap directions to create new annotations in the table. For annotations of a nominal/actual comparison, the search distance specified on the **Settings** tab of the analysis will be considered. Note: Pasted annotations will be interpreted in the selected coordinate system at the time of pasting. The information in the clipboard must have the following structure: • x-, y-, and z-coordinate of the annotation or • x-, y-, and z-coordinate of the annotation as well as x-, y-, and z-component of the vector for the snap direction The parameters can be separated by space, tab, semicolon, or comma (if a comma is already used as a decimal mark or digit grouping symbol, the values must be enclosed in double quotation marks). Example: 8.89;25.82;-0.55;1;0;0 You can also copy the information directly from the cells of a spreadsheet. In order to paste the annotation information, you can also press the **Ctrl** + **V** keyboard shortcut.
Set as active column	If applicable: Makes the current column the active column, i.e., the results of this column are color-coded according to their values as defined by the color lookup table and the colors specified in the **Sections** section of the **Colors** tab.

Control	Description
Unset active column	If applicable: Deselects the currently active column and sets the **Active column** drop-down list on the corresponding **Settings** tab to **Uncoded**, i.e., removes any color coding.
Enter/change value (all items)	If applicable: Opens the **Enter value** dialog (see below) where you can enter the desired value for the selected parameter. This value will be applied to all entries in the table.
Enter/change value (selected items)	If applicable: Opens the **Enter value** dialog (see below) where you can enter the desired value for the selected parameter. This value will be applied to the selected entries in the table.
Delete selected items	If applicable: Removes the selected items from the scene.

The **Enter value** dialog includes the following controls:

Table 34-25: Controls in the **Enter value** dialog

Control	Description
Enter value field	Allows you to enter the desired value.
OK button	Sets the selected parameter to the specified value.
Reset button	For analyses only: Resets the selected parameter to undefined.
Set from tolerance settings button	For analyses only: Enters the value specified in the tolerance settings of the analysis for the selected parameter.
Cancel button	Discards the changes and closes the dialog.

Images Tab

Allows you to take screenshots of the selected workspace views and/or add bookmark references to the report. In the final report, the captured images will be listed separately from the screenshots created on other tabs.

- **Snapshots** section

  Table 34-26: Controls in the **Snapshots** section

Control	Description
Capture from button	Adds the image of the view selected from the drop-down list to the preview area above.

Control	Description
Delete selected button	Deletes the selected image(s) from the preview area.
use LMB to click and drag one or more images, then release LMB	Moves the image(s) to the new position.
double-click the image	Opens the **Snapshot display** window showing the image: • **Zoom in**/**Zoom out** button: Zooms the image in/out. You can also move the mouse pointer on the image area and turn the mouse wheel. • **Fit to window** button: Resets the zoom so that the image fits into the window.
click the **<no description>** place-holder twice (first click to select, second click to enable renaming)	Allows you to label the image.

- **Automatic 3D images** section (if available)

  Check the corresponding checkbox to include the desired 3D view (e.g., **Top**, **Front**, **Top-left-front**, and **Current camera settings**) in the report without changing the 3D view.

- **Bookmark references** section

  Allows you to add bookmark references via drag and drop from the **Bookmarks and views** tool or the **Bookmark editor** to the preview area. The images of the referenced bookmarks will then be included in VGRF-based reports.

  When you open a project with missing bookmark images, placeholders will be shown instead.

  Bookmark references are stored in evaluations and can be used in automation scenarios.

You will still need to import a bookmark template containing the actual bookmarks in these cases, as evaluations store only references to them.

Table 34-27: Controls in the **Bookmark references** section

Control	Description
New bookmark button	Adds a bookmark of the current view to the preview area.
Remove button	Removes the bookmark currently selected in the preview area.

Control	Description
click the bookmark title twice (first click to select, second click to enable renaming) or press the **F2** key	Allows you to rename the bookmark. The changes made on the **Images** tab will also affect the **Bookmark editor** and the **Bookmarks and views** tool. If the renamed bookmark is referenced by one or more objects for reporting, a warning message will be displayed indicating that the referenced bookmark will also be renamed for all these objects in the report.

☞ The global concept of bookmark references allows for multiple objects to reference the same bookmark and for objects to reference bookmarks that show arbitrary information, e.g., other analyses or objects.

Digital Volume Correlation Module

Introduction

The **Digital Volume Correlation** module is a tool used to measure the displacement and strains in time series of volumetric images. Currently, time series with two time points A (“before”) and B (“after”) are supported. Typically, volume A is an initial, undeformed volume, and volume B is a deformed volume. The deformation may be caused by the elastic strain of mechanical in-situ tests to characterize a composite material, cyclic loading during actual use of a component, or swelling of a structure in water.

Digital volume correlation relates each point x in volume A to a visually corresponding point y in volume B by establishing the transformation function y = T(x). “Visually corresponding” means that the neighborhoods of both points x and y have a matching spatial gray value distribution, i.e., the surrounding image patches look alike.

Figure 35-1 illustrates the correlation process. Volume A and volume B are two CT data sets of the same object, in an initial and a deformed state. In the first step, the digital volume correlation calculates the transformation function T, which assigns to each point x in volume A a point y in volume B. In the second step, the inverse transformation T is applied to volume B, generating an artificial data set “Rectified volume B”. The rectified volume B can be directly compared to volume A in order to check the correctness of the correlation or to identify remaining differences between volume A and volume B, e.g., cracks.

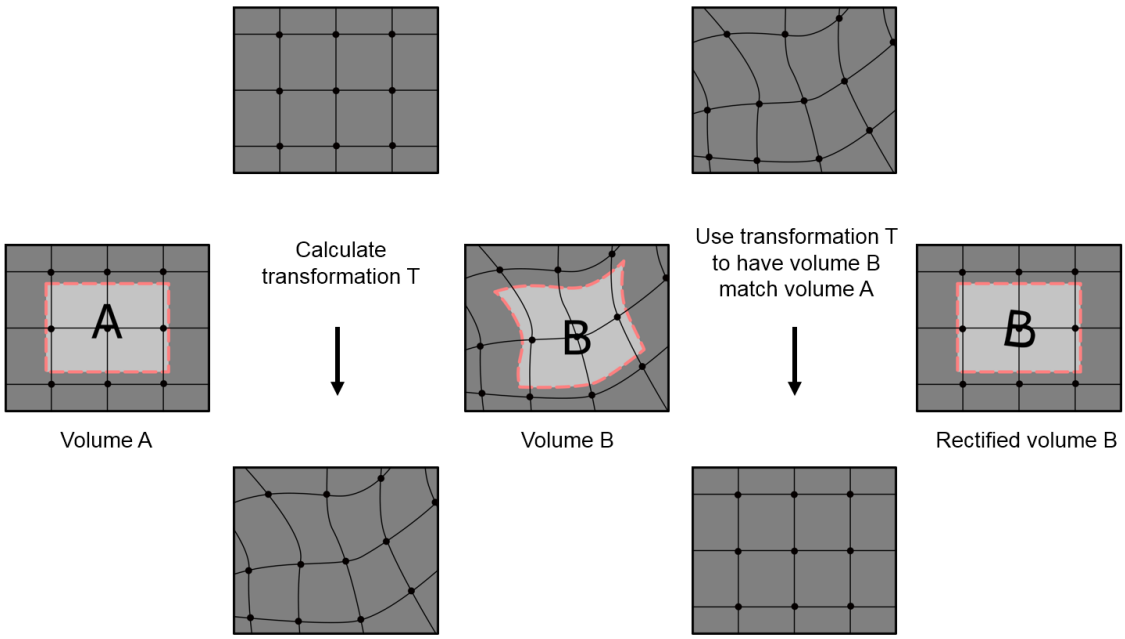
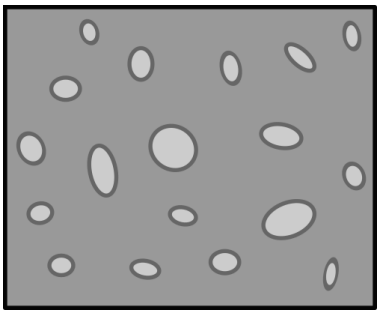
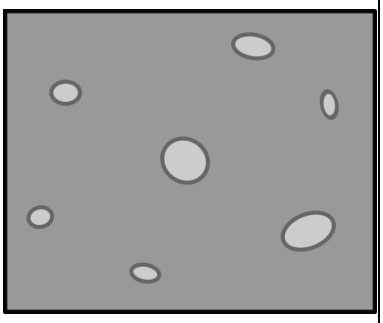
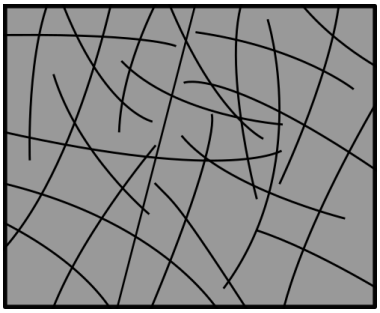
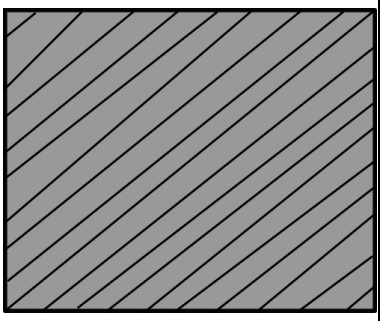


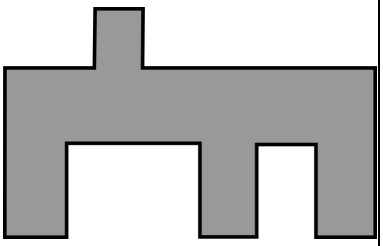
Figure 35-1: Correlation process

In order to obtain good results, the volumes to be correlated must fulfill certain conditions. Visible structures need to be distributed over the entire material fraction of the volume. Therefore, composite materials and foams are good candidates for digital volume correlation.

The following table shows some examples of potential structures and their suitability for digital volume correlation:

Table 35-1: Potential structures and their suitability for digital volume correlation

Material type	Example 1	Example 2
Material with particles or voids	 Dense: Suitable for digital volume correlation.	 Sparse: Suitable for digital volume correlation, but displacements cannot be measured locally.
Fiber materials	 Random fiber orientation: Suitable for digital volume correlation.	 Unidirectional fiber orientation: Displacements can only be measured perpendicularly to the fiber direction. There are no features in fiber direction. The same applies, for example, to stacked plates.

Material type	Example 1	Example 2
Homogeneous materials	 Subvolume of homogeneous material that does not include the surface: No digital volume correlation possible, as there is no structure in the volume.	 The entire part includes the surface: This is not optimal, but if the surface is included in the analysis region, it is possible to get good results by using suitable control point spacing. When you use the **ROI from volume/CAD/mesh** function to define the analysis region, make sure to dilate it to ensure that the gradient of the edge is taken into account.

License Information

This module is an optional add-on module for VGSTUDIO MAX. It is not available for myVGL. However, if a project loaded in myVGL contains results obtained with this module, they can be viewed and reported in myVGL.

If you are interested in a more comprehensive functionality than the one offered by myVGL, you have the chance to evaluate VGSTUDIO MAX. You can request an evaluation license of VGSTUDIO MAX on our website:

https://volumegraphics.hexagon.com/en/products/evaluation

If you have further questions about our product portfolio, please contact us:

- For Europe, Middle East, and Africa:

  Write an e-mail to sales@volumegraphics.com or call +49 6221 73920 744.
- For Japan:

  Write an e-mail to sales@volumegraphics.jp or call +81 52 508 9682.
- For the Americas:

  Write an e-mail to sales-us@volumegraphics.com or call +1 704 248 7736.
- For China, including Mainland China, Hong Kong, Macao, and Taiwan:

  Write an e-mail to sales@volumegraphics.cn or call +86 10 8532 6305.
- For Singapore and other parts of Asia (except China and Japan), Australia, and parts of Oceania:

  Write an e-mail to sales@volumegraphics.sg or call +65 6665 0310.

Opening the Dialog

In order to open the **Digital volume correlation** dialog,

- right-click the corresponding entry in the Scene Tree and select **Properties** from the context menu or
- double-click the corresponding entry in the Scene Tree.

The **Digital volume correlation** dialog consists of several tabs on which you can view the results of the analysis.

To close the dialog, click the **Close** button at the bottom of the dialog.

A status bar at the bottom of the dialog indicates the current status of the analysis. The status can be one of the following:

Table 35-2: Messages in the status bar

Status	Description
Calculation required	All required parameters have been specified and are consistent, but the analysis was not calculated or was invalidated by some user action before the project was saved.
Result is up to date	The current analysis result is valid.
License missing	The add-on module is not licensed.

☞ An invalid or outdated status of an analysis is indicated in the Scene Tree by a warning sign. Double-click this analysis to open it and check the status bar for messages.

☞ The units of the dialog depend on the global unit settings (see section *Units Drop-down List* on page 33 in chapter 2 *Workspace*).

Settings Tab

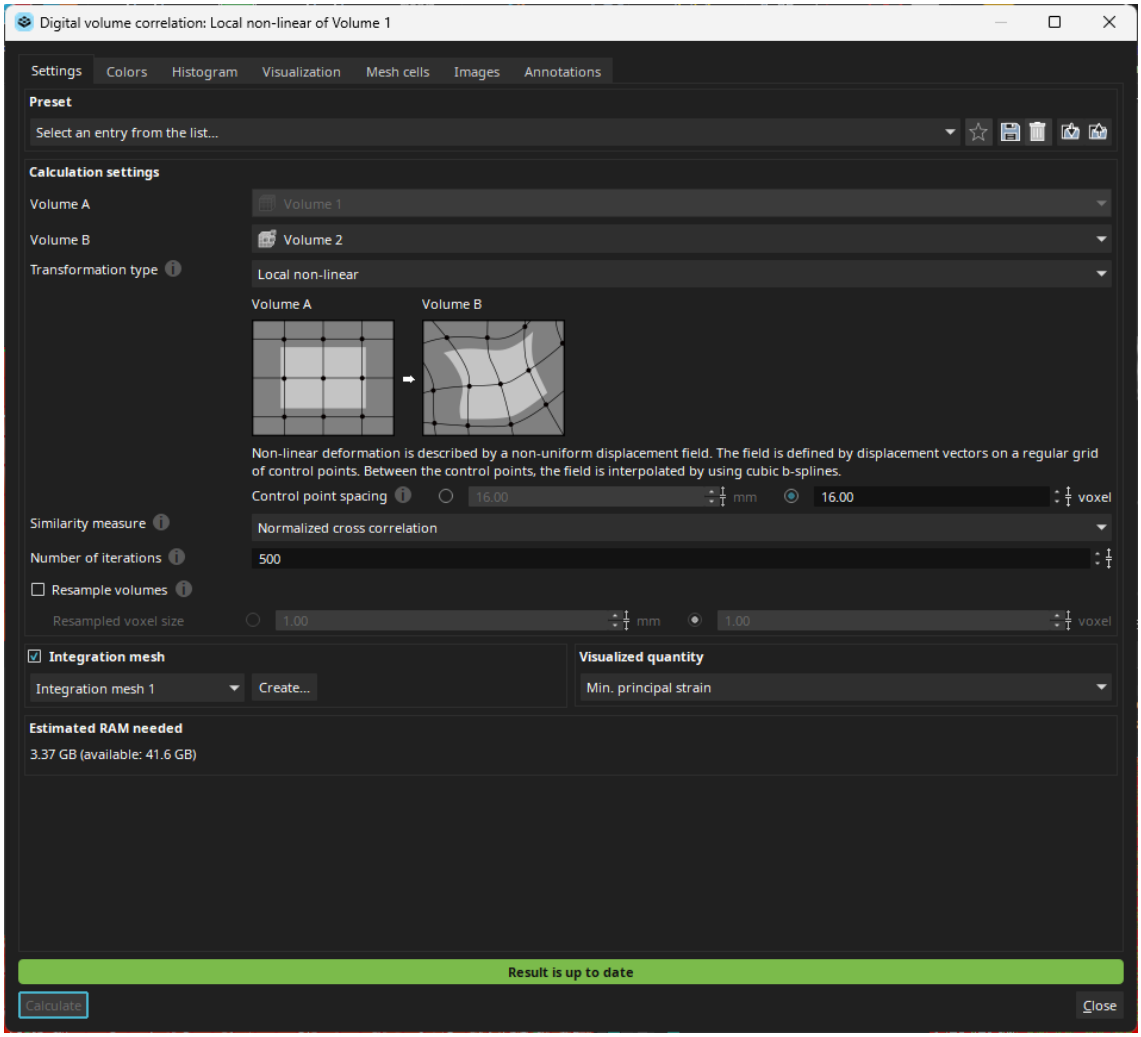


Figure 35-2: **Digital volume correlation** dialog, **Settings** tab

In myVGL, all parameter settings are displayed. Most of these parameters are read-only in myVGL. The complete functional range is available with VGSTUDIO MAX and the respective add-on module(s).

Preset selection Section

Table 35-3: Controls in the **Preset selection** section

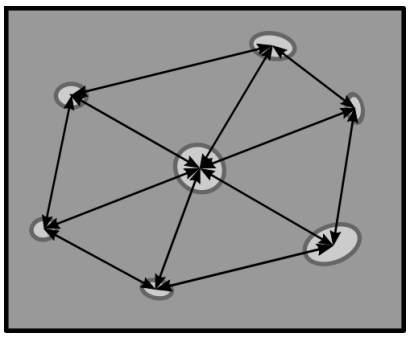
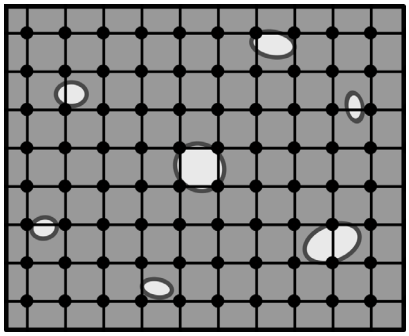
Icon	Item	Description
	drop-down list	Specifies the preset to be applied, to be edited, or to be taken as a basis for a new preset. The following icons are used: • analysis factory settings • customized preset • appears next to the icon of a preset that has been modified but not yet saved
	Set this preset as default	Sets the selected preset as default. The default preset will be applied when creating a new analysis of the same type. If the selected preset is already set as default, the button is disabled.
	Save preset	Saves the selected preset. When saving a preset, the **Save preset** dialog will open, which allows you to set the new preset as default by checking the **Set as default for new analyses** checkbox.
	Remove preset	Removes the selected preset from the preset drop-down list. If the removed preset is the default preset, the next time an analysis of the same type is created, the factory settings will be used.
	Import preset	Imports a preset from the specified location.
	Export preset	Exports the selected preset to the specified location.

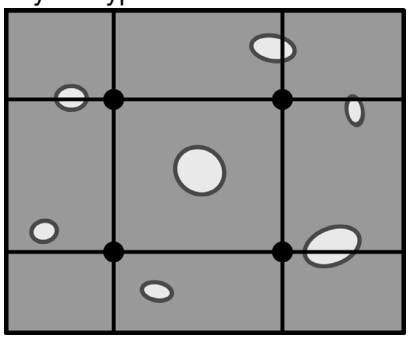
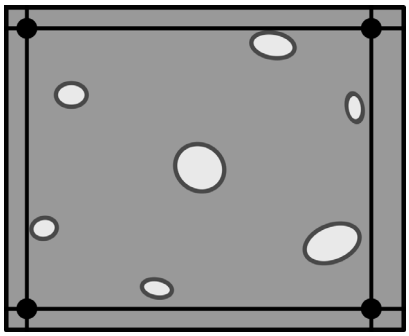
Calculation settings Section

Table 35-4: Controls of the **Calculation settings** section

Control	Description
Volume A field	Indicates the volume or ROI (region of interest) for which the analysis is to be performed. The field cannot be edited. If the object has a determined surface, it will not be considered in the analysis. If an ROI is selected as **Volume A**, only data in the ROI will be considered for correlation. It is recommended that you use an ROI that includes the object plus a small margin into the air, but excludes most of the air around, if present.

Control	Description
Volume B drop-down list	Specifies the volume against which to align the object selected as **Volume A**. It is not possible to select an ROI for **Volume B**.
Transformation type drop-down list	Allows you to select a motion model, i.e., to restrict the transformation function T to a specific type of motion. The transformation types are ordered from the most to the least restrictive one: **Rigid**, **Affine**, and **Local non-linear**. Motions and deformations that can be represented by a more restrictive transformation type can also be represented by a less restrictive one. Nevertheless, it is recommended that you select the most restrictive transformation type that is just enough to represent the motion you would like to detect. For example, if you know that your object only performs rigid-body motion, it is not useful to select the **Local non-linear** transformation type. Ideally, both settings are expected to yield the same results, since the **Local non-linear** transformation type also includes rigid-body motion. But in practice—with the presence of noise and for numerical reasons—the local deformation will tend to “over-fit”. This means that the calculation of the digital volume correlation may be impaired by random fluctuations in the image and detect unrealistic deformations or not converge at all. • **Rigid**: Rigid alignment allows for global rotation and translation. It is defined as y = Rx + t, with R representing a 3x3 rotation matrix and t the translation vector. • **Affine**: Affine transformation allows for global rotation, translation, scaling, and shearing. It is defined by y = Ax + t, with A representing a 3x3 transformation matrix and t the translation vector. • **Local non-linear**: Non-linear deformation is described by a non-uniform displacement field (see [1] in section *References* on page 618). The field is defined by displacement vectors on a regular grid of control points. Between the control points, the field is interpolated by using cubic b-splines. The spacing of the control points can be adjusted via the **Control point spacing** spin box.

Control	Description
Control point spacing spin box	Only available for the **Local non-linear** transformation type. Specifies the spacing of the control points. With small spacing, you may detect more fine-scaled deformations, but there is a risk of over-fitting. With large spacing, the results will be more robust, but only large-scale deformations can be detected. It is recommended that you choose the largest spacing that is just enough to detect the results you expect and that you do not use spacing that is smaller than the typical feature size. If the value is specified in voxels, the voxel size will refer to the original resolution of **Volume A** and be independent of the **Resample volumes** parameter. Typical feature size:  Control point spacing is too small. There are no features in most of the cells and the results will most likely be noisy. 

Control	Description
	Suitable control point spacing. The grid size matches approximately the typical feature size.  Large control point spacing. The results will be robust, but the transformation is restricted. 
Similarity measure drop-down list	• **Normalized cross correlation** (see [1] in section *References* on page 618): This is the default method. It works best for the correlation of volume data sets that were acquired in the same way. • **Mutual information** (see [2] in section *References* on page 618): This is the preferred method for the correlation of volume data sets with different modalities (e.g., if computed tomography (CT) data is to be correlated with magnetic resonance (MR) data).
Number of iterations spin box	Specifies the number of iterations for the iterative optimization method (see [3] in section *References* on page 618). The default value is 500, which is sufficient for most applications. If the volumes do not match after correlation, it is recommended that you retry with a higher number of iterations.

Control	Description
Resample volumes checkbox	When this option is checked, the data set is resampled in order to save memory, which is especially useful for large data sets. Setting the value in the **Resampled voxel size** spin box to, e.g., **2** voxels, will decrease the memory required for the volume data by a factor of approximately eight. Both **Volume A** and **Volume B** will be resampled to the same resolution. If the value is specified in voxels, the voxel size will refer to the original resolution of **Volume A**.

Integration mesh Section

Allows you to create an integration mesh or select an existing integration mesh to obtain the results of the digital volume correlation for each mesh cell. Visualizing displacement arrows is possible only if an integration mesh is used. For this purpose, it is recommended that you create a regular integration mesh with the desired arrow distance as grid spacing.

Table 35-5: Controls of the **Integration mesh** section

Control	Description
Integration mesh checkbox	When this option is checked, the options for using an integration mesh will be enabled.
Integration mesh drop-down list	Allows you to specify an integration mesh by selecting an existing mesh from the drop-down list.
Create… button	Creates an integration mesh and opens the **Mesh** dialog for adjusting the parameters manually.

Visualized quantity Section

Specifies the quantity to be displayed in the color overlay and in the histogram.

Table 35-6: Options of the **Visualized quantity** drop-down list

Option	Description
Displacement x, **y**, **z**	Displays the x-, y-, and z-components of the displacement vector of a point from **Volume A** to **Volume B**.
Displacement magnitude	Displays the Euclidean norm of the displacement.
Difference volume	Displays the point-by-point difference between **Volume A** and the rectified **Volume B**, with the gray values normalized to standard deviation.
Rectified vol. B	Displays **Volume B** with transformation T applied, so that it will match the structures of **Volume A**.

Option	Description
Von Mises strain	For the transformation types **Affine** and **Local non-linear**: Displays the von Mises strain.
Strain xx, **yy**, **zz**, **xy**, **yz**, **zx**	For the transformation types **Affine** and **Local non-linear**: Displays the xx-, yy-, zz-, xy-, yz-, and zx-components of the strain tensor.
Max. principal strain	For the transformation types **Affine** and **Local non-linear**: Displays the maximum principal strain, which is the largest eigenvalue of the strain tensor.
Mid principal strain	For the transformation types **Affine** and **Local non-linear**: Displays the middle principal strain, which is the middle eigenvalue of the strain tensor.
Min. principal strain	For the transformation types **Affine** and **Local non-linear**: Displays the minimum principal strain, which is the smallest eigenvalue of the strain tensor.

Estimated RAM needed Section

Indicates the predicted approximate peak memory requirement.

Colors Tab

Here you can specify the color-coding scheme used for representing the correlation results.

Caption Section

Table 35-7: Controls of the **Caption** section

Control	Description
Caption field	Indicates the color bar headline as specified in the **Caption** field of the **Color bar** section.
Share color bar checkbox	When this option is checked, all analyses of the same type (and—if applicable—of the same algorithm) will use the same color bar. When this option is unchecked, the color bar settings will apply to the selected analysis only.

LUT – Color Lookup Table

The color lookup table (LUT) shows the partitioning into color sections.

Sections Section

Defines the appearance of each color section.

Table 35-8: Controls in the **Sections** section

Control	Description
From/To fields	Specify the start and end values of the color sections. The first color section represents all values above the upper limit, i.e., the value in the **From** field (**+inf** signifies positive infinity), while the last color section represents all values below the lower limit, i.e., the value in the **To** field (**-inf** signifies negative infinity). The default limits are calculated from the results of the analysis (for an analysis color bar) or taken from the **Default** preset (for a tolerance deviation color bar).
Type field	Switches between the color schemes **Continue**, **Constant**, **Gradient**, **Rainbow**, **Reverse rainbow**, **Hue cycle**, **Green to red**, and **Red to green**.
Color/transparency field	Double-clicking the field for the **Continue**, **Constant**, and **Gradient** color schemes opens the **Select Color** dialog where you can modify the appearance of the selected color scheme. For the **Gradient** color scheme, you can specify the start and end colors by double-clicking the left or right side of the field, respectively. Double-clicking the field for the **Rainbow**, **Reverse rainbow**, **Hue cycle**, **Green to red**, and **Red to green** color schemes opens the **Transparency** dialog, where you can set the transparency for the selected color scheme.
use RMB to click a color section	Opens a context menu with the following items: • **Split**: Subdivides the color section into two new color sections where each represents half of the original section. • **Merge**: Combines several color sections to a single color section. Only consecutive intervals can be merged.
Create smooth button	Opens the **Create smooth table** dialog to generate one color section. • **Type** drop-down list: Allows you to select the type of coloring scheme. • **From/To** spin boxes: Specify the value range covered by the color section.

Control	Description
Create stepped button	Opens the **Create stepped table** dialog to generate a set of color sections. • **Type** drop-down list: Allows you to select the type of coloring scheme. • **From/To** spin boxes: Specify the value range covered by the color sections. • **Step** spin box: Specifies the step size of the individual color sections.
Auto scale button	If available: Fits the color LUT to the range of the results of all available analyses.
Auto scale color bar range on calculate checkbox	If available: When this option is checked, the color LUT will be automatically fitted to the range of the results of all available analyses.
Default button	If available: Resets any changes made to the **Sections** table.

Visualized quantity Section

This drop-down list allows you to select the quantity that is to be shown according to the specified color-coding.

The **Visualized quantity** section is also available on the **Settings** tab. The changes made on the **Colors** tab will also affect the **Settings** tab and vice versa. For details on the quantity, see section *Visualized quantity Section* on page 601.

Preset selection Section

Table 35-9: Controls in the **Preset selection** section

Icon	Item	Description
	drop-down list	Specifies the preset to be applied, to be edited, or to be taken as a basis for a new preset. The following icons are used: • default preset • customized preset • appears next to the icon of a preset that has been modified but not yet saved

Icon	Item	Description
	Save preset	Opens the **Save preset** dialog for saving the color LUT of the current data set under the specified name. • **Absolute preset**: When this option is checked and the preset applied, the settings of the original data set, including the LUT range, will be applied. When this option is unchecked, the color settings of the preset will be mapped relatively to the actual range of results of the analysis to which the preset will be applied.
	Remove preset	Removes the selected preset from the preset drop-down list.
	Import preset	Imports a preset from the specified location.
	Export preset	Exports the selected preset to the specified location.

Color LUT Settings Section

Specifies the appearance of the color lookup table.

Table 35-10: Options for the appearance of the color lookup table

Control	Description
Auto tick marks checkbox	When this option is checked, equidistant tick marks will be produced for the color bars. When this option is unchecked, tick marks will appear only at the color section boundaries of the color lookup table.
Auto scale color bar range on calculate checkbox	When this option is checked, the color LUT will be automatically fitted to the range of the results of all available analyses.

Color bar Section

Specifies the settings for the color bar.

Table 35-11: Settings for the color bar

Control	Description
Visibility drop-down list	Switches the color bar on/off.
Positioning drop-down list	Specifies the location of the color bar within the 2D and 3D windows: **Left, Right, Top, Bottom, All - automatic, Left or right - automatic, Top or bottom - automatic**.
Caption field	Specifies the color bar headline by using placeholders.
Reset button	Resets the **Caption** field to the default entry.

Histogram Tab

Shows the volume histogram within the determined surface of the selected object for the selected quantity. The histogram bars can be colored according to the settings on the **Colors** tab.

Controls of the **Histogram** Tab

Table 35-12: Controls of the **Histogram** tab

Control	Description
Color drop-down list	• **From color bar**: The values in the histogram are shown according to the color bar. • **Gray**: All values in the histogram are shown in gray.
Normalization drop-down list	• **Absolute**: Displays the volume in absolute values. • **Relative**: Displays the volume in relative values with respect to the entire volume within the determined surface.
Binning drop-down list	• **Off**: No binning is applied to the values shown in the histogram. • **From color bar**: The original values in the histogram are replaced by a value representative for the corresponding interval (“bin”) of the color bar. The “bins” become visible when “stepped” sections are created on the **Colors** tab. • **Manual number of bins**: Enables the **Bin count** spin box, where you can enter the required number of “bins.” • **Manual bin width**: Enables the **Bin width** spin box, where you can specify the width of the bins.
Left/**Right** spin box	Only enabled when an interval has been created: Moves the left or right interval border to the specified value. You can also click and drag the interval borders using the left mouse button.
Create button	Creates a new interval. On the right hand side of a selected interval, statistical information is displayed: • **Left**: Indicates the minimum value of the selected quantity within the interval, i.e., the left interval border. • **Right**: Indicates the maximum value of the selected quantity within the interval, i.e., the right interval border.

Control	Description
	• **Mean**: Indicates the mean value of the selected quantity within the interval. • **Dev**: Indicates the standard deviation of the selected quantity within the interval. • **Sum**: Indicates the volume within the interval. • **Percentage**: Indicates the percentage of the volume within the interval. Note that the statistical information may change with the number of bins.
Remove button	Removes the selected interval.
Create ROI button	Generates a new ROI containing all voxels whose volumes lie within the selected interval.
use RMB to click the chart area	Displays a context menu (see below).
scroll MW in chart area or x-axis up/down	Zooms the x-axis of the chart out/in.
scroll MW in y-axis up/down	Zooms the y-axis of the chart out/in.
use LMB to click and drag the x-axis	Scrolls the x-axis.
use LMB to click and drag the y-axis	Scrolls the y-axis.
Zoom in/out	Zooms the corresponding axis in/out.
Reset zoom	Fits the entire chart to the current window size.

Context Menu of the **Histogram** Tab

Right-clicking anywhere in the chart area opens a context menu with the following options:

Table 35-13: Context menu items

Control	Description
Export as CSV...	Opens a dialog for saving the chart values to a *.csv* file.
Copy to clipboard	Copies a screenshot of the chart to the system clipboard so you can paste it into another application.
Show/Hide x/y grid	Toggles the visibility of the grid lines for the corresponding axis.
Reset zoom	Fits the entire chart to the current window size.
Create interval	Creates a new interval. For details on the statistical information, see section *Controls of the Histogram Tab* on page 606.
Remove interval	Removes the selected interval.

Control	Description
Create ROI	Generates a new ROI containing all voxels whose volumes lie within the selected interval.

Visualization Tab

Specifies the appearance of the displacement lines and strain lines (for the transformation types **Affine** and **Local non-linear**) as well as the displacement arrows for the 2D windows and the 3D window.

Table 35-14: Controls of the **Displacement lines** and **Strain lines** sections

Control	Description
Length (1-100) spin box	Specifies the length of the individual displacement or strain lines.
Density (1-100) spin box	Specifies the density and thus the number of displacement or strain lines.
Width (1-100) spin box	Specifies the width of the individual displacement or strain lines.
Show in 3D window checkbox	Switches the visibility of the displacement or strain lines in the 3D window on or off. Note that the **Displacement lines** or the **Strain lines** checkbox in the Scene Tree must also be checked in order to display the corresponding lines.

The displacement arrows will be displayed only when the digital volume correlation was performed on an integration mesh.

Table 35-15: Controls of the **Displacement arrows** section

Control	Description
Scale spin box	Specifies the length of the displacement arrows. If the value is 1, the arrows are drawn to scale, i.e., they show exactly the length of the calculated displacement. Use values greater than 1 to show exaggerated displacements.
3D rendering checkbox	When this option is checked, the displacement arrows will be displayed in the 3D window.
Thickness spin box	Specifies the diameter of the displacement arrows.
Color field	Double-clicking the color field opens the **Select Color** dialog, where you can set the color of the displacement arrows.

Results Tab

Only available for rigid and affine transformations.

For a *rigid* transformation, the transformation matrix and the translation are shown, while for an *affine* transformation, the transformation matrix, the strain tensor, and an eigenvalue analysis of the strain tensor are shown.

Fields of the **Results** Tab

The fields in the **Transformation matrix** section provide the following information for a rigid or an affine transformation:

Table 35-16: Fields in the **Transformation matrix** section

Field	Description
Matrix components xx, **yx**, **zx**, **xy**, **yy**, **zy**, **xz**, **yz**, **zz**	Indicate the components of the 3x3 transformation matrix M in y = Mx + t.
Translation [<length unit>] x, **y**, **z**	Indicate the components of the translation vector t in y = Mx + t.

The fields in the **Strain tensor** section provide the following information for an affine transformation:

Table 35-17: Fields in the **Strain tensor** section

Field	Description
Matrix components xx, **yx**, **zx**, **xy**, **yy**, **zy**, **xz**, **yz**, **zz**	Indicate the matrix components of the strain tensor.
Eigenvalues λ**1**, λ**2**, λ**3**	Indicate the eigenvalues (principal strains) of the strain tensor.
Eigenvectors E.v. 1, **E.v. 2**, **E.v. 3 x**, **y**, **z**	Indicate the x-, y-, and z-components of the three eigenvectors of the strain tensor.

Controls of the **Results** Tab

Table 35-18: Controls of the **Results** tab

Control	Description
Store alignment systems button	Only available if the **Rigid** transformation type is selected. Creates an alignment system under the corresponding **Coordinate systems** entries of **Volume A** and **Volume B** in the Scene Tree. By right-clicking the alignment system of **Volume B** and selecting **Apply transformation** from the context menu, the transformation of the alignment system can be applied.

Control	Description
Copy CSV to clipboard button	Copies the transformation in CSV format to the system clipboard.
Export CSV to file… button	Allows you to export the transformation in CSV format.

Mesh cells Tab

Shows the results of the tensor calculation. When the **Integration mesh** option on the **Settings** tab is checked, the results will be listed in a table, with each table row showing the results for an integration mesh cell.

The **Results** tab provides following information:

Table 35-19: Columns of the **Results** table

Column	Description
Element ID	If available, indicates the ID of the mesh cell for imported integration mesh files.
Pos. x, y, z	Indicates the x-, y-, and z-position of the mesh cell center.
Displacement x, y, z	Indicates the x-, y-, and z-components of the displacement vector of a point from **Volume A** to **Volume B**.
Strain tensor xx, **xy**, **xz**, **yy**, **yz**, **zz**	For the transformation types **Affine** and **Local non-linear**: Indicates the matrix components of the strain tensor.
Von Mises strain	For the transformation types **Affine** and **Local non-linear**: Indicates the von Mises strain of the mesh cell.
Min. principal strain	For the transformation types **Affine** and **Local non-linear**: Indicates the minimum principal strain, which is the smallest eigenvalue of the strain tensor.
Mid principal strain	For the transformation types **Affine** and **Local non-linear**: Indicates the middle principal strain, which is the middle eigenvalue of the strain tensor.
Max. principal strain	For the transformation types **Affine** and **Local non-linear**: Indicates the maximum principal strain, which is the largest eigenvalue of the strain tensor.

Column	Description
Min. principal strain dir. x, y, z	For the transformation types **Affine** and **Local non-linear**: Indicates the x-, y-, and z-components of the normalized direction of the minimum principal strain.
Mid principal strain dir. x, y, z	For the transformation types **Affine** and **Local non-linear**: Indicates the x-, y-, and z-components of the normalized direction of the middle principal strain.
Max. principal strain dir. x, y, z	For the transformation types **Affine** and **Local non-linear**: Indicates the x-, y-, and z-components of the normalized direction of the maximum principal strain.
Description	Allows you to enter a description for the cell used for reporting.
Captures	Indicates the number of images captured for this cell by using the **Capture from** button in the **Screenshots** section.

Images Tab

Allows you to take screenshots of the selected workspace views and/or add bookmark references to the report. In the final report, the captured images will be listed separately from the screenshots created on other tabs.

- **Snapshots** section

  Table 35-20: Controls in the **Snapshots** section

Control	Description
Capture from button	Adds the image of the view selected from the drop-down list to the preview area above.
Delete selected button	Deletes the selected image(s) from the preview area.
use LMB to click and drag one or more images, then release LMB	Moves the image(s) to the new position.
double-click the image	Opens the **Snapshot display** window showing the image: • **Zoom in**/**Zoom out** button: Zooms the image in/out. You can also move the mouse pointer on the image area and turn the mouse wheel. • **Fit to window** button: Resets the zoom so that the image fits into the window.

Control	Description
click the **<no description>** placeholder twice (first click to select, second click to enable renaming)	Allows you to label the image.

- **Automatic 3D images** section (if available)

  Check the corresponding checkbox to include the desired 3D view (e.g., **Top**, **Front**, **Top-left-front**, and **Current camera settings**) in the report without changing the 3D view.

- **Bookmark references** section

  Allows you to add bookmark references via drag and drop from the **Bookmarks and views** tool or the **Bookmark editor** to the preview area. The images of the referenced bookmarks will then be included in VGRF-based reports.

  When you open a project with missing bookmark images, placeholders will be shown instead.

  Bookmark references are stored in evaluations and can be used in automation scenarios.

You will still need to import a bookmark template containing the actual bookmarks in these cases, as evaluations store only references to them.

Table 35-21: Controls in the **Bookmark references** section

Control	Description
New bookmark button	Adds a bookmark of the current view to the preview area.
Remove button	Removes the bookmark currently selected in the preview area.
click the bookmark title twice (first click to select, second click to enable renaming) or press the **F2** key	Allows you to rename the bookmark. The changes made on the **Images** tab will also affect the **Bookmark editor** and the **Bookmarks and views** tool. If the renamed bookmark is referenced by one or more objects for reporting, a warning message will be displayed indicating that the referenced bookmark will also be renamed for all these objects in the report.

The global concept of bookmark references allows for multiple objects to reference the same bookmark and for objects to reference bookmarks that show arbitrary information, e.g., other analyses or objects.

Annotations Tab

Lists all annotations created for the selected digital volume correlation. You can view the information supplied by the annotations or edit the annotation properties.

For details on how to create an annotation, see section *Annotation* on page 124 in chapter 6 *Inspect Tab*.

To create new annotations in the table, it is also possible to paste previously copied coordinates by right-clicking the table and selecting **Paste** from the context menu or by pressing the **Ctrl** + **V** keyboard shortcut. For details, see the **Paste** menu item in section *Table Context Menu*.

Double-clicking an analysis annotation in the Scene Tree will directly open the **Annotations** tab of the properties dialog of the corresponding analysis.

The **Annotations** table consists of the following columns:

Table 35-22: Columns of the **Annotations** table

Column	Description
Name	Indicates the name of the annotation.
Pos. x/y/z [<length unit>]	Indicates the position of the annotation.
Displacement x/y/z [<length unit>]	Indicate the x-, y-, and z-components of the displacement vector at the position of the annotation.
Strain tensor xx/yy/zz/xy/yz/zx [<unit>]	For the transformation types **Affine** and **Local non-linear**: Indicate the xx-/yy-/zz-/xy-/yz-/zx-components of the strain tensor.
Von Mises strain [<unit>]	For the transformation types **Affine** and **Local non-linear**: Indicates the von Mises strain at the position of the annotation.
Description	Allows you to enter a description of the annotation used for reporting.
Captures	Indicates the number of images captured for this annotation using the **Capture from** button in the **Screenshots** section.
Tolerance status	Currently not implemented.
Type	Indicates how the annotation has been created: • **Manually defined**: The annotation has been defined by the user.

General Table Controls

- List section

  The following table provides an overview of the general controls available in the various list views:

Table 35-23: Controls in the list section

Control	Description
button	Opens a submenu for selecting the filter/search mode.
Filter	Clicking the **Click to add a filter or search criterion** field to the right of the icon opens a series of drop-down lists from which you can select a table column, an operator, and—depending on the column—a value. If a column does not offer a value drop-down list, you can type in a value. When the selection is complete, the table shows the rows matching the filter criterion. Clicking the **+** button or the **Click to add a filter or search criterion** field allows you to specify more filter criteria. Clicking the **x** button removes the filter.
Search	Clicking the **Click to add a filter or search criterion** field to the right of the icon opens a series of drop-down lists from which you can select a table column, an operator, and—depending on the column—a value. If a column does not offer a value drop-down list, you can type in a value. When the selection is complete, the table rows matching the search criterion are highlighted. Clicking the **+** button or the **Click to add a filter or search criterion** field allows you to specify more search criteria. Pressing **F3** jumps to the next search result in the list. Clicking the **x** button removes the search.
Full-text filter	Entering a value or text string into the input field to the right of the icon filters the table accordingly and shows the rows that match the filter criterion.
Full-text search	Entering a value or text string into the input field to the right of the icon searches the table accordingly and highlights the rows that match the search criterion.
use LMB to click on a table row	Selects the row and the corresponding object in the Scene Tree. In analysis result lists, the result, e.g., the component, is marked by a cross-hairs cursor in each of the 2D views.
hold **Ctrl** key + use LMB to click on several table rows	Selects the rows and the corresponding objects in the Scene Tree.

Control	Description
hold **Shift** key + use LMB to click on two separate table rows	Selects the two rows, including all rows between the two as well as the corresponding objects in the Scene Tree.
hold **Shift** key + use up/down arrow keys	Selects the rows and the corresponding objects in the Scene Tree.
press **Ctrl+A**	Selects all table rows.
use up and down arrow keys	Steps up and down through the table rows.
use RMB to click into the table area	Displays a context menu. See below.
use LMB to click a column heading	Sorts the table according to the values of the column. Clicking subsequently toggles between ascending and descending.
use LMB to click and drag column heading to new position, then release LMB	Inserts the column at the new position.
use LMB to double-click cell highlighted in white (light theme) or medium gray (dark theme)	If applicable: Allows you to edit the contents of the cell.

- **Screenshots** section (if available)

  The **Screenshots** section below the list section allows you to capture images from one of the 2D windows, the 3D window, or the current window layout for the item currently selected in the table. Only available if exactly one row is selected.

  Table 35-24: Controls in the **Screenshots** section

Control	Description
Capture from button	Adds the image of the view selected from the drop-down list to the preview area above.
use LMB to click and drag one or more images, then release LMB	Moves the image(s) to the new position.
double-click the image	Opens the **Snapshot display** window showing the image: • **Zoom in**/**Zoom out** button: Zooms the image in/out. You can also move the mouse pointer in the image area and turn the mouse wheel. • **Fit to window** button: Resets the zoom so that the image fits into the window.
click the **<no description>** placeholder twice (first click to select, second click to enable renaming)	Allows you to label the image.

Control	Description
Delete selected button	Deletes the selected image from the preview area.

Table Context Menu

Right-clicking anywhere in the table area shows a context menu with the following options:

Table 35-25: Context menu items

Control	Description
Columns	Allows you to toggle the visibility of each column by checking/unchecking the respective item. • **Show all**: Checks all columns to set them to visible. • **Hide all**: Unchecks all columns to set them to invisible. • **Hide empty**: Unchecks all not editable columns which are empty or **n/a** to set them to invisible.
Trim columns	Resizes all columns to their smallest possible size.
Apply default column layout	Applies the default column layout previously saved by the user to the current table. If no default column layout has been saved, the original column layout will be applied.
Save as default column layout	Saves modifications applied to the table—e.g., the visibility of a column, the order in which the columns appear, the column width—as default column layout. This layout will be applied when you create a new project.
Apply original column layout	Restores the original table layout and discards any modifications applied by the user. The original table layout is predefined and cannot be modified by the user.
Remove entries	If applicable: Deletes the selected row(s) from the table.
Create annotations	If applicable: Creates annotations for the selected items.
Export as CSV...	Opens the **Export as CSV...** dialog for exporting the table values as **.csv* file. This option always exports the complete table even if a filter was applied. In order to export only the filtered rows, press **Ctrl** + **A** to highlight all filtered rows and use the **Copy to clipboard** menu item.

Control	Description
Copy to clipboard	Copies the selected rows as well as the column heading into the system clipboard. The clipboard information is provided both as plain text and rich-text table, so when pasting into a rich-text-capable application like a word processor, you will see a proper table with cell borders and bold headings.
Paste	For annotation tables: Pastes previously copied coordinates and—optionally—snap directions to create new annotations in the table. For annotations of a nominal/actual comparison, the search distance specified on the **Settings** tab of the analysis will be considered. Note: Pasted annotations will be interpreted in the selected coordinate system at the time of pasting. The information in the clipboard must have the following structure: • x-, y-, and z-coordinate of the annotation or • x-, y-, and z-coordinate of the annotation as well as x-, y-, and z-component of the vector for the snap direction The parameters can be separated by space, tab, semicolon, or comma (if a comma is already used as a decimal mark or digit grouping symbol, the values must be enclosed in double quotation marks). Example: 8.89;25.82;-0.55;1;0;0 You can also copy the information directly from the cells of a spreadsheet. In order to paste the annotation information, you can also press the **Ctrl** + **V** keyboard shortcut.
Set as active column	If applicable: Makes the current column the active column, i.e., the results of this column are color-coded according to their values as defined by the color lookup table and the colors specified in the **Sections** section of the **Colors** tab.
Unset active column	If applicable: Deselects the currently active column and sets the **Active column** drop-down list on the corresponding **Settings** tab to **Uncoded**, i.e., removes any color coding.
Enter/change value (all items)	If applicable: Opens the **Enter value** dialog (see below) where you can enter the desired value for the selected parameter. This value will be applied to all entries in the table.

Control	Description
Enter/change value (selected items)	If applicable: Opens the **Enter value** dialog (see below) where you can enter the desired value for the selected parameter. This value will be applied to the selected entries in the table.
Delete selected items	If applicable: Removes the selected items from the scene.

The **Enter value** dialog includes the following controls:

Table 35-26: Controls in the **Enter value** dialog

Control	Description
Enter value field	Allows you to enter the desired value.
OK button	Sets the selected parameter to the specified value.
Reset button	For analyses only: Resets the selected parameter to undefined.
Set from tolerance settings button	For analyses only: Enters the value specified in the tolerance settings of the analysis for the selected parameter.
Cancel button	Discards the changes and closes the dialog.

References

[1] D Rückert et al.: Nonrigid registration using free-form deformations: application to breast MR images. IEEE transactions on medical imaging 18.8 (1999): 712-721.

[2] D Mattes et al.: PET-CT image registration in the chest using free-form deformations. IEEE transactions on medical imaging 22.1 (2003): 120-128.

[3] S Klein et al.: Adaptive stochastic gradient descent optimisation for image registration. International journal of computer vision 81.3 (2009): 227.

Gray Value Analysis

Introduction

The **Gray Value Analysis** is designed to examine the selected volume or ROI for its gray value distribution and density hot spots. If you want to perform fully automated analysis and evaluations, you can specify various tolerances in the **Tolerance settings** section of the **Settings** tab and use the **Automation** tool for recording the analysis steps in a macro file for further processing with **VGinLINE**, our software solution for automated in-line or at-line inspection and analysis.

License Information

This module is included in the scope of VGSTUDIO MAX. It is not available for myVGL. However, if a project loaded in myVGL contains an analysis, its results can be viewed and reported in myVGL.

If you are interested in a more comprehensive functionality than the one offered by myVGL, you have the chance to evaluate VGSTUDIO MAX. You can request an evaluation license of VGSTUDIO MAX on our website:

https://volumegraphics.hexagon.com/en/products/evaluation

For further questions about our product portfolio, please contact us:

- For Europe, Middle East, and Africa:
  Write an e-mail to sales@volumegraphics.com or call +49 6221 73920 744.
- For Japan:
  Write an e-mail to sales@volumegraphics.jp or call +81 52 508 9682.
- For the Americas:
  Write an e-mail to sales-us@volumegraphics.com or call +1 704 248 7736.
- For China, including Mainland China, Hong Kong, Macao, and Taiwan:
  Write an e-mail to sales@volumegraphics.cn or call +86 10 8532 6305.
- For Singapore and other parts of Asia (except China and Japan), Australia, and parts of Oceania:
  Write an e-mail to sales@volumegraphics.sg or call +65 6665 0310.

Opening the Dialog

In order to open the **Gray value analysis** dialog,

- right-click the corresponding entry in the Scene Tree and select **Properties** from the context menu or
- double-click the corresponding entry in the Scene Tree.

The **Gray value analysis** dialog consists of several tabs on which you can view the results of the gray value analysis.

To close the dialog, click the **Close** button at the bottom of the dialog.

A status bar at the bottom of the dialog indicates the current status of the analysis. The status can be one of the following:

Table 36-1: Messages in the status bar

Status	Description
Result is up to date	The current analysis result is valid.
Calculation required	All required parameters have been specified and are consistent, but the analysis was not calculated or was invalidated by some user action before the project was saved.
Object has no surface determination	No surface determination information is available for the selected object. See also section *Surface determination* on page 949 in chapter 48 *Glossary*.

An invalid or outdated status of an analysis is indicated in the Scene Tree by a warning sign. Double-click the analysis to open it and check the status bar for messages.

The units of the dialog are set according to the global unit settings (see section *Units Drop-down List* on page 33 in chapter 2 *Workspace*).

Settings Tab

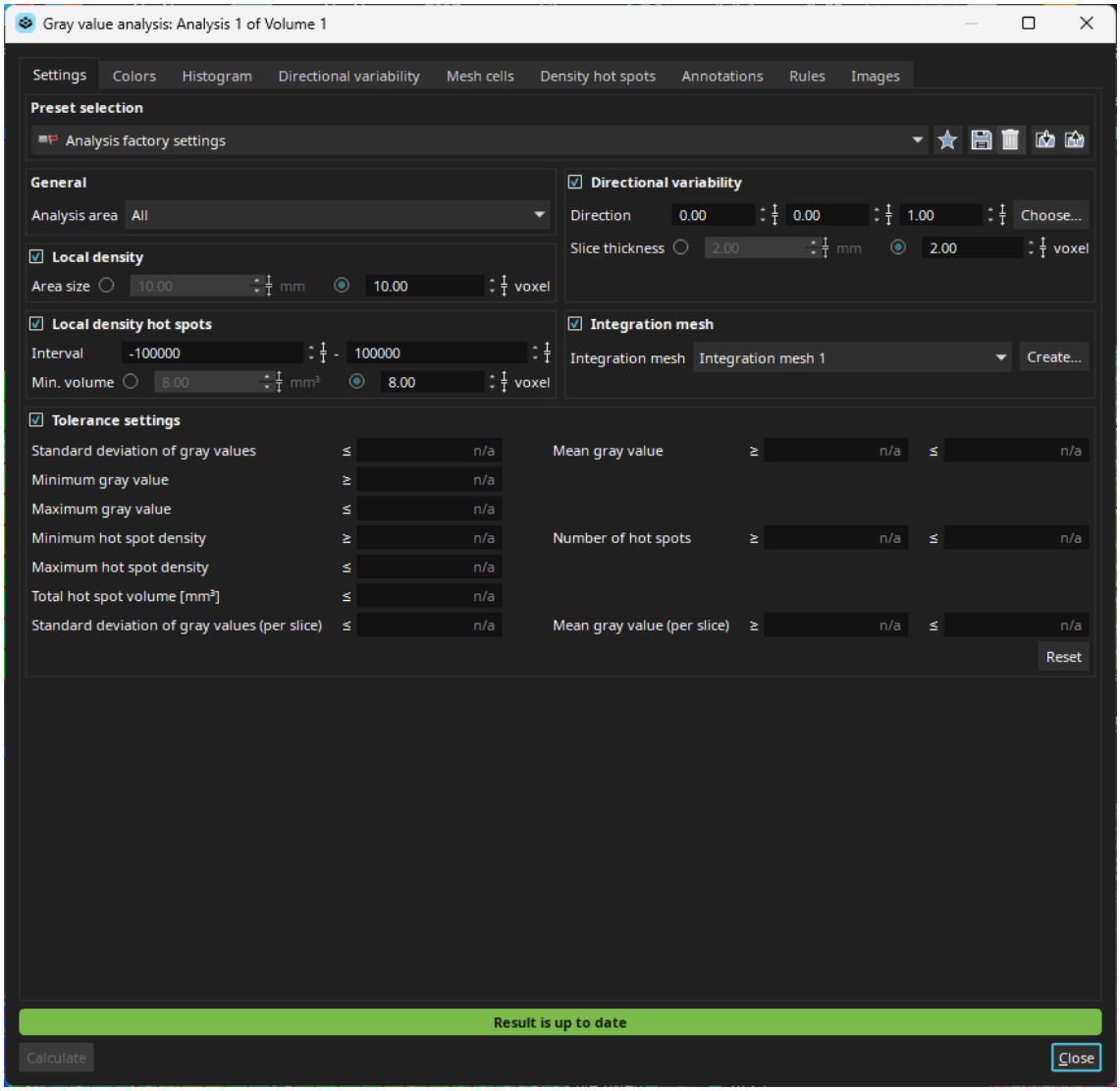


Figure 36-1: **Gray value analysis** dialog, **Settings** tab

In myVGL, all parameter settings are displayed. Most of these parameters are read-only in myVGL. The complete functional range is available with VGSTUDIO MAX and the respective add-on module(s).

Preset selection Section

Table 36-2: Controls in the **Preset selection** section

Icon	Item	Description
	drop-down list	Specifies the preset to be applied, to be edited, or to be taken as a basis for a new preset. The following icons are used: • analysis factory settings • customized preset • appears next to the icon of a preset that has been modified but not yet saved
	Set this preset as default	Sets the selected preset as default. The default preset will be applied when creating a new analysis of the same type. If the selected preset is already set as default, the button is disabled.
	Save preset	Saves the selected preset. When saving a preset, the **Save preset** dialog will open, which allows you to set the new preset as default by checking the **Set as default for new analyses** checkbox.
	Remove preset	Removes the selected preset from the preset drop-down list. If the removed preset is the default preset, the next time an analysis of the same type is created, the factory settings will be used.
	Import preset	Imports a preset from the specified location.
	Export preset	Exports the selected preset to the specified location.

General Section

Table 36-3: Controls in the **General** section

Control	Description
Analysis area drop-down list	• **All**: The analysis is performed on the material and on the background. • **Material**: The analysis is performed on the material. • **Background**: The analysis is performed on the background.

Performing the analysis on the material or on the background is only possible if a surface determination has been performed.

Local density Section

Table 36-4: Controls in the **Local density** section

Control	Description
Local density checkbox	When this option is checked, the mean gray value within the **Area size** will be calculated for each voxel.
Area size spin box	Specifies the standard deviation of a normal distribution in physical units (e.g., mm) or in voxels of the area considered for calculating the local density, starting from the center of each voxel. The resulting 3-dimensional normal distribution function will be used as a weight function for the calculation of local density.

Local density hot spots Section

Table 36-5: Controls in the **Local density hot spots** section

Control	Description
Local density hot spots checkbox	When this option is checked, the local density hot spots will be calculated. Local density hot spots can be used for identifying connected areas with similar gray values (within the specified interval).
Interval spin boxes	Specify the gray value interval for the local density hot spots. Only density hot spots within this interval are calculated and displayed on the **Density hot spots** tab.
Min. volume spin boxes	Specify the minimum size for a hot spot to be listed as a result, either as a volumetric dimension or as a number of voxels. Hot spots smaller than the specified minimum size will not be included in the results.

Tolerance settings Section

☞ Tolerance values will be interpreted according to DIN EN ISO 8015 (see also section *Rounding Rules* on page 4 in chapter 1 *Welcome*).

Table 36-6: Controls in the **Tolerance settings** section

Control	Description
Standard deviation of gray values <= field	Specifies the maximum permissible standard deviation of the gray values.

Control	Description
Mean gray value >=/<= field	Specifies a permissible range for the mean gray value. When you specify the upper limit only, the actual value will be within the tolerance (shown in green) if it is below the upper limit. When you specify the lower limit only, the actual value will be within the tolerance (shown in green) if it is above the lower limit.
Minimum gray value >= field	Specifies the minimum permissible gray value.
Maximum gray value <= field	Specifies the maximum permissible gray value.
Minimum hot spot density >= field	Specifies the minimum permissible local mean gray value of the detected hot spots.
Maximum hot spot density <= field	Specifies the maximum permissible local mean gray value of the detected hot spots.
Number of hot spots >=/<= field	Specifies a permissible range for the number of hot spots. When you specify the upper limit only, the actual value will be within the tolerance (shown in green) if it is below the upper limit. When you specify the lower limit only, the actual value will be within the tolerance (shown in green) if it is above the lower limit.
Total hot spot volume [<length unit>³] <= field	Specifies the maximum permissible sum of volumes of all hot spots.
Standard deviation of gray values (per slice) <= field	Specifies the maximum permissible standard deviation of the gray values per slice.
Mean gray value (per slice) >=/<= field	Specifies a permissible range for the mean gray value per slice. For this tolerance setting, the **Directional variability** function needs to be activated. When you specify the upper limit only, the actual value will be within the tolerance (shown in green) if it is below the upper limit. When you specify the lower limit only, the actual value will be within the tolerance (shown in green) if it is above the lower limit.
Reset button	Deletes all tolerance settings.

Depending on the results of this evaluation, the tolerances on the **Settings** tab will be highlighted in the following colors:

- Green: The tolerance is met for all components.
- Red: The tolerance is not met for one or more components.
- White (light theme)/black (dark theme): No tolerance settings have been specified, or they are deactivated.

- Yellow: A tolerance has been specified but the analysis has to be (re-)calculated. Note that this color will also be used if the entered tolerance value is invalid.

The result of the evaluation will also be displayed graphically in the Scene Tree. For more information on evaluations, see chapter 46 *Evaluations*.

Directional variability Section

Table 36-7: Controls of the **Directional variability** section

Control	Description
Directional variability checkbox	When this option is checked, the options for specifying a direction in which the analysis is to be performed will be enabled.
Direction fields	Specify the direction (in the currently selected coordinate system) in which the gray value distribution is to be analyzed. The specified vector is normalized to unit length before it is taken into account in the calculation. When you change the coordinate system, the specified vector will automatically be recalculated accordingly.
Choose... button	Opens a drop-down list showing the windows currently available in the workspace for specifying the direction in which the analysis is to be performed. The direction is the normal of the selected 2D window or the current direction of view of the 3D window.
Slice thickness spin boxes	Specify the thickness in physical units (e.g., mm) or in voxels of the individual slices to be analyzed.

Integration mesh Section

Allows you to create an integration mesh or select an existing integration mesh to obtain the results of the gray value analysis for each mesh cell.

Table 36-8: Controls of the **Integration mesh** section

Control	Description
Integration mesh checkbox	When this option is checked, the options for using an integration mesh will be enabled.
Integration mesh drop-down list	Allows you to specify an integration mesh by selecting an existing mesh from the drop-down list.
Create… button	Creates an integration mesh and opens the **Mesh** dialog for adjusting the parameters manually.

Colors Tab

Here you can specify the color-coding scheme used for representing the analysis results.

Caption Section

Table 36-9: Controls of the **Caption** section

Control	Description
Caption field	Indicates the color bar headline as specified in the **Caption** field of the **Color bar** section.
Share color bar checkbox	When this option is checked, all analyses of the same type (and—if applicable—of the same algorithm) will use the same color bar. When this option is unchecked, the color bar settings will apply to the selected analysis only.

LUT – Color Lookup Table

The color lookup table (LUT) shows the partitioning into color sections.

Sections Section

Defines the appearance of each color section.

Table 36-10: Controls in the **Sections** section

Control	Description
From/To fields	Specify the start and end values of the color sections. The first color section represents all values above the upper limit, i.e., the value in the **From** field (**+inf** signifies positive infinity), while the last color section represents all values below the lower limit, i.e., the value in the **To** field (**-inf** signifies negative infinity). The default limits are calculated from the results of the analysis (for an analysis color bar) or taken from the **Default** preset (for a tolerance deviation color bar).
Type field	Switches between the color schemes **Continue**, **Constant**, **Gradient**, **Rainbow**, **Reverse rainbow**, **Hue cycle**, **Green to red**, and **Red to green**.

Control	Description
Color/transparency field	Double-clicking the field for the **Continue**, **Constant**, and **Gradient** color schemes opens the **Select Color** dialog where you can modify the appearance of the selected color scheme. For the **Gradient** color scheme, you can specify the start and end colors by double-clicking the left or right side of the field, respectively. Double-clicking the field for the **Rainbow**, **Reverse rainbow**, **Hue cycle**, **Green to red**, and **Red to green** color schemes opens the **Transparency** dialog, where you can set the transparency for the selected color scheme.
use RMB to click a color section	Opens a context menu with the following items: • **Split**: Subdivides the color section into two new color sections where each represents half of the original section. • **Merge**: Combines several color sections to a single color section. Only consecutive intervals can be merged.
Create smooth button	Opens the **Create smooth table** dialog to generate one color section. • **Type** drop-down list: Allows you to select the type of coloring scheme. • **From/To** spin boxes: Specify the value range covered by the color section.
Create stepped button	Opens the **Create stepped table** dialog to generate a set of color sections. • **Type** drop-down list: Allows you to select the type of coloring scheme. • **From/To** spin boxes: Specify the value range covered by the color sections. • **Step** spin box: Specifies the step size of the individual color sections.
Auto scale button	If available: Fits the color LUT to the range of the results of all available analyses.
Auto scale color bar range on calculate checkbox	If available: When this option is checked, the color LUT will be automatically fitted to the range of the results of all available analyses.
Default button	If available: Resets any changes made to the **Sections** table.

Preset selection Section

Table 36-11: Controls in the **Preset selection** section

Icon	Item	Description
	drop-down list	Specifies the preset to be applied, to be edited, or to be taken as a basis for a new preset. The following icons are used: • default preset • customized preset • appears next to the icon of a preset that has been modified but not yet saved
	Save preset	Opens the **Save preset** dialog for saving the color LUT of the current data set under the specified name. • **Absolute preset**: When this option is checked and the preset applied, the settings of the original data set, including the LUT range, will be applied. When this option is unchecked, the color settings of the preset will be mapped relatively to the actual range of results of the analysis to which the preset will be applied.
	Remove preset	Removes the selected preset from the preset drop-down list.
	Import preset	Imports a preset from the specified location.
	Export preset	Exports the selected preset to the specified location.

Color LUT Settings Section

Specifies the appearance of the color lookup table.

Table 36-12: Options for the appearance of the color lookup table

Control	Description
Auto tick marks checkbox	When this option is checked, equidistant tick marks will be produced for the color bars. When this option is unchecked, tick marks will appear only at the color section boundaries of the color lookup table.
Auto scale color bar range on calculate checkbox	When this option is checked, the color LUT will be automatically fitted to the range of the results of all available analyses.

Color bar Section

Specifies the settings for the color bar.

Table 36-13: Settings for the color bar

Control	Description
Visibility drop-down list	Switches the color bar on/off.
Positioning drop-down list	Specifies the location of the color bar within the 2D and 3D windows: **Left, Right, Top, Bottom, All - automatic, Left or right - automatic, Top or bottom - automatic**.
Caption field	Specifies the color bar headline by using placeholders.
Reset button	Resets the **Caption** field to the default entry.

Annotations Section

The **Color mode** drop-down list specifies the color of the annotation:

- **Tolerance status**: Colors the annotations according to the tolerance status at this position.
- **As lookup table**: Colors the annotations according to their values (e.g., indication volume, deviation, wall thickness) at this position.

Histogram Tab

Shows the gray value distribution in the selected object (number of voxels versus the gray values). The histogram bars are colored according to the settings on the **Colors** tab.

Controls of the **Histogram** Tab

- **Options** section

  Table 36-14: Controls of the **Histogram** tab, **Options** section

Control	Description
Color drop-down list	• **From color bar**: The values in the histogram are shown according to the color bar. • **Gray**: All values in the histogram are shown in gray.
Ordinate scaling drop-down list	• **Linear**: Applies a linear scale to the y-axis of the histogram. • **Logarithmic**: Applies a logarithmic scale to the y-axis of the histogram.

Control	Description
Binning drop-down list	• **Off**: No binning is applied to the values shown in the histogram. • **From color bar**: The original values in the histogram are replaced by a value representative for the corresponding interval ("bin") of the color bar. The "bins" become visible when creating "stepped" sections on the **Colors** tab. • **Manual number of bins**: Enables the **Bin count** spin box, where you can enter the required number of "bins." • **Manual bin width**: Enables the **Bin width** spin box, where you can specify the width of the bins.

- **Intervals** section

Table 36-15: Controls of the **Histogram** tab, **Intervals** section

Control	Description
Left/**Right** spin box	Only enabled when an interval has been created: Moves the left or right interval border to the specified value. You can also click and drag the interval borders by using the left mouse button.
Create button	Creates a new interval. On the right hand side of a selected interval, statistical information is displayed: • **Left**: Indicates the minimum gray value within the interval, i.e., the left interval border. • **Right**: Indicates the maximum gray value within the interval, i.e., the right interval border. • **Mean**: Indicates the mean gray value within the interval. • **Dev**: Indicates the standard deviation of the gray values within the interval. • **Sum**: Indicates the number of voxels within the interval. • **Percentage**: Indicates the percentage of voxels with gray values within the interval. Note that the statistical information may change with the number of bins.
Remove button	Removes the selected interval.

- **Statistics** section

Table 36-16: Controls of the **Histogram** tab, **Statistics** section

Control	Description
Minimum gray value field	Indicates the minimum gray value within the analyzed area.
Maximum gray value field	Indicates the maximum gray value within the analyzed area.
Mean gray value field	Indicates the mean gray value within the analyzed area.
Standard deviation of gray values field	Indicates the standard deviation of the gray values within the analyzed area.

- General controls

Table 36-17: General controls of the **Histogram** tab

Control	Description
use RMB to click the chart area	Displays a context menu (see below).
scroll MW in chart area or x-axis up/down	Zooms the x-axis of the chart out/in.
scroll MW in y-axis up/down	Zooms the y-axis of the chart out/in.
use LMB to click and drag the x-axis	Scrolls the x-axis.
use LMB to click and drag the y-axis	Scrolls the y-axis.
Zoom in/out	Zooms the corresponding axis in/out.
Reset zoom	Fits the entire chart to the current window size.

Context Menu of the **Histogram** Tab

Right-clicking anywhere in the chart area shows a context menu with the following options:

Table 36-18: Context menu items

Control	Description
Export as CSV...	Opens a dialog for saving the chart values to a *.csv* file.
Copy to clipboard	Copies a screenshot of the chart to the system clipboard so you can paste it into another application.
Hide/Show x/y grid	Toggles the visibility of the grid lines for the corresponding axis.
Reset zoom	Fits the entire chart to the current window size.
Create interval	Creates a new interval. For details on the statistical information, see section *Controls of the Histogram Tab* on page 629.

Control	Description
Remove interval	Removes the selected interval.

Directional variability Tab

Shows how the gray value distribution changes with respect to the direction specified in the **Directional variability** section on the **Settings** tab.

Controls of the **Directional variability** Tab

- Chart area

  Table 36-19: Controls of the **Directional variability** tab, chart area

Control	Description
Mean gray value	When this curve is selected, the mean gray value per slice will be displayed. The light gray area around the curve indicates the standard deviation of the gray values.
Minimum gray value	When this curve is selected, the minimum gray value in the specified direction will be displayed.
Maximum gray value	When this curve is selected, the maximum gray value in the specified direction will be displayed.
use LMB to click an option of the list	Toggles the visibility of the corresponding curve.
hover the mouse pointer over the curve	Displays the legend of the function along with its values at the specified location and highlights the curve of the selected function.
use LMB to click and drag the vertical line in the histogram	Indicates the function values at the specified location and updates the slice views accordingly. Hold down the **Ctrl** key while left-clicking in the chart area to display the vertical line in case you dragged it out of the chart area.
use RMB to click the chart area	Displays a context menu (see below).
scroll MW in chart area or x-axis up/down	Zooms the x-axis of the chart out/in.
scroll MW in y-axis up/down	Zooms the y-axis of the chart out/in.
use LMB to click and drag the x-axis	Scrolls the x-axis.
use LMB to click and drag the y-axis	Scrolls the y-axis.

Control	Description
Zoom in/out	Zooms the corresponding axis in/out.
Reset zoom	Fits the entire chart to the current window size.

- **Statistics** section

Table 36-20: Controls of the **Directional variability** tab, **Statistics** section

Control	Description
Minimum gray value field	Indicates the range of minimum gray values in the analyzed direction.
Maximum gray value field	Indicates the range of maximum gray values in the analyzed direction.
Mean gray value field	Indicates the range of mean gray values in the analyzed direction.
Standard deviation of gray values field	Indicates the range of the standard deviations of the gray values in the analyzed direction.

Context Menu of the **Directional variability** Tab

Right-clicking anywhere in the chart area shows a context menu with the following options:

Table 36-21: Context menu items

Control	Description
Export as CSV...	Opens a dialog for saving the chart values to a *.csv* file.
Copy to clipboard	Copies a screenshot of the chart to the system clipboard so you can paste it into another application.
Show/Hide x/y grid	Toggles the visibility of the grid lines for the corresponding axis.
Reset zoom	Fits the entire chart to the current window size.
Show/Hide legend	Displays or hides the legend for the plotted curves.

Mesh cells Tab

Displays the results of the gray value analysis for each cell of the integration mesh.

The **Mesh cells** tab is available only if an integration mesh has been specified in the **Integration mesh** section on the **Settings** tab.

You can export the results from the **Mesh cells** tab and use them to compare real part properties with simulations of manufacturing processes or to improve FE simulations for testing the stability of different parts (e.g., injection-molded parts).

Table 36-22: Columns of the **Mesh cells** list

Column	Description
Element ID	If available, indicates the ID of the mesh cell for imported integration mesh files.
Pos. x/y/z [<length unit>]	Indicates the x-, y-, and z-position of the mesh cell.
Mean gray value	Indicates the mean gray value within the mesh cell.
Standard deviation of gray values	Indicates the standard deviation of the gray values within the mesh cell.
Description	Allows you to enter a description for the cell used for reporting.
Image	Allows you to add a detailed 2D image and object description on a separate page of the report. • **Off**: No image is created (default). • **Orthographic projection**: Creates three orthogonal views. • **Top/Bottom/Left/Right/Front/Back**: Creates a single 2D view in the specified orientation. The image orientation is relative to the currently selected coordinate system. The image will be generated according to the render settings specified during report creation or VGRF-based export. The 2D slice position used for taking the image is determined by the position of the cell. The zoom factor of the image is chosen so that the entire parent volume is visible.
Focused image	This option is almost identical to the **Image** option but will generate an image that focuses on the respective item and is zoomed in by the **Zoom factor** specified during report creation or VGRF-based export.
Captures	Indicates the number of images captured for this cell by using the **Capture from** button in the **Screenshots** section.

Density hot spots Tab

Displays the density hot spots detected by the gray value analysis.

The **Density hot spots** tab will only be available if the **Local density hot spots** option has been checked on the **Settings** tab.

Table 36-23: Columns of the **Density hot spots** list

Column	Description
Position x/y/z [<length unit>]	Indicates the x-, y-, and z-position of the hot spot.
Volume [<length unit>³]	Indicates the volume of the hot spot.
Surface [<length unit>²]	Indicates the surface area of the hot spot.
Mean	Indicates the mean density value of the hot spot.
Deviation	Indicates the standard deviation of the density of the hot spot.
Minimum hot spot density	Indicates the minimum local mean gray value of the detected hot spots.
Maximum hot spot density	Indicates the maximum local mean gray value of the detected hot spots.
Voxel count	Indicates the number of voxels the hot spot consists of.
Sphericity	Indicates the ratio between the surface of a sphere with the same volume as the density hot spot and the surface of the density hot spot. $\text{Sphericity} = \frac{A_{\text{sphere}}}{A_{\text{density hot spot}}}$
Compactness	Indicates the ratio between the volume of the density hot spot and the volume of the circumscribed sphere. $\text{Compactness} = \frac{V_{\text{density hot spot}}}{V_{\text{sphere}}}$
Description	Allows you to enter a description for the hot spot used for reporting.

Column	Description
Image	Allows you to add a detailed 2D image and object description on a separate page of the report. • **Off**: No image is created (default). • **Orthographic projection**: Creates three orthogonal views. • **Top/Bottom/Left/Right/Front/Back**: Creates a single 2D view in the specified orientation. The orientation of the image will be relative to the currently selected coordinate system. The image will be generated according to the render settings specified during report creation or VGRF-based export. The 2D slice position used for taking the image is determined by the position of the cell. The zoom factor of the image is chosen so that the entire parent volume is visible.
Focused image	This option is almost identical to the **Image** option but will generate an image that focuses on the respective item and is zoomed in by the **Zoom factor** specified during report creation or VGRF-based export.
Captures	Indicates the number of images captured for this hot spot by using the **Capture from** button in the **Screen-shots** section.
Tolerance status	Indicates the tolerance status of the hot spots according to the tolerances specified for the hot spot density in the **Tolerance settings** section of the **Settings** tab: **Valid** (green), **Out of tolerance** (red), or **No tolerance** (gray).

Annotations Tab

Lists all annotations created for the selected gray value analysis. You can view the information supplied by the annotations or edit the annotation properties.

For details on how to create an annotation, see section *Annotation* on page 124 in chapter 6 *Inspect Tab*.

To create new annotations in the table, it is also possible to paste previously copied coordinates by right-clicking the table and selecting **Paste** from the context menu or by pressing the **Ctrl** + **V** keyboard shortcut. For details, see the **Paste** menu item in section *Table Context Menu*.

Double-clicking an analysis annotation in the Scene Tree will directly open the **Annotations** tab of the properties dialog of the corresponding analysis.

Tolerance values will be interpreted according to DIN EN ISO 8015 (see also section *Rounding Rules* on page 4 in chapter 1 *Welcome*).

The **Annotations** table consists of the following columns:

Table 36-24: Columns of the **Annotations** table

Column	Description
Name	Indicates the name of the annotation.
Pos. x/y/z [<length unit>]	Indicates the position of the annotation.
Gray value	Indicates the gray value of the analyzed data set at the current annotation position. The gray value is interpolated in all three directions regardless of whether the **Interpolation mode** in the 2D windows is switched on or off.
Min. gray value	Allows you to specify the minimum value for tolerancing the gray value at the current annotation position. Double-click the cell to edit it.
Max. gray value	Allows you to specify the maximum value for tolerancing the gray value at the current annotation position via double-click. Double-click the cell to edit it.
Local density	Indicates the local density at the current annotation position.
Min. local density	Allows you to specify the minimum value for tolerancing the local density at the current annotation position. Double-click the cell to edit it.
Max. local density	Allows you to specify the maximum value for tolerancing the local density at the current annotation position. Double-click the cell to edit it.
Description	Allows you to enter a description of the annotation used for reporting.

Column	Description
Image	Allows you to add a detailed 2D image and object description on a separate page of the report. • **Off**: No image is created (default). • **Orthographic projection**: Creates three orthogonal views. • **Top/Bottom/Left/Right/Front/Back**: Creates a single 2D view in the specified orientation. • **... - If not OK**: Automatically creates the image if the tolerance status is **Out of tolerance**. The orientation of the image will correspond to the currently selected coordinate system. The image will be generated according to the render settings specified during report creation or VGRF-based export. The 2D slice position used for taking the image is determined by the position of the annotation. The zoom factor of the image is chosen so that the entire parent volume is visible.
Focused image	This option is almost identical to the **Image** option but will generate an image that focuses on the respective item and is zoomed in by the **Zoom factor** specified during report creation or VGRF-based export.
Captures	Indicates the number of images captured for this annotation using the **Capture from** button in the **Screenshots** section.
Tolerance status	Indicates the tolerance status at the position of the annotation if an individual tolerance has been specified in the **Min./Max. gray value** and/or **Min./Max. local density** fields of the **Annotations** table: **Valid** (green), **Out of tolerance** (red), or **No tolerance** (gray).
Type	Indicates how the annotation has been created: • **Rule based**: The annotation has been created by a report rule. • **Manually defined**: The annotation has been defined by the user.

General Table Controls

- List section

  The following table provides an overview of the general controls available in the various list views:

Table 36-25: Controls in the list section

Control	Description
button	Opens a submenu for selecting the filter/search mode.
Filter	Clicking the **Click to add a filter or search criterion** field to the right of the icon opens a series of drop-down lists from which you can select a table column, an operator, and—depending on the column—a value. If a column does not offer a value drop-down list, you can type in a value. When the selection is complete, the table shows the rows matching the filter criterion. Clicking the **+** button or the **Click to add a filter or search criterion** field allows you to specify more filter criteria. Clicking the **x** button removes the filter.
Search	Clicking the **Click to add a filter or search criterion** field to the right of the icon opens a series of drop-down lists from which you can select a table column, an operator, and—depending on the column—a value. If a column does not offer a value drop-down list, you can type in a value. When the selection is complete, the table rows matching the search criterion are highlighted. Clicking the **+** button or the **Click to add a filter or search criterion** field allows you to specify more search criteria. Pressing **F3** jumps to the next search result in the list. Clicking the **x** button removes the search.
Full-text filter	Entering a value or text string into the input field to the right of the icon filters the table accordingly and shows the rows that match the filter criterion.
Full-text search	Entering a value or text string into the input field to the right of the icon searches the table accordingly and highlights the rows that match the search criterion.
use LMB to click on a table row	Selects the row and the corresponding object in the Scene Tree. In analysis result lists, the result, e.g., the component, is marked by a cross-hairs cursor in each of the 2D views.
hold **Ctrl** key + use LMB to click on several table rows	Selects the rows and the corresponding objects in the Scene Tree.

Control	Description
hold **Shift** key + use LMB to click on two separate table rows	Selects the two rows, including all rows between the two as well as the corresponding objects in the Scene Tree.
hold **Shift** key + use up/down arrow keys	Selects the rows and the corresponding objects in the Scene Tree.
press **Ctrl+A**	Selects all table rows.
use up and down arrow keys	Steps up and down through the table rows.
use RMB to click into the table area	Displays a context menu. See below.
use LMB to click a column heading	Sorts the table according to the values of the column. Clicking subsequently toggles between ascending and descending.
use LMB to click and drag column heading to new position, then release LMB	Inserts the column at the new position.
use LMB to double-click cell highlighted in white (light theme) or medium gray (dark theme)	If applicable: Allows you to edit the contents of the cell.

- **Screenshots** section (if available)

  The **Screenshots** section below the list section allows you to capture images from one of the 2D windows, the 3D window, or the current window layout for the item currently selected in the table. Only available if exactly one row is selected.

  Table 36-26: Controls in the **Screenshots** section

Control	Description
Capture from button	Adds the image of the view selected from the drop-down list to the preview area above.
use LMB to click and drag one or more images, then release LMB	Moves the image(s) to the new position.
double-click the image	Opens the **Snapshot display** window showing the image: • **Zoom in**/**Zoom out** button: Zooms the image in/out. You can also move the mouse pointer in the image area and turn the mouse wheel. • **Fit to window** button: Resets the zoom so that the image fits into the window.
click the **<no description>** placeholder twice (first click to select, second click to enable renaming)	Allows you to label the image.

Control	Description
Delete selected button	Deletes the selected image from the preview area.

Table Context Menu

Right-clicking anywhere in the table area shows a context menu with the following options:

Table 36-27: Context menu items

Control	Description
Columns	Allows you to toggle the visibility of each column by checking/unchecking the respective item. • **Show all**: Checks all columns to set them to visible. • **Hide all**: Unchecks all columns to set them to invisible. • **Hide empty**: Unchecks all not editable columns which are empty or **n/a** to set them to invisible.
Trim columns	Resizes all columns to their smallest possible size.
Apply default column layout	Applies the default column layout previously saved by the user to the current table. If no default column layout has been saved, the original column layout will be applied.
Save as default column layout	Saves modifications applied to the table—e.g., the visibility of a column, the order in which the columns appear, the column width—as default column layout. This layout will be applied when you create a new project.
Apply original column layout	Restores the original table layout and discards any modifications applied by the user. The original table layout is predefined and cannot be modified by the user.
Remove entries	If applicable: Deletes the selected row(s) from the table.
Create annotations	If applicable: Creates annotations for the selected items.
Export as CSV...	Opens the **Export as CSV...** dialog for exporting the table values as **.csv* file. This option always exports the complete table even if a filter was applied. In order to export only the filtered rows, press **Ctrl** + **A** to highlight all filtered rows and use the **Copy to clipboard** menu item.

Control	Description
Copy to clipboard	Copies the selected rows as well as the column heading into the system clipboard. The clipboard information is provided both as plain text and rich-text table, so when pasting into a rich-text-capable application like a word processor, you will see a proper table with cell borders and bold headings.
Paste	For annotation tables: Pastes previously copied coordinates and—optionally—snap directions to create new annotations in the table. For annotations of a nominal/actual comparison, the search distance specified on the **Settings** tab of the analysis will be considered. Note: Pasted annotations will be interpreted in the selected coordinate system at the time of pasting. The information in the clipboard must have the following structure: • x-, y-, and z-coordinate of the annotation or • x-, y-, and z-coordinate of the annotation as well as x-, y-, and z-component of the vector for the snap direction The parameters can be separated by space, tab, semicolon, or comma (if a comma is already used as a decimal mark or digit grouping symbol, the values must be enclosed in double quotation marks). Example: 8.89;25.82;-0.55;1;0;0 You can also copy the information directly from the cells of a spreadsheet. In order to paste the annotation information, you can also press the **Ctrl** + **V** keyboard shortcut.
Set as active column	If applicable: Makes the current column the active column, i.e., the results of this column are color-coded according to their values as defined by the color lookup table and the colors specified in the **Sections** section of the **Colors** tab.
Unset active column	If applicable: Deselects the currently active column and sets the **Active column** drop-down list on the corresponding **Settings** tab to **Uncoded**, i.e., removes any color coding.
Enter/change value (all items)	If applicable: Opens the **Enter value** dialog (see below) where you can enter the desired value for the selected parameter. This value will be applied to all entries in the table.

Control	Description
Enter/change value (selected items)	If applicable: Opens the **Enter value** dialog (see below) where you can enter the desired value for the selected parameter. This value will be applied to the selected entries in the table.
Delete selected items	If applicable: Removes the selected items from the scene.

The **Enter value** dialog includes the following controls:

Table 36-28: Controls in the **Enter value** dialog

Control	Description
Enter value field	Allows you to enter the desired value.
OK button	Sets the selected parameter to the specified value.
Reset button	For analyses only: Resets the selected parameter to undefined.
Set from tolerance settings button	For analyses only: Enters the value specified in the tolerance settings of the analysis for the selected parameter.
Cancel button	Discards the changes and closes the dialog.

Rules Tab

Shows existing rules for selecting features (e.g., probability, radius) with defined properties to be included in the final report. Apart from that, the **Rule** dialog allows you to create new rules and edit or delete existing rules.

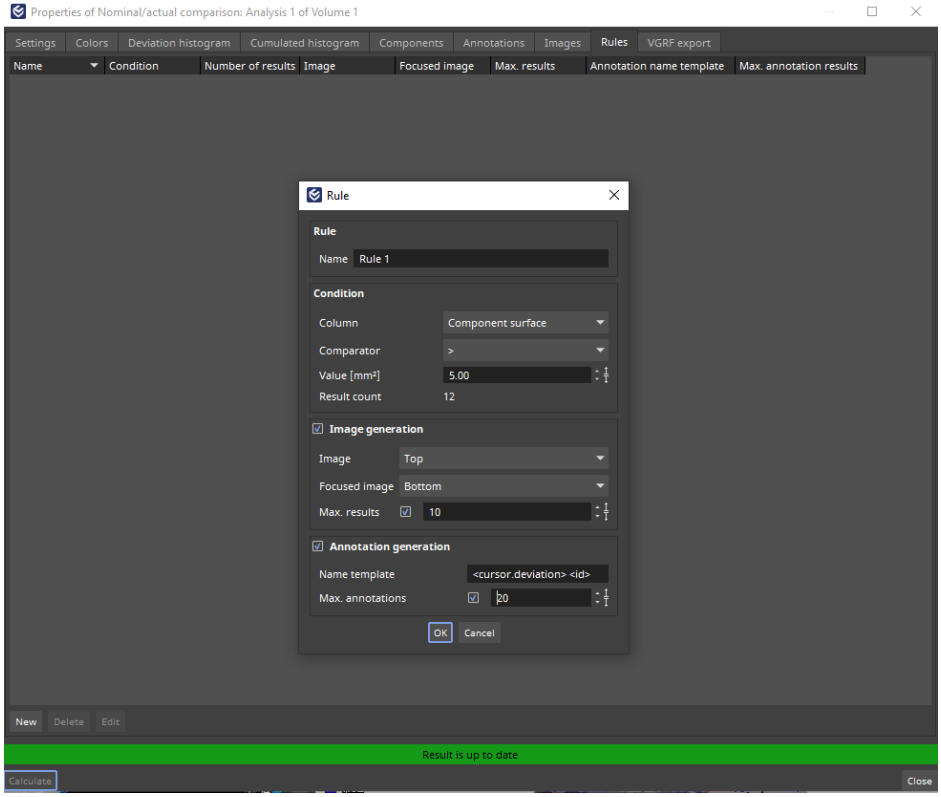


Figure 36-2: **Rules** tab with **Rule** dialog

- **New** button
  Opens the **Rule** dialog for creating a new rule.
- **Delete** button
  Deletes a selected rule.
- **Edit** button
  Opens the **Rule** dialog for editing a selected rule.

You can also double-click a rule to open the **Rule** dialog for editing a selected rule.

Rule Dialog

- **Rule** section
  The **Name** field allows you to enter a name for the new rule. This name has to be unique.
- **Condition** section

  Table 36-29: Controls in the **Condition** section

Control	Description
Column drop-down list	Selects the property of the feature (e.g., probability, radius, diameter) that defines the rule.

Control	Description
Comparator drop-down list	Specifies the comparator to be applied to the selected property.
Value [<unit>] spin box or drop-down list	Specifies the reference value or status of the selected property for comparison.
Result count field	Indicates the number of results that meet the specified condition.

- **Image generation** section

Table 36-30: Controls in the **Image generation** section

Control	Description
Image drop-down list	Allows you to add a detailed 2D image and object description on a separate page of the report. • **Off**: No image is created (default). • **Orthographic projection**: Creates three orthogonal views. • **Top/Bottom/Left/Right/Front/Back**: Creates a single 2D view in the specified orientation. • If applicable: **... - If not OK**: Automatically creates the image if the tolerance status is **Out of tolerance**.
Focused image drop-down list	This option is almost identical to the **Image** option, but will generate an image that focuses on the respective item and is zoomed in by the **Zoom factor** specified during report creation or VGRF-based export.
Max. results checkbox and spin box	When this option is checked, you will be able to use the corresponding spin box to specify the maximum number of results to be included in the report.

- **Annotation generation** section

Table 36-31: Controls in the **Annotation generation** section

Control	Description
Name template field	Allows you to enter a name for the annotations. If this is not done, a name of the form <*annotation type*> <*id*> will automatically be generated.
Max. annotations checkbox and spin box	When this option is checked, you will be able to use the corresponding spin box to specify the maximum number of annotations to be generated.

In contrast to manually created annotations, rule-based annotations can neither be moved nor deleted. This is indicated by a closed padlock symbol next to the annotation name in the annotation label.

Rule-based annotations that are based on components are created at the position of the component that fulfills the condition. For wall thickness analyses performed with the **Sphere method** algorithm and nominal/actual comparisons, the position of the component is always the spatial center (or—if the spatial center lies outside the component—a position within the component that is closest to the spatial center), while for wall thickness analyses performed with the **Ray method** algorithm, the position is defined by the **Position property** option on the **Settings** tab of the properties dialog.

- **OK** button

  Closes the dialog, adds the new rule to the list in the **Rules** tab and updates the annotations.
- **Cancel** button

  Discards the settings and closes the dialog.

Images Tab

Allows you to take screenshots of the selected workspace views and/or add bookmark references to the report. In the final report, the captured images will be listed separately from the screenshots created on other tabs.

- **Snapshots** section

  Table 36-32: Controls in the **Snapshots** section

Control	Description
Capture from button	Adds the image of the view selected from the drop-down list to the preview area above.
Delete selected button	Deletes the selected image(s) from the preview area.
use LMB to click and drag one or more images, then release LMB	Moves the image(s) to the new position.
double-click the image	Opens the **Snapshot display** window showing the image: • **Zoom in**/**Zoom out** button: Zooms the image in/out. You can also move the mouse pointer on the image area and turn the mouse wheel. • **Fit to window** button: Resets the zoom so that the image fits into the window.
click the **<no description>** placeholder twice (first click to select, second click to enable renaming)	Allows you to label the image.

- **Automatic 3D images** section (if available)

  Check the corresponding checkbox to include the desired 3D view (e.g., **Top**, **Front**, **Top-left-front**, and **Current camera settings**) in the report without changing the 3D view.
- **Bookmark references** section

Allows you to add bookmark references via drag and drop from the **Bookmarks and views** tool or the **Bookmark editor** to the preview area. The images of the referenced bookmarks will then be included in VGRF-based reports.

When you open a project with missing bookmark images, placeholders will be shown instead.

Bookmark references are stored in evaluations and can be used in automation scenarios.

You will still need to import a bookmark template containing the actual bookmarks in these cases, as evaluations store only references to them.

Table 36-33: Controls in the **Bookmark references** section

Control	Description
New bookmark button	Adds a bookmark of the current view to the preview area.
Remove button	Removes the bookmark currently selected in the preview area.
click the bookmark title twice (first click to select, second click to enable renaming) or press the **F2** key	Allows you to rename the bookmark. The changes made on the **Images** tab will also affect the **Bookmark editor** and the **Bookmarks and views** tool. If the renamed bookmark is referenced by one or more objects for reporting, a warning message will be displayed indicating that the referenced bookmark will also be renamed for all these objects in the report.

The global concept of bookmark references allows for multiple objects to reference the same bookmark and for objects to reference bookmarks that show arbitrary information, e.g., other analyses or objects.

Data Quality Analysis

Introduction

The **Data Quality Analysis** function allows you to analyze the CT image of a uniform disk of material to determine the spatial resolution and contrast sensitivity of X-ray images according to the ASTM standard E 1695 - 20 (or the deprecated version E 1695 - 95 (2006)): “Standard Test Method for Measurement of Computed Tomography (CT) System Performance”.[1]

The *spatial resolution* of an image is derived from the image analysis of the sharpness at the edge of the disk and is quantified in terms of the modulation transfer function (MTF), which describes by which factor the contrast is reduced by the unsharpness of the CT system. The MTF is determined through a number of steps: First, to determine how a CT system resolves a sharp edge, the edge response function (ERF) is found by plotting the average gray value over its radial distance to a circle representing the surface. The derivative of the ERF is then calculated to obtain the point spread function (PSF). Finally, the amplitude of the Fourier transform of the PSF is calculated, and the results are normalized to unity at zero frequency to obtain the MTF.

The *contrast sensitivity* of an image is derived from the image analysis of the statistical noise at the center of the disk and is quantified in terms of the contrast discrimination function (CDF), which is a curve that describes the detectability of a feature of size D* in voxels as well as the minimum contrast in a field of noise. The CDF is determined through a number of steps: From the CT image data, a sequence of tile patterns that fit in the central region of the disk is generated. For each pattern, the mean CT value is calculated in each tile and the result is stored in a table specific to that pattern. For each table of results, the standard deviation is calculated to obtain the standard error in the mean, and the result is stored in a separate table in order of ascending tile size.

Each standard error in the mean is expressed as a percentage of its respective ensemble average. In the deprecated version ASTM E 1695 - 95 (2006), it is multiplied by a factor of 3 to obtain the CDF. This factor is no longer included in the updated standard version ASTM E 1695 − 20.

While the CDF determines the detectability of a feature while neglecting unsharpness, the MTF almost exclusively deals with the unsharpness of a feature. Both can thus be combined in the *contrast-detail diagram* (CDD), which combines perceived and physical contrast to provide the overall capability of the CT system to resolve and discriminate features under given evaluation conditions. The expected CDF and CDD are described by the ASTM standard E 1441 “Standard Guide for Computed Tomography (CT).”[2]

License Information

This module is included in the scope of VGSTUDIO MAX and VGSTUDIO. It is not available for myVGL. However, if a project loaded in myVGL contains an analysis, its results can be viewed and reported in myVGL.

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1 Based on the edition approved on December 1, 2006.
2 Based on the edition approved on July 1, 2019.

If you are interested in a more comprehensive functionality than the one offered by myVGL, you have the chance to evaluate VGSTUDIO MAX. You can request an evaluation license of VGSTUDIO MAX on our website:

https://volumegraphics.hexagon.com/en/products/evaluation

For further questions about our product portfolio, please contact us:

- For Europe, Middle East, and Africa:
  Write an e-mail to sales@volumegraphics.com or call +49 6221 73920 744.
- For Japan:
  Write an e-mail to sales@volumegraphics.jp or call +81 52 508 9682.
- For the Americas:
  Write an e-mail to sales-us@volumegraphics.com or call +1 704 248 7736.
- For China, including Mainland China, Hong Kong, Macao, and Taiwan:
  Write an e-mail to sales@volumegraphics.cn or call +86 10 8532 6305.
- For Singapore and other parts of Asia (except China and Japan), Australia, and parts of Oceania:
  Write an e-mail to sales@volumegraphics.sg or call +65 6665 0310.

Opening the Dialog

In order to open the **Data quality analysis (ASTM E 1441/ASTM E 1695)** dialog,

- right-click the corresponding entry in the Scene Tree and select **Properties** from the context menu or
- double-click the corresponding entry in the Scene Tree.

The **Data quality analysis (ASTM E 1441/ASTM E 1695)** dialog consists of several tabs on which you can view the results of the data quality analysis.

To close the dialog, click the **Close** button at the bottom of the dialog.

A status bar at the bottom of the dialog indicates the current status of the analysis. The status can be one of the following:

Table 37-1: Messages in the status bar

Status	Description
Result is up to date	The current analysis result is valid.
Calculation required	All required parameters have been specified and are consistent, but the analysis was not calculated or was invalidated by some user action before the project was saved.
Object has no surface determination	The **Use surface determination to compute center of mass** option has been checked, but no surface determination information is available for the selected object. See also section *Surface determination* on page 949 in chapter 48 *Glossary*.
Evaluation area exceeds slice image	The evaluation area, which is defined by the disk radius and the search distance, lies outside the slice image.

Status	Description
Disk radius too small for given search distance	The disk radius must be larger than the search distance.
Bin size too small	The value in the **Bin size** field must be larger than zero.
Search distance too small	The value in the **Search distance** field must be larger than zero.
Fit point count will be rounded to next odd value	The value entered in the **Fit point count** field is an even value, but an odd value is required; the value will be automatically rounded up to an odd value.
The voxels are not isotropic, the default values might not be reliable	The voxels in this data set are not isotropic. Although a computation is possible, the results may not be reliable.

An invalid or outdated status of an analysis is indicated in the Scene Tree by a warning sign. Double-click this analysis to open it and check the status bar for messages.

The units of the dialog are set according to the global unit settings (see section *Units Drop-down List* on page 33 in chapter 2 *Workspace*).

Settings Tab

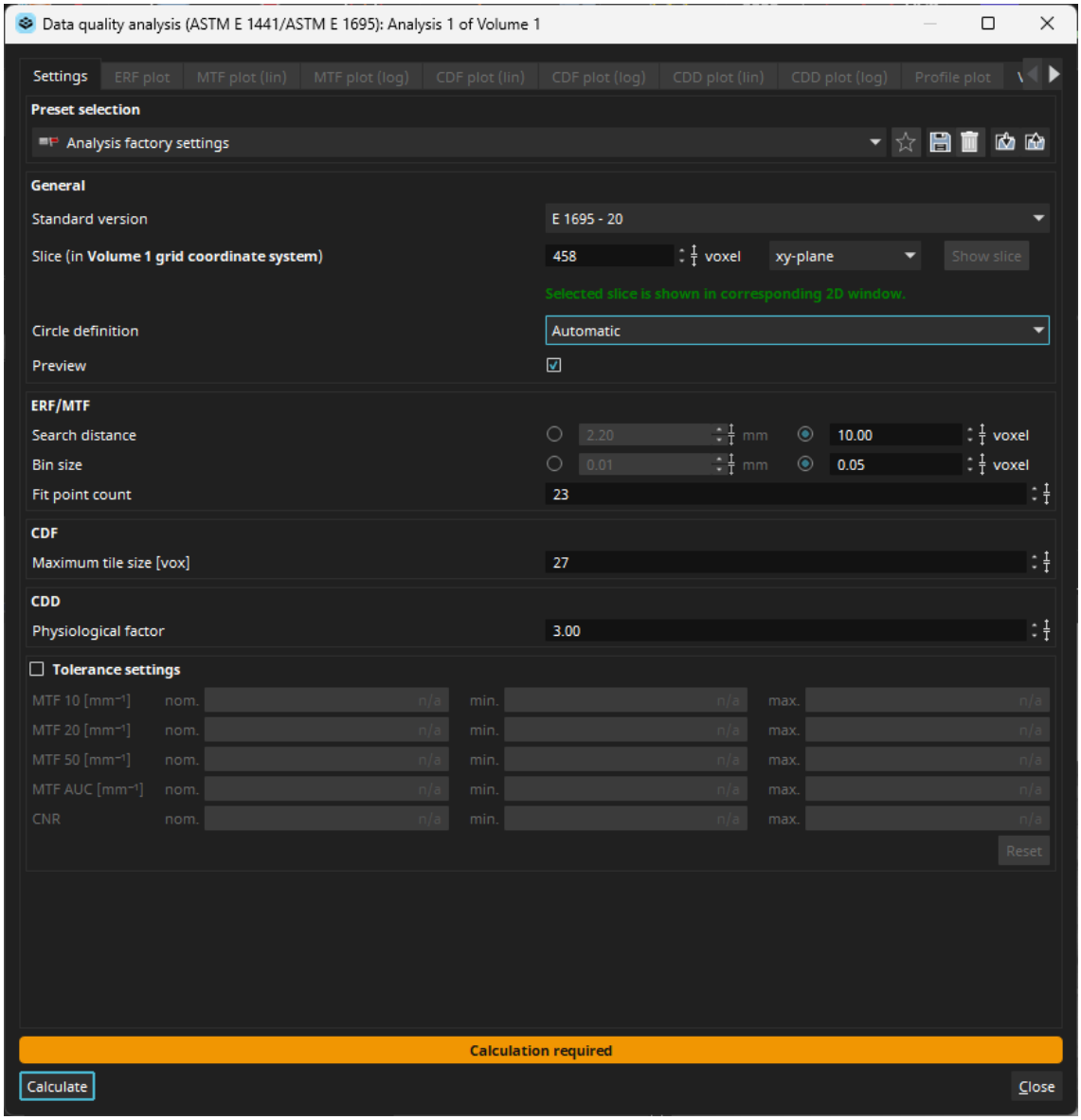


Figure 37-1: **Data quality analysis** dialog, **Settings** tab

In myVGL, all parameter settings are displayed. Most of these parameters are read-only in myVGL. The complete functional range is available in VGSTUDIO MAX.

Preset selection Section

Table 37-2: Controls in the **Preset selection** section

Icon	Item	Description
	drop-down list	Specifies the preset to be applied, to be edited, or to be taken as a basis for a new preset. The following icons are used: • analysis factory settings • customized preset • appears next to the icon of a preset that has been modified but not yet saved
	Set this preset as default	Sets the selected preset as default. The default preset will be applied when creating a new analysis of the same type. If the selected preset is already set as default, the button is disabled.
	Save preset	Saves the selected preset. When saving a preset, the **Save preset** dialog will open, which allows you to set the new preset as default by checking the **Set as default for new analyses** checkbox.
	Remove preset	Removes the selected preset from the preset drop-down list. If the removed preset is the default preset, the next time an analysis of the same type is created, the factory settings will be used.
	Import preset	Imports a preset from the specified location.
	Export preset	Exports the selected preset to the specified location.

General Section

Table 37-3: Controls in the **General** section

Control	Description
Standard version drop-down list	Specifies the version of the standard according to which the analysis is performed.
Slice spin box and drop-down list	Specify the slice position of the disk to be analyzed and the suitable plane in the volume grid coordinate system of the volume object.
Show slice button	Shows the specified slice in the corresponding 2D window.
Disk radius spin box	Specifies the radius of the disk.

Control	Description
Use surface determination to compute center of mass checkbox	When this option is checked, the surface determination will be used to calculate the center of mass of the disk. When this option is unchecked, the center of mass will be calculated from the gray values of the complete 2D slice. Note that in this case, the calculation of the center of mass may be affected by artifacts.
Circle definition drop-down list	Available for standard version **E 1695 - 20**: Specifies how the radius is determined: • **Automatic**: The radius of the disk is calculated automatically. In this mode, the center of mass will always be determined using the surface determination. • **Fixed radius**: Allows you to specify the radius of the disk manually.
Preview checkbox	This option is checked by default and shows a preview of the areas to be analyzed: • Green circle: edge of the disk, specified by the disk radius, used for determining the spatial resolution • Red circles: inner and outer radii, specified by the search distance, used for determining the spatial resolution • Blue center area: central region of the disk for the tile pattern, used for determining the contrast sensitivity

ERF/MTF Section

The following parameters are available for determining the spatial resolution in terms of the modulation transfer function (MTF):

Table 37-4: Controls in the **ERF/MTF** section

Control	Description
Search distance spin box	Specifies the search distance in both directions from the edge.
Bin size spin box	Specifies the bin size for the segregation of the gray values. The size of the bins should be a small fraction of one voxel and be chosen so that no bins are empty. For a suitable bin size value, refer to the ASTM E 1695 standard.
Fit point count spin box	Specifies the number of points to be included in the least-squares cubic fit. The higher the fit point count, the smoother the curve of the MTF (modulation transfer function). For a suitable fit point count value, refer to the ASTM E 1695 standard.

CDF Section

The following parameter is available for determining the contrast sensitivity in terms of the contrast discrimination function (CDF):

Table 37-5: Controls in the **CDF** section

Control	Description
Maximum tile size [vox] spin box	Specifies the maximum size of the tiles in the central region around the center of mass of the disk (indicated in blue in the preview). For a suitable maximum tile size value, refer to the ASTM E 1695 standard.

CDD Section

The following parameter is available for determining the expected contrast that can be detected by human beings for a feature of a given size in a CT scan.

Table 37-6: Controls in the **CDD** section

Control	Description
Physiological factor spin box	Specifies the factor for detection based on human observation for a 50% probability of detection.

Tolerance settings Section

Tolerance values will be interpreted according to DIN EN ISO 8015 (see also section *Rounding Rules* on page 4 in chapter 1 *Welcome*).

Table 37-7: Controls in the **Tolerance settings** section

Control	Description
Tolerance settings checkbox	Checking this option allows you to define and apply the corresponding tolerance settings to the modulation transfer function (MTF) and/or contrast-to-noise ratio (CNR).
MTF 10 [mm^{-1}] nom./min./max. fields	Specify a nominal value and the tolerance range for the frequency at 10% contrast modulation.
MTF 20 [mm^{-1}] nom./min./max. fields	Specify a nominal value and the tolerance range for the frequency at 20% contrast modulation.
MTF 50 [mm^{-1}] nom./min./max. fields	Specify a nominal value and the tolerance range for the frequency at 50% contrast modulation.

Control	Description
MTF AUC [mm^{-1}] nom./min./max. fields	Specify a nominal value and the tolerance range for the frequency for the area under curve (AUC). A larger area under the MTF curve value indicates better image quality but should not be the only measure for the quality characteristics of the scan.
CNR nom./min./max. fields	Specify a nominal value and the tolerance range for the contrast-to-noise ratio.
Reset button	Deletes all tolerance settings.

Depending on the results of this evaluation, the tolerances on the **Settings** tab will be highlighted in the following colors:

- Green: The tolerance is met for all components.
- Red: The tolerance is not met for one or more components.
- White (light theme)/black (dark theme): No tolerance settings have been specified, or they are deactivated.
- Yellow: A tolerance has been specified but the analysis has to be (re-)calculated. Note that this color will also be used if the entered tolerance value is invalid.

The result of the evaluation is also displayed graphically in the Scene Tree. For more information on evaluations, see chapter 46 *Evaluations*.

ERF plot Tab

Shows the edge response function (ERF), i.e., the normalized gray values of the voxels within the search area versus their distance to the edge of the disk (represented by the position 0.0 mm). Apart from that, the point spread function (PSF), which is the derivative of the ERF, is shown.

For a description of the controls available in the chart area, see section *Controls of the Plot Tab(s)* on page 657. For a description of the context menu, which can be opened by right-clicking the chart area, see section *Context Menu of the Plot Tab(s)* on page 657.

MTF plot (lin) and MTF plot (log) Tabs

The **MTF plot (lin)** and **MTF plot (log)** tabs show the modulation transfer function (MTF), i.e., the contrast versus the spatial frequency, in linear or logarithmic scaling of the y-axis, respectively.

For a description of the controls available in the chart area, see section *Controls of the Plot Tab(s)* on page 657. For a description of the context menu, which can be opened by right-clicking the chart area, see section *Context Menu of the Plot Tab(s)* on page 657.

Apart from that, the following information is provided at the bottom of the **MTF plot (lin)** and **MTF plot (log)** tabs:

Table 37-8: Fields of the **MTF plot (lin)** and **MTF plot (log)** tabs

Field	Description
MTF 10 [mm^{-1}] field	Indicates the frequency at 10% contrast modulation.
MTF 20 [mm^{-1}] field	Indicates the frequency at 20% contrast modulation.
MTF 50 [mm^{-1}] field	Indicates the frequency at 50% contrast modulation.
MTF AUC [mm^{-1}] field	Indicates the frequency for the area under curve (AUC). A larger area under the MTF curve value indicates better image quality but should not be the only measure for the quality characteristics of the scan.
CNR field	Indicates the contrast-to-noise ratio.

CDF plot (lin) and CDF plot (log) Tabs

The **CDF plot (lin)** and **CDF plot (log)** tabs show the contrast discrimination function (CDF), i.e., the standard error in the central region around the center of mass of the disk, in linear or logarithmic scaling of the x- and y-axis, respectively.

For a description of the controls available in the chart area, see section *Controls of the Plot Tab(s)* on page 657. For a description of the context menu, which can be opened by right-clicking the chart area, see section *Context Menu of the Plot Tab(s)* on page 657.

CDD plot (lin) and CDD plot (log) Tabs

The **CDD plot (lin)** and **CDD plot (log)** tabs show the contrast-detail diagram (CDD), which combines perceived and physical contrast to determine the overall capability of the CT system to resolve and discriminate features under given evaluation conditions. More specifically, they show the expected contrast of a feature of size D* in voxels that can be detected in a CT scan by human observers in linear or logarithmic scaling of the x- and y-axis. The CDD is characterized by the MTF, the CDF, and the physiological factor c, which is a physiology-based constant that generally falls between 2 and 5.

The CDD is calculated according to the following formula:

$$CDD\ (D^*) = c\ \frac{CDF\ (D^*)}{MTF\ \left(\frac{1}{2D^*}\right)}$$

For a description of the controls available in the chart area, see section *Controls of the Plot Tab(s)* on page 657. For a description of the context menu, which can be opened by right-clicking the chart area, see section *Context Menu of the Plot Tab(s)* on page 657.

The physiological factor specified on the **Settings** tab is indicated at the bottom of the **CDD plot (lin)** and **CDD plot (log)** tabs.

Profile plot Tab

The **Profile plot** tab shows the profiles of the normalized gray values of the voxels in the x- and y-directions versus their distance to the center of mass.

For a description of the controls available in the chart area, see section *Controls of the Plot Tab(s)* on page 657. For a description of the context menu, which can be opened by right-clicking the chart area, see section *Context Menu of the Plot Tab(s)* on page 657.

Controls of the Plot Tab(s)

The following controls are available for the plot tab(s):

Table 37-9: Controls of the **Plot** tab

Control	Description
use LMB to click an option of the list	Toggles the visibility of the corresponding curve.
hover the mouse pointer over one of the curves	Displays the legend of the selected function together with its values at the specified location and highlights the curve of the selected function.
use LMB to click and drag the vertical line in the histogram	Indicates the function values at the specified location. Hold down the **Ctrl** key while left-clicking in the chart area to display the vertical line in case you dragged it out of the chart area.
use RMB to click the chart area	Displays a context menu, see below.
scroll MW in chart area or x-axis up/down	Zooms the x-axis of the chart out/in.
scroll MW in y-axis up/down	Zooms the y-axis of the chart out/in.
use LMB to click and drag the x-axis	Scrolls the x-axis.
use LMB to click and drag the y-axis	Scrolls the y-axis.
Zoom in/out	Zooms the corresponding axis in/out.
Reset zoom	Fits the entire chart to the current window size.

Context Menu of the Plot Tab(s)

Right-clicking anywhere in the chart area shows a context menu with the following options:

Table 37-10: Context menu items

Control	Description
Export as CSV...	Opens a dialog for saving the chart values to a *.csv* file.

Control	Description
Copy to clipboard	Copies a screenshot of the chart to the system clipboard so you can paste it into another application.
Show/Hide x/y grid	Toggles the visibility of the grid lines for the corresponding axis.
Reset zoom	Fits the entire chart to the current window size.
Show/Hide legend	Displays/hides the legend for the plotted curves.

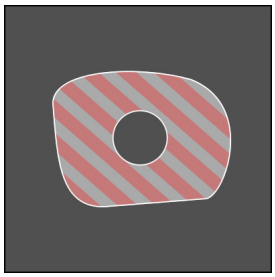
Slice Area Analysis

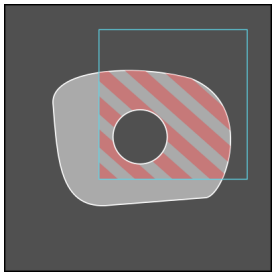
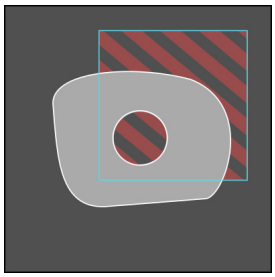
Introduction

The **Slice Area Analysis** has been designed to calculate the area of a volume or an ROI or the area enclosed by the surface determination in a slice.

There are the following scenarios:

Table 38-1: Areas calculated with the slice area analysis

Scenario	Calculated area
The analysis is run on the volume.	The area of the entire volume slice will be calculated: This can be useful if you want to calculate the area of an extracted ROI.
The analysis is run on the volume, and the option **Intersect with surface and measure** is checked.	**Material area**: The area enclosed by the surface determination will be calculated:  **Background area**: The background area of the volume slice will be calculated:

Scenario	Calculated area
The analysis is run on an ROI.	The area of the ROI in the specified slice will be calculated:
The analysis is run on an ROI, and the option **Intersect with surface and measure** is checked.	**Material area**: The area enclosed by the surface determination in the ROI in the specified slice will be calculated:  **Background area**: The background area inside the ROI will be calculated: 

The slice specified for the analysis will be indicated permanently by means of a magenta plane in all views that are not parallel to the specified slice. In the 2D windows, the dashed part of this plane indicates the area that will be/has been calculated:

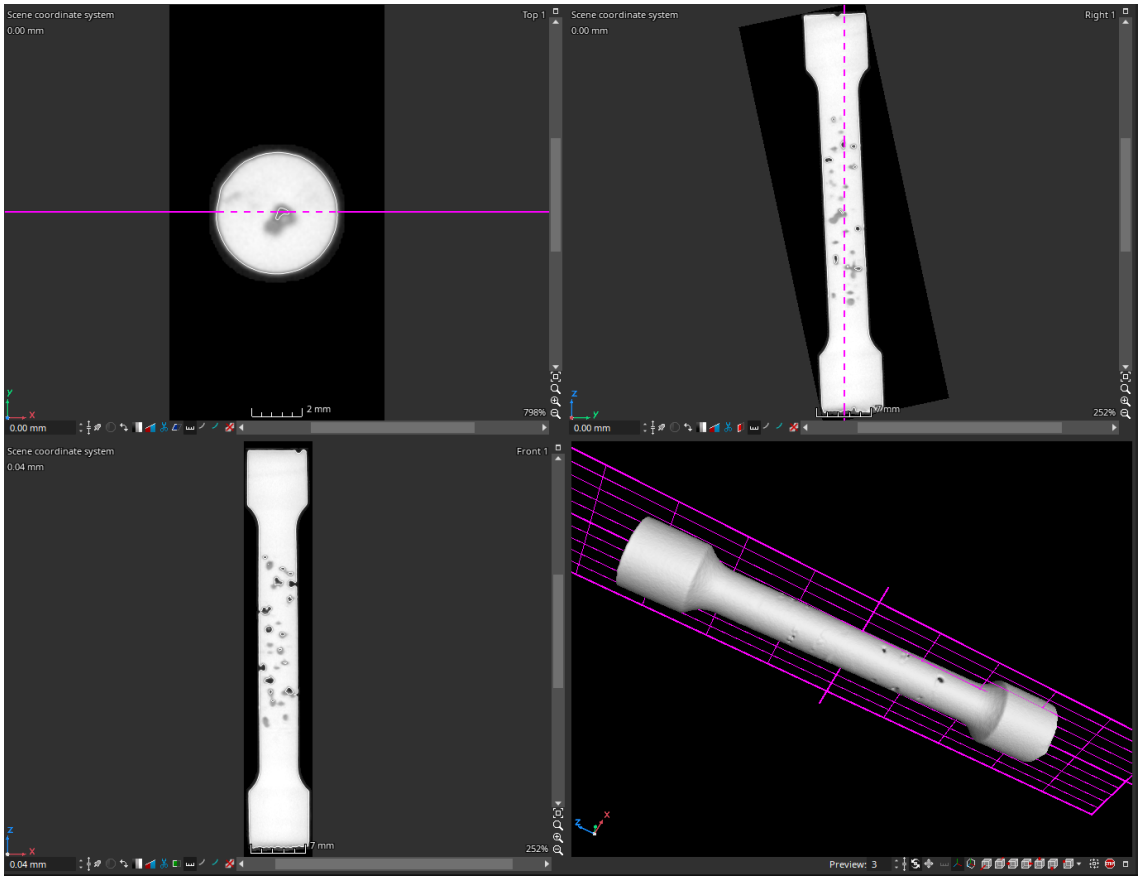


Figure 38-1: Dashed line indicating calculated area

A preview shows the area that will be calculated:

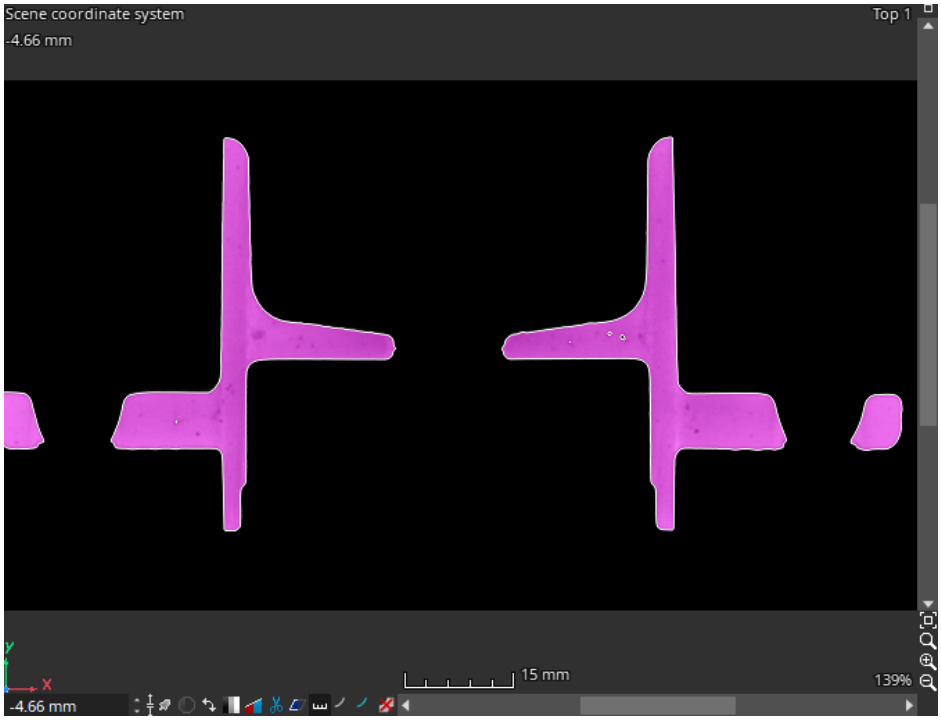


Figure 38-2: Preview of the area to be calculated

License Information

This module is included in the scope of VGSTUDIO MAX. It is not available for myVGL. However, if a project loaded in myVGL contains an analysis, its results can be viewed and reported in myVGL.

If you are interested in a more comprehensive functionality than the one offered by myVGL, you have the chance to evaluate VGSTUDIO MAX. You can request an evaluation license of VGSTUDIO MAX on our website:

https://volumegraphics.hexagon.com/en/products/evaluation

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  Write an e-mail to sales@volumegraphics.jp or call +81 52 508 9682.
- For the Americas:

  Write an e-mail to sales-us@volumegraphics.com or call +1 704 248 7736.
- For China, including Mainland China, Hong Kong, Macao, and Taiwan:

  Write an e-mail to sales@volumegraphics.cn or call +86 10 8532 6305.
- For Singapore and other parts of Asia (except China and Japan), Australia, and parts of Oceania:

  Write an e-mail to sales@volumegraphics.sg or call +65 6665 0310.

Opening the Dialog

In order to open the **Slice area analysis** dialog,

- right-click the corresponding entry in the Scene Tree and select **Properties** from the context menu or
- double-click the corresponding entry in the Scene Tree.

The **Slice area analysis** dialog consists of several tabs on which you can view the results of the gray value analysis.

To close the dialog, click the **Close** button at the bottom of the dialog.

A status bar at the bottom of the dialog indicates the current status of the analysis. The status can be one of the following:

Table 38-2: Messages in the status bar

Status	Description
Result is up to date	The current analysis result is valid.
Calculation required	All required parameters have been specified and are consistent, but the analysis was not calculated or was invalidated by some user action before the project was saved.
Object has no surface determination	No surface determination information is available for the selected object. See also section *Surface determination* on page 949 in chapter 48 *Glossary*.
Specify a plane	No plane has been specified in the **Settings** section of the **Slice area** tab. To perform the slice area analysis, specify a plane.

☞ An invalid or outdated status of an analysis is indicated in the Scene Tree by a warning sign. Double-click the analysis to open it and check the status bar for messages.

☞ The units of the dialog are set according to the global unit settings (see section *Units Drop-down List* on page 33 in chapter 2 *Workspace*).

Slice area Tab

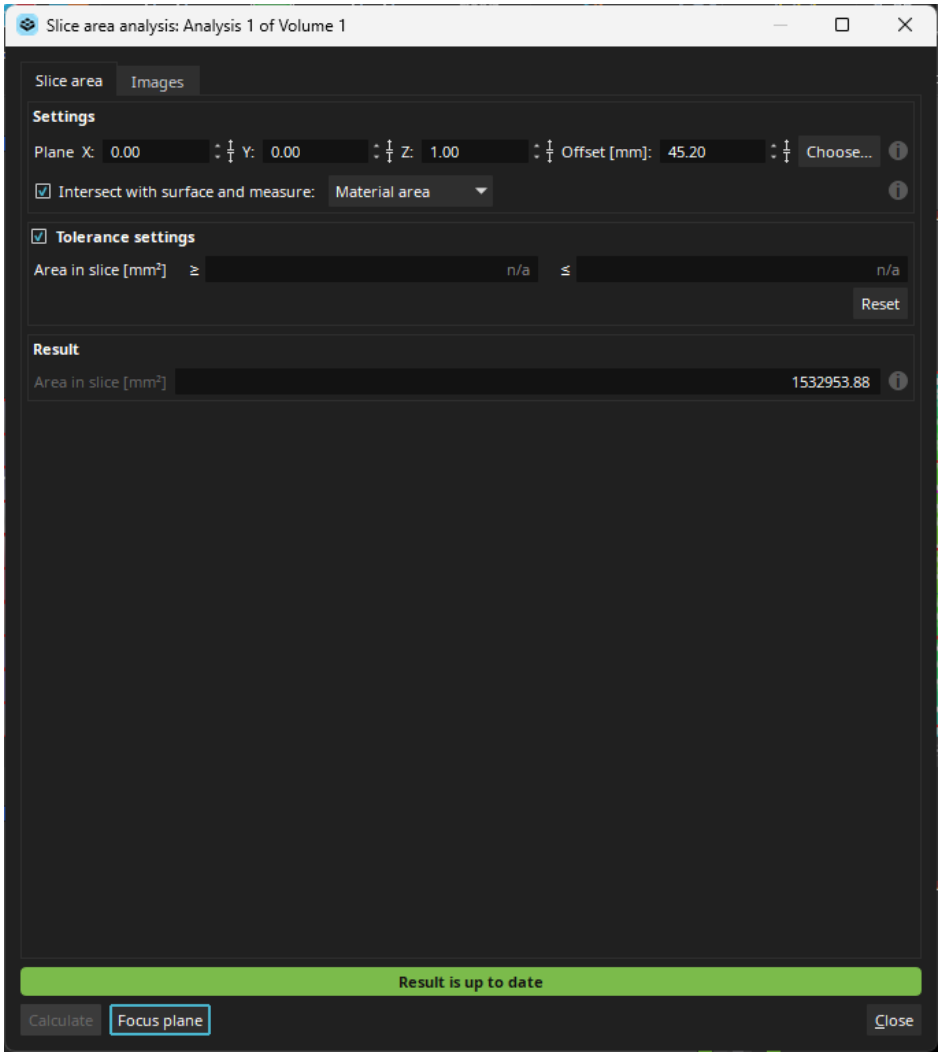

Figure 38-3: **Slice area analysis** dialog, **Slice area** tab

In myVGL, all parameter settings are displayed. Most of these parameters are read-only in myVGL. The complete functional range is available with VGSTUDIO MAX.

Settings Section

In the **Settings** section, you can select the slice to be analyzed by scrolling to the desired slice in a 2D window and selecting the respective 2D view by clicking the **Choose** button. Apart from that, you can also specify the plane by entering an arbitrary normal vector.

Table 38-3: Controls in the **Settings** section

Control	Description
Plane X/Y/Z fields	Specify the normal of the plane in which the slice area analysis will be calculated. The specified vector is normalized to unit length before it is taken into account in the calculation.
Offset [<length unit>] spin box	Specifies the distance of the plane to be analyzed to the origin of the currently selected coordinate system.
Choose button	Opens a drop-down list that shows the 2D windows currently available in the workspace for specifying the plane to be analyzed.
Intersect with surface and measure checkbox	Intersects the area of the volume or ROI with the area enclosed by the surface determination. • **Material area**: Calculates the material within the ROI • **Background area**: Calculates the background within the ROI

Tolerance settings Section

Table 38-4: Controls in the **Tolerance settings** section

Control	Description
Tolerance settings checkbox	Checking this option allows you to define and apply the corresponding tolerance settings.
Area in slice fields	Specify the tolerance range.
Reset button	Deletes all tolerance settings.

Depending on the results of this evaluation, the tolerances on the **Settings** tab will be highlighted in the following colors:

- Green: The tolerance is met for all components.
- Red: The tolerance is not met for one or more components.
- White (light theme)/black (dark theme): No tolerance settings have been specified, or they are deactivated.
- Yellow: A tolerance has been specified but the analysis has to be (re-)calculated. Note that this color will also be used if the entered tolerance value is invalid.

The result of the evaluation is also displayed graphically in the Scene Tree. For more information on evaluations, see chapter 46 *Evaluations*.

Result Section

Table 38-5: Controls in the **Result** section

Control	Description
Area in slice field	Displays the resulting area.

Images Tab

Allows you to take screenshots of the selected workspace views and/or add bookmark references to the report. In the final report, the captured images will be listed separately from the screenshots created on other tabs.

- **Snapshots** section

  Table 38-6: Controls in the **Snapshots** section

Control	Description
Capture from button	Adds the image of the view selected from the drop-down list to the preview area above.
Delete selected button	Deletes the selected image(s) from the preview area.
use LMB to click and drag one or more images, then release LMB	Moves the image(s) to the new position.
double-click the image	Opens the **Snapshot display** window showing the image: • **Zoom in**/**Zoom out** button: Zooms the image in/out. You can also move the mouse pointer on the image area and turn the mouse wheel. • **Fit to window** button: Resets the zoom so that the image fits into the window.
click the **<no description>** placeholder twice (first click to select, second click to enable renaming)	Allows you to label the image.

- **Automatic 3D images** section (if available)

  Check the corresponding checkbox to include the desired 3D view (e.g., **Top**, **Front**, **Top-left-front**, and **Current camera settings**) in the report without changing the 3D view.

- **Bookmark references** section

  Allows you to add bookmark references via drag and drop from the **Bookmarks and views** tool or the **Bookmark editor** to the preview area. The images of the referenced bookmarks will then be included in VGRF-based reports.

  When you open a project with missing bookmark images, placeholders will be shown instead.

  Bookmark references are stored in evaluations and can be used in automation scenarios.

You will still need to import a bookmark template containing the actual bookmarks in these cases, as evaluations store only references to them.

Table 38-7: Controls in the **Bookmark references** section

Control	Description
New bookmark button	Adds a bookmark of the current view to the preview area.
Remove button	Removes the bookmark currently selected in the preview area.
click the bookmark title twice (first click to select, second click to enable renaming) or press the **F2** key	Allows you to rename the bookmark. The changes made on the **Images** tab will also affect the **Bookmark editor** and the **Bookmarks and views** tool. If the renamed bookmark is referenced by one or more objects for reporting, a warning message will be displayed indicating that the referenced bookmark will also be renamed for all these objects in the report.

The global concept of bookmark references allows for multiple objects to reference the same bookmark and for objects to reference bookmarks that show arbitrary information, e.g., other analyses or objects.

OCR Analysis

Introduction

OCR analysis (OCR = optical character recognition) allows you to transfer textual information from the CT scan, mesh, or scan object of a part to the metainformation in the object properties. This is especially useful for selecting inputs that should be processed differently when using VGinLINE, our software solution for automated in-line or at-line inspection and analysis.

Performing an OCR analysis is currently supported for Microsoft Windows operating systems only.

License Information

This module is included in the scope of VGSTUDIO MAX. It is not available for myVGL. However, if a project loaded in myVGL contains an analysis, its results can be viewed and reported in myVGL.

If you are interested in a more comprehensive functionality than the one offered by myVGL, you have the chance to evaluate VGSTUDIO MAX. You can request an evaluation license of VGSTUDIO MAX on our website:

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- For Singapore and other parts of Asia (except China and Japan), Australia, and parts of Oceania:
  Write an e-mail to sales@volumegraphics.sg or call +65 6665 0310.

Opening the Dialog

In order to open the **OCR analysis** dialog,

- right-click the corresponding entry in the Scene Tree and select **Properties** from the context menu or
- double-click the corresponding entry in the Scene Tree.

To close the dialog, click the **Close** button at the bottom of the dialog.

A status bar at the bottom of the dialog indicates the current status of the analysis. The status can be one of the following:

Table 39-1: Messages in the status bar

Status	Description
Calculation required	All required parameters have been specified and are consistent, but the analysis was not calculated or was invalidated by some user action before the project was saved.
Result is up to date	The current analysis result is valid.
No ROI selected	Select at least one ROI from the **Text region** drop-down lists.

An invalid or outdated status of an analysis is indicated in the Scene Tree by a warning sign. Double-click the analysis to open it and check the status bar for messages.

OCR analysis Dialog

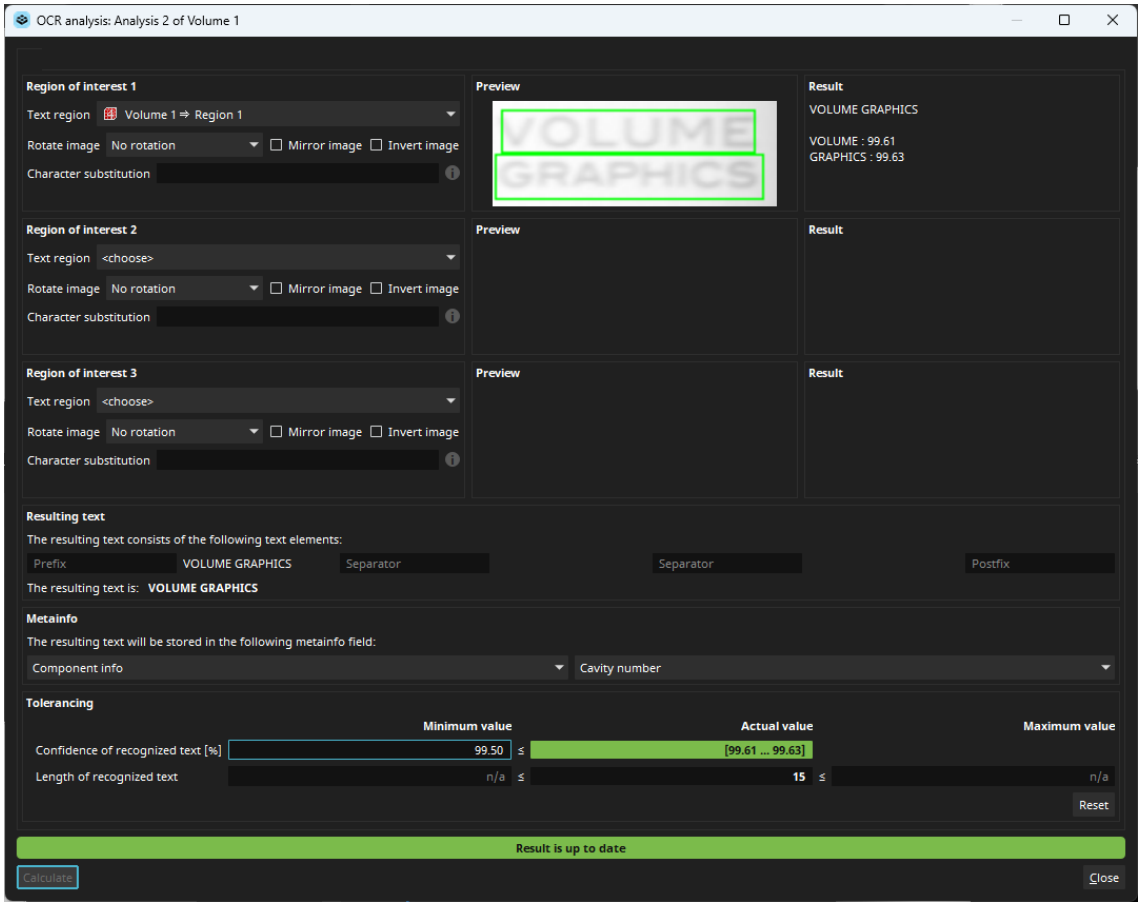


Figure 39-1: **OCR analysis** dialog

In myVGL, all parameter settings are displayed. Most of these parameters are read-only in myVGL. The complete functional range is available with VGSTUDIO MAX.

Region of interest 1/2/3 Sections

Table 39-2: Controls of the **Region of interest 1/2/3** sections

Control	Description
Text region drop-down list	Specifies the previously created ROI that encompasses the text to be recognized. Note that the ROI should be as thin as possible to obtain reliable results.
Rotate image drop-down list	Allows the image to be rotated by 90, 180, or 270 degrees.
Mirror image checkbox	Check this option to mirror the image if the text is mirror-inverted.
Invert image checkbox	Check this option to invert the image, i.e., gray values interpreted as black will be displayed in white and vice versa.

Character substitution field	Allows you to replace and overwrite characters recognized by the OCR. The expression has to have the following syntax:
	a:b>c
	• **a**: Defines the position(s) of the character(s) to be replaced. Can be an integer or the character "*".
	  • Integer: Refers to the position of a character in the recognized text. The position begins with 1.
	  • *: Refers to all characters in the recognized text.
	• **b**: Defines the character to be replaced by c.
	• **c**: Defines the character that replaces b.
	Multiple character substitution expressions can be concatenated using comma ",". They will be executed from left to right and will not overwrite characters that have already been replaced.
	Example:
	• Recognized text: "**Jerro**"
	• Expression: "**1:J>H,*:r>l**"
	• Result: "**Hello**"

To obtain reliable results, the textual information to be recognized must not be distorted but aligned in a readable manner.

Preview Sections

Display an image of the region(s) of interest selected from the **Text region** drop-down list(s). The recognized text will be surrounded by a green frame.

Result Sections

Show the recognized text with a numerical value between 0 and 100 that indicates the confidence, i.e., the degree to which the textual information has been recognized correctly.

Resulting text Section

Four customizable text fields allow you to add a prefix, separators, and a postfix to the recognized text. The resulting text will be stored in the metainformation of the object.

Metainfo Section

The drop-down lists in the **Metainfo** section allow you to select the tab and the tag where the analysis result is to be displayed in the **Object properties** dialog of the object.

Tolerancing Section

Table 39-3: Controls of the **Tolerancing** section

Control	Description
Confidence of recognized text [<ratio unit>] <= fields	Indicate the recognized text confidence and allow you to specify the minimum permissible text confidence. The recognized text confidence will be highlighted in green or red according to its tolerance state.
Length of recognized text <= fields	Indicate the recognized text length and allow you to specify the minimum and maximum permissible text length. The recognized text length will be highlighted according to its tolerance state: • Green: The specified tolerance range is met. • Yellow: The specified tolerance range is invalid. • Red: The specified tolerance range is not met.
Reset button	Deletes all tolerance settings.

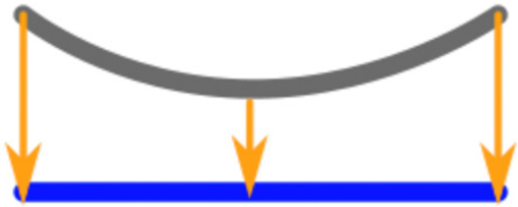
Fixture Simulation Module

Introduction

The **Fixture Simulation** module has been designed to simulate the assembled state of a deformed part to replace the need to scan the surface of the part with a special fixturing device.

The following points should be noted:

- A CAD model of the part is required for defining the fixture conditions.
- For accurate simulation, the deformations of the scanned surface should not be too large. A linear-elastic finite element method is used to simulate the fixtured part. Deformations below 5 degrees are recommended to obtain a valid approximation. Too large bending angles will lead to distorted simulated parts, which, for example, will appear too short or too long (see image below).



- For best results, the scanned surface should be thin-walled.
- The scanned surface should not bend under its own weight, i.e., gravity effects should be negligible.

Method of Simulation

To simulate the assembled state, a finite element simulation forces the actual part (scanned surface) to match the nominal part (CAD model) using the following steps:

a) Deformation field:

The deformation field is a point-to-point correspondence of the nominal part to the actual part. This information is needed to transfer the fixture ROIs from the nominal part to the actual part and is used as a predefined displacement boundary condition.

b) Fixture ROIs:

Fixture ROIs define the areas where the actual part (scanned surface) is forced to match the assembled state.

c) Parameters for the final finite element simulations, e.g., the finite element size:

The finite element size has a direct influence on the computation time, i.e., a too small element size will increase the RAM usage. It is recommended that you use at least two to three elements over the cross-section of the part. A graphical representation of the finite element grid will be displayed in the 2D windows before the calculation.

License Information

This module is an optional add-on module for VGSTUDIO MAX. It is not available for myVGL. However, if a project loaded in myVGL contains results obtained with this module, they can be viewed and reported in myVGL.

If you are interested in a more comprehensive functionality than the one offered by myVGL, you have the chance to evaluate VGSTUDIO MAX. You can request an evaluation license of VGSTUDIO MAX on our website:

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- For China, including Mainland China, Hong Kong, Macao, and Taiwan:
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- For Singapore and other parts of Asia (except China and Japan), Australia, and parts of Oceania:
  Write an e-mail to sales@volumegraphics.sg or call +65 6665 0310.

Opening the Dialog

In order to open the **Fixture simulation** dialog,

- right-click the corresponding entry in the Scene Tree and select **Properties** from the context menu or
- double-click the corresponding entry in the Scene Tree.

The **Fixture simulation** dialog consists of several tabs on which you can view the simulation parameters.

To close the dialog, click the **Close** button at the bottom of the dialog.

A status bar at the bottom of the dialog indicates the current status of the analysis. The status can be one of the following:

Table 40-1: Messages in the status bar

Status	Description
Result is up to date	The current analysis result is valid.
License missing	The add-on module is not licensed.

☞ An invalid or outdated status of an analysis is indicated in the Scene Tree by a warning sign. Double-click this analysis to open it and check the status bar for messages.

The units of the dialog depend on the global unit settings (see section *Units Drop-down List* on page 33 in chapter 2 *Workspace*).

Settings Tab

The **Settings** tab of the **Fixture simulation** dialog allows you to set physics and simulation parameters to control the details of the simulation.

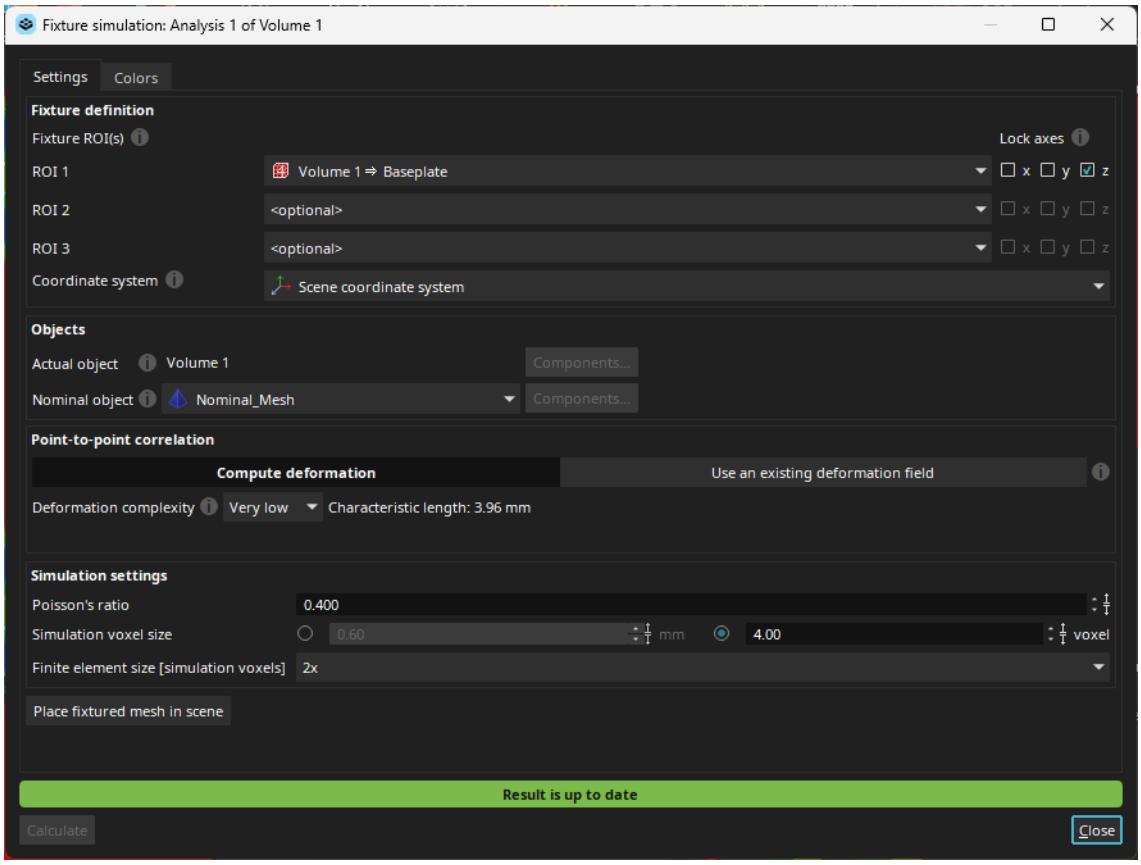
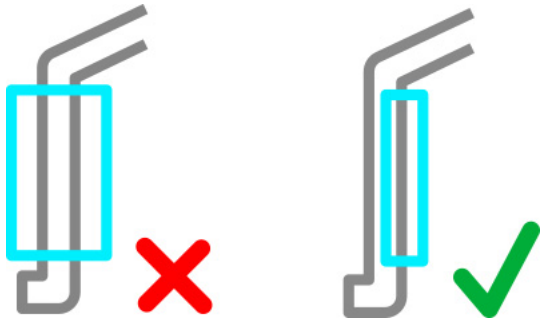


Figure 40-1: **Fixture simulation** dialog, **Settings** tab

In myVGL, all parameter settings are displayed. Most of these parameters are read-only in myVGL. The complete functional range is available with VGSTUDIO MAX and the respective add-on module(s).

Fixture definition Section

Table 40-2: Controls of the **Fixture definition** section

Control	Description
ROI 1/**ROI 2**/**ROI 3** drop-down lists	Specify the ROIs enclosing the surface areas where the actual part (scanned surface) is forced to match the nominal part (CAD model). Only in these regions is the virtual force applied to match the CAD model, the areas outside the ROIs will move according to the law of physics. Note: The ROIs can be specified either on the nominal part or on the actual part. It is recommended that you specify them on the nominal part. Note: Avoid clamping both sides of a thin wall to prevent unrealistic constraint forces in the simulation. 
Lock axes checkboxes	For each fixture ROI: When an axis is checked, fixturing is enforced in its direction. Movement remains free in the directions of unchecked axes. Tip: For example, when simulating the fixturing of a warped sheet to a flat table (assuming the table plane extends in the x- and y-directions), specify the bottom side of the sheet as fixture ROI and lock only the z-direction, only allowing movement in the xy-plane. Note: In the free directions, rigid-body movement will be prevented automatically.
Coordinate system drop-down list	Specifies the coordinate system in which the locked axes are defined.

Objects Section

Table 40-3: Controls in the **Objects** section

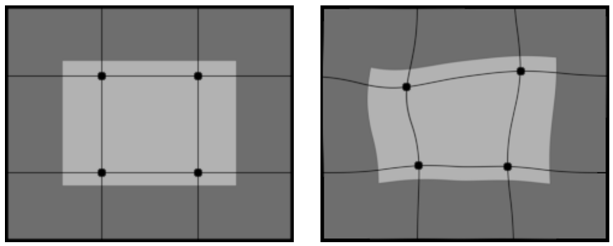
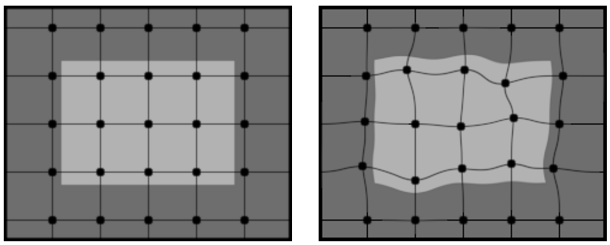
Control	Description
Actual object field	Indicates the object for which the fixture simulation is to be performed. Usually, this is the scanned surface of a manufactured part.
Nominal object drop-down list	Specifies the object to be used for defining the displacement boundary conditions. Usually, this is a CAD model.
Components… buttons	These buttons are enabled when the **Actual object** or the **Nominal object**, respectively, is an object with components. Clicking them opens a dialog box where you can specify the components for which the fixture simulation is to be performed: • Checkbox of component: Clicking it checks/unchecks the component including all child components. • **Select all** button: Selects all components of the object. • **Deselect all** button: Deselects all components of the object. • **Apply visibility** button: Selects all components which are set to visible in the Scene Tree. For volume objects that consist of several volume components, the analysis will be based on the outer surface of all united components unless otherwise specified in the **Components** option.

Point-to-point correlation Section

For applying the fixture conditions, accurate point-to-point correlations between actual object (scanned surface) and nominal object (CAD model) must be established. This is done using a deformation field.

Table 40-4: Controls of the **Point-to-point correlation** section

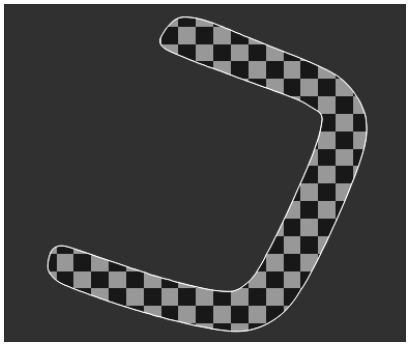
Control	Description
Compute deformation segmented button	The deformation field will be computed in the background. This option requires a clean surface determination (no pores or particles) and a fully matching nominal object (e.g., no additional structures in the scanned surface or CAD model). Check that the simulated fixtured object perfectly matches the nominal object in the fixture ROI(s). If not, select **Use an existing deformation field** instead.

Control	Description
Deformation complexity drop-down list	A higher deformation complexity is suited for complex deformations between actual object and nominal object, at the cost of longer calculation time. Low deformation complexity corresponds to a long characteristic length and is thus suitable for coarse deformations.  High deformation complexity corresponds to a short characteristic length and is thus suitable for complex deformations.  **Very low**, **Low**, **Medium**, **High**: Allows you to select a predefined characteristic length.
Characteristic length field	Indicates the scale at which significant variations in deformation are still handled accurately.
Use an existing deformation field segmented button	Create a deformation field manually and select it here. This option provides more powerful settings and allows for a visual check of the deformation field. If a small warning triangle appears in the icon of the deformation field, this indicates that the surfaces could not be properly matched everywhere.

Simulation settings Section

Table 40-5: Controls of the **Simulation settings** section

Control	Description
Poisson's ratio spin box	Specifies the Poisson's ratio of the object material. Tip: The exact value of the Poisson's ratio has little influence on the overall warpage for the simulation of thin-walled objects with largely uniform wall thickness.

Control	Description
Simulation voxel size spin box	Specifies the voxel size to which the volume object will be resampled before simulation. It is recommended that you use the smallest simulation voxel size to preserve the details of the determined surface. For typical CT scan resolutions, a simulation voxel size of 2 is acceptable. Tip: You can use the **Merge and resample** function on the **Volume** tab to verify whether the surface details will be preserved for the selected simulation voxel size. Note: Resampling will only affect the geometry used internally to simulate a deformation field. The resulting surface mesh of the simulation will be based on the determined surface of the actual object. Note: This setting is important to keep small structures but affects the computation time the most. To save computation resources, adjust the **Finite element size**. This parameter has a weaker effect on the computation time but does not change geometry.
Finite element size [simulation voxels] drop-down list	Specifies the factor for the finite element size, based on the simulation voxel size. Example: With a **Simulation voxel size** of 0.2 mm and a **Finite element size** of 4x, the finite elements used for simulation will be 4 x 0.2 mm = 0.8 mm. It is recommended that you use at least two to three elements over the cross-section of the part. The image below illustrates the recommended element size. Results may be inaccurate for larger element sizes and RAM usage may be excessive for smaller element sizes.  Tip: When you open the dialog of an uncalculated simulation, a graphical representation of the finite element grid will be displayed in the 2D windows. Each tile in the checkerboard pattern represents one finite element.

Place fixtured mesh in scene Button

Creates the simulated fixtured object as surface mesh in the Scene Tree.

If you want to record the creation of the fixtured mesh as a macro step, for example, to perform analyses or measurement tasks on the fixtured object in automated scenarios, use the **Place fixtured mesh in scene** option in the **Fixture simulation** drop-down list on the **Analysis** tab.

Colors Tab

Here you can specify the color-coding scheme used for the representation of the analysis results.

Caption Section

Table 40-6: Controls of the **Caption** section

Control	Description
Caption field	Indicates the color bar headline as specified in the **Caption** field of the **Color bar** section.
Share color bar checkbox	When this option is checked, all analyses of the same type (and—if applicable—of the same algorithm) will use the same color bar. When this option is unchecked, the color bar settings will apply to the selected analysis only.

LUT – Color Lookup Table

The color lookup table (LUT) shows the partitioning into color sections.

Sections Section

Defines the appearance of each color section.

Table 40-7: Controls in the **Sections** section

Control	Description
From/To fields	Specify the start and end values of the color sections. The first color section represents all values above the upper limit, i.e., the value in the **From** field (**+inf** signifies positive infinity), while the last color section represents all values below the lower limit, i.e., the value in the **To** field (**-inf** signifies negative infinity). The default limits are calculated from the results of the analysis (for an analysis color bar) or taken from the **Default** preset (for a tolerance deviation color bar).

Control	Description
Type field	Switches between the color schemes **Continue**, **Constant**, **Gradient**, **Rainbow**, **Reverse rainbow**, **Hue cycle**, **Green to red**, and **Red to green**.
Color/transparency field	Double-clicking the field for the **Continue**, **Constant**, and **Gradient** color schemes opens the **Select Color** dialog where you can modify the appearance of the selected color scheme. For the **Gradient** color scheme, you can specify the start and end colors by double-clicking the left or right side of the field, respectively. Double-clicking the field for the **Rainbow**, **Reverse rainbow**, **Hue cycle**, **Green to red**, and **Red to green** color schemes opens the **Transparency** dialog, where you can set the transparency for the selected color scheme.
use RMB to click a color section	Opens a context menu with the following items: • **Split**: Subdivides the color section into two new color sections where each represents half of the original section. • **Merge**: Combines several color sections to a single color section. Only consecutive intervals can be merged.
Create smooth button	Opens the **Create smooth table** dialog to generate one color section. • **Type** drop-down list: Allows you to select the type of coloring scheme. • **From/To** spin boxes: Specify the value range covered by the color section.
Create stepped button	Opens the **Create stepped table** dialog to generate a set of color sections. • **Type** drop-down list: Allows you to select the type of coloring scheme. • **From/To** spin boxes: Specify the value range covered by the color sections. • **Step** spin box: Specifies the step size of the individual color sections.
Auto scale button	If available: Fits the color LUT to the range of the results of all available analyses.
Auto scale color bar range on calculate checkbox	If available: When this option is checked, the color LUT will be automatically fitted to the range of the results of all available analyses.
Default button	If available: Resets any changes made to the **Sections** table.

Color LUT Settings Section

Specifies the appearance of the color lookup table.

Table 40-8: Options for the appearance of the color lookup table

Control	Description
Auto tick marks checkbox	When this option is checked, equidistant tick marks will be produced for the color bars. When this option is unchecked, tick marks will appear only at the color section boundaries of the color lookup table.
Auto scale color bar range on calculate checkbox	When this option is checked, the color LUT will be automatically fitted to the range of the results of all available analyses.

Color bar Section

Specifies the settings for the color bar.

Table 40-9: Settings for the color bar

Control	Description
Visibility drop-down list	Switches the color bar on/off.
Positioning drop-down list	Specifies the location of the color bar within the 2D and 3D windows: **Left, Right, Top, Bottom, All - automatic, Left or right - automatic, Top or bottom - automatic**.
Caption field	Specifies the color bar headline by using placeholders.
Reset button	Resets the **Caption** field to the default entry.

Simulated mesh Section

Table 40-10: Controls in the **Simulated mesh** section

Controls	Description
Color field	Double-clicking the field opens the **Select Color** dialog, where you can specify a color for the simulated mesh.
Transparency spin box	Specifies the transparency of the simulated mesh (0 = opaque…100 = transparent).
Render wireframe checkbox	When this option is checked, the wireframe of the simulated mesh will be rendered.

Visualization of the Analysis Results

Various overlays are provided for the visualization of the analysis results in the 2D and 3D windows. These overlays can be switched on or off in the Scene Tree below the analysis by checking or unchecking the corresponding checkboxes.

When the dialog of an uncalculated simulation is open, a graphical representation of the finite element grid is displayed in the 2D windows.

- **Displacement** overlay

  The displacement is shown color-coded (according to the settings on the **Colors** tab of the **Fixture simulation** dialog) at each point in the object.
- **Fixtured object** overlay

  The simulated fixtured object is show in the 2D and 3D windows.

Volume Meshing Module

Introduction

The **Volume Meshing** module has been designed to convert a volume object, an ROI on a volume object, or an integration mesh that consists of tetrahedra to a tetrahedral volume mesh.

License Information

This module is an optional add-on module for VGSTUDIO MAX. It is not available for myVGL. However, if a project loaded in myVGL contains results obtained with this module, they can be viewed and reported in myVGL.

If you are interested in a more comprehensive functionality than the one offered by myVGL, you have the chance to evaluate VGSTUDIO MAX. You can request an evaluation license of VGSTUDIO MAX on our website:

https://volumegraphics.hexagon.com/en/products/evaluation

If you have further questions about our product portfolio, please contact us:

- For Europe, Middle East, and Africa:

  Write an e-mail to sales@volumegraphics.com or call +49 6221 73920 744.
- For Japan:

  Write an e-mail to sales@volumegraphics.jp or call +81 52 508 9682.
- For the Americas:

  Write an e-mail to sales-us@volumegraphics.com or call +1 704 248 7736.
- For China, including Mainland China, Hong Kong, Macao, and Taiwan:

  Write an e-mail to sales@volumegraphics.cn or call +86 10 8532 6305.
- For Singapore and other parts of Asia (except China and Japan), Australia, and parts of Oceania:

  Write an e-mail to sales@volumegraphics.sg or call +65 6665 0310.

Opening the Dialog

In order to open the properties dialog of an existing volume mesh to view its settings,

- right-click the corresponding entry in the Scene Tree and select **Properties** from the context menu or
- double-click the corresponding entry in the Scene Tree.

The **Tetrahedral mesh** dialog consists of several tabs on which you can view the results of volume meshing. See section *Tetrahedral mesh Dialog* on page 684.

Tetrahedral mesh Dialog

The **Tetrahedral mesh** dialog shows the properties of the selected tetrahedral mesh or tetrahedral mesh component and consists of several tabs that will be described in the following sections.

The following buttons are available at the bottom of the dialog:

Table 41-1: Buttons of the **Tetrahedral mesh** dialog

Button	Description
Recreate button	Re-opens the **Convert to tetrahedral volume mesh** dialog with the same parameters to create a new tetrahedral mesh for the same volume object. You can change the parameters before creating it. This option is available with VGSTUDIO MAX and the respective add-on module(s).
Close button	Closes the dialog.

Settings Tab

Displays the settings used for creating the tetrahedral mesh in VGSTUDIO MAX.

In myVGL, all parameter settings are displayed. Most of these parameters are read-only in myVGL. The complete functional range is available with VGSTUDIO MAX and the respective add-on module(s).

- **Units** radio buttons

  Specify the length unit for the parameters for setting up the tetrahedral mesh(es).
- **Mode** radio buttons

  Toggles between **Simple** and **Expert** mode. The **Simple** mode enables quick and easy definition of the main settings resulting in good meshes for typical meshing tasks. The **Expert** mode can be used to control advanced settings to further improve mesh quality if needed.
- **Use same settings as** drop-down list

  Allows you to copy the parameters of existing tetrahedral meshes to either apply or use as a basis.
- **Volume components** section

  Table 41-2: Controls in the **Volume components** section

Control	Description
Background component/Volume component checkboxes	Check the corresponding checkbox to create a tetrahedral mesh component for the background and/or the material(s).

Control	Description
Min. element size/**Max. element size** spin boxes	Specify the minimum/maximum circumsphere radius R for the tetrahedra. These settings will be fulfilled only approximately. The element sizes in the final mesh may differ from the settings by up to a factor of 2. The **Min. element size** spin boxes may constrain the tetrahedra so that the mesh will not fulfill the **Max. deviation from determined surface** specified in the **General mesh settings** section. To ensure that the specified deviation is fulfilled, set **Min. element size** to **0**. This may, however, result in a large number of very small tetrahedra in the vicinity of highly curved surface areas (e.g., corners). At the border between adjacent components, where different element sizes are specified, the smaller element size will win.

- **Local mesh refinement** section

Sometimes it is sufficient to simulate only specified critical regions with high resolution and use a coarser mesh for the rest of the structure in order to save computation resources.

The **Local mesh refinement** option allows you to override the settings for the minimum and maximum element sizes specified in the **Volume components** section within specified regions of interest (ROIs). The refinement option can be used to refine or to coarsen the tetrahedral mesh. The ROI may extend over different components. If the specified ROIs have overlapping areas, the smallest values will be considered.

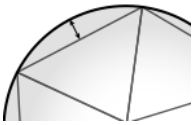
Table 41-3: Controls in the **Local mesh refinement** section

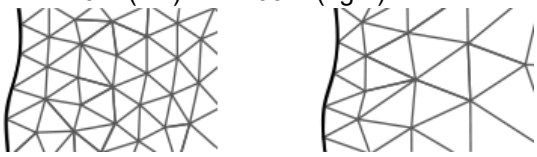
Control	Description
Refinement ROI drop-down list(s)	Specifies an ROI where a finer or coarser mesh resolution is desired.
Min. element size/**Max. element size** spin boxes	Specify the minimum/maximum circumsphere radius for the tetrahedra, which overrides the settings in the **Volume components** section. In order to efficiently decrease the number of elements outside the refinement ROI, it is recommended that you increase the minimum element size in the **Volume components** section. At the border of the refinement ROI, where different element sizes are specified, the smaller element size will win.
Add button	Adds a **Refinement ROI** drop-down list.

Control	Description
Remove button	Removes a **Refinement ROI** drop-down list.

- **General mesh settings** section

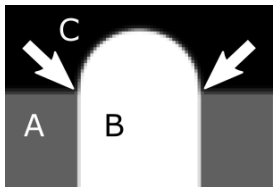
Table 41-4: Controls in the **General mesh settings** section

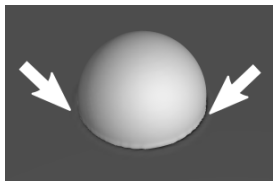
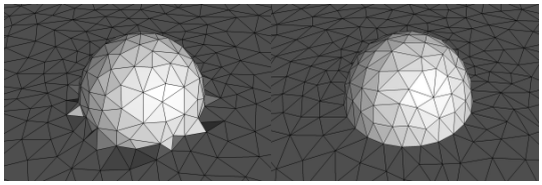
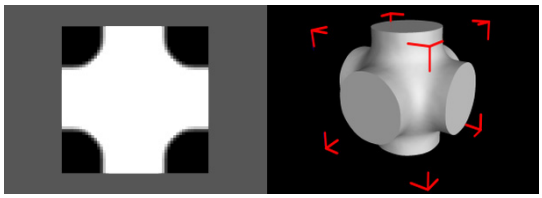
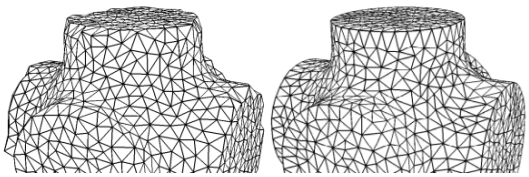
Control	Description
Max. deviation from determined surface spin box	Specifies the maximum distance between the tetrahedral mesh facets and the determined surface. This results in a refinement of the mesh according to the surface curvature. Smaller elements will be generated where the surface curvature is high.  The **Min. element size** spin boxes may constrain the tetrahedra so that the mesh will not fulfill the **Max. deviation from determined surface** setting. To ensure that the specified deviation is fulfilled, set **Min. element size** to **0**. This may, however, result in a large number of very small tetrahedra in the vicinity of highly curved surface areas (e.g., corners).
Curvature-based refinement checkbox	Enables the **Elements per quarter circle** spin box to specify the number of elements based on the surface curvature. Use this option to refine the tetrahedral mesh specifically along curved surfaces while keeping larger elements in the remaining tetrahedral mesh.
Wall-thickness-based refinement checkbox	Use this option to ensure reliable results for thin walls in accordance with the specified minimum element size. • **Elements across wall thickness** spin box: Specifies the number of elements across the thickness of a wall. • **Wall thickness analyses** drop-down list: Specifies the wall thickness analysis to be used for refinement. When you select multiple analyses by clicking the **Add** button, the analysis with the smallest wall thickness will have priority.

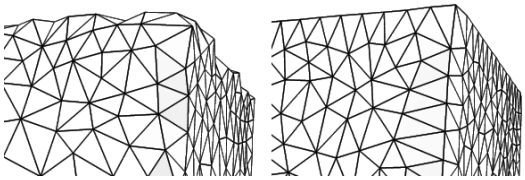
Control	Description
Element size grading factor spin box	Specifies the maximum percentage by which the size of neighboring tetrahedra can differ. The tetrahedra increase in size from the object boundaries to its interior. A low grading factor results in more tetrahedra, but usually of a higher quality. Grading factors larger than 100% are allowed. The images below illustrate meshes with grading factors of 0% (left) and 100% (right). 
Surface smoothing checkbox	Very complex surfaces might result in meshes that do not exhibit good mesh quality, even after sufficient optimization (see **Element smoothing** option). In this case, it might be necessary to smoothen the surface before meshing. This option will flatten structures that are below the length specified in the **Smoothen structures smaller than** spin box.
Smoothen structures smaller than spin box	Specifies the size of the structures to be smoothened. Moderate values (e.g., 0.5 to 1 voxel) will usually significantly improve the mesh quality without altering the surface too much.

- **Generate sharp lines** section

Table 41-5: Controls in the **Generate sharp lines** section

Control	Description
Multi-material triple junctions checkbox	This option is only relevant for multi-component meshes. The unmeshed background is considered a separate component. Aligns nodes on junction lines where three components meet. It will be ensured that nodes are placed on the exact triple junction as defined by the advanced (multi-material) surface determination.  Figure 41-1: A, B = two different materials; C = air: triple junction, formed by the three components A, B, and C, indicated by white arrows

Control	Description
	 Figure 41-2: Advanced multi-material surface determination (3D view): triple junction indicated by white arrows  Figure 41-3: **Multi-material triple junctions** option: left: off; right: on Note: This option constrains the nodes on the junction line, which may also limit the quality of the elements unless the option **Sharp lines may be broken** is checked in the **Mesh optimization** section.
Edges at volume/ROI clipping bounds checkbox	This option is only relevant for clipped objects. Aligns nodes on cutting edges resulting from the meshed object being clipped by the bounding box of the data set or by the ROI. It will be ensured mathematically that nodes are positioned exactly on the volume/ROI boundaries.  Figure 41-4: Clipped data set: left: 2D slice; right: 3D view  Figure 41-5: **Edges at volume/ROI clipping bounds** option: left: off; right: on

Control	Description
	Note: This option constrains the nodes on the junction line, which may also limit the quality of the elements unless the option **Sharp lines may be broken** is checked in the **Mesh optimization** section.
Sharp surface features checkbox	Aligns nodes on sharp surface features (edges, ridges, grooves, etc.) using a shape analysis algorithm. As a general edge detector, it may re-detect lines already covered by the other **Generate sharp lines** options, but without ensuring numerical exactness. This option has lowest priority, i.e., if the same line is detected both by this option and one of the other ones, the other one wins.  Figure 41-6: **Sharp surface features** option: left: off; right: on Note: This option constrains the nodes on the junction line, which may also limit the quality of the elements unless the option **Sharp lines may be broken** is checked in the **Mesh optimization** section.
Search distance spin box	Specifies the search distance for detecting sharp surface features. The search distance should be • well above the width of the image blur and • smaller than the separation between two edges. Edges that are separated by less than the search distance may not be properly detected. A value of 10 voxels is usually adequate for an average-quality CT scan. Increase the value for poorer-quality scans caused by significant surface noise, strong blurring, etc.

- **Mesh quality settings** section

Table 41-6: Controls in the **Mesh quality settings** section

Control	Description
Element smoothing checkbox	Check this option to improve the quality of the tetrahedron shapes. It is recommended that you check this option as first optimization.
Max. number of iterations spin box	The **Max. number of iterations** spin box limits the iteration steps. More iteration steps might improve the tetrahedron shape quality but prolong the calculation time. It is recommended that you at least keep the default value.
Mesh optimization checkbox	The **Mesh optimization** option allows you to specify quality metrics as additional optimization criteria for the tetrahedral mesh computation. For details on the different quality metrics, see Table 41-9: *Entries in the Quality metrics table* on page 692. Mesh optimization will move mesh nodes and possibly reconnect nodes (see **Flip edges to improve mesh quality** below). Surface nodes can only move along the original surface. Nodes on sharp lines cannot move at all unless **Sharp lines may be broken** is checked (see below). It is highly recommended that you use the **Element smoothing** option prior to the **Mesh optimization** option. Tip: To assess the used mesh and for working out adequate settings, it is best to first create a mesh without optimization and optimize afterwards if necessary.
Optimization criterion drop-down list	Specifies the quality metric to be considered for the optimization.
Target value spin box	Specifies a target value for the selected quality metric.
Add button	Creates an additional **Optimization criterion** drop-down list.
Remove button	Removes the corresponding **Optimization criterion** drop-down list.
Max. number of iterations spin box	Limits the iteration steps. More iteration steps might improve the tetrahedron shape quality but prolong the calculation time.

Control	Description
Quality vs. geometry tradeoff preset drop-down list	Provides presets that prioritize either the **Element quality** or the **Geometry conformance**. The presets specify the settings of the following options: • **Sharp lines may be broken** checkbox: When this option is checked, nodes aligned on sharp edges may be moved during optimization and the alignment may be broken if it improves mesh quality. Edge nodes on the surface are still only allowed to move along the surface. • **Flip edges to improve mesh quality** checkbox: When this option is checked, mesh nodes may be reconnected differently if it improves mesh quality. Only interior connections will be changed, meaning that connections between surface nodes will not be changed.

- **FE entity sets** section

  In the **FE entity sets** section, finite element sets of facets and nodes can be created on the surface of the tetrahedral mesh. These sets may be used in the Abaqus Software for the definition of the simulation model. Note that the nodes of the volume mesh will be aligned to the borders of the ROIs defining the sets and that the sets will be preserved for refinement, optimization and purge.

If the simultaneous alignment of the nodes for two or more **FE entity sets** is not feasible, the uppermost FE entity set in the list will be determinative.

For the FE entity sets to be available to third-party software, the tetrahedral mesh must be exported as Abaqus input file (*.inp*).

Table 41-7: Controls in the **FE entity sets** section

Control	Description
Region of interest drop-down list(s)	Specify ROIs for the scope of the FE entity set.
Entity type drop-down list(s)	Specify the type of the entities in the set. Select **Facets** or **Nodes** to set the respective type.
Add button	Adds a **Region of interest** drop-down list.
Remove button	Removes a **Region of interest** drop-down list.

- **Convert** button

  Creates the tetrahedral mesh.
- **Cancel** button

  Discards all settings and closes the dialog.

Statistics Tab

The **Statistics** tab provides the total number of tetrahedra and an overview of the different quality metrics with their respective histograms.

- **General** section

  Table 41-8: Entries in the **General** section

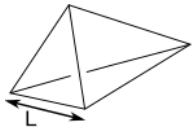
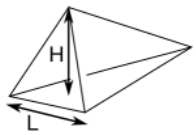
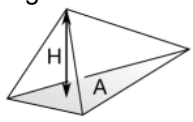
Field	Description
Tetrahedron count	Indicates the total number of tetrahedra composing the mesh.
Node count	Indicates the total number of nodes in the mesh.
Creation duration	Indicates the time that was required for creating the tedrahedral mesh.

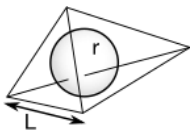
- **Quality metrics** section

  The table in this section displays the total range of the quality metrics, i.e., the minimum and the maximum value for each quality metric of the tetrahedra composing the mesh.

  The table below describes the available metrics.

  Table 41-9: Entries in the **Quality metrics** table

Metrics	Description
Max./min. edge aspect	The **Max./min. edge aspect** is defined as the longest edge $\mathbf{L_{max}}$ divided by the shortest edge $\mathbf{L_{min}}$ of the tetrahedron. 
Edge/height aspect	The **Edge/height aspect** is defined as the longest edge $\mathbf{L_{max}}$ of the corresponding base of the tetrahedron divided by its minimum height $\mathbf{H_{min}}$. 
Collapse	The **Collapse** is defined as $\mathbf{(H/\sqrt{A})_{min}/1.24}$, i.e., the smallest quotient of a height **H** and the square root of the corresponding base **A** divided by **1.24**. 

Metrics	Description
Stretch	The **Stretch** is defined as **r/L$_{max}$*√24**, where **r** is the radius of the inscribed sphere and **L$_{max}$** is the longest edge of the tetrahedron. 
Shape factor/skewness	The **Shape factor/skewness** is defined as the quotient of the tetrahedron volume **V** and the volume **V´** of a regular tetrahedron with the same circumsphere.
Smallest face corner angle [<angle unit>]	The **Smallest face corner angle [<angle unit>]** indicates the smallest angle where two edges of the triangular face meet.
Largest face corner angle [<angle unit>]	The **Largest face corner angle [<angle unit>]** indicates the largest angle where two edges of the triangular face meet.
Min. edge size [<length unit>]	Indicates the shortest edge of the tetrahedron.
Radius of circumsphere [<length unit>]	Indicates the radius of the circumscribed sphere.

Histograms Tab

Shows a histogram of the metric selected from the drop-down list.

When opening the **Histograms** tab, the tetrahedra will be color-coded according to the selected metric.

The following controls are available on the **Histograms** tab:

Table 41-10: Controls of the **Histograms** tab

Control	Description
Entire mesh radio button	When this option is checked, the histogram shows all tetrahedra of the tetrahedral mesh.
Within ROI radio button	Check this option to show a histogram for the tetrahedra within the specified ROI.
Drop-down list for metrics	Specifies the metric shown in the histogram.
Number of bins spin box	Specifies the number of bins of the histogram.
Interval spin boxes	Indicate the left and right interval borders with two blue vertical lines. If link status is linked, specify the start and end values for the color range mapping.
Color range spin boxes	Available if link status is unlinked. Allow you to manually specify the start and end values for the color range mapping.
/ icon	Toggles the link status of the **Interval** and the **Color range**.
Count inside interval field	Indicates the total number of tetrahedra within the specified interval.
Percentage inside interval field	Indicates the percentage of tetrahedra within the specified interval.
use LMB to click and drag the left or right interval border (blue vertical lines) in the histogram area	Moves the left or right interval border.
scroll MW in chart area or x-axis up/down	Zooms the x-axis of the chart out/in.
scroll MW in y-axis up/down	Zooms the y-axis of the chart out/in.
use LMB to click and drag the x-axis	Scrolls the x-axis.
use LMB to click and drag the y-axis	Scrolls the y-axis.

FE entity sets Tab

The **FE entity sets** tab lists finite element sets of nodes, facets, or tetrahedra. With VGSTUDIO MAX, the sets can be exported along with the tetrahedral mesh as Abaqus input file format (*.inp*). These sets may be used in the Abaqus software to perform tasks such as defining contact pairs and boundary conditions.

- **FE entity set** table

  When you create an entity set, it will be listed as a row in this table.

Table 41-11: Columns in the **FE entity sets** table

Column	Description
Name	Indicates the name of the entity set. The default name indicates the type of entity the set is made of and whether the set is restricted to a volume and an ROI.
Entity type	Indicates the type of entities the set is made of.
Visibility checkbox	Indicates whether the entity set is visible in the 3D view.
Color field	Indicates the color of the entity set.
Count	Indicates the number of entities that compose the set.
Unique	Available for tetrahedral meshes with more than one component. Indicates the number of entities that belong to solely one component. The **Unique** value only differs from the **Total** value for node entity sets. This is because a node can belong to more than one component, whereas a tetrahedron is always unique. Since a facet is defined based on a tetrahedron, it is also always unique.
<name of the component>	Available for tetrahedral meshes with more than one component. Indicates the number of entities in the respective component. Note that a node entity can belong to more than one component.

Connectivity Tab

On the **Connectivity** tab, the mesh is analyzed with respect to its rigidly connected components (“connected element sets”). Two tetrahedra are regarded as rigidly connected if they share three vertices, i.e., if they have a common face. In multi-material meshes, connected element sets are analyzed independently of the logical material components. Connected element sets span across logical component interfaces. If you need to analyze a logical mesh component separately, open the **Tetrahedral mesh** dialog directly on the desired component. To do so, double-click the tetrahedral mesh component instead of the tetrahedral mesh in the Scene Tree.

- **Connected element sets** section

  Lists the connected element sets of the tetrahedral mesh or mesh component. For each element set, an ID and the number of elements it consists of are indicated.

- **Purge small connected sets** section

  Depending on the quality of the underlying volumetric image, the generated mesh may contain noise particles, e.g., small free-floating element sets or element sets that are not rigidly connected to the main object. These can prohibit a numerically stable FEM simulation. The **Purge small connected sets** section allows you to purge the mesh from small connected element sets.

Table 41-12: Controls in the **Purge small connected sets** section

Control	Description
Min. element count in set spin box	All connected element sets with an element count that is lower than specified will be deleted.
Max. number of sets to keep spin box	Specifies the maximum number of connected element sets to be kept after purging.
status bar	If purging the mesh is not possible, the status bar will indicate the reason.
Create purged mesh radio button	When this option is enabled, a tetrahedral mesh will be created with respect to the specified purge settings.
Create additional mesh from removed connected element sets checkbox	When this option is enabled, an additional tetrahedral mesh consisting of the removed element sets will be created.
Create mesh with all connected element sets as separate material components for visualization radio button	When this option is enabled, a tetrahedral mesh containing all element sets will be created. Each element set will be a separate component of the mesh. This option is for visualization purposes. With respect to the specified purge settings, the retained components will be shown in green, and the removed components will be shown in red.

- **Create** button

  Creates tetrahedral meshes according to the specified settings and shows the respective entries in the Scene Tree.

Structural Mechanics Simulation Module

Introduction

The **Structural Mechanics Simulation** module calculates the mechanical stress distribution in an object based on a user-defined loading setup. The part can be either voxel data from a CT scan or surface mesh data (e.g., imported from a CAD model). A linear-response material model is assumed, which is defined by Young's modulus and Poisson's ratio. As such, the simulation is valid only for deformations that are very small compared to the extent of the analyzed object.

In order to define the load case, part of the object can be defined as fixed, and another part can be defined as subject to load. The load can be a directed force, a torque around a given axis, or pressure/suction.

The simulation is carried out using a mesh-free finite-element method, with linear basis functions and a conjugate gradient solver.

License Information

This module is an optional add-on module for VGSTUDIO MAX. It is not available for myVGL. However, if a project loaded in myVGL contains results obtained with this module, they can be viewed and reported in myVGL.

If you are interested in a more comprehensive functionality than the one offered by myVGL, you have the chance to evaluate VGSTUDIO MAX. You can request an evaluation license of VGSTUDIO MAX on our website:

https://volumegraphics.hexagon.com/en/products/evaluation

If you have further questions about our product portfolio, please contact us:

- For Europe, Middle East, and Africa:
  Write an e-mail to sales@volumegraphics.com or call +49 6221 73920 744.
- For Japan:
  Write an e-mail to sales@volumegraphics.jp or call +81 52 508 9682.
- For the Americas:
  Write an e-mail to sales-us@volumegraphics.com or call +1 704 248 7736.
- For China, including Mainland China, Hong Kong, Macao, and Taiwan:
  Write an e-mail to sales@volumegraphics.cn or call +86 10 8532 6305.
- For Singapore and other parts of Asia (except China and Japan), Australia, and parts of Oceania:
  Write an e-mail to sales@volumegraphics.sg or call +65 6665 0310.

Opening the Dialog

In order to open the **Structural mechanics simulation** dialog,

- right-click the corresponding entry in the Scene Tree and select **Properties** from the context menu or
- double-click the corresponding entry in the Scene Tree.

The **Structural mechanics simulation** dialog consists of several tabs on which you can view the results of the analysis.

To close the dialog, click the **Close** button at the bottom of the dialog.

A status bar at the bottom of the dialog indicates the current status of the analysis. The status can be one of the following:

Table 42-1: Messages in the status bar

Status	Description
Calculation required	All required parameters have been specified and are consistent, but the analysis was not calculated or was invalidated by some user action before the project was saved.
Result is up to date	The current analysis result is valid.
Manually stopped	The calculation was stopped manually and cannot be continued. The internal information necessary to continue is no longer available. This state occurs when a stopped analysis is saved to and re-loaded from disk or when the **Free memory/Clear undo queue** function was executed.
Object has no surface determination	No surface determination information is available for the object. See also section *Surface determination* on page 949 in chapter 48 *Glossary*.
License missing	The add-on module is not licensed.

An invalid or outdated status of an analysis is indicated in the Scene Tree by a warning sign. Double-click this analysis to open it and check the status bar for messages.

In the **Manually stopped** and **Manually stopped (continuable)** states, the values of the **Convergence error** and/or **Max. number of iterations** settings do not correspond to the actual result. The analysis result may not be reproducible.

The units of the dialog depend on the global unit settings (see section *Units Drop-down List* on page 33 in chapter 2 *Workspace*).

Settings Tab

The **Settings** tab of the **Structural mechanics simulation** dialog allows you to set physics and simulation parameters to control the details of the simulation.

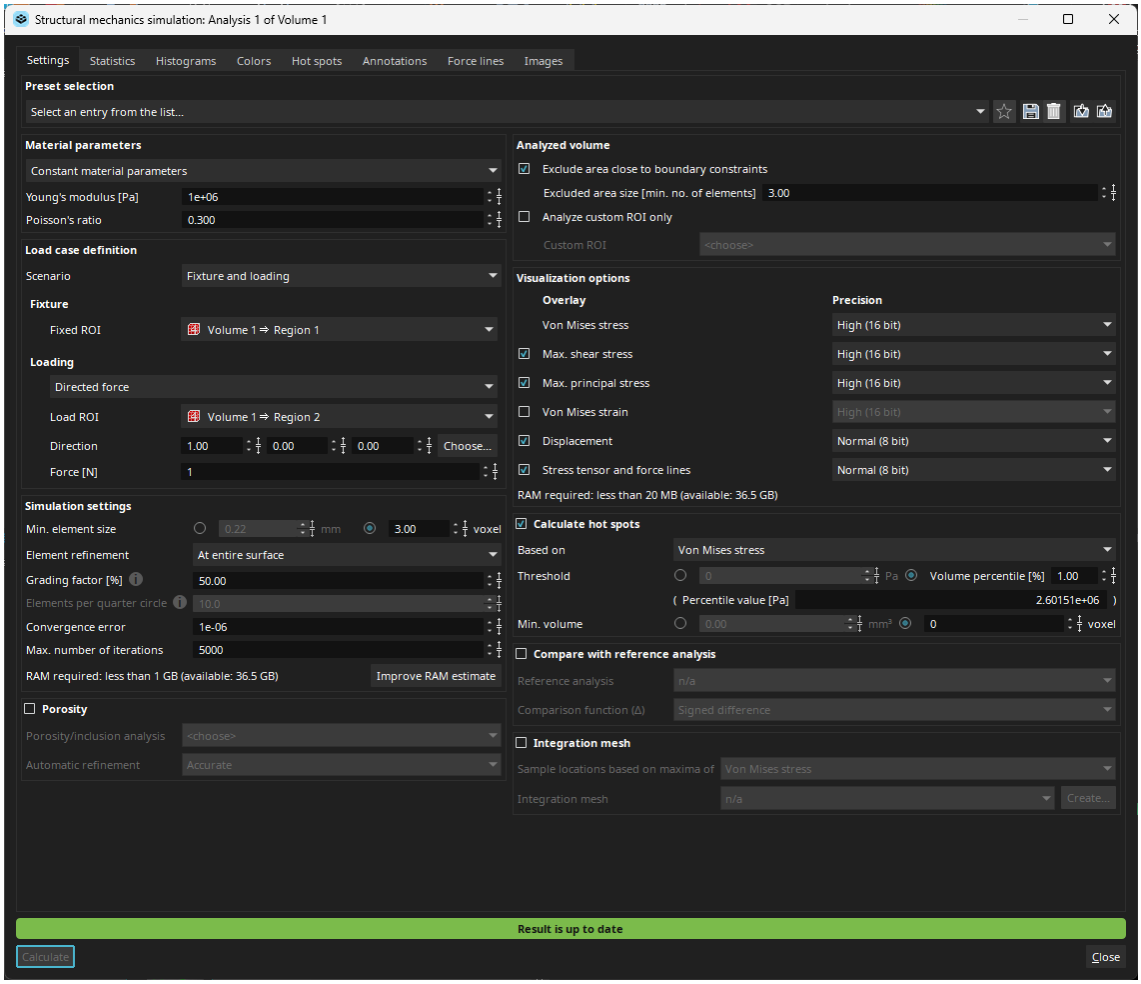


Figure 42-1: **Structural mechanics simulation** dialog, **Settings** tab

☞ In myVGL, all parameter settings are displayed. Most of these parameters are read-only in myVGL. The complete functional range is available with VGSTUDIO MAX and the respective add-on module(s).

Preset selection Section

Table 42-2: Controls in the **Preset selection** section

Icon	Item	Description
	drop-down list	Specifies the preset to be applied, to be edited, or to be taken as a basis for a new preset. The following icons are used: • analysis factory settings • customized preset • appears next to the icon of a preset that has been modified but not yet saved
	Set this preset as default	Sets the selected preset as default. The default preset will be applied when creating a new analysis of the same type. If the selected preset is already set as default, the button is disabled.
	Save preset	Saves the selected preset. When saving a preset, the **Save preset** dialog will open, which allows you to set the new preset as default by checking the **Set as default for new analyses** checkbox.
	Remove preset	Removes the selected preset from the preset drop-down list. If the removed preset is the default preset, the next time an analysis of the same type is created, the factory settings will be used.
	Import preset	Imports a preset from the specified location.
	Export preset	Exports the selected preset to the specified location.

Material parameters Section

Defines the elastic properties of the object material. A linear material model is used, which is determined by the Young's modulus and the Poisson's ratio.

Constant material parameters mode vs. **Variable material parameters** mode

In the **Constant material parameters** mode, the entire simulated volume is assumed to consist of the same physical material that is characterized by Young's modulus and Poisson's ratio. The simulated volume is the volume enclosed by the determined surface and will be intersected by an ROI if the analysis is created below an ROI, or diminished by the indication volume if a porosity/inclusion analysis is taken into account. In the **Variable material parameters** mode, the simulated volume consists of material with locally varying parameters based on the local gray value of the loaded volume.

The **Variable material parameters** mode does not work with geometry or CAD data, or when gray-value data is unloaded.

On the **Settings** tab, the user imports two lookup curves that map a given gray value to the material parameters. One lookup curve determines the Young's modulus; the other lookup curve determines the Poisson's ratio.

Interfaces between domains with different material parameters are not explicitly modeled. The simulated domain is assumed to be coherent with no occurrence of slipping or cracking. Due to the partial voxel effect, the gray values tend to diminish near the determined surface. This might result in apparent, unwanted material variations. By default, the partial voxel effect is corrected in a narrow band around the determined surface. The corrected gray values will be used for the material lookup.

- **Constant material parameters** option

Table 42-3: Controls of the **Material parameters** section

Control	Description
Young's modulus spin box	Specifies the Young's modulus (also known as the "elastic modulus") of the object material.
Poisson's ratio spin box	Specifies the Poisson's ratio of the object material.

- **Variable material parameters** option

Table 42-4: Controls of the **Material parameters** section

Control	Description
Young's modulus field	Indicates the Young's modulus after import of a *.csv* file.
Poisson's ratio field	Indicates the Poisson's ratio after import of a *.csv* file.
Import CSV button (Young's modulus)	Allows you to import a *.csv* file that contains value pairs of gray value and Young's modulus. In order to obtain a complete gray value range, a linear interpolation is performed between the gray values. For missing gray values at the beginning and end of the gray value range, the first and last gray values available in the csv table will be used, respectively.
Import CSV button (Poisson's ratio)	Allows you to import a *.csv* file that contains value pairs of gray value and Poisson's ratio. In order to obtain a complete gray value range, a linear interpolation is performed between the gray values. For missing gray values at the beginning and end of the gray value range, the first and last gray values available in the csv table will be used, respectively.
Correction of partial voxel effect checkbox	The partial voxel effect (i.e., image blurring) causes a drop in the gray values near the determined object surface. Depending on the user-supplied lookup curves, this can cause unwanted artifacts in the assumed material properties. When this option is checked, the gray values will be corrected in a small band around the determined surface to compensate for the gray value drop.

Control	Description
Correction distance radio buttons	Specifies the distance for the correction of the partial voxel effect in mm or in number of voxels.

Load case definition Section

Defines how a load is applied to the volume object. Different scenarios are available in the **Scenario** drop-down list.

- **Fixture and loading** option

  In the **Fixture and loading** scenario, the load case is defined by two ROIs, one for the load and one for the support.

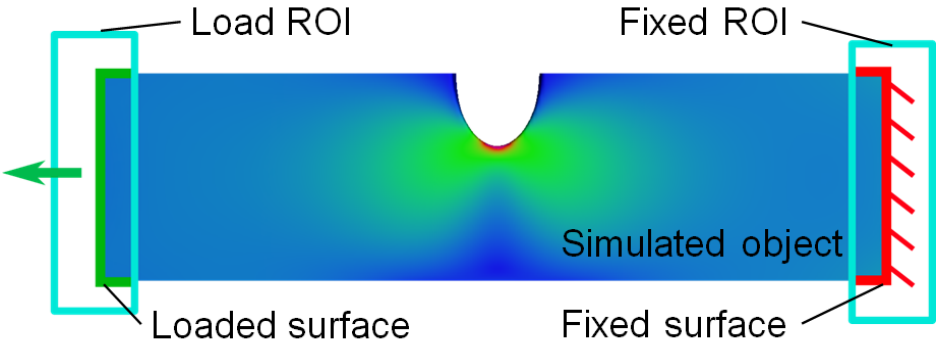


Figure 42-2: Representation of the loaded and fixed surfaces

Table 42-5: Controls of the **Load case definition** section

Control	Description
Fixed ROI drop-down list	Specifies an ROI for the fixed part of the object. The intersection of the object surface with this ROI is regarded as fixed. The fixed ROI is represented by a red color overlay in the 2D and the 3D windows. See Figure 42-2 for an illustration. Note that if the fixed ROI overlaps with the load ROI, the overlapping area will be considered fixed.
drop-down list	Specifies the type of load applied to the object (**Directed force**, **Torque**, or **Pressure**).
Load ROI drop-down list	Specifies an ROI for the part of the object that is to be subjected to load. The intersection of the object surface with this ROI is regarded as subject to load. The load ROI is represented by a green color overlay in the 2D and the 3D windows. See Figure 42-2 for an illustration. Note that if the load ROI overlaps with the fixed ROI, the overlapping area will be considered fixed.

Control	Description
Direction fields	For load type **Directed force** only: Specify the direction of the force applied to the surface. The specified vector is normalized to unit length before it is taken into account in the calculation.
Axis fields	For load type **Torque** only: Specify the direction of the axis for the torque applied to the surface. The specified vector is normalized to unit length before it is taken into account in the calculation.
Choose... button	Opens a drop-down list that shows the windows currently available in the workspace for specifying the direction. The direction is the normal of the selected 2D window or the current direction of view of the 3D window.
Force spin box	For load type **Directed force** only: Specifies the magnitude of the force to be applied. A negative value reverses the orientation.
Torque spin box	For load type **Torque** only: Specifies the magnitude of the torque to be applied. A negative value reverses the sense of rotation.
Pressure spin box	For load type **Pressure** only: Specifies the magnitude of the pressure to be applied. A negative value represents suction.

- **Submodeling** option

  In the **Submodeling** scenario, predefined displacement boundary conditions are imposed on the submodel ROI where it intersects the simulated object. Displacements are taken from the results of the parent simulation. No constraints are applied to any material/air interfaces (traction-free surface).

The material parameters in the **Material parameters** section must match the material parameters of the parent simulation.

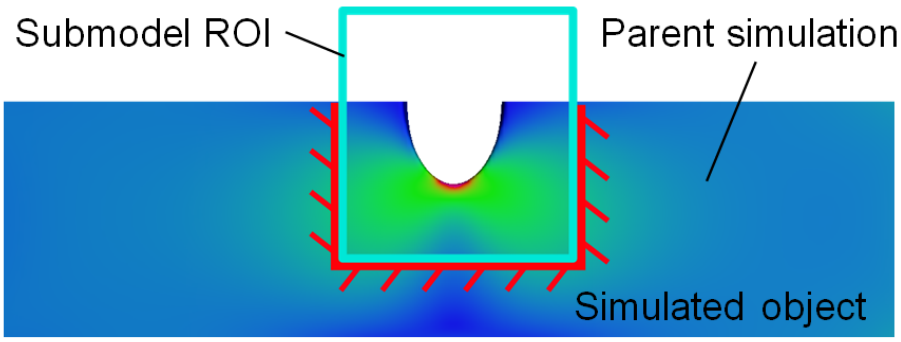


Figure 42-3: Representation of submodel ROI and parent simulation

Table 42-6: Controls of the **Load case definition** section

Control	Description
Submodel ROI drop-down list	Specifies the ROI that defines the simulated volume.
Parent simulation drop-down list	Specifies the simulation that holds the displacements used for the desired load case. Note: The precision for the displacement from the parent simulation must be at least 16 bit per voxel.

- **Submodeling (entire volume)** option

  In the **Submodeling (entire volume)** scenario, the submodel comprises the entire simulated object and the displacements from the global model are imposed on the boundaries of the object accordingly.

Simulation settings Section

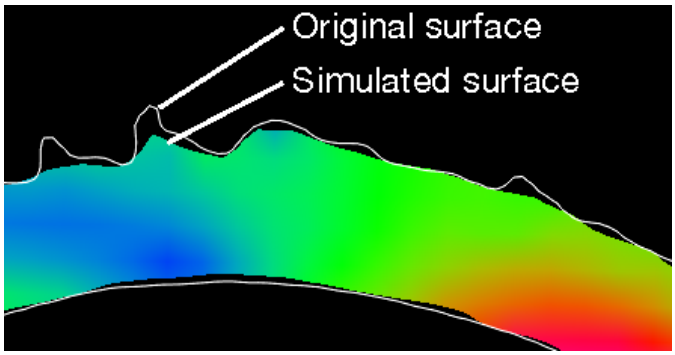
Sets the rules for the element grid generation and the solver behavior.

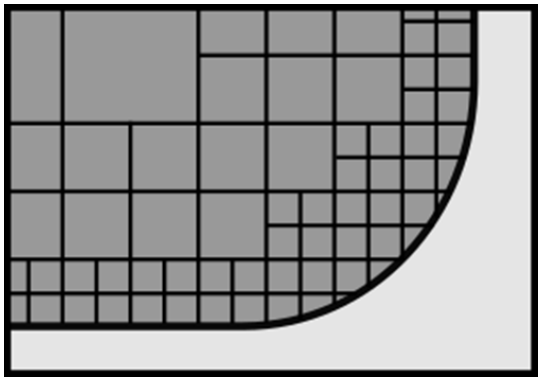
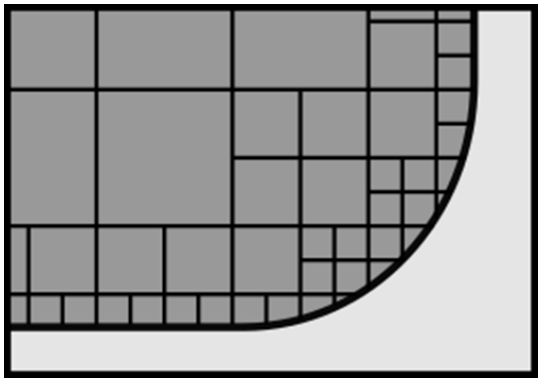
The resulting element grid can be visualized after the simulation by checking **Element grid** under **Auxiliary visualizations** in the Scene Tree.

You can quickly verify the element grid, by running the simulation for one iteration only.

Table 42-7: Controls of the **Simulation settings** section

Control	Description
Min. element size spin boxes	Specify the simulation resolution. You can enter a value either as a physical unit or in a number of voxels. Larger values result in faster simulation and less memory requirement, while smaller values produce more accurate results. A value smaller than 1 voxel is recommended in cases where the diameters of relevant gaps in the object are below 2 to 3 voxels or where the thicknesses of relevant material structures are less than 4 to 5 voxels, to avoid shear locking. For a simulation cell size larger than 1 voxel, the simulation is carried out on a subsampled version of the determined surface. Small structures in the surface are smoothed out and will not be accounted for in the simulation. The effect is stronger for larger simulation cell sizes.

Control	Description
	 Figure 42-4: Smoothing of the determined surface for simulation cell size greater than the voxel size In Figure 42-4, a stress simulation was conducted with a simulation cell size of four times the original voxel size. A slice that shows the von Mises stress field as a color overlay is depicted. The original determined surface is displayed as a white line. The boundary of the color overlay corresponds to the simulated object boundary. The simulation is carried out on a multi-resolution grid of linear hexahedral elements, with a sub-element treatment of material/air boundaries. In particular, elements cutting a material surface are integrated with a non-uniform internal stiffness where only the parts of the element actually located within the object receive a non-zero stiffness. The **Min. element size** controls the size of the smallest elements in the grid. Grid refinement is controlled by the following controls.
Element refinement drop-down list	The simulation is carried out on a multi-resolution grid of linear hexahedral elements, with a sub-element treatment of material/air boundaries. This parameter controls the overall element refinement strategy. • **Based on surface curvature**: The element sizes near surfaces (i.e., determined object surface and the pore surfaces of an included porosity analysis) are determined according to the surface curvature, with smaller elements where the curvature is high. Elements are gradually coarser moving away from the surface. • **At entire surface**: All surfaces are covered by the smallest elements according to **Min. element size**. Elements are gradually coarser moving away from the surface.

Control	Description
Grading factor [%] spin box	Defines a percentage by which neighboring elements are allowed to differ on average. Since actual element sizes can only differ by powers of two, this parameter effectively controls the minimum number of layers of a given element size until an element of the next larger level can appear. • A grading factor of 50% will result in layers with a thickness of 2 elements  Figure 42-5: Element layers with a Grading factor of 50% • A grading of 100% will result in layers with a thickness of 1 element  Figure 42-6: Element layers with a Grading factor of 100%

Control	Description
Elements per quarter circle spin box	Only available when **Based on surface curvature** is selected. This parameter defines an upper limit for the element size near the surface, based on the local curvature radius. It is defined as the number of elements spanning across a distance equal to the curvature radius. Values below 5 are sufficient for coarse grids and values above 10 are recommended for fine grids. Note that the element size will never be less than the **Min. element size**.
Convergence error spin box	The simulation algorithm is an iterative process through which the calculation result converges to the exact solution iteration by iteration. The convergence error is an estimate of how close a given solution is to the exact solution. This parameter specifies an upper threshold for the convergence error. The computation finishes when either the convergence error is below this threshold or the maximum number of iterations (see below) has been performed. A smaller value of the convergence error means higher accuracy in the results. A value of 10^{-6} is usually safe.
Max. number of iterations spin box	A fall-back stopping criterion if the desired convergence error (see above) cannot be reached. The algorithm will stop at the latest iteration after the specified number of iterations has been reached.

Porosity Section

Table 42-8: Controls of the **Porosity** section

Control	Description
Porosity checkbox	When this option is checked, an existing porosity/inclusion analysis (**Void** analysis mode) can be selected in order to consider the effects of the detected voids in the structural mechanics simulation.
Porosity/inclusion analysis drop-down list	Specifies the porosity/inclusion analysis.
Automatic refinement drop-down list	• **Fast**: If necessary, smoothens the indication geometry. • **Accurate**: If necessary, refines the indication geometry to subvoxel accuracy by using Hexagon's surface determination technology.

Analyzed volume Section

Table 42-9: Controls of the **Analyzed volume** section

Control	Description
Exclude area close to boundary constraints checkbox	The simulation result can be unrealistic in the vicinity of the object boundary within the fixed/load ROI because of boundary effects. When this option is checked, the area defined in the **Excluded area size [sim. cells]** spin box around the object boundary within the load ROI or fixed ROI will not be considered in the results.
Excluded area size [min. no. of elements] spin box	Specifies the number of simulation cells around the object boundaries that will not be considered in the results (e.g., hot spots and histograms). Note that this value is multiplied by the **Min. element size** in the **Simulation settings** section, to account for an area size in terms of physical unit (mm) or voxels.
Analyze custom ROI only checkbox	When this option is checked, only the area defined by the ROI specified in the **Custom ROI** drop-down list will be considered in the results (e.g., hot spots and histograms).
Custom ROI drop-down list	Specifies the ROI for defining the area to be considered in the results.

Visualization options Section

Since each visualization option requires additional memory, you can enable or disable the creation of color overlays and force lines for the visualization of the results as well as specify the precision with which they are created. Higher precision results in higher memory consumption. The settings here can be changed even after the calculation has been completed. In this case, you will need to click the **Calculate** button again, but the update will happen quickly because the internal simulation results will be re-used.

Table 42-10: Controls of the **Visualization options** section

Control	Description
Overlay checkboxes	Allow you to enable or disable the creation of color overlays for the following quantities: **Von Mises stress**, **Max. shear stress**, **Max. principal stress**, **Von Mises strain**, **Displacement**, and **Stress tensor and force lines**. For the definition of these quantities, see section *Visualization of the Analysis Results* on page 730. Note that the von Mises stress overlay will always be created. If the creation of a color overlay is enabled, its visibility can still be turned on and off in the Scene Tree after the calculation has been completed.

Control	Description
Precision drop-down lists	• **Normal (8 bit)**: Color/force line information is stored with 8 bit per voxel. This option can encode up to 256 different values. • **High (16 bit)**: Color/force line information is stored with 16 bit per voxel. This option can encode up to 65536 different values. • **Full (32 bit float)**: Color/force line information is stored as a 32 bit floating point number per voxel. This option preserves the full simulation precision. The specified precisions affect the color overlays, the annotations, and the hot spot calculation. The histograms, however, are always based on the full simulation precision, regardless of these settings.
RAM required field	Indicates the predicted approximate peak additional memory requirement, which corresponds to the current settings.

Calculate hot spots Section

Allows you to detect local maxima of an underlying field (e.g., the von Mises stress field).

Table 42-11: Controls of the **Calculate hot spots** section

Control	Description
Calculate hot spots checkbox	When this option is checked, local maxima of an underlying field, e.g., the stress field, will be detected. Hot spots can be calculated for the quantities checked in the **Visualization options** section as well as for the differences between these quantities if a comparison of two analyses has been calculated.
Based on drop-down list	Specifies the quantity for hot spot calculation: **Von Mises stress**, **Max. shear stress**, **Max. principal stress**, **Von Mises strain**, or **Magnitude of displacement**. For the definition of these quantities, see section *Visualization of the Analysis Results* on page 730. For **Max. shear stress**, **Max. principal stress**, or **Magnitude of displacement**: The selected option must be checked in the **Visualization options** section. For **Δvon Mises stress**, **Δmax. shear stress**, **Δmax. principal stress**, **Δvon Mises strain** or **Δmagnitude of displacement**: The quantity must be calculated in two analyses, and the comparison must have been calculated.

Control	Description
Threshold spin box	Specifies a threshold to be applied to the field. The areas where the field value is larger than the threshold are regarded as hot spots. You can set an absolute value or a volume percentile. If the volume percentile is selected, the respective volume fraction with the highest stress value will be regarded as a hot spot. After calculation, the corresponding absolute threshold will be displayed in the field at the far right.
Min. volume spin box	Specifies the minimum volume of a hot spot to be included in the result, i.e., hot spots smaller than the specified volume will be filtered out. You can enter a value as a physical unit or in a number of voxels.

Stress hot spots found directly adjacent to the fixed or loaded ROIs may be numerical artifacts. For details, see section *Singularities Near the Boundary Conditions* on page 735.

Compare with reference analysis Section

Table 42-12: Controls of the **Compare with reference analysis** section

Control	Description
Compare with reference analysis checkbox	When this option is checked, results from a reference structural mechanics simulation that was conducted on the same or a similar object can be loaded for comparison purposes.
Reference analysis drop-down list	Specifies the reference analysis that the current analysis is to be compared to.
Comparison function (Δ) drop-down list	This function only affects the fields shown in the Scene Tree as **Comparison results** (Δ). • **Signed difference**: Uses the signed difference between current analysis and reference analysis as a basis for the calculation of the comparison. • **Magnitude of difference**: Uses the magnitude of difference between the current analysis and reference analysis as a basis for the calculation of the comparison.

Integration mesh Section

Allows you to create an integration mesh or select an existing integration mesh to obtain the results of the structural mechanics simulation for each mesh cell.

On the **Mesh cells** tab, the values for the stress tensors, the von Mises stress, the maximum shear stress, and the maximum principal stress will depend on the specified stress.

Table 42-13: Controls of the **Integration mesh** section

Control	Description
Integration mesh checkbox	When this option is checked, the options for using an integration mesh will be enabled.
Sample locations based on maxima of drop-down list	Allows you to specify which stress field maximum is indicated by the **Position** entry of each cell.
Integration mesh drop-down list	Allows you to specify an integration mesh by selecting an existing mesh from the drop-down list.
Create… button	Creates an integration mesh and opens the **Mesh** dialog for adjusting the parameters manually.

File list Tab

Displays a list of the files containing the data of the imported simulation results.

Statistics Tab

Simulation performance Section

Table 42-14: Fields of the **Simulation performance** section

Control	Description
Convergence error	Indicates the convergence error actually reached. This value can be greater than the target error set by the user (for example, when the algorithm stops because the maximum number of iterations has been reached).
Degrees of freedom	Indicates the total number of degrees of freedom of the finite elements in the simulation.
Simulation time	Indicates the actual time spent for simulating.
Total number of iterations	Indicates the actual number of iterations calculated. This value is equal to or less than the corresponding simulation parameter set by the user.

Geometry of analyzed volume Section

Table 42-15: Controls of the **Geometry of analyzed volume** section

Control	Description
Volume [<length unit>³] field	Indicates the volume that is analyzed in the simulation. This volume depends on the simulation cell size and on the settings specified in the **Analyzed volume** section.
Simulation cell size field	Indicates the simulation grid resolution as a length.
Simulation cell volume field	Indicates the simulation grid resolution in a volumetric dimension.

Von Mises stress, **Max. shear stress**, **Max. principal stress**, **Von Mises strain**, and **Magnitude of displacement** Sections

Table 42-16: Controls of the **Von Mises stress**, **Max. shear stress**, **Max. principal stress**, **Von Mises Strain**, and **Magnitude of displacement** sections

Control	Description
Max. value field	Indicates the maximum value of the quantity.
Mean value field	Indicates the mean value of the quantity.
Percentile field	Indicates the value of percentile defined in the **Percentile** spin box at the bottom of the tab.

Table 42-17: Controls of the **Statistics** tab

Control	Description
Percentile spin box	Specifies a volume percentile for each of the **von Mises stress**, **Max. shear stress**, **Max. principle stress**, **von Mises strain**, and **Magnitude of displacement** quantities.
Copy CSV to clipboard button	Copies the statistics results in CSV format to the system clipboard.
Export CSV to file button	Allows you to export the statistics results in CSV format.

Histograms Tab

Shows the volume histogram within the determined surface of the selected object for the selected quantity. The histogram bars can be colored according to the settings on the **Colors** tab.

Controls of the **Histograms** Tab

Table 42-18: Controls of the **Histograms** tab

Control	Description
Select drop-down list	Specifies the quantity to be shown in the histogram.
Color drop-down list	• **From color bar**: The values in the histogram are shown according to the color bar. • **Gray**: All values in the histogram are shown in gray.
Normalization drop-down list	• **Absolute**: Displays the volume in absolute values. • **Relative**: Displays the volume in relative values with respect to the entire volume within the determined surface.
Binning drop-down list	• **Off**: No binning is applied to the values shown in the histogram. • **From color bar**: The original values in the histogram are replaced by a value representative for the corresponding interval (“bin”) of the color bar. The “bins” become visible when “stepped” sections are created on the **Colors** tab. • **Manual number of bins**: Enables the **Bin count** spin box, where you can enter the required number of “bins.” • **Manual bin width**: Enables the **Bin width** spin box, where you can specify the width of the individual bins.
Left/**Right** spin box	Only enabled when an interval has been created: Moves the left or right interval border to the specified value. You can also click and drag the interval borders using the left mouse button.

Control	Description
Create button	Creates a new interval. On the right hand side of a selected interval, statistical information is displayed: • **Left**: Indicates the minimum value of the selected quantity within the interval, i.e., the left interval border. • **Right**: Indicates the maximum value of the selected quantity within the interval, i.e., the right interval border. • **Mean**: Indicates the mean value of the selected quantity within the interval. • **Dev**: Indicates the standard deviation of the selected quantity within the interval. • **Sum**: Indicates the volume within the interval. • **Percentage**: Indicates the percentage of the volume within the interval. Note that the statistical information may change with the number of bins specified in the **Bins** field.
Remove button	Removes the selected interval.
Create ROI button	Generates a new ROI containing all voxels whose volumes lie within the selected interval.
use RMB to click the chart area	Displays a context menu (see below).
scroll MW in chart area or x-axis up/down	Zooms the x-axis of the chart out/in.
scroll MW in y-axis up/down	Zooms the y-axis of the chart out/in.
use LMB to click and drag the x-axis	Scrolls the x-axis.
use LMB to click and drag the y-axis	Scrolls the y-axis.
Zoom in/out	Zooms the corresponding axis in/out.
Reset zoom	Fits the entire chart to the current window size.

Context Menu of the **Histograms** Tab

Right-clicking anywhere in the chart area opens a context menu with the following options:

Table 42-19: Context menu items

Control	Description
Export as CSV...	Opens a dialog for saving the chart values to a *.csv* file.
Copy to clipboard	Copies a screenshot of the chart to the system clipboard so you can paste it into another application.

Control	Description
Show/Hide x/y grid	Toggles the visibility of the grid lines for the corre-sponding axis.
Reset zoom	Fits the entire chart to the current window size.
Create interval	Creates a new interval. For details on the statistical information, see section *Controls of the Histograms Tab* on page 713.
Remove interval	Removes the selected interval.
Create ROI	Generates a new ROI containing all voxels whose volumes lie within the selected interval.

Colors Tab

Here you can specify the color-coding scheme used for the representation of the simulation results.

Select Section

Specifies the quantity for which you want to specify the color-coding scheme.

Caption Section

Table 42-20: Controls of the **Caption** section

Control	Description
Caption field	Indicates the color bar headline as specified in the **Caption** field of the **Color bar** section.
Share color bar checkbox	When this option is checked, all analyses of the same type (and—if applicable—of the same algorithm) will use the same color bar. When this option is unchecked, the color bar settings will apply to the selected analysis only.

LUT – Color Lookup Table

The color lookup table (LUT) shows the partitioning into color sections.

Sections Section

Defines the appearance of each color section.

Table 42-21: Controls in the **Sections** section

Control	Description
From/To fields	Specify the start and end values of the color sections. The first color section represents all values above the upper limit, i.e., the value in the **From** field (**+inf** signifies positive infinity), while the last color section represents all values below the lower limit, i.e., the value in the **To** field (**-inf** signifies negative infinity). The default limits are calculated from the results of the analysis (for an analysis color bar) or taken from the **Default** preset (for a tolerance deviation color bar).
Type field	Switches between the color schemes **Continue**, **Constant**, **Gradient**, **Rainbow**, **Reverse rainbow**, **Hue cycle**, **Green to red**, and **Red to green**.
Color/transparency field	Double-clicking the field for the **Continue**, **Constant**, and **Gradient** color schemes opens the **Select Color** dialog where you can modify the appearance of the selected color scheme. For the **Gradient** color scheme, you can specify the start and end colors by double-clicking the left or right side of the field, respectively. Double-clicking the field for the **Rainbow**, **Reverse rainbow**, **Hue cycle**, **Green to red**, and **Red to green** color schemes opens the **Transparency** dialog, where you can set the transparency for the selected color scheme.
use RMB to click a color section	Opens a context menu with the following items: • **Split**: Subdivides the color section into two new color sections where each represents half of the original section. • **Merge**: Combines several color sections to a single color section. Only consecutive intervals can be merged.
Create smooth button	Opens the **Create smooth table** dialog to generate one color section. • **Type** drop-down list: Allows you to select the type of coloring scheme. • **From/To** spin boxes: Specify the value range covered by the color section.

Control	Description
Create stepped button	Opens the **Create stepped table** dialog to generate a set of color sections. • **Type** drop-down list: Allows you to select the type of coloring scheme. • **From/To** spin boxes: Specify the value range covered by the color sections. • **Step** spin box: Specifies the step size of the individual color sections.
Auto scale button	If available: Fits the color LUT to the range of the results of all available analyses.
Auto scale color bar range on calculate checkbox	If available: When this option is checked, the color LUT will be automatically fitted to the range of the results of all available analyses.
Default button	If available: Resets any changes made to the **Sections** table.

Color LUT Settings Section

Specifies the appearance of the color lookup table.

Table 42-22: Options for the appearance of the color lookup table

Control	Description
Auto tick marks checkbox	When this option is checked, equidistant tick marks will be produced for the color bars. When this option is unchecked, tick marks will appear only at the color section boundaries of the color lookup table.
Auto scale color bar range on calculate checkbox	When this option is checked, the color LUT will be automatically fitted to the range of the results of all available analyses.

Preset selection Section

Table 42-23: Controls in the **Preset selection** section

Icon	Item	Description
	drop-down list	Specifies the preset to be applied, to be edited, or to be taken as a basis for a new preset. The following icons are used: • default preset • customized preset • appears next to the icon of a preset that has been modified but not yet saved

Icon	Item	Description
	Save preset	Opens the **Save preset** dialog for saving the color LUT of the current data set under the specified name. • **Absolute preset**: When this option is checked and the preset applied, the settings of the original data set, including the LUT range, will be applied. When this option is unchecked, the color settings of the preset will be mapped relatively to the actual range of results of the analysis to which the preset will be applied.
	Remove preset	Removes the selected preset from the preset drop-down list.
	Import preset	Imports a preset from the specified location.
	Export preset	Exports the selected preset to the specified location.

Color bar Section

Specifies the settings for the color bar.

Table 42-24: Settings for the color bar

Control	Description
Visibility drop-down list	Switches the color bar on/off.
Positioning drop-down list	Specifies the location of the color bar within the 2D and 3D windows: **Left, Right, Top, Bottom, All - automatic, Left or right - automatic, Top or bottom - automatic**.
Caption field	Specifies the color bar headline by using placeholders.
Reset button	Resets the **Caption** field to the default entry.

Hot spots Tab

Lists all calculated hot spots and their properties.

The **Hot spots** table consists of the following columns:

Table 42-25: Columns of the **Hot spots** table

Column	Description
Max./Min./Mean value [<unit>]	Indicates the maximum, minimum, and mean value of the quantity selected for the calculation of the hot spot.
Std. deviation [<unit>]	Indicates the standard deviation.
Volume [<length unit>^{3}]	Indicates the volume of the hot spot.

Column	Description
Pos. of max. value x/y/z [<length unit>]	Indicates the position of the largest value of the hot spot.
Description	Allows you to enter a description for the hot spot used for reporting.
Image	Allows you to add a detailed 2D image and object description on a separate page of the report. • **Off**: No image is created (default). • **Orthographic projection**: Creates three orthogonal views. • **Top/Bottom/Left/Right/Front/Back**: Creates a single 2D view in the specified orientation. • **... - If not OK**: Automatically creates the image if the tolerance status is **Out of tolerance**. (Currently not implemented.) The image orientation corresponds to the currently selected coordinate system. The image will be generated according to the render settings specified during report creation or VGRF-based export. If **Automatic** is selected from the **Visibility** drop-down list in the **General rendering settings** section, the color overlay specified by the **Based on** option in the **Calculate hot spots** section of the **Settings** tab will be shown. The 2D slice position used for taking the image is determined by the position of the maximum value of the hot spot. The zoom factor of the image is selected so that the entire parent object is visible.
Focused image	This option is almost identical to the **Image** option but will generate an image that focuses on the respective item and is zoomed in by the **Zoom factor** specified during report creation or VGRF-based export.
Captures	Indicates the number of images captured for this hot spot by using the **Capture from** button in the **Screen-shots** section.

Annotations Tab

Lists all annotations created for the selected simulation. You can view the information supplied by the annotations or edit the annotation properties.

For details on how to create an annotation, see section *Annotation* on page 124 in chapter 6 *Inspect Tab*.

To create new annotations in the table, it is also possible to paste previously copied coordinates by right-clicking the table and selecting **Paste** from the context menu or by pressing the **Ctrl** + **V** keyboard shortcut. For details, see the **Paste** menu item in section *Table Context Menu*.

Double-clicking an analysis annotation in the Scene Tree will directly open the **Annotations** tab of the properties dialog of the corresponding analysis.

The **Annotations** table consists of the following columns:

Table 42-26: Columns of the **Annotations** table

Column	Description
Name	Indicates the name of the annotation.
Pos. x/y/z [<length unit>]	Indicates the position of the annotation.
Von Mises stress [<unit>]	Indicates the von Mises stress at the position of the annotation.
Magnitude of displacement [<length unit>]	Indicates the magnitude of displacement at the position of the annotation.
Displacement x/y/z [<length unit>]	Indicate the x-, y-, and z-components of the displacement vector at the position of the annotation. In the linear approximation used here, the simulation results are valid only if the displacements are very small compared to the extent of the simulated object.
Stress tensor xx/xy/xz/yy/yz/zz [<unit>]	Indicate the xx-/xy-/xz-/yy-/yz-/zz-components of the stress tensor.
Von Mises strain	Indicates the von Mises strain at the position of the annotation.
Description	Allows you to enter a description of the annotation used for reporting.

Column	Description
Image	Allows to add a detailed 2D image and object description on a separate page of the report. • **Off**: No image is created (default). • **Orthographic projection**: Creates three orthogonal views. • **Top/Bottom/Left/Right/Front/Back**: Creates a single 2D view in the specified orientation. • **... - If not OK**: Automatically creates the image if the tolerance status is **Out of tolerance**. (Currently not implemented.) The image orientation corresponds to the currently selected coordinate system. The image will be generated according to the render settings specified during report creation or VGRF-based export. If **Automatic** is selected from the **Visibility** drop-down list in the **General rendering settings** section, the **Von Mises stress** color overlay is shown. The 2D slice position used for taking the image is determined by the position of the annotation. The zoom factor of the image is chosen such that the entire parent object is visible.
Focused image	This option is almost identical to the **Image** option, but will generate an image that focuses on the respective item and is zoomed in by the **Zoom factor** specified during report creation or VGRF-based export.
Captures	Indicates the number of images captured for this object using the **Capture from** button in the **Screenshots** section.
Tolerance status	Currently not implemented.
Type	Indicates how the annotation has been created: • **Manually defined**: The annotation has been defined by the user.

Force lines Tab

Specifies the appearance of the force lines for the 2D windows and the 3D window.

Table 42-27: Controls of the **Force lines** tab

Control	Description
Length (1-100) spin box	Specifies the length of the individual force lines.
Density (1-100) spin box	Specifies the density and thus the number of force lines.

Control	Description
Width (1-100) spin box	Specifies the width of the individual force lines.
Show in 3D window checkbox	Switches the visibility of the force lines in the 3D window on or off. Note that the **Force lines** checkbox in the Scene Tree must also be checked in order to display the force lines.

Mesh cells Tab

Displays the results of the structural mechanics simulation for each cell of the integration mesh.

The **Mesh cells** tab is available only if an integration mesh has been specified in the **Integration mesh** section on the **Settings** tab.

Assignment of the stress values to the integration mesh cells:

a) For an integration mesh cell that does not contain the center of a simulation cell, the stress value at its center will be assigned to that cell.

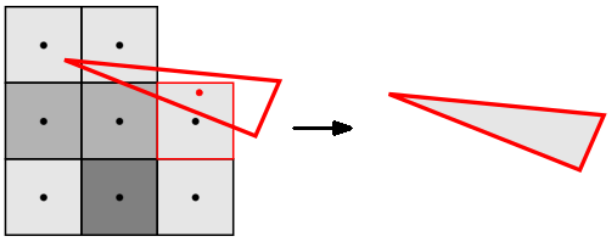


Figure 42-7: Stress value at the center of the integration mesh cell assigned to the cell

b) For an integration mesh cell that contains one or more simulation cell centers, the stress values of those simulation cells are taken into account together with the stress value at the center of the integration mesh cell. The highest stress value will be assigned to the integration mesh cell.

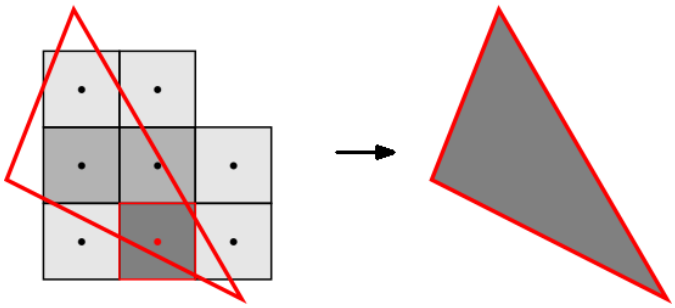


Figure 42-8: Highest stress value assigned to the cell

c) For an integration mesh cell that does not contain the center of a simulation cell and has its center outside any simulation cell, no stress value is assigned to the integration mesh cell.

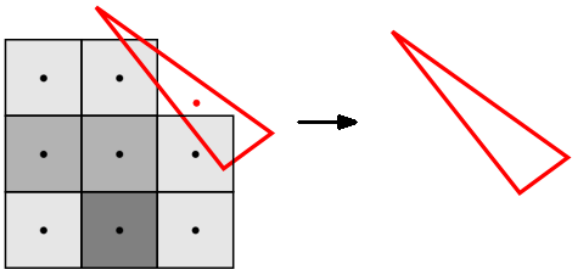


Figure 42-9: No stress value assigned to the cell

The **Position** entries depend on the stress specified in the **Sample locations based on maxima of** drop-down list on the **Settings** tab. The remaining entries are the results at the indicated position.

You can export the results from the **Mesh cells** tab and use them to compare real part properties with simulations of manufacturing processes or improving FE simulations for testing the stability of objects (e.g., of injection-molded parts).

Table 42-28: Columns of the **Mesh cells** list

Column	Description
Element ID	If available, indicates the ID of the mesh cell for imported integration mesh files.
Pos. x/y/z [<length unit>]	Indicates the position of the stress specified in the **Integration mesh** section on the **Settings** tab.
Stress tensor xx/xy/xz/yy/yz/zz [<unit>]	Indicate the xx-/xy-/xz-/yy-/yz-/zz-components of the stress tensor at the indicated position.
Von Mises stress [<unit>]	Indicates the von Mises stress at the indicated position.
Max. shear stress [<unit>]	Indicates the maximum shear stress at the indicated position.
Max. principal stress [<unit>]	Indicates the maximum principal stress at the indicated position.
Von Mises strain	Indicates the von Mises strain at the indicated position.
Displacement x/y/z [<length unit>]	Indicates the displacement in the x-, y-, and z-direction of the mesh cell.
Magnitude of displacement [<length unit>]	Indicates the magnitude of displacement of the mesh cell.
Description	Allows you to enter a description for the cell used for reporting.

Column	Description
Image	Allows you to add a detailed 2D image and object description on a separate page of the report. • **Off**: No image is created (default). • **Orthographic projection**: Creates three orthogonal views. • **Top/Bottom/Left/Right/Front/Back**: Creates a single 2D view in the specified orientation. The image orientation is relative to the currently selected coordinate system. The image will be generated according to the render settings specified during report creation or VGRF-based export. The 2D slice position used for taking the image is determined by the position of the cell. The zoom factor of the image is chosen so that the entire parent volume is visible.
Focused image	This option is almost identical to the **Image** option but will generate an image that focuses on the respective item and is zoomed in by the **Zoom factor** specified during report creation or VGRF-based export.
Captures	Indicates the number of images captured for this cell by using the **Capture from** button in the **Screenshots** section.

General Table Controls

- List section

  The following table provides an overview of the general controls available in the various list views:

  Table 42-29: Controls in the list section

Control	Description
button	Opens a submenu for selecting the filter/search mode.

Control	Description
Filter	Clicking the **Click to add a filter or search criterion** field to the right of the icon opens a series of drop-down lists from which you can select a table column, an operator, and—depending on the column—a value. If a column does not offer a value drop-down list, you can type in a value. When the selection is complete, the table shows the rows matching the filter criterion. Clicking the **+** button or the **Click to add a filter or search criterion** field allows you to specify more filter criteria. Clicking the **x** button removes the filter.
Search	Clicking the **Click to add a filter or search criterion** field to the right of the icon opens a series of drop-down lists from which you can select a table column, an operator, and—depending on the column—a value. If a column does not offer a value drop-down list, you can type in a value. When the selection is complete, the table rows matching the search criterion are highlighted. Clicking the **+** button or the **Click to add a filter or search criterion** field allows you to specify more search criteria. Pressing **F3** jumps to the next search result in the list. Clicking the **x** button removes the search.
Full-text filter	Entering a value or text string into the input field to the right of the icon filters the table accordingly and shows the rows that match the filter criterion.
Full-text search	Entering a value or text string into the input field to the right of the icon searches the table accordingly and highlights the rows that match the search criterion.
use LMB to click on a table row	Selects the row and the corresponding object in the Scene Tree. In analysis result lists, the result, e.g., the component, is marked by a cross-hairs cursor in each of the 2D views.
hold **Ctrl** key + use LMB to click on several table rows	Selects the rows and the corresponding objects in the Scene Tree.
hold **Shift** key + use LMB to click on two separate table rows	Selects the two rows, including all rows between the two as well as the corresponding objects in the Scene Tree.
hold **Shift** key + use up/down arrow keys	Selects the rows and the corresponding objects in the Scene Tree.

Control	Description
press **Ctrl+A**	Selects all table rows.
use up and down arrow keys	Steps up and down through the table rows.
use RMB to click into the table area	Displays a context menu. See below.
use LMB to click a column heading	Sorts the table according to the values of the column. Clicking subsequently toggles between ascending and descending.
use LMB to click and drag column heading to new position, then release LMB	Inserts the column at the new position.
use LMB to double-click cell highlighted in white (light theme) or medium gray (dark theme)	If applicable: Allows you to edit the contents of the cell.

- **Screenshots** section (if available)

  The **Screenshots** section below the list section allows you to capture images from one of the 2D windows, the 3D window, or the current window layout for the item currently selected in the table. Only available if exactly one row is selected.

  Table 42-30: Controls in the **Screenshots** section

Control	Description
Capture from button	Adds the image of the view selected from the drop-down list to the preview area above.
use LMB to click and drag one or more images, then release LMB	Moves the image(s) to the new position.
double-click the image	Opens the **Snapshot display** window showing the image: • **Zoom in**/**Zoom out** button: Zooms the image in/out. You can also move the mouse pointer in the image area and turn the mouse wheel. • **Fit to window** button: Resets the zoom so that the image fits into the window.
click the **<no description>** placeholder twice (first click to select, second click to enable renaming)	Allows you to label the image.
Delete selected button	Deletes the selected image from the preview area.

Table Context Menu

Right-clicking anywhere in the table area shows a context menu with the following options:

Table 42-31: Context menu items

Control	Description
Columns	Allows you to toggle the visibility of each column by checking/unchecking the respective item. • **Show all**: Checks all columns to set them to visible. • **Hide all**: Unchecks all columns to set them to invisible. • **Hide empty**: Unchecks all not editable columns which are empty or **n/a** to set them to invisible.
Trim columns	Resizes all columns to their smallest possible size.
Apply default column layout	Applies the default column layout previously saved by the user to the current table. If no default column layout has been saved, the original column layout will be applied.
Save as default column layout	Saves modifications applied to the table—e.g., the visibility of a column, the order in which the columns appear, the column width—as default column layout. This layout will be applied when you create a new project.
Apply original column layout	Restores the original table layout and discards any modifications applied by the user. The original table layout is predefined and cannot be modified by the user.
Remove entries	If applicable: Deletes the selected row(s) from the table.
Create annotations	If applicable: Creates annotations for the selected items.
Export as CSV...	Opens the **Export as CSV...** dialog for exporting the table values as **.csv* file. This option always exports the complete table even if a filter was applied. In order to export only the filtered rows, press **Ctrl** + **A** to highlight all filtered rows and use the **Copy to clipboard** menu item.
Copy to clipboard	Copies the selected rows as well as the column heading into the system clipboard. The clipboard information is provided both as plain text and rich-text table, so when pasting into a rich-text-capable application like a word processor, you will see a proper table with cell borders and bold headings.

Control	Description
Paste	For annotation tables: Pastes previously copied coordinates and—optionally—snap directions to create new annotations in the table. For annotations of a nominal/actual comparison, the search distance specified on the **Settings** tab of the analysis will be considered. Note: Pasted annotations will be interpreted in the selected coordinate system at the time of pasting. The information in the clipboard must have the following structure: • x-, y-, and z-coordinate of the annotation or • x-, y-, and z-coordinate of the annotation as well as x-, y-, and z-component of the vector for the snap direction The parameters can be separated by space, tab, semicolon, or comma (if a comma is already used as a decimal mark or digit grouping symbol, the values must be enclosed in double quotation marks). Example: 8.89;25.82;-0.55;1;0;0 You can also copy the information directly from the cells of a spreadsheet. In order to paste the annotation information, you can also press the **Ctrl** + **V** keyboard shortcut.
Set as active column	If applicable: Makes the current column the active column, i.e., the results of this column are color-coded according to their values as defined by the color lookup table and the colors specified in the **Sections** section of the **Colors** tab.
Unset active column	If applicable: Deselects the currently active column and sets the **Active column** drop-down list on the corresponding **Settings** tab to **Uncoded**, i.e., removes any color coding.
Enter/change value (all items)	If applicable: Opens the **Enter value** dialog (see below) where you can enter the desired value for the selected parameter. This value will be applied to all entries in the table.
Enter/change value (selected items)	If applicable: Opens the **Enter value** dialog (see below) where you can enter the desired value for the selected parameter. This value will be applied to the selected entries in the table.
Delete selected items	If applicable: Removes the selected items from the scene.

The **Enter value** dialog includes the following controls:

Table 42-32: Controls in the **Enter value** dialog

Control	Description
Enter value field	Allows you to enter the desired value.
OK button	Sets the selected parameter to the specified value.
Reset button	For analyses only: Resets the selected parameter to undefined.
Set from tolerance settings button	For analyses only: Enters the value specified in the tolerance settings of the analysis for the selected parameter.
Cancel button	Discards the changes and closes the dialog.

Images Tab

Allows you to take screenshots of the selected workspace views and/or add bookmark references to the report. In the final report, the captured images will be listed separately from the screenshots created on other tabs.

- **Snapshots** section

  Table 42-33: Controls in the **Snapshots** section

Control	Description
Capture from button	Adds the image of the view selected from the drop-down list to the preview area above.
Delete selected button	Deletes the selected image(s) from the preview area.
use LMB to click and drag one or more images, then release LMB	Moves the image(s) to the new position.
double-click the image	Opens the **Snapshot display** window showing the image: • **Zoom in**/**Zoom out** button: Zooms the image in/out. You can also move the mouse pointer on the image area and turn the mouse wheel. • **Fit to window** button: Resets the zoom so that the image fits into the window.
click the **<no description>** placeholder twice (first click to select, second click to enable renaming)	Allows you to label the image.

- **Automatic 3D images** section (if available)

  Check the corresponding checkbox to include the desired 3D view (e.g., **Top**, **Front**, **Top-left-front**, and **Current camera settings**) in the report without changing the 3D view.

- **Bookmark references** section

  Allows you to add bookmark references via drag and drop from the **Bookmarks and views** tool or the **Bookmark editor** to the preview area. The images of the referenced bookmarks will then be included in VGRF-based reports.

  When you open a project with missing bookmark images, placeholders will be shown instead.

  Bookmark references are stored in evaluations and can be used in automation scenarios.

You will still need to import a bookmark template containing the actual bookmarks in these cases, as evaluations store only references to them.

Table 42-34: Controls in the **Bookmark references** section

Control	Description
New bookmark button	Adds a bookmark of the current view to the preview area.
Remove button	Removes the bookmark currently selected in the preview area.
click the bookmark title twice (first click to select, second click to enable renaming) or press the **F2** key	Allows you to rename the bookmark. The changes made on the **Images** tab will also affect the **Bookmark editor** and the **Bookmarks and views** tool. If the renamed bookmark is referenced by one or more objects for reporting, a warning message will be displayed indicating that the referenced bookmark will also be renamed for all these objects in the report.

The global concept of bookmark references allows for multiple objects to reference the same bookmark and for objects to reference bookmarks that show arbitrary information, e.g., other analyses or objects.

Visualization of the Analysis Results

Various overlays are provided for the visualization of the analysis results in the 2D and 3D windows. These overlays can be switched on or off in the Scene Tree tool below the analysis node by checking or unchecking the corresponding checkboxes.

Auxiliary Visualizations

- **Element grid**

  Displays a graphical representation of the finite element grid in the 2D windows. Each tile in the checkerboard pattern represents one hexahedral element.

Load Case Definition

- **Fixed ROI** overlay

  The fixed ROI is represented in red. This overlay is available both in uncalculated and calculated states.
- **Load ROI** overlay

  The load ROI is represented in green. This overlay is available both in uncalculated and calculated states.
- **Force arrow** overlay

  This overlay visualizes the applied force. Depending on the force type, the force is either represented by a single arrow (for **Directed force**) or by five arrows in a circle (for **Torque**). For the force type **Pressure**, this overlay is not available. This overlay is available both in uncalculated and calculated states.

Simulation Results

All stress- and strain-related results (**Max. principal stress**, **Max. shear stress**, **Von Mises strain**, and **Von Mises stress**) are provided as average values within each simulation element. To display the exact results, interpolation of colors is disabled, regardless of whether the **Interpolation mode** in the 2D windows is switched on or off.

- **Force lines** overlay

  The stress tensor field is shown in the form of force lines (tension = green, compression = red). The force lines point in the direction of the eigenvectors of the stress tensor. As such, they cross each other in the normal direction. The magnitudes of the eigenvalues are encoded in the force line density. The appearance of the force lines can be tuned by setting their base length, width, and density. If the force lines are enabled in the **Visualization options** section, the full stress tensor will be available in the **Annotations** table.
- **Magnitude of displacement** overlay

  The length of the displacement vector is shown color-coded at each point in the object. If the displacement is turned on in the **Visualization options** section, the x-, y-, and z-components of the displacement will be available in the **Annotations** table.

In the linear approximation used here, the simulation results will only be valid if the magnitude of displacement is very small compared to the extent of the simulated object.

- **Max. principal stress** overlay

  The maximum principal stress is shown color-coded at each point in the object. The maximum principal stress is the largest eigenvalue of the stress tensor.
- **Max. shear stress** overlay

  The maximum shear stress, also known as the Tresca yield criterion, is used for predicting failure of ductile material, such as most metals, because of yielding. It is shown color-coded at each point in the object.
- **Von Mises strain** overlay

  The von Mises strain is the equivalent strain used for describing the state of strain of ductile material, such as most metals, based on the von Mises criterion.
- **Von Mises stress** overlay

The von Mises stress is used for predicting the failure of ductile material, such as most metals, because of yielding based on the von Mises criterion. It is shown color-coded at each point in the object.

Comparison Results

- Δ **max. principal stress** overlay

  The Δ maximum principal stress is the difference between the maximum principal stress of the current analysis and the reference analysis, and is shown color-coded at each point in the object.
- Δ **magnitude of displacement** overlay

  The Δ magnitude of displacement is the difference between the magnitude of displacement of the current analysis and the reference analysis, and is shown color-coded at each point in the object.
- Δ **max. shear stress** overlay

  The Δ maximum shear stress is the difference between the maximum shear stress of the current analysis and the reference analysis, and is shown color-coded at each point in the object.
- Δ **von Mises strain** overlay

  The Δ von Mises strain is the difference between the von Mises strain of the current analysis and the reference analysis, and is shown color-coded at each point in the object.
- Δ **von Mises stress** overlay

  The Δ von Mises stress is the difference between the von Mises stress of the current analysis and the reference analysis, and is shown color-coded at each point in the object.

Continuing or Recalculating a Structural Mechanics simulation

There are several possibilities for continuing or recalculating a structural mechanics simulation by making use of previously computed results:

- Stop a running calculation and continue it with the same or with different parameters (status **Manually stopped (continuable)**).
- Continue a finished calculation with different parameters (status **Result is up to date (continuable)**).

☞ The parameters that can be changed for continuing a simulation are **Convergence error** and/or **Max. number of iterations**. Changing any other parameter will invalidate the intermediate results, and—depending on the parameter changed—a complete or a partial recalculation may be necessary.

- Partially recalculate the simulation with different visualization options and/or hot spots parameters (status **Result is up to date**, **Result is up to date (continuable)**, **Manually stopped**, or **Manually stopped (continuable)**).

Stopping and Continuing a Calculation

Depending on the selected parameters, calculating a structural mechanics simulation may take a long time. In order to view intermediate results and decide on the suitability of the parameters, it may be useful to stop the analysis, inspect the intermediate results, and either continue with the same or with different parameters.

After you have clicked the **Calculate** button on the **Settings** tab, the progress of the calculation will be shown in the **Calculating...** dialog.

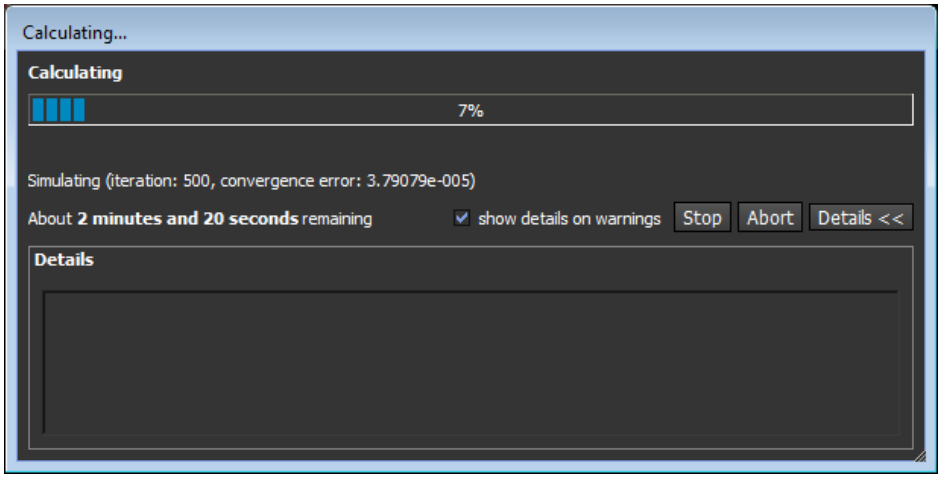


Figure 42-10: Calculating... dialog

Table 42-35: Controls of the **Calculating...** dialog

Control	Description
Show details on warnings checkbox	When this option is checked, the messages section will automatically unfold if a warning message is issued. Apart from that, the **Calculating...** dialog will remain open after the calculation has been completed. When this option is unchecked, the messages section will only unfold when you click the **Details** button, and the **Calculating...** dialog will close automatically after the calculation has been completed.
Stop button	This button becomes enabled as soon as intermediate results are available. Clicking this button stops the calculation and changes the status of the analysis to **Manually stopped (continuable)**. The intermediate results are shown.
Abort button	Aborts the analysis without displaying any results.
Details button	Unfolds or collapses the messages section.
Close button	Available after the calculation has been finished if the **Show details on warnings** checkbox had been checked and warnings are present in the messages section. Closes the **Calculating...** dialog.

To continue the analysis with the same parameters, click the **Calculate** button at the bottom of the **Structural mechanics simulation** dialog. The analysis will continue from the point where it has been stopped.

To continue the analysis with different parameters, change at least one of the **Convergence error** and **Max. number of iterations** parameters. As soon as you change one of these parameters, the status will change to **Calculation required**. Clicking the **Calculate** button will start the calculation from the point where it has been stopped.

Changing any parameter other than **Convergence error** or **Max. number of iterations** will invalidate the intermediate results, and—depending on the parameter changed—a complete or a partial recalculation will be necessary.

Continuing a Finished Calculation

After an analysis has been completed and the project has not yet been closed and reloaded and the **Edit > Free memory/Clear undo queue** command has not been carried out, it is still possible to continue the simulation with different **Convergence error** or **Max. number of iterations** parameters. This status is indicated by the message **Result is up to date (continuable)** in the status bar of the **Structural mechanics simulation** dialog. As soon as you change one of these parameters, the status will change to **Calculation required**. Clicking the **Calculate** button will start the calculation from the point where it has been stopped.

Changing any parameter other than **Convergence error** or **Max. number of iterations** will invalidate the intermediate results, and—depending on the parameter changed—a complete or a partial recalculation will be necessary.

Freeing Temporary Memory

In order to keep a calculation continuable, large amounts of internal information as well as the actual calculation results must be stored in memory. When a calculation is finished, it is therefore recommended that you delete the internal information in order to ensure that the application remains most responsive. For this purpose, either select **Edit > Free memory/clear undo queue** or save and reload the project.

Since the internal information required for continuing a calculation is not saved in the project, a calculation cannot be continued after the project has been closed and reloaded.

Partially Recalculating the Simulation

If the analysis is in one of the green states—**Result is up to date**, **Result is up to date (continuable)**, **Manually stopped**, or **Manually stopped (continuable)**—and one of parameters in the **Visualization options** or **Calculate hot spots** sections is changed, the analysis will go to the **Calculation required** state. However, when the **Calculate** button is clicked, the recalculation will be performed quickly, since the internally stored results will be re-used.

How to Obtain Reliable Results

Convergence Error

The simulation algorithms in VGSTUDIO MAX are iterative processes. The calculation result converges towards the exact solution iteration by iteration. In some cases, especially in highly structured or porous objects and/or with the Poisson's ratio reaching its upper limit of 0.5, approaching the exact solution is numerically difficult. It is therefore important to let the algorithm converge sufficiently, i.e., run a sufficient number of iterations. You can set the maximum convergence error, i.e., an estimate of how close the result is to the exact solution, and the maximum number of iterations in the analysis settings (see section *Settings Tab* on page 699.) Whichever of these two criteria is fulfilled first will stop the algorithm. The number of iterations and the convergence error required to achieve the desired quality of the result depend on the specific case and need to be determined by trial and error. The default convergence error of 10^{-6} will be small enough in many (but not all) cases. For other cases, a larger convergence error may provide a sufficiently accurate solution while saving a huge amount of calculation time. In order to determine a reasonable convergence error for a given type of data, it is a good idea to inspect the result for a series of convergence errors (e.g., 10^{-5}, 10^{-6}, or 10^{-7}). For example, to inspect the results, you can set a number of analysis annotations at critical (e.g., high-stress) locations in your data set and refer to the reported stress values. In order to see small changes, set the precision of the von Mises stress in the **Visualization options** section to **Full (32 bit float)**.

Simulation Cell Size

The spatial discretization is another main source affecting the accuracy of the result. It consists of the representation of the geometry (the image) and the size of the finite elements.

The discretization is controlled by the settings **Min. element size**, **Element refinement**, **Grading factor**, and **Elements per quarter circle** (see *Simulation settings Section* on page 704). A coarser discretization can save huge amounts of simulation time and required computer memory. However, to capture the effects of small structures, such as small pores, a fine resolution is necessary. It is recommended that the diameter of a structure (e.g., a pore or a thin wall) is covered by at least 4–5 simulation elements to prevent effects like shear locking, i.e., an overestimation of shear stresses. You can visualize the element grid by checking **Element grid** under **Auxiliary visualizations** in the Scene Tree.

Just as with the convergence error, it is a good idea to do test simulations with a representative data set with different resolutions, from coarse to fine, to determine the point at which the results no longer change significantly.

Singularities Near the Boundary Conditions

In Figure 42-11, a beam is fixed at two drill holes at one end, and a bending force is applied at the other end. Points of very high stress are visible at the border of the fixed boundary conditions. Here, the stress is likely unrealistically high. The simulation assumes a hard transition between a region of infinite rigidity to a region that is elastic. In a physical setup, infinite rigidity does not exist, and the transition from constrained to moving parts is smooth because of the yielding effects. In general, stress hot spots that are directly adjacent to the fixed and force ROIs are to be interpreted with care. As a recommendation, plan the simulation setup so that relevant object parts are far from the fixed and force boundary condition. In some cases, the object may be

extended by an artificial support structure, which, in place of the object itself, is subject to the boundary conditions.

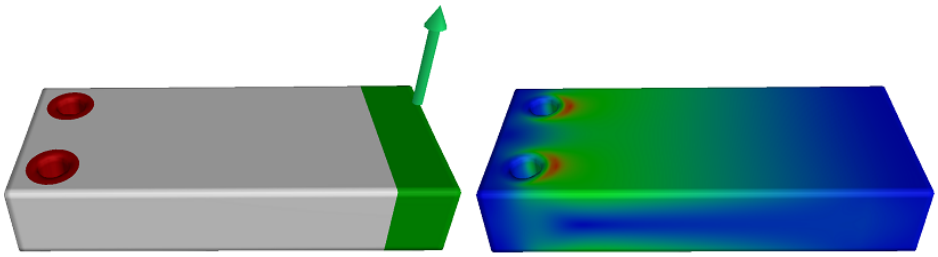


Figure 42-11: Left: Fixed regions (red) and area of applied force (green); Right: The points of high stress near the fixture are overestimated

Physics Reference

Notation Conventions

The following conventions are used for denoting quantities and operations:

- Scalar quantities are denoted with italic letters, e.g., x.
- Vector-valued quantities are marked with an underline, e.g., $\underline{x}$.
- The i-th component of a vector-valued quantity is written as x_i.
- Tensor-valued quantities are denoted with bold letters, e.g., $\mathbf{x}$.
- The matrix component (i, j) of a tensor-valued quantity is written as x_{ij}.
- The partial derivative of a function $f(\underline{r})$ with respect to the i-th component of the vector $\underline{r}$ is denoted by $f_{,i}(\underline{r})$.
- The dependence on the position vector $\underline{r}$ is sometimes omitted for a clearer appearance of formulas, e.g., instead of $s_{ij}(\underline{r})$, we will simply write s_{ij}.

Mathematical Description

The equilibrium state of an isotropic, linear elastic solid S characterized by the Young's modulus E and the Poisson's ratio ν is calculated.

Let $\underline{u}(\underline{r})$ be the field of displacements at every point $\underline{r} \in S$ of the solid object. The linearized strain tensor $\mathbf{e}$ is defined as:

$$e_{ij}(\underline{r}) = (u_{i,j}(\underline{r}) + u_{j,i}(\underline{r}))/2$$

The stress tensor $\mathbf{s}$ is calculated from $\mathbf{e}$ by means of the generalized Hooke's law:

$$s_{ij}(\underline{r}) = \frac{E}{1+\nu}\left(e_{ij}(\underline{r}) + \frac{\nu}{1-2\nu}\mathrm{tr}(\mathbf{e}(\underline{r})\delta_{ij}\right)$$

where δ_{ij} is the Kronecker symbol, assuming 1 for $i = j$ and 0 otherwise.

The equilibrium state is defined by the canceling of forces at every point, which is expressed by the equations:

$$\sum_{i=1}^{3} s_{ij,i} = 0 \qquad \text{for} \qquad j = 1..3 \qquad (1)$$

The loading boundary conditions are applied to portions of the surface of S, dS_{fixed} and dS_{force}:

$$\underline{u}(\underline{r}) = 0 \qquad \text{for} \qquad \underline{r} \in dS_{\text{fixed}} \qquad (2)$$

$$\sum_{i=1}^{3} s_{ij} n_i = t_j^* \qquad \text{for} \qquad \underline{r} \in dS_{\text{force}} \qquad (3)$$

where $\underline{n}(\underline{r})$ is the unit vector normal to the surface dS_{force} and $\underline{t^*}(\underline{r})$ is a prescribed traction.

Equation (1) is solved with the boundary conditions (2) and (3) using a mesh-free finite element method with linear basis functions.

Validation

Bending a Cantilever Beam

A beam with the dimensions 500 mm x 50 mm x 50 mm is used, which is represented as a volume data set with a voxel size of 1 mm. As shown in Figure 42-12, the leftmost x/y-slice is fixed (red surface), and the rightmost x/y-slice is subject to a lateral force in negative y-direction (green surface and arrow).

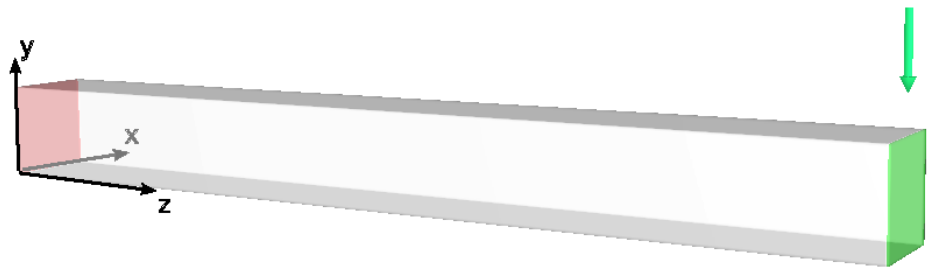


Figure 42-12: Cantilever beam subject to bending

VGSTUDIO MAX was used for simulating this setup with a simulation cell size of 1 voxel. Three simulation runs were conducted with different settings for the Young's modulus E and the applied force F. The results were compared to theoretical predictions.

Displacement

According to the Bernoulli beam theory, the displacement in y-direction varies along the beam's central axis:

$$u_y(r_z) = \frac{2Fr_z^2}{Ea^4}(3L - r_z)$$

where r_z is the distance from the fixed end, F is the applied force, E is the Young's modulus, a is the side length of the beam's cross section, and L is the total length of the beam. The lateral displacement was checked at 13 points along the central axis using the import annotations function of VGSTUDIO MAX to define the points (see Figure 42-13). Picture a in Figure 42-15 shows that the simulation results match the theory.

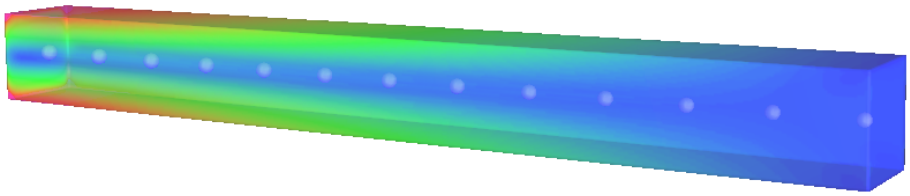


Figure 42-13: Von Mises stress visualization: 13 sample points on the central axis

Stress Tensor

The stress components were checked for the simulation run with $E = 1\ MPa$ and $F = 1\ N$. The stress component s_{zz} carries the bending moment. It is expected as

$$s_{zz} = \frac{12r_y}{a^4}(L - r_z)$$

where r_y is the y-component of the distance from the beam's central axis. The stress tensor was checked at three cross sections at 50 mm, 250 mm, and 450 mm from the fixed end. Each cross section was sampled using the import annotations function of VGSTUDIO MAX at 10x10 equally spaced points (see Figure 42-14).

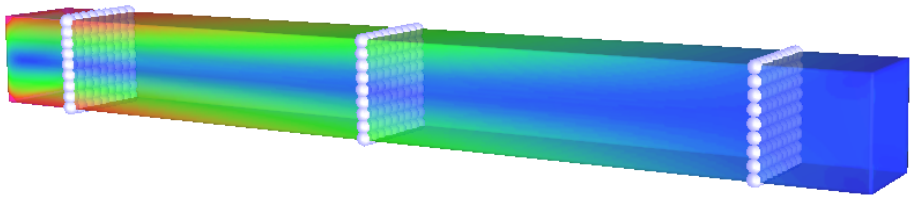


Figure 42-14: Von Mises stress visualization: Sample points at planes at z = 50 mm, z = 250 mm, and z = 450 mm, 10 x 10 points each

Picture b in Figure 42-15 shows the simulation results vs. the theory. Note that the plot contains 300 points, but every 10 points almost exactly overlap because they share the same y- and z-coordinates. The blue data points (at z = 450 mm) are slightly outside the theory. This is because the points are very close to the loaded end of the beam, where the Bernoulli beam theory breaks down. The theory is only valid for distances from the end that are much larger than the diameter

of the beam. The stress component s_{yz} carries the shear force. It is independent of the z-position and assumes a parabolic shape:

$$s_{yz} = \frac{6F}{a^4}(a^2/4 - r_y^2)$$

The tensor components are checked for 10x10 points at the cross section at z = 250 mm (see Figure 42-14, middle plane). Picture c in Figure 42-15 shows the simulation results vs. the theory. The scattering of the simulated points is due to the fact that the theory neglects the dependence of the stress on the x-coordinate. Independently of the Bernoulli theory, the integral of s_{yz} about any cross section must be equal to the applied force:

$$\int s_{yz} dA = F$$

This was checked for the three planes (z = 50 mm, z = 250 mm, and z = 450 mm) by numerically integrating the 10x10 sampled points. Picture d in Figure 42-15 shows that the simulation matches the physical requirement.

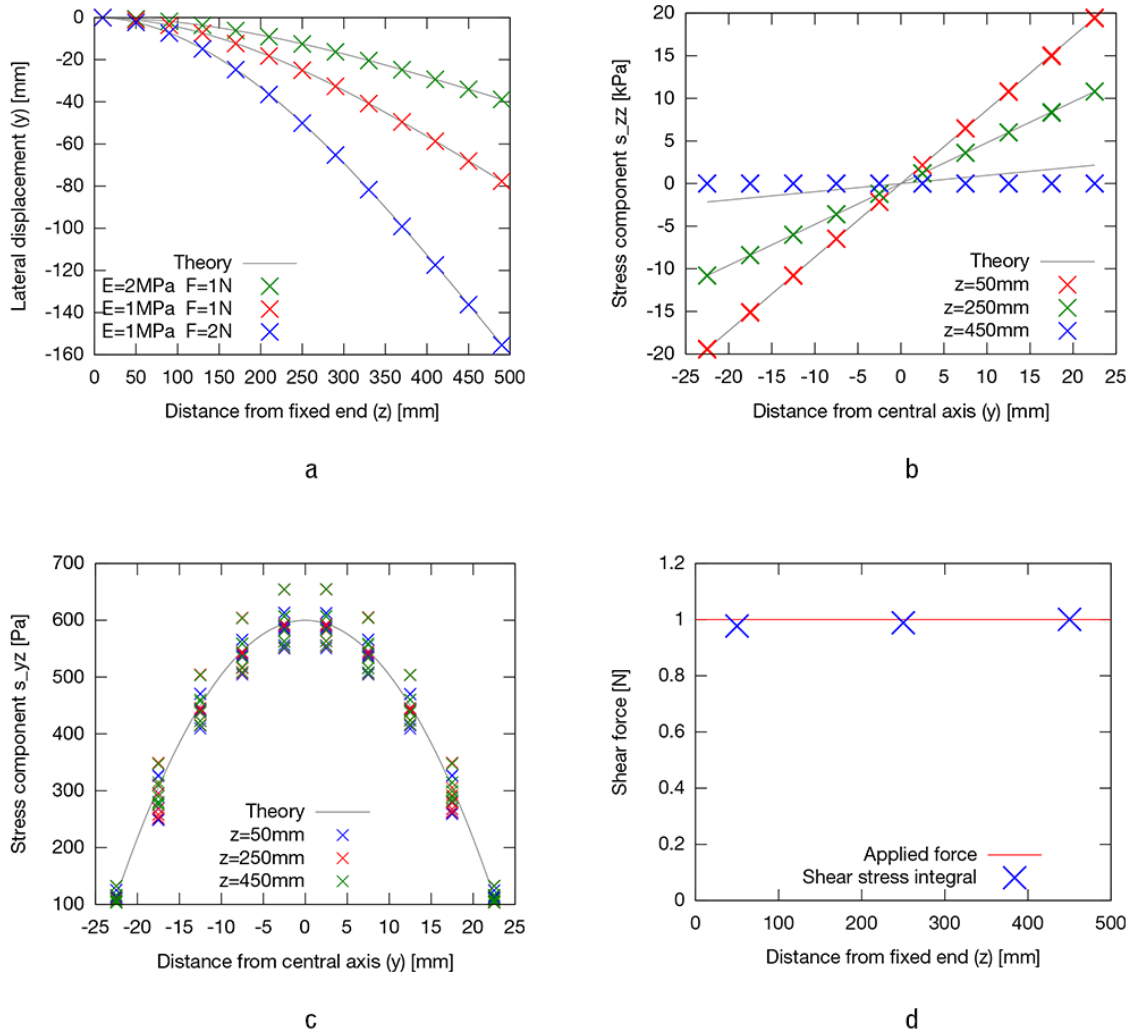


Figure 42-15: Bent cantilever beam—simulation vs. theory. a: Lateral displacement; b: Horizontal stress component s_{zz}; c and d: Shear stress component s_{yz}

Twisting a Cylindrical Rod

A cylinder with a length of $\mathrm{L} = 500\ \mathrm{mm}$ and a radius $\mathrm{R} = 50\ \mathrm{mm}$ is used, represented as a volume data set with a voxel size of 1 mm and a gray value resolution of 8 bit per voxel to obtain a smooth surface. As shown in Figure 42-16, the leftmost xy-slice is fixed (red surface) and the rightmost xy-slice is subject to a torque of $\mathrm{T} = 0.1\ \mathrm{Nm}$ around the z-axis (green surface and arrows).

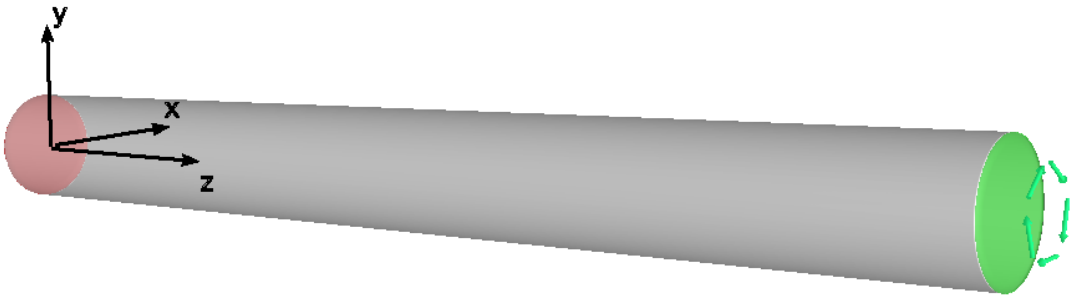


Figure 42-16: Cylindrical rod subject to twisting

VGSTUDIO MAX was used for simulating this setup with a simulation cell size of 1 voxel. Three simulation runs were conducted with a Young's modulus $\mathrm{E} = 1\ \mathrm{MPa}$ and three different settings for the Poisson's ratio $\nu = 0$, $\nu = 0.3$, and $\nu = 0.49$.

From solid mechanics theory, the resulting twisting angle ϕ is expected to vary over the rod length as follows:

$$\phi = \frac{2TL}{\pi G R^4}$$

where G is the shear modulus, connected to E and ν by the formula

$$G = \frac{E}{2(1+\nu)}$$

For small twisting angles, the tangential displacement at the surface is $u_t = \phi R$. The displacement was determined at 13 points along the rod length using the analysis annotations function of VGSTUDIO MAX (see Figure 42-17). Note that for the selected points, u_x can be identified as u_t.

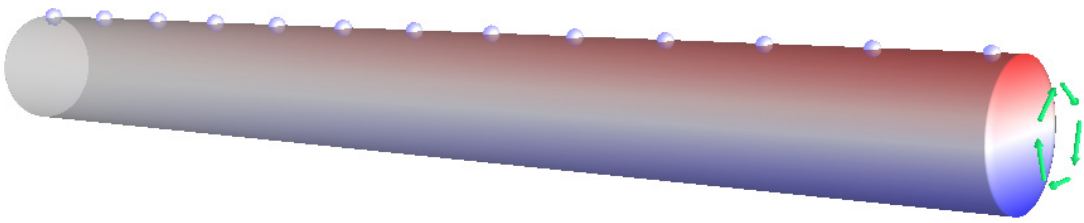


Figure 42-17: Displacement in x-direction with 13 sample points along the z-axis

Figure 42-18 shows that the simulation results align well with the theory:

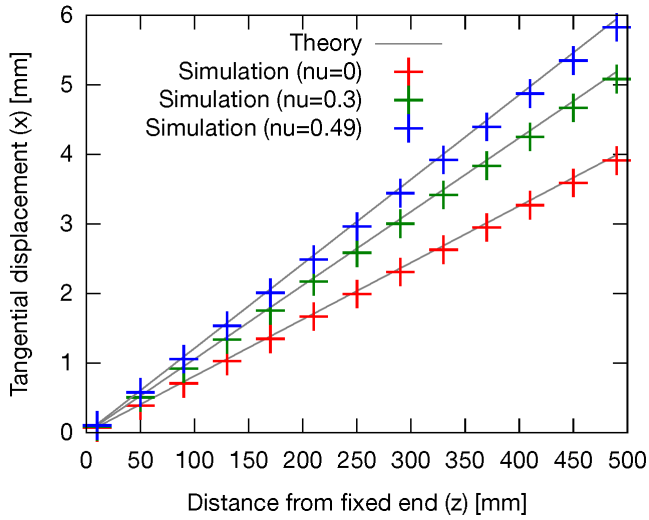


Figure 42-18: Twisted cylindrical rod: Lateral displacement at the surface along the length of the rod for three different values of the Poisson's ratio

Hollow Sphere Subject to Internal Pressure

A hollow sphere with an inner radius $a = 12.5\ \mathrm{mm}$ and an outer radius $b = 25\ \mathrm{mm}$ is represented as a volume data set with a voxel size of 1 mm and a gray value resolution of 8 bit per voxel to obtain a smooth surface. The inner surface is subject to a pressure of $p = 1\ \mathrm{Pa}$, while the outer surface can move freely. In order to prevent divergence of the simulation, a fixture is needed. Therefore, a small patch at the negative z-pole of the surface is fixed. In Figure 42-19, the upper half-sphere is drawn semi-transparently. The inner surface, which is subject to pressure, is colored in green. The small fixed patch at the negative z-pole of the surface is colored in red.

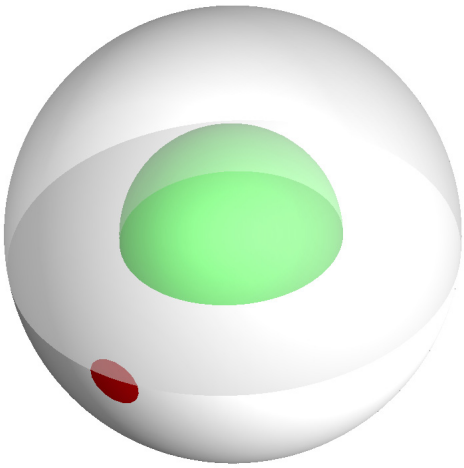


Figure 42-19: Hollow sphere subject to internal pressure

VGSTUDIO MAX was used for simulating this setup with a simulation cell size of 0.5 voxels, a Young's modulus of $E = 1\ \mathrm{MPa}$, and a Poisson's ratio of $\nu = 0.3$. From solid mechanics theory, the resulting radial displacement is (for example, [1], Chapter 4.1.4):

$$u_r(r) = \frac{pa^3}{E(b^3 - a^3)r^2}[(1 - 2\nu)r^3 + (1 + \nu)b^3/2]$$

The radial and tangential stress components are:

$$\begin{aligned} s_{rr}(r) &= \frac{pa^3}{b^3 - a^3}(1 - b^3/r^3) \\ s_{\phi\phi}(r) &= \frac{pa^3}{b^3 - a^3}(1 + 0.5b^3/r^3) \end{aligned}$$

The radial displacement was determined at 13 points along the y-axis between $y = a$ and $y = b$ using the analysis annotations function of VGSTUDIO MAX. Figure 42-20 shows the simulated displacement in y-direction (color-coded) and the 13 sample points along the y-axis. Note that for these points, the y-direction is identical to the r-direction, and the z-direction is identical to the ϕ-direction.

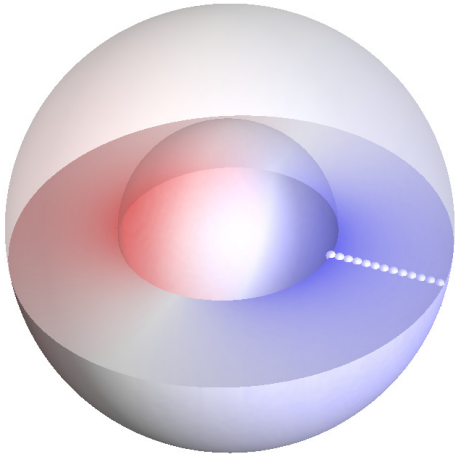


Figure 42-20: Hollow sphere subject to internal pressure: Displacement in y-direction with 13 sample points along the y-axis

Figure 42-21 shows that the simulation matches the theory:

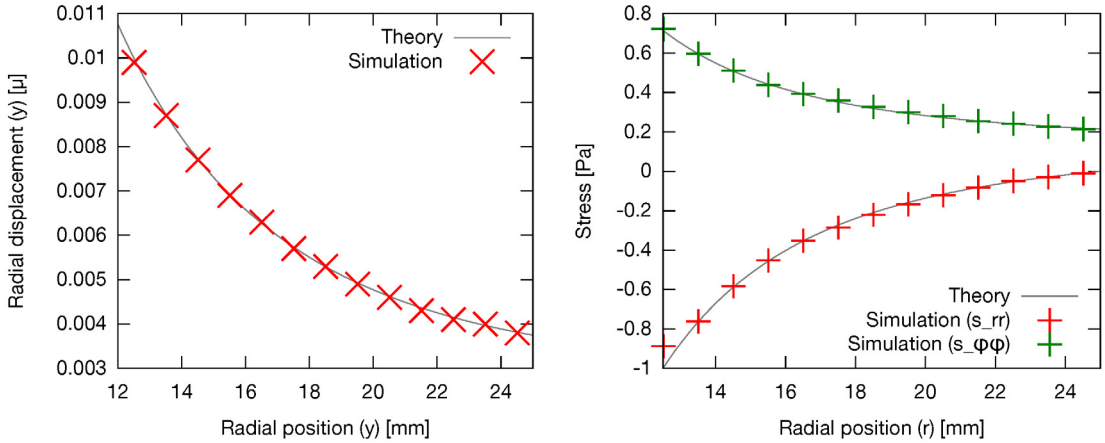


Figure 42-21: Hollow sphere: left: Radial displacement; right: Radial and tangential stress components

References

[1] A. F. Bower: Applied Mechanics of Solids. CRC Press (2010)

Transport Phenomena Simulation Module

Introduction

The **Transport Phenomena Simulation** module has been designed to simulate transport processes in porous or two-component materials for the following physical phenomena:

- **Viscous flow/permeability**

  Stationary low-Reynolds flow of an incompressible fluid through the voids of a porous material that are assumed to be completely flooded with the fluid.
- **Electric conduction**

  Stationary electric current through a two-component material where the components have different specific conductances. Porous material is modeled by setting the conductivity of one of the components to zero.
- **Molecular diffusion**

  Stationary diffusion of a solute through the voids of a porous material that are assumed to be completely flooded with the solvent. The solid component can also have a non-zero diffusion coefficient.
- **Thermal conduction**

  Stationary conduction of heat through a two-component material (e.g., fiber-reinforced plastics) where the components have different thermal conductivities. Porous material is modeled by setting the conductivity of one of the components to zero.
- **Capillary pressure**

  Pore size distribution and capillary pressure drainage curve for a scanned porous material sample.

Each of the first four transport simulations comes in two flavors, which correspond to two different simulation goals: experiment mode and tensor calculation mode.

The covered transport processes can be characterized by their transported quantity, driving quantity, and effective material properties:

Table 43-1: Transport processes provided by myVGL

Transport process	Transported quantity	Driving quantity	Material properties
Viscous flow/permeability	Fluid matter	Pressure	Absolute permeability, hydraulic tortuosity
Electric conduction	Electric charge	Voltage	Electric conductivity, formation factor
Molecular diffusion	Dissolved molecules	Molar concentration	Diffusion coefficient, diffusive tortuosity

Transport process	Transported quantity	Driving quantity	Material properties
Thermal conduction	Heat	Temperature	Thermal conductivity
Capillary pressure	Fluid matter	Capillary force	Capillary pressure curve

License Information

This module is an optional add-on module for VGSTUDIO MAX. It is not available for myVGL. However, if a project loaded in myVGL contains results obtained with this module, they can be viewed and reported in myVGL.

If you are interested in a more comprehensive functionality than the one offered by myVGL, you have the chance to evaluate VGSTUDIO MAX. You can request an evaluation license of VGSTUDIO MAX on our website:

https://volumegraphics.hexagon.com/en/products/evaluation

If you have further questions about our product portfolio, please contact us:

- For Europe, Middle East, and Africa:
  Write an e-mail to sales@volumegraphics.com or call +49 6221 73920 744.
- For Japan:
  Write an e-mail to sales@volumegraphics.jp or call +81 52 508 9682.
- For the Americas:
  Write an e-mail to sales-us@volumegraphics.com or call +1 704 248 7736.
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  Write an e-mail to sales@volumegraphics.cn or call +86 10 8532 6305.
- For Singapore and other parts of Asia (except China and Japan), Australia, and parts of Oceania:
  Write an e-mail to sales@volumegraphics.sg or call +65 6665 0310.

Opening the Dialog

In order to open the **Properties** dialog of a transport phenomena simulation,

- right-click the corresponding entry in the Scene Tree and select **Properties** from the context menu or
- double-click the corresponding entry in the Scene Tree.

The **Properties** dialog consists of several tabs on which you can view the results of the analysis.

To close the dialog, click the **Close** button at the bottom of the dialog.

A status bar at the bottom of the dialog indicates the current status of the analysis. The status can be one of the following:

Table 43-2: Messages in the status bar

Status	Description
Calculation required	All required parameters have been specified and are consistent, but the analysis was not calculated or was invalidated by some user action before the project was saved.
Result is up to date	The current analysis result is valid.
Manually stopped	The calculation was stopped manually and cannot be continued. The internal information necessary to continue is no longer available. This state occurs when a stopped analysis is saved to and re-loaded from disk or when the **Free memory/Clear undo queue** function was executed.
Object has no surface determination	No surface determination information is available for the object. See also section *Surface determination* on page 949 in chapter 48 *Glossary*.
License missing	The add-on module is not licensed.

An invalid or outdated status of an analysis is indicated in the Scene Tree by a warning sign. Double-click this analysis to open it and check the status bar for messages.

In the **Manually stopped** and **Manually stopped (continuable)** states, the values of the **Convergence error** and/or **Max. number of iterations** settings do not correspond to the actual result. The analysis result may not be reproducible.

The units of the dialog depend on the global unit settings (see section *Units Drop-down List* on page 33 in chapter 2 *Workspace*).

Transport Phenomena Experiment

For experiment mode, inlet and outlet are defined by two parallel planes that intersect the simulated volume or ROI. Two different values of the driving quantity are assigned to inlet and outlet. For example, for viscous flow, the differential pressure between inlet plane and outlet plane is set. The resulting stationary transport field (e.g., velocity) is computed. The results include a visualization of the transport field and the driving quantity field along with the (non-tensorial) effective material properties (in case of viscous flow: the absolute permeability and hydraulic tortuosity), and various statistical evaluations of the computed fields.

To avoid boundary effects in the vicinity of the volume border, it is possible to specify the amount of volume to be considered for computing the effective material properties (analyzed volume):

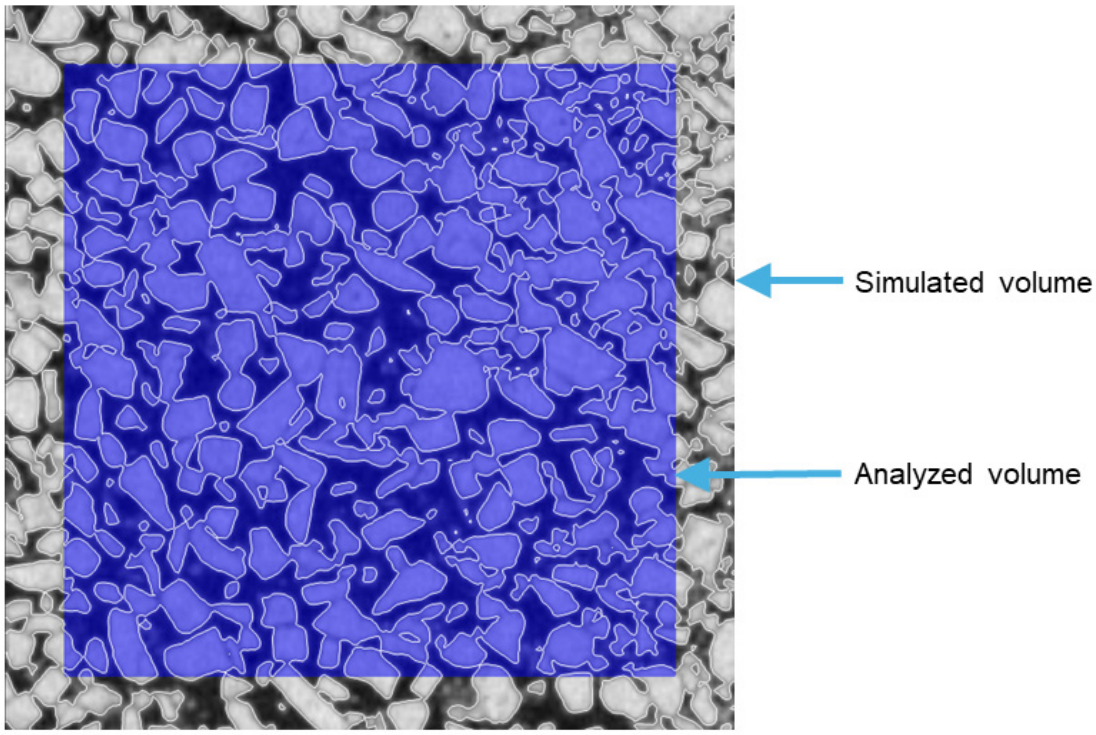


Figure 43-1: Simulated volume and analyzed volume

Settings Tab

The **Settings** tab of the **... experiment** dialog allows you to set all physics and simulation parameters to control the details of the simulation.

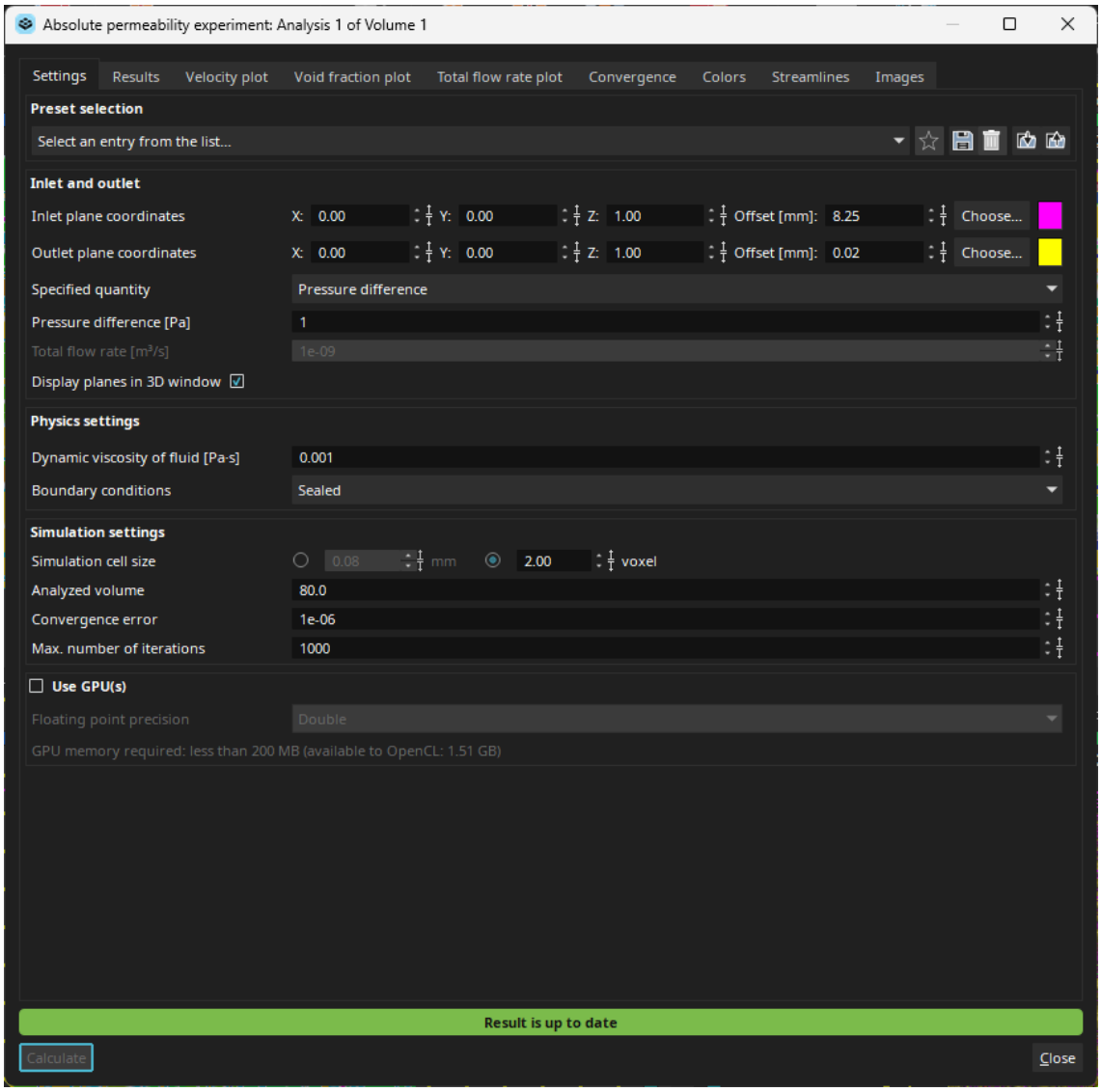


Figure 43-2: **... experiment** dialog, **Settings** tab

In myVGL, all parameter settings are displayed. Most of these parameters are read-only in myVGL. The complete functional range is available with VGSTUDIO MAX and the respective add-on module(s).

Preset selection Section

Table 43-3: Controls in the **Preset selection** section

Icon	Item	Description
	drop-down list	Specifies the preset to be applied, to be edited, or to be taken as a basis for a new preset. The following icons are used: • analysis factory settings • customized preset • appears next to the icon of a preset that has been modified but not yet saved
	Set this preset as default	Sets the selected preset as default. The default preset will be applied when creating a new analysis of the same type. If the selected preset is already set as default, the button is disabled.
	Save preset	Saves the selected preset. When saving a preset, the **Save preset** dialog will open, which allows you to set the new preset as default by checking the **Set as default for new analyses** checkbox.
	Remove preset	Removes the selected preset from the preset drop-down list. If the removed preset is the default preset, the next time an analysis of the same type is created, the factory settings will be used.
	Import preset	Imports a preset from the specified location.
	Export preset	Exports the selected preset to the specified location.

Inlet and outlet Section

Table 43-4: Controls of the **Inlet and outlet** section

Control	Description
Inlet/Outlet plane coordinates X, Y, Z fields	Specify the normal of the inlet and outlet planes, respectively. The specified vector is normalized to unit length before it is taken into account in the calculation.
Offset spin boxes	Specify the distances of the inlet and outlet planes, respectively, to the coordinate system origin. The current positions of the planes are displayed in the 2D and 3D windows.
Choose... button	Opens a drop-down list that shows the 2D windows currently available in the workspace for specifying the planes for the inlet and outlet of the transport process.

Control	Description
color box	Double-clicking the box opens the **Select Color** dialog, where you can specify the colors for the inlet and outlet planes, respectively.
Specified quantity drop-down list	Absolute permeability experiment only. Specifies the quantity imposed between inlet and outlet, either **Pressure difference** or **Total flow rate**.
Pressure difference spin box	Absolute permeability experiment only. Enabled when the **Pressure difference** option is selected in the **Specified quantity** field. Specifies the differential pressure imposed between inlet and outlet.
Total flow rate spin box	Absolute permeability experiment only. Enabled when the **Total flow rate** option is selected in the **Specified quantity** field. Specifies the total flow rate imposed between inlet and outlet.
Potential difference spin box	Electric conductivity experiment only. Specifies the potential drop imposed between inlet and outlet.
Molar concentration difference spin box	Molecular diffusivity experiment only. Specifies the concentration difference imposed between inlet and outlet.
Relative temperature difference spin box	Thermal conductivity experiment only. Specifies the temperature difference imposed between inlet and outlet.
Display planes in 3D window checkbox	When this option is checked, the inlet and outlet planes are displayed in the 3D window.

Physics settings Section

Table 43-5: Controls of the **Physics settings** section

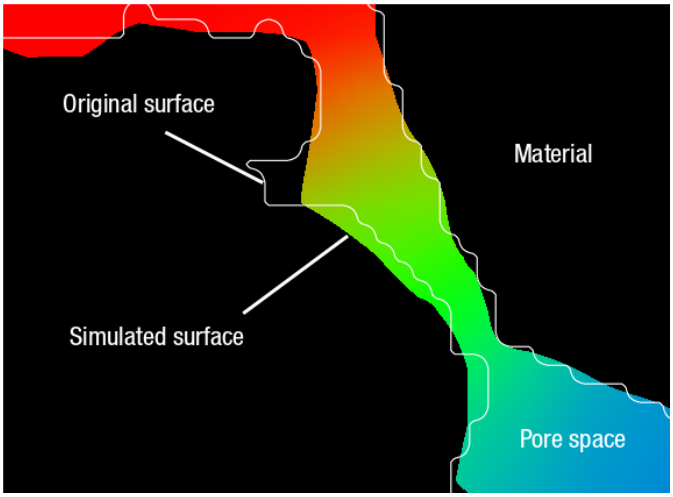
Control	Description
Dynamic viscosity of fluid spin box	Absolute permeability experiment only. Specifies the dynamic viscosity of the fluid. The default setting of 0.001 Pa·s is the dynamic viscosity of water. The material space is assumed to be impenetrable.
Electric conductivity (material)/(pore space) spin boxes	Electric conductivity experiment only. Specify the specific conductance of the material or pore space, respectively.
Molar diffusion coefficient (material)/(pore space) spin boxes	Molecular diffusivity experiment only. Specify the diffusion coefficient of the material or pore space, respectively.

Control	Description
Thermal conductivity (material)/(pore space) spin boxes	Thermal conductivity experiment only. Specify the thermal conductivity of the material or pore space, respectively.
Boundary conditions drop-down list	• **Sealed**: The simulated volume boundaries other than inlet and outlet are assumed to be impenetrable. • **Embedded**: The simulated volume boundaries other than inlet and outlet are assumed to be penetrable. The surrounding (unknown) material is approximated by a fixed-pressure boundary condition where the prescribed pressure (concentration, temperature, and voltage, respectively) drops linearly between inlet and outlet. This is based on the assumption that the flow follows Darcy's law. See the physics reference on boundary conditions (section *Absolute Permeability Experiment and Tensor Calculation* on page 796) for more information.

Simulation settings Section

Table 43-6: Controls of the **Simulation settings** section

Control	Description
Simulation cell size spin boxes	Specify the simulation grid resolution. You can either enter a value as a physical unit or in a number of voxels. Larger values result in faster simulation and less memory requirement, while smaller values produce more accurate results. A value smaller than 1 voxel is recommended in cases where the diameters of the flow channels (i.e., the pore diameter) are below 4 to 5 voxels. The predicted approximate peak additional memory requirement corresponding to the current setting is shown in the **RAM required** field to the right. For a simulation cell size larger than 1 voxel, the simulation is carried out on a subsampled version of the determined surface. Small structures in the surface are smoothed out and will not be accounted for in the simulation. The effect is stronger for larger simulation cell sizes.

Control	Description
	 Figure 43-3: Smoothing of the determined surface for simulation cell size greater than the voxel size In Figure 43-3, a permeability simulation was carried out with a simulation cell size of three times the original voxel size. The figure depicts a slice that shows the pressure field as a color overlay. The original pore surface is displayed as a white line. The boundary of the color overlay corresponds to the simulated pore surface.
RAM required field	Indicates the predicted approximate peak additional memory requirement corresponding to the current setting in the **Simulation cell size** field. If the RAM is not sufficient, increase the simulation cell size.
Analyzed volume spin box	The simulation result can be unrealistic in the vicinity of the volume border because of boundary effects. For this reason, only the inner part of the simulated volume is considered when effective material properties (e.g., absolute permeability) are calculated. This value specifies the amount of volume to be considered. A value of 100 means that the entire volume will be regarded. A value below 100 means that the volume up to a certain distance from the border will be disregarded. You can visualize the analyzed volume by checking the corresponding element in the Scene Tree.

Control	Description
	All numeric results and plots are calculated within the analyzed volume except for the **Total flow rate plot**, which is calculated for the entire simulated volume. Changing the **Analyzed volume** value in either of the states **Result is up to date (continuable)** or **Manually stopped (continuable)** will invalidate the analysis. However, since internal simulation results are still present, re-calculation will go quickly. On the **Convergence** tab, the plot showing the current estimate of the effective material property will be removed.
Convergence error spin box	The simulation algorithm is an iterative process through which the calculation result converges to the exact solution iteration by iteration. The convergence error is an estimate of how close a given solution is to the exact solution. This parameter specifies an upper threshold for the convergence error. The computation finishes when either the convergence error is below this threshold or a maximum number of iterations (see below) has been performed. A smaller value of the convergence error means better accuracy of the result. A value of 10^{-6} is usually safe. In many cases, using larger values, e.g., 10^{-5}, will yield good results in much shorter time. In other situations, e.g., very tortuous and low-porosity samples, you might need even smaller values. See also section *How to Obtain Reliable Results* on page 761.
Max. number of iterations spin box	A fall-back stopping criterion if the desired convergence error (see above) cannot be reached. The algorithm will stop at the latest after the specified number of iterations.

Use GPU(s) Section

Available for absolute permeability analysis only.

Table 43-7: Controls of the **Use GPU(s)** section

Control	Description
Use GPU(s) checkbox	When this option is checked, calculation will be performed on the available GPUs (graphics processing unit) instead of the CPU (central processing unit).

Control	Description
Floating point precision drop-down list	Specifies the numeric precision for GPU calculations. Generally, **Double** is recommended. On some graphics cards, calculating in single precision has a significant speed advantage over calculating in double precision. However, convergence to the desired error might be impossible using **Single**. If the convergence error does not decrease any more using **Single**, stop the calculation, select **Double**, and click **Calculate** again. The computation will continue using double precision.
GPU memory required field	Indicates the predicted approximate GPU memory requirement corresponding to the current setting.

Results Tab

The **Results** tab of the **... experiment** dialog window shows the numeric results of the experiment.

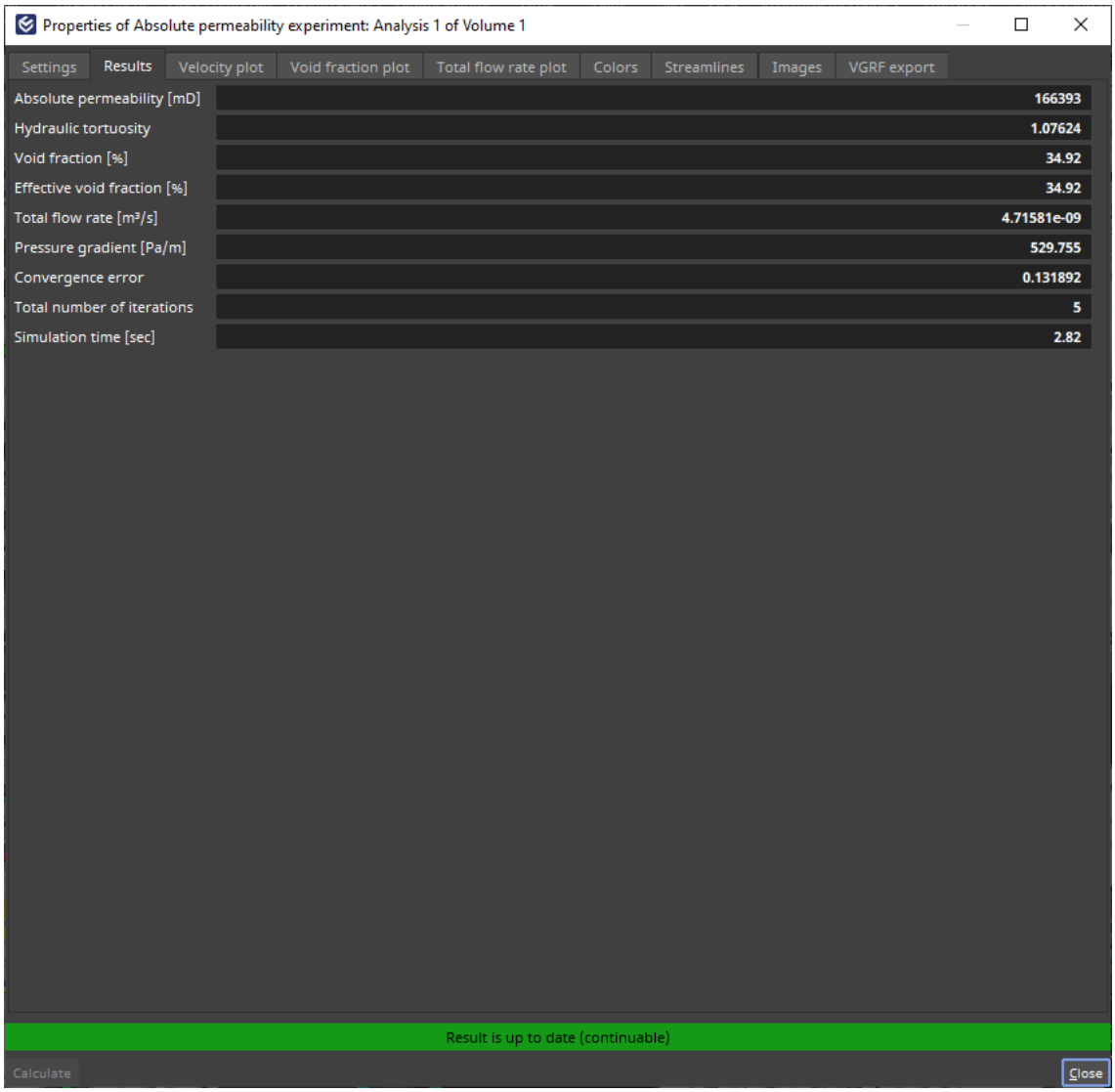


Figure 43-4: **... experiment** dialog, **Results** tab

Table 43-8: Fields of the **Results** tab

Field	Description
Absolute permeability/Effective electric conductivity/Effective diffusion coefficient/Effective thermal conductivity coefficient	Indicates the effective transport-enabling material property of the simulated volume. The effective diffusion coefficient D_{eff} is reported as the apparent diffusion coefficient in <length unit>²/<time unit>. In some texts, the term “effective diffusion coefficient” denotes the unitless ratio D_{eff}/D, where D is the bulk diffusivity of the unconstrained solution.

Field	Description
Hydraulic tortuosity	Absolute permeability experiment only. This unitless quantity is the factor by which the length of a typical fluid streamline through the medium deviates from the length of a straight line. It is calculated according to [4] (see section *References* on page 813) as $T_H = \langle u \rangle / \langle u_n \rangle$ where $\langle u \rangle$ is the volume-averaged magnitude of the velocity and $\langle u_n \rangle$ is the volume-averaged velocity component in the direction of the applied pressure gradient. The average is taken over the **Analyzed volume** (see section *Simulation settings Section* on page 751).
Diffusive tortuosity (geometric)/(algebraic)	Molecular diffusivity, thermal conductivity and electric conductivity experiments only. This unitless quantity is the factor by which the average path length of a diffusing molecule (electron or heat phonon, respectively) deviates from the length of a straight line. • **Diffusive tortuosity (geometric)** In analogy to the hydraulic tortuosity, the geometric diffusive tortuosity is calculated as $T_D = \langle j \rangle / \langle j_n \rangle$ where $\langle j \rangle$ is the volume-averaged magnitude of the molar flux, and $\langle j_n \rangle$ is the volume-averaged molar flux component in the direction of the applied pressure gradient. The average is taken over the **Analyzed volume** (see section *Simulation settings Section* on page 751). • **Diffusive tortuosity (algebraic)** The algebraic diffusive tortuosity is calculated according to [9] (see section *References* on page 813) as $\theta = \sqrt{\varphi D / D_{eff}}$ where D is the diffusion coefficient of the solute in the bulk solvent, φ is the porosity, D_{eff} the effective (apparent) diffusion coefficient of the porous material, and Θ is the algebraic diffusive tortuosity.

Field	Description
	For a parallel set of inclined straight capillaries, the geometric and algebraic definitions of the tortuosity are equivalent. The tortuosity is reported only if either the pore space or the material has zero conductivity or diffusion coefficient. Otherwise, the tortuosity will be undefined.
Formation factor	Molecular diffusivity, thermal conductivity, and electric conductivity experiments only. The formation factor f is a dimension-less quantity that corresponds to the overall hindering of transport processes by the porous medium. In the context of diffusion, the quantity is defined as $f = \Theta^2/\varphi = D/D_{eff}$. In the context of electric conductivity experiments, the formation factor is $f = R_{eff}/R_0$, where R_{eff} is the effective resistivity of the saturated porous medium and R_0 is the resistivity of the unconstrained bulk solution. The tortuosity is reported only if either the pore space or the material has zero conductivity or diffusion coefficient. Otherwise, the tortuosity will be undefined.
Void fraction	Indicates the fraction of void volume divided by the total analyzed volume (including both voids and material). This quantity is also known as porosity.
Effective void fraction	Absolute permeability experiment only. Indicates the fraction of the void volume that is actually accessible for transport. Isolated pores do not count for the effective void fraction.
Total flow rate/Total current/Total mass transport/Total heat transport	Indicates the total fluid volume/charge/mass/heat per second transported through the analyzed volume.
Pressure gradient/Electric field strength/Concentration gradient/Temperature gradient	Indicates the specified difference in pressure/electric field strength/concentration/temperature divided by the normal distance between the inlet and outlet planes.
Convergence error	Indicates the convergence error actually reached. This value can be greater than the target error set by the user (for example, when the algorithm stops because the maximum number of iterations has been reached).
Total number of iterations	Indicates the actual number of iterations calculated. This value is equal to or less than the corresponding simulation parameter set by the user.
Simulation time	Indicates the actual time spent for simulating.

Plot Tabs

Some results are shown in the form of plots. The x-axis of each plot corresponds to the position on a line that connects the inlet plane and the outlet plane. The plots show quantities integrated on slices parallel to the inlet and outlet planes that cut through each point on the x-axis.

Velocity plot/Current density plot/Molar flux plot/Heat flux plot Tab

Shows the x-, y-, and z-components of the flow velocity (current density, molar flux, or heat flux, respectively), averaged over slices between inlet and outlet. The vector components are given in the coordinate system selected in the application toolbar. The average is taken only in the intersection of the slice, the **Analyzed volume** (see section *Simulation settings Section* on page 751), and the conducting domain. In the absolute permeability experiment, the conducting domain is the pore volume. In the electric and thermal conductivity as well as the molecular diffusivity experiments, the conducting domain is the volume where the conductivity is non-zero.

Void fraction plot Tab

Shows the fraction of the void volume within each slice between inlet and outlet. The void fraction is computed in the analyzed volume (see section *Simulation settings Section* on page 751). In the absolute permeability experiment, the effective void fraction is additionally reported. This is the fraction of the void volume that is actually accessible for transport. Isolated pores do not count for the effective void fraction.

Total flow rate plot/Total current plot/Total mass transport plot/Total heat transport plot Tab

Shows the total flow rate (total current, total mass transport, or total heat transport, respectively) through the slices between inlet and outlet. This plot considers all simulated volume (not only the analyzed volume). When computed with the boundary condition **Sealed**, this plot should be constant. This plot can be used as an indicator of numerical convergence of the calculation (see also section *How to Obtain Reliable Results* on page 761).

Convergence Plot

Shows both the development of the convergence error and the current estimate of the effective material property (absolute permeability, effective diffusion coefficient, effective thermal conductivity, or effective electric conductivity, respectively) against the iteration number. In a successful simulation run, the convergence error should converge to zero while the material property estimate should settle at a constant value (see also section *How to Obtain Reliable Results* on page 761).

☞ The preliminary material property shown in the plot is computed on a coarser level than the final result shown in the **Result** tab. Therefore, the values can differ slightly. The value shown in the **Result** tab is the more accurate one.

Controls of the **Plot** Tab

Table 43-9: Controls of the **Plot** tab

Control	Description
use RMB to click the chart area	Displays a context menu (see below).
scroll MW in chart area or x-axis up/down	Zooms the x-axis of the chart out/in.
scroll MW in y-axis up/down	Zooms the y-axis of the chart out/in.
use LMB to click and drag the x-axis	Scrolls the x-axis.
use LMB to click and drag the y-axis	Scrolls the y-axis.
Zoom in/out	Zooms the corresponding axis in/out.
Reset zoom	Fits the entire chart to the current window size.

Context Menu of the **Plot** Tab

Right-clicking anywhere in the chart area opens a context menu with the following options:

Table 43-10: Context menu items

Control	Description
Export as CSV...	Opens a dialog for saving the chart values to a *.csv* file.
Copy to clipboard	Copies a screenshot of the chart to the system clipboard so you can paste it into another application.
Show/Hide x/y grid	Toggles the visibility of the grid lines for the corresponding axis.
Reset zoom	Fits the entire chart to the current window size.
Show/Hide legend	Displays or hides the legend for the plotted curves.

Streamlines Tab

Specifies the layout of the streamlines for the 2D and 3D windows.

Table 43-11: Controls of the **Streamlines** tab

Control	Description
Length (1-100) spin box	Specifies the length of the individual streamlines.
Density (1-100) spin box	Specifies the density and thus the number of streamlines.
Width (1-100) spin box	Specifies the width of the individual streamlines.

Control	Description
Show in 3D window checkbox	Switches the visibility of the streamlines in the 3D window on/off. Note that the **Streamlines** checkbox in the Scene Tree must also be checked in order to display the streamlines.

Visualization of the Analysis Results

Various overlays are provided for the visualization of the analysis results in the 2D and 3D windows. When the analysis status is **Result is up to date**, these overlays can be switched on and off in the Scene Tree tool below the analysis node by checking and unchecking the corresponding checkboxes.

- Color overlay of the analysis result

  The color mappings of the various color overlays can be adapted in the corresponding sections of the **Colors** tab.

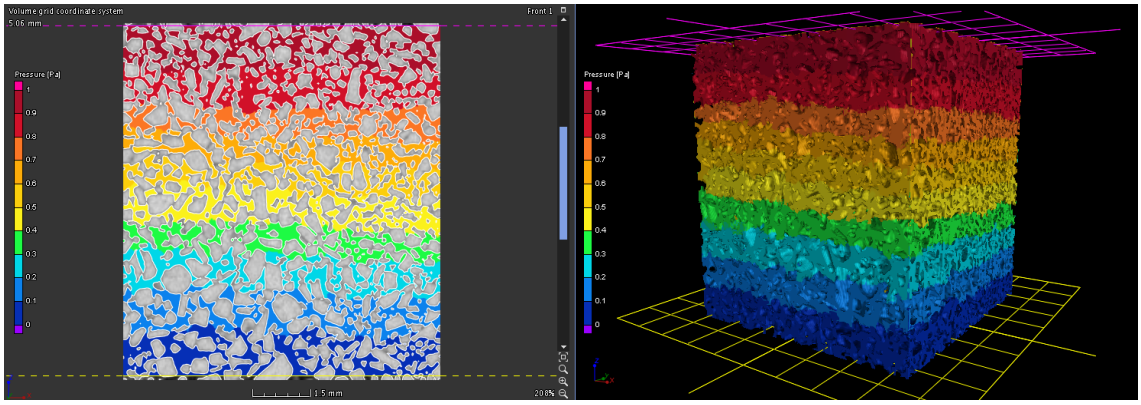


Figure 43-5: Visualization of the pressure overlay for a permeability experiment

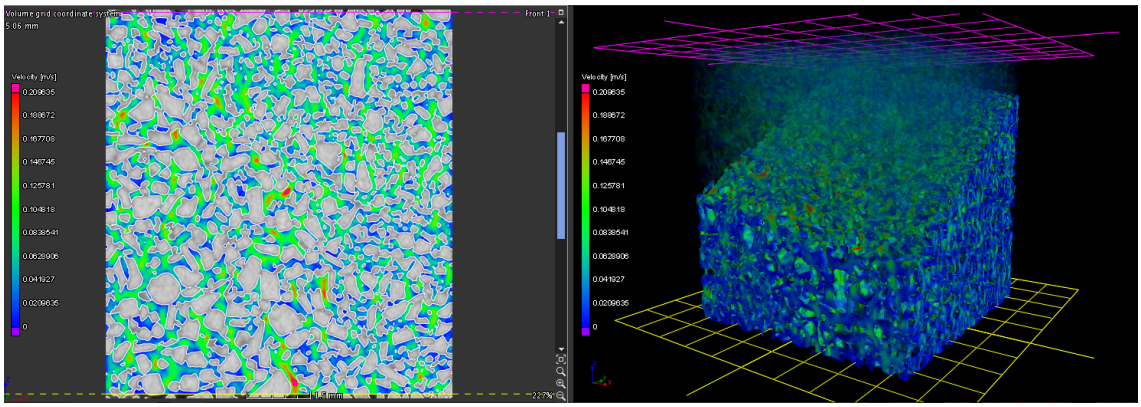


Figure 43-6: Visualization of the velocity overlay for a permeability experiment

- **Streamlines**

  In the 2D windows, white streamlines illustrate the local direction of the flow. For the 3D window, the streamlines can be switched on and off by checking and unchecking the corre-

sponding checkbox on the **Streamlines** tab (note that the **Streamlines** checkbox in the Scene Tree must also be checked in order to display the streamlines).

The layout of the streamlines for the 2D and 3D windows can be adapted in the corresponding sections of the **Streamlines** tab.

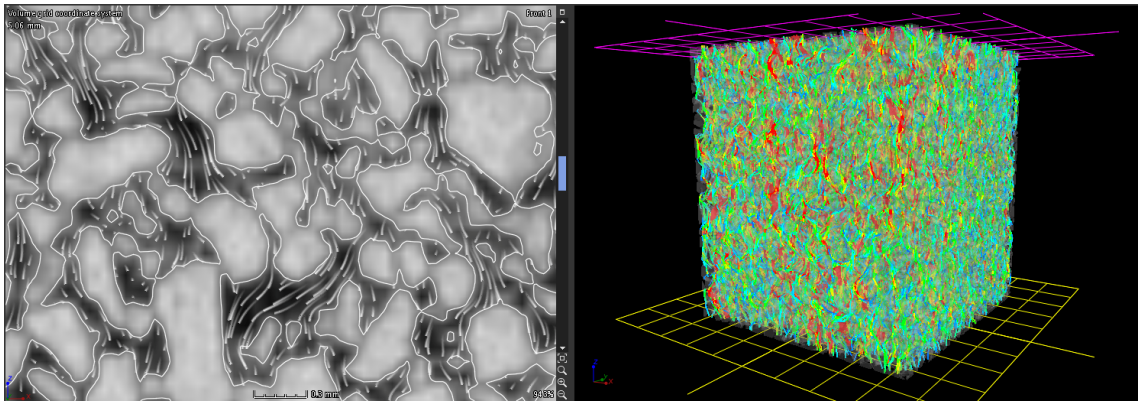


Figure 43-7: Visualization of the streamlines

- **Analyzed volume**

  The analyzed volume is shown in blue.

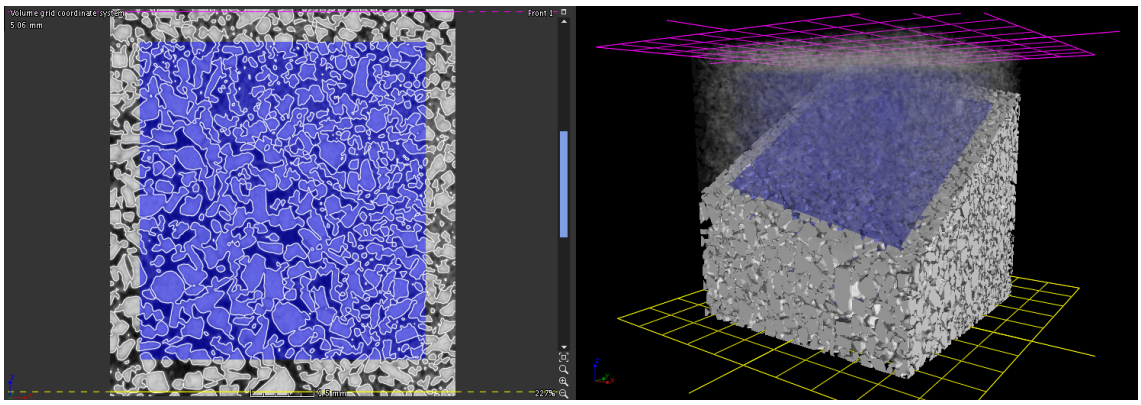


Figure 43-8: Visualization of the analyzed volume

How to Obtain Reliable Results

Convergence

The simulation algorithms in VGSTUDIO MAX are iterative processes. The calculation result converges towards the exact solution iteration by iteration. In some cases, especially in porous material, approaching the exact solution is numerically difficult, since the coupling between far-away points is weak and indirect (e.g., narrow throats between pores). It is therefore important to let the algorithm converge sufficiently, i.e., run a sufficient number of iterations. You can set the maximum convergence error, i.e., an estimate of how close the result is to the exact solution, and the maximum number of iterations in the analysis settings. Whichever of these two criteria is reached first will stop the algorithm. The number of iterations and the convergence error required to achieve the desired quality of the results depend on the specific case and need to be determined by trial and error.

For any given type of data set, it is recommended that you determine viable stopping criteria by using at least one example. Similar data sets may then be run with the same stopping criteria. Viable stopping criteria are best determined using the **Experiment** analysis types. The **Tensor** analysis types do not report as much information on the simulation details. The techniques described next are based on the premise that you are running an **Experiment** analysis type.

As a first check of convergence, it is recommended that you look at the **Convergence** tab, which plots the development of the convergence error and the effective material property estimate (absolute permeability, effective diffusivity, and specific electric or thermal conductance) against the iteration number. Once the algorithm has converged sufficiently, there should be no big change in the results when the algorithm is run for more additional iterations. In the plot, the estimated effective material property should have settled at a constant value. The convergence error has fallen to close to zero.

The following figure shows the convergence plots of a electric conductivity calculation. In the plot to the left, the estimated effective conductivity has settled at its final value, and the convergence error has decreased to nearly zero. The simulation has converged. In the plot to the right, both the estimated effective specific conductance and the convergence error have not yet settled at a final value. More iterations are necessary in order to obtain reliable results.

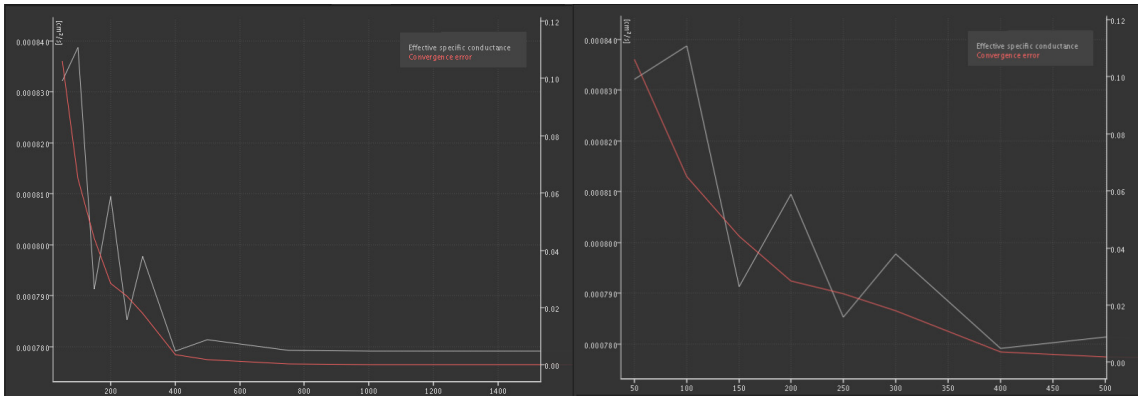


Figure 43-9: Convergence plots of an electric conductivity calculation

Another useful indicator of convergence is the total flow rate plot. Here, the transported volume, mass flux, heat transport, or electric current, depending on the simulator type, is integrated separately over parallel slices between inlet and outlet. For sealed lateral faces, the total transport through all planes must be constant; otherwise, mass or energy conservation (div $v = 0$) will not be fulfilled.

The following figure depicts the total flow rate plots of a permeability calculation in sandstone with 13% porosity. In the plot to the left, the computed total fluid transport through parallel slices varies between 1.405 x $10^{-12}m^3/s$ and 1.425 x $10^{-12}m^3/s$ (1.4% variation). This is considered almost constant, as expected from theory. In the plot to the right, the computed total flow rate varies between 1.6 x $10^{-12}m^3/s$ and 2.6 x $10^{-12}m^3/s$ (63% variation). This is not constant, in contradiction to theory. The cause might be the insufficient convergence of the simulation algorithm or numerical limitations.

The total flow rate plot is expected to be constant only if the boundary condition setting is set to **Sealed**.

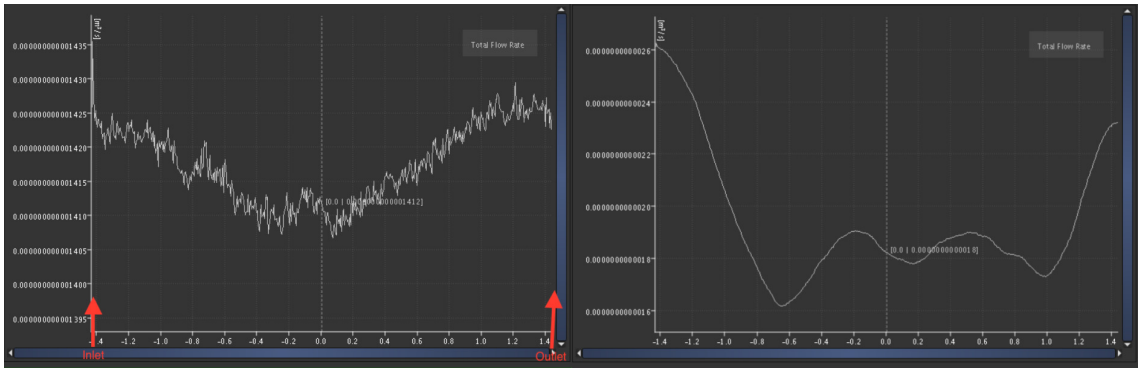


Figure 43-10: Total flow rate plot of a permeability calculation in sandstone with 13% porosity

In some cases, an approximately constant total flow plot cannot be obtained even after a huge number of iterations, which indicates that the algorithm is operating beyond its numerical limits. This can happen when the porosity is very low or the pores throats are very small (<4–5 voxels in diameter). It may help to chose a subvoxel simulation grid by choosing a simulation cell size of less than one voxel. It might, however, be necessary to provide CT data sets with a higher resolution.

To facilitate the determination of adequate stopping criteria, VGSTUDIO MAX supports a start-stop-continue function. You can stop the calculation after several iterations, inspect the intermediate results, and decide whether to continue with the calculation or whether the results are already satisfactory. It is also possible to continue a finished calculation from the point where it had stopped without having to start from scratch.

Representative Elementary Volume (REV)

The effective material properties (absolute permeability, effective diffusivity, or effective conductivity) are calculated by averaging the volume of pore-scale effects. In order to capture the effective properties in a statistically meaningful way, the simulated material sample must be large enough so that local fluctuations can reliably average out. In other words, the material sample must capture the typical behavior of the given material type as a whole. However, if the analyzed sample is too large, long-range fluctuations may appear, such as cracks or long-range variations of the overall porosity. Practically, the size of the simulated samples is limited by the resources necessary for CT scanning and simulating. Therefore, it is recommended that you determine the size of the representative elementary volume (REV), which can be defined as the smallest volume size that still allows for representative measurements.

In practice, a reasonable REV size can be found by starting with a very small volume size and performing simulations for a number of such volumes (e.g., a number of small ROIs in a larger data set). Since the volume is likely to be smaller than the REV, the computed averaged material property will fluctuate. This procedure is repeated for larger and larger volume sizes. The fluctuations should get smaller and smaller until they level out at an acceptable range when the REV has been reached. See the following figure for an illustration (drawing adapted from [1]).

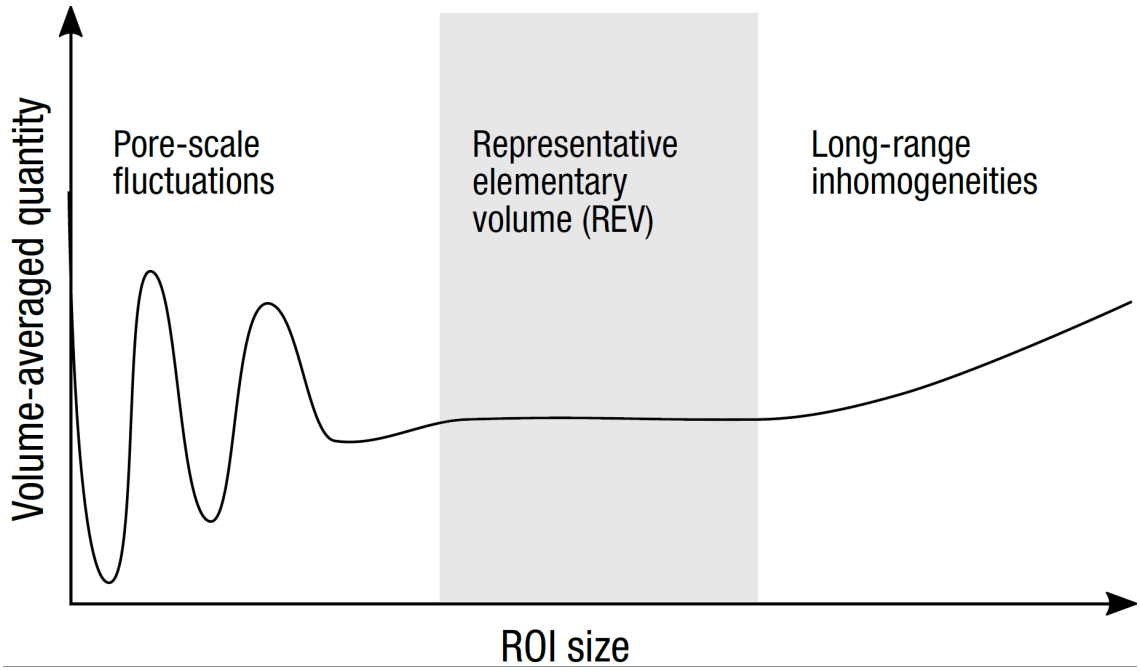


Figure 43-11: Dependence of a volume-averaged quantity on the size of the analyzed sample

Transport Phenomena Tensor

In tensor calculation mode, the tensorial effective material properties are calculated. The effective material property is a macroscopic quantity that indicates the ability of the porous or compound material to conduct the transported quantity. For example, in case of viscous flow, the material property is absolute permeability. A foam sample with large pores and high inter-pore connectivity has a higher permeability than a foam sample with small pores and low inter-pore connectivity. In the general case of anisotropic material, the transport-enabling material property assumes different values for transport along different orientations. Mathematically, such an orientation-dependent quantity is described as a tensor that is defined by six independent values. In the tensor calculation mode, the simulator performs three transport simulations in perpendicular directions to determine the six tensor values.

To avoid boundary effects in the vicinity of the volume border, it is possible to specify the amount of volume to be considered for computing the effective material properties (analyzed volume):

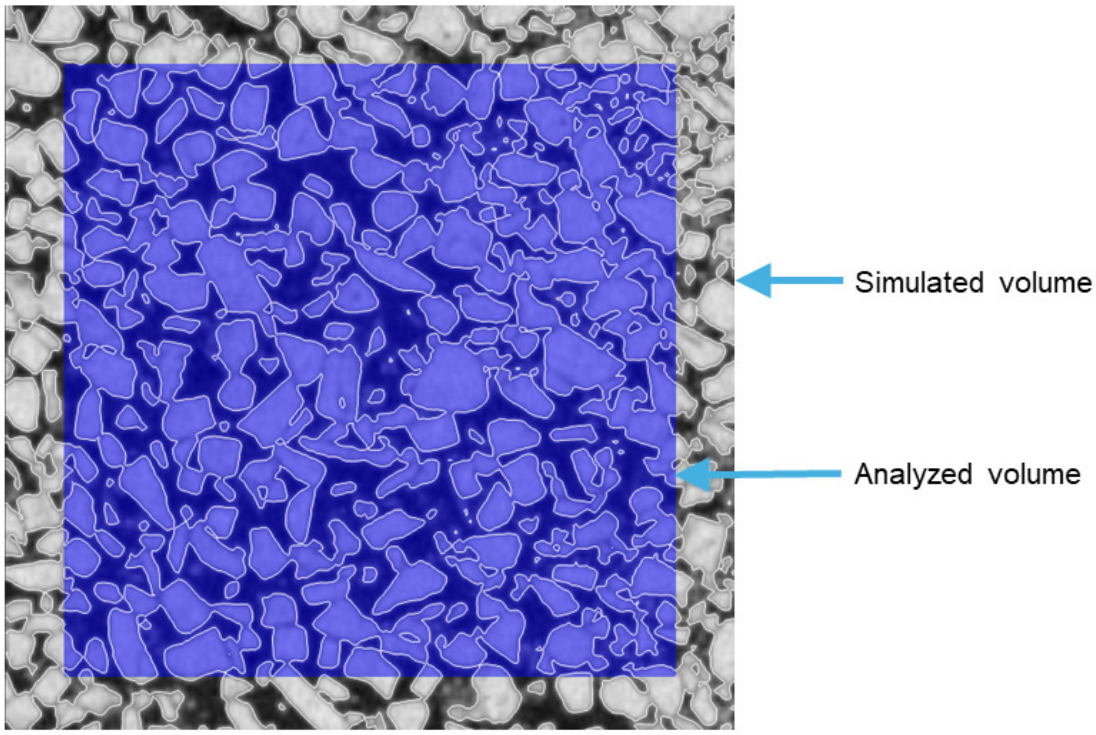


Figure 43-12: Simulated volume and analyzed volume

Settings Tab

The **Settings** tab of the **... tensor** dialog allows you to set all simulation parameters to control the details of the simulation.

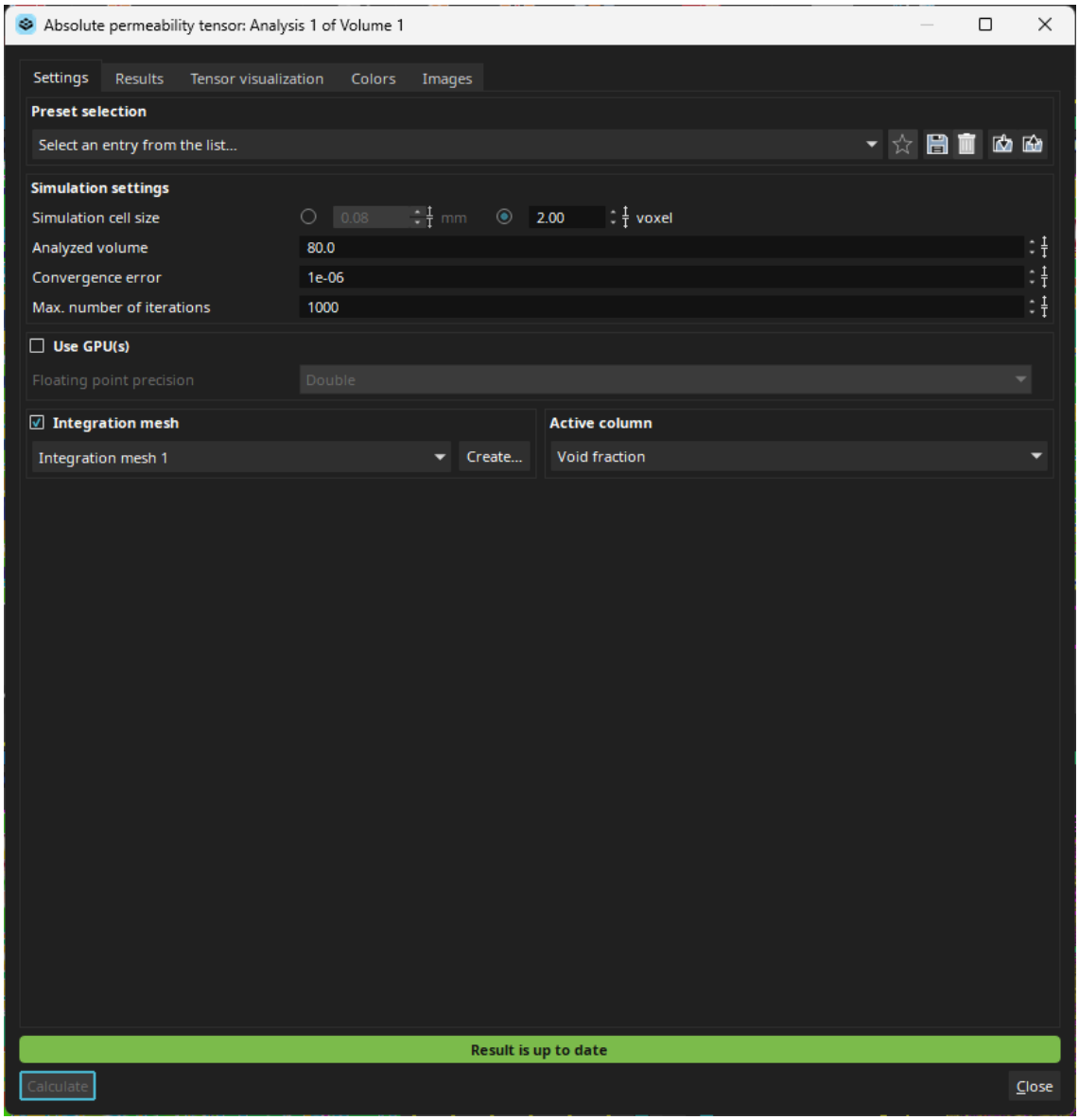


Figure 43-13: **... tensor** dialog, **Settings** tab

In myVGL, all parameter settings are displayed. Most of these parameters are read-only in myVGL. The complete functional range is available with VGSTUDIO MAX and the respective add-on module(s).

Preset selection Section

Table 43-12: Controls in the **Preset selection** section

Icon	Item	Description
	drop-down list	Specifies the preset to be applied, to be edited, or to be taken as a basis for a new preset. The following icons are used: • analysis factory settings • customized preset • appears next to the icon of a preset that has been modified but not yet saved
	Set this preset as default	Sets the selected preset as default. The default preset will be applied when creating a new analysis of the same type. If the selected preset is already set as default, the button is disabled.
	Save preset	Saves the selected preset. When saving a preset, the **Save preset** dialog will open, which allows you to set the new preset as default by checking the **Set as default for new analyses** checkbox.
	Remove preset	Removes the selected preset from the preset drop-down list. If the removed preset is the default preset, the next time an analysis of the same type is created, the factory settings will be used.
	Import preset	Imports a preset from the specified location.
	Export preset	Exports the selected preset to the specified location.

Physics settings Section

Available for electric and thermal conductivity as well as molecular diffusivity tensor calculations only.

Table 43-13: Controls of the **Physics settings** section

Control	Description
Electric conductivity (material)/(pore space) spin boxes	Electric conductivity tensor calculation only. Specify the specific conductance of the material or pore space, respectively.
Molar diffusion coefficient (material)/(pore space) spin boxes	Molecular diffusivity tensor calculation only. Specify the diffusion coefficient of the material or pore space, respectively. The material space is assumed to be impenetrable.

Control	Description
Thermal conductivity (material)/(pore space) spin boxes	Thermal conductivity tensor calculation only. Specify the thermal conductivity of the material or pore space, respectively.

Simulation settings Section

Table 43-14: Controls of the **Simulation settings** section

Control	Description
Simulation cell size spin boxes	Specify the simulation grid resolution. You can either enter a value as a physical unit or in a number of voxels. Larger values result in a faster simulation and a lower memory requirement, while smaller values produce more accurate results. A value smaller than 1 voxel is recommended in cases where the diameters of the flow channels (i.e., the pore diameters) are below 4 to 5 voxels. The predicted approximate peak additional memory requirement corresponding to the current setting is shown in the **RAM required** field to the right (not available for integration meshes). For more detailed information, see section *Simulation settings Section* on page 751 in section *Transport Phenomena Experiment*.
RAM required field	Not available for integration meshes. Indicates the predicted approximate peak additional memory requirement corresponding to the current setting in the **Simulation cell size** field. If the RAM is not sufficient, increase the simulation cell size.
Analyzed volume spin box	The simulation result can be unrealistic in the vicinity of the volume border because of boundary effects. For this reason, only the inner part of the simulated volume is considered when effective material properties (e.g., absolute permeability) are calculated. This value specifies the amount of volume to be considered. A value of 100 means that the entire volume is regarded. A value below 100 means that the volume up to a certain distance from the border is disregarded. You can visualize the analyzed volume by checking the corresponding element in the Scene Tree. When an integration mesh is selected, the analyzed volume is applied to each mesh cell separately. For performance reasons, the analyzed volumes are only visualized for the first 1000 mesh cells.

Control	Description
Convergence error spin box	The simulation algorithm is an iterative process through which the calculation result converges to the exact solution iteration by iteration. The convergence error is an estimate of how close a given solution is to the exact solution. This parameter specifies an upper threshold for the convergence error. The computation finishes when either the convergence error is below this threshold or a maximum number of iterations (see below) has been performed. A smaller value of the convergence error means better accuracy of the result. A value of 10^{-6} is usually safe. In many cases, using larger values, e.g., 10^{-5}, will yield good results in a much shorter time. In other situations, such as in very tortuous and low-porosity samples, you might need even smaller values. See also section *How to Obtain Reliable Results* on page 761.
Max. number of iterations spin box	A fall-back stopping criterion if the desired convergence error (see above) cannot be reached. The algorithm will stop at the latest after the specified number of iterations has been reached.

Use GPU(s) Section

Available for absolute permeability analysis only.

Table 43-15: Controls of the **Use GPU(s)** section

Control	Description
Use GPU(s) checkbox	When this option is checked, a calculation will be performed on the available GPUs (graphics processing unit) instead of the CPU (central processing unit).
Floating point precision drop-down list	Specifies the numeric precision for GPU calculations. Generally, **Double** is recommended. On some graphics cards, calculating in single precision has a significant speed advantage over calculating in double precision. However, convergence to the desired error might be impossible using **Single**. If the convergence error does not decrease any more when using **Single**, stop the calculation, select **Double**, and click **Calculate** again. The computation will continue using double precision.
GPU memory required field	Not available for integration meshes. Indicates the predicted approximate GPU memory requirement corresponding to the current setting.

Integration mesh Section

When this option is checked, the drop-down list will be enabled, which lists all integration meshes available in the Scene Tree.

Separate simulation runs will be executed on each mesh cell, and for each cell, the result tensor will be computed. Cells outside the simulated volume will be assigned a zero tensor, and for cells that intersect the simulated volume border, only the intersecting volume will be simulated.

Active column Section

Only enabled when the analysis is performed on an integration mesh.

This drop-down list allows you to select the property to be shown according to the settings on the **Colors** tab. The default setting is **Void fraction**, i.e., all cells are shown in gray, independently of their values. The **Colors** tab is not visible in this case. When you select a cell property, e.g., **Void fraction**, from the **Active column** drop-down list, the cells will be color-coded according to their void fraction value as defined by the color lookup table and the colors specified in the **Sections** section of the **Colors** tab. In the list on the **Results** tab, the column of the selected cell property becomes the “active” column, and its values are highlighted in bold and italic font.

You can also select the active column on the **Results** tab by right-clicking the column and select the **Set as active column** item from the context menu.

Results Tab

Shows the results of the tensor calculation. When the **Integration mesh** option on the **Settings** tab is checked, the results will be listed in a table, with each table row showing the results for an integration mesh cell.

The **Results** tab provides the following information:

Table 43-16: Columns of the **Results** table

Column	Description
Cell index	Results table only: Indicates the global cell index, starting from 0.
Void fraction	Indicates the fraction of void volume divided by the total analyzed volume (including voids and material).
Mean abs. permeability/Mean eff. diffusion coefficient/Mean eff. conductivity	Indicates the mean of the eigenvalues of the permeability/diffusion coefficient/thermal conductivity/electric conductivity tensor.
Abs. permeability tensor/Eff. diffusion coefficient tensor/Eff. conductivity tensor xx/yx/zy/xy/yy/zy/xz/yz/zz	Indicates the matrix components of the permeability/diffusion coefficient/thermal conductivity/electric conductivity tensor.
Abs. permeability/Eff. diffusion coefficient/Eff. conductivity (1st/2nd/3rd eigenvalue) **Eigenvalues λ1, λ2, λ3**	Indicates the eigenvalues of the permeability/diffusion coefficient/thermal conductivity/electric conductivity tensor.

Column	Description
Abs. permeability/Eff. diffusion coefficient/Eff. conductivity (1st/2nd/3rd eigenvector) x/y/z **Eigenvectors v1**, **v2**, **v3 x**, **y**, **z**	Indicates the x-, y-, and z-components of the three eigenvectors of the permeability/diffusion coefficient/thermal conductivity/electric conductivity tensor.
Conv. error (run 1/2/3)	Indicates the convergence error actually achieved in each of the three simulation runs.
Num. iterations (run 1/2/3)	Indicates the number of iterations actually calculated in each of the three simulation runs.
Status (run 1/2/3)	Indicates the result status of each of the three simulation runs. Possible status messages: • **OK**: The calculation has reached the desired convergence error and no error has occurred. • **Maximum number of iterations reached**: The convergence error was not reached within the maximum number of iterations. • **Analyzed volume too small or outside of ROI**: The analyzed volume in the integration mesh cell is too small or its intersection with the ROI is too small. • **Simulated volume too small or outside of ROI**: The simulated volume in the integration mesh cell is too small or its intersection with the ROI is too small. • **No further improvement**: The algorithm does not converge. This can happen if the cell contains no or too few pores. All vector-valued quantities are expressed in the coordinate system currently selected for the application.
Cell position x/y/z	Results table only: Indicates the x-, y-, and z-position of the cell center.
Description	Results table only: Allows you to enter a description for the result row used for reporting.
Captures	Results table only: Indicates the number of images captured for this result row using the **Capture from** button in the **Screenshots** section.

General Table Controls

- List section

  The following table provides an overview of the general controls available in the various list views:

Table 43-17: Controls in the list section

Control	Description
button	Opens a submenu for selecting the filter/search mode.
Filter	Clicking the **Click to add a filter or search criterion** field to the right of the icon opens a series of drop-down lists from which you can select a table column, an operator, and—depending on the column—a value. If a column does not offer a value drop-down list, you can type in a value. When the selection is complete, the table shows the rows matching the filter criterion. Clicking the **+** button or the **Click to add a filter or search criterion** field allows you to specify more filter criteria. Clicking the **x** button removes the filter.
Search	Clicking the **Click to add a filter or search criterion** field to the right of the icon opens a series of drop-down lists from which you can select a table column, an operator, and—depending on the column—a value. If a column does not offer a value drop-down list, you can type in a value. When the selection is complete, the table rows matching the search criterion are highlighted. Clicking the **+** button or the **Click to add a filter or search criterion** field allows you to specify more search criteria. Pressing **F3** jumps to the next search result in the list. Clicking the **x** button removes the search.
Full-text filter	Entering a value or text string into the input field to the right of the icon filters the table accordingly and shows the rows that match the filter criterion.
Full-text search	Entering a value or text string into the input field to the right of the icon searches the table accordingly and highlights the rows that match the search criterion.
use LMB to click on a table row	Selects the row and the corresponding object in the Scene Tree. In analysis result lists, the result, e.g., the component, is marked by a cross-hairs cursor in each of the 2D views.
hold **Ctrl** key + use LMB to click on several table rows	Selects the rows and the corresponding objects in the Scene Tree.

Control	Description
hold **Shift** key + use LMB to click on two separate table rows	Selects the two rows, including all rows between the two as well as the corresponding objects in the Scene Tree.
hold **Shift** key + use up/down arrow keys	Selects the rows and the corresponding objects in the Scene Tree.
press **Ctrl+A**	Selects all table rows.
use up and down arrow keys	Steps up and down through the table rows.
use RMB to click into the table area	Displays a context menu. See below.
use LMB to click a column heading	Sorts the table according to the values of the column. Clicking subsequently toggles between ascending and descending.
use LMB to click and drag column heading to new position, then release LMB	Inserts the column at the new position.
use LMB to double-click cell highlighted in white (light theme) or medium gray (dark theme)	If applicable: Allows you to edit the contents of the cell.

- **Screenshots** section (if available)

  The **Screenshots** section below the list section allows you to capture images from one of the 2D windows, the 3D window, or the current window layout for the item currently selected in the table. Only available if exactly one row is selected.

  Table 43-18: Controls in the **Screenshots** section

Control	Description
Capture from button	Adds the image of the view selected from the drop-down list to the preview area above.
use LMB to click and drag one or more images, then release LMB	Moves the image(s) to the new position.
double-click the image	Opens the **Snapshot display** window showing the image: • **Zoom in**/**Zoom out** button: Zooms the image in/out. You can also move the mouse pointer in the image area and turn the mouse wheel. • **Fit to window** button: Resets the zoom so that the image fits into the window.
click the **<no description>** placeholder twice (first click to select, second click to enable renaming)	Allows you to label the image.

Control	Description
Delete selected button	Deletes the selected image from the preview area.

Table Context Menu

Right-clicking anywhere in the table area shows a context menu with the following options:

Table 43-19: Context menu items

Control	Description
Columns	Allows you to toggle the visibility of each column by checking/unchecking the respective item. • **Show all**: Checks all columns to set them to visible. • **Hide all**: Unchecks all columns to set them to invisible. • **Hide empty**: Unchecks all not editable columns which are empty or **n/a** to set them to invisible.
Trim columns	Resizes all columns to their smallest possible size.
Apply default column layout	Applies the default column layout previously saved by the user to the current table. If no default column layout has been saved, the original column layout will be applied.
Save as default column layout	Saves modifications applied to the table—e.g., the visibility of a column, the order in which the columns appear, the column width—as default column layout. This layout will be applied when you create a new project.
Apply original column layout	Restores the original table layout and discards any modifications applied by the user. The original table layout is predefined and cannot be modified by the user.
Remove entries	If applicable: Deletes the selected row(s) from the table.
Create annotations	If applicable: Creates annotations for the selected items.
Export as CSV...	Opens the **Export as CSV...** dialog for exporting the table values as **.csv* file. This option always exports the complete table even if a filter was applied. In order to export only the filtered rows, press **Ctrl** + **A** to highlight all filtered rows and use the **Copy to clipboard** menu item.

Control	Description
Copy to clipboard	Copies the selected rows as well as the column heading into the system clipboard. The clipboard information is provided both as plain text and rich-text table, so when pasting into a rich-text-capable application like a word processor, you will see a proper table with cell borders and bold headings.
Paste	For annotation tables: Pastes previously copied coordinates and—optionally—snap directions to create new annotations in the table. For annotations of a nominal/actual comparison, the search distance specified on the **Settings** tab of the analysis will be considered. Note: Pasted annotations will be interpreted in the selected coordinate system at the time of pasting. The information in the clipboard must have the following structure: • x-, y-, and z-coordinate of the annotation or • x-, y-, and z-coordinate of the annotation as well as x-, y-, and z-component of the vector for the snap direction The parameters can be separated by space, tab, semicolon, or comma (if a comma is already used as a decimal mark or digit grouping symbol, the values must be enclosed in double quotation marks). Example: 8.89;25.82;-0.55;1;0;0 You can also copy the information directly from the cells of a spreadsheet. In order to paste the annotation information, you can also press the **Ctrl** + **V** keyboard shortcut.
Set as active column	If applicable: Makes the current column the active column, i.e., the results of this column are color-coded according to their values as defined by the color lookup table and the colors specified in the **Sections** section of the **Colors** tab.
Unset active column	If applicable: Deselects the currently active column and sets the **Active column** drop-down list on the corresponding **Settings** tab to **Uncoded**, i.e., removes any color coding.
Enter/change value (all items)	If applicable: Opens the **Enter value** dialog (see below) where you can enter the desired value for the selected parameter. This value will be applied to all entries in the table.

Control	Description
Enter/change value (selected items)	If applicable: Opens the **Enter value** dialog (see below) where you can enter the desired value for the selected parameter. This value will be applied to the selected entries in the table.
Delete selected items	If applicable: Removes the selected items from the scene.

The **Enter value** dialog includes the following controls:

Table 43-20: Controls in the **Enter value** dialog

Control	Description
Enter value field	Allows you to enter the desired value.
OK button	Sets the selected parameter to the specified value.
Reset button	For analyses only: Resets the selected parameter to undefined.
Set from tolerance settings button	For analyses only: Enters the value specified in the tolerance settings of the analysis for the selected parameter.
Cancel button	Discards the changes and closes the dialog.

Visualization of the Analysis Results

Various overlays are provided for the visualization of the analysis results in the 2D and 3D windows. When the analysis status is **Result is up to date**, these overlays can be switched on and off in the Scene Tree tool below the analysis node by checking and unchecking the corresponding checkboxes.

- **Tensor visualization**

  The computed tensor is shown as an ellipsoid in the center of the simulated volume or—when the analysis is performed on an integration mesh—in the center of each cell. The main axes of the ellipsoid are aligned with the eigenvectors of the tensor, while the lengths of the axes are proportional to the eigenvalues of the tensor.

  The representation of the tensor can be adjusted on the **Tensor visualization** tab.

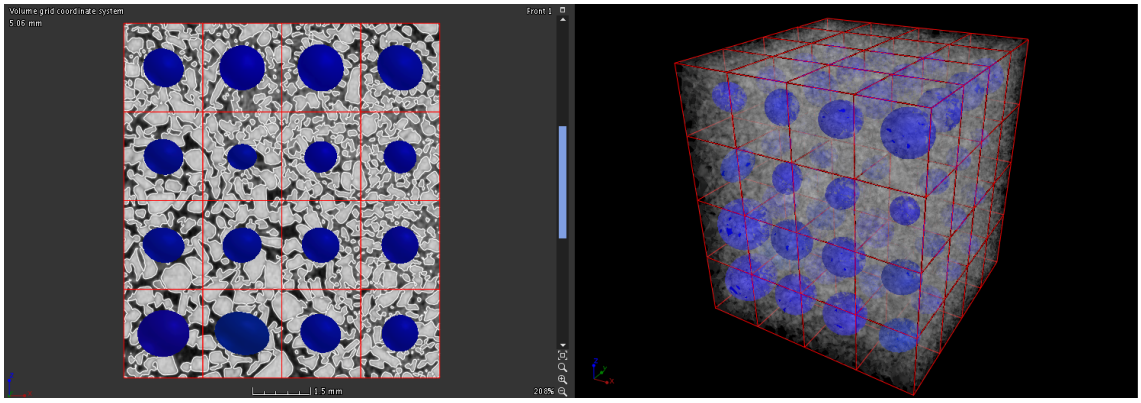


Figure 43-14: Visualization of the tensors computed for an integration mesh

- Color overlay of the selected active column

  When the analysis is performed on an integration mesh, you can select a column of the **Results** table as the active column to display its values according to the color mapping specified on the **Colors** tab.

In order to specify an active column, select the column from the **Active column** drop-down list on the **Settings** tab or right-click the column in the **Results** table and select **Set as active column** from the context menu.

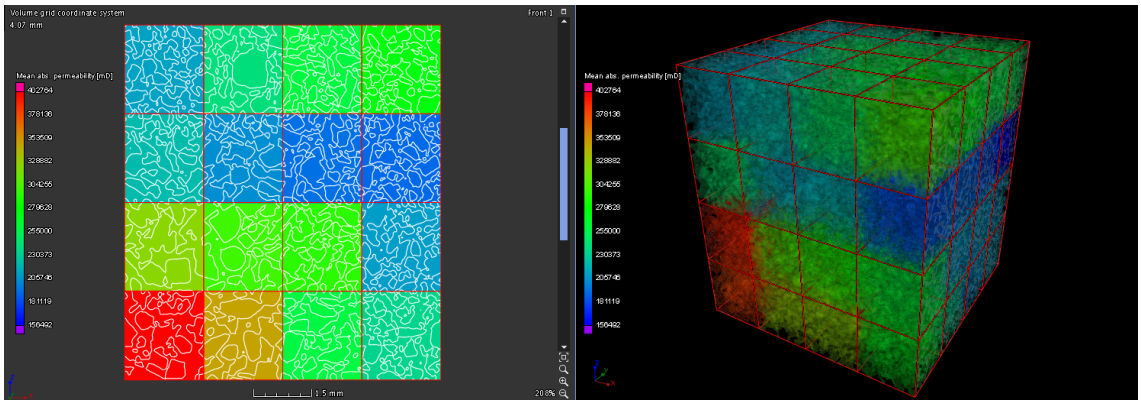


Figure 43-15: Visualization of the values in the active column as color overlay

- **Avg. perfusion** color overlay

  The average perfusion color overlay is similar to a velocity (mass flux density, power density, or current density field), averaged over all flow directions. The average perfusion as defined as the weighted summed flow velocity (mass flux density, power density, or current density) at any point over the three simulation runs. The velocities are weighted by the inverse applied pressure gradient (gradient of concentration, temperature, or voltage) to compensate for variations in the side length of the sample.

  This quantity is shown only in the analyzed volume. It is reported as a unitless value in the interval [0,1].

  The average perfusion overlay is not shown when a calculation with an integration mesh is performed.

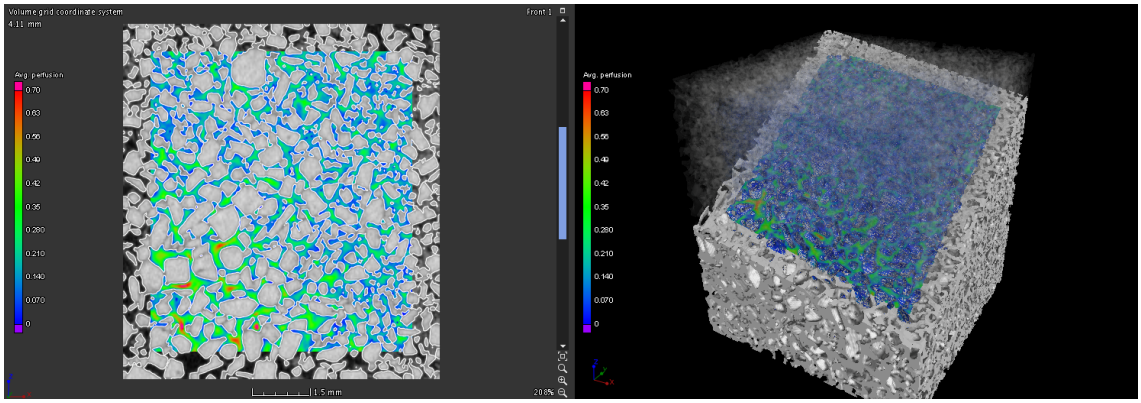


Figure 43-16: Visualization of the average perfusion color overlay

Tensor visualization Tab

Table 43-21: Controls on the **Tensor visualization** tab

Control	Description
Scale spin box	Specifies the size of the ellipsoids that represent the tensors.
3D rendering checkbox	When this option is checked, the ellipsoids that represent the tensors will be displayed in the 3D window.
Linear/Planar/Spherical fields	Double-clicking a color box opens the **Select Color** dialog, where you can set the color of the linear, planar, or spherical components of the ellipsoids that represent the tensors.

How to Obtain Reliable Results

The same conditions as described for the transport phenomena experiment apply (see section *Convergence* on page 761 and section *Representative Elementary Volume (REV)* on page 763 in section *How to Obtain Reliable Results*).

Capillary Pressure Curve

The capillary pressure function computes the pore size distribution and the capillary pressure drainage curve for a scanned porous material sample.

The pore size distribution is calculated using the approach of maximal inscribed spheres. Spheres of varying size are used as probes and attempted to be fit into the pore space. For each point, the largest fitting sphere that overlaps this point is located. The diameter of that sphere is assigned to this point as the local pore diameter.

For determining the capillary pressure curve, a quasi-static drainage experiment is simulated. The sample is connected to two fluid reservoirs, a wetting phase (WP) and a non-wetting phase (NWP) reservoir, at user-defined sections of the volume boundary. The pore space is initially

filled with WP. The pressure in the NWP reservoir is increased in discrete steps, resulting in the injection of NWP into the pore space. After each increase in pressure, equilibrium will be reached before the next increase.

Settings Tab

The **Settings** tab of the **Capillary pressure curve** dialog allows you to set several physics and simulation parameters to control the details of the simulation.

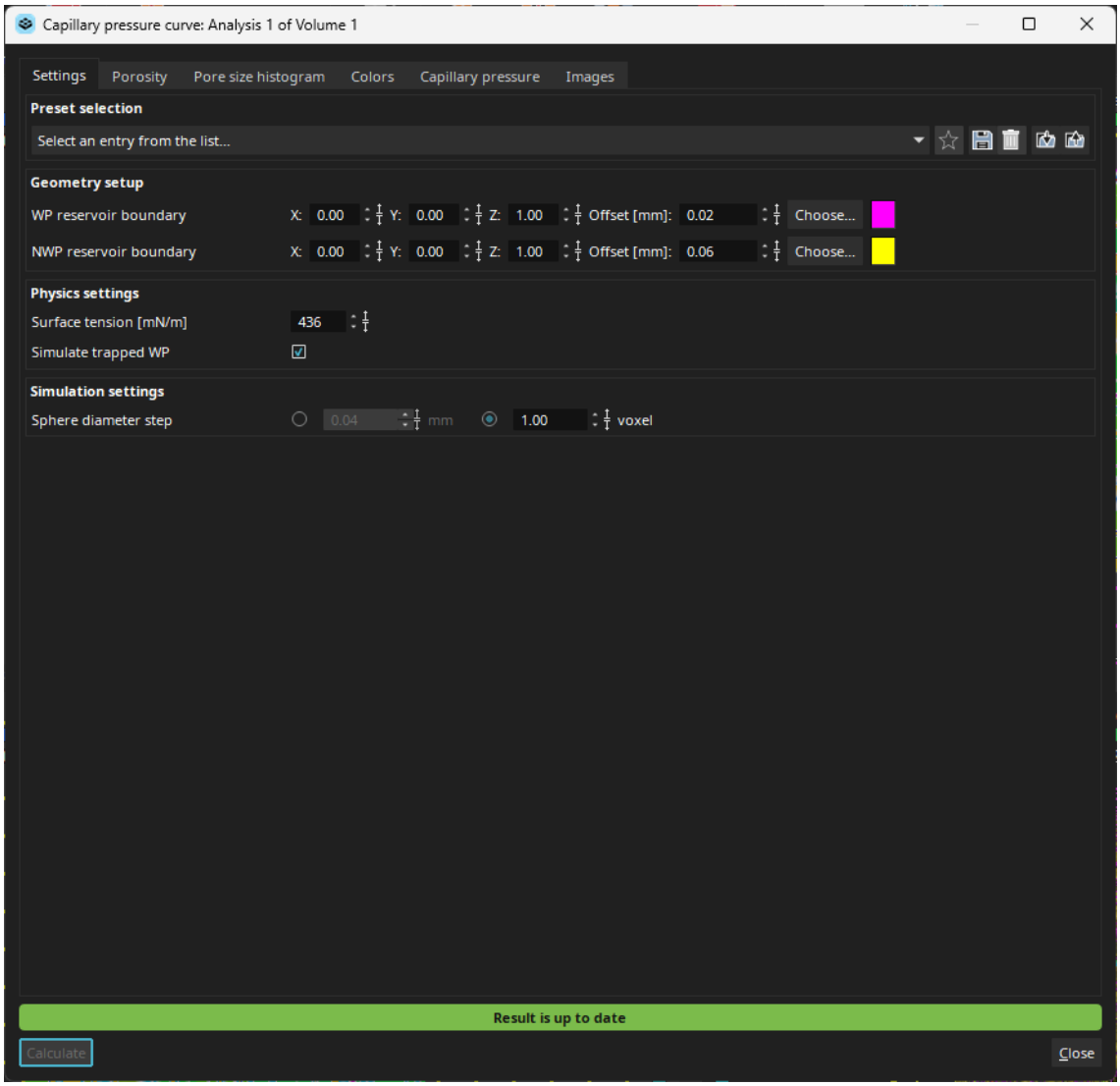


Figure 43-17: **Capillary pressure curve** dialog, **Settings** tab

In myVGL, all parameter settings are displayed. Most of these parameters are read-only in myVGL. The complete functional range is available with VGSTUDIO MAX and the respective add-on module(s).

Preset selection Section

Table 43-22: Controls in the **Preset selection** section

Icon	Item	Description
	drop-down list	Specifies the preset to be applied, to be edited, or to be taken as a basis for a new preset. The following icons are used: • analysis factory settings • customized preset • appears next to the icon of a preset that has been modified but not yet saved
	Set this preset as default	Sets the selected preset as default. The default preset will be applied when creating a new analysis of the same type. If the selected preset is already set as default, the button is disabled.
	Save preset	Saves the selected preset. When saving a preset, the **Save preset** dialog will open, which allows you to set the new preset as default by checking the **Set as default for new analyses** checkbox.
	Remove preset	Removes the selected preset from the preset drop-down list. If the removed preset is the default preset, the next time an analysis of the same type is created, the factory settings will be used.
	Import preset	Imports a preset from the specified location.
	Export preset	Exports the selected preset to the specified location.

Geometry setup Section

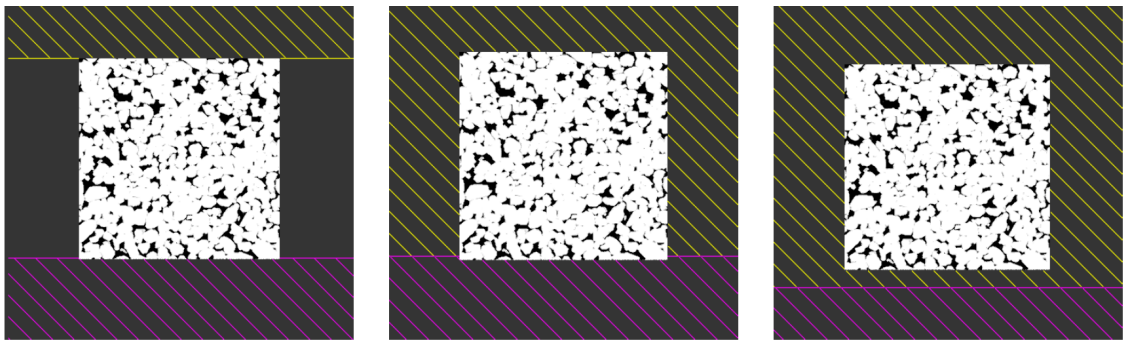
Table 43-23: Controls of the **Geometry setup** section

Control	Description
WP/NWP reservoir boundary X, Y, Z fields	Specify the normal of the boundary plane for the wetting phase (WP)/non-wetting phase (NWP) reservoir. The specified vector is normalized to unit length before it is taken into account in the calculation. The half space at the side of the WP/NWP plane facing away from the NWP/WP plane is regarded as the WP/NWP reservoir. Portions of the simulated volume that intersect with a reservoir are subtracted from the reservoir, so the simulated volume itself is never part of a reservoir. The portion of the simulated volume boundary that does not interface a reservoir is regarded as sealed. The reservoirs are indicated by a magenta and yellow stripe pattern in the 2D views. By placing the reservoir bounds in specific ways, several experimental settings can be mimicked. See also Figure 43-18: *Example settings of reservoir boundaries* on page 782.
Offset spin boxes	Specify the distances of the wetting phase and non-wetting phase boundary planes, respectively, to the coordinate system origin. The current positions of the planes are displayed in the 2D and 3D windows.
Choose... button	Opens a drop-down list that shows the 2D windows currently available in the workspace for specifying the boundary planes for the wetting phase (WP) and non-wetting phase reservoirs.
color box	Double-clicking the box opens the **Select Color** dialog, where you can specify the colors for the boundary planes.

The following figure shows example settings of reservoir boundaries:

- Setup a): Top and bottom are connected to reservoirs, sides sealed. This resembles a Tempe cell.
- Setup b): Bottom is connected to WP, all other faces are connected to NWP. This resembles a porous-plate setup.
- Setup c): All faces are connected to NWP. This resembles a mercury injection experiment, where an evacuated sample is completely submerged in mercury.

Setup c) is not valid when **Simulate trapped WP** is selected in the **Physics settings** section.



a b c

Figure 43-18: Example settings of reservoir boundaries

Physics settings Section

Table 43-24: Controls of the **Physics settings** section

Control	Description
Surface tension spin box	The surface tension between WP and NWP. For air and water at room temperature, this is about 73 mN/m. For mercury and vacuum, it is about 436 mN/m.
Simulate trapped WP checkbox	When this option is checked, portions of the WP that are isolated from the WP reservoir will be regarded as trapped and form the residual WP. When this option is unchecked, the WP will be allowed to drain even if it is not directly connected to the WP reservoir. In the latter case, the WP reservoir is not required to interface the simulated volume.

Simulation settings Section

Table 43-25: Controls of the **Simulation settings** section

Control	Description
Sphere diameter step spin box	The capillary pressure curve is computed at a finite number of sampling points. This parameter influences the number of sampling points. The lower the parameter, the more sampling points will be computed. The default is 1 voxel width. If you feel that there are too few sampling points computed, lower this value to 0.5 voxels, then to 0.25 voxels. Setting even lower values is not logical, since this is already below the resolution of the image data. The sampling points are determined by starting with a sequence of length values L_i = (V/2, V/2+S, V/2+2S, V/2+3S, ... , MAX), where V is the side length of a voxel, S is the sphere diameter step, and MAX is the maximum pore diameter present in the analyzed volume. The values L_i are converted into pressure values by the Young-Laplace Equation $P_i = 4\gamma/L_i$. The values P_i are the sampling points.

Porosity Tab

Displays the porosity values as a slice profile. The x-axis corresponds to a line connecting the WP and NWP reservoir planes in the normal direction. The y-axis corresponds to the porosity averaged over planes parallel to the WP and NWP reservoir planes that pass through the points defined on the x-axis.

Controls of the **Porosity** Tab

Table 43-26: Fields of the **Porosity** tab

Field	Description
Accessible porosity field	Indicates the accessible porosity as a fraction of the region of interest volume.
Isolated porosity field	Indicates the isolated porosity (i.e., pores without a connection to either the WP reservoir or the NWP reservoir) as a fraction of the region of interest volume.
Total porosity field	Indicates the total porosity (accessible + isolated) as a fraction of the region of interest volume.
Accessible pore volume field	Indicates the volume of all accessible pores in the region of interest.
Isolated pore volume field	Indicates the volume of all isolated pores (i.e., pores without a connection to either the WP reservoir or the NWP reservoir) in the region of interest.

Field	Description
Total pore volume field	Indicates the volume of all pores (accessible + isolated) in the region of interest.
use RMB to click the chart area	Displays a context menu (see below).
scroll MW in chart area or x-axis up/down	Zooms the x-axis of the chart out/in.
scroll MW in y-axis up/down	Zooms the y-axis of the chart out/in.
use LMB to click and drag the x-axis	Scrolls the x-axis.
use LMB to click and drag the y-axis	Scrolls the y-axis.
use LMB to click and drag the vertical line in the chart	Moves the line to the new position on the x-axis. The corresponding 2D window will be updated to show the slice at the selected position.
use LMB to click an entry in the legend	Toggles the visibility of the corresponding curve.
hover over a border of the legend and when mouse pointer changes to a hand use LMB to click and drag the legend	Moves the legend to a different position.
Zoom in/out	Zooms the corresponding axis in/out.
Reset zoom	Fits the entire chart to the current window size.

Context Menu of the **Porosity** Tab

Right-clicking anywhere in the chart area opens a context menu with the following options:

Table 43-27: Context menu items

Control	Description
Export as CSV...	Opens a dialog for saving the chart values to a *.csv* file.
Copy to clipboard	Copies a screenshot of the chart to the system clipboard so you can paste it into another application.
Show/Hide x/y grid	Toggles the visibility of the grid lines for the corresponding axis.
Reset zoom	Fits the entire chart to the current window size.
Show/Hide legend	Displays or hides the legend for the plotted curves.

Pore size histogram Tab

Shows a histogram of the pore diameters in the accessible pore volume of the specified region of interest.

The average values and the histogram are based on the accessible pore volume only.

Controls of the **Pore size histogram** Tab

Table 43-28: Controls of the **Pore size histogram** tab

Control	Description
Color drop-down field	• **From color bar**: The values in the histogram are shown according to the color bar. • **Gray**: All values in the histogram are shown in gray.
Normalization drop-down field	• **Absolute**: Displays the volume in absolute values. • **Relative**: Displays the volume in relative values with respect to the entire accessible pore volume.
Binning drop-down field	• **Off**: No binning is applied to the values shown in the histogram. • **From color bar**: The original values in the histogram are replaced by a value representative for the corresponding interval (“bin”) of the color bar. The “bins” become visible when “stepped” sections are created on the **Colors** tab. • **Manual number of bins**: Enables the **Bin count** spin box, where you can enter the required number of “bins.” • **Manual bin width**: Enables the **Bin width** spin box, where you can specify the width of the individual bins.
Left/**Right** spin box	Only enabled when an interval has been created: Moves the left or right interval border to the specified value. You can also click and drag the interval borders.
Create button	Creates a new interval. On the right hand side of a selected interval, statistical information is displayed: • **Left**: Indicates the minimum pore diameter within the interval, i.e., the value of the left interval border. • **Right**: Indicates the maximum pore diameter within the interval, i.e., the value of the right interval border. • **Mean**: Indicates the mean value of the pore diameters within the interval. • **Dev**: Indicates the standard deviation of the pore diameters within the interval.

Control	Description
	• **Sum**: Indicates the pore volume within the interval. • **Percentage**: Indicates the percentage of the pore volume within the interval. Note that the statistical information may change with the number of bins.
Remove button	Removes the selected interval.
Average pore diameter [<length unit>] field	Indicates the average pore diameter.
Std. dev. of pore diameter [<length unit>] field	Indicates the standard deviation of the pore diameters.
Accessible pore volume [<length unit>³] field	Indicates the volume of all accessible pores in the region of interest.
use RMB to click the chart area	Displays a context menu (see below).
scroll MW in chart area or x-axis up/down	Zooms the x-axis of the chart out/in.
scroll MW in y-axis up/down	Zooms the y-axis of the chart out/in.
use LMB to click and drag the x-axis	Scrolls the x-axis.
use LMB to click and drag the y-axis	Scrolls the y-axis.
Zoom in/out	Zooms the corresponding axis in/out.
Reset zoom	Fits the entire chart to the current window size.

Context Menu of the **Pore size histogram** Tab

Right-clicking anywhere in the chart area opens a context menu with the following options:

Table 43-29: Context menu items

Control	Description
Export as CSV...	Opens a dialog for saving the chart values to a *.csv* file.
Copy to clipboard	Copies a screenshot of the chart to the system clipboard so you can paste it into another application.
Show/Hide x/y grid	Toggles the visibility of the grid lines for the corresponding axis.
Reset zoom	Fits the entire chart to the current window size.
Create interval	Creates a new interval. For details on the statistical information, see section *Controls of the Pore size histogram Tab* on page 785.
Remove interval	Removes the selected interval.

Visualization of the Analysis Results

Four overlays are provided for the visualization of the results in the 2D and 3D windows. When the analysis status is **Result is up to date**, the overlays can be switched on and off in the Scene Tree tool below the analysis node by checking and unchecking the corresponding checkboxes.

For an optimal 3D view of the pore diameter, swap the inner and outer areas of the volume to visualize pores instead of material, and use clipping objects to look inside the sample.

For an optimal 3D view of the isolated pore space, NWP, and trapped WP, it is recommended that you set the transparency of the scanned volume to a large value.

- **Isolated pore space**

  The pore space not connected to either WP or NWP reservoir is shown in red.

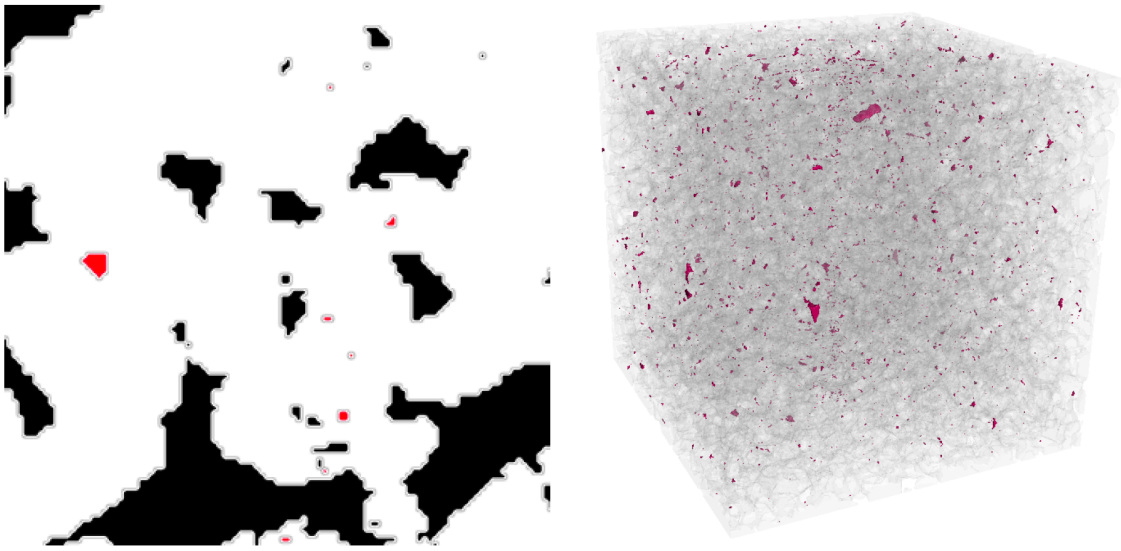


Figure 43-19: Visualization of the isolated pore space

- **Non-wetting phase (NWP)**

  The space occupied by the NWP is displayed in yellow. The visualization corresponds to the point on the capillary pressure curve currently selected in the **Capillary pressure** tab.

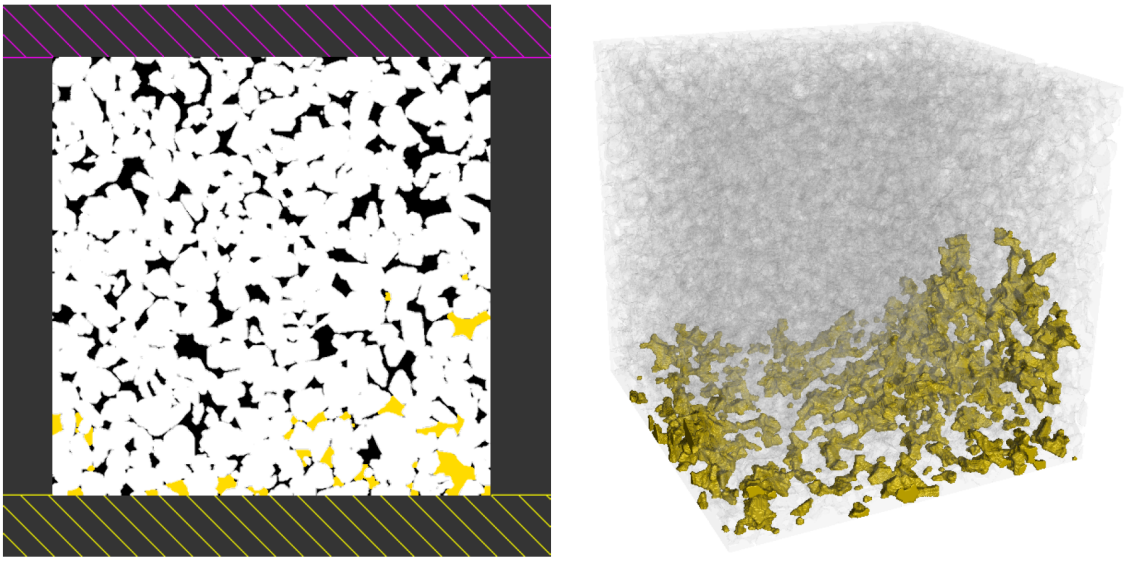


Figure 43-20: Visualization of the non-wetting phase

- **Pore size**

  The pore diameter at any point in the pore space. The color mapping can be adjusted in the **Colors** tab.

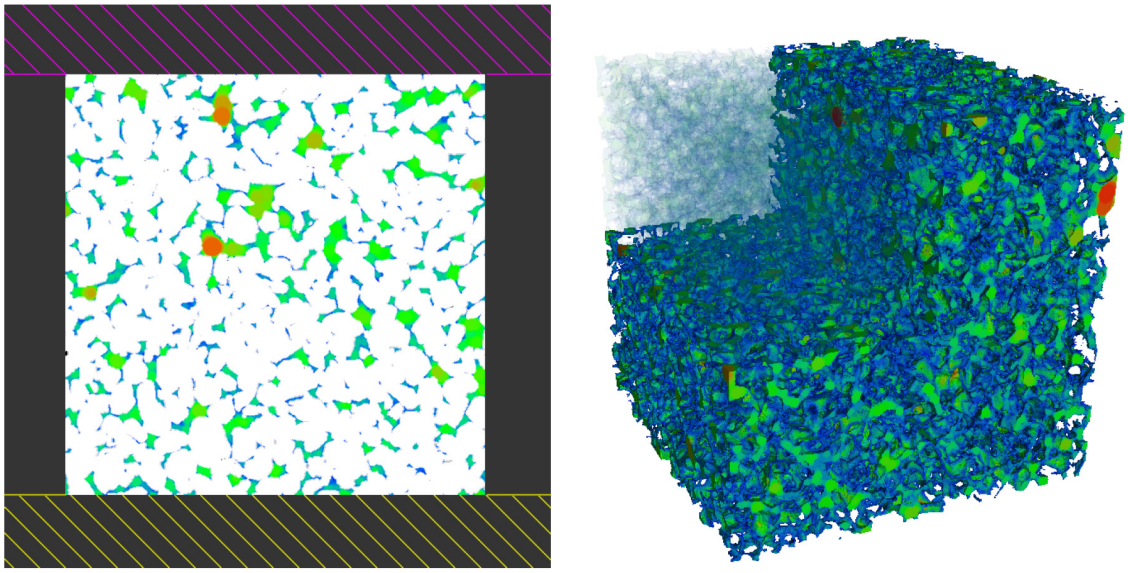


Figure 43-21: Visualization of the pore diameter

- **Trapped wetting phase (WP)**

  The residual wetting phase is shown in magenta.

The trapped WP overlay is present only if the analysis was calculated with the **Simulate trapped WP** option checked.

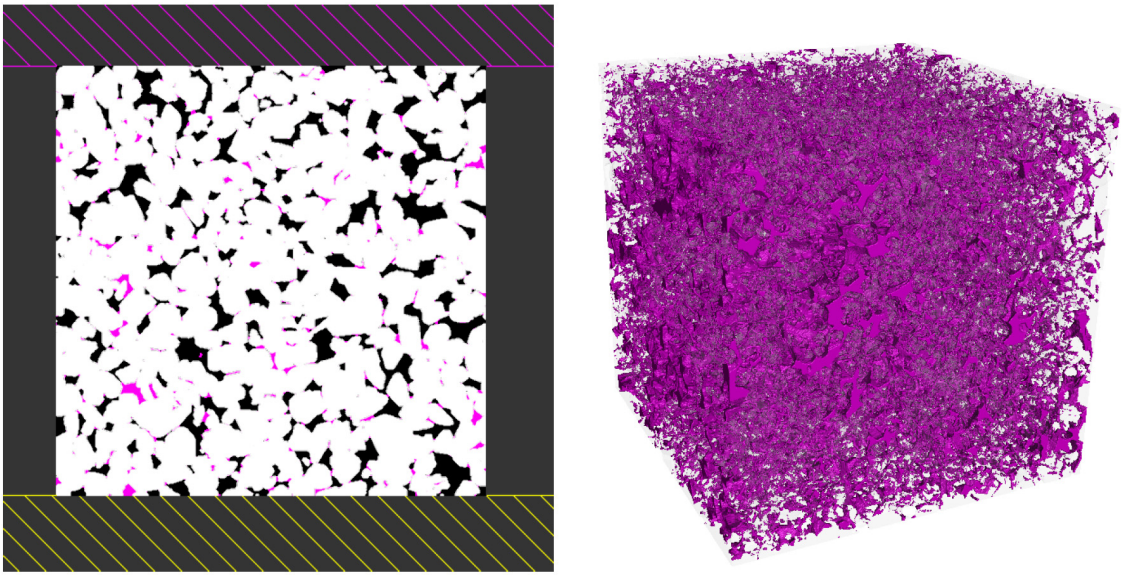


Figure 43-22: Visualization of residual (trapped) wetting phase

Capillary pressure Tab

- **Capillary pressure curve**

  Displays the WP saturation on the x-axis and the capillary pressure on the y-axis.
- **Saturation profiles**

  Displays the WP saturation as a slice profile. The x-axis corresponds to a line that connects the WP and NWP reservoir planes in the normal direction. The y-axis corresponds to the WP saturation averaged over planes parallel to the WP and NWP reservoir planes that pass through the points defined on the x-axis.

  Three saturation profiles are shown:
  - Maximum pressure on the capillary pressure curve
  - Pressure at NWP break-through (i.e., the pressure where the NWP first reaches the WP reservoir)
  - Pressure selected in the **Capillary pressure curve** plot

Controls of the **Capillary pressure** Tab

Table 43-30: Controls of the **Capillary pressure** tab

Control	Description
Break-through pressure field	Indicates the pressure where the NWP first reaches the WP reservoir.
Break-through wetting saturation field	Indicates the WP saturation corresponding to the break-through pressure.
Max. pressure field	Indicates the maximum pressure computed (left end of capillary pressure curve).

Control	Description
Max. pressure WP saturation field	Indicates the WP saturation corresponding to the max. pressure.
Selected pressure field	Indicates the pressure currently selected in the capillary pressure curve plot.
Selected wetting saturation field	Indicates the WP saturation corresponding to the max. pressure.
Diameter of max. percolating sphere field	Indicates the diameter of the largest spherical probe that can reach the WP reservoir starting from the NWP reservoir.
use RMB to click the chart area	Displays a context menu (see below).
scroll MW in chart area or x-axis up/down	Zooms the x-axis of the chart out/in.
scroll MW in y-axis up/down	Zooms the y-axis of the chart out/in.
use LMB to click and drag the x-axis	Scrolls the x-axis.
use LMB to click and drag the y-axis	Scrolls the y-axis.
hold down **Ctrl** key + use LMB to click into the chart	Capillary pressure curve: Displays a handle to select a point on the capillary pressure curve. Saturation profiles: Displays a handle to select a position on the x-axis. The corresponding 2D window will be updated to show the slice at the selected position.
use LMB to click an entry in the legend	Toggles the visibility of the corresponding curve.
hover over a border of the legend; when the mouse pointer changes to a hand, use LMB to click and drag the legend	Moves the legend to a different position.
Zoom in/out	Zooms the corresponding axis in/out.
Reset zoom	Fits the entire chart to the current window size.

Context Menu of the **Capillary pressure** Tab

Right-clicking anywhere in the chart area shows a context menu with the following options:

Table 43-31: Context menu items

Control	Description
Export as CSV...	Opens a dialog for saving the chart values to a *.csv* file.
Copy to clipboard	Copies a screenshot of the chart to the system clipboard so you can paste it into another application.

Control	Description
Show/Hide x/y grid	Toggles the visibility of the grid lines for the corresponding axis.
Reset zoom	Fits the entire chart to the current window size.
Show/Hide legend	Displays or hides the legend for the plotted curves.

How to Obtain Reliable Results

The same conditions as described for the transport phenomena experiment regarding the representative elementary volume apply (see section *Representative Elementary Volume (REV)* on page 763).

Colors Tab

Here you can specify the color-coding scheme used for the representation of the analysis results.

Select Section

Specifies the quantity for which you want to specify the color-coding scheme.

Caption Section

Table 43-32: Controls of the **Caption** section

Control	Description
Caption field	Indicates the color bar headline as specified in the **Caption** field of the **Color bar** section.
Share color bar checkbox	When this option is checked, all analyses of the same type (and—if applicable—of the same algorithm) will use the same color bar. When this option is unchecked, the color bar settings will apply to the selected analysis only.

LUT – Color Lookup Table

The color lookup table (LUT) shows the partitioning into color sections.

Sections Section

Defines the appearance of each color section.

Table 43-33: Controls in the **Sections** section

Control	Description
From/To fields	Specify the start and end values of the color sections. The first color section represents all values above the upper limit, i.e., the value in the **From** field (**+inf** signifies positive infinity), while the last color section represents all values below the lower limit, i.e., the value in the **To** field (**-inf** signifies negative infinity). The default limits are calculated from the results of the analysis (for an analysis color bar) or taken from the **Default** preset (for a tolerance deviation color bar).
Type field	Switches between the color schemes **Continue**, **Constant**, **Gradient**, **Rainbow**, **Reverse rainbow**, **Hue cycle**, **Green to red**, and **Red to green**.
Color/transparency field	Double-clicking the field for the **Continue**, **Constant**, and **Gradient** color schemes opens the **Select Color** dialog where you can modify the appearance of the selected color scheme. For the **Gradient** color scheme, you can specify the start and end colors by double-clicking the left or right side of the field, respectively. Double-clicking the field for the **Rainbow**, **Reverse rainbow**, **Hue cycle**, **Green to red**, and **Red to green** color schemes opens the **Transparency** dialog, where you can set the transparency for the selected color scheme.
use RMB to click a color section	Opens a context menu with the following items: • **Split**: Subdivides the color section into two new color sections where each represents half of the original section. • **Merge**: Combines several color sections to a single color section. Only consecutive intervals can be merged.
Create smooth button	Opens the **Create smooth table** dialog to generate one color section. • **Type** drop-down list: Allows you to select the type of coloring scheme. • **From/To** spin boxes: Specify the value range covered by the color section.

Control	Description
Create stepped button	Opens the **Create stepped table** dialog to generate a set of color sections. • **Type** drop-down list: Allows you to select the type of coloring scheme. • **From/To** spin boxes: Specify the value range covered by the color sections. • **Step** spin box: Specifies the step size of the individual color sections.
Auto scale button	If available: Fits the color LUT to the range of the results of all available analyses.
Auto scale color bar range on calculate checkbox	If available: When this option is checked, the color LUT will be automatically fitted to the range of the results of all available analyses.
Default button	If available: Resets any changes made to the **Sections** table.

Color LUT Settings Section

Specifies the appearance of the color lookup table.

Table 43-34: Options for the appearance of the color lookup table

Control	Description
Auto tick marks checkbox	When this option is checked, equidistant tick marks will be produced for the color bars. When this option is unchecked, tick marks will appear only at the color section boundaries of the color lookup table.
Auto scale color bar range on calculate checkbox	When this option is checked, the color LUT will be automatically fitted to the range of the results of all available analyses.

Preset selection Section

Table 43-35: Controls in the **Preset selection** section

Icon	Item	Description
	drop-down list	Specifies the preset to be applied, to be edited, or to be taken as a basis for a new preset. The following icons are used: • default preset • customized preset • appears next to the icon of a preset that has been modified but not yet saved

Icon	Item	Description
	Save preset	Opens the **Save preset** dialog for saving the color LUT of the current data set under the specified name. • **Absolute preset**: When this option is checked and the preset applied, the settings of the original data set, including the LUT range, will be applied. When this option is unchecked, the color settings of the preset will be mapped relatively to the actual range of results of the analysis to which the preset will be applied.
	Remove preset	Removes the selected preset from the preset drop-down list.
	Import preset	Imports a preset from the specified location.
	Export preset	Exports the selected preset to the specified location.

Color bar Section

Specifies the settings for the color bar.

Table 43-36: Settings for the color bar

Control	Description
Visibility drop-down list	Switches the color bar on/off.
Positioning drop-down list	Specifies the location of the color bar within the 2D and 3D windows: **Left, Right, Top, Bottom, All - automatic, Left or right - automatic, Top or bottom - automatic**.
Caption field	Specifies the color bar headline by using placeholders.
Reset button	Resets the **Caption** field to the default entry.

Images Tab

Allows you to take screenshots of the selected workspace views and/or add bookmark references to the report. In the final report, the captured images will be listed separately from the screenshots created on other tabs.

- **Snapshots** section

  Table 43-37: Controls in the **Snapshots** section

Control	Description
Capture from button	Adds the image of the view selected from the drop-down list to the preview area above.

Control	Description
Delete selected button	Deletes the selected image(s) from the preview area.
use LMB to click and drag one or more images, then release LMB	Moves the image(s) to the new position.
double-click the image	Opens the **Snapshot display** window showing the image: • **Zoom in**/**Zoom out** button: Zooms the image in/out. You can also move the mouse pointer on the image area and turn the mouse wheel. • **Fit to window** button: Resets the zoom so that the image fits into the window.
click the **<no description>** placeholder twice (first click to select, second click to enable renaming)	Allows you to label the image.

- **Automatic 3D images** section (if available)

  Check the corresponding checkbox to include the desired 3D view (e.g., **Top**, **Front**, **Top-left-front**, and **Current camera settings**) in the report without changing the 3D view.

- **Bookmark references** section

  Allows you to add bookmark references via drag and drop from the **Bookmarks and views** tool or the **Bookmark editor** to the preview area. The images of the referenced bookmarks will then be included in VGRF-based reports.

  When you open a project with missing bookmark images, placeholders will be shown instead.

  Bookmark references are stored in evaluations and can be used in automation scenarios.

You will still need to import a bookmark template containing the actual bookmarks in these cases, as evaluations store only references to them.

Table 43-38: Controls in the **Bookmark references** section

Control	Description
New bookmark button	Adds a bookmark of the current view to the preview area.
Remove button	Removes the bookmark currently selected in the preview area.

Control	Description
click the bookmark title twice (first click to select, second click to enable renaming) or press the **F2** key	Allows you to rename the bookmark. The changes made on the **Images** tab will also affect the **Bookmark editor** and the **Bookmarks and views** tool. If the renamed bookmark is referenced by one or more objects for reporting, a warning message will be displayed indicating that the referenced bookmark will also be renamed for all these objects in the report.

The global concept of bookmark references allows for multiple objects to reference the same bookmark and for objects to reference bookmarks that show arbitrary information, e.g., other analyses or objects.

Physics Reference

Notation Conventions

The following conventions are used for denoting quantities and operations:

- Scalar quantities are denoted with italic letters, e.g., x.
- Vector-valued quantities are marked with an underline, e.g., $\underline{x}$.
- The i-th component of a vector-valued quantity is written as x_i.
- Tensor-valued quantities are denoted with bold letters, e.g., $\mathbf{x}$.
- The matrix component (i, j) of a tensor-valued quantity is written as x_{ij}.
- The partial derivative of a function $f(\underline{r})$ with respect to the i-th component of the vector $\underline{r}$ is denoted by $f_{,i}(\underline{r})$.
- The dependence on the position vector $\underline{r}$ is sometimes omitted for a clearer appearance of formulas, e.g., instead of $s_{ij}(\underline{r})$, we will simply write s_{ij}.

Absolute Permeability Experiment and Tensor Calculation

The Stokes flow, also known as creeping flow, is simulated, which is a simplification of the stationary Navier-Stokes equation for an incompressible fluid at low Reynolds numbers, i.e., low flow velocity or high viscosity. Note that for high flow velocities or low viscosities, or for compressible material like gases, the results will be unreliable. In particular, the occurrence of vortices is not covered, and the flow is assumed to be laminar. A one-component flow is simulated, i.e., the pore space is assumed to be entirely flooded. The Stokes flow is described by the equations

$$\begin{aligned} \mu\Delta\underline{v} - \operatorname{grad} p &= 0 \\ \operatorname{div} \underline{v} &= 0, \end{aligned}$$

where $\underline{v}$ is the velocity of the fluid, p is the pressure, μ is the dynamic viscosity of the fluid, Δ is the Laplace operator, grad is the gradient operator, and div is the divergence operator.

The simulation is performed using a Lattice-Boltzmann method with the BGK collision model (see [8] in section *References* on page 813). The following boundary conditions are applied (for

an illustration of the symbols, see Figure 43-23: *Boundaries of the simulated volume* on page 798):

$\underline{v} = 0$	at Γ_{pm}
$p = p_0$	at Γ_i
$p = 0$	at Γ_o
$\underline{v} = 0$	at Γ_R in **Sealed** mode
$p(\underline{r}) = \frac{d_o(\underline{r})}{d_{io}} p_0$	at Γ_R in **Embedded** mode

where

Γ_{pm}	boundary between pore and material (= determined object surface)
Γ_i, Γ_o	inlet and outlet planes, respectively
Γ_R	remaining volume or ROI boundary (except inlet and outlet)
p_0	user-defined pressure difference
$\underline{r}$	position
$d_o(\underline{r})$	normal distance of $\underline{r}$ to the outlet plane
d_{io}	normal distance between inlet and outlet plane
Sealed, **Embedded**	user-defined boundary mode

The following figure illustrates the geometry of the simulated volume. Only the dotted region is simulated. The parts of the ROI that are not between the inlet and outlet planes are excluded from the simulation.

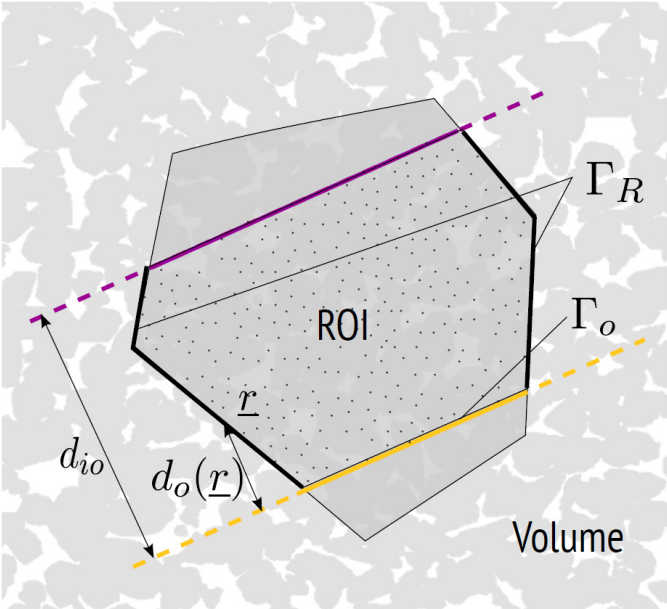


Figure 43-23: Boundaries of the simulated volume

The **Boundary condition** used in the **Embedded** mode is based on a mean-field approximation of the (unknown) surrounding material and requires a deeper explanation. In some situations, especially with anisotropic materials, sealing the lateral boundaries will produce unreliable results. This is because sealing introduces artificial barriers in the material. In Figure 43-24, the white square is the ROI on which a simulation experiment is performed. The upper and lower edges of the square are inlet and outlet, respectively. The right and left edges are considered to be sealed. Only the green capillary can be used for transport. The red capillaries cannot be used for transport because they are dead ends. These dead ends are artificially introduced by the boundary condition and are thus not a property of the original material. The computed permeability will be incorrect.

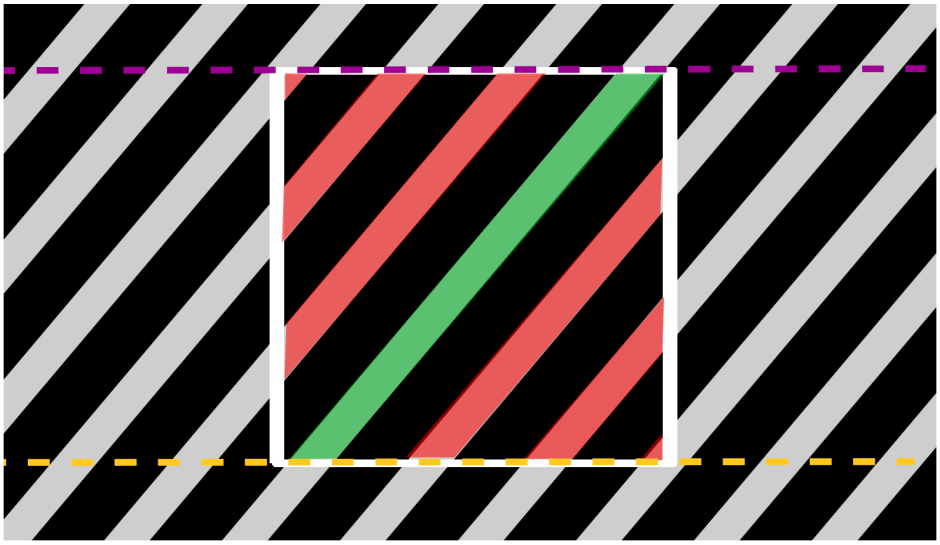


Figure 43-24: Material with inclined capillaries

Generally, it is recommended that the porous sample is simulated in its natural context, i.e., without introducing artificial barriers. Often, periodic boundary conditions are imposed to achieve this goal. This approach works well with artificial data, but it is problematic with natural samples since opposing faces do not match on the pore scale. In VGSTUDIO MAX, a different approach is chosen based on the assumption that the surrounding material obeys Darcy's law (which is reasonable, since otherwise, the concept of absolute permeability would not be defined at all). Darcy's law postulates a linear pressure drop in the sample. This is exactly what the **Embedded** boundary condition prescribes.

The absolute permeability k of the material is defined by Darcy's law as

(Darcy's law)

$$\langle v \rangle = \frac{-k}{\mu}\frac{dp}{dL}$$

where dp is the pressure difference between inlet and outlet, dL is the length of the sample (thus, dp/dL is the *volume-averaged* pressure gradient), μ is the dynamic viscosity of the fluid, and $\langle v \rangle$ is the volume-averaged flow velocity in the medium. In an isotropic medium, the average flow velocity points to the same direction as the applied pressure gradient. Generally, the average velocity can deviate from this direction, in which case $\langle v \rangle$ is the component of the average flow velocity in the direction of the pressure gradient. According to Darcy's law, k is computed from the simulation result as:

$k = -\langle v \rangle \mu dL/dp,$

with $dp = p_0$, $dL = d_{io}$, μ being the dynamic viscosity of the fluid, and the average velocity component is in the direction of the pressure gradient, averaged over the **Analyzed volume** (see section *Simulation settings Section* on page 751), including non-pore space, where we assume $v = 0$.

In three dimensions, Darcy's law reads

(Darcy's law 3 dim.)

$$\langle \underline{v} \rangle = \frac{-\mathbf{k}}{\mu} \langle \mathrm{grad}\ p \rangle$$

where $\underline{v}$ and $\mathrm{grad}\ p$ are the three-dimensional flow velocity and the pressure gradient, respectively, $\langle \cdot \rangle$ denotes volume averaging, and $\mathbf{k}$ is the symmetric absolute permeability tensor of rank two. In order to infer all the six independent components of this tensor, three distinct virtual experiments simulation runs are performed with the pressure gradient pointing along each of the three coordinate axes, $\mathrm{j} = 1...3$. The three runs are performed automatically in a sequence. Let dp_j and dL_j be the pressure difference and the distance between inlet and outlet, respectively, applied in the j-th simulation run, and $\underline{v}^j$ be the resulting computed velocity field, with vector components v_i^j, $i = 1...3$. The absolute permeability tensor is then calculated according to Darcy's law as

$$\mathbf{k}_{ij} = -\langle v_i^j \rangle \mu dL_j / dp_j,$$

where $\langle v_i^j \rangle$ is the average over the **Analyzed volume** (see section *Simulation settings Section* on page 768), including non-pore space, where we assume $\underline{v} = 0$. Due to computational artifacts, the computed tensor is only approximately symmetric. In order to obtain a perfectly symmetric tensor, the result is finally symmetrized as

$$\mathbf{k}_{ij}^{final} = (\mathbf{k}_{ij} + \mathbf{k}_{ji})/2.$$

Molecular Diffusivity Experiment and Tensor Calculation

The stationary molecular concentration and flux fields, which are reached asymptotically when a sample is connected to reservoirs of different molar concentrations, are computed. The pores of the sample are assumed to be completely filled with the solvent. The concentration in the reservoirs is assumed to be constant, like in very large reservoirs. The asymptotically reached stationary concentration and molar flux fields are provided by the following differential equations.

$\Delta C = 0$	in Ω	(Time-independent Fick's 2nd Law)
$\underline{J} = -D_a \mathrm{grad}\, C$	in Ω_a	(Fick's 1st Law)

where Ω is the entire simulation domain and Ω_a is the domain of component a (with $a = 1$ for pore space and $a = 2$ for material). It is assumed that $\Omega_1 \cup \Omega_2 = \Omega$ and $\Omega_1 \cap \Omega_2 = \emptyset$. C is the molecular concentration, $\underline{J}$ is the molar flux, D_a is the diffusion coefficient of component a, Δ is the Laplace operator, and grad is the gradient operator.

A mesh-free finite-element method with linear basis functions and a conjugate gradient solver is used.

The following boundary conditions are applied (see also Figure 43-23: *Boundaries of the simulated volume* on page 798):

$C = C_0$	at Γ_i
$C = 0$	at Γ_o
$D_1 \mathrm{grad_n} C_1 = D_2 \mathrm{grad_n} C_2$	at Γ_{12}
$\mathrm{grad_n} C = 0$	at Γ_R in **Sealed** mode
	at Γ_R in **Embedded** mode
$C(\underline{r}) = \frac{d_o(\underline{r})}{d_{io}} C_0$	

where

Γ_{12}	boundary between Ω_1 and Ω_2 (= determined object surface)
Γ_i, Γ_o	inlet and outlet planes, respectively
Γ_R	remaining volume or ROI boundary (except inlet and outlet)
$\mathrm{grad_n}$	spatial derivative in direction of the boundary normal
C_0	user-defined concentration difference
$\underline{r}$	position
$d_o(\underline{r})$	normal distance of $\underline{r}$ to the outlet plane
d_{io}	normal distance between inlet and outlet plane
Sealed, Embedded	user-defined boundary mode

For an explanation of the **Embedded** boundary condition, see section *Absolute Permeability Experiment and Tensor Calculation* on page 796 and Figure 43-24: *Material with inclined capillaries* on page 799.

The effective diffusivity D^{eff} relates the macroscopic (volume-averaged) concentration gradient to the macroscopic (volume-averaged) molar flux, which conforms to Fick's first law:

$$\langle J \rangle = -D^{\mathrm{eff}} dC/dL$$

where dC is the concentration difference between inlet and outlet and dL is the length of the sample (thus, dC/dL is the applied *volume-averaged* concentration gradient), and $\langle J \rangle$ is the volume-averaged molecular flux. In an isotropic medium, the flux points to the same direction as the applied concentration gradient. Generally, the flux can deviate from this direction, in which case $\langle J \rangle$ is the component of the average flux in the direction of the concentration gradient.

According to the above equation, D^{eff} is computed from the simulation result as:

$$D^{\mathrm{eff}} = -\langle J \rangle dL/dC$$

with $dC = C_0$, $dL = d_{io}$, and $\langle J \rangle$ the average molar flux component is in the direction of the concentration gradient, averaged over the **Analyzed Volume** (see section *Simulation settings Section* on page 751).

In three dimensions, the volume-averaged Fick's law reads

$\langle \underline{J} \rangle = -\mathbf{D}^{\text{eff}} \langle \text{grad } C \rangle,$

where $\underline{J}$ and $\text{grad } C$ are the three-dimensional average molar flux and concentration gradient, respectively, $\langle \cdot \rangle$ denotes volume averaging, and $\mathbf{D}^{\text{eff}}$ is the symmetric effective diffusivity tensor of rank two. In order to infer all components of this tensor, three distinct virtual experiment simulation runs are performed with the concentration gradient pointing along each of the three coordinate axes, $j = 1...3$. The three runs are performed automatically in a sequence. Let dC_j and dL_j be the concentration difference and the distance between inlet and outlet, respectively, applied in the j-th simulation run, and $\underline{J}^j$ be the resulting computed molar flux field, with vector components J_i^j, $i = 1...3$. The effective diffusivity tensor is then calculated as

$$\mathbf{D}_{ij}^{\text{eff}} = -\langle J_i^j \rangle dL_j / dC_j,$$

where $\langle J_i^j \rangle$ is the average over the analyzed volume (see section *Simulation settings Section* on page 768). Due to computational artifacts, the computed tensor is only approximately symmetric. In order to obtain a perfectly symmetric tensor, the result is finally symmetrized as

$$\mathbf{D}_{ij}^{\text{eff,final}} = (\mathbf{D}_{ij}^{\text{eff}} + \mathbf{D}_{ji}^{\text{eff}})/2.$$

Thermal Conductivity Experiment and Tensor Calculation

The stationary temperature and thermal flux fields in a two-component material are simulated, where each material has a different thermal conductivity, with the boundary condition that the inlet and outlet are connected to heat reservoirs, each at a different constant temperature. Convection and heat radiation are neglected. If any of the components is fully non-conducting, the respective conductivity can be set to zero. The stationary temperature and heat flux fields in a two-component material are described by the following differential equations:

$\Delta T = 0$	in Ω	
$\underline{q} = -k_a \text{grad}\, T$	in Ω_a	(Fourier's Law)

where Ω is the entire simulation domain and Ω_a is the domain of component a (with $a = 1, 2$). It is assumed that $\Omega_1 \cup \Omega_2 = \Omega$ and $\Omega_1 \cap \Omega_2 = \emptyset$. T is the temperature, $\underline{q}$ is the heat flux, k_a is the thermal conductivity of component a, Δ is the Laplace operator, and grad is the gradient operator.

A mesh-free finite-element method with linear basis functions and a conjugate gradient solver is used.

The following boundary conditions are applied (see also Figure 43-23: *Boundaries of the simulated volume* on page 798):

$T = T_0$	at Γ_i
$T = 0$	at Γo
$T_1 = T_2$	at Γ_{12}

$k_1 \mathrm{grad}_\mathrm{n} T_1 = k_2 \mathrm{grad}_\mathrm{n} T_2$	at Γ_{12}
$\mathrm{grad}_\mathrm{n} T = 0$	at Γ_R in **Sealed** mode
$T(\underline{r}) = \frac{d_o(\underline{r})}{d_{io}} T_0$	at Γ_R in **Embedded** mode

where

Γ_{12}	boundary between Ω_1 and Ω_2 (= determined object surface)
$T_1,\ T_2$	temperatures adjacent to Γ_{12} in Ω_1 and Ω_2, respectively
Γ_i, Γ_o	inlet and outlet planes, respectively
Γ_R	remaining volume or ROI boundary (except inlet and outlet)
grad_n	spatial derivative in direction of the boundary normal
T_0	user-defined temperature difference
$\underline{r}$	position
$d_o(\underline{r})$	normal distance of $\underline{r}$ to the outlet plane
d_{io}	normal distance between inlet and outlet plane
Sealed, Embedded	user-defined boundary mode

For an explanation of the **Embedded** boundary condition, see section *Absolute Permeability Experiment and Tensor Calculation* on page 796 and Figure 43-24: *Material with inclined capillaries* on page 799.

The effective thermal conductivity k^{eff} relates the macroscopic (volume-averaged) temperature gradient to the macroscopic (volume-averaged) heat flux, which conforms to Fourier's law:

$$\langle \varphi \rangle = -k^{\mathrm{eff}} dT/dL$$

where dT is the temperature difference between inlet and outlet, dL is the length of the sample (thus, dT/dL is the applied *volume-averaged* temperature gradient), and $\langle \varphi \rangle$ is the volume-averaged heat flux. In an isotropic medium, the flux points into the same direction as the applied temperature gradient. Generally, the flux can deviate from this direction, in which case $\langle \varphi \rangle$ is the component of the average flux in the direction of the temperature gradient. According to the above equation, k^{eff} is computed from the simulation results as:

$$k^{\mathrm{eff}} = -\langle \varphi \rangle dL/dT$$

with $dT = T_0$, $dL = d_{io}$, and $\langle \varphi \rangle$ being the average heat flux component in the direction of the temperature gradient, averaged over the **Analyzed volume** (see section *Simulation settings Section* on page 751).

In three dimensions, the volume-averaged Fourier's law reads

$$\langle \underline{\varphi} \rangle = -\mathbf{k}^{\mathrm{eff}} \langle \mathrm{grad}\ T \rangle,$$

where $\underline{\varphi}$ and $\mathrm{grad}\ T$ are the three-dimensional heat flux and temperature gradient, respectively, $\langle \cdot \rangle$ denotes volume averaging, and $\mathbf{k}^{\mathrm{eff}}$ is the symmetric effective thermal conductivity tensor of rank two. In order to infer all components of this tensor, three distinct virtual experiment

simulation runs are performed with the temperature gradient pointing along each of the three coordinate axes, $j = 1...3$. The three runs are performed automatically in a sequence. Let dT_j and dL_j be the temperature difference and the distance between inlet and outlet, respectively, applied in the j-th simulation run, and $\underline{\varphi}^j$ be the resulting computed heat flux field, with vector components φ_i^j , $i = 1...3$. The effective thermal conductivity tensor is then calculated as

$$\mathbf{k}_{ij}^{\text{eff}} = -\langle \varphi_i^j \rangle dL_j / dT_j,$$

where $\langle \varphi_i^j \rangle$ is the average over the **Analyzed volume** (see section *Simulation settings Section* on page 768). Due to computational artifacts, the computed tensor is only approximately symmetric. In order to obtain a perfectly symmetric tensor, the result is finally symmetrized as

$$\mathbf{k}_{ij}^{\text{eff,final}} = (\mathbf{k}_{ij}^{\text{eff}} + \mathbf{k}_{ji}^{\text{eff}})/2.$$

Electric Conductivity Experiment and Tensor Calculation

The stationary electric potential and current fields in a two-component material are simulated, where each material has a different electric conductivity, with the boundary condition that the inlet and outlet are each clamped to a different constant electric potential. If any of the components is fully non-conducting, the respective conductivity can be set to zero. The stationary voltage and current density fields in a two-component material are described by the following differential equations:

$\Delta U = 0$	in Ω	
$\underline{J} = -\sigma_a \text{grad}\, U$	in Ω_a	(Fourier's law)

where Ω is the entire simulation domain and Ω_a is the domain of component a (with $a = 1, 2$). It is assumed that $\Omega_1 \cup \Omega_2 = \Omega$ and $\Omega_1 \cap \Omega_2 = \emptyset$. U is the electric potential (in volts), $\underline{J}$ is the current density, σ_a is the conductivity of component a, Δ is the Laplace operator, and grad is the gradient operator.

A mesh-free finite-element method with linear basis functions and a conjugate gradient solver is used.

The following boundary conditions are applied (see also Figure 43-23: *Boundaries of the simulated volume* on page 798):

$U = U_0$	at Γ_i
$U = 0$	at Γo
$U_1 = U_2$	at Γ_{12}
$\sigma_1 \text{grad}_n U_1 = \sigma_2 \text{grad}_n U_2$	at Γ_{12}
$\text{grad}_n U = 0$	at Γ_R in **Sealed** mode
$U(\underline{r}) = \frac{d_o(\underline{r})}{d_{io}} U_0$	at Γ_R in **Embedded** mode

where

Γ_{12}	boundary between Ω_1 and Ω_2 (= determined object surface)
$U_1,\ U_2$	electric potentials adjacent to Γ_{12} in Ω_1 and Ω_2, respectively
$\Gamma_i,\ \Gamma_o$	inlet and outlet planes, respectively
Γ_R	remaining volume or ROI boundary (except inlet and outlet)
grad_n	spatial derivative in direction of the boundary normal
U_0	user-defined potential difference
$\underline{r}$	position
$d_o(\underline{r})$	normal distance of $\underline{r}$ to the outlet plane
d_{io}	normal distance between inlet and outlet plane
Sealed, Embedded	user-defined boundary mode

For an explanation of the **Embedded** boundary condition, see section *Absolute Permeability Experiment and Tensor Calculation* on page 796 and Figure 43-24: *Material with inclined capillaries* on page 799.

The effective conductivity σ^{eff} relates the macroscopic (volume-averaged) electric field strength to the macroscopic (volume-averaged) current density, which conforms to Ohm's law:

$$\langle J\rangle = -\sigma^{\text{eff}} dU/dL$$

where dU is the potential difference between inlet and outlet, dL is the length of the sample (thus, dU/dL is the applied *volume-averaged* electric field strength), and $\langle J\rangle$ is the volume-averaged current density. In an isotropic medium, the current points into the same direction as the applied field. Generally, the current can deviate from this direction, in which case $\langle J\rangle$ is the component of the current in the direction of the electric field. According to the above equation, σ^{eff} is computed from the simulation result as:

$$\sigma^{\text{eff}} = -\langle J\rangle dL/dU,$$

with $dU = U_0$, $dL = d_{io}$, and $\langle J\rangle$ being the average current density component in the direction of the electric field, averaged over the **Analyzed volume** (see section *Simulation settings Section* on page 751).

In three dimensions, the volume-averaged Ohm's law reads

$$\langle \underline{J}\rangle = -\mathbf{s}^{\text{eff}}\langle \mathrm{grad}\ U\rangle,$$

where $\underline{J}$ and $\mathrm{grad}\ U$ are the three-dimensional current density and electric field strength, respectively, $\langle\cdot\rangle$ denotes volume averaging, and $\mathbf{s}^{\text{eff}}$ is the symmetric effective electric conductivity tensor of rank two. In order to infer all components of this tensor, three distinct virtual experiment simulation runs are performed with the electric field pointing along each of the three coordinate axes, $j = 1...3$. The three runs are performed automatically in a sequence. Let dU_j and dL_j be the potential difference and the distance between inlet and outlet, respectively, applied in the j-th simulation run, and $\underline{J}^j$ be the resulting computed current density field, with vector components J_i^j, $i = 1...3$. The electric conductivity tensor is then calculated as

$$\mathbf{s}_{ij}^{\text{eff}} = -\langle J_i^j \rangle dL_j / dU_j,$$

where $\langle \mathrm{J}_i^j \rangle$ is the average over the **Analyzed volume** (see section *Simulation settings Section* on page 768). Due to computational artifacts, the computed tensor is only approximately symmetric. In order to obtain a perfectly symmetric tensor, the result is finally symmetrized as

$$\mathbf{s}_{ij}^{\text{eff,final}} = (\mathbf{s}_{ij}^{\text{eff}} + \mathbf{s}_{ji}^{\text{eff}})/2.$$

Capillary Pressure Curve

The pore size distribution is calculated using the approach of maximal inscribed spheres. Spheres of varying size are used as probes and attempted to be fit into the pore space. For each point, the largest fitting sphere overlapping this point is found. The diameter of that sphere is assigned to this point as the local pore diameter.

For determining the capillary pressure curve, a quasi-static drainage experiment is simulated. The sample is connected to two fluid reservoirs (a wetting phase (WP) and a non-wetting phase (NWP) reservoir) at user-defined sections of the volume boundary. The pore space is initially filled with WP. The pressure in the NWP reservoir is increased in discrete steps, which results in the injection of NWP into the pore space. After each increase in pressure, equilibrium is attained before the next increase. The simulation is conducted using a pore-morphological heuristic approach (see [10] in section *References* on page 813). The pressure is connected to the curvature diameter of the phase interface using the Young-Laplace Equation:

$$d = 4\gamma \cos\Theta / p_c,$$

where d is the diameter of curvature of the interface, γ is the interfacial tension, and p_c is the capillary pressure. The contact angle Θ is a property of the specific fluid-fluid-solid system considered and is assumed to be zero. In this model, the space occupied by the NWP at a given pressure is defined as the domain reachable by a spherical probe of diameter *d* starting from the NWP reservoir.

Optionally, the residual WP can be computed as described in [11] (see section *References* on page 813). Portions of WP which are isolated from the WP reservoir during the drainage process are regarded to be trapped and form the residual WP.

Validation

Stokes Flow

For the fluid simulations, a Lattice-Boltzmann algorithm with the BGK collision model is used (see [8] in section *References* on page 813). It was validated against theoretical and experimental data. The comparison with theoretical data was done with synthetic data sets of cubic packings of spheres. The comparison with experimental data was performed with scanned data sets of Fontainebleau sandstone samples.

Inclined Capillaries

The absolute permeability was calculated for gratings of inclined parallel capillaries. The artificial data sets had a dimension of 147^3 voxels. The capillaries were aligned in a hexagonal packing

with inter-capillary spacing *d*. The following figure shows a 3D rendering of one of the data sets with annotated geometry.

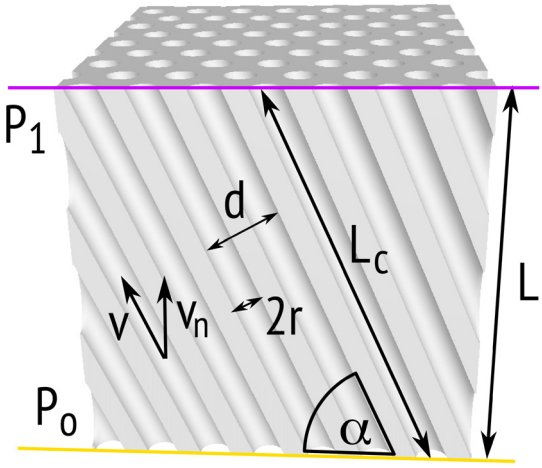


Figure 43-25: Example of a capillary data set

The computed permeability was compared to theory, as follows:
The total volume flux Φ through a pipe of radius r, length L_c, and a pressure at inlet and outlet of P_0 and P_1, respectively, is

(Hagen-Poisseuille Law) (1)

$$\Phi = \frac{\pi r^4 (P_1 - P_0)}{8 \mu L_c}$$

where μ is the viscosity.
In a hexagonal grid of parallel pipes, the average velocity *in pipe direction* is
$\langle v \rangle = \Phi / (d^2 \sin 60°)$
where $d^2 \sin 60°$ is the cross-sectional area occupied by one pipe in the hexagonal packing with spacing d. With an inclination angle α, the average velocity component in the z-direction is

$$\langle v_z \rangle = \langle v \rangle \cos \alpha = \Phi \cos \alpha / (d^2 \sin 60°) \quad (2)$$

The permeability k is calculated according to Darcy's law (see section *Absolute Permeability Experiment and Tensor Calculation* on page 796) as

$$k = \langle v_z \rangle \mu L / |P_1 - P_0|, \quad (3)$$

where *L* is the height of the sample and P_1 and P_0 are the pressures applied at the top and bottom faces, respectively (see Figure 43-25: *Example of a capillary data set*). Substituting (1) and (2) into (3) and canceling terms yields

$$k = \frac{\pi r^4 \cos^2 \alpha}{8d^2 \sin 60^\circ}, \tag{4}$$

where $L = L_c \cos \alpha$.

The pressure difference was applied in the z-direction and the boundary conditions were set to **Embedded** mode. The calculations were repeated with varying capillary radius r (left in the figure below) and inclination angle α (right in the figure below). For varying capillary radius r, k is normalized by the capillary spacing d. The voxel size was 1 mm³, so 1 mm corresponds to 1 voxel length. The results are depicted in the following figure. The theoretical curves are given by equation (4).

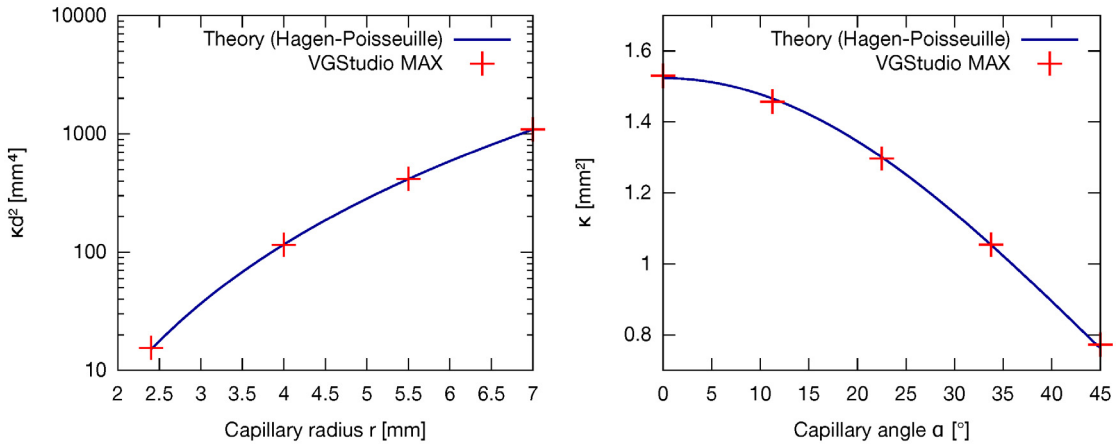


Figure 43-26: Computed vs. theoretical permeabilities *K* of capillary gratings

Cubic Lattice of Spheres

The absolute permeability was calculated on artificial data sets of simple cubic lattices of spheres of varying diameters. Depending on the diameter, the spheres were allowed to overlap. The data sets had a size of 300³ voxels and a voxel resolution of 1 mm³. The sphere centers were spaced 20 voxels apart.

The absolute permeability was calculated in the z-direction using the **Embedded** boundary condition for the faces that are not inlet or outlet. (Using the **Sealed** boundary condition yields indistinguishable results, except for very high porosity (> 90%), where **Sealed** yields slightly too low values.) The porosity was varied by changing the sphere diameter while keeping the lattice spacing *d* constant. The permeability values are normalized by d^2. Theoretical algebraic results published in [3] (see section *References* on page 813) were used as a reference. The results are depicted in the following figure.

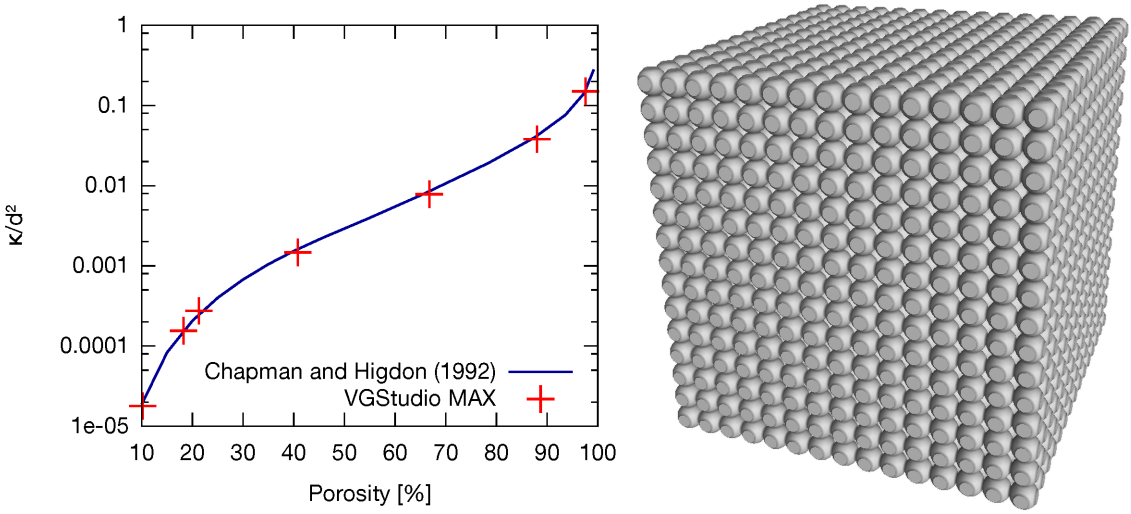


Figure 43-27: Left: Computed vs. theoretical values of the absolute permeability *K* of spheres on a simple cubic lattice; Right: Rendering of one of the data sets used (40 % porosity)

Fontainebleau Sandstone

The absolute permeability was calculated on micro-tomography scans of Fontainebleau sandstone samples with varying porosity. The scans had a size of 512³ voxels and a voxel resolution of 5.72 µm. (Data sets were kindly provided by the authors of [5] (see section *References* on page 813).) The absolute permeability was calculated in the z-direction, and all faces except inlet and outlet were sealed. The results were compared to experimental measurements performed on a large number of Fontainebleau sandstone samples published in [2] (see section *References* on page 813). The results are depicted in the following figure.

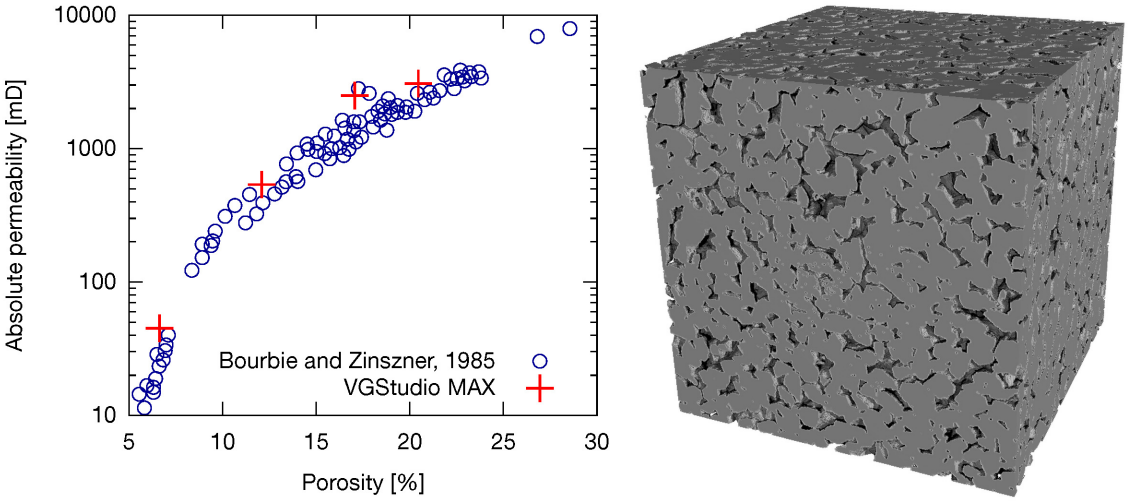


Figure 43-28: Left: Computed versus experimental values of the absolute permeability of Fontainebleau sandstone samples; Right: Rendering of scanned sandstone sample with 22% porosity

Diffusion/Heat Conduction/Electric Conduction

For the simulation of diffusion, heat conduction, and electric conduction, a mesh-free finite-element code with linear basis functions and a conjugate gradient solver is used. All three phenomena obey the same mathematical equation, namely the Poisson equation. Therefore, they are validated simultaneously by the example of heat conduction. Validation is performed against theoretical data.

Inclined Capillaries

The effective thermal conductivity was calculated for gratings of inclined parallel capillaries, where the capillaries had a conductivity of D and the inter-capillary space was completely non-conducting. The artificial data sets had a dimension of 147³ voxels. The capillaries were aligned in a hexagonal packing with radius r and inter-capillary spacing $3r$. Figure 43-25: *Example of a capillary data set* on page 807 shows a 3D rendering of one of the data sets with annotated geometry. The computed effective thermal conductivity was compared to theory, as follows:

For a hexagonal grating of capillaries with capillary radius r and inter-capillary spacing d, the effective thermal conductivity *in capillary direction* is

$$D_{\text{eff}} = D\Phi \tag{5}$$

where Φ is the porosity. This is because the cross section available for heat transport is reduced by the factor Φ compared to the unrestricted conduction.

If the effective thermal conductivity is measured in a direction inclined from the capillary direction by an angle α, the value of D_{eff} will be decreased by the factor $\cos\alpha$ because of the increase in capillary length as well as the factor $\cos\alpha$, because only the heat flux component in the measuring direction will account for effective conductivity. All in all, for the present data sets, the theory predicts

$$D_{\text{eff}} = D\Phi\cos^2\alpha \tag{6}$$

The samples were calculated with the **Boundary condition** parameter set to **Embedded**. The calculations were repeated with varying capillary radii r (left in the following figure) and inclination angles α (right in the following figure). The values are given as a deviation from the theoretical values according to equation (6). For computing the deviation from theory, the observed porosity in each data sample was assumed as Φ in (6). The theoretical porosity of 40.31% was usually missed by a few percent in the data samples, since the samples were not multiples of the unit cell. The results are depicted in the following figure:

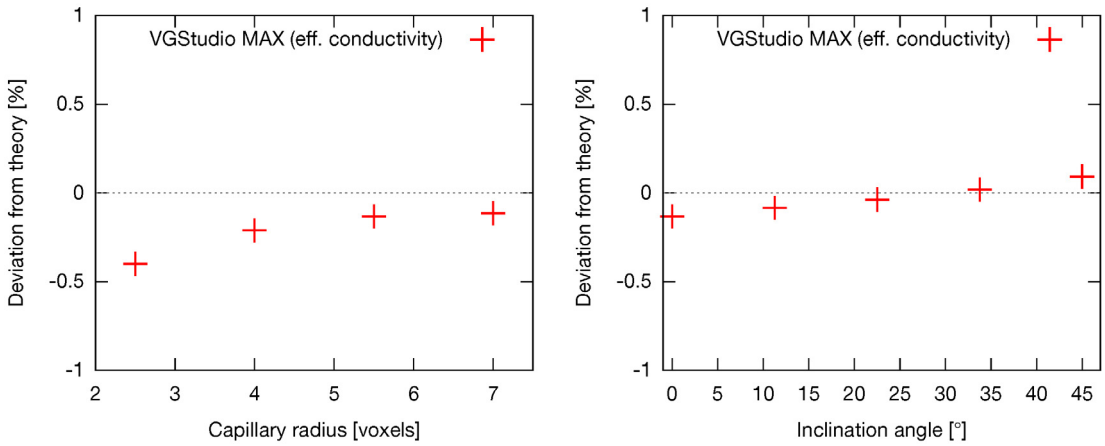


Figure 43-29: Computed effective conductivities of capillary gratings

Sphere Packings

Thermal conduction was simulated on different close packings of equal-sized spheres: Simple cubic, body-centered cubic, and face-centered cubic packings. The data sets had a size of 300³ voxels. The sphere radius was 10 voxels. Using the **Thermal conductivity experiment** analysis, the effective conductivity k^* was determined given a homogeneous conductivity of k_1 of the spheres and k_0 of the inter-sphere matrix. Analytically derived values published in [7] (see section *References* on page 813) serve as a reference. In order to most closely resemble the theoretical case of infinitely extended sphere arrays, the calculations were done on regions of interest that cover most of the data set while having boundaries at integer multiples of the respective lattice's unit cell. The **Analyzed volume** parameter was set to 100%, and the **Boundary condition** parameter was set to **Embedded**. The used data sets are displayed in Figure 43-30:

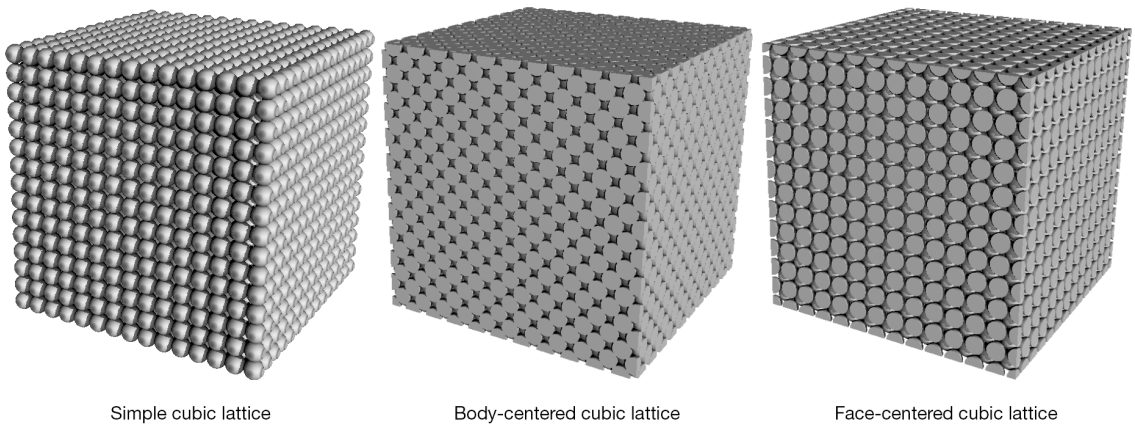


Figure 43-30: Packed spheres data sets used for validation of the finite-element code

The following figure shows the computed versus the algebraically derived values of the effective conductivity k^* of various sphere packings for varying conductivity ratios k_1/k_0 of spheres to matrix. The simulations were conducted on data sets with spheres with a radius of 10 voxels, except for $k_1/k_0 = 5$, where the spheres had a radius of 30 voxels. For k_1/k_0 much greater than 1, the heat flux is dominated by the (in theory) infinitely small contact points between the

spheres. However, in the representation by a discrete voxel data set, the singular contact points are always of finite size that is proportional to the voxel size. In order to reach a satisfactory agreement to theory, the voxel resolution was increased. The results achieved with a sphere radius of 10 voxels are depicted as green crosses (x).

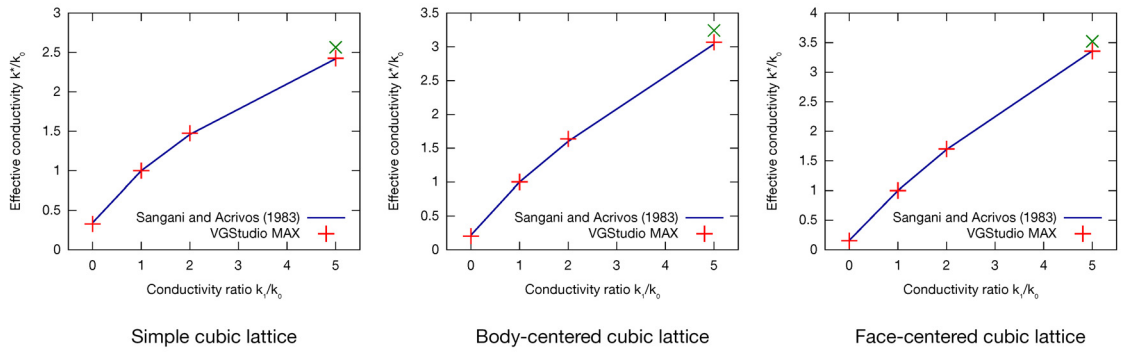


Figure 43-31: Computed vs algebraically derived values of the effective conductivity *k** of various sphere packings for varying conductivity ratios k_1/k_0 of spheres to matrix

Capillary Pressure

Results were validated against experimental data and against simulations using a reference implementation. The results used as a reference were published in [10] (see section *References* on page 813). The digital voxel data was provided by one of the authors. The samples consisted of two different bead packs labeled C-109 and Gb1b. The digital volumes were available as binarized images with 800³ voxels each. The capillary pressure curves detected in the experiment were compared with the simulated capillary pressure curves for each of the two samples. The simulations in VGSTUDIO MAX were performed without the **Simulate trapped WP** option set, since this is equivalent to the reference implementation. A very good agreement was found between VGSTUDIO MAX and the reference data, as shown in the following figure:

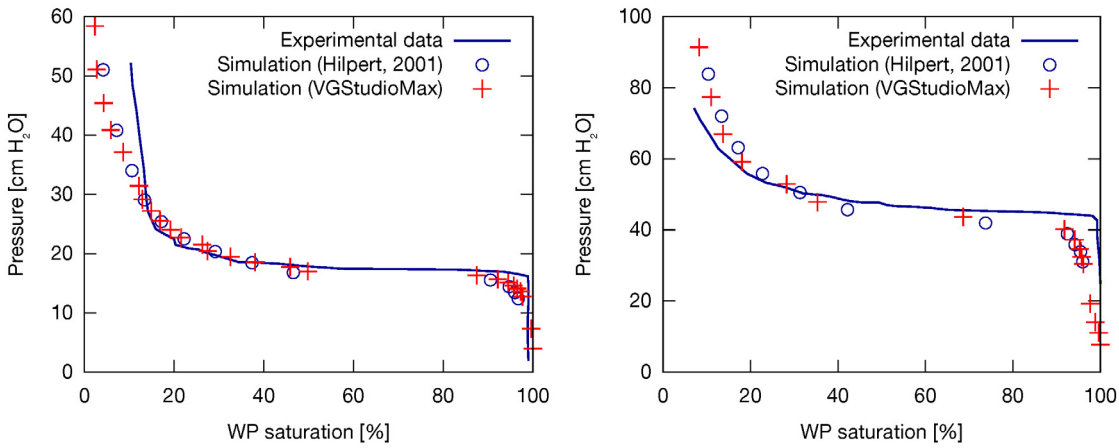


Figure 43-32: Experimentally determined and simulated capillary pressure curves for two bead pack samples; left: C-109, right: Gb1b

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Battery Analysis Module

Introduction

The optional **Battery Analysis** module includes the **Battery anode overhang** analysis, which was designed to examine the quality of batteries and provide detailed electrode information, such as anode overhang length and maximum curvature. This analysis allows you to specify tolerances and obtain visualization results and detailed reports.

License Information

This module is an optional add-on module for VGSTUDIO MAX. It is not available for myVGL. However, if a project loaded in myVGL contains results obtained with this module, they can be viewed and reported in myVGL.

If you are interested in a more comprehensive functionality than the one offered by myVGL, you have the chance to evaluate VGSTUDIO MAX. You can request an evaluation license of VGSTUDIO MAX on our website:

https://volumegraphics.hexagon.com/en/products/evaluation

If you have further questions about our product portfolio, please contact us:

- For Europe, Middle East, and Africa:

  Write an e-mail to sales@volumegraphics.com or call +49 6221 73920 744.
- For Japan:

  Write an e-mail to sales@volumegraphics.jp or call +81 52 508 9682.
- For the Americas:

  Write an e-mail to sales-us@volumegraphics.com or call +1 704 248 7736.
- For China, including Mainland China, Hong Kong, Macao, and Taiwan:

  Write an e-mail to sales@volumegraphics.cn or call +86 10 8532 6305.
- For Singapore and other parts of Asia (except China and Japan), Australia, and parts of Oceania:

  Write an e-mail to sales@volumegraphics.sg or call +65 6665 0310.

Opening the Dialog

In order to open the **Battery anode overhang analysis** dialog,

- right-click the corresponding entry in the Scene Tree and select **Properties** from the context menu or
- double-click the corresponding entry in the Scene Tree.

The **Battery anode overhang analysis** dialog consists of several tabs on which you can view the results of the analysis.

To close the dialog, click the **Close** button at the bottom of the dialog.

A status bar at the bottom of the dialog indicates the current status of the analysis. The status can be one of the following:

Table 44-1: Messages in the status bar

Status	Description
Result is up to date	The current analysis result is valid.
Calculation required	All required parameters have been specified and are consistent, but the analysis was not calculated or was invalidated by some user action before the project was saved.

An invalid or outdated status of an analysis is indicated in the Scene Tree by a warning sign. Double-click this analysis to open it and check the status bar for messages.

The units of the dialog depend on the global unit settings (see section *Units Drop-down List* on page 33 in chapter 2 *Workspace*).

Settings Tab

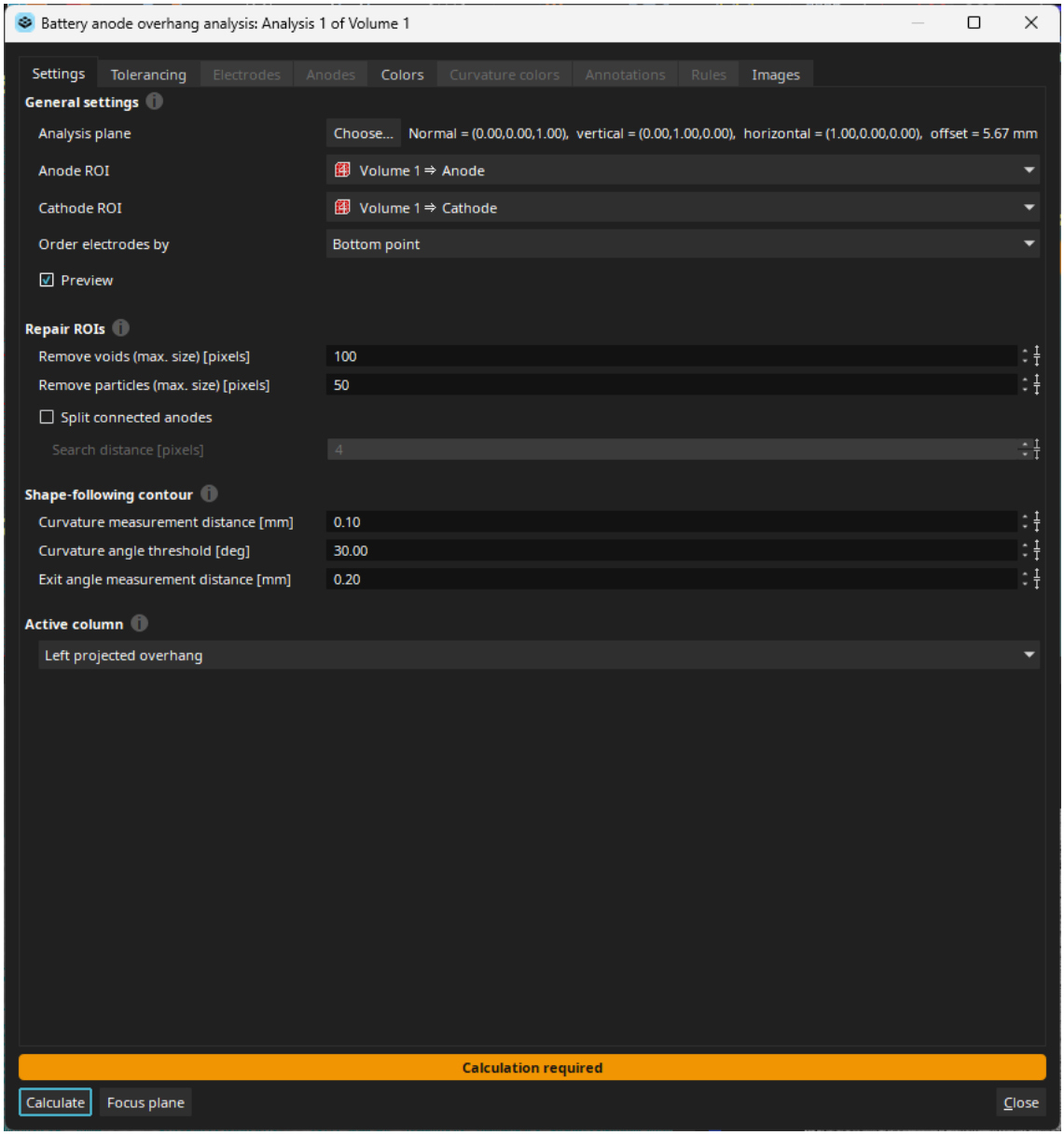
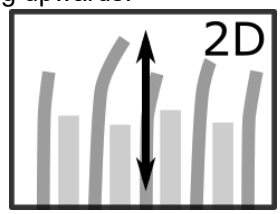
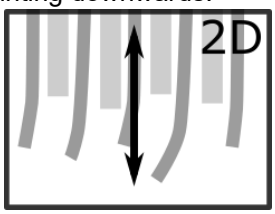


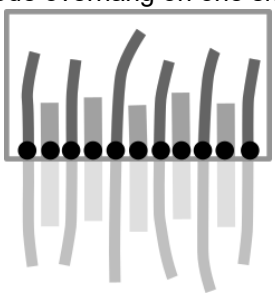
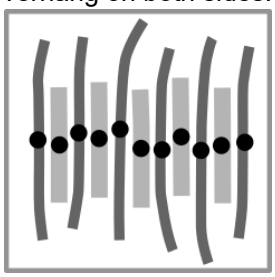
Figure 44-1: **Battery anode overhang analysis** dialog, **Settings** tab

In myVGL, all parameter settings are displayed. Most of these parameters are read-only in myVGL. The complete functional range is available with VGSTUDIO MAX and the respective add-on module(s).

General settings Section

Table 44-2: Controls of the **General settings** section

Control	Description
Choose… button for the **Analysis plane**	Specifies a 2D view as the plane on which the analysis will be performed. Note that the volume data set must be aligned so that the main electrode direction is vertically oriented in the specified 2D view. • Select the **upright** entry to analyze the anode overhang pointing upwards.  • Select the **upside down** entry to analyze the anode overhang pointing downwards.  Note that an incorrectly specified orientation may cause the color-coded results to mask the electrodes.
Anode ROI drop-down list	Specifies an ROI to comprise the anodes.
Cathode ROI drop-down list	Specifies an ROI to comprise the cathodes.

Control	Description
Order electrodes by drop-down list	Defines the reference points on the segmented electrodes. • **Bottom point**: Select this option for volume data sets with anode overhang on one side.  • **Center point**: Select this option for volume data sets with anode overhang on both sides. 
Preview checkbox	When this option is checked, a preview of the results will be displayed in the specified 2D view.

Repair ROIs Section

Table 44-3: Controls of the **Repair ROIs** section

Control	Description
Remove voids (max. size) [voxels] spin box	Removes voids so that they are considered part of the electrodes.
Remove particles (max. size) [voxels] spin box	Removes particles so that they are considered part of the electrodes.
Split connected anodes checkbox	If individual anodes appear connected in the ROI specified for anodes, such as in cases of blurring, check this option to split the anodes.
Search distance [voxels] spin box	Specifies the search distance for splitting anodes.

Shape-following contour Section

Table 44-4: Controls of the **Shape-following contour** section

Control	Description
Curvature measurement distance [<length unit>] spin box	Specifies the minimum spacing between the points considered for curvature measurement.
Curvature angle threshold [<angle unit>] spin box	Specifies the minimum angle considered for curvature measurement.
Exit angle measurement distance [<length unit>] spin box	Specifies the distance from the anode exit point considered for the exit angle measurement.

Reducing the **Curvature measurement distance** or **Curvature angle threshold** parameter allows you to find smaller bends in the anodes while at the same time increasing the number of very high curvatures that are likely false positives.

Active column Section

This drop-down list allows you to select the property of the anode that is to be shown according to the settings on the **Colors** tab.

You can also select the active column on the **Anodes** tab by right-clicking the column and selecting the **Select column** item from the context menu.

Table 44-5: Options of the **Active column** section drop-down list

Option	Description
Left projected overhang	Vertical distance from the topmost anode point to the topmost point of the left-adjacent cathode.
Right projected overhang	Vertical distance from the topmost anode point to the topmost point of the right-adjacent cathode.
Left shape-following overhang	Distance along the shape-following curve from the anode exit point with respect to the left-adjacent cathode to the anode tip.
Right shape-following overhang	Distance along the shape-following curve from the anode exit point with respect to the right-adjacent cathode to the anode tip.
Max. curvature	Max. curvature of the shape-following curve in the overhang part of the anode. A high max. curvature is an indicator for a sharp bend.
Avg. thickness	The anode width, separately for each anode, calculated as an average along the anode length.

Option	Description
Exit angle	The angle defined by the line connecting the anode exit point and a second point on the anode further up, and the vertical. The location of the second point is specified in the **Exit angle measurement distance** field. If there are two adjacent cathodes, the cathode resulting in the larger exit angle will be taken.
Adjacent cathode count	Number of adjacent cathodes. This can be zero, one, or two.

Tolerancing Tab

- **Active column** section

  This drop-down list allows you to select the property of the electrode that is to be shown according to the specified color-coding.

The **Active column** section is also available on the **Settings** tab. The changes made on the **Tolerancing** tab will also affect the **Settings** tab and vice versa. For details, see section *Active column Section* on page 819 in section *Settings Tab*.

- **Tolerance settings** section

Tolerance values will be interpreted according to DIN EN ISO 8015 (see also section *Rounding Rules* on page 4 in chapter 1 *Welcome*).

Tolerance the total anode/cathode count to ensure the correct number of anodes/cathodes or to detect segmentation failures.

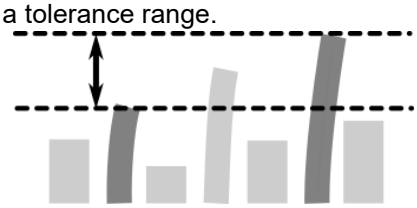
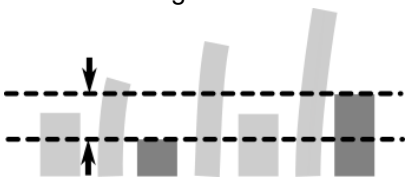
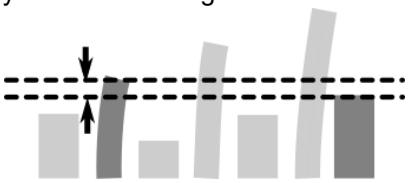
Tolerance the specific count to ensure the correct type of border electrodes, to detect missing electrodes, or to detect segmentation failures.

Table 44-6: Controls of the **Electrode count** section

Control	Description
Total anode count fields	Display the anode count and allow you to specify a tolerance range.
Total cathode count fields	Display the cathode count and allow you to specify a tolerance range.
Anodes with left and right cathode fields	Display the number of anodes with left and right cathodes and allow you to specify a tolerance range.
Anodes with left cathode only fields	Display the number of anodes with only a left cathode and allow you to specify a tolerance range.

Control	Description
Anodes with right cathode only fields	Display the number of anodes with only a right cathode and allow you to specify a tolerance range.
Anodes without adjacent cathode fields	Display the number of anodes without an adjacent cathode and allow you to specify a tolerance range.
Cathodes with left and right anode fields	Display the number of cathodes with left and right anodes and allow you to specify a tolerance range.
Cathodes with left anode only fields	Display the number of cathodes with only a left anode and allow you to specify a tolerance range.
Cathodes with right anode only fields	Display the number of cathodes with only a right anode and allow you to specify a tolerance range.
Cathodes without adjacent anode fields	Display the number of cathodes without an adjacent anode and allow you to specify a tolerance range.

Table 44-7: Controls of the **Global distances** section

Control	Description
Projected distance from lowest to highest anode [<length unit>] fields	Display the actual value of the projected distance from lowest to highest anode and allow you to specify a tolerance range. 
Projected distance from lowest to highest cathode [<length unit>] fields	Display the actual value of the projected distance from lowest to highest cathode and allow you to specify a tolerance range. 
Projected distance from highest cathode to lowest anode [<length unit>] fields	Display the actual value of the projected distance from highest cathode to lowest anode and allow you to specify a tolerance range. 

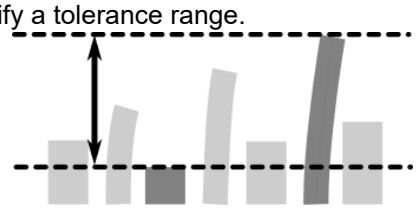
Control	Description
Projected distance from lowest cathode to highest anode [<length unit>] fields	Display the actual value of the projected distance from lowest cathode to highest anode and allow you to specify a tolerance range. 

Table 44-8: Controls of the **Individual anode measurements** section

Control	Description
Left projected overhang [<length unit>] fields	Display the actual value range of left projected overhangs and allow you to specify a tolerance range.
Right projected overhang [<length unit>] fields	Display the actual value range of right projected overhangs and allow you to specify a tolerance range.
Left shape-following overhang [<length unit>] fields	Display the actual value range of left shape-following overhangs and allow you to specify a tolerance range.
Right shape-following overhang [<length unit>] fields	Display the actual value range of right shape-following overhangs and allow you to specify a tolerance range.
Avg. thickness [<length unit>] fields	Display the actual value range of average thicknesses and allow you to specify a tolerance range.
Max. curvature [<length unit>$^{-1}$] fields	Display the actual value range of maximum curvatures and allow you to specify a tolerance range.
Exit angle [<angle unit] fields	Display the actual value range of exit angles and allow you to specify a tolerance range.

- **Reset** button

  Deletes all tolerance settings.

Depending on the results of this evaluation, the tolerances on the **Tolerancing** tab are highlighted in the following colors:

- Green: The tolerance is met.
- Red: The tolerance is not met.
- White (light theme)/black (dark theme): No tolerance settings have been specified or they are deactivated.
- Yellow: A tolerance has been specified but the analysis has to be (re-)calculated. Note that this color will also be used if the entered tolerance value is invalid.

The result of the evaluation is also displayed graphically in the Scene Tree. For more information on evaluations, see chapter 46 *Evaluations* on page 941.

Electrodes Tab

Lists all the electrodes detected by the battery anode overhang analysis.

The **Electrodes** table consists of the following columns:

Table 44-9: Columns of the **Electrodes** tab

Column	Description
Electrode type	Indicates the type of the electrode.
Top point x/y/z [<length unit>]	Indicates the position of the top point of the electrode.
Description	Allows you to enter a description for the electrode used for reporting.

Anodes Tab

Lists all the anodes evaluated by the battery anode overhang analysis.

The **Anodes** table consists of the following columns:

Table 44-10: Columns of the **Anodes** tab

Column	Description
Top point x/y/z [<length unit>]	Indicates the position of the top point of the anode.
Label	Indicates the position in the ordering of the anodes.
Left/Right projected overhang [<length unit>]	Indicates the left/right projected overhang.
Left/Right shape-following overhang [<length unit>]	Indicates the left/right shape-following overhang.
Max. curvature [<length unit>$^{-1}$]	Indicates the maximum curvature.
Avg. thickness [<length unit>]	Indicates the average thickness.
Exit angle [<angle unit>]	Indicates the exit angle.
Adjacent cathode count	Indicates the number of adjacent cathodes.
Left/Right exit point x/y/z [<length unit>]	Indicates the point where the anode begins to overhang the left/right adjacent cathode.
Tip x/y/z [<length unit>]	Indicates the position of the tip of the anode.
Description	Allows you to enter a description for the anode used for reporting.

Column	Description
Image	Allows you to add a detailed 2D image and object description on a separate page of the report. • **Off**: No image is created (default). • **On**: Creates a suitable slice image and anode description. • **If not OK**: Automatically includes an image if the tolerance status is **Out of tolerance**. The image will be generated according to the render settings specified during report creation or VGRF-based export.
Focused image	This option is nearly identical to the **Image** option but will generate an image focused on the corresponding item and additionally zoomed in by the **Zoom factor** specified during report creation or VGRF-based export.
Tolerance status	Indicates the tolerance status of the anode depending on the tolerances specified for the anodes in the **Tolerance settings** section of the **Settings** tab: **Valid** (green), **Out of tolerance** (red), or **No tolerance** (gray)

Colors Tab

Here you can specify the color-coding scheme used for the representation of the analysis results. To specify the color-coding scheme for the local curvature of the anodes, see section *Curvature colors Tab* on page 829.

To view the color-coded results in the 3D view, create a clipping plane in the 2D view on the slice where the analysis was performed.

Caption Section

Table 44-11: Controls of the **Caption** section

Control	Description
Caption field	Indicates the color bar headline as specified in the **Caption** field of the **Color bar** section.
Share color bar checkbox	When this option is checked, all analyses of the same type (and—if applicable—of the same algorithm) will use the same color bar. When this option is unchecked, the color bar settings will apply to the selected analysis only.

LUT – Color Lookup Table

The color lookup table (LUT) shows the partitioning into color sections.

Sections Section

Defines the appearance of each color section.

Table 44-12: Controls in the **Sections** section

Control	Description
From/To fields	Specify the start and end values of the color sections. The first color section represents all values above the upper limit, i.e., the value in the **From** field (**+inf** signifies positive infinity), while the last color section represents all values below the lower limit, i.e., the value in the **To** field (**-inf** signifies negative infinity). The default limits are calculated from the results of the analysis (for an analysis color bar) or taken from the **Default** preset (for a tolerance deviation color bar).
Type field	Switches between the color schemes **Continue**, **Constant**, **Gradient**, **Rainbow**, **Reverse rainbow**, **Hue cycle**, **Green to red**, and **Red to green**.
Color/transparency field	Double-clicking the field for the **Continue**, **Constant**, and **Gradient** color schemes opens the **Select Color** dialog where you can modify the appearance of the selected color scheme. For the **Gradient** color scheme, you can specify the start and end colors by double-clicking the left or right side of the field, respectively. Double-clicking the field for the **Rainbow**, **Reverse rainbow**, **Hue cycle**, **Green to red**, and **Red to green** color schemes opens the **Transparency** dialog, where you can set the transparency for the selected color scheme.
use RMB to click a color section	Opens a context menu with the following items: • **Split**: Subdivides the color section into two new color sections where each represents half of the original section. • **Merge**: Combines several color sections to a single color section. Only consecutive intervals can be merged.
Create smooth button	Opens the **Create smooth table** dialog to generate one color section. • **Type** drop-down list: Allows you to select the type of coloring scheme. • **From/To** spin boxes: Specify the value range covered by the color section.

Control	Description
Create stepped button	Opens the **Create stepped table** dialog to generate a set of color sections. • **Type** drop-down list: Allows you to select the type of coloring scheme. • **From/To** spin boxes: Specify the value range covered by the color sections. • **Step** spin box: Specifies the step size of the individual color sections.
Auto scale button	If available: Fits the color LUT to the range of the results of all available analyses.
Auto scale color bar range on calculate checkbox	If available: When this option is checked, the color LUT will be automatically fitted to the range of the results of all available analyses.
Default button	If available: Resets any changes made to the **Sections** table.

Active column Section

This drop-down list allows you to select the property of the electrode that is to be shown according to the specified color-coding.

The **Active column** section is also available on the **Settings** tab. The changes made on the **Colors** tab will also affect the **Settings** tab and vice versa. For details, see section *Active column Section* on page 819 in section *Settings Tab*.

Preset selection Section

Table 44-13: Controls in the **Preset selection** section

Icon	Item	Description
	drop-down list	Specifies the preset to be applied, to be edited, or to be taken as a basis for a new preset. The following icons are used: • default preset • customized preset • appears next to the icon of a preset that has been modified but not yet saved

Icon	Item	Description
	Save preset	Opens the **Save preset** dialog for saving the color LUT of the current data set under the specified name. • **Absolute preset**: When this option is checked and the preset applied, the settings of the original data set, including the LUT range, will be applied. When this option is unchecked, the color settings of the preset will be mapped relatively to the actual range of results of the analysis to which the preset will be applied.
	Remove preset	Removes the selected preset from the preset drop-down list.
	Import preset	Imports a preset from the specified location.
	Export preset	Exports the selected preset to the specified location.

Color LUT Settings Section

Specifies the appearance of the color lookup table.

Table 44-14: Options for the appearance of the color lookup table

Control	Description
Auto tick marks checkbox	When this option is checked, equidistant tick marks will be produced for the color bars. When this option is unchecked, tick marks will appear only at the color section boundaries of the color lookup table.
Auto scale color bar range on calculate checkbox	When this option is checked, the color LUT will be automatically fitted to the range of the results of all available analyses.

Color bar Section

Specifies the settings for the color bar.

Table 44-15: Settings for the color bar

Control	Description
Visibility drop-down list	Switches the color bar on/off.
Positioning drop-down list	Specifies the location of the color bar within the 2D and 3D windows: **Left, Right, Top, Bottom, All - automatic, Left or right - automatic, Top or bottom - automatic**.
Caption field	Specifies the color bar headline by using placeholders.
Reset button	Resets the **Caption** field to the default entry.

Line settings Section

Defines the appearance of the shape-following contours, the top points of the electrodes, and the color for the lines that connect the electrode tips.

Click the checkbox in front of an entry to toggle the visibility of the corresponding color overlay.

Table 44-16: Controls in the **Line settings** section

Control	Description
Electrode top points checkbox	• **Line color** color field: Double-clicking the field opens the **Select Color** dialog, where you can specify a color for the electrode top point indicator. • **Line width** spin box: Specifies the width (in pixels) of the lines.
Max. curvature locations checkbox	• **Line color** color field: Double-clicking the field opens the **Select Color** dialog, where you can specify a color for the location of the maximum curvature. • **Line width** spin box: Specifies the width (in pixels) of the lines.
Shape-following contours checkbox	• **Line colors** color fields: Double-clicking the fields opens the **Select Color** dialog, where you can specify a color. The first color field specifies the color indicating where the anode does not overhang. The second color field specifies the color indicating where the anode overhangs one of two adjacent cathodes. The third color field specifies the color indicating where the anode overhangs all adjacent cathodes. • **Line width** spin box: Specifies the width (in pixels) of the lines.
Electrode order checkbox	• **Line color** color field: Double-clicking the field opens the **Select Color** dialog, where you can specify a color for the lines that connect the electrode tips to verify if the electrodes are correctly ordered. • **Line width** spin box: Specifies the width (in pixels) of the lines.

Control	Description
Selected anode overhang checkbox	If checked, selecting an entry in the table on the **Anodes** tab will display measure lines for the projected overhangs. • **Line colors** color fields: Double-clicking the fields opens the **Select Color** dialog, where you can specify a color. The first color field specifies the color of the measure line for the left projected overhang. The second color field specifies the color for the extension lines. The third color field specifies the color of the measure line for the right projected overhang. • **Line width** spin box: Specifies the width (in pixels) of the lines.

Curvature colors Tab

Here you can specify the color-coding scheme used for the representation of the calculated local curvatures of the anodes.

Caption Section

Table 44-17: Controls of the **Caption** section

Control	Description
Caption field	Indicates the color bar headline as specified in the **Caption** field of the **Color bar** section.
Share color bar checkbox	When this option is checked, all analyses of the same type (and—if applicable—of the same algorithm) will use the same color bar. When this option is unchecked, the color bar settings will apply to the selected analysis only.

LUT – Color Lookup Table

The color lookup table (LUT) shows the partitioning into color sections.

Sections Section

Defines the appearance of each color section.

Table 44-18: Controls in the **Sections** section

Control	Description
From/To fields	Specify the start and end values of the color sections. The first color section represents all values above the upper limit, i.e., the value in the **From** field (**+inf** signifies positive infinity), while the last color section represents all values below the lower limit, i.e., the value in the **To** field (**-inf** signifies negative infinity). The default limits are calculated from the results of the analysis (for an analysis color bar) or taken from the **Default** preset (for a tolerance deviation color bar).
Type field	Switches between the color schemes **Continue**, **Constant**, **Gradient**, **Rainbow**, **Reverse rainbow**, **Hue cycle**, **Green to red**, and **Red to green**.
Color/transparency field	Double-clicking the field for the **Continue**, **Constant**, and **Gradient** color schemes opens the **Select Color** dialog where you can modify the appearance of the selected color scheme. For the **Gradient** color scheme, you can specify the start and end colors by double-clicking the left or right side of the field, respectively. Double-clicking the field for the **Rainbow**, **Reverse rainbow**, **Hue cycle**, **Green to red**, and **Red to green** color schemes opens the **Transparency** dialog, where you can set the transparency for the selected color scheme.
use RMB to click a color section	Opens a context menu with the following items: • **Split**: Subdivides the color section into two new color sections where each represents half of the original section. • **Merge**: Combines several color sections to a single color section. Only consecutive intervals can be merged.
Create smooth button	Opens the **Create smooth table** dialog to generate one color section. • **Type** drop-down list: Allows you to select the type of coloring scheme. • **From/To** spin boxes: Specify the value range covered by the color section.

Control	Description
Create stepped button	Opens the **Create stepped table** dialog to generate a set of color sections. • **Type** drop-down list: Allows you to select the type of coloring scheme. • **From/To** spin boxes: Specify the value range covered by the color sections. • **Step** spin box: Specifies the step size of the individual color sections.
Auto scale button	If available: Fits the color LUT to the range of the results of all available analyses.
Auto scale color bar range on calculate checkbox	If available: When this option is checked, the color LUT will be automatically fitted to the range of the results of all available analyses.
Default button	If available: Resets any changes made to the **Sections** table.

Preset selection Section

Table 44-19: Controls in the **Preset selection** section

Icon	Item	Description
	drop-down list	Specifies the preset to be applied, to be edited, or to be taken as a basis for a new preset. The following icons are used: • default preset • customized preset • appears next to the icon of a preset that has been modified but not yet saved
	Save preset	Opens the **Save preset** dialog for saving the color LUT of the current data set under the specified name. • **Absolute preset**: When this option is checked and the preset applied, the settings of the original data set, including the LUT range, will be applied. When this option is unchecked, the color settings of the preset will be mapped relatively to the actual range of results of the analysis to which the preset will be applied.
	Remove preset	Removes the selected preset from the preset drop-down list.
	Import preset	Imports a preset from the specified location.
	Export preset	Exports the selected preset to the specified location.

Color LUT Settings Section

Specifies the appearance of the color lookup table.

Table 44-20: Options for the appearance of the color lookup table

Control	Description
Auto tick marks checkbox	When this option is checked, equidistant tick marks will be produced for the color bars. When this option is unchecked, tick marks will appear only at the color section boundaries of the color lookup table.
Auto scale color bar range on calculate checkbox	When this option is checked, the color LUT will be automatically fitted to the range of the results of all available analyses.

Color bar Section

Specifies the settings for the color bar.

Table 44-21: Settings for the color bar

Control	Description
Visibility drop-down list	Switches the color bar on/off.
Positioning drop-down list	Specifies the location of the color bar within the 2D and 3D windows: **Left, Right, Top, Bottom, All - automatic, Left or right - automatic, Top or bottom - automatic**.
Caption field	Specifies the color bar headline by using placeholders.
Reset button	Resets the **Caption** field to the default entry.

Annotations Tab

Lists all annotations created for the selected battery anode overhang analysis. You can view the information supplied by the annotations or edit the annotation properties.

For details on how to create an annotation, see section *Annotation* on page 124 in chapter 6 *Inspect Tab*.

To create new annotations in the table, it is also possible to paste previously copied coordinates by right-clicking the table and selecting **Paste** from the context menu or by pressing the **Ctrl** + **V** keyboard shortcut. For details, see the **Paste** menu item in section *Table Context Menu*.

Double-clicking an analysis annotation in the Scene Tree will directly open the **Annotations** tab of the properties dialog of the corresponding analysis.

Tolerance values will be interpreted according to DIN EN ISO 8015 (see also section *Rounding Rules* on page 4 in chapter 1 *Welcome*).

The **Annotations** table consists of the following columns:

Table 44-22: Columns of the **Annotations** table

Column	Description
Name	Indicates the name of the annotation.
Pos. x/y/z [<length unit>]	Indicates the position of the annotation.
Label	Indicates the position in the ordering of the anodes.
Left/Right projected overhang [<length unit>]	Indicates the left/right projected overhang.
Left/Right shape-following overhang [<length unit>]	Indicates the left/right shape-following overhang.
Max. curvature [<length unit>$^{-1}$]	Indicates the maximum curvature.
Avg. thickness [<length unit>]	Indicates the average thickness.
Exit angle [<angle unit>]	Indicates the exit angle.
Adjacent cathode count	Indicates the number of adjacent cathodes.
Description	Allows you to enter a description of the annotation used for reporting.
Image	Allows you to add a detailed 2D image and object description on a separate page of the report. • **Off**: No image is created (default). • **Orthographic projection**: Creates three orthogonal views. • **Top/Bottom/Left/Right/Front/Back**: Creates a single 2D view in the specified orientation. • **... - If not OK**: Automatically creates the image if the tolerance status is **Out of tolerance**. The image orientation corresponds to the currently selected coordinate system. The image will be generated according to the render settings specified during report creation or VGRF-based export. The 2D slice position used for taking the image is determined by the position of the annotation. The zoom factor of the image is selected so that the entire parent volume is visible.
Focused image	This option is almost identical to the **Image** option but will generate an image that focuses on the respective item and is zoomed in by the **Zoom factor** specified during report creation or VGRF-based export.

Column	Description
Captures	Indicates the number of images that were captured for this object with the **Capture from** button in the **Screenshots** section.
Tolerance status	Indicates the tolerance status of the anode depending on the tolerances specified for the anodes in the **Tolerance settings** section of the **Tolerancing** tab: **Valid** (green), **Out of tolerance** (red), or **No tolerance** (gray).
Type	Indicates how the annotation has been created: • **Manually defined**: The annotation has been defined by the user. • **Rule based**: The annotation has been created by a report rule.

General Table Controls

- List section

  The following table provides an overview of the general controls available in the various list views:

  Table 44-23: Controls in the list section

Control	Description
button	Opens a submenu for selecting the filter/search mode.
Filter	Clicking the **Click to add a filter or search criterion** field to the right of the icon opens a series of drop-down lists from which you can select a table column, an operator, and—depending on the column—a value. If a column does not offer a value drop-down list, you can type in a value. When the selection is complete, the table shows the rows matching the filter criterion. Clicking the **+** button or the **Click to add a filter or search criterion** field allows you to specify more filter criteria. Clicking the **x** button removes the filter.

Control	Description
Search	Clicking the **Click to add a filter or search criterion** field to the right of the icon opens a series of drop-down lists from which you can select a table column, an operator, and—depending on the column—a value. If a column does not offer a value drop-down list, you can type in a value. When the selection is complete, the table rows matching the search criterion are highlighted. Clicking the **+** button or the **Click to add a filter or search criterion** field allows you to specify more search criteria. Pressing **F3** jumps to the next search result in the list. Clicking the **x** button removes the search.
Full-text filter	Entering a value or text string into the input field to the right of the icon filters the table accordingly and shows the rows that match the filter criterion.
Full-text search	Entering a value or text string into the input field to the right of the icon searches the table accordingly and highlights the rows that match the search criterion.
use LMB to click on a table row	Selects the row and the corresponding object in the Scene Tree. In analysis result lists, the result, e.g., the component, is marked by a cross-hairs cursor in each of the 2D views.
hold **Ctrl** key + use LMB to click on several table rows	Selects the rows and the corresponding objects in the Scene Tree.
hold **Shift** key + use LMB to click on two separate table rows	Selects the two rows, including all rows between the two as well as the corresponding objects in the Scene Tree.
hold **Shift** key + use up/down arrow keys	Selects the rows and the corresponding objects in the Scene Tree.
press **Ctrl+A**	Selects all table rows.
use up and down arrow keys	Steps up and down through the table rows.
use RMB to click into the table area	Displays a context menu. See below.
use LMB to click a column heading	Sorts the table according to the values of the column. Clicking subsequently toggles between ascending and descending.
use LMB to click and drag column heading to new position, then release LMB	Inserts the column at the new position.

Control	Description
use LMB to double-click cell highlighted in white (light theme) or medium gray (dark theme)	If applicable: Allows you to edit the contents of the cell.

- **Screenshots** section (if available)

  The **Screenshots** section below the list section allows you to capture images from one of the 2D windows, the 3D window, or the current window layout for the item currently selected in the table. Only available if exactly one row is selected.

  Table 44-24: Controls in the **Screenshots** section

Control	Description
Capture from button	Adds the image of the view selected from the drop-down list to the preview area above.
use LMB to click and drag one or more images, then release LMB	Moves the image(s) to the new position.
double-click the image	Opens the **Snapshot display** window showing the image: • **Zoom in**/**Zoom out** button: Zooms the image in/out. You can also move the mouse pointer in the image area and turn the mouse wheel. • **Fit to window** button: Resets the zoom so that the image fits into the window.
click the **<no description>** placeholder twice (first click to select, second click to enable renaming)	Allows you to label the image.
Delete selected button	Deletes the selected image from the preview area.

Table Context Menu

Right-clicking anywhere in the table area shows a context menu with the following options:

Table 44-25: Context menu items

Control	Description
Columns	Allows you to toggle the visibility of each column by checking/unchecking the respective item. • **Show all**: Checks all columns to set them to visible. • **Hide all**: Unchecks all columns to set them to invisible. • **Hide empty**: Unchecks all not editable columns which are empty or **n/a** to set them to invisible.

Control	Description
Trim columns	Resizes all columns to their smallest possible size.
Apply default column layout	Applies the default column layout previously saved by the user to the current table. If no default column layout has been saved, the original column layout will be applied.
Save as default column layout	Saves modifications applied to the table—e.g., the visibility of a column, the order in which the columns appear, the column width—as default column layout. This layout will be applied when you create a new project.
Apply original column layout	Restores the original table layout and discards any modifications applied by the user. The original table layout is predefined and cannot be modified by the user.
Remove entries	If applicable: Deletes the selected row(s) from the table.
Create annotations	If applicable: Creates annotations for the selected items.
Export as CSV...	Opens the **Export as CSV...** dialog for exporting the table values as **.csv* file. This option always exports the complete table even if a filter was applied. In order to export only the filtered rows, press **Ctrl** + **A** to highlight all filtered rows and use the **Copy to clipboard** menu item.
Copy to clipboard	Copies the selected rows as well as the column heading into the system clipboard. The clipboard information is provided both as plain text and rich-text table, so when pasting into a rich-text-capable application like a word processor, you will see a proper table with cell borders and bold headings.
Paste	For annotation tables: Pastes previously copied coordinates and—optionally—snap directions to create new annotations in the table. For annotations of a nominal/actual comparison, the search distance specified on the **Settings** tab of the analysis will be considered. Note: Pasted annotations will be interpreted in the selected coordinate system at the time of pasting.

Control	Description
	The information in the clipboard must have the following structure: • x-, y-, and z-coordinate of the annotation or • x-, y-, and z-coordinate of the annotation as well as x-, y-, and z-component of the vector for the snap direction The parameters can be separated by space, tab, semi-colon, or comma (if a comma is already used as a decimal mark or digit grouping symbol, the values must be enclosed in double quotation marks). Example: 8.89;25.82;-0.55;1;0;0 You can also copy the information directly from the cells of a spreadsheet. In order to paste the annotation information, you can also press the **Ctrl** + **V** keyboard shortcut.
Set as active column	If applicable: Makes the current column the active column, i.e., the results of this column are color-coded according to their values as defined by the color lookup table and the colors specified in the **Sections** section of the **Colors** tab.
Unset active column	If applicable: Deselects the currently active column and sets the **Active column** drop-down list on the corresponding **Settings** tab to **Uncoded**, i.e., removes any color coding.
Enter/change value (all items)	If applicable: Opens the **Enter value** dialog (see below) where you can enter the desired value for the selected parameter. This value will be applied to all entries in the table.
Enter/change value (selected items)	If applicable: Opens the **Enter value** dialog (see below) where you can enter the desired value for the selected parameter. This value will be applied to the selected entries in the table.
Delete selected items	If applicable: Removes the selected items from the scene.

The **Enter value** dialog includes the following controls:

Table 44-26: Controls in the **Enter value** dialog

Control	Description
Enter value field	Allows you to enter the desired value.
OK button	Sets the selected parameter to the specified value.

Control	Description
Reset button	For analyses only: Resets the selected parameter to undefined.
Set from tolerance settings button	For analyses only: Enters the value specified in the tolerance settings of the analysis for the selected parameter.
Cancel button	Discards the changes and closes the dialog.

Rules Tab

Shows existing rules for selecting features (e.g., probability, radius) with defined properties to be included in the final report. Apart from that, the **Rule** dialog allows you to create new rules and edit or delete existing rules.

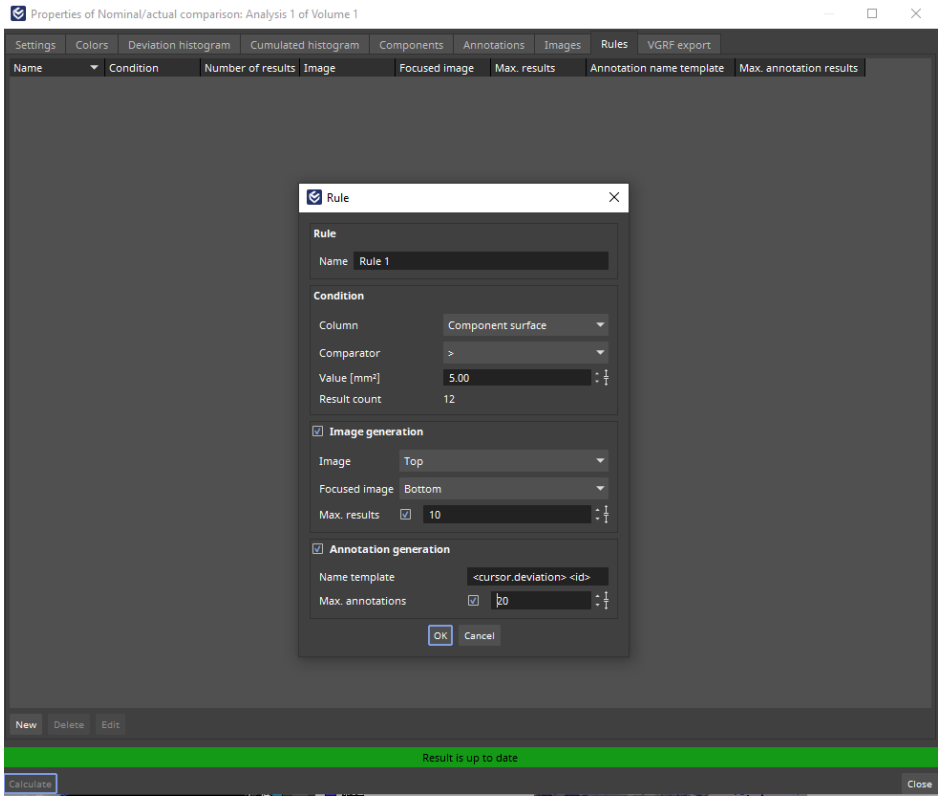


Figure 44-2: **Rules** tab with **Rule** dialog

- **New** button
  Opens the **Rule** dialog for creating a new rule.
- **Delete** button
  Deletes a selected rule.
- **Edit** button
  Opens the **Rule** dialog for editing a selected rule.

You can also double-click a rule to open the **Rule** dialog for editing a selected rule.

Rule Dialog

- **Rule** section

  The **Name** field allows you to enter a name for the new rule. This name has to be unique.
- **Condition** section

  Table 44-27: Controls in the **Condition** section

Control	Description
Column drop-down list	Selects the property of the feature (e.g., probability, radius, diameter) that defines the rule.
Comparator drop-down list	Specifies the comparator to be applied to the selected property.
Value [<unit>] spin box or drop-down list	Specifies the reference value or status of the selected property for comparison.
Result count field	Indicates the number of results that meet the specified condition.

- **Image generation** section

  Table 44-28: Controls in the **Image generation** section

Control	Description
Image drop-down list	Allows you to add a detailed 2D image and object description on a separate page of the report. • **Off**: No image is created (default). • **Orthographic projection**: Creates three orthogonal views. • **Top/Bottom/Left/Right/Front/Back**: Creates a single 2D view in the specified orientation. • If applicable: **... - If not OK**: Automatically creates the image if the tolerance status is **Out of tolerance**.
Focused image drop-down list	This option is almost identical to the **Image** option, but will generate an image that focuses on the respective item and is zoomed in by the **Zoom factor** specified during report creation or VGRF-based export.
Max. results checkbox and spin box	When this option is checked, you will be able to use the corresponding spin box to specify the maximum number of results to be included in the report.

- **Annotation generation** section

Table 44-29: Controls in the **Annotation generation** section

Control	Description
Name template field	Allows you to enter a name for the annotations. If this is not done, a name of the form <*annotation type*> <*id*> will automatically be generated.
Max. annotations checkbox and spin box	When this option is checked, you will be able to use the corresponding spin box to specify the maximum number of annotations to be generated.

In contrast to manually created annotations, rule-based annotations can neither be moved nor deleted. This is indicated by a closed padlock symbol next to the annotation name in the annotation label.

Rule-based annotations that are based on components are created at the position of the component that fulfills the condition. For wall thickness analyses performed with the **Sphere method** algorithm and nominal/actual comparisons, the position of the component is always the spatial center (or—if the spatial center lies outside the component—a position within the component that is closest to the spatial center), while for wall thickness analyses performed with the **Ray method** algorithm, the position is defined by the **Position property** option on the **Settings** tab of the properties dialog.

- **OK** button

  Closes the dialog, adds the new rule to the list in the **Rules** tab and updates the annotations.
- **Cancel** button

  Discards the settings and closes the dialog.

Images Tab

Allows you to take screenshots of the selected workspace views and/or add bookmark references to the report. In the final report, the captured images will be listed separately from the screenshots created on other tabs.

- **Snapshots** section

  Table 44-30: Controls in the **Snapshots** section

Control	Description
Capture from button	Adds the image of the view selected from the drop-down list to the preview area above.
Delete selected button	Deletes the selected image(s) from the preview area.
use LMB to click and drag one or more images, then release LMB	Moves the image(s) to the new position.

Control	Description
double-click the image	Opens the **Snapshot display** window showing the image: • **Zoom in**/**Zoom out** button: Zooms the image in/out. You can also move the mouse pointer on the image area and turn the mouse wheel. • **Fit to window** button: Resets the zoom so that the image fits into the window.
click the **<no description>** placeholder twice (first click to select, second click to enable renaming)	Allows you to label the image.

- **Automatic 3D images** section (if available)

  Check the corresponding checkbox to include the desired 3D view (e.g., **Top**, **Front**, **Top-left-front**, and **Current camera settings**) in the report without changing the 3D view.

- **Bookmark references** section

  Allows you to add bookmark references via drag and drop from the **Bookmarks and views** tool or the **Bookmark editor** to the preview area. The images of the referenced bookmarks will then be included in VGRF-based reports.

  When you open a project with missing bookmark images, placeholders will be shown instead.

  Bookmark references are stored in evaluations and can be used in automation scenarios.

You will still need to import a bookmark template containing the actual bookmarks in these cases, as evaluations store only references to them.

Table 44-31: Controls in the **Bookmark references** section

Control	Description
New bookmark button	Adds a bookmark of the current view to the preview area.
Remove button	Removes the bookmark currently selected in the preview area.
click the bookmark title twice (first click to select, second click to enable renaming) or press the **F2** key	Allows you to rename the bookmark. The changes made on the **Images** tab will also affect the **Bookmark editor** and the **Bookmarks and views** tool. If the renamed bookmark is referenced by one or more objects for reporting, a warning message will be displayed indicating that the referenced bookmark will also be renamed for all these objects in the report.

The global concept of bookmark references allows for multiple objects to reference the same bookmark and for objects to reference bookmarks that show arbitrary information, e.g., other analyses or objects.

Porosity/Inclusion Analysis Module (legacy)

Introduction

The legacy **Porosity/inclusion analysis** function has been designed to investigate voxel data sets for internal discontinuities, such as voids and inclusions, and to provide detailed analysis results with information on each individual indication as well as overall statistical information. An analysis report will be generated, which contains information such as position, size, surface, and volume of each individual indication.

The indication analysis procedure consists of two steps:

a) Each voxel is checked whether it is part of an indication. Groups of connected indication candidates are created.

b) Each group of indication candidates is checked whether it matches the parameters specified by the user.

The following algorithms are provided:

- **VGEasyPore**:

  This algorithm is easy to parametrize and immediately shows a preview of the expected results. This approach identifies voxels as indications based on the actual local gray value of the material in relation to a specified local contrast threshold and can detect indications that are connected to the surrounding air. In contrast to the other indication detection algorithms, the **VGEasyPore** algorithm provides the possibility to calculate certain indication properties with *subvoxel* accuracy.

- **VGDefX/Only threshold**:
  - **VGDefX**: This is the most sophisticated algorithm. It allows for gray value variations, includes noise reduction for seed point location, and can detect indications which are connected to the surrounding air. It offers several probability criteria according to which the indications will be detected.
  - **Only threshold**: With this algorithm, each group of indication candidates is considered an indication if the gray value is below the specified threshold.

- **From indication ROI**:

  With this algorithm, the porosity/inclusion analysis is based on a region of interest (ROI) that is supposed to contain the indication candidates. The analysis parameters are applied to each voxel group of the ROI. The ROI can be defined manually, by importing an ROI template, or via an indication mask. Note that with the current version of VGSTUDIO MAX, the indication properties will always be calculated with voxel accuracy, regardless of the accuracy of the indication ROI.

- **2.x compatibility**:

  These algorithms from VGSTUDIO MAX 2.x are available in the current software version to enable inspections using existing inspection plans. The **Default** algorithm is optimized for speed, while the **Enhanced** algorithm is optimized for accuracy.

License Information

This module is an optional add-on module for VGSTUDIO MAX. It is not available for myVGL. However, if a project loaded in myVGL contains results obtained with this module, they can be viewed and reported in myVGL.

If you are interested in a more comprehensive functionality than the one offered by myVGL, you have the chance to evaluate VGSTUDIO MAX. You can request an evaluation license of VGSTUDIO MAX on our website:

https://volumegraphics.hexagon.com/en/products/evaluation

If you have further questions about our product portfolio, please contact us:

- For Europe, Middle East, and Africa:
  Write an e-mail to sales@volumegraphics.com or call +49 6221 73920 744.
- For Japan:
  Write an e-mail to sales@volumegraphics.jp or call +81 52 508 9682.
- For the Americas:
  Write an e-mail to sales-us@volumegraphics.com or call +1 704 248 7736.
- For China, including Mainland China, Hong Kong, Macao, and Taiwan:
  Write an e-mail to sales@volumegraphics.cn or call +86 10 8532 6305.
- For Singapore and other parts of Asia (except China and Japan), Australia, and parts of Oceania:
  Write an e-mail to sales@volumegraphics.sg or call +65 6665 0310.

Opening the Dialog

In order to open the **Porosity/inclusion analysis** dialog,

- right-click the corresponding entry in the Scene Tree and select **Properties** from the context menu or
- double-click the corresponding entry in the Scene Tree.

The **Porosity/inclusion analysis** dialog consists of several tabs on which you can view the results of the porosity/inclusion analysis.

To close the dialog, click the **Close** button at the bottom of the dialog.

A status bar at the bottom of the dialog indicates the current status of the analysis. The status can be one of the following:

Table 45-1: Messages in the status bar

Status	Description
Result is up to date	The current analysis result is valid.
Calculation required	All required parameters have been specified and are consistent, but the analysis was not calculated or was invalidated by some user action before the project was saved.

Status	Description
Object has no surface determination	No surface determination information is available for the selected volume object. See also section *Surface determination* on page 949 in chapter 48 *Glossary*.
Void max. value must be larger than background value	**2.x compatibility**: **Define manually** mode for analysis mode **Void**: The **Background** gray value specified in the **Material definition** section is larger than the **Void max.** gray value.
Void max. value must be larger	**VGDefX/Only threshold**: **Define manually** mode for analysis mode **Void**: The **Void max.** gray value specified in the **Material definition** section is smaller than or equal to the minimum gray value in the volume object.
Inclusion min. value must be smaller	**VGDefX/Only threshold** and **2.x compatibility**: **Define manually** mode for analysis mode **Inclusion**: The **Inclusion min.** gray value specified in the **Material definition** section is larger than or equal to the maximum gray value in the volume object.
Invalid deviation factor	**VGDefX/Only threshold** and **2.x compatibility**: **Use sample ROIs** mode or **Use determined surface** mode: The selected **Deviation factor** is too large, so that the resulting **Inclusion min.** value is larger than or equal to the maximum gray value in the volume object, or too small, so that the resulting **Void max.** value is smaller than or equal to the minimum gray value in the volume object (**VGDefX/Only threshold**) or the **Background** value (**2.x compatibility**), respectively.
Invalid interpolation factor	**VGDefX/Only threshold** and **2.x compatibility**: **Use sample ROIs** mode or **Use determined surface** mode: The selected **Interpolation factor** is too large, so that the resulting **Inclusion min.** value is larger than or equal to the maximum gray value in the volume object, or too small, so that the resulting **Void max.** value is smaller than or equal to the minimum gray value in the volume object (**VGDefX/Only threshold**) or the **Background** value (**2.x compatibility**), respectively.
Select the background ROI	**VGDefX/Only threshold** and **2.x compatibility**: **Use sample ROIs** mode combined with **Interpolation** mode: No **Background ROI** for defining the mean gray value used as a basis for calculating the **Void max.** or **Inclusion min.** value, respectively, has been selected.
Select the material ROI	**VGDefX/Only threshold** and **2.x compatibility**: **Use sample ROIs** mode: No **Material ROI** for defining the mean gray value used as a basis for calculating the **Void max.** or **Inclusion min.** value, respectively, has been selected.

Status	Description
Gray value deviation of the selected material ROI must not be zero	**VGDefX/Only threshold** and **2.x compatibility**: **Use sample ROIs** mode combined with **Deviation** mode: The standard deviation of the gray values in the selected **Material ROI** is zero.
Selected material and background ROI must not be the same	**VGDefX/Only threshold** and **2.x compatibility**: **Use sample ROIs** mode combined with **Interpolation** mode: The **Material ROI** and **Background ROI** are identical.
Mean gray value of material ROI must be larger than mean gray value of background ROI	**VGDefX/Only threshold** and **2.x compatibility**: **Use sample ROIs** mode combined with **Interpolation** mode: The mean gray value of the **Material ROI** is smaller than or equal to that of the **Background ROI**.
Select an indication ROI	**From indication ROI**: No indication ROI has been specified.
Select a reference object for edge distance calculation	The **Edge distance calculation** option has been checked, but no reference object has been selected.
Edge distance reference has no surface determination	From the **Reference** drop-down list in the **Edge distance calculation** section, a volume object was selected for which no surface determination information is available. See also section *Surface determination* on page 949 in chapter 48 *Glossary*.
Select a wall thickness analysis	The **Wall thickness analysis** option has been checked, but no wall thickness analysis has been selected.
Selected wall thickness analysis has no results	No results are available in the selected wall thickness analysis.
Size range: Max. value must be larger than min. value	The specified minimum value is larger than the maximum value.
Compactness range: Max. value must be larger than min. value	The minimum value specified in the **Compactness range** fields is larger than the maximum value.
Sphericity range: Max. value must be larger than min. value	The minimum value specified in the **Sphericity range** fields is larger than the maximum value.
Edge distance range: Max. value must be larger than min. value	The minimum value specified in the **Edge distance range** fields is larger than the maximum value.

Status	Description
Cut face range: Max. value must be larger than min. value	The minimum value specified in the **Cut face range** fields is larger than the maximum value.
Select analysis direction	**VGEasyPore**, **VGDefX/Only threshold**, and **From indication ROI**: The **Directional variability** option has been checked, but no analysis direction has been specified.
Manual changes to result	Some voids/inclusions have been manually deleted.
License missing	The add-on module is not licensed.

An invalid or outdated status of an analysis is indicated in the Scene Tree by a warning sign. Double-click this analysis to open it and check the status bar for messages.

The units of the dialog are set according to the global unit settings (see section *Units Drop-down List* on page 33 in chapter 2 *Workspace*).

Settings Tab for the VGEasyPore Algorithm

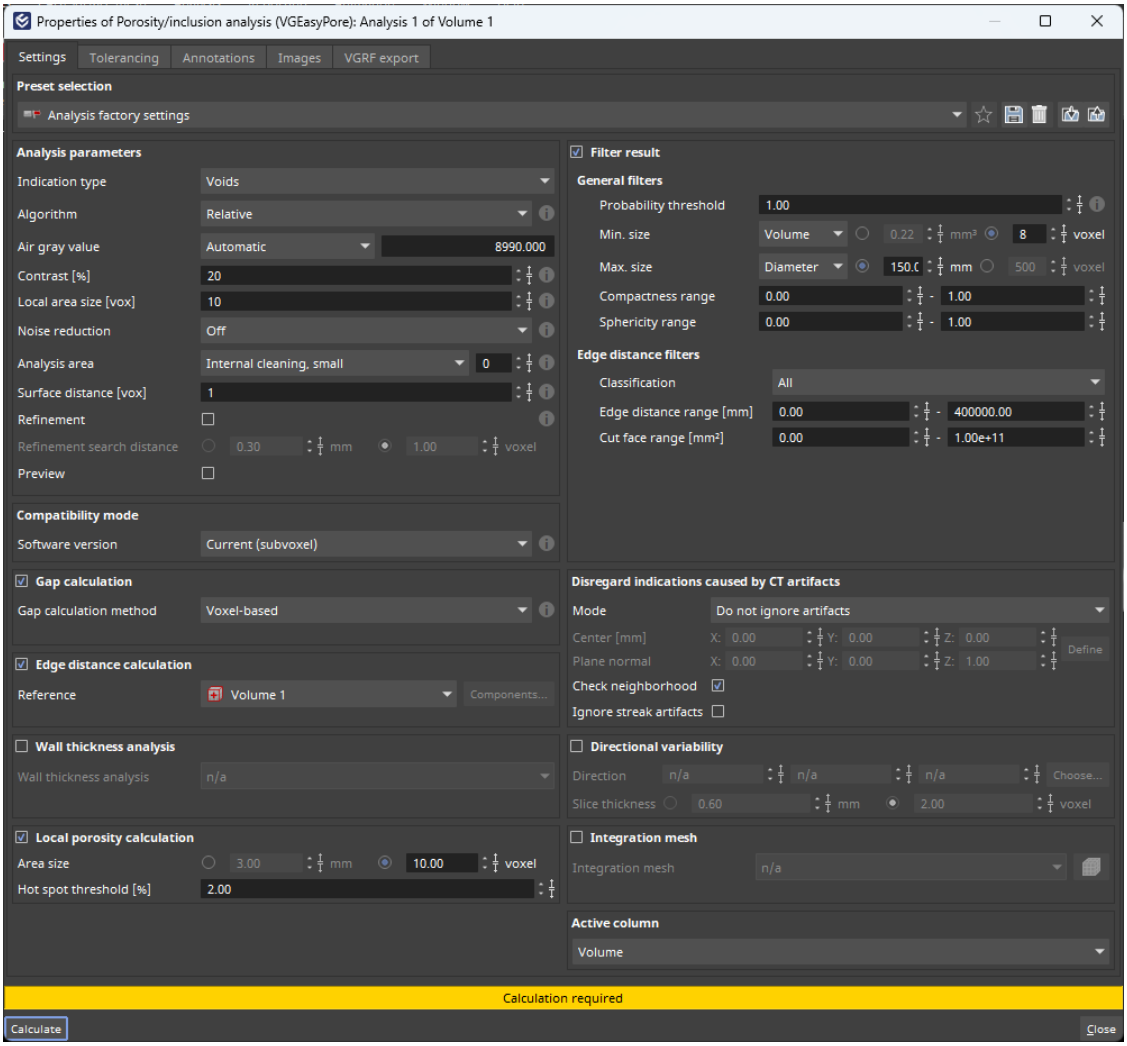


Figure 45-1: **Porosity/inclusion analysis (VGEasyPore)** dialog, **Settings** tab

In myVGL, all parameter settings are displayed. Most of these parameters are read-only in myVGL. The complete functional range is available with VGSTUDIO MAX and the respective add-on module(s).

Preset selection Section

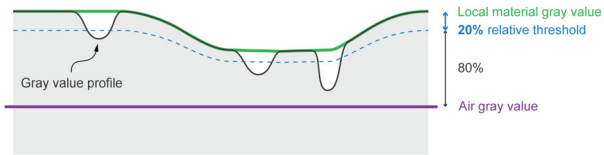
Table 45-2: Controls in the **Preset selection** section

Icon	Item	Description
	drop-down list	Specifies the preset to be applied, to be edited, or to be taken as a basis for a new preset. The following icons are used: • analysis factory settings • customized preset • appears next to the icon of a preset that has been modified but not yet saved
	Set this preset as default	Sets the selected preset as default. The default preset will be applied when creating a new analysis of the same type. If the selected preset is already set as default, the button is disabled.
	Save preset	Saves the selected preset. When saving a preset, the **Save preset** dialog will open, which allows you to set the new preset as default by checking the **Set as default for new analyses** checkbox.
	Remove preset	Removes the selected preset from the preset drop-down list. If the removed preset is the default preset, the next time an analysis of the same type is created, the factory settings will be used.
	Import preset	Imports a preset from the specified location.
	Export preset	Exports the selected preset to the specified location.

Analysis parameters Section (**VGEasyPore** Algorithm)

Table 45-3: Controls in the **Analysis parameters** section

Control	Description
Indication type drop-down list	Only available in **Subvoxel** mode. • **Voids**: Detects voxels with gray values *lower* than those of the surrounding material. • **Inclusions**: Detects voxels with gray values *higher* than those of the surrounding material.

Control	Description
Algorithm drop-down list	• **Absolute**: This algorithm determines the voxels that belong to an indication on the basis of an absolute contrast threshold. Voxels with a gray value difference compared to the surrounding (material) voxels larger than the absolute contrast threshold will be marked as indications. • **Relative**: This algorithm detects indications based on a relative contrast threshold. This threshold is calculated from the local material gray value, the global air gray value, and a user-defined contrast. The air gray value can be determined automatically or manually from the gray value histogram. The default value for the relative contrast threshold is 20%: All voxels with a contrast difference greater than 20% compared to their surrounding material voxels will be defined as indications.  Figure 45-2: Relative contrast threshold In **Relative** mode, the threshold itself is relative to the surrounding material gray values. As a result, this algorithm is particularly resistant to fluctuations of the material gray values across the scan, as caused by beam hardening, for example.
Contrast spin box	Available for **Absolute** algorithm: Specifies the absolute contrast threshold. Each voxel with a local contrast that is higher than the absolute contrast threshold is considered part of an indication if the surrounding voxels in the search area are brighter than this voxel.
Estimate button	Available for **Absolute** algorithm: Automatically detects the absolute contrast threshold based on the gray value histogram and enters the value into the **Contrast** spin box, where it can be adapted manually.

Control	Description
Air gray value drop-down list	Available for the **Relative** algorithm: The air gray value is needed for calculating the relative contrast threshold. There are two ways of getting this value: • **Automatic**: Automatically determines the air gray value based on the left-most peak of the gray value histogram. • **Manual**: The air gray value is entered by the user.
Contrast [%] spin box	Available for **Relative** algorithm: Specifies the relative contrast threshold, i.e., the percentage of (material gray value – air gray value). Every voxel with a gray value smaller than or equal to the gray value derived from the relative contrast threshold is considered part of an indication.
Noise reduction drop-down list	Applies a low-pass filter to the gray values in order to reduce high-frequency noise. High-frequency noise introduces variations in the gray values, which makes the identification of actual indications harder, leading to false positive analysis results. The following options for the noise reduction filter are available: • **Off**: No filtering is applied. • **Low**: Use this setting for data sets with little noise. • **High**: Use this setting for data sets with a lot of noise. Consider activating the **Noise reduction** option only when noise is present in your scan and adjusting the value for **Contrast** does not lead to satisfactory results. Note that activating this option increases the amount of memory required during the calculation.
Local area size [vox] spin box	Specifies the diameter of the search area around each voxel for determining the contrast.
Analysis area drop-down list	Specifies the area of the selected volume/ROI on which the **VGEasyPore** algorithm will be performed. The analysis area is based on the surface determination of the volume. This option does not change the actual surface determination. This is an internal representation used for porosity/inclusion analysis only.

Control	Description

	• **Automatic**: Automatically selects the appropriate setting based on the part's surface determination and on the **Indication type** (**Voids**/**Inclusions**).
	  • **Indication type > Voids**
	  If you selected **Voids** as **Indication type** and the voids have not been filtered in the advanced surface determination with the **Filter voids** option, this option will remove all voids.
	  • **Indication type > Inclusions**
	  In **Inclusions** mode, no voids will be filtered. The basis for the calculation will be the determined surface (**Surface as seen**).
	• **From surface (as seen)**: Uses the area within the original surface determination.
	• **Internal cleaning, small**: Also includes small indications that are separated by the determined surface from the material.
	• **Internal cleaning, all**: Also includes larger indications that are separated by the determined surface from the material. This will use the entire area enclosed by the outermost defined surface.
	• **Overall closing**: Also includes indications that are separated by the determined surface from the material. This is achieved by performing a closing with the specified number of voxels.
	
	When you specify a number of voxels after having selected **Internal cleaning, small** or **Internal cleaning, all**, **Overall closing** is done additionally.

Surface distance [vox] spin box	Restrains the indication detection to the analysis area. To avoid detecting "false" indications along the surface caused by the partial voxel effect, you can reduce the area by the selected number of voxels.
Refinement checkbox	When this option is checked, the borders of the initially detected indications will be adjusted by using the local gray value gradients within the search distance. This local refinement reduces the effect of the **Contrast** parameter on the size of the detected indications. Indications will not extend outside the analysis area.
Refinement search distance spin box	Specifies the area (in physical units (e.g., mm) or in voxels) around the indication border to be considered for refinement.

Control	Description
Preview checkbox	When this option is checked, a preview of the indications is displayed. The preview is calculated by using the specified contrast, local area size, and surface distance. The preview also considers the effect of the **Refinement** and **Analysis area** options.

Compatibility mode Section

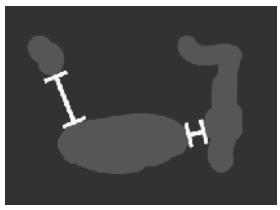
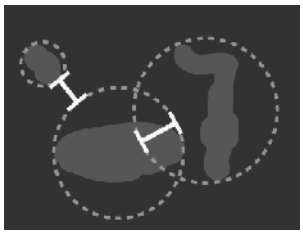
The **Compatibility mode** can be used to reproduce the detection procedure of an earlier version of VGEasyPore by selecting the corresponding software version. This makes it possible to reproduce old analysis results, for example, for automated setups. Indication filtering is not affected by the compatibility mode.

Table 45-4: Options of the **Compatibility mode** drop-down list

Option	Description
Software version	The **Software version** drop-down list allows you to reproduce the detection procedure using earlier versions of VGEasyPore.

Gap calculation Section

Table 45-5: Controls in the **Gap calculation** section

Control	Description
Gap calculation checkbox	Calculates the closest distance to the nearest neighbor of each pore. There are two calculation methods: **Voxel-based** Calculates the closest distance based on the actual voxel boundaries of the indications.  **Sphere-based (legacy)** Approximates the closest distance by finding the circumscribed sphere of each indication and calculating the distance to the closest neighboring sphere. If the spheres intersect, the distance will be negative.  **Voxel-based and sphere-based** Calculates the gap according to both calculation methods.

Edge distance calculation Section

This function is highly important for virtual machining. For example, prior to actually eroding a sealing surface or cutting a screw thread, this analysis parameter delivers the information if indications will be cut open by the machining process. This information can be significant when you are interested in the sealing or crack opening properties of an object area.

Table 45-6: Controls in the **Edge distance calculation** section

Control	Description
Edge distance calculation checkbox	When this option is checked, the distance of each indication to the object selected in the **Reference** field will be calculated. The edge distance will be calculated relative to the nearest surface of the reference object. If you use a surface determination as reference, make sure it does not include areas within the material (e.g., indications).

Control	Description
Reference drop-down list	Specifies the object to which the edge distance calculation refers. Note: If a CAD model or a surface mesh is referenced, it should be a solid object with a closed surface.
Components... button	This button is enabled when you select an object with components from the **Reference** drop-down list. Clicking it opens a dialog box where you can specify the components to be used as reference for the edge distance calculation: • Checkbox of component: Clicking it checks/unchecks the component, including all child components. • **Select all** button: Selects all components of the object. • **Deselect all** button: Deselects all components of the object. • **Apply visibility** button: Selects all components which are set to visible in the Scene Tree.

Wall thickness analysis Section

When the **Wall thickness analysis** checkbox is checked, the **Wall thickness analysis** drop-down list where you can select the wall thickness analysis to be used for combined analysis will be enabled. The detected indications will then not only be analyzed with respect to their size but also with respect to their relative size referring to the smallest local wall thickness.

Performing a wall thickness analysis may require additional licensing. Contact us for details.

Local porosity calculation Section

Table 45-7: Controls in the **Local porosity calculation** section

Control	Description
Local porosity calculation checkbox	When this option is checked, the corresponding controls for calculating areas of particularly high porosity will be enabled.
Area size spin box	Specifies the standard deviation of a normal distribution (in physical units (e.g., mm) or in voxels)—starting from the center of each voxel—of the area considered for calculating the ratio of pore voxels to material voxels. The resulting 3-dimensional normal distribution function will be used as a weight function for the calculation of porosity.

Control	Description
Hot spot threshold [<ratio unit>] spin box	Specifies a threshold to be applied to the porosity of the analyzed areas. The areas where the porosity is larger than the threshold are regarded as hot spots.

Integration mesh Section

Allows you to create an integration mesh or select an existing integration mesh to obtain the results of the porosity/inclusion analysis for each mesh cell.

Table 45-8: Controls of the **Integration mesh** section

Control	Description
Integration mesh checkbox	When this option is checked, the options for using an integration mesh will be enabled.
Integration mesh drop-down list	Allows you to specify an integration mesh by selecting an existing mesh from the drop-down list.
Create regular integration mesh button	Creates an integration mesh and opens the **Mesh** dialog for adjusting the parameters manually.

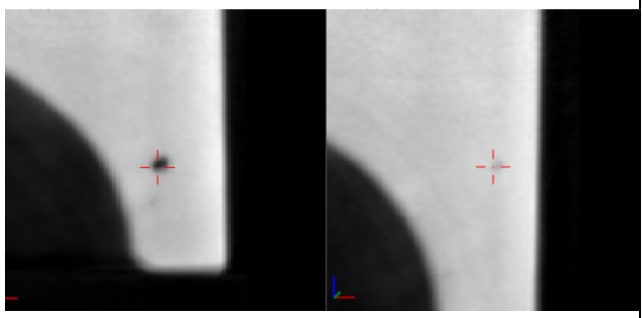
Filter result Section

When the **Filter result** checkbox is checked, only indications that meet the specified filter criteria will be included in the results, e.g., the indication list and statistics.

- **General filters** section

  Table 45-9: Controls in the **General filters** section

Control	Description
Probability threshold spin box	All potential indication areas that pass the size check will be further processed by several analysis stages. These stages try to differentiate between real indications and artifacts by utilizing sophisticated image processing algorithms. Each detected indication is tagged with a value indicating the probability that it is a real indication. Specify the **Probability threshold** so that only indications with a probability above the threshold will be included in the list. Start with a **Probability threshold** of zero if you are running the indication detection on a new data set for the first time to make sure you do not filter real indications from the list. There is no absolute value for the threshold applicable to all data sets.

Control	Description
	The following figure shows two indications with different probabilities, where the indication on the left-hand side has a probability that is ten times higher than the indication on the right-hand side:  Figure 45-3: Probability threshold
Min. size spin boxes	Indicates the minimum indication size. Due to the nature of CT data, the value for **Min. size** should be no less than 8 voxels in edge length (i.e., an area of 2x2x2 voxels). Increase the value when data quality decreases.
Max. size spin boxes	Indicates the maximum indication size. When specifying the **Max. size** of the indication, consider that longish cracks have a rather large volume and that an accumulation of nearby small indications might be interpreted as one large indication. Specify the **Max. size** generously.
Compactness range spin boxes	Specifies the range for the compactness of the indication, i.e., the ratio between the volume of the indication and the volume of the circumscribed sphere. $\text{Compactness} = \frac{V_{indication}}{V_{sphere}}$
Sphericity range spin boxes	Specifies the range for the sphericity of the indication, i.e., the ratio between the surface of a sphere with the same volume as the indication and the surface of the indication. $\text{Sphericity} = \frac{A_{sphere}}{A_{indication}}$

- **Edge distance filters** section

  Enabled only if the **Edge distance calculation** option is checked.

Table 45-10: Controls in the **Edge distance filters** section

Control	Description
Classification drop-down list	Specifies the position of the indication relative to the object selected in the **Reference** field of the **Edge distance calculation** section: **All**, **Cut**, **Inside**, **Outside**, **Not cut**, **Not inside**, or **Not outside**.
Edge distance range [<length unit>] spin boxes	Specifies the range for the distance between the surface of the indication and the surface of the object selected in the **Reference** field of the **Edge distance calculation** section.
Cut face range [<length unit>²] spin boxes	Specifies the range for the surface area where the indication intersects the surface of the object selected in the **Reference** field of the **Edge distance calculation** section.

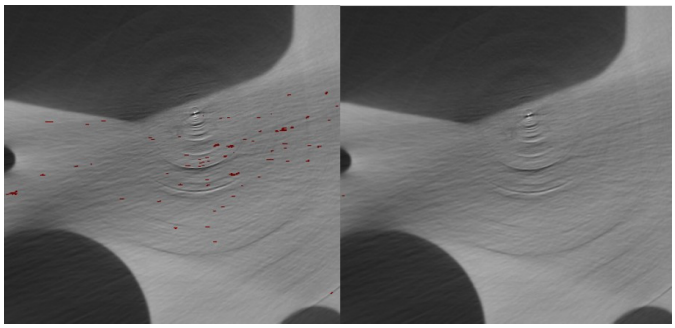
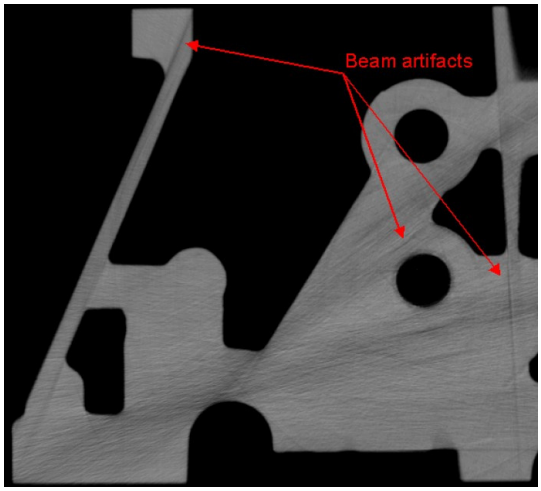
Disregard indications caused by CT artifacts Section

Ring artifacts may appear within (industrial) CT data as dark circles or arcs. The voxel in the rotation center may also appear as a dark area. Depending on the selected mode, the circular structures around the specified center and/or the center itself will be considered ring artifacts and/or center artifacts, respectively, and will not be included in the indication list.

Table 45-11: Controls in the **Disregard indications caused by CT artifacts** section

Control	Description
Mode drop-down list	• **Do not ignore artifacts**: If present, center and ring artifacts will possibly be detected as indications. • **Center artifacts**: The center voxel will not be detected as indication. • **Ring artifacts**: Circular structures around the center voxel will less likely be detected as indications. • **Center and ring artifacts**: Both the center voxel and circular structures around the center voxel will less likely be detected as indications.

Control	Description
	Important: • If **Ring artifacts** is activated, a real indication connected to a *ring artifact* might not be detected. • If **Center artifacts** is activated, a real indication connected to a *center artifact* might not be detected. • If **Center and ring artifacts** is activated, a real indication connected to a *center or ring artifact* might not be detected. Note that the **Ring artifacts** and **Center and ring artifacts** modes will change the probability of the indications. With a **Probability threshold** > 0, result filtering and thus the number of indications in the **Indications** table will also be affected.
Define button	Opens a dialog that prompts you to specify the position of the (rotation) center by holding down the left mouse button and dragging a circle in the corresponding 2D view. The center of the circle must coincide with the center of the ring artifact. When you release the left mouse button, the position of the center of the circle will be adopted as center and the direction of the 2D view will be adopted as plane normal. When you do not drag a circle, the old position and normal will be maintained.
Center X/Y/Z [<length unit>] spin boxes	Indicate the position of the rotation center of the specified artifact area.
Plane normal X/Y/Z spin boxes	Indicate the plane normal of the specified artifact area.
Check neighborhood checkbox	When this option is checked, the indication detection algorithm will compare the potential indication with its local neighborhood. If the appearance of a potential indication is very similar to the surrounding structure, its probability will be reduced. This option is useful for reducing the number of erroneously detected artifacts.

Control	Description
	The following figure illustrates the effect of this option: The image on the left has been obtained without using neighborhood check; the right image with neighborhood check.  Figure 45-4: check neighborhood
Ignore streak artifacts checkbox	Beam artifacts may appear in (industrial) CT data as linear dark streaks. When this option is checked, these structures will be detected and assigned a low indication probability value. The following figure shows an example of beam artifacts:  Figure 45-5: Beam artifacts A real indication might not be detected when **Ignore streak artifacts** is activated if it is connected to and/or fits into the shape of a beam artifact. A beam artifact might not be removed by the ignore streak artifacts algorithm in cases where a beam artifact is connected to another indication (i.e., resulting shape is no longer a straight, line-like structure).

Directional variability Section

Table 45-12: Controls of the **Directional variability** section

Control	Description
Directional variability checkbox	When this option is checked, the options for specifying a direction in which the analysis is to be performed will be enabled.
Direction fields	Specify the direction (in the currently selected coordinate system) in which the porosity is to be analyzed. The specified vector is normalized to unit length before it is taken into account in the calculation. When you change the coordinate system, the specified vector will automatically be recalculated accordingly.
Choose... button	Opens a drop-down list that shows the windows currently available in the workspace for specifying the direction in which the analysis is to be performed. The direction is the normal of the selected 2D window or the current direction of view of the 3D window.
Slice thickness spin boxes	Specify the thickness (in physical units (e.g., mm) or voxels) of the individual slices to be analyzed.

Note that for calculating the directional variability of a porosity/inclusion analysis the object surface must be determined.

Active column Section

This drop-down list allows you to select the property of the indication that is to be shown according to the settings on the **Colors** tab.

When you select an indication property, e.g., **Surface**, from the **Active column** drop-down list, the indications will be color-coded according to their surface area as defined by the color lookup table and the colors specified in the **Sections** section of the **Colors** tab. In the indication list on the **Indications** tab, the column of the selected property becomes the “active” column, and its values are highlighted in bold and italic font.

When you select **Uncoded** from the **Active column** drop-down list, all indications will be shown in the same color regardless of their properties, e.g., radius and volume. The color can be specified in the **Uncoded indications** field of the **Other colors** section on the **Colors** tab.

The property selected in the **Active column** drop-down list will be added to the information provided in the annotation labels.

The **Active column** section is also available on the **Colors** tab. The changes made on the **Settings** tab will also affect the **Colors** tab and vice versa.

You can also select the active column on the **Indications** tab by right-clicking the column and choosing the **Set as active column** item from the context menu.

Settings Tab for the From indication ROI Algorithm

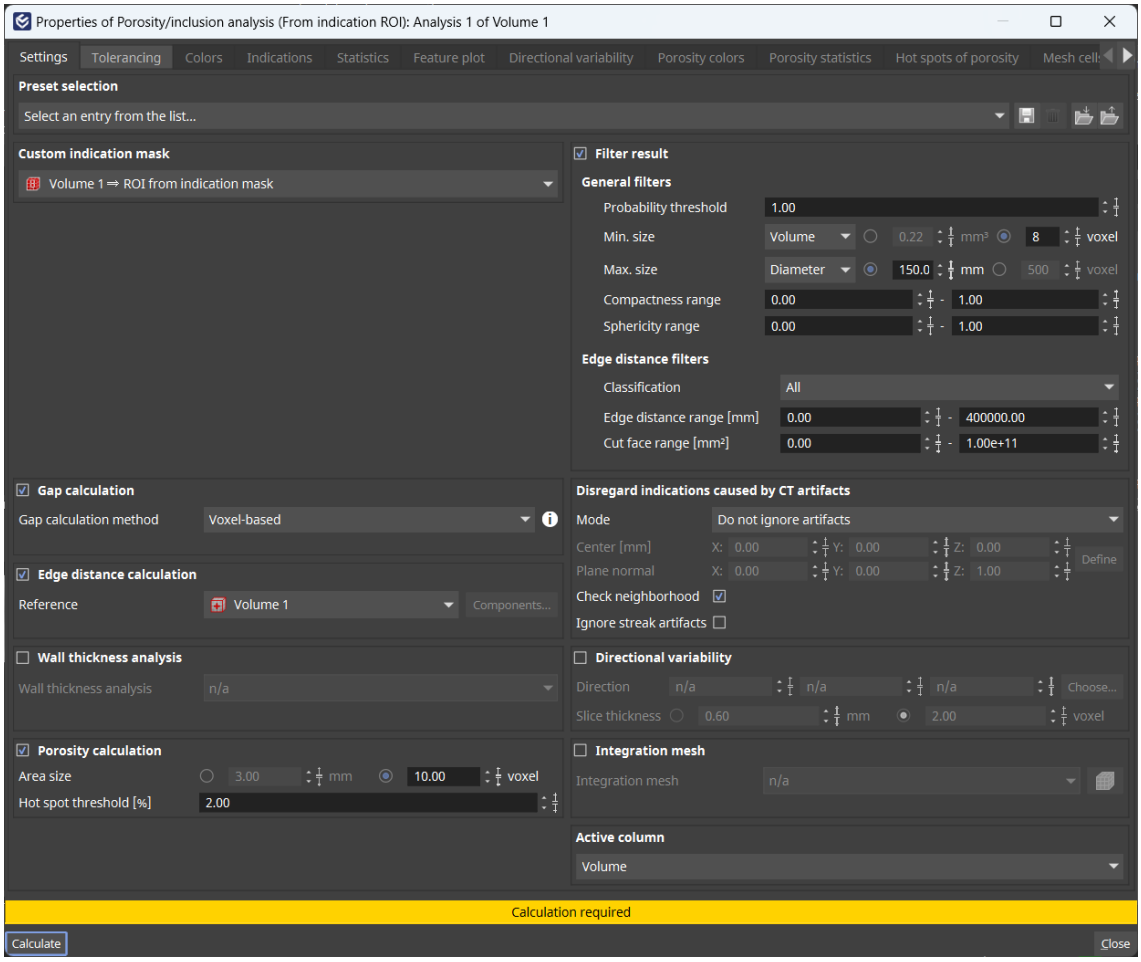


Figure 45-6: **Porosity/inclusion analysis (from indication ROI)** dialog, **Settings** tab

In myVGL, all parameter settings are displayed. Most of these parameters are read-only in myVGL. The complete functional range is available with VGSTUDIO MAX and the respective add-on module(s).

Preset selection Section

Table 45-13: Controls in the **Preset selection** section

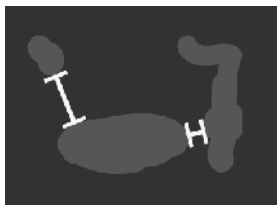
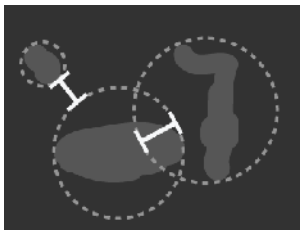
Icon	Item	Description
	drop-down list	Specifies the preset to be applied, to be edited, or to be taken as a basis for a new preset. The following icons are used: • analysis factory settings • customized preset • appears next to the icon of a preset that has been modified but not yet saved
	Set this preset as default	Sets the selected preset as default. The default preset will be applied when creating a new analysis of the same type. If the selected preset is already set as default, the button is disabled.
	Save preset	Saves the selected preset. When saving a preset, the **Save preset** dialog will open, which allows you to set the new preset as default by checking the **Set as default for new analyses** checkbox.
	Remove preset	Removes the selected preset from the preset drop-down list. If the removed preset is the default preset, the next time an analysis of the same type is created, the factory settings will be used.
	Import preset	Imports a preset from the specified location.
	Export preset	Exports the selected preset to the specified location.

Custom indication mask Section

The **Custom indication mask** drop-down list specifies the indication mask, which defines the voxels that are part of indications and those that are not.

Gap calculation Section

Table 45-14: Controls in the **Gap calculation** section

Control	Description
Gap calculation checkbox	Calculates the closest distance to the nearest neighbor of each pore. There are two calculation methods: **Voxel-based** Calculates the closest distance based on the actual voxel boundaries of the indications.  **Sphere-based (legacy)** Approximates the closest distance by finding the circumscribed sphere of each indication and calculating the distance to the closest neighboring sphere. If the spheres intersect, the distance will be negative.  **Voxel-based and sphere-based** Calculates the gap according to both calculation methods.

Edge distance calculation Section

This function is highly important for virtual machining. For example, prior to actually eroding a sealing surface or cutting a screw thread, this analysis parameter delivers the information if indications will be cut open by the machining process. This information can be significant when you are interested in the sealing or crack opening properties of an object area.

Table 45-15: Controls in the **Edge distance calculation** section

Control	Description
Edge distance calculation checkbox	When this option is checked, the distance of each indication to the object selected in the **Reference** field will be calculated. The edge distance will be calculated relative to the nearest surface of the reference object. If you use a surface determination as reference, make sure it does not include areas within the material (e.g., indications).

Control	Description
Reference drop-down list	Specifies the object to which the edge distance calculation refers. Note: If a CAD model or a surface mesh is referenced, it should be a solid object with a closed surface.
Components... button	This button is enabled when you select an object with components from the **Reference** drop-down list. Clicking it opens a dialog box where you can specify the components to be used as reference for the edge distance calculation: • Checkbox of component: Clicking it checks/unchecks the component, including all child components. • **Select all** button: Selects all components of the object. • **Deselect all** button: Deselects all components of the object. • **Apply visibility** button: Selects all components which are set to visible in the Scene Tree.

Wall thickness analysis Section

When the **Wall thickness analysis** checkbox is checked, the **Wall thickness analysis** drop-down list where you can select the wall thickness analysis to be used for combined analysis will be enabled. The detected indications will then not only be analyzed with respect to their size but also with respect to their relative size referring to the smallest local wall thickness.

Performing a wall thickness analysis may require additional licensing. Contact us for details.

Local porosity calculation Section

Table 45-16: Controls in the **Local porosity calculation** section

Control	Description
Local porosity calculation checkbox	When this option is checked, the corresponding controls for calculating areas of particularly high porosity will be enabled.
Area size spin box	Specifies the standard deviation of a normal distribution (in physical units (e.g., mm) or in voxels)—starting from the center of each voxel—of the area considered for calculating the ratio of pore voxels to material voxels. The resulting 3-dimensional normal distribution function will be used as a weight function for the calculation of porosity.

Control	Description
Hot spot threshold [<ratio unit>] spin box	Specifies a threshold to be applied to the porosity of the analyzed areas. The areas where the porosity is larger than the threshold are regarded as hot spots.

Integration mesh Section

Allows you to create an integration mesh or select an existing integration mesh to obtain the results of the porosity/inclusion analysis for each mesh cell.

Table 45-17: Controls of the **Integration mesh** section

Control	Description
Integration mesh checkbox	When this option is checked, the options for using an integration mesh will be enabled.
Integration mesh drop-down list	Allows you to specify an integration mesh by selecting an existing mesh from the drop-down list.
Create regular integration mesh button	Creates an integration mesh and opens the **Mesh** dialog for adjusting the parameters manually.

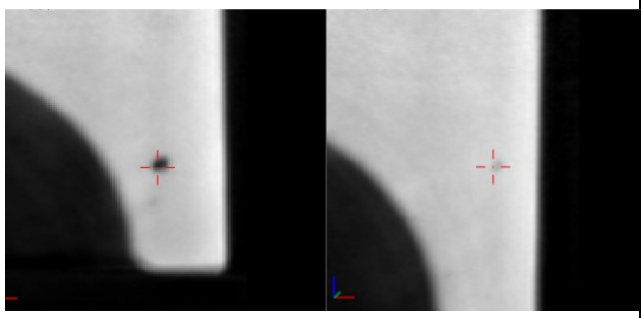
Filter result Section

When the **Filter result** checkbox is checked, only indications that meet the specified filter criteria will be included in the results, e.g., the indication list and statistics.

- **General filters** section

  Table 45-18: Controls in the **General filters** section

Control	Description
Probability threshold spin box	All potential indication areas that pass the size check will be further processed by several analysis stages. These stages try to differentiate between real indications and artifacts by utilizing sophisticated image processing algorithms. Each detected indication is tagged with a value indicating the probability that it is a real indication. Specify the **Probability threshold** so that only indications with a probability above the threshold will be included in the list. Start with a **Probability threshold** of zero if you are running the indication detection on a new data set for the first time to make sure you do not filter real indications from the list. There is no absolute value for the threshold applicable to all data sets.

Control	Description
	The following figure shows two indications with different probabilities, where the indication on the left-hand side has a probability that is ten times higher than the indication on the right-hand side:  Figure 45-7: Probability threshold
Min. size spin boxes	Indicates the minimum indication size. Due to the nature of CT data, the value for **Min. size** should be no less than 8 voxels in edge length (i.e., an area of 2x2x2 voxels). Increase the value when data quality decreases.
Max. size spin boxes	Indicates the maximum indication size. When specifying the **Max. size** of the indication, consider that longish cracks have a rather large volume and that an accumulation of nearby small indications might be interpreted as one large indication. Specify the **Max. size** generously.
Compactness range spin boxes	Specifies the range for the compactness of the indication, i.e., the ratio between the volume of the indication and the volume of the circumscribed sphere. $\text{Compactness} = \frac{V_{indication}}{V_{sphere}}$
Sphericity range spin boxes	Specifies the range for the sphericity of the indication, i.e., the ratio between the surface of a sphere with the same volume as the indication and the surface of the indication. $\text{Sphericity} = \frac{A_{sphere}}{A_{indication}}$

- **Edge distance filters** section

  Enabled only if the **Edge distance calculation** option is checked.

Table 45-19: Controls in the **Edge distance filters** section

Control	Description
Classification drop-down list	Specifies the position of the indication relative to the object selected in the **Reference** field of the **Edge distance calculation** section: **All**, **Cut**, **Inside**, **Outside**, **Not cut**, **Not inside**, or **Not outside**.
Edge distance range [<length unit>] spin boxes	Specifies the range for the distance between the surface of the indication and the surface of the object selected in the **Reference** field of the **Edge distance calculation** section.
Cut face range [<length unit>²] spin boxes	Specifies the range for the surface area where the indication intersects the surface of the object selected in the **Reference** field of the **Edge distance calculation** section.

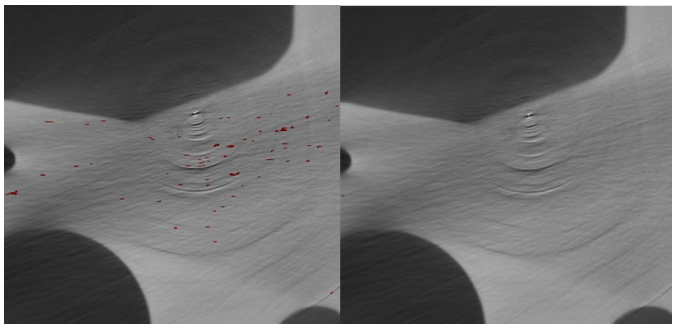
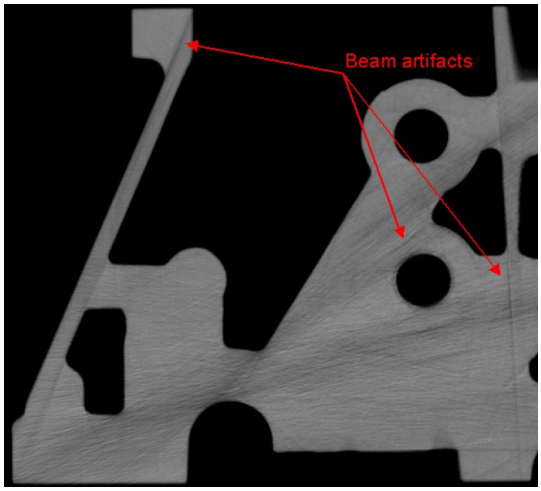
Disregard indications caused by CT artifacts Section

Ring artifacts may appear within (industrial) CT data as dark circles or arcs. The voxel in the rotation center may also appear as a dark area. Depending on the selected mode, the circular structures around the specified center and/or the center itself will be considered ring artifacts and/or center artifacts, respectively, and will not be included in the indication list.

Table 45-20: Controls in the **Disregard indications caused by CT artifacts** section

Control	Description
Mode drop-down list	• **Do not ignore artifacts**: If present, center and ring artifacts will possibly be detected as indications. • **Center artifacts**: The center voxel will not be detected as indication. • **Ring artifacts**: Circular structures around the center voxel will less likely be detected as indications. • **Center and ring artifacts**: Both the center voxel and circular structures around the center voxel will less likely be detected as indications.

Control	Description
	Important: • If **Ring artifacts** is activated, a real indication connected to a *ring artifact* might not be detected. • If **Center artifacts** is activated, a real indication connected to a *center artifact* might not be detected. • If **Center and ring artifacts** is activated, a real indication connected to a *center or ring artifact* might not be detected. Note that the **Ring artifacts** and **Center and ring artifacts** modes will change the probability of the indications. With a **Probability threshold** > 0, result filtering and thus the number of indications in the **Indications** table will also be affected.
Define button	Opens a dialog that prompts you to specify the position of the (rotation) center by holding down the left mouse button and dragging a circle in the corresponding 2D view. The center of the circle must coincide with the center of the ring artifact. When you release the left mouse button, the position of the center of the circle will be adopted as center and the direction of the 2D view will be adopted as plane normal. When you do not drag a circle, the old position and normal will be maintained.
Center X/Y/Z [<length unit>] spin boxes	Indicate the position of the rotation center of the specified artifact area.
Plane normal X/Y/Z spin boxes	Indicate the plane normal of the specified artifact area.
Check neighborhood checkbox	When this option is checked, the indication detection algorithm will compare the potential indication with its local neighborhood. If the appearance of a potential indication is very similar to the surrounding structure, its probability will be reduced. This option is useful for reducing the number of erroneously detected artifacts.

Control	Description
	The following figure illustrates the effect of this option: The image on the left has been obtained without using neighborhood check; the right image with neighborhood check.  Figure 45-8: check neighborhood
Ignore streak artifacts checkbox	Beam artifacts may appear in (industrial) CT data as linear dark streaks. When this option is checked, these structures will be detected and assigned a low indication probability value. The following figure shows an example of beam artifacts:  Figure 45-9: Beam artifacts A real indication might not be detected when **Ignore streak artifacts** is activated if it is connected to and/or fits into the shape of a beam artifact. A beam artifact might not be removed by the ignore streak artifacts algorithm in cases where a beam artifact is connected to another indication (i.e., resulting shape is no longer a straight, line-like structure).

Directional variability Section

Table 45-21: Controls of the **Directional variability** section

Control	Description
Directional variability checkbox	When this option is checked, the options for specifying a direction in which the analysis is to be performed will be enabled.
Direction fields	Specify the direction (in the currently selected coordinate system) in which the porosity is to be analyzed. The specified vector is normalized to unit length before it is taken into account in the calculation. When you change the coordinate system, the specified vector will automatically be recalculated accordingly.
Choose... button	Opens a drop-down list that shows the windows currently available in the workspace for specifying the direction in which the analysis is to be performed. The direction is the normal of the selected 2D window or the current direction of view of the 3D window.
Slice thickness spin boxes	Specify the thickness (in physical units (e.g., mm) or voxels) of the individual slices to be analyzed.

Note that for calculating the directional variability of a porosity/inclusion analysis the object surface must be determined.

Active column Section

This drop-down list allows you to select the property of the indication that is to be shown according to the settings on the **Colors** tab.

When you select an indication property, e.g., **Surface**, from the **Active column** drop-down list, the indications will be color-coded according to their surface area as defined by the color lookup table and the colors specified in the **Sections** section of the **Colors** tab. In the indication list on the **Indications** tab, the column of the selected property becomes the “active” column, and its values are highlighted in bold and italic font.

When you select **Uncoded** from the **Active column** drop-down list, all indications will be shown in the same color regardless of their properties, e.g., radius and volume. The color can be specified in the **Uncoded indications** field of the **Other colors** section on the **Colors** tab.

The property selected in the **Active column** drop-down list will be added to the information provided in the annotation labels.

The **Active column** section is also available on the **Colors** tab. The changes made on the **Settings** tab will also affect the **Colors** tab and vice versa.

You can also select the active column on the **Indications** tab by right-clicking the column and choosing the **Set as active column** item from the context menu.

Settings Tab for the VGDefX/Only threshold Algorithms

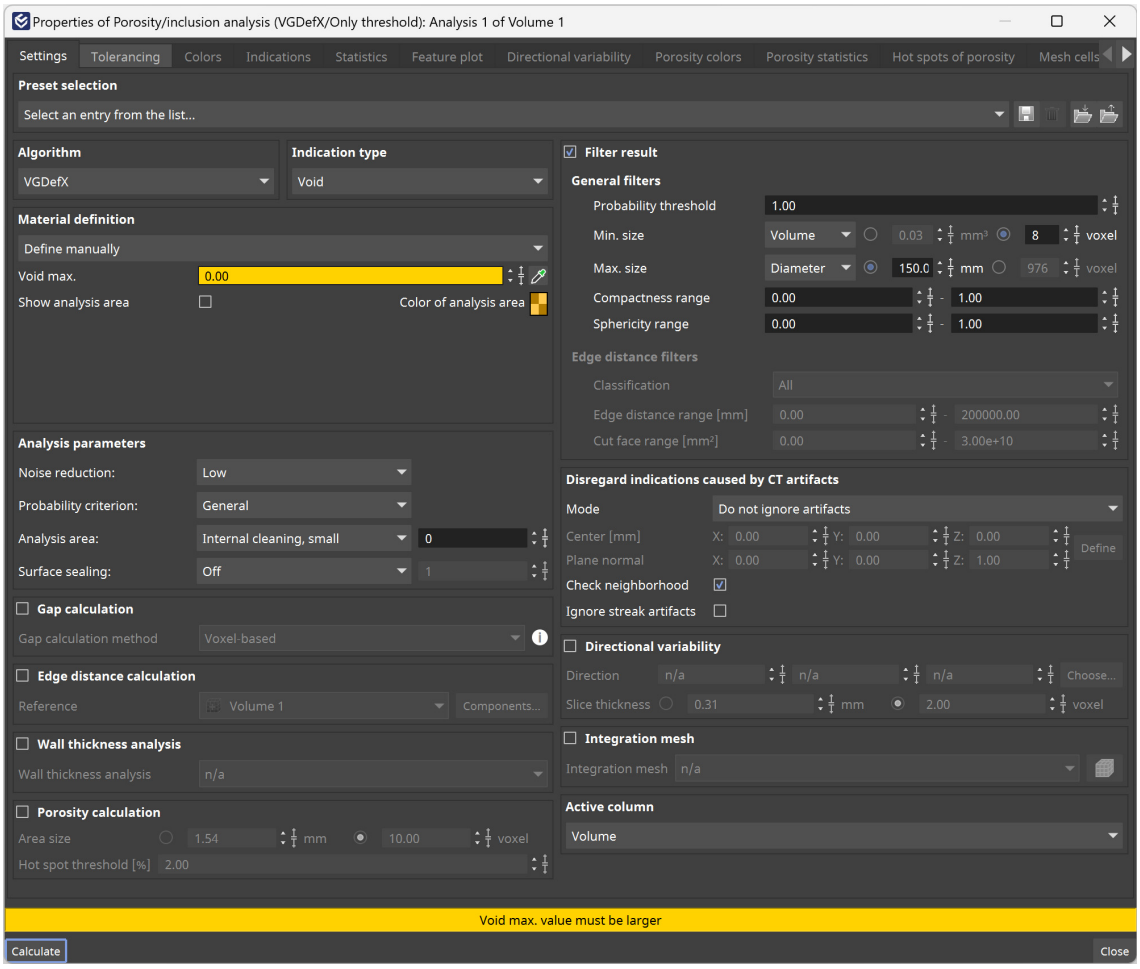


Figure 45-10: **Porosity/inclusion analysis (VGDefX/Only threshold)** dialog, **Settings** tab

In myVGL, all parameter settings are displayed. Most of these parameters are read-only in myVGL. The complete functional range is available with VGSTUDIO MAX and the respective add-on module(s).

Preset selection Section

Table 45-22: Controls in the **Preset selection** section

Icon	Item	Description
	drop-down list	Specifies the preset to be applied, to be edited, or to be taken as a basis for a new preset. The following icons are used: • analysis factory settings • customized preset • appears next to the icon of a preset that has been modified but not yet saved
	Set this preset as default	Sets the selected preset as default. The default preset will be applied when creating a new analysis of the same type. If the selected preset is already set as default, the button is disabled.
	Save preset	Saves the selected preset. When saving a preset, the **Save preset** dialog will open, which allows you to set the new preset as default by checking the **Set as default for new analyses** checkbox.
	Remove preset	Removes the selected preset from the preset drop-down list. If the removed preset is the default preset, the next time an analysis of the same type is created, the factory settings will be used.
	Import preset	Imports a preset from the specified location.
	Export preset	Exports the selected preset to the specified location.

Algorithm Section

Table 45-23: Controls in the **Algorithm** section

Control	Description
Algorithm drop-down list	• **VGDefX**: This is the most sophisticated algorithm available. It allows for gray value variations, includes noise reduction for seed point location, and can detect indications which are connected to the surrounding air. It offers several probability criteria according to which the indications will be detected. • **Only threshold**: With this algorithm, each group of indication candidates is considered an indication if the gray value is below the specified threshold.

Analysis mode Section

Table 45-24: Controls in the **Analysis mode** section

Control	Description
Analysis mode drop-down list	• **Void**: Detects voxels with gray values *lower* than those of the surrounding material. • **Inclusion**: Detects voxels with gray values *higher* than those of the surrounding material.

Material definition Section

- **Define manually** mode

  Allows you to specify the gray value for determining the seed voxels—i.e., **Void max.** (for the analysis mode **Void**) or **Inclusion min.** (for the analysis mode **Inclusion**)—by either using the corresponding spin box or selecting a sample area. This mode is recommended for multi-material objects and/or images with an average or above-average noise level, as it allows you to select the sample area specifically with regard to indications.

  Table 45-25: Controls of the **Material definition** section in **Define manually** mode

Control	Description
Void max. spin box	For analysis mode **Void**: Specifies the maximum gray value of the seed voxels for void candidates. Starting from these seed voxels, the void candidates are determined in an iterative manner.
Inclusion min. spin box	For analysis mode **Inclusion**: Specifies the minimum gray value of the seed voxels for inclusion candidates. Starting from these seed voxels, the inclusion candidates are determined in an iterative manner.
button	Allows you to specify the **Void max.** or **Inclusion min.** gray value, respectively, by selecting sample areas. This procedure is similar to a surface determination, but does not (re-)determine the object surface.
Show analysis area checkbox	**VGDefX** algorithm only. Check this option to display a preview of the area searched for indications. The preview is calculated using the **Void max.**, **Analysis area**, and **Surface sealing** parameters.
Color of analysis area field	**VGDefX** algorithm only. Double-clicking the field opens the **Select Color** dialog, where you can set the color for the preview of the area searched for indications.

Control	Description
Preview checkbox	**Only threshold** algorithm only. Check this option to display a preview of the indications. The preview is calculated using the **Void max.** or **Inclusion min.** parameters, respectively.
Preview color field	**Only threshold** algorithm only. Double-clicking the field opens the **Select Color** dialog, where you can set the color for the preview of the indications.

- **Use determined surface** mode

  Automatically sets the **Void max.** (for the analysis mode **Void**) or the **Inclusion min.** gray value (for the analysis mode **Inclusion**) based on the surface determination of the object and the selected **Auto threshold mode** settings. This mode is recommended for single-material objects and images with a very low noise level.

  Table 45-26: Controls of the **Material definition** section in **Use determined surface** mode

Control	Description
Auto threshold mode drop-down list	Allows you to dynamically adapt the gray value for **Void max.** or **Inclusion min.**, e.g., in the context of automation. • **Deviation**: Adds the standard deviation, multiplied by the **Deviation factor**, to the material peak of the gray value distribution to obtain the **Void max.** or **Inclusion min.** value, respectively. • **Interpolation**: Adds the difference (interpolation) between the background and material peaks of the gray value distribution, multiplied by the **Interpolation factor**, to the background peak value to obtain the **Void max.** or **Inclusion min.** value, respectively.
Deviation/Interpolation factor spin box	• **Deviation factor**: Specifies a factor for the standard deviation of the material peak of the gray value distribution. • **Interpolation factor**: Specifies a factor for the interpolation value between the background and material peaks of the gray value distribution. For more details, see the **Auto threshold mode** option.

Control	Description
Void max. field	For analysis mode **Void**: Indicates the maximum gray value of the seed voxels for void candidates. Starting from these seed voxels, the void candidates are determined in an iterative manner. • In **Deviation** mode, this value is calculated from the material gray value of the surface determination and the **Deviation** settings: **Void max.** = $mean_{material}$ + standard $deviation_{material}$ * **Deviation factor** • In **Interpolation** mode, this value is calculated from the background and material gray values of the surface determination and the **Interpolation** settings: **Void max.** = $mean_{background}$ + ($mean_{material}$ – $mean_{background}$) * **Interpolation factor**
Inclusion min. field	For analysis mode **Inclusion**: Indicates the minimum gray value of the seed voxels for inclusion candidates. Starting from these seed voxels, the inclusion candidates are determined in an iterative manner. • In **Deviation** mode, this value is calculated from the material gray value of the surface determination and the **Deviation** settings: **Inclusion min.** = $mean_{material}$ + standard $deviation_{material}$ * **Deviation factor** • In **Interpolation** mode, this value is calculated from the background and material gray values of the surface determination and the **Interpolation** settings: **Inclusion min.** = $mean_{background}$ + ($mean_{material}$ – $mean_{background}$) * **Interpolation factor**
Show analysis area checkbox	**VGDefX** algorithm only. Check this option to display a preview of the area searched for indications. The preview is calculated using the **Void max.**, **Analysis area**, and **Surface sealing** parameters.
Color of analysis area field	**VGDefX** algorithm only. Double-clicking the field opens the **Select Color** dialog, where you can set the color for the preview of the area searched for indications.

Control	Description
Preview checkbox	**Only threshold** algorithm only. Check this option to display a preview of the indications. The preview is calculated using the **Void max.** or **Inclusion min.** parameters, respectively.
Preview color field	**Only threshold** algorithm only. Double-clicking the field opens the **Select Color** dialog, where you can set the color for the preview of the indications.

- **Use sample ROIs** mode

Automatically sets the **Void max.** (for the analysis mode **Void**) or the **Inclusion min.** gray value (for the analysis mode **Inclusion**) based on the mean gray values of selected regions of interest (ROI) and the selected **Auto threshold mode** settings.

Table 45-27: Controls of the **Material definition** section in **Use sample ROIs** mode

Control	Description
Background ROI drop-down list	**Interpolation** mode only: The mean gray value of the selected ROI is used as the basis for calculating the **Void max**. value or **Inclusion min.** value, respectively.
Material ROI drop-down list	The mean gray value of the selected ROI is used as the basis for calculating the **Void max**. value or **Inclusion min.** value, respectively.
Auto threshold mode drop-down list	Allows you to dynamically adapt the gray value for **Void max.** or **Inclusion min.**, e.g., in the context of automation. • **Deviation**: Adds the standard deviation, multiplied by the **Deviation factor**, to the material peak of the gray value distribution to obtain the **Void max.** or **Inclusion min.** value, respectively. • **Interpolation**: Adds the difference (interpolation) between the background and material peaks of the gray value distribution, multiplied by the **Interpolation factor**, to the background peak value to obtain the **Void max.** or **Inclusion min.** value, respectively.
Deviation/Interpolation factor spin box	• **Deviation factor**: Specifies a factor for the standard deviation of the material peak of the gray value distribution. • **Interpolation factor**: Specifies a factor for the interpolation value between the background and material peaks of the gray value distribution. For more details, see the **Auto threshold mode** option.

Control	Description
Void max. field	For analysis mode **Void**: Indicates the maximum gray value of the seed voxels for void candidates. Starting from these seed voxels, the void candidates are determined in an iterative manner. • In **Deviation** mode, this value is calculated from the selected **Material ROI** and the **Deviation** settings: **Void max.** = $mean_{material}$ + standard $deviation_{material}$ * **Deviation factor** • In **Interpolation** mode, this value is calculated from the selected **Background ROI** and **Material ROI** and the **Interpolation** settings: **Void max.** = $mean_{background}$ + ($mean_{material}$ – $mean_{background}$) * **Interpolation factor**
Inclusion min. field	For the analysis mode **Inclusion**: Indicates the minimum gray value of the seed voxels for inclusion candidates. Starting from these seed voxels, the inclusion candidates are determined in an iterative manner. • In **Deviation** mode, this value is calculated from the selected **Material ROI** and the **Deviation** settings: **Inclusion min.** = $mean_{material}$ + standard $deviation_{material}$ * **Deviation factor** • In **Interpolation** mode, this value is calculated from the selected **Background ROI** and **Material ROI** and the **Interpolation** settings: **Inclusion min.** = $mean_{background}$ + ($mean_{material}$ – $mean_{background}$) * **Interpolation factor**
Show analysis area checkbox	**VGDefX** algorithm only. Check this option to display a preview of the area searched for indications. The preview is calculated using the **Void max**, **Analysis area**, and **Surface sealing** parameters.
Color of analysis area field	**VGDefX** algorithm only. Double-clicking the field opens the **Select Color** dialog, where you can set the color for the preview of the area searched for indications.
Preview checkbox	**Only threshold** algorithm only. Check this option to display a preview of the indications. The preview is calculated using the **Void max.** or **Inclusion min.** parameters, respectively.

Control	Description
Preview color field	**Only threshold** algorithm only. Double-clicking the field opens the **Select Color** dialog, where you can set the color for the preview of the indications.

Analysis parameters Section (**VGDefX** Algorithm)

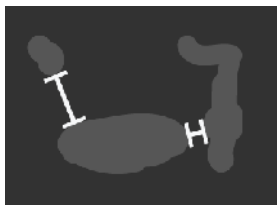
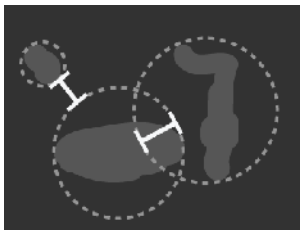
Table 45-28: Controls in the **Analysis parameters** section

Control	Description
Noise reduction drop-down list	Specifies a noise reduction mode to filter the data when looking for seed points. Several (adaptive) Gauss filters (**Low, Low adaptive, Medium, Medium adaptive, High, High adaptive**) as well as **Median** filtering are available. This option influences the seed point location only. All other calculations during porosity/inclusion analysis will be done on the original raw data.
Probability criterion drop-down list	Specifies the criterion according to which the indications will be grown and their probability calculated. • **General**: For this criterion, the balance of **Size**, **Pore**, and **Contrast** has been optimized. This is the default setting. • **General (v2.2.2 and earlier)**: This criterion ensures comparability of your results to results calculated in VGSTUDIO MAX versions 2.2.2 or earlier. • **Size**: This criterion gives more weight to larger voids. • **Pore**: This criterion gives more weight to the roundness of the voids, i.e., the rounder the shape, the higher the probability that it is an indication. • **Contrast**: This criterion gives more weight to larger gray value differences compared to the material voxels. • **Custom (expert mode)**: Allows you to define a custom probability criterion (see section *Probability factors Section* on page 884).
Analysis area drop-down list	Specifies the area of the selected volume/ROI on which the **VGDefX** algorithm will be performed. The analysis area is based on the surface determination of the volume. This option does not change the actual surface determination. This is an internal representation used for porosity/inclusion analysis only.

Control	Description
	• **Automatic**: Automatically selects the appropriate setting based on the part's surface determination. If voids have been filtered in the surface determination, no further filtering will take place. Otherwise, this option will remove all voids. • **From surface (as seen)**: Uses the area within the original surface determination. • **Internal cleaning, small**: Also includes small indications that are separated by the determined surface from the material. • **Internal cleaning, all**: Also includes larger indications that are separated by the determined surface from the material. This will use the entire area enclosed by the outermost defined surface. • **Overall closing**: Also includes indications that are separated by the determined surface from the material. This is achieved by performing a closing with the specified number of voxels. When you specify a number of voxels after having selected **Internal cleaning, small** or **Internal cleaning, all**, **Overall closing** is done additionally.
Surface sealing	• **Off**: Restrains the indication growing according to the **Material definition** parameters and **Probability criterion**. Indications connected to the surrounding air will be neglected completely for the final result of the indication detection. • **On**: Restrains the indication growing to the analysis area (as seen in the preview). As a result, indications that grow up to the surface will be included in the final result of the indication detection, even if they are connected to the surrounding air. As such, if you want to find indications connected to the determined surface, set **Surface sealing** to **On**. To avoid detecting "false" indications along the surface caused by the partial voxel effect, you can reduce the area by the selected number of voxels.

Gap calculation Section

Table 45-29: Controls in the **Gap calculation** section

Control	Description
Gap calculation checkbox	Calculates the closest distance to the nearest neighbor of each pore. There are two calculation methods: **Voxel-based** Calculates the closest distance based on the actual voxel boundaries of the indications.  **Sphere-based (legacy)** Approximates the closest distance by finding the circumscribed sphere of each indication and calculating the distance to the closest neighboring sphere. If the spheres intersect, the distance will be negative.  **Voxel-based and sphere-based** Calculates the gap according to both calculation methods.

Edge distance calculation Section

This function is highly important for virtual machining. For example, prior to actually eroding a sealing surface or cutting a screw thread, this analysis parameter delivers the information if indications will be cut open by the machining process. This information can be significant when you are interested in the sealing or crack opening properties of an object area.

Table 45-30: Controls in the **Edge distance calculation** section

Control	Description
Edge distance calculation checkbox	When this option is checked, the distance of each indication to the object selected in the **Reference** field will be calculated. The edge distance will be calculated relative to the nearest surface of the reference object. If you use a surface determination as reference, make sure it does not include areas within the material (e.g., indications).

Control	Description
Reference drop-down list	Specifies the object to which the edge distance calculation refers. Note: If a CAD model or a surface mesh is referenced, it should be a solid object with a closed surface.
Components... button	This button is enabled when you select an object with components from the **Reference** drop-down list. Clicking it opens a dialog box where you can specify the components to be used as reference for the edge distance calculation: • Checkbox of component: Clicking it checks/unchecks the component, including all child components. • **Select all** button: Selects all components of the object. • **Deselect all** button: Deselects all components of the object. • **Apply visibility** button: Selects all components which are set to visible in the Scene Tree.

Wall thickness analysis Section

When the **Wall thickness analysis** checkbox is checked, the **Wall thickness analysis** drop-down list where you can select the wall thickness analysis to be used for combined analysis will be enabled. The detected indications will then not only be analyzed with respect to their size but also with respect to their relative size referring to the smallest local wall thickness.

Performing a wall thickness analysis may require additional licensing. Contact us for details.

Local porosity calculation Section

Table 45-31: Controls in the **Local porosity calculation** section

Control	Description
Local porosity calculation checkbox	When this option is checked, the corresponding controls for calculating areas of particularly high porosity will be enabled.
Area size spin box	Specifies the standard deviation of a normal distribution (in physical units (e.g., mm) or in voxels)—starting from the center of each voxel—of the area considered for calculating the ratio of pore voxels to material voxels. The resulting 3-dimensional normal distribution function will be used as a weight function for the calculation of porosity.

Control	Description
Hot spot threshold [<ratio unit>] spin box	Specifies a threshold to be applied to the porosity of the analyzed areas. The areas where the porosity is larger than the threshold are regarded as hot spots.

Integration mesh Section

Allows you to create an integration mesh or select an existing integration mesh to obtain the results of the porosity/inclusion analysis for each mesh cell.

Table 45-32: Controls of the **Integration mesh** section

Control	Description
Integration mesh checkbox	When this option is checked, the options for using an integration mesh will be enabled.
Integration mesh drop-down list	Allows you to specify an integration mesh by selecting an existing mesh from the drop-down list.
Create regular integration mesh button	Creates an integration mesh and opens the **Mesh** dialog for adjusting the parameters manually.

Probability factors Section

Available when the **Probability criterion** in the **Analysis parameters** section is set to **Custom (expert mode)**. Allows you to specify a weight for each probability factor you want to use for the probability calculation. You can assign both positive and negative values.

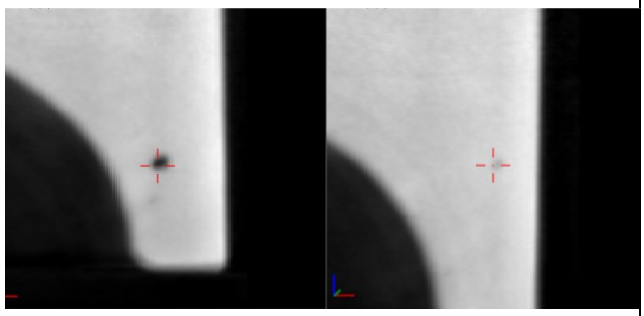
Filter result Section

When the **Filter result** checkbox is checked, only indications that meet the specified filter criteria will be included in the results, e.g., the indication list and statistics.

- **General filters** section

  Table 45-33: Controls in the **General filters** section

Control	Description
Probability threshold spin box	All potential indication areas that pass the size check will be further processed by several analysis stages. These stages try to differentiate between real indications and artifacts by utilizing sophisticated image processing algorithms. Each detected indication is tagged with a value indicating the probability that it is a real indication.

Control	Description
	Specify the **Probability threshold** so that only indications with a probability above the threshold will be included in the list. Start with a **Probability threshold** of zero if you are running the indication detection on a new data set for the first time to make sure you do not filter real indications from the list. There is no absolute value for the threshold applicable to all data sets. The following figure shows two indications with different probabilities, where the indication on the left-hand side has a probability that is ten times higher than the indication on the right-hand side:  Figure 45-11: Probability threshold
Min. size spin boxes	Indicates the minimum indication size. Due to the nature of CT data, the value for **Min. size** should be no less than 8 voxels in edge length (i.e., an area of 2x2x2 voxels). Increase the value when data quality decreases.
Max. size spin boxes	Indicates the maximum indication size. When specifying the **Max. size** of the indication, consider that longish cracks have a rather large volume and that an accumulation of nearby small indications might be interpreted as one large indication. Specify the **Max. size** generously.
Compactness range spin boxes	Specifies the range for the compactness of the indication, i.e., the ratio between the volume of the indication and the volume of the circumscribed sphere. $\text{Compactness} = \frac{V_{indication}}{V_{sphere}}$
Sphericity range spin boxes	Specifies the range for the sphericity of the indication, i.e., the ratio between the surface of a sphere with the same volume as the indication and the surface of the indication. $\text{Sphericity} = \frac{A_{sphere}}{A_{indication}}$

- **Edge distance filters** section

  Enabled only if the **Edge distance calculation** option is checked.

  Table 45-34: Controls in the **Edge distance filters** section

Control	Description
Classification drop-down list	Specifies the position of the indication relative to the object selected in the **Reference** field of the **Edge distance calculation** section: **All**, **Cut**, **Inside**, **Outside**, **Not cut**, **Not inside**, or **Not outside**.
Edge distance range [<length unit>] spin boxes	Specifies the range for the distance between the surface of the indication and the surface of the object selected in the **Reference** field of the **Edge distance calculation** section.
Cut face range [<length unit>²] spin boxes	Specifies the range for the surface area where the indication intersects the surface of the object selected in the **Reference** field of the **Edge distance calculation** section.

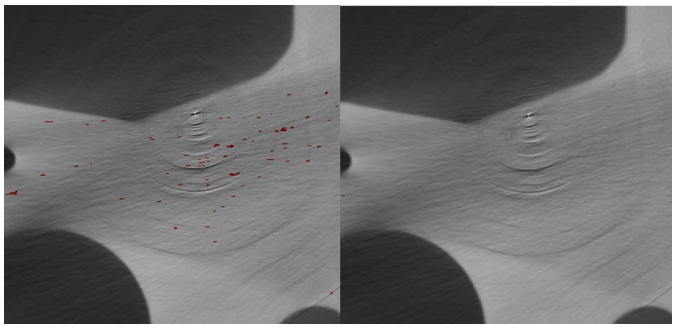
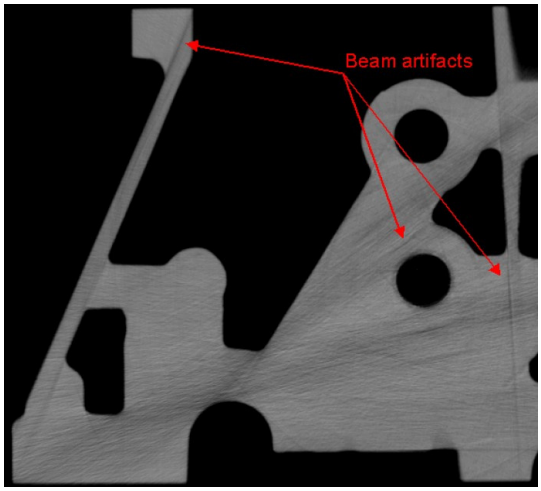
Disregard indications caused by CT artifacts Section

Ring artifacts may appear within (industrial) CT data as dark circles or arcs. The voxel in the rotation center may also appear as a dark area. Depending on the selected mode, the circular structures around the specified center and/or the center itself will be considered ring artifacts and/or center artifacts, respectively, and will not be included in the indication list.

Table 45-35: Controls in the **Disregard indications caused by CT artifacts** section

Control	Description
Mode drop-down list	• **Do not ignore artifacts**: If present, center and ring artifacts will possibly be detected as indications. • **Center artifacts**: The center voxel will not be detected as indication. • **Ring artifacts**: Circular structures around the center voxel will less likely be detected as indications. • **Center and ring artifacts**: Both the center voxel and circular structures around the center voxel will less likely be detected as indications.

Control	Description
	Important: • If **Ring artifacts** is activated, a real indication connected to a *ring artifact* might not be detected. • If **Center artifacts** is activated, a real indication connected to a *center artifact* might not be detected. • If **Center and ring artifacts** is activated, a real indication connected to a *center or ring artifact* might not be detected. Note that the **Ring artifacts** and **Center and ring artifacts** modes will change the probability of the indications. With a **Probability threshold** > 0, result filtering and thus the number of indications in the **Indications** table will also be affected.
Define button	Opens a dialog that prompts you to specify the position of the (rotation) center by holding down the left mouse button and dragging a circle in the corresponding 2D view. The center of the circle must coincide with the center of the ring artifact. When you release the left mouse button, the position of the center of the circle will be adopted as center and the direction of the 2D view will be adopted as plane normal. When you do not drag a circle, the old position and normal will be maintained.
Center X/Y/Z [<length unit>] spin boxes	Indicate the position of the rotation center of the specified artifact area.
Plane normal X/Y/Z spin boxes	Indicate the plane normal of the specified artifact area.
Check neighborhood checkbox	When this option is checked, the indication detection algorithm will compare the potential indication with its local neighborhood. If the appearance of a potential indication is very similar to the surrounding structure, its probability will be reduced. This option is useful for reducing the number of erroneously detected artifacts.

Control	Description
	The following figure illustrates the effect of this option: The image on the left has been obtained without using neighborhood check; the right image with neighborhood check.  Figure 45-12: check neighborhood
Ignore streak artifacts checkbox	Beam artifacts may appear in (industrial) CT data as linear dark streaks. When this option is checked, these structures will be detected and assigned a low indication probability value. The following figure shows an example of beam artifacts:  Figure 45-13: Beam artifacts A real indication might not be detected when **Ignore streak artifacts** is activated if it is connected to and/or fits into the shape of a beam artifact. A beam artifact might not be removed by the ignore streak artifacts algorithm in cases where a beam artifact is connected to another indication (i.e., resulting shape is no longer a straight, line-like structure).

Directional variability Section

Table 45-36: Controls of the **Directional variability** section

Control	Description
Directional variability checkbox	When this option is checked, the options for specifying a direction in which the analysis is to be performed will be enabled.
Direction fields	Specify the direction (in the currently selected coordinate system) in which the porosity is to be analyzed. The specified vector is normalized to unit length before it is taken into account in the calculation. When you change the coordinate system, the specified vector will automatically be recalculated accordingly.
Choose... button	Opens a drop-down list that shows the windows currently available in the workspace for specifying the direction in which the analysis is to be performed. The direction is the normal of the selected 2D window or the current direction of view of the 3D window.
Slice thickness spin boxes	Specify the thickness (in physical units (e.g., mm) or voxels) of the individual slices to be analyzed.

Note that for calculating the directional variability of a porosity/inclusion analysis the object surface must be determined.

Active column Section

This drop-down list allows you to select the property of the indication that is to be shown according to the settings on the **Colors** tab.

When you select an indication property, e.g., **Surface**, from the **Active column** drop-down list, the indications will be color-coded according to their surface area as defined by the color lookup table and the colors specified in the **Sections** section of the **Colors** tab. In the indication list on the **Indications** tab, the column of the selected property becomes the “active” column, and its values are highlighted in bold and italic font.

When you select **Uncoded** from the **Active column** drop-down list, all indications will be shown in the same color regardless of their properties, e.g., radius and volume. The color can be specified in the **Uncoded indications** field of the **Other colors** section on the **Colors** tab.

The property selected in the **Active column** drop-down list will be added to the information provided in the annotation labels.

The **Active column** section is also available on the **Colors** tab. The changes made on the **Settings** tab will also affect the **Colors** tab and vice versa.

You can also select the active column on the **Indications** tab by right-clicking the column and choosing the **Set as active column** item from the context menu.

Settings Tab for the 2.x Compatibility Algorithms

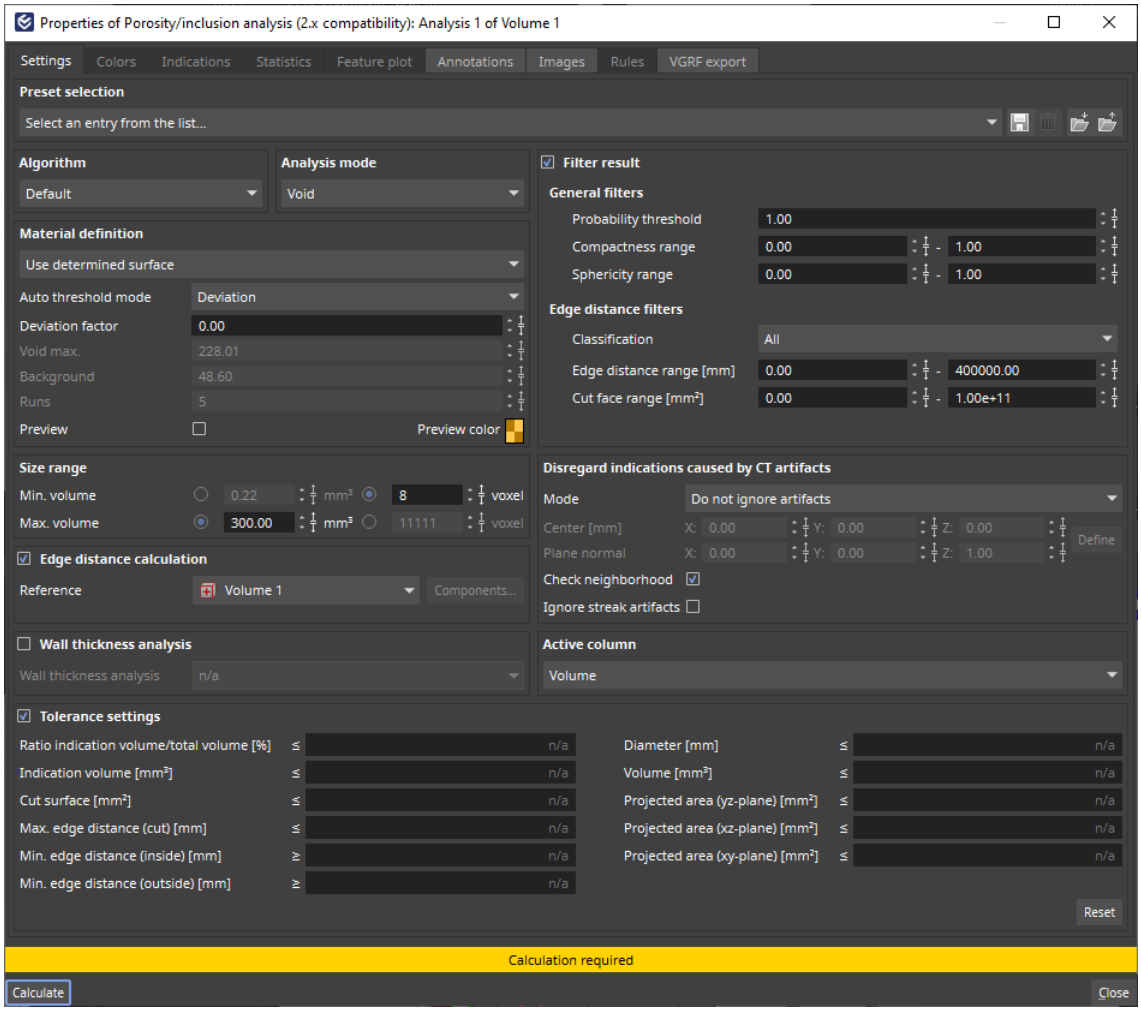


Figure 45-14: **Porosity/inclusion analysis (2.x compatibility)** dialog, **Settings** tab

In myVGL, all parameter settings are displayed. Most of these parameters are read-only in myVGL. The complete functional range is available with VGSTUDIO MAX and the respective add-on module(s).

Preset selection Section

Table 45-37: Controls in the **Preset selection** section

Icon	Item	Description
	drop-down list	Specifies the preset to be applied, to be edited, or to be taken as a basis for a new preset. The following icons are used: • analysis factory settings • customized preset • appears next to the icon of a preset that has been modified but not yet saved
	Set this preset as default	Sets the selected preset as default. The default preset will be applied when creating a new analysis of the same type. If the selected preset is already set as default, the button is disabled.
	Save preset	Saves the selected preset. When saving a preset, the **Save preset** dialog will open, which allows you to set the new preset as default by checking the **Set as default for new analyses** checkbox.
	Remove preset	Removes the selected preset from the preset drop-down list. If the removed preset is the default preset, the next time an analysis of the same type is created, the factory settings will be used.
	Import preset	Imports a preset from the specified location.
	Export preset	Exports the selected preset to the specified location.

Algorithm Section

Table 45-38: Controls in the **Algorithm** section

Control	Description
Algorithm drop-down list	• **Default**: This approach allows for gray value variations, thereby also detecting indications, for example, in dark areas. • **Enhanced**: This is a variation of the **Default** algorithm in a more fine-grained mode that provides more sophisticated results but requires more time.

Analysis mode Section

Table 45-39: Controls in the **Analysis mode** section

Control	Description
Analysis mode drop-down list	• **Void**: Detects voxels with gray values *lower* than those of the surrounding material. • **Inclusion**: Detects voxels with gray values *higher* than those of the surrounding material.

Material definition Section

- **Define manually** mode

  Allows you to specify the background and material gray values by either using the corresponding spin boxes or selecting sample areas. This mode is recommended for multi-material objects and/or images with an average or above-average noise level, as it allows you to select the sample areas specifically with regard to indications.

  Table 45-40: Controls of the **Material definition** section in **Define manually** mode

Control	Description
Void max. spin box	For analysis mode **Void**: Specifies the maximum gray value of the seed voxels for void candidates. Starting from these seed voxels, the void candidates are determined in an iterative manner.
Background spin box	For analysis mode **Void**: Specifies the minimum gray value of the seed voxels for void candidates. Along with the **Void max.** value, this value defines the gray value range for the seed voxels used for iteratively determining the void candidates. Changing this value has less significance than changing **Void max.** or **Runs**.
Inclusion min. spin box	For analysis mode **Inclusion**: Specifies the minimum gray value of the seed voxels for inclusion candidates. Starting from these seed voxels, the inclusion candidates are determined in an iterative manner.
button	Allows you to specify the **Void max.** and **Background** gray values or **Inclusion min.** gray value, respectively, by selecting sample areas. This procedure is similar to a surface determination, but does not (re-)determine the object surface.

Control	Description
Runs	Specifies the number of iterations for determining and flooding a potential indication. High values will lead to more reliable results at the cost of a longer processing time. For **Enhanced** algorithm: Specifies the number of iterations for identifying seed voxels. Flooding will be executed until a precision of one gray value is reached.
Preview checkbox	Check this option to display a preview of the indications. The preview is calculated using the **Void max.** or **Inclusion min.** parameters, respectively.
Preview color field	Double-clicking the field opens the **Select Color** dialog where you can set the color for the preview of the indications.

- **Use determined surface** mode

  Automatically sets the **Void max.** and **Background** gray values (for the analysis mode **Void**) or the **Inclusion min.** gray value (for the analysis mode **Inclusion**) as well as the number of runs on the basis of the surface determination of the object and the selected **Auto threshold mode** setting. This mode is recommended for single-material objects and images with a very low noise level.

  Table 45-41: Controls of the **Material definition** section in **Use determined surface** mode

Control	Description
Auto threshold mode drop-down list	Allows you to dynamically adapt the gray value for **Void max.** or **Inclusion min.**, e.g., in the context of automation. • **Deviation**: Adds the standard deviation, multiplied by the **Deviation factor**, to the material peak of the gray value distribution to obtain the **Void max.** or **Inclusion min.** value, respectively. • **Interpolation**: Adds the difference (interpolation) between the background and material peaks of the gray value distribution, multiplied by the **Interpolation factor**, to the background peak value to obtain the **Void max.** or **Inclusion min.** value, respectively.
Deviation/Interpolation factor spin box	• **Deviation factor**: Specifies a factor for the standard deviation of the material peak of the gray value distribution. • **Interpolation factor**: Specifies a factor for the interpolation value between the background and material peaks of the gray value distribution. For more details, see the **Auto threshold mode** option.

Control	Description
Void max. field	For analysis mode **Void**: Indicates the maximum gray value of the seed voxels for void candidates. Starting from these seed voxels, the void candidates are determined in an iterative manner. • In **Deviation** mode, this value is calculated from the material gray value of the surface determination and the **Deviation** settings: **Void max.** = $mean_{material}$ + standard $deviation_{material}$ * **Deviation factor** • In **Interpolation** mode, this value is calculated from the background and material gray values of the surface determination and the **Interpolation** settings: **Void max.** = $mean_{background}$ + ($mean_{material}$ – $mean_{background}$) * **Interpolation factor**
Background field	For analysis mode **Void**: Indicates the minimum gray value of the seed voxels for void candidates derived from the background gray value of the surface determination. Along with the **Void max.** value, this value defines the gray value range for the seed voxels used for iteratively determining the void candidates.
Inclusion min. spin box	For analysis mode **Inclusion**: Indicates the minimum gray value of the seed voxels for inclusion candidates. Starting from these seed voxels, the inclusion candidates are determined in an iterative manner. • In **Deviation** mode, this value is calculated from the material gray value of the surface determination and the **Deviation** settings: **Inclusion min.** = $mean_{material}$ + standard $deviation_{material}$ * **Deviation factor** • In **Interpolation** mode, this value is calculated from the background and material gray values of the surface determination and the **Interpolation** settings: **Inclusion min.** = $mean_{background}$ + ($mean_{material}$ – $mean_{background}$) * **Interpolation factor**

Control	Description
Runs field	For **Default** algorithm: Indicates the number of iterations for determining and flooding a potential indication. High values will lead to more reliable results at the cost of a longer processing time. For **Enhanced** algorithm: Indicates the number of iterations for identifying seed voxels. Flooding will be executed until a precision of one gray value is reached.
Preview checkbox	Check this option to display a preview of the indications. The preview is calculated using the **Void max.** or **Inclusion min.** parameters, respectively.
Preview color field	Double-clicking the field opens the **Select Color** dialog, where you can set the color for the preview of the indications.

- **Use sample ROIs** mode

  Automatically sets the **Void max.** and **Background** gray values (for the analysis mode **Void**) or the **Inclusion min.** gray value (for the analysis mode **Inclusion**) as well as the number of runs based on the mean gray values of selected regions of interest (ROI) and the selected **Auto threshold mode** setting.

  Table 45-42: Controls of the **Material definition** section in **Use sample ROIs** mode

Control	Description
Background ROI drop-down list	The mean gray value of the selected ROI is used as basis for calculating the **Background** value.
Material ROI drop-down list	The mean gray value of the selected ROI is used as basis for calculating the **Void max.** value or **Inclusion min.** value, respectively.
Auto threshold mode drop-down list	Allows you to dynamically adapt the gray value for **Void max.** or **Inclusion min.**, e.g., in the context of automation. • **Deviation**: Adds the standard deviation, multiplied by the **Deviation factor**, to the material peak of the gray value distribution to obtain the **Void max.** or **Inclusion min.** value, respectively. • **Interpolation**: Adds the difference (interpolation) between the background and material peaks of the gray value distribution, multiplied by the **Interpolation factor**, to the background peak value to obtain the **Void max.** or **Inclusion min.** value, respectively.

Control	Description
Deviation/Interpolation factor spin box	• **Deviation factor**: Specifies a factor for the standard deviation of the material peak of the gray value distribution. • **Interpolation factor**: Specifies a factor for the interpolation value between the background and material peaks of the gray value distribution. For more details, see the **Auto threshold mode** option.
Void max. field	For analysis mode **Void**: Indicates the maximum gray value of the seed voxels for void candidates. Starting from these seed voxels, the void candidates are determined in an iterative manner. • In **Deviation** mode, this value is calculated from the selected **Material ROI** and the **Deviation** settings: **Void max.** = $\text{mean}_{\text{material}}$ + standard $\text{deviation}_{\text{material}}$ * **Deviation factor** • In **Interpolation** mode, this value is calculated from the selected **Background ROI** and **Material ROI** and the **Interpolation** settings: **Void max.** = $\text{mean}_{\text{background}}$ + ($\text{mean}_{\text{material}}$ – $\text{mean}_{\text{background}}$) * **Interpolation factor**
Background field	For analysis mode **Void**: Indicates the minimum gray value of the seed voxels for void candidates derived from the selected ROIs. Along with the **Void max.** value, this value defines the gray value range for the seed voxels used for iteratively determining the void candidates.
Inclusion min. field	For analysis mode **Inclusion**: Indicates the minimum gray value of the seed voxels for inclusion candidates. Starting from these seed voxels, the inclusion candidates are determined in an iterative manner. • In **Deviation** mode, this value is calculated from the selected **Material ROI** and the **Deviation** settings: **Inclusion min.** = $\text{mean}_{\text{material}}$ + standard $\text{deviation}_{\text{material}}$ * **Deviation factor** • In **Interpolation** mode, this value is calculated from the selected **Background ROI** and **Material ROI** and the **Interpolation** settings: **Inclusion min.** = $\text{mean}_{\text{background}}$ + ($\text{mean}_{\text{material}}$ – $\text{mean}_{\text{background}}$) * **Interpolation factor**

Control	Description
Runs field	For **Default** algorithm: Indicates the number of iterations for determining and flooding a potential indication. High values will lead to more reliable results at the cost of a longer processing time. For **Enhanced** algorithm: Indicates the number of iterations for identifying seed voxels. Flooding will be executed until a precision of one gray value is reached.
Preview checkbox	Check this option to display a preview of the indications. The preview is calculated using the **Void max.** or **Inclusion min.** parameters, respectively.
Preview color field	Double-clicking the field opens the **Select Color** dialog where you can set the color for the preview of the indications.

Size range Section

Table 45-43: Controls in the **Size range** section

Control	Description
Min. volume spin box	Due to the nature of CT data, the value for **Min. volume** should be no less than 8 voxels in edge length (i.e., an area of 2x2x2 voxels). Increase the value when data quality decreases.
Max. volume spin box	When you specify the **Max. volume** of the indication, consider that longish cracks have a rather large volume and that an accumulation of nearby small indications might be interpreted as one large indication. Specify the **Max. volume** generously.

Edge distance calculation Section

This function is highly important for virtual machining. For example, prior to actually eroding a sealing surface or cutting a screw thread, this analysis parameter delivers the information if

indications will be cut open by the machining process. This information can be significant when you are interested in the sealing or crack opening properties of an object area.

Table 45-44: Controls in the **Edge distance calculation** section

Control	Description
Edge distance calculation checkbox	When this option is checked, the distance of each indication to the object selected in the **Reference** field will be calculated. The edge distance will be calculated relative to the nearest surface of the reference object. If you use a surface determination as reference, make sure it does not include areas within the material (e.g., indications).
Reference drop-down list	Specifies the object to which the edge distance calculation refers. Note: If a CAD model or a surface mesh is referenced, it should be a solid object with a closed surface.
Components... button	This button is enabled when you select an object with components from the **Reference** drop-down list. Clicking it opens a dialog box where you can specify the components to be used as reference for the edge distance calculation: • Checkbox of component: Clicking it checks/unchecks the component, including all child components. • **Select all** button: Selects all components of the object. • **Deselect all** button: Deselects all components of the object. • **Apply visibility** button: Selects all components which are set to visible in the Scene Tree.

Wall thickness analysis Section

When the **Wall thickness analysis** checkbox is checked, the **Wall thickness analysis** drop-down list where you can select the wall thickness analysis to be used for combined analysis will be enabled. The detected indications will then not only be analyzed with respect to their size but also with respect to their relative size referring to the smallest local wall thickness.

Performing a wall thickness analysis may require additional licensing. Contact us for details.

Tolerance settings Section

Tolerance values will be interpreted according to DIN EN ISO 8015 (see also section *Rounding Rules* on page 4 in chapter 1 *Welcome*).

Table 45-45: Controls in the **Tolerance settings** section

Control	Description
Tolerance settings checkbox	Checking this option allows you to define and apply the corresponding tolerance settings.
Ratio indication volume/total volume [<ratio unit>] field	Specifies the maximum permissible ratio between the total indication volume and the total material volume.
Equivalent diameter [<length unit>] field	Specifies the diameter of a sphere with the same maximum permissible volume as the indication.
Indication volume [<length unit>³] field	Specifies the maximum permissible total volume of all indications.
Cut surface [<length unit>²] field	Specifies the maximum permissible surface area where the indication intersects the surface of the object selected in the **Reference** field of the **Edge distance calculation** section.
Max. edge distance (cut) [<length unit>] field	For an indication classified as **Cut**: Specifies the maximum permissible maximum distance between the surface of the indication in the material and the surface of the object selected in the **Reference** field of the **Edge distance calculation** section.
Min. edge distance (inside) [<length unit>] field	For an indication classified as **Inside**: Specifies the minimum permissible minimum distance between the surface of the indication and the surface of the object selected in the **Reference** field of the **Edge distance calculation** section.
Min. edge distance (outside) [<length unit>] field	For an indication classified as **Outside**: Specifies the minimum permissible minimum distance between the surface of the indication and the surface of the object selected in the **Reference** field of the **Edge distance calculation** section.
Diameter [<length unit>] field	Specifies the maximum permissible diameter of an indication.
Volume [<length unit>³] field	Specifies the maximum permissible volume of an individual indication.
Projected area (yz-plane)/(xz-plane)/ (xy-plane) [<length unit>²] fields	Specifies the maximum permissible projected surface of an indication.
Directional variability (Porosity) [<ratio unit>]	**VGEasyPore** algorithm only: Specifies the maximum porosity with respect to the direction specified in the **Direction** fields of the **Directional variability** section.

Depending on the results of this evaluation, the tolerances on the **Settings** tab are highlighted in the following colors:

- Green: The tolerance is met.
- Red: The tolerance is not met.

- White (Bright Theme)/black (Dark Theme): No tolerance settings have been specified or they are deactivated.
- Yellow: A tolerance has been specified but the analysis has to be (re-)calculated. Note that this color will also be used if the entered tolerance value is invalid.

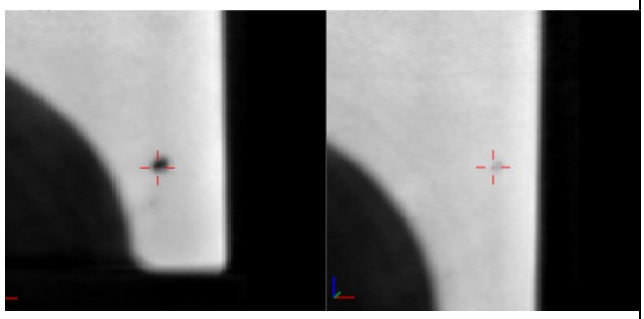
The result of the evaluation is also displayed graphically in the Scene Tree. For more information on evaluations, see chapter 46 *Evaluations*.

Filter result Section

When the **Filter result** checkbox is checked, only indications that meet the specified filter criteria will be included in the results, e.g., the indication list and statistics.

- **General filters** section

  Table 45-46: Controls in the **General filters** section

Control	Description
Probability threshold spin box	All potential indication areas that pass the size check will be further processed by several analysis stages. These stages try to differentiate between real indications and artifacts by utilizing sophisticated image processing algorithms. Each detected indication is tagged with a value indicating the probability that it is a real indication. Specify the **Probability threshold** so that only indications with a probability above the threshold will be included in the list. Start with a **Probability threshold** of zero if you are running the indication detection on a new data set for the first time to make sure you do not filter real indications from the list. There is no absolute value for the threshold applicable to all data sets. The following figure shows two indications with different probabilities, where the indication on the left-hand side has a probability that is ten times higher than the indication on the right-hand side:  Figure 45-15: Probability threshold

Control	Description
Compactness range spin boxes	Specifies the range for the compactness of the indication, i.e., the ratio between the volume of the indication and the volume of the circumscribed sphere. $$\text{Compactness} = \frac{V_{indication}}{V_{sphere}}$$
Sphericity range spin boxes	Specifies the range for the sphericity of the indication, i.e., the ratio between the surface of a sphere with the same volume as the indication and the surface of the indication. $$\text{Sphericity} = \frac{A_{sphere}}{A_{indication}}$$

- **Edge distance filters** section

  Enabled only if the **Edge distance calculation** option is checked.

  Table 45-47: Controls in the **Edge distance filters** section

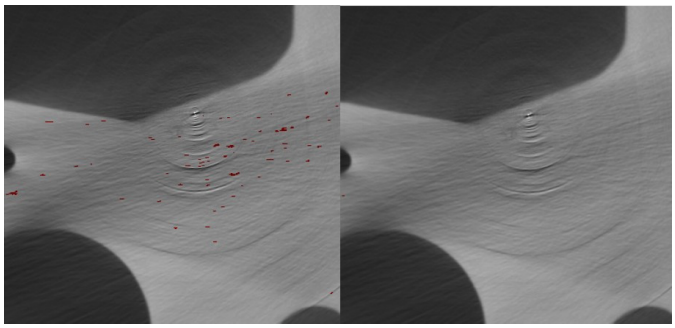
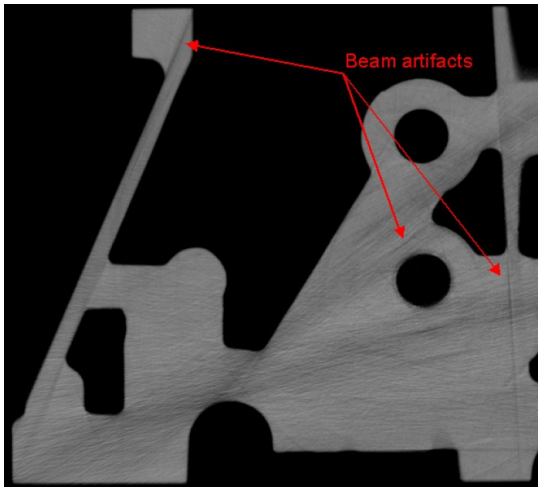
Control	Description
Classification drop-down list	Specifies the position of the indication relative to the object selected in the **Reference** field of the **Edge distance calculation** section: **All**, **Cut**, **Inside**, **Outside**, **Not cut**, **Not inside**, or **Not outside**.
Edge distance range [<length unit>] spin boxes	Specifies the range for the distance between the surface of the indication and the surface of the object selected in the **Reference** field of the **Edge distance calculation** section.
Cut face range [<length unit>²] spin boxes	Specifies the range for the surface area where the indication intersects the surface of the object selected in the **Reference** field of the **Edge distance calculation** section.

Disregard indications caused by CT artifacts Section

Ring artifacts may appear within (industrial) CT data as dark circles or arcs. The voxel in the rotation center may also appear as a dark area. Depending on the selected mode, the circular structures around the specified center and/or the center itself will be considered ring artifacts and/or center artifacts, respectively, and will not be included in the indication list.

Table 45-48: Controls in the **Disregard indications caused by CT artifacts** section

Control	Description
Mode drop-down list	• **Do not ignore artifacts**: If present, center and ring artifacts will possibly be detected as indications. • **Center artifacts**: The center voxel will not be detected as indication. • **Ring artifacts**: Circular structures around the center voxel will less likely be detected as indications. • **Center and ring artifacts**: Both the center voxel and circular structures around the center voxel will less likely be detected as indications. Important: • If **Ring artifacts** is activated, a real indication connected to a *ring artifact* might not be detected. • If **Center artifacts** is activated, a real indication connected to a *center artifact* might not be detected. • If **Center and ring artifacts** is activated, a real indication connected to a *center or ring artifact* might not be detected. Note that the **Ring artifacts** and **Center and ring artifacts** modes will change the probability of the indications. With a **Probability threshold** > 0, result filtering and thus the number of indications in the **Indications** table will also be affected.
Define button	Opens a dialog that prompts you to specify the position of the (rotation) center by holding down the left mouse button and dragging a circle in the corresponding 2D view. The center of the circle must coincide with the center of the ring artifact. When you release the left mouse button, the position of the center of the circle will be adopted as center and the direction of the 2D view will be adopted as plane normal. When you do not drag a circle, the old position and normal will be maintained.
Center X/Y/Z [<length unit>] spin boxes	Indicate the position of the rotation center of the specified artifact area.
Plane normal X/Y/Z spin boxes	Indicate the plane normal of the specified artifact area.
Check neighborhood checkbox	When this option is checked, the indication detection algorithm will compare the potential indication with its local neighborhood. If the appearance of a potential indication is very similar to the surrounding structure, its probability will be reduced. This option is useful for reducing the number of erroneously detected artifacts.

Control	Description
	The following figure illustrates the effect of this option: The image on the left has been obtained without using neighborhood check; the right image with neighborhood check.  Figure 45-16: check neighborhood
Ignore streak artifacts checkbox	Beam artifacts may appear in (industrial) CT data as linear dark streaks. When this option is checked, these structures will be detected and assigned a low indication probability value. The following figure shows an example of beam artifacts:  Figure 45-17: Beam artifacts A real indication might not be detected when **Ignore streak artifacts** is activated if it is connected to and/or fits into the shape of a beam artifact. A beam artifact might not be removed by the ignore streak artifacts algorithm in cases where a beam artifact is connected to another indication (i.e., resulting shape is no longer a straight, line-like structure).

Active column Section

This drop-down list allows you to select the property of the indication that is to be shown according to the settings on the **Colors** tab.

When you select an indication property, e.g., **Surface**, from the **Active column** drop-down list, the indications will be color-coded according to their surface area as defined by the color lookup table and the colors specified in the **Sections** section of the **Colors** tab. In the indication list on the **Indications** tab, the column of the selected property becomes the “active” column, and its values are highlighted in bold and italic font.

When you select **Uncoded** from the **Active column** drop-down list, all indications will be shown in the same color regardless of their properties, e.g., radius and volume. The color can be specified in the **Uncoded indications** field of the **Other colors** section on the **Colors** tab.

The property selected in the **Active column** drop-down list will be added to the information provided in the annotation labels.

The **Active column** section is also available on the **Colors** tab. The changes made on the **Settings** tab will also affect the **Colors** tab and vice versa.

You can also select the active column on the **Indications** tab by right-clicking the column and choosing the **Set as active column** item from the context menu.

Tolerancing Tab

Tolerance values will be interpreted according to DIN EN ISO 8015 (see also section *Rounding Rules* on page 4 in chapter 1 *Welcome*).

Table 45-49: Controls on the **Tolerancing** tab

Control	Description
Ratio indication volume/total volume [<ratio unit>] field	Specifies the maximum permissible ratio between the total indication volume and the total material volume.
Equivalent diameter [<length unit>] field	Specifies the diameter of a sphere with the same maximum permissible volume as the indication.
Volume [<length unit>³] field	Specifies the maximum permissible volume of an individual indication.
Projected area (yz-plane)/(xz-plane)/ (xy-plane) [<length unit>²] fields	Specifies the maximum permissible projected surface of an indication.
Directional variability (Porosity) [<ratio unit>]	**VGEasyPore** algorithm only: Specifies the maximum porosity with respect to the direction specified in the **Direction** fields of the **Directional variability** section.
Gap (voxel) [<length unit>] field	Specifies the minimum permissible distance between the surfaces of two indications.

Control	Description
Diameter [<length unit>] field	Specifies the maximum permissible diameter of an indication.
Indication volume [<length unit>³] field	Specifies the maximum permissible total volume of all indications.
Cut surface [<length unit>²] field	Specifies the maximum permissible surface area where the indication intersects the surface of the object selected in the **Reference** field of the **Edge distance calculation** section.
Max. edge distance (cut) [<length unit>] field	For an indication classified as **Cut**: Specifies the maximum permissible maximum distance between the surface of the indication in the material and the surface of the object selected in the **Reference** field of the **Edge distance calculation** section.
Min. edge distance (inside) [<length unit>] field	For an indication classified as **Inside**: Specifies the minimum permissible minimum distance between the surface of the indication and the surface of the object selected in the **Reference** field of the **Edge distance calculation** section.
Min. edge distance (outside) [<length unit>] field	For an indication classified as **Outside**: Specifies the minimum permissible minimum distance between the surface of the indication and the surface of the object selected in the **Reference** field of the **Edge distance calculation** section.
Indication count	Specifies the maximum permissible number of pores.
Reset button	Deletes all tolerance settings.

Depending on the results of this evaluation, the tolerances are highlighted in the following colors:

- Green: The tolerance is met.
- Red: The tolerance is not met.
- White (light theme)/black (dark theme): No tolerance settings have been specified or they are deactivated.
- Yellow: A tolerance has been specified but the analysis has to be (re-)calculated. Note that this color will also be used if the entered tolerance value is invalid.

The result of the evaluation is also displayed graphically in the Scene Tree. For more information on evaluations, see chapter 46 *Evaluations*.

Colors/Porosity colors Tab

Here you can specify the color-coding scheme used for the representation of the analysis results.

Caption Section

Table 45-50: Controls of the **Caption** section

Control	Description
Caption field	Indicates the color bar headline as specified in the **Caption** field of the **Color bar** section.
Share color bar checkbox	When this option is checked, all analyses of the same type (and—if applicable—of the same algorithm) will use the same color bar. When this option is unchecked, the color bar settings will apply to the selected analysis only.

LUT – Color Lookup Table

The color lookup table (LUT) shows the partitioning into color sections.

Sections Section

Defines the appearance of each color section.

Table 45-51: Controls in the **Sections** section

Control	Description
From/To fields	Specify the start and end values of the color sections. The first color section represents all values above the upper limit, i.e., the value in the **From** field (**+inf** signifies positive infinity), while the last color section represents all values below the lower limit, i.e., the value in the **To** field (**-inf** signifies negative infinity). The default limits are calculated from the results of the analysis (for an analysis color bar) or taken from the **Default** preset (for a tolerance deviation color bar).
Type field	Switches between the color schemes **Continue**, **Constant**, **Gradient**, **Rainbow**, **Reverse rainbow**, and **Hue cycle**.
Color/transparency field	Double-clicking the field for the **Continue**, **Constant**, and **Gradient** color schemes opens the **Select Color** dialog where you can modify the appearance of the selected color scheme. For the **Gradient** color scheme, you can specify the start and end colors by double-clicking the left or right side of the field, respectively. Double-clicking the field for the **Rainbow**, **Reverse rainbow**, **Green to red**, **Red to green**, and **Hue cycle** color schemes opens the **Transparency** dialog, where you can set the transparency for the selected color scheme.

Control	Description
use RMB to click a color section	Opens a context menu with the following items: • **Split**: Subdivides the color section into two new color sections where each represents half of the original section. • **Merge**: Combines several color sections to a single color section. Only consecutive intervals can be merged.
Create smooth button	Opens the **Create smooth table** dialog to generate one color section. • **Type** drop-down list: Allows you to select the type of coloring scheme. • **From/To** spin boxes: Specify the value range covered by the color section.
Create stepped button	Opens the **Create stepped table** dialog to generate a set of color sections. • **Type** drop-down list: Allows you to select the type of coloring scheme. • **From/To** spin boxes: Specify the value range covered by the color sections. • **Step** spin box: Specifies the step size of the individual color sections.
Auto scale button	Fits the color LUT to the range of the results of all available analyses. For example, if you have a minimal porosity of 2% and maximal porosity of 10%, these values will be your minimum and maximum on your color LUT. The gradient changing from green to red will be used. Note that if you load an old project, you may have to manually click the **Auto scale** button to rescale the color LUT, because the relevant settings in the old project remain unchanged in the current version.

Active column Section

This drop-down list allows you to select the property of the indication that is to be shown according to the specified color-coding.

The **Active column** section is also available on the **Settings** tab. The changes made on the **Colors** tab will also affect the **Settings** tab and vice versa. For details, see the “**Settings** tab” chapter of the corresponding analysis.

Outline rendering Section

Specifies the rendering of the results of a porosity/inclusion analysis.

Table 45-52: Settings in the **Outline rendering** section

Control	Description
Outline rendering checkbox	When this option is checked, only the outline of the color-coded indications is shown such that the indications will not be covered by the color-coding.
Outline width spin box	Specifies the outline width for the color-coded indications. Note that when increasing the outline width, the outline will grow equally inward and outward. The real outline of the indication lies in the middle of the line.

To visualize the outline of the indications, you can also create a colored mesh by right-clicking the analysis in the Scene Tree and selecting **Convert to > Colored surface mesh from analysis result(s)** from the context menu. The color of the mesh corresponds to the color-coding of the analysis results.

Display mode in 3D Section

Table 45-53: Controls in the **Display mode in 3D** section

Control	description
Opacity mode drop-down list	Specifies the visual representation of the analysis results. The following modes are available: • **Constant**: Each indication is fully opaque independently of its gray value. • **Ramp**: The lower the gray value of the respective indication, the lower its opacity value. The higher the gray value of the respective indication, the higher its opacity value. Available only if the volume data of the object is loaded. • **Inverse ramp**: The lower the gray value of the respective indication, the higher its opacity value. The higher the gray value of the respective indication, the lower its opacity value. Available only if the volume data of the object is loaded. This option allows you to see through the indications that lie on top and discover indications that may lie behind them.

Other Colors Section

Depending on the analysis type, this option is only available when **Uncoded** is selected in the **Active column** field on the **Settings** tab. Double-clicking the **Uncoded indications** field opens the **Select Color** dialog, where you can set the color for the detected indications. All indications will be shown in this color.

Color LUT Settings Section

Specifies the appearance of the color lookup table.

Table 45-54: Options for the appearance of the color lookup table

Control	Description
Auto tick marks checkbox	When this option is checked, equidistant tick marks will be produced for the color bars. When this option is unchecked, tick marks will appear only at the color section boundaries of the color lookup table.
Auto scale color bar range on calculate checkbox	When this option is checked, the color LUT will be automatically fitted to the range of the results of all available analyses. The gradient changing from green to red will be used.

Preset selection Section

Table 45-55: Controls in the **Preset selection** section

Icon	Item	Description
	drop-down list	Specifies the preset to be applied, to be edited, or to be taken as a basis for a new preset. The following icons are used: • default preset • customized preset • appears next to the icon of a preset that has been modified but not yet saved
	Save preset	Opens the **Save preset** dialog for saving the color LUT of the current data set under the specified name. • **Absolute preset**: When this option is checked and the preset applied, the settings of the original data set, including the LUT range, will be applied. When this option is unchecked, the color settings of the preset will be mapped relatively to the actual range of results of the analysis to which the preset will be applied.
	Remove preset	Removes the selected preset from the preset drop-down list.
	Import preset	Imports a preset from the specified location.
	Export preset	Exports the selected preset to the specified location.

Color bar Section

Specifies the settings for the color bar.

Table 45-56: Settings for the color bar

Control	Description
Visibility drop-down list	Switches the color bar on/off.
Positioning drop-down list	Specifies the location of the color bar within the 2D and 3D windows: **Left, Right, Top, Bottom, All - automatic, Left or right - automatic, Top or bottom - automatic**.
Caption field	Specifies the color bar headline by using placeholders.
Reset button	Resets the **Caption** field to the default entry.

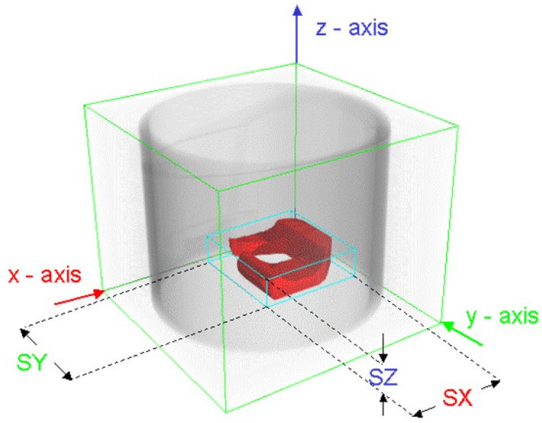
Indications Tab

Lists all indications detected by the analysis.

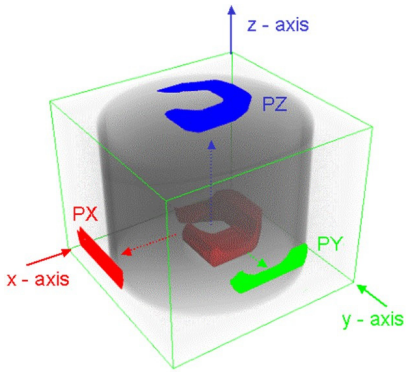
The **Indications** table consists of the following columns:

Table 45-57: Columns of the **Indications** table

Column	Description
Probability	Indicates the probability that the discontinuity is an indication.
Radius [<length unit>]	Indicates the radius of the circumscribed sphere of the indication.
Diameter [<length unit>]	Indicates the diameter of the circumscribed sphere of the indication.
Equivalent diameter [<length unit>]	Indicates the diameter of a sphere that has the same volume as the indication.
Center x/y/z [<length unit>]	Indicates the center position of the circumscribed sphere of the indication.
Volume [<length unit>^{3}]	Indicates the volume of the indication.
Voxel	Indicates the number of voxels the indication consists of.
Surface [<length unit>^{2}]	Indicates the surface area of the indication.
Classification	Indicates the position of the indication relative to the object selected in the **Reference** field of the **Edge distance calculation** section: **Cut**, **Inside**, or **Outside**.
Gap [<length unit>]	Indicates the minimum distance between the surfaces of the circumscribed spheres of two indications. Note that this value may also be negative.

Column	Description
Compactness	Indicates the ratio between the volume of the indication and the volume of the circumscribed sphere. $$\text{Compactness} = \frac{V_{indication}}{V_{sphere}}$$
Sphericity	Indicates the ratio between the surface of a sphere with the same volume as the indication and the surface of the indication. $$\text{Sphericity} = \frac{A_{sphere}}{A_{indication}}$$
Pos. x/y/z [<length unit>]	Analysis mode **Void**: Indicates the position of the darkest voxel of the indication. Analysis mode **Inclusion**: Indicates the position of the brightest voxel of the indication.
Projected size x/y/z [<length unit>]	Indicates the size of the bounding box surrounding the indication in the scene coordinate system. See the following figure for an illustration:  Figure 45-18: Projected size
PCA deviation 1/2/3 [<length unit>]	Indicate the standard deviations along each of the three mutually orthogonal axes calculated, from a Principal Component Analysis (PCA), with **PCA deviation 1** corresponding to the standard deviation along the most pronounced axis of the indication. The standard deviations are the square root of the eigenvalues.
PCA max. deviation ratio [<ratio unit>]	Indicates the ratio between **PCA deviation 1** and the radius of the circumscribed sphere of the indication. $$\text{Max. relative PCA deviation} = \frac{\text{PCA deviation 1}}{r_{sphere}}$$

Column	Description
PCA min. deviation ratio [<ratio unit>]	Indicates the ratio between **PCA deviation 3** and the radius of the circumscribed sphere of the indication. $$\text{Min. relative PCA deviation} = \frac{\text{PCA deviation 3}}{r_{sphere}}$$
Min. gray value	Indicates the minimum gray value within the indication.
Max. gray value	Indicates the maximum gray value within the indication.
Mean gray value	Indicates the mean gray value within the indication.
Deviation of gray values	Indicates the standard deviation of the gray values within the indication.
Label	Indicates the consecutive number of the indication.
Min. thickness [<length unit>]	Indicates the minimum wall thickness within the region of the indication.
Max. thickness [<length unit>]	Indicates the maximum wall thickness within the region of the indication.
Mean thickness [<length unit>]	Indicates the mean wall thickness within the region of the indication.
Relative diameter	Indicates a measurement for the diameter of the circumscribed sphere of the indication with respect to the minimum wall thickness within the region of the indication. $$\text{Relative diameter} = \frac{Ø_{sphere}}{t_{min}}$$
Cut surface [<length unit>²]	Indicates the surface area where the indication intersects the surface of the object selected in the **Reference** field of the **Edge distance calculation** section.
Min. edge distance (inside) [<length unit>]	For an indication classified as **Inside**: Indicates the smallest distance between the surface of the indication and the surface of the object selected in the **Reference** field of the **Edge distance calculation** section.
Min. edge distance (outside) [<length unit>]	For an indication classified as **Outside**: Indicates the smallest distance between the surface of the indication and the surface of the object selected in the **Reference** field of the **Edge distance calculation** section.
Max. edge distance (cut) [<length unit>]	For an indication classified as **Cut**: Indicates the largest distance between the surface of the indication in the material and the surface of the object selected in the **Reference** field of the **Edge distance calculation** section.

Column	Description
Projected area (yz-plane)/(xz-plane)/ (xy-plane) [<length unit>²]	Indicates the surface area of the indication shape projected along each of the axes of the scene coordinate system. See the following figure for an illustration:  Figure 45-19: Projected area
Description	Allows you to enter a description for the component used for reporting.
Image	Allows you to add a detailed 2D image and object description on a separate page of the report. • **Off**: No image is created (default). • **Orthographic projection**: Creates three orthogonal views. • **Top/Bottom/Left/Right/Front/Back**: Creates a single 2D view in the specified orientation. • **... - If not OK**: Automatically creates the image if the tolerance status is **Out of tolerance**. The image orientation corresponds to the currently selected coordinate system. The image will be generated according to the render settings specified during report creation or VGRF-based export. The 2D slice position used for taking the image is determined by the position of the indication. The zoom factor of the image is selected so that the entire parent volume is visible.
Focused image	This option is almost identical to the **Image** option but will generate an image that focuses on the respective item and is zoomed in by the **Zoom factor** specified during report creation or VGRF-based export.
Captures	Indicates the number of images captured for this object using the **Capture from** button in the **Screenshots** section.

Column	Description
Tolerance status	Indicates the tolerance status of the indication depending on the tolerances specified for the indications in the **Tolerance settings** section of the **Settings** tab: **Valid** (green), **Out of tolerance** (red), or **No tolerance** (gray).

If a column shows a parameter for which a tolerance has been specified (see section *Tolerancing Tab* on page 904), each entry will be evaluated separately according to the specified tolerance and highlighted in the following colors:

- Green: The tolerance is met.
- Red: The tolerance is not met.

Statistics Tab

Shows a histogram of the indication distribution in the selected object (number versus the property selected in the **Active column** field). The histogram bars are colored according to the settings on the **Colors** tab.

Controls of the **Statistics** Tab

- **Options** section

  Table 45-58: Controls of the **Statistics** tab, **Options** section

Control	Description
Color drop-down list	• **From color bar**: The values in the histogram are shown according to the color bar. • **Gray**: All values in the histogram are shown in gray.
Ordinate scaling drop-down list	• **Linear**: Applies a linear scale to the y-axis of the histogram. • **Logarithmic**: Applies a logarithmic scale to the y-axis of the histogram.
Binning drop-down list	• **Off**: No binning is applied to the values shown in the histogram. • **From color bar**: The original values in the histogram are replaced by a value representative for the corresponding interval (“bin”) of the color bar. The “bins” become visible when “stepped” sections on the **Colors** tab are created. • **Manual number of bins**: Enables the **Bin count** spin box, where you can enter the required number of “bins.” • **Manual bin width**: Enables the **Bin width** spin box, where you can specify the width of the bins.

- **Intervals** section

Table 45-59: Controls of the **Statistics** tab, **Intervals** section

Control	Description
Left/**Right** spin box	Only enabled when an interval has been created: Moves the left or right interval border to the specified value. You can also click and drag the interval borders by using the left mouse button.
Create button	Creates a new interval. On the right-hand side of a selected interval, statistical information is displayed: • **Left**: Indicates the minimum value of the parameter selected in the **Active column** field of the **Settings** tab within the interval, i.e., the left interval border. • **Right**: Indicates the maximum value of the parameter selected in the **Active column** field of the **Settings** tab within the interval, i.e., the right interval border. • **Mean**: Indicates the mean value of the parameter selected in the **Active column** field of the **Settings** tab within the interval. • **Dev**: Indicates the standard deviation of the values of the parameter selected in the **Active column** field of the **Settings** tab within the interval. • **Sum:** Indicates the number of indications within the interval. • **Percentage**: Indicates the percentage of the parameter selected in the **Active column** field of the **Settings** tab within the interval. Note that the statistical information may change with the number of bins specified in the **Options** section.
Remove button	Removes the selected interval.

- **Voids/Inclusions** section

Table 45-60: Controls of the **Statistics** tab, **Voids/Inclusions** section

Control	Description
Σ **Voxel**	Indicates the total number of voxels in all voids/inclusions.
Σ **Volume [<length unit>³]**	Indicates the total volume of all voids/inclusions.
Σ **Surface [<length unit>²]**	Indicates the total surface of all voids/inclusions.

Control	Description
∑ Proj. area (yz)/(xz)/(xy) [<length unit>²]	Indicates the total surface of all projected voids/inclusions. The projection of the indications refers to the scene coordinate system.
Indication count	Indicates the total number of pores found.

- **Material** section

Table 45-61: Controls of the **Statistics** tab, **Material** section

Control	Description
Material volume [<length unit>³] field	Indicates the volume enclosed by the determined surface minus the volume of the voids/inclusions inside this volume.
Indication volume [<length unit>³] field	Indicates the total volume of all voids/inclusions.
Ratio indication volume/total volume [<ratio unit>] field	Indicates the total volume of all voids/inclusions in relation to **Material volume** plus **Indication volume**.

Some indications may cover a region that includes a determined surface (see figure below). If you remove such an indication from the indication table, the decrease in indication volume and the increase in material volume will not correspond with each other. While the complete indication volume will be subtracted from **Indication volume**, only the volume of the indication that lies within the determined surface will be added to **Material volume**.

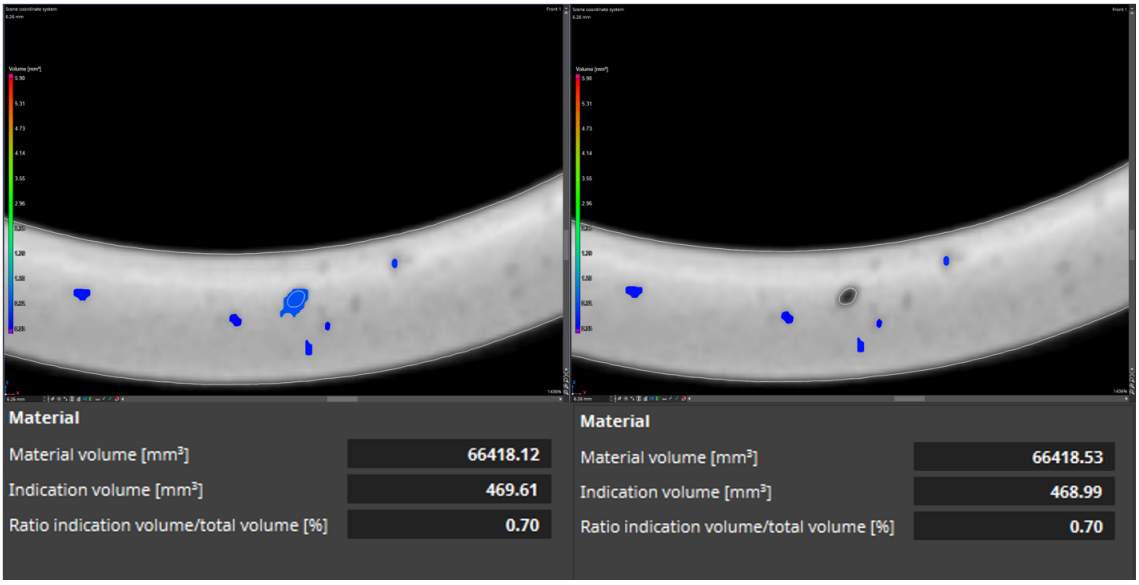


Figure 45-20: Left: initial situation; right: indication removed

- General controls

Table 45-62: General controls of the **Statistics** tab

Control	Description
use RMB to click the chart area	Displays a context menu (see below).
scroll MW in chart area or x-axis up/down	Zooms the x-axis of the chart out/in.
scroll MW in y-axis up/down	Zooms the y-axis of the chart out/in.
use LMB to click and drag the x-axis	Scrolls the x-axis.
use LMB to click and drag the y-axis	Scrolls the y-axis.
Zoom in/out	Zooms the corresponding axis in/out.
Reset zoom	Fits the entire chart to the current window size.

Context Menu of the **Statistics** Tab

Right-clicking anywhere in the chart area shows a context menu with the following options:

Table 45-63: Context menu items

Control	Description
Export as CSV...	Opens a dialog for saving the chart values to a *.csv* file.
Copy to clipboard	Copies a screenshot of the chart to the system clipboard so you can paste it in another application.
Hide/Show x/y grid	Toggles the visibility of the grid lines for the corresponding axis.
Reset zoom	Fits the entire chart to the current window size.
Create interval	Creates a new interval. For details on the statistical information, see section *Controls of the Statistics Tab* on page 914.
Remove interval	Removes the selected interval.

Feature plot Tab

Allows you to plot an indication property (e.g., the compactness) versus another property (e.g., the diameter). This allows you to draw certain conclusions about the characteristics of the indications in the scanned object.

Controls of the **Feature plot** Tab

Table 45-64: Controls of the **Feature plot** tab

Control	Description
Ordinate feature drop-down list	Specifies the property to be shown on the y-axis of the plot.
Abscissa feature drop-down list	Specifies the property to be shown on the x-axis of the plot.
use RMB to click the chart area	Displays a context menu (see below).
scroll MW in chart area or x-axis up/down	Zooms the x-axis of the chart out/in.
scroll MW in y-axis up/down	Zooms the y-axis of the chart out/in.
use LMB to click and drag the x-axis	Scrolls the x-axis.
use LMB to click and drag the y-axis	Scrolls the y-axis.
Zoom in/out	Zooms the corresponding axis in/out.
Reset zoom	Fits the entire chart to the current window size.

Context Menu of the **Feature plot** Tab

Right-clicking anywhere in the chart area shows a context menu with the following options:

Table 45-65: Context menu items

Control	Description
Export as CSV...	Opens a dialog for saving the chart values to a *.csv* file.
Copy to clipboard	Copies a screenshot of the chart to the system clipboard so you can paste it into another application.
Hide/Show x/y grid	Toggles the visibility of the grid lines for the corresponding axis.
Reset zoom	Fits the entire chart to the current window size.

Directional variability Tab

This curve shows how the porosity changes with respect to the direction specified in the **Direction** field on the **Settings** tab. If a tolerance has been specified for the directional variability, the tolerance status will be indicated by a horizontal line. A red line indicates that the porosity of at least one slice exceeds the specified tolerance. A green line indicates that the porosity of all slices is within the specified tolerance. You can use the **Directional variability** curve to answer questions such as “How high is the porosity at a specific slice position?”

Controls of the **Directional variability** Tab

Table 45-66: Controls of the **Directional variability** Tab

Control	Description
hover the mouse pointer over the curve	Displays the legend of the function as well as its values at the specified location.
use LMB to click and drag the vertical line in the histogram	Indicates the function values at the specified location and updates the slice views accordingly. Hold down the **Ctrl** key while left-clicking in the chart area to display the vertical line in case you dragged it out of the chart area.
use RMB to click the chart area	Displays a context menu, see below.
scroll MW in chart area or x-axis up/down	Zooms the x-axis of the chart out/in.
scroll MW in y-axis up/down	Zooms the y-axis of the chart out/in.
use LMB to click and drag the x-axis	Scrolls the x-axis.
use LMB to click and drag the y-axis	Scrolls the y-axis.
Zoom in/out	Zooms the corresponding axis in/out.
Reset zoom	Fits the entire chart to the current window size.

Directional variability rules Tab

This tab is only enabled for a porosity/inclusion analysis that was calculated using the **VGEasyPore** algorithm and for which the **Directional variability** option has been checked on the **Settings** tab.

The **Directional variability rules** table lists the individual slices that have been analyzed using the **Directional variability** option. It includes their positions, the calculated values, and the tolerance states.

The **Directional variability rules** table consists of the following columns:

Table 45-67: Controls of the **Directional variability rules** table

Control	Description
Slice center x/y/z [<length unit>]	Indicates the x-, y-, and z-coordinates of the center of the slice.
Directional variability (Porosity) [<ratio unit>]	Indicates the porosity with respect to the direction specified in the **Directional variability** section on the **Settings** tab.
Description	Allows you to enter a description for the slice used for reporting.

Control	Description
Image	Allows you to add a detailed 2D image and object description on a separate page of the report. • **Off**: No image is created (default). • **On**: Creates a 2D view in the direction specified in the **Directional variability** section on the **Settings** tab. The image will be generated according to the render settings specified during report creation or VGRF-based export. The zoom factor of the image is chosen so that the entire parent volume is visible.
Focused image	This option is almost identical to the **Image** option but will generate an image that focuses on the respective item and is zoomed in by the **Zoom factor** specified during report creation or VGRF-based export.
Tolerance status	Indicates the tolerance status of the slice depending on the tolerances specified for the slices in the **Tolerance settings** section of the **Settings** tab: **Valid** (green), **Out of tolerance** (red), or **No tolerance** (gray).

If a column shows a parameter for which a tolerance has been specified (see section *Tolerancing Tab* on page 904), each entry will be evaluated separately according to the specified tolerance and highlighted in the following colors:

- Green: The tolerance is met.
- Red: The tolerance is not met.
- Gray: There is no porosity value available for this slice.

The table in the lower part of the **Directional variability rules** tab shows the existing rules for selecting porosities with defined directional variability or tolerance status to be included in the final report. Clicking the **New** button opens the **Rule** dialog, which allows you to create new rules and edit or delete existing rules.

Rule Dialog

- **Rule** section

  The **Name** field allows you to enter a name for the new rule. This name has to be unique.
- **Condition** section

  Table 45-68: Controls in the **Condition** section

Control	Description
Column drop-down list	Selects the property of the feature that defines the rule.
Comparator drop-down list	Specifies the comparator to be applied to the selected property.
Value [<unit>] spin box or drop-down list	Specifies the reference value or status of the selected property for comparison.

Control	Description
Result count field	Indicates the number of results that meet the specified condition.

- **Image generation** section

  Table 45-69: Controls in the **Image generation** section

Control	Description
Image drop-down list	Allows you to add a detailed 2D image and object description on a separate page of the report. • **Off**: No image is created (default). • **On**: Creates a 2D view in the direction specified in the **Directional variability** section on the **Settings** tab.
Focused image drop-down list	This option is almost identical to the **Image** option, but will generate an image that focuses on the respective item and is zoomed in by the **Zoom factor** specified during report creation or VGRF-based export.
Max. results checkbox and spin box	When this option is checked, you will be able to use the corresponding spin box to specify the maximum number of results to be included in the report.

- **OK** button

  Closes the dialog, adds the new rule to the list in the **Rules** tab, and updates the annotations.
- **Cancel** button

  Discards the settings and closes the dialog.

Porosity statistics Tab

Shows a histogram of the calculated porosity for the entire analyzed object (number of voxels versus the percentage of the porosity). The histogram bars are colored according to the settings on the **Porosity colors** tab. You can use the **Porosity statistics** tab to answer questions such as “How many voxels have a porosity of 4%?”

Controls of the **Porosity statistics** Tab

- **Options** section

  Table 45-70: Controls of the **Porosity statistics** tab, **Options** section

Control	Description
Color drop-down list	• **From color bar**: The values in the histogram are shown according to the color bar. • **Gray**: All values in the histogram are shown in gray.

Control	Description
Ordinate scaling drop-down list	• **Linear**: Applies a linear scale to the y-axis of the histogram. • **Logarithmic**: Applies a logarithmic scale to the y-axis of the histogram.
Binning drop-down list	• **Off**: No binning is applied to the values shown in the histogram. • **From color bar**: The original values in the histogram are replaced by a value representative for the corresponding interval (“bin”) of the color bar. The “bins” become visible when creating “stepped” sections on the **Colors** tab. • **Manual number of bins**: Enables the **Bin count** spin box, where you can enter the required number of “bins.” • **Manual bin width**: Enables the **Bin width** spin box, where you can specify the width of the bins.

- **Intervals** section

Table 45-71: Controls of the **Porosity statistics** tab, **Intervals** section

Control	Description
Left/**Right** spin box	Only enabled when an interval has been created: Moves the left or right interval border to the specified value. You can also click and drag the interval borders by using the left mouse button.

Control	Description
Create button	Creates a new interval. On the right hand side of a selected interval, statistical information is displayed: • **Left**: Indicates the minimum value of the parameter selected in the **Active column** field of the **Settings** tab within the interval, i.e., the left interval border. • **Right**: Indicates the maximum value of the parameter selected in the **Active column** field of the **Settings** tab within the interval, i.e., the right interval border. • **Mean**: Indicates the mean value of the parameter selected in the **Active column** field of the **Settings** tab within the interval. • **Dev**: Indicates the standard deviation of the values of the parameter selected in the **Active column** field of the **Settings** tab within the interval. • **Percentage**: Indicates the percentage of the parameter selected in the **Active column** field of the **Settings** tab within the interval. Note that the statistical information may change with the number of bins specified in the **Options** section.
Remove button	Removes the selected interval.

- General controls

Table 45-72: General controls of the **Porosity statistics** tab

Control	Description
use RMB to click the chart area	Displays a context menu (see below).
scroll MW in chart area or x-axis up/down	Zooms the x-axis of the chart out/in.
scroll MW in y-axis up/down	Zooms the y-axis of the chart out/in.
use LMB to click and drag the x-axis	Scrolls the x-axis.
use LMB to click and drag the y-axis	Scrolls the y-axis.
Zoom in/out	Zooms the corresponding axis in/out.
Reset zoom	Fits the entire chart to the current window size.

Context Menu of the **Porosity statistics** Tab

Right-clicking anywhere in the chart area shows a context menu with the following options:

Table 45-73: Context menu items

Control	Description
Export as CSV...	Opens a dialog for saving the chart values to a *.csv* file.
Copy to clipboard	Copies a screenshot of the chart to the system clipboard so you can paste it in another application.
Hide/Show x/y grid	Toggles the visibility of the grid lines for the corresponding axis.
Reset zoom	Fits the entire chart to the current window size.
Create interval	Creates a new interval. For details on the statistical information, see section *Controls of the Porosity statistics Tab* on page 921.
Remove interval	Removes the selected interval.

Hot spots of porosity Tab

Displays the hot spots resulting from the porosity calculation.

The **Hot spots of porosity** tab is available only if the **Porosity calculation** option has been checked on the **Settings** tab.

Table 45-74: Columns of the **Hot spots of porosity** list

Column	Description
Position x/y/z [<length unit>]	Indicates the x-, y-, and z-position of the hot spot.
Volume [<length unit>^{3}]	Indicates the volume of the hot spot.
Surface [<length unit>^{2}]	Indicates the surface area of the hot spot.
Mean porosity [<ratio unit>]	Indicates the mean porosity value of the hot spot.
Porosity deviation [<ratio unit>]	Indicates the standard deviation of the porosity value of the hot spot.
Maximum porosity [<ratio unit>]	Indicates the maximum porosity within the hot spot.
Description	Allows you to enter a description for the hot spot used for reporting.

Column	Description
Image	Allows you to add a detailed 2D image and object description on a separate page of the report. • **Off**: No image is created (default). • **Orthographic projection**: Creates three orthogonal views. • **Top/Bottom/Left/Right/Front/Back**: Creates a single 2D view in the specified orientation. The image orientation is relative to the currently selected coordinate system. The image will be generated according to the render settings specified during report creation or VGRF-based export. The 2D slice position used for taking the image is determined by the position of the hot spot. The zoom factor of the image is chosen so that the entire parent volume is visible.
Focused image	This option is almost identical to the **Image** option but will generate an image that focuses on the respective item and is zoomed in by the **Zoom factor** specified during report creation or VGRF-based export.
Captures	Indicates the number of images captured for this hot spot by using the **Capture from** button in the **Screen-shots** section.

Mesh cells Tab

Displays the results of the porosity/inclusion analysis for each cell of the integration mesh.

The **Mesh cells** tab is available only if an integration mesh has been specified in the **Integration mesh** section on the **Settings** tab.

You can export the results from the **Mesh cells** tab and use them for comparing real part properties with simulations of manufacturing processes or improving FE simulations for testing the stability of objects (e.g., of injection-molded parts).

Table 45-75: Columns of the **Mesh cells** list

Column	Description
Element ID	If available, indicates the ID of the mesh cell for imported integration mesh files.
Pos. x/y/z [<length unit>]	Indicates the x-, y-, and z-position of the mesh cell.
Porosity [<ratio unit>]	Indicates the porosity within the mesh cell.

Column	Description
Description	Allows you to enter a description for the cell used for reporting.
Image	Allows you to add a detailed 2D image and object description on a separate page of the report. • **Off**: No image is created (default). • **Orthographic projection**: Creates three orthogonal views. • **Top/Bottom/Left/Right/Front/Back**: Creates a single 2D view in the specified orientation. The image orientation is relative to the currently selected coordinate system. The image will be generated according to the render settings specified during report creation or VGRF-based export. The 2D slice position used for taking the image is determined by the position of the cell. The zoom factor of the image is chosen so that the entire parent volume is visible.
Focused image	This option is almost identical to the **Image** option but will generate an image that focuses on the respective item and is zoomed in by the **Zoom factor** specified during report creation or VGRF-based export.
Captures	Indicates the number of images captured for this cell by using the **Capture from** button in the **Screenshots** section.

Annotations Tab

Lists all annotations created for the selected analysis. You can view the information supplied by the annotations or edit the annotation properties.

For details on how to create an annotation, see section *Annotation* on page 124 in chapter 6 *Inspect Tab*.

To create new annotations in the table, it is also possible to paste previously copied coordinates by right-clicking the table and selecting **Paste** from the context menu or by pressing the **Ctrl** + **V** keyboard shortcut. For details, see the **Paste** menu item in section *Table Context Menu*.

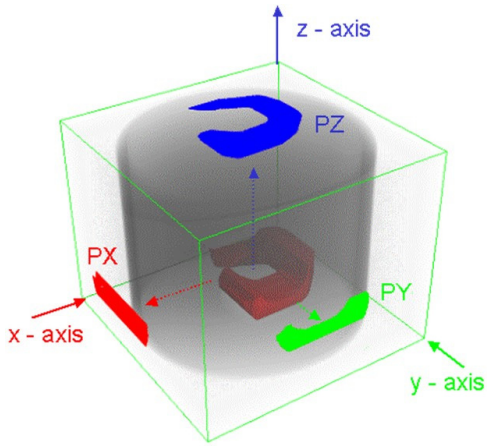
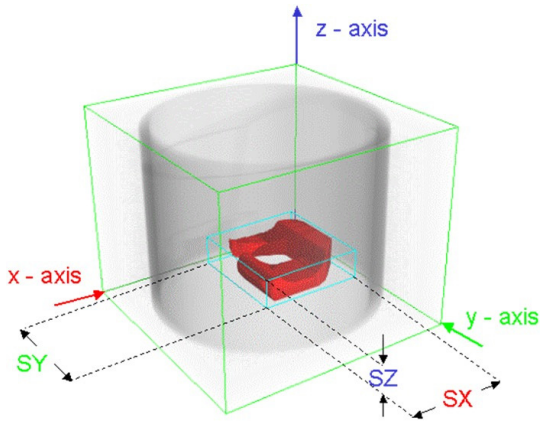
Double-clicking an analysis annotation in the Scene Tree will directly open the **Annotations** tab of the properties dialog of the corresponding analysis.

Tolerance values will be interpreted according to DIN EN ISO 8015 (see also section *Rounding Rules* on page 4 in chapter 1 *Welcome*).

The **Annotations** table consists of the following columns:

Table 45-76: Columns of the **Annotations** table

Column	Description
Name	Indicates the name of the annotation.
Pos. x/y/z [<length unit>]	Indicates the position of the annotation.
Probability	Indicates the probability that the discontinuity is an indication.
Volume [<length unit>³]	Indicates the volume of the indication at the current annotation position.
Radius [<length unit>]	Indicates the radius of the circumscribed sphere of the indication.
Diameter [<length unit>]	Indicates the diameter of the circumscribed sphere of the indication.
Equivalent diameter [<length unit>]	Indicates the diameter of a sphere that has the same volume as the indication.
Classification	Indicates the position of the indication relative to the object selected in the **Reference** field of the **Edge distance calculation** section: **Inside**, **Outside**, or **Cut**.
Edge distance (inside) [<length unit>]	For an indication classified as **Inside**: Indicates the smallest distance between the surface of the indication and the surface of the object selected in the **Reference** field of the **Edge distance calculation** section.
Edge distance (outside) [<length unit>]	For an indication classified as **Outside**: Indicates the smallest distance between the surface of the indication and the surface of the object selected in the **Reference** field of the **Edge distance calculation** section.
Edge distance (cut) [<length unit>]	For an indication classified as **Cut**: Indicates the largest distance between the surface of the indication and the surface of the object selected in the **Reference** field of the **Edge distance calculation** section.
Cut surface [<length unit>²]	Indicates the surface area where the indication intersects the surface of the object selected in the **Reference** field of the **Edge distance calculation** section.
Gap [<length unit>]	Indicates the minimum distance between the surfaces of the circumscribed spheres of two indications.

Column	Description
Projected area x/y/z [<length unit>²]	The surface area of the indication shape projected along each of the axes of the scene coordinate system. See the following figure for an illustration:  Figure 45-21: Projected area
Projected size x/y/z [<length unit>]	Indicates the size of the bounding box surrounding the indication in the scene coordinate system. See the following figure for an illustration:  Figure 45-22: Projected size
Surface [<length unit>²]	Indicates the surface area of the indication.
Compactness	Indicates the ratio between the volume of the indication and the volume of the circumscribed sphere. $\text{Compactness} = \frac{V_{indication}}{V_{sphere}}$
Sphericity	Indicates the ratio between the surface of a sphere with the same volume as the indication and the surface of the indication. $\text{Sphericity} = \frac{A_{sphere}}{A_{indication}}$

Column	Description
Min. gray value	Indicates the minimum gray value within the indication.
Max. gray value	Indicates the maximum gray value within the indication.
Mean gray value	Indicates the mean gray value within the indication.
Deviation of gray values	Indicates the standard deviation of the gray values within the indication.
PCA deviation 1/2/3 [<length unit>]	Indicate the standard deviations along each of the three mutually orthogonal axes calculated from a Principal Component Analysis (PCA), with **PCA deviation 1** corresponding to the standard deviation along the most pronounced axis of the indication. The standard deviations are the square root of the eigenvalues.
PCA min. deviation ratio [<ratio unit>]	A measure for the ratio between **PCA deviation 3** and the radius of the circumscribed sphere of the indication. $\text{Min. relative PCA deviation} = \frac{\text{PCA deviation 3}}{r_{sphere}}$
PCA max. deviation ratio [<ratio unit>]	A measure for the ratio between **PCA deviation 1** and the radius of the circumscribed sphere of the indication. $\text{Max. relative PCA deviation} = \frac{\text{PCA deviation 1}}{r_{sphere}}$
Min. thickness [<length unit>]	Indicates the minimum wall thickness within the indication.
Max. thickness [<length unit>]	Indicates the maximum wall thickness within the indication.
Mean thickness [<length unit>]	Indicates the mean wall thickness within the indication.
Relative diameter [<ratio unit>]	Indicates a measure for the diameter of the circumscribed sphere of the indication with respect to the minimum wall thickness covered by the indication. $\text{Relative diameter} = \frac{Ø_{sphere}}{t_{min}}$
Porosity [<ratio unit>]	Indicates the porosity in percent at the current annotation position.
Nom. porosity [<ratio unit>]	Allows you to specify the nominal value for tolerancing the porosity at the current annotation position. Double-click the cell to edit it.
Min. porosity [<ratio unit>]	Allows you to specify the minimum value for tolerancing the porosity at the current annotation position. Double-click the cell to edit it. If the value for **Nom. porosity** is specified, **Min. porosity** will refer to this value. If the value for **Nom. porosity** is not specified, the value for **Min. porosity** will be considered as an absolute value.

Column	Description
Max. porosity [<ratio unit>]	Allows you to specify the maximum value for tolerancing the porosity at the current annotation position. Double-click the cell to edit it. If the value for **Nom. porosity** is specified, **Max. porosity** will refer to this value. If the value for **Nom. porosity** is not specified, the value for **Max. porosity** will be considered as an absolute value.
Description	Allows you to enter a description of the annotation used for reporting.
Image	Allows you to add a detailed 2D image and object description on a separate page of the report. • **Off**: No image is created (default). • **Orthographic projection**: Creates three orthogonal views. • **Top/Bottom/Left/Right/Front/Back**: Creates a single 2D view in the specified orientation. • **... - If not OK**: Automatically creates the image if the tolerance status is **Out of tolerance**. The image orientation corresponds to the currently selected coordinate system. The image will be generated according to the render settings specified during report creation or VGRF-based export. The 2D slice position used for taking the image is determined by the position of the indication. The zoom factor of the image is selected so that the entire parent volume is visible.
Focused image	This option is almost identical to the **Image** option but will generate an image that focuses on the respective item and is zoomed in by the **Zoom factor** specified during report creation or VGRF-based export.
Captures	Indicates the number of images captured for this object using the **Capture from** button in the **Screenshots** section.
Tolerance status	Indicates the tolerance status of the indication depending on the tolerances specified for the indications in the **Tolerance settings** section of the **Settings** tab: **Valid** (green), **Out of tolerance** (red), or **No tolerance** (gray).
Type	Indicates how the annotation has been created: • **Rule based**: The annotation has been created by a report rule. • **Manually defined**: The annotation has been defined by the user.

If a column shows a parameter for which a tolerance has been specified (see section *Tolerancing Tab* on page 904), each entry will be evaluated separately according to the specified tolerance and highlighted in the following colors:

- Green: The tolerance is met.
- Red: The tolerance is not met.

General Table Controls

- List section

  The following table provides an overview of the general controls available in the various list views:

  Table 45-77: Controls in the list section

Control	Description
button	Opens a submenu for selecting the filter/search mode.
Filter	Clicking the **Click to add a filter or search criterion** field to the right of the icon opens a series of drop-down lists from which you can select a table column, an operator, and—depending on the column—a value. If a column does not offer a value drop-down list, you can type in a value. When the selection is complete, the table shows the rows matching the filter criterion. Clicking the **+** button or the **Click to add a filter or search criterion** field allows you to specify more filter criteria. Clicking the **x** button removes the filter.
Search	Clicking the **Click to add a filter or search criterion** field to the right of the icon opens a series of drop-down lists from which you can select a table column, an operator, and—depending on the column—a value. If a column does not offer a value drop-down list, you can type in a value. When the selection is complete, the table rows matching the search criterion are highlighted. Clicking the **+** button or the **Click to add a filter or search criterion** field allows you to specify more search criteria. Pressing **F3** jumps to the next search result in the list. Clicking the **x** button removes the search.
Full-text filter	Entering a value or text string into the input field to the right of the icon filters the table accordingly and shows the rows that match the filter criterion.

Control	Description
Full-text search	Entering a value or text string into the input field to the right of the icon searches the table accordingly and highlights the rows that match the search criterion.
use LMB to click on a table row	Selects the row and the corresponding object in the Scene Tree. In analysis result lists, the result, e.g., the component, is marked by a cross-hairs cursor in each of the 2D views.
hold **Ctrl** key + use LMB to click on several table rows	Selects the rows and the corresponding objects in the Scene Tree.
hold **Shift** key + use LMB to click on two separate table rows	Selects the two rows, including all rows between the two as well as the corresponding objects in the Scene Tree.
hold **Shift** key + use up/down arrow keys	Selects the rows and the corresponding objects in the Scene Tree.
press **Ctrl**+**A**	Selects all table rows.
use up and down arrow keys	Steps up and down through the table rows.
use RMB to click into the table area	Displays a context menu. See below.
use LMB to click a column heading	Sorts the table according to the values of the column. Clicking subsequently toggles between ascending and descending.
use LMB to click and drag column heading to new position, then release LMB	Inserts the column at the new position.
use LMB to double-click cell highlighted in white (light theme) or medium gray (dark theme)	If applicable: Allows you to edit the contents of the cell.

- **Screenshots** section (if available)

  The **Screenshots** section below the list section allows you to capture images from one of the 2D windows, the 3D window, or the current window layout for the item currently selected in the table. Only available if exactly one row is selected.

  Table 45-78: Controls in the **Screenshots** section

Control	Description
Capture from button	Adds the image of the view selected from the drop-down list to the preview area above.
use LMB to click and drag one or more images, then release LMB	Moves the image(s) to the new position.

Control	Description
double-click the image	Opens the **Snapshot display** window showing the image: • **Zoom in**/**Zoom out** button: Zooms the image in/out. You can also move the mouse pointer in the image area and turn the mouse wheel. • **Fit to window** button: Resets the zoom so that the image fits into the window.
click the **<no description>** place-holder twice (first click to select, second click to enable renaming)	Allows you to label the image.
Delete selected button	Deletes the selected image from the preview area.

Table Context Menu

Right-clicking anywhere in the table area shows a context menu with the following options:

Table 45-79: Context menu items

Control	Description
Columns	Allows you to toggle the visibility of each column by checking/unchecking the respective item. • **Show all**: Checks all columns to set them to visible. • **Hide all**: Unchecks all columns to set them to invis-ible. • **Hide empty**: Unchecks all not editable columns which are empty or **n/a** to set them to invisible.
Trim columns	Resizes all columns to their smallest possible size.
Apply default column layout	Applies the default column layout previously saved by the user to the current table. If no default column layout has been saved, the original column layout will be applied.
Save as default column layout	Saves modifications applied to the table—e.g., the visi-bility of a column, the order in which the columns appear, the column width—as default column layout. This layout will be applied when you create a new project.
Apply original column layout	Restores the original table layout and discards any modifications applied by the user. The original table layout is predefined and cannot be modified by the user.
Remove entries	If applicable: Deletes the selected row(s) from the table.

Control	Description
Create annotations	If applicable: Creates annotations for the selected items.
Export as CSV...	Opens the **Export as CSV...** dialog for exporting the table values as **.csv* file. This option always exports the complete table even if a filter was applied. In order to export only the filtered rows, press **Ctrl** + **A** to highlight all filtered rows and use the **Copy to clipboard** menu item.
Copy to clipboard	Copies the selected rows as well as the column heading into the system clipboard. The clipboard information is provided both as plain text and rich-text table, so when pasting into a rich-text-capable application like a word processor, you will see a proper table with cell borders and bold headings.
Paste	For annotation tables: Pastes previously copied coordinates and—optionally—snap directions to create new annotations in the table. For annotations of a nominal/actual comparison, the search distance specified on the **Settings** tab of the analysis will be considered. Note: Pasted annotations will be interpreted in the selected coordinate system at the time of pasting. The information in the clipboard must have the following structure: • x-, y-, and z-coordinate of the annotation or • x-, y-, and z-coordinate of the annotation as well as x-, y-, and z-component of the vector for the snap direction The parameters can be separated by space, tab, semicolon, or comma (if a comma is already used as a decimal mark or digit grouping symbol, the values must be enclosed in double quotation marks). Example: 8.89;25.82;-0.55;1;0;0 You can also copy the information directly from the cells of a spreadsheet. In order to paste the annotation information, you can also press the **Ctrl** + **V** keyboard shortcut.
Set as active column	If applicable: Makes the current column the active column, i.e., the results of this column are color-coded according to their values as defined by the color lookup table and the colors specified in the **Sections** section of the **Colors** tab.

Control	Description
Unset active column	If applicable: Deselects the currently active column and sets the **Active column** drop-down list on the corresponding **Settings** tab to **Uncoded**, i.e., removes any color coding.
Enter/change value (all items)	If applicable: Opens the **Enter value** dialog (see below) where you can enter the desired value for the selected parameter. This value will be applied to all entries in the table.
Enter/change value (selected items)	If applicable: Opens the **Enter value** dialog (see below) where you can enter the desired value for the selected parameter. This value will be applied to the selected entries in the table.
Delete selected items	If applicable: Removes the selected items from the scene.

The **Enter value** dialog includes the following controls:

Table 45-80: Controls in the **Enter value** dialog

Control	Description
Enter value field	Allows you to enter the desired value.
OK button	Sets the selected parameter to the specified value.
Reset button	For analyses only: Resets the selected parameter to undefined.
Set from tolerance settings button	For analyses only: Enters the value specified in the tolerance settings of the analysis for the selected parameter.
Cancel button	Discards the changes and closes the dialog.

Images Tab

Allows you to take screenshots of the selected workspace views and/or add bookmark references to the report. In the final report, the captured images will be listed separately from the screenshots created on other tabs.

- **Snapshots** section

  Table 45-81: Controls in the **Snapshots** section

Control	Description
Capture from button	Adds the image of the view selected from the drop-down list to the preview area above.

Control	Description
Delete selected button	Deletes the selected image(s) from the preview area.
use LMB to click and drag one or more images, then release LMB	Moves the image(s) to the new position.
double-click the image	Opens the **Snapshot display** window showing the image: • **Zoom in**/**Zoom out** button: Zooms the image in/out. You can also move the mouse pointer on the image area and turn the mouse wheel. • **Fit to window** button: Resets the zoom so that the image fits into the window.
click the **<no description>** place-holder twice (first click to select, second click to enable renaming)	Allows you to label the image.

- **Automatic 3D images** section (if available)

  Check the corresponding checkbox to include the desired 3D view (e.g., **Top**, **Front**, **Top-left-front**, and **Current camera settings**) in the report without changing the 3D view.

- **Bookmark references** section

  Allows you to add bookmark references via drag and drop from the **Bookmarks and views** tool or the **Bookmark editor** to the preview area. The images of the referenced bookmarks will then be included in VGRF-based reports.

  When you open a project with missing bookmark images, placeholders will be shown instead.

  Bookmark references are stored in evaluations and can be used in automation scenarios.

You will still need to import a bookmark template containing the actual bookmarks in these cases, as evaluations store only references to them.

Table 45-82: Controls in the **Bookmark references** section

Control	Description
New bookmark button	Adds a bookmark of the current view to the preview area.
Remove button	Removes the bookmark currently selected in the preview area.

Control	Description
click the bookmark title twice (first click to select, second click to enable renaming) or press the **F2** key	Allows you to rename the bookmark. The changes made on the **Images** tab will also affect the **Bookmark editor** and the **Bookmarks and views** tool. If the renamed bookmark is referenced by one or more objects for reporting, a warning message will be displayed indicating that the referenced bookmark will also be renamed for all these objects in the report.

The global concept of bookmark references allows for multiple objects to reference the same bookmark and for objects to reference bookmarks that show arbitrary information, e.g., other analyses or objects.

Rules Tab

Shows existing rules for selecting features (e.g., probability, radius) with defined properties to be included in the final report. Apart from that, the **Rule** dialog allows you to create new rules and edit or delete existing rules.

With the default rule **Big five**, images of the five indications with the largest diameters will automatically be created and included in your standard report.

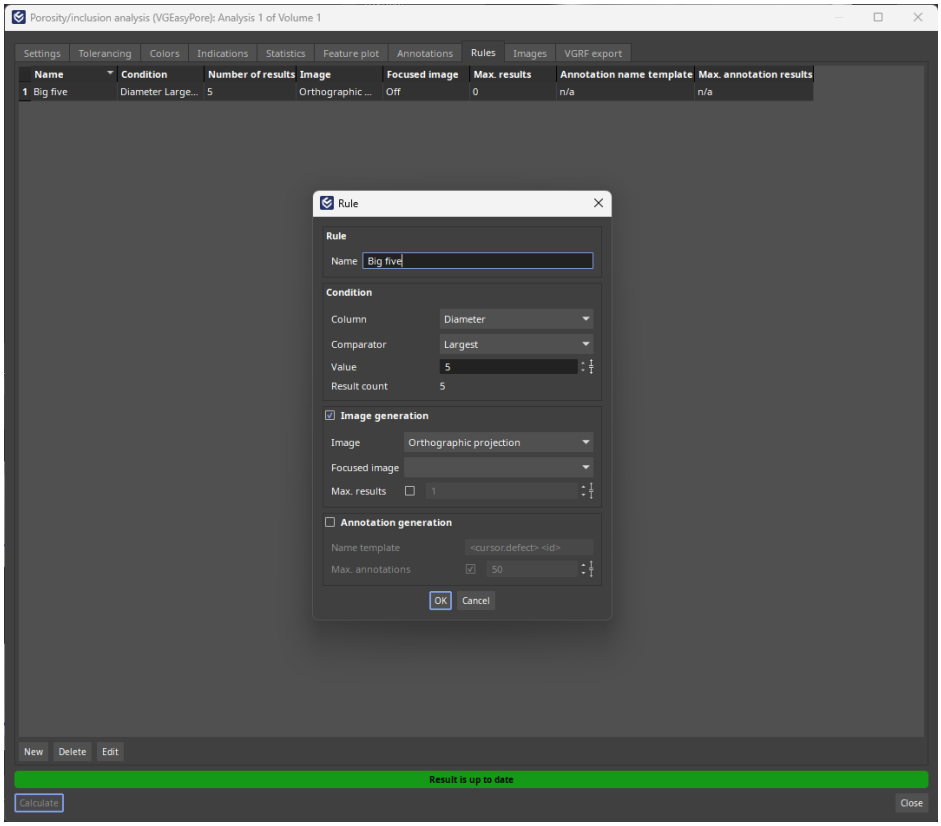


Figure 45-23: **Rules** tab with **Rule** dialog

- **New** button
  Opens the **Rule** dialog for creating a new rule.
- **Delete** button
  Deletes a selected rule.
- **Edit** button
  Opens the **Rule** dialog for editing a selected rule.

You can also double-click a rule to open the **Rule** dialog for editing a selected rule.

Rule Dialog

- **Rule** section
  The **Name** field allows you to enter a name for the new rule. This name has to be unique.
- **Condition** section

  Table 45-83: Controls in the **Condition** section

Control	Description
Column drop-down list	Selects the property of the feature (e.g., probability, radius, diameter) that defines the rule.

Control	Description
Comparator drop-down list	Specifies the comparator to be applied to the selected property.
Value [<unit>] spin box or drop-down list	Specifies the reference value or status of the selected property for comparison.
Result count field	Indicates the number of results that meet the specified condition.

- **Image generation** section

Table 45-84: Controls in the **Image generation** section

Control	Description
Image drop-down list	Allows you to add a detailed 2D image and object description on a separate page of the report. • **Off**: No image is created (default). • **Orthographic projection**: Creates three orthogonal views. • **Top/Bottom/Left/Right/Front/Back**: Creates a single 2D view in the specified orientation. • If applicable: **... - If not OK**: Automatically creates the image if the tolerance status is **Out of tolerance**.
Focused image drop-down list	This option is almost identical to the **Image** option, but will generate an image that focuses on the respective item and is zoomed in by the **Zoom factor** specified during report creation or VGRF-based export.
Max. results checkbox and spin box	When this option is checked, you will be able to use the corresponding spin box to specify the maximum number of results to be included in the report.

- **Annotation generation** section

Table 45-85: Controls in the **Annotation generation** section

Control	Description
Name template field	Allows you to enter a name for the annotations. If this is not done, a name of the form <*annotation type*> <*id*> will automatically be generated.
Max. annotations checkbox and spin box	When this option is checked, you will be able to use the corresponding spin box to specify the maximum number of annotations to be generated.

In contrast to manually created annotations, rule-based annotations can neither be moved nor deleted. This is indicated by a closed padlock symbol next to the annotation name in the annotation label.

Rule-based annotations that are based on components are created at the position of the component that fulfills the condition. For wall thickness analyses performed with the **Sphere method** algorithm and nominal/actual comparisons, the position of the component is always the spatial center (or—if the spatial center lies outside the component—a position within the component that is closest to the spatial center), while for wall thickness analyses performed with the **Ray method** algorithm, the position is defined by the **Position property** option on the **Settings** tab of the properties dialog.

- **OK** button

  Closes the dialog, adds the new rule to the list in the **Rules** tab and updates the annotations.
- **Cancel** button

  Discards the settings and closes the dialog.

Evaluations

Introduction

In VGSTUDIO MAX, it is possible to evaluate items in the Scene Tree, e.g., volume objects, analyses, or GD&T features.

The result of the evaluation is indicated by an evaluation icon in front of each item in the Scene Tree, which shows whether the item is invalid, valid, or without evaluation. For a list of evaluation icons, see section *Entries in the Scene Tree* on page 218 in chapter 21 *Scene Tree Tool*.

The evaluation status is passed on from the child items to the parent items in the Scene Tree hierarchy. An item can only be valid if all child items are valid. For example, if a volume object has several analyses and one of the analyses is invalid, the volume object will also be invalid.

The information that a geometry element is invalid (e.g., the geometry element could not be fitted) will not affect the evaluation state of its parent item in the Scene Tree.

If a GD&T feature depends on this geometry element, the GD&T feature will be marked with a warning sign and its evaluation status will be “invalid.”

The warning sign of a GD&T feature is only passed upwards if a tolerance has been defined for it.

This default behavior can be overwritten by a user-defined evaluation using the **Evaluation** dialog (see section *Evaluation properties* on page 942). To open this dialog,

- right-click the object in the Scene Tree and select **Evaluation properties** from the context menu or
- double-click the evaluation icon in front of the volume object, CAD model, or surface mesh in the Scene Tree.

In myVGL, all parameter settings are displayed. Most of these parameters are read-only in myVGL. The complete functional range is available with VGSTUDIO MAX and the respective add-on module(s).

Evaluation Criteria

The following paragraph describes the evaluation criteria applied to the individual objects in the Scene Tree.

- Volume object
  - A volume object will have no evaluation if it has no child items or if all of its child items have no evaluation.
  - A volume object without a user-defined evaluation will be valid if all its child items are valid. If one or more of its child items are invalid, the volume object will be invalid.
  - If the volume object has a user-defined evaluation, it will be evaluated according to the result of the user-defined evaluation.
- CAD model, surface mesh, or ROI

- A CAD model, a surface mesh, or an ROI will have no evaluation if it has no child items or if all its child items have no evaluation.
- A CAD model, a surface mesh, or an ROI without a user-defined evaluation will be valid if all its child items are valid. If one or more of its child items are invalid, the CAD model, surface mesh, or ROI will be invalid.
- If the CAD model, surface mesh, or ROI has a user-defined evaluation, it will be evaluated according to the result of the user-defined evaluation.

- GD&T feature

  A GD&T feature will be invalid if it does not fulfill its tolerance. It will be valid if it fulfills its tolerance or if it does not have a tolerance.
- Analysis
  - An analysis will be marked as having no evaluation and no tolerance if no tolerance is defined for it or if it has not been calculated yet.
  - An analysis will be invalid if it does not fulfill one of its tolerances. An analysis will be valid if it fulfills all its tolerances.
  - The tolerances available for the individual analysis types are described in the chapter on the corresponding analysis.

Evaluation properties

The default evaluation behavior (i.e., passing on the evaluation status to parent entries) can be overwritten by a user-defined evaluation that can be defined for a volume object, a CAD model, a surface mesh, an ROI, or the scene by using the **Evaluation** dialog.

In order to open the **Evaluation** dialog,

- right-click the object in the Scene Tree and select **Evaluation properties** from the context menu or
- double-click the evaluation icon in front of the volume object, CAD model, or surface mesh in the Scene Tree.

The **Evaluation** dialog lists the evaluation rules for the volume object, CAD model, or surface mesh selected in the Scene Tree.

☞ You can define more rules in VGSTUDIO MAX or VGMETROLOGY only.

A rule can be based on:

- The evaluation of a child item.
- The tolerance of a GD&T feature.

  The tolerance must be defined in the dialog of the GD&T feature, e.g., in the **Dimensioning** dialog or in the **Geometric tolerancing** dialog.
- The tolerance of an analysis.

  The tolerance can either be set in the **Evaluation** dialog or in the **Tolerance settings** section of the **Properties** dialog of the analysis. If a tolerance is specified in both places, the tolerance settings in the **Evaluation** dialog will overwrite the tolerance settings of the analysis.

Rules can be combined by the logical operators AND, OR, NOT. You can use parentheses to logically group the rules.

Tolerance values will be interpreted according to DIN EN ISO 8015 (see also section *Rounding Rules* on page 4 in chapter 1 *Welcome*).

Columns of the Rules List

Table 46-1: Columns of the rules list

Column	Description
Name	Name of the rule. By default, the rules are named rule1, rule2, rule3, etc.
Source Object	All child items being evaluated can be used as source object for a rule.
Property	Lists the properties of the source object. The properties of an analysis are all tolerances of this type of analysis. The properties of an analysis annotation can either be its deviation value or its evaluation status. For all other source objects, it is their evaluation status.
Actual Value	Indicates the actual value of the property if it is a value and not a status.
Nominal Value	Indicates the nominal value of the property if it is a value and not a status.
Min. Tolerance	Indicates the minimum tolerance of the property if the property specifies a minimum value.
Max. Tolerance	Indicates the maximum tolerance of the property if the property specifies a maximum value.
Visual tolerance	Graphically indicates the tolerance of the property if it is a value and not a status.

Column	Description

Status	Indicates the status of the rule:
	• **No Tolerance**: No tolerance settings have been defined for the source object.
	• **Out of Tolerance**: The tolerance is not fulfilled.
	• **Undefined**:
	  • Tolerance settings have been defined for the *feature*, but at least one of its source objects is in an undefined or inconsistent state, i.e., there is a warning sign in the Scene Tree.
	  • Tolerance settings have been defined for the *analysis* or *annotation*, but the analysis must be recalculated or the annotation is not snapped to the surface.
	• **Undefined Source Object**: No source object has been specified.
	• **Undefined Source Parameter**: No property has been specified.
	• **Valid**: The tolerance is fulfilled.
	• **Valid But Unused**: The tolerance is fulfilled, but the rule is not applied.

VGEXPLORER INTEGRATION

The VGEXPLORER INTEGRATION allows you to get information on the contents of a project without opening it.

This feature is only available on Microsoft Windows operating systems.

In the Windows Explorer, right-click a project file and select **Preview** from the context menu to open the preview dialog.

The following controls are available:

- **Preview**

  The **Preview** shows a screenshot of the 3D view as it was last saved with an icon that shows the overall evaluation state. You can use the **Preview** to visually identify a project.
- Top-level objects such as volume objects, CAD models, and surface meshes

  If a volume includes ROIs, this will be indicated by a + sign in front of the volume. Clicking the + sign lists all ROIs.

  Click one of the top-level objects to see more information on the content of the project. Some information is only available for volumes.
  - **Alignment**

    Provides information on the alignment method and corresponding tolerance settings, if available. For details, see section *Alignment Tab* on page 86 in chapter 5 *Edit Tab*.
  - **Scanner manufacturer information**

    Shows the scanner manufacturer information that is available in the project file. For details, see section *Scanner manufacturer info Dialog* on page 44 in chapter 3 *File Tab*.
  - **Component information**

    Shows the information on the scanned part that is available in the project file. For details, see section *Component info Dialog* on page 44 in chapter 3 *File Tab*.
  - **Scan information**

    Shows the scan information that is available in the project file. For details, see section *Scan info Dialog* on page 44 in chapter 3 *File Tab*.
  - **Reconstruction parameters**

    Shows the parameters used for reconstructing the volume.

This information is available only if the volume data has been reconstructed using the optional CT reconstruction module of VGSTUDIO MAX/VGSTUDIO.

  - **Import settings**

    Shows the settings used for importing the data into the project.
  - **Analysis information**

    Shows the number of analyses, geometry elements, and GD&T features attached to the selected object as well as their evaluation state.
  - **File list**

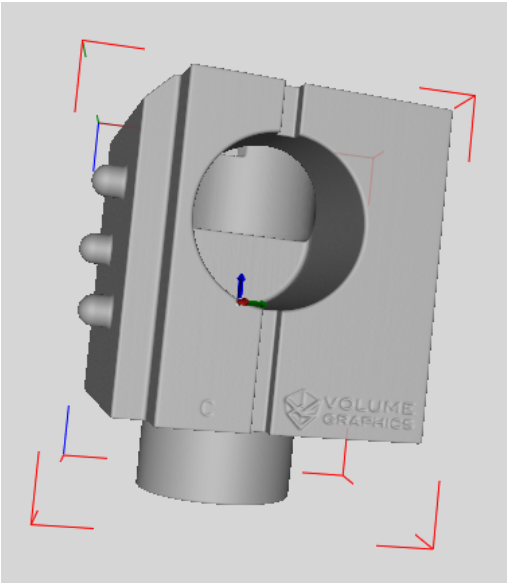
    Shows a list of the CT data files that are referenced in the project and some of their properties (file path, dimensions, format, type, etc.).

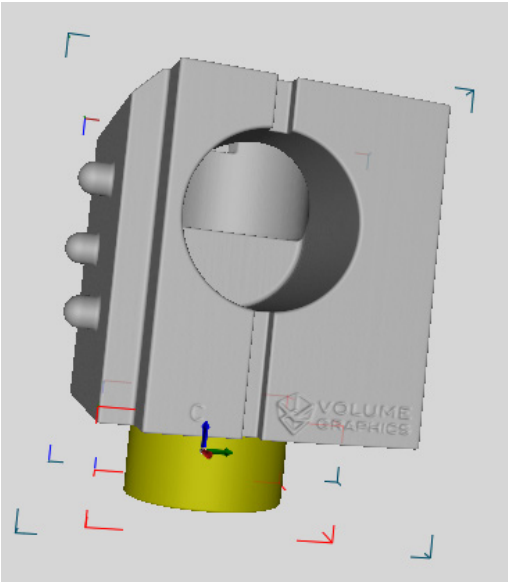
- **Bookmarks**
  Show the titles and bookmark images of all bookmarks included in the project.
- **open all**
  Shows all ROIs.
- **close all**
  Shows only the top-level objects.
- Printer icon
  Clicking the printer icon at the bottom right of the dialog will open the **Choose pdf file name…** dialog where you can specify a path and file name for saving the project information as *.pdf* file.

Glossary

Alignment
Aligning an object changes its position in the scene. Reasons for aligning an object include setting it to an upright position, preparing it for GD&T tasks in a given coordinate system, and comparing its geometries to another part. Two simple alignment options are available in VGSTUDIO. Additional advanced alignment options are available in VGSTUDIO MAX and VGMETROLOGY.

Bounding box
The bounding box delimits the data set of a scanned object (left) or the region of interest (right) in the 3D view, usually including the surrounding air.





Comma separated values (*.csv*)
Files of the *.csv* format store tabular data that use a semicolon, a tab, or a blank to separate values.

Coordinate system
myVGL uses right-handed Cartesian coordinate systems to display data. The orientation of each 2D or 3D window with respect to the currently chosen coordinate system is indicated by the tripod in the lower left corner. To align the slices in the 2D windows in different ways, you can choose between several coordinate systems.

Endianness
Specifies the byte order used for representing certain data. There are two choices: big endian and little endian. Big-endian systems store the most significant byte of a word in the smallest address and the least significant byte in the largest address. In contrast, little-endian systems store the least significant byte in the smallest address and the most significant byte in the largest address.

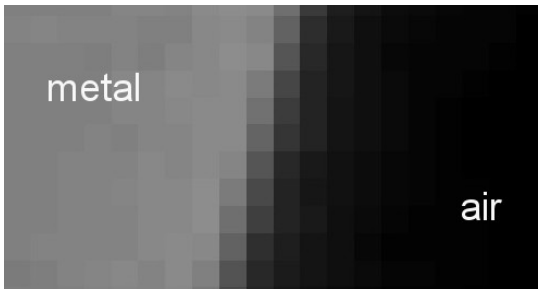
Imperfection
In non-destructive examination (NDE), an imperfection is a departure of a quality characteristic from its intended condition. Imperfections can be **voids** or **inclusions**.

Indication
An indication is the result of a non-destructive examination (NDE). It can be imperfections in metal castings, additive manufacturing components, plastic injection parts, and weldings.
An indication requires interpretation to determine its relevance as relevant, non-relevant, false. If an indication is interpreted as detrimental, it may be called a defect.

Isovalue line
Defines the surface of the object, i.e., the boundary between darker gray values (e.g., air) and brighter gray values (e.g., metal) by using a global surface gray value for the whole data set.

Keyframe
An individual image in a series of consecutive images used for creating an animation or movie.

Partial Voxel Effect
Describes the effect that occurs when properties of different materials can be merged within a single voxel because of the limited resolution of CT scans. For example, if you zoom into an air/metal transition, you will see voxels with intermediate gray values (see image below). myVGL uses these voxels of intermediate gray values to determine the surface of an object with sub-voxel precision.



PCA, Principal Component Analysis
A statistical procedure that allows you to reduce a large number of variables to a few linear combinations of the data, each of which corresponds to a principal component.

Preset
In myVGL, you can save various sets of parameters as presets (e.g., the settings made for a specific object in the **Rendering** tool). You can load these presets later to apply them to different objects or export them to different computers.

Geometry element
VGSTUDIO MAX offers the following geometry elements: points, lines, (corner) circles, planes, spheres, cylinders, cones, tori, freeform lines, and freeform surfaces. They can be fitted to the volume object, CAD model, or surface mesh, defined by entering the required coordinates, or constructed through geometry element manipulation. Geometry elements can be used for creating dimensioning or tolerance features. You can also use geometry elements to align an object.

Rendering
Rendering is the process of computing and displaying an image based on a model. The rendering process can include the application of shadows, lighting, perspective, and texture.

Spin box
A spin box is a combination of a text box with an up/down control. The value ascends or descends incrementally. The user can

- manually edit the text box,
- position the cursor in the text box and press the up or down arrow key on the keyboard,

- click the up/down arrow buttons of the spin box,
- move the mouse pointer in the scroll area to the right of the up/down arrows until the mouse pointer changes shape and drag the mouse up or down while holding down the left mouse button, or
- position the mouse pointer anywhere in the spin box and scroll the mouse wheel.

Surface determination

A surface determination defines the boundary between a material component and the background (e.g., the surrounding air) or another material component. This boundary is displayed as an outline in the 2D windows (except in **Original** display mode). While the isovalue-based surface determination uses one gray value that is globally applied to the object, the advanced modes determine the surface on the basis of the local gray value differences. Performing a surface determination is only possible using VGSTUDIO MAX and VGMETROLOGY (during import).

Voids

In non-destructive examination (NDE), voids are hollow spots, depressions, or cavities. Voids and inclusions are considered imperfections.

Shortcuts

Introduction

This chapter provides an overview of the default keyboard shortcuts and mouse actions available in myVGL. You can customize the keyboard shortcuts via **File > Customize > Configure shortcuts**.

General

Global Actions

Table 49-1: Keyboard shortcuts for global actions

Objective	Shortcut
Create an empty scene	**Ctrl+N**
Open project	**Ctrl+O**
Undo last action	**Ctrl+Z**
Redo last action	**Ctrl+Y**
Delete selected object(s)	**Del**
Open reference manual	**F12**
Open **Preferences** dialog	**F9**
Open **Save images** dialog	**Ctrl+Shift+G**
Create **Bookmark**	**Ctrl+B**
Create **View**	**Ctrl+Shift+V**
Activate/deactivate the **Navigation Cursor**	**Ctrl+Shift+C**
Activate/deactivate the **Indicator**	**Alt+A**
Copy visual state	**Alt+C**
Paste visual state	**Alt+V**
Switch to **Rotate** mode	**Ctrl+Shift+R**
Switch to **Move** mode	**Ctrl+Shift+M**
Activate/deactivate the **Distance** instrument	**Alt+D**
Activate/deactivate the **Scene Tree** tool	**Ctrl+Shift+8**
Activate/deactivate the **Light** tool	**Ctrl+Shift+7**

Objective	Shortcut
Activate/deactivate the **Camera** tool	**Ctrl+Shift+6**
Activate/deactivate the **Clipping** tool	**Ctrl+Shift+5**
Activate/deactivate the **Rendering** tool	**Ctrl+Shift+3**
Activate/deactivate the **Bookmarks and views** tool	**Ctrl+Shift+2**
Activate/deactivate the **Automation** tool	**Ctrl+Shift+1**
Open **Search** function	**F1**
Quit application	**Alt+F4**

Tables

Table 49-2: Shortcuts in tables

Objective	Shortcut
Select table row	Click table row
Select several disconnected rows	Hold down **Ctrl** + click several table rows
Select several consecutive rows	• Click first table row to be included in selection, hold down **Shift**, and click last table row to be included in selection • Click first table row to be included in selection, hold down **Shift**, and press up or down arrow key
Select all table rows	**Ctrl+A**
Step up or down through table rows	Press up or down arrow key
Display context menu	Use RMB to click table area
Sort table	Click column heading; clicking subsequently toggles between ascending and descending order
Move column to new position	Click and drag column heading to new position and release LMB
Edit cell contents	If applicable: Double-click cell highlighted in white (light theme) or medium gray (dark theme)

Charts or Histograms

Table 49-3: Shortcuts in charts or histograms

Objective	Shortcut
Display context menu	Use RMB to click chart area
Zoom x-axis of chart out/in	Scroll MW in chart area or x-axis up/down
Zoom y-axis of chart out/in	Scroll MW in y-axis up/down
Scroll x-axis	Click and drag x-axis
Scroll y-axis	Click and drag y-axis

File Import

Table 49-4: Shortcuts for file import

Objective	Shortcut
Import one or more CAD, surface mesh, or point cloud files	Drag file(s) from file browser into myVGL
Open **CAD import** dialog while importing one or more CAD files via drag and drop	Hold down **Ctrl** + drag file(s) from file browser into myVGL
Open **Mesh import** dialog while importing one or more surface mesh files via drag and drop	Hold down **Ctrl** + drag file(s) from file browser into myVGL
Open **Specify file format** (for text files) while importing one or more point cloud files via drag and drop	Hold down **Ctrl** + drag file(s) from file browser into myVGL
Open context menu with import settings options while importing one or more CAD, surface mesh, or point cloud files via drag and drop	• Use RMB to drag file(s) from file browser into myVGL • Hold down **Alt** + drag file(s) from file browser into myVGL

Scene Tree

Table 49-5: Shortcuts in the Scene Tree

Objective	Shortcut
Select object	Click corresponding entry in Scene Tree
Select several objects	Hold down **Ctrl** + click several entries in Scene Tree

Objective	Shortcut
Select several consecutive objects	• Click first entry to be included in selection, hold down **Shift**, and click last entry to be included in selection • Click first entry to be included in selection, hold down **Shift**, and press the up or down arrow key
Display context menu for object	Use RMB to click corresponding entry in Scene Tree
Open properties dialog for object	Double-click corresponding entry in Scene Tree
Delete object	Click corresponding entry in Scene Tree + press **Del**
Rename object	• Click corresponding entry in Scene Tree + press **F2** • Click corresponding entry in Scene Tree twice (first click to select, second click to enable renaming)
Rename several objects at a time	Click corresponding entries in Scene Tree + press **F2** to open **Rename objects** dialog
Show/hide object in scene	Check/uncheck checkbox in front of corre-sponding entry in Scene Tree
Show/hide one or more objects in scene	Select the object(s) in the Scene Tree and press the space bar
Open **Evaluation** dialog for volume object, CAD model, or surface mesh	Double-click evaluation indicator in front of volume object, CAD model, or surface mesh

3D Window

General

Table 49-6: Shortcuts in the 3D window

Objective	Shortcut
Toggle window between full size and current window layout	**F11**
Toggle between **Move** and **Rotate** mode	Use MMB to double-click in window
Switch to **Rotate** mode	**Ctrl+Shift+R**
Switch to **Move** mode	**Ctrl+Shift+M**

Objective	Shortcut
Enter the **Select objects (3D)** mode	**Ctrl+Shift+D**
Enter the **Select fit point (3D)** mode	**Ctrl+Shift+F**
Select object	Double-click object
Select multiple objects	Hold down **Ctrl** + double-click objects
Deselect all objects	Double-click background
Zoom object at POI (point of interest), i.e., at current mouse pointer position out/in	Scroll MW up or down Tip: If you are using a laptop without a mouse, you can touch the touchpad with two fingers and move them apart or together to zoom (make sure the **Pinch to zoom** option is activated in the Windows touchpad settings). Alternatively, you can drag two fingers up and down (make sure the **Drag two fingers to scroll** option is activated in the Windows touchpad settings). Note: To reverse the zoom direction, check the **Reverse mouse wheel zoom** option in the **3D window** section of the **Preferences > General > Window** dialog.
Center object and adjust zoom level	When the **Spherical** navigation mode is selected in the preferences: Use MMB to double-click in window
Set the rotation center	When the **Spherical** navigation mode is selected in the preferences: Hold down **Shift** + click
Open **Colors** tab of analysis	Double-click analysis color bar
Create analysis annotation	When the **Create analysis annotation** function is active: Hold down **Ctrl** + click
Open **Tolerance visualization settings** dialog	Double-click tolerance color bar

Select objects (3D)

Table 49-7: Shortcuts in the 3D window in the **Select objects (3D)** mode

Objective	Shortcut
Select several objects at a time	Click and drag in 3D window to draw a rectangle, ellipse, or lasso; when you hold down **Ctrl** while clicking and dragging, the object selection mode will remain active until you release the **Ctrl** key
Deselect several objects at a time	Hold down **Shift** + click and drag in 3D window to draw a rectangle, ellipse, or lasso; the object selection mode will remain active until you release the **Shift** key
Select an individual object	Click the center of mass of the object in 3D
Add an object to the selection	Hold down **Ctrl** + click the center of mass of the object
Remove an object from the selection	Hold down **Shift** + click the center of mass of the object
Display a label that indicates object type and name	Hover the mouse pointer over the center of mass of the object
Quit the object selection mode	Press **Esc**

Select fit points (3D)

Table 49-8: Shortcuts in the 3D window in the **Select fit points (3D)** mode

Objective	Shortcut
Select several fit points at a time	Click and drag in 3D window to draw a rectangle, ellipse, or lasso; when you hold down **Ctrl** while clicking and dragging, the fit point selection mode will remain active until you release the **Ctrl** key
Deselect several fit points at a time	Hold down **Shift** + click and drag in 3D window to draw a rectangle, ellipse, or lasso; the fit point selection mode will remain active until you release the **Shift** key
Select an individual fit point	Click the fit point in 3D
Add a fit point to the selection	Hold down **Ctrl** + click the fit point
Remove a fit point from the selection	Hold down **Shift** + click the fit point
Quit the fit point selection mode	Press **Esc**

Select CAD elements (3D)

Table 49-9: Shortcuts in the 3D window in the **Rectangle**, **Ellipse**, or **Lasso** mode

Objective	Shortcut
Select several topological entities at a time	Click and drag in 3D window to draw a rectangle, ellipse, or lasso; when you hold down **Ctrl** while clicking and dragging, the selection mode will remain active until you release the **Ctrl** key
Deselect several topological entities at a time	Hold down **Shift** + click and drag in 3D window to draw a rectangle, ellipse, or lasso; the selection mode will remain active until you release the **Shift** key

Rotate Mode: Rotate Object

Controls available in the 3D window for rotating an object in the scene (object is unlocked):

Table 49-10: Shortcuts in the 3D window, **Rotate** mode: rotate object

Objective	Shortcut
Rotate object	Click + drag
Rotate object more slowly	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Hold down **Ctrl** + LMB + drag
Rotate object around either vertical or horizontal screen axis	• When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Hold down **Shift** + LMB + drag • When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Always** or **Hotkey**: Hold down **Ctrl** + **Shift** + LMB + drag
Rotate object more slowly around either vertical or horizontal screen axis	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Hold down **Ctrl** + **Shift** + LMB + drag
Rotate object counterclockwise or clockwise	Hold down MMB + move up or down

Rotate Mode: Rotate Camera

Controls available in the 3D window for rotating the camera around an object (object is locked):

Table 49-11: Shortcuts in the 3D window, **Rotate** mode: rotate camera

Objective	Shortcut
Rotate camera around object	Click + drag
Rotate camera more slowly around object	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Hold down **Ctrl** + LMB + drag
Rotate camera around either vertical or horizontal screen axis	• When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Hold down **Shift** + LMB + drag • When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Always** or **Hotkey**: Hold down **Ctrl** + **Shift** + LMB + drag
Rotate camera more slowly around either vertical or horizontal screen axis	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Hold down **Ctrl** + **Shift** + LMB + drag
Rotate camera using current mouse pointer position as rotation center	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Hotkey**: Hold down **Shift** + LMB + drag
Rotate camera counterclockwise or clockwise	Hold down MMB + move up/down
Rotate camera around vertical screen axis	Press left or right arrow key
Rotate camera around horizontal screen axis	Press up or down arrow key

Move Mode: Move Object

Controls available in the 3D window for moving an object in the scene (object is unlocked)

Table 49-12: Shortcuts in the 3D window, **Move** mode: move object

Objective	Shortcut
Move object	Click + drag

Objective	Shortcut
Move object more slowly	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Hold down **Ctrl** + LMB + drag
Move object along either vertical or horizontal screen axis	• When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Hold down **Shift** + LMB + drag • When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Always** or **Hotkey**: Hold down **Ctrl** + **Shift** + LMB + drag
Move object more slowly along either vertical or horizontal screen axis	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Hold down **Ctrl** + **Shift** + LMB + drag
Move object to back or front	Hold down MMB + move up or down

Move Mode: Move Camera

Controls available in the 3D window for moving the camera (object is locked):

Table 49-13: Shortcuts in the 3D window, **Move** mode: move camera

Objective	Shortcut
Move camera along object	Click + drag
Move camera more slowly along object	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Hold down **Ctrl** + LMB + drag

Objective	Shortcut
Move camera along either vertical or horizontal screen axis	• When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Hold down **Shift** + LMB + drag • When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Always** or **Hotkey**: Hold down **Ctrl** + **Shift** + LMB + drag
Move camera more slowly along either vertical or horizontal screen axis	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Hold down **Ctrl** + **Shift** + LMB + drag
Move camera to back or front	Hold down MMB + move up/down
Move camera along vertical screen axis	Press up or down arrow key
Move camera along horizontal screen axis	Press left or right arrow key

2D Windows

General

Table 49-14: Shortcuts in the 2D windows

Objective	Shortcut
Activate **Original display mode**	**Ctrl+T**
Toggle window between full size and current window layout	**F11**
Scroll through slices	**Page Up/Page Down** Or: • When the **Mouse wheel** option in the **2D windows** section of the **Preferences > General > Window** dialog is set to **Scroll slices**: Scroll MW • When the **Mouse wheel** option in the **2D windows** section of the **Preferences > General > Window** dialog is set to **Zoom view**: Hold down **Ctrl** + scroll MW

Objective	Shortcut
Go to first or last slice in data set	**Home**/**End**
Scroll in horizontal direction	Press left or right arrow key
Scroll in vertical direction	Press up or down arrow key
Scroll in horizontal or vertical direction	• Click object with MMB and drag • Hold **Alt** + click and drag object
Zoom in	**Ctrl++**
Zoom out	**Ctrl+–**
Reset zoom	**Ctrl+0**
Zoom object at POI (point of interest), i.e., at current mouse pointer position out/in	• When the **Mouse wheel** option in the **2D windows** section of the **Preferences > General > Window** dialog is set to **Scroll slices**: Hold down **Ctrl** + scroll MW up or down • When the **Mouse wheel** option in the **2D windows** section of the **Preferences > General > Window** dialog is set to **Zoom view**: Scroll MW up or down Note: To reverse the zoom direction, check the **Reverse mouse wheel zoom** option in the **2D window** section of the **Preferences > General > Window** dialog.
Reset zoom	**Ctrl+0**
Center slice view of object and adjust zoom level	**Ctrl+Alt+0** When the **Spherical** navigation mode is selected in the preferences: Use MMB to double-click in window
Open **Colors** tab of analysis	Double-click analysis color bar
Create analysis annotation	When the **Create analysis annotation** function is active: Hold down **Ctrl** + click
Open **Tolerance visualization settings** dialog	Double-click tolerance color bar

Profile Window

General

Table 49-15: Shortcuts in **Profile** window

Objective	Shortcut
Move start or end point of instrument	Click and drag vertical line A or B, respectively

Analysis Interval

Table 49-16: Shortcuts for analysis intervals in **Profile** window

Objective	Shortcut
Move interval	Click and drag interval
Increase or decrease interval width	Click and drag interval border
Resize interval	Scroll MW
Resize interval faster	Hold down **Shift** + scroll MW
Display the values of all selected intervals	Hold down **Ctrl** + click several intervals

Rendering Tool

Table 49-17: Shortcuts on the **Voxel** tab of the **Rendering** tool

Objective	Shortcut
Change isosurface	For isosurface renderer only: Click and drag red isosurface line Note: The isosurface line can only be moved if the selected object has no surface determination or if the surface determination render settings of the selected volume have been disabled by clicking the **Disable surface determination render settings** button.
Display axis tick labels	Hover mouse pointer over histogram axis
Display gray value of isosurface line	Click and hold LMB in histogram area
Display minimum and maximum gray value of volume	Click and hold LMB in histogram area
Insert color handle	Use MMB to click color area
Remove color handle	Use MMB to click handle in color area

Objective	Shortcut
Show gray value of color handle	Click color handle
Move color handle	Click and drag color handle
Assign color to gray value of color handle	Double-click color handle to open **Select Color** dialog
Move color segment	Possible only if color handle is not associated with start or end of interval: Click and drag color segment
Assign color to all gray values in color segment	Double-click color segment to open **Select Color** dialog
Insert opacity handle	Use MMB to click histogram area
Remove opacity handle	Use MMB to click opacity handle
Move opacity handle	Click and drag opacity handle
If more than one interval is available: Move interval divider line to new position	Hover mouse pointer over interval divider line until mouse pointer changes to double-headed arrow, then click and drag double-headed arrow
If more than one interval is available: Create new interval	Hover the mouse pointer over an interval divider line until triangular handles appear to the left and right of the interval divider line; then, click and drag the right or left handle in the indicated direction to create the new interval from the interval divider line to the point where you release the mouse button
Rename interval label	Click interval label
Zoom y-axis of gray value histogram out/in	Scroll MW on left y-axis up/down
Zoom opacity curve out/in	Scroll MW on right y-axis up/down
Zoom x-axis of gray value histogram out/in	Scroll MW in histogram area or x-axis up/down
Open context menu	Use RMB to click the histogram area or the color area

Bookmark editor

Table 49-18: Keyboard shortcuts in the **Bookmark editor**

Objective	Shortcut
Delete one or more bookmarks	Select the bookmark(s) and press **Del**

Bookmarks and views Tool

Table 49-19: Keyboard shortcuts in the **Bookmarks and views** tool

Objective	Shortcut
Delete one or more bookmarks	Select the bookmark(s) and press **Del**
Delete one or more views	Select the view(s) and press **Del**

Reporting

The following shortcuts are available only in **Edit** mode.

Table 49-20: Shortcuts in the **Reporting** tool

Objective	Shortcut
Copy the selected page element(s) to the system clipboard and remove them from the page	**Ctrl+X**
Copy the selected page element(s) to the system clipboard	**Ctrl+C**
Paste the page element(s) from the system clipboard to the page	**Ctrl+V**
Save the current modifications applied to the layout	**Ctrl+S**
Undo the last action	**Ctrl+Z**
Redo the last action	**Ctrl+Y**
In **Background** mode: Select all elements in the background In **Content** mode: Select all elements in the active section	**Ctrl+A**
Move page element to new position	Click and drag page element
Display context menu	Use RMB to click page element
Resize page element	Click and drag handles on the frame around page element
Move or remove multiple page elements at once (multi-selection)	Click and drag on a page and draw a selection rectangle, starting from a corner. All page elements that are fully included when releasing the mouse button will be selected.
Remove page element from multi-selection	Hold down **Ctrl** or **Shift** and click a selected page element

Objective	Shortcut
Add page element to multi-selection	Hold down **Ctrl** or **Shift** and click an unselected page element
Resize table column	For tables only: Hover over column header and click and drag vertical line next to header Note: • A manually resized column will be locked (indicated by a 📌 pin icon) and retain the size. • If the table width is too small to display all the content, some content might be cut off.
Unlock table column	For tables only: Click 📌 pin icon
Move section group to new position	Click and drag headline to new position and release LMB
Move section within section group to new position	Click and drag section to new position and release LMB

Clipping Functions

Clipping Plane: **Rotate** Mode

Table 49-21: Shortcuts for the clipping plane in **Rotate** mode

Objective	Shortcut
Rotate clipping plane around its origin	Click and drag
Slowly rotate clipping plane around its origin	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Hold down **Ctrl** + click and drag
Rotate clipping plane around its origin and the viewing direction	Use MMB to click and drag
Slowly rotate the clipping plane around its origin and the viewing direction	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Hold down **Ctrl** + use MMB to click and drag

Clipping Plane: **Move** Mode

Table 49-22: Shortcuts for the clipping plane in **Move** mode

Objective	Shortcut
Move clipping plane relative to 3D view, i.e., perpendicularly to the viewing direction	Click and drag
Move clipping plane relative to 3D view, i.e., perpendicularly to the viewing direction, restricting movement to the horizontal or vertical direction	Hold down **Shift** + click and drag
Slowly move clipping plane relative to 3D view, i.e., perpendicularly to the viewing direction	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Hold down **Ctrl** + click and drag
Slowly move clipping plane relative to 3D view, i.e., perpendicularly to the viewing direction, restricting movement to horizontal or vertical direction	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Hold down **Shift** + **Ctrl** + click and drag
Move clipping plane in/out relative to 3D view, i.e., along the viewing direction	Use MMB to click and drag
Slowly move clipping plane in and out relative to 3D view, i.e., along the viewing direction	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Hold down **Ctrl** + use MMB to click and drag

Clipping Box: **Rotate** Mode

Table 49-23: Shortcuts for the clipping box in **Rotate** mode

Objective	Shortcut
Resize clipping box perpendicularly to sides of clipping box	Click and drag yellow handles
Rotate clipping box around its origin	Click and drag
Slowly rotate clipping box around its origin	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Hold down **Ctrl** + click and drag
Rotate clipping box around its origin and the viewing direction	Use MMB to click and drag

Objective	Shortcut
Slowly rotate clipping box around its origin and the viewing direction	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Hold down **Ctrl** + use MMB to click and drag

Clipping Box: **Move** Mode

Table 49-24: Shortcuts for the clipping box in **Move** mode

Objective	Shortcut
Resize clipping box perpendicularly to sides of clipping box	Click and drag yellow handles
Move clipping box relative to 3D view, i.e., perpendicularly to the viewing direction	Click and drag
Move clipping box relative to 3D view, i.e., perpendicularly to the viewing direction, restricting movement to the horizontal or vertical direction	Hold down **Shift** + click and drag
Slowly move clipping box relative to 3D view, i.e., perpendicularly to the viewing direction	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Hold down **Ctrl** + click and drag
Slowly move clipping box relative to 3D view, i.e., perpendicularly to the viewing direction, restricting movement to the horizontal or vertical direction	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Hold down **Shift**+ **Ctrl** + click and drag
Move clipping box in and out relative to 3D view, i.e., along the viewing direction	Use MMB to click and drag
Slowly move clipping box in and out relative to 3D view, i.e., along the viewing direction	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Hold down **Ctrl** + use MMB to click and drag

Clipping Polyline 3D: General

Table 49-25: Shortcuts for the clipping polyline 3D in general

Objective	Shortcut
Create control point	Hold down **Ctrl** + click
Remove control point	Hold down **Alt** + click control point
Move control point to new position	Click and drag red control point
Move line segment to new position	Click and drag yellow line segment
Move polyline to new position	Click and drag yellow polyline area
Close polyline	Click with MMB
Resize polygon perpendicularly to top and bottom faces	Click and drag yellow handles at top and bottom of clipping polygon

Clipping Polyline 3D: **Rotate** Mode

Table 49-26: Shortcuts for the clipping polyline 3D in **Rotate** mode

Objective	Shortcut
Rotate clipping polygon around its origin	Click and drag
Slowly rotate clipping polygon around its origin	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Hold down **Ctrl** + click and drag
Rotate clipping polygon around its origin and the viewing direction	Use MMB to click and drag
Slowly rotate clipping polygon around its origin and the viewing direction	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Hold down **Ctrl** + use MMB to click and drag

Clipping Polyline 3D: **Move** Mode

Table 49-27: Shortcuts for the clipping polyline 3D in **Move** mode

Objective	Shortcut
Move clipping polygon relative to 3D view, i.e., perpendicularly to the viewing direction	Click and drag

Objective	Shortcut
Move clipping polygon relative to 3D view, i.e., perpendicularly to the viewing direction, restricting movement to the horizontal or vertical direction	Hold down **Shift** + click and drag
Slowly move clipping polygon relative to 3D view, i.e., perpendicularly to the viewing direction	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Hold down **Ctrl** + click and drag
Slowly move clipping polygon relative to 3D view, i.e., perpendicularly to the viewing direction, restricting movement to horizontal or vertical direction	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Hold down **Shift** + **Ctrl** + click and drag
Move clipping polygon in and out relative to 3D view, i.e., along the viewing direction	Use MMB to click and drag
Slowly move clipping polygon in and out relative to 3D view, i.e., along the viewing direction	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Hold down **Ctrl** + use MMB to click and drag

Clipping Sphere: **Rotate** Mode

Table 49-28: Shortcuts for the clipping sphere in **Rotate** mode

Objective	Shortcut
Resize clipping sphere/ellipsoid	Click and drag yellow handles
Resize clipping sphere/ellipsoid proportionally	Hold down **Ctrl** + click and drag yellow handles
Force a clipping sphere and resize it proportionally	Hold down **Alt** + click and drag yellow handles
Rotate clipping sphere/ellipsoid around its origin	Click and drag
Slowly rotate clipping sphere/ellipsoid around its origin	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Hold down **Ctrl** + click and drag
Rotate clipping sphere/ellipsoid around its origin and the viewing direction	Use MMB to click and drag

Objective	Shortcut
Slowly rotate clipping sphere/ellipsoid around its origin and the viewing direction	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Hold down **Ctrl** + use MMB to click and drag

Clipping Sphere: **Move** Mode

Table 49-29: Shortcuts for the clipping sphere in **Move** mode

Objective	Shortcut
Resize clipping sphere/ellipsoid	Click and drag yellow handles
Resize clipping sphere/ellipsoid proportionally	Hold down **Ctrl** + click and drag yellow handles
Force a clipping sphere and resize it proportionally	Hold down **Alt** + click and drag yellow handles
Move clipping sphere/ellipsoid relative to 3D view, i.e., perpendicularly to the viewing direction	Click and drag
Move clipping sphere/ellipsoid relative to 3D view, i.e., perpendicularly to the viewing direction, restricting movement to the horizontal or vertical direction	Hold down **Shift** + click and drag
Slowly move clipping sphere/ellipsoid relative to 3D view, i.e., perpendicularly to the viewing direction	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Hold down **Ctrl** + click and drag
Slowly move clipping sphere/ellipsoid relative to 3D view, i.e., perpendicularly to the viewing direction, restricting movement to the horizontal or vertical direction	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Hold down **Shift** + **Ctrl** + click and drag
Move clipping sphere/ellipsoid in/out relative to 3D view, i.e., along the viewing direction	Use MMB to click and drag
Slowly move clipping sphere/ellipsoid in/out relative to 3D view, i.e., along the viewing direction	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Hold down **Ctrl** + use MMB to click and drag

Clipping Cylinder: **Rotate** Mode

Table 49-30: Shortcuts for the clipping cylinder in **Rotate** mode

Objective	Shortcut
Resize clipping cylinder/cone	Click and drag yellow handles
Force a clipping cylinder	Hold down **Ctrl** + click and drag yellow handles
Form truncated cone from cone	Hold down **Alt** + click and drag yellow handle of cone tip
Rotate clipping cylinder/cone around its origin	Click and drag
Slowly rotate clipping cylinder/cone around its origin	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Hold down **Ctrl** + click and drag
Rotate clipping cylinder/cone around its origin and the viewing direction	Use MMB to click and drag
Slowly rotate clipping cylinder/cone around its origin and the viewing direction	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Hold down **Ctrl** + use MMB to click and drag

Clipping Cylinder: **Move** Mode

Table 49-31: Shortcuts for the clipping cylinder in **Move** mode

Objective	Shortcut
Resize clipping cylinder/cone	Click and drag yellow handles
Force a clipping cylinder	Hold down **Ctrl** + click and drag yellow handles
Form truncated cone from cone	Hold down **Alt** + click and drag yellow handle of cone tip
Move clipping cylinder/cone relative to 3D view, i.e., perpendicularly to the viewing direction	Click and drag
Move clipping cylinder/cone relative to 3D view, i.e., perpendicularly to the viewing direction, restricting movement to the horizontal or vertical direction	Hold down **Shift** + click and drag

Objective	Shortcut
Slowly move clipping cylinder/cone relative to 3D view, i.e., perpendicularly to the viewing direction	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Hold down **Ctrl** + click and drag
Slowly move clipping cylinder/cone relative to 3D view, i.e., perpendicularly to the viewing direction, restricting movement to the horizontal or vertical direction	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Hold down **Shift** + **Ctrl** + click and drag
Move clipping cylinder/cone in/out relative to 3D view, i.e., along the viewing direction	Use MMB to click and drag
Slowly move clipping cylinder/cone in/out relative to 3D view, i.e., along the viewing direction	When the **Use dynamic rotation center** option in the **3D window** section of the **Preferences > General > Window** dialog is set to **Never**: Hold down **Ctrl** + use MMB to click and drag

Aligned Clipping Box

Table 49-32: Shortcuts for the aligned clipping box

Objective	Shortcut
Resize clipping box perpendicularly to sides of aligned clipping box	Click and drag yellow handles

Instruments

Distance Instrument

Table 49-33: Shortcuts for the **Distance** instrument

Objective	Shortcut
Draw line for measuring distance between start and end points	Click and drag
Modify position of start or end point	Click and drag handle
Modify position of start or end point, allowing current direction of measurement line to change only in steps of 45°	Hold down **Ctrl** + **Shift** + click and drag handle

Objective	Shortcut
Modify position of start or end point, restricting measurement line to the horizontal or vertical direction	Hold down **Shift** + click and drag handle
Move whole instrument	Click and drag baseline between handles

Angle Instrument

Table 49-34: Shortcuts for the **Angle** instrument

Objective	Shortcut
Modify angle	Click and drag handle
Modify current direction of line only in steps of 45°	Hold down **Ctrl** + **Shift** + click and drag handle
Modify position of handle, restricting movement to the horizontal or vertical direction	Hold down **Shift** + click and drag handle
Move whole instrument	Click and drag baseline between handles

Polyline length Instrument

Table 49-35: Shortcuts for the **Polyline length** instrument

Objective	Shortcut
Create control points	• 2D window: Click • 3D window: Hold down **Ctrl** + click
Add new point	• 2D window: Use MMB to click between existing points • 3D window: Hold down **Ctrl** + use MMB to click between existing points
Remove point	• 2D window: Use MMB to click point • 3D window: Hold down **Ctrl** + use MMB to click point
Move point to new position	Click and drag point
Move whole instrument	2D window: Click and drag baseline between handles
Scale polyline	Hold down **Alt** + scroll MW
Scale polyline only in one direction	Hold down **Alt** + **X** or **Y** + scroll MW

Caliper Instrument

Table 49-36: Shortcuts for the **Caliper** instrument

Objective	Shortcut
Draw line for measuring distance between start and end points	Click and drag
Modify position of start or end point	Click and drag middle handle
Resize additional line	Click and drag handle of additional line
Modify current direction of measurement line only in steps of 45°	Hold down **Ctrl** + **Shift** + click and drag handle
Modify position of handle, restricting measurement line to the horizontal or vertical direction	Hold down **Shift** + click and drag handle
Move whole instrument	Click and drag baseline between handles

Navigation Cursor

Table 49-37: Shortcuts for the **Navigation Cursor**

Objective	Shortcut
Position **Navigation Cursor**	Hold down **Ctrl** + click a point in any (2D or 3D) window
Modify position of **Navigation Cursor**	Click and drag **Navigation Cursor**

Paint & Segment

Table 49-38: Shortcuts for **Paint & Segment**

Objective	Shortcut
Change permanently between **Paint** and **Erase**	**X**
Change temporarily between **Paint** and **Erase**	Hold down **Shift**
Scroll through the classes	**Alt** + scroll MW
Switch between classes (from top to bottom)	**Ctrl**+**Tab** (Windows)/**Alt**+**Tab** (Linux)
Switch between classes (from bottom to top)	**Alt**+**Shift**+**Tab**
Change brush size	**Alt**+**Shift** + scroll MW
Activate and deactivate **Preview**	**P**

Objective	Shortcut
Deactivate the **Preview** temporarily	Hold down **O**

Draw to data Mode

This function will change the gray values of the volume data set.

Table 49-39: Shortcuts in **Draw to data** mode

Objective	Shortcut
Add painted area to data	2D window: Click and drag
Change gray value	Hold down **Shift**+**Ctrl** + scroll MW
Change radius of brush	Hold down **Shift** + scroll MW
Change smoothing value	Hold down **Alt** + scroll MW
Select gray value from data	Hold down **Ctrl** + click

Appendix

Data Types

The following table gives an overview of the data types used by myVGL:

Table 50-1: Data types

Data type	Description
8 bit unsigned/8 bit signed	8-bit code one gray value, each bit has either value 0 or value 1. Consequently, 2^8= 256 different gray values are possible. Gray values range from 0 to 255 (unsigned) or -128 to 127 (signed).
16 bit unsigned/16 bit signed	2^{16}= 65536 different gray values. Gray values range from 0 to 65535 (unsigned) or -32768 to 32767 (signed).
32 bit unsigned/32 bit signed[a]	More than one million different gray values. Gray values range from 0 to 1048575 (unsigned) or -524288 to 524287 (signed).
32 bit float	Effective gray value dynamics 32-bit float, 3D rendering as 16 bit.
RGB 8	8 bit per RGB component color images for a total of 24-bit color.

[a] Objects with 32-bit signed/unsigned data have an effective data range of 20 bit for all rendering procedures (full data range for analysis procedures).

File Formats

File Formats for Saving an Image, Image Stack, or Movie

Table 50-2: File formats for saving an image, image stack, or movie

Format	Extension	Description
Bitmap	**.bmp*	Color and grayscale images
JPEG	**.jpg*, **.jpeg*	Color and grayscale images
JPEG2000	**.jp2*	8/16-bit grayscale images, 8-bit RGB, 8-bit RGBA

Format	Extension	Description
PNG	*.png*	**Save image(s)**: 8-bit RGB **Save movie/image stack**: 8-bit RGB with optional and separate 8-bit grayscale alpha channel and 8/16-bit depth channel
PNG (with transparency)	*.png*	**Save image(s)**: 8-bit RGBA, available if only the **3D** option is checked in the **Views** section
Portable PixMap	*.ppm*	Color and grayscale images, binary 24-bit
Tiff	*.tif*, *.tiff*	Signed/unsigned 8/16-bit integer, 8-bit RGB, 8-bit RGBA
AVI movie	*.avi*	Uses the codecs installed on your system. Operating systems usually provide a set of standard codecs. Codecs are not part of the myVGL product package. In order to obtain optimal results, it may be useful to manually install a state-of-the-art codec.
ASF movie	*.wmv*	Uses the Windows Media Video codec.

Creating AVI (*.avi*) or ASF (*.wmv*) movies is only possible on Microsoft Windows systems.

If a codec does not show up on the selection list, it may be due to one of the following reasons:

- The codec is a 32-bit codec, but you are working on a 64-bit system.
- The selected settings do not meet the requirements of the codec, such as restrictions regarding the aspect ratio.

File Extensions

The table below lists the file extensions used by myVGL.

Do not edit or delete files in the project folder. This can lead to inconsistencies and system crashes or simply destroy your project.

Table 50-3: File extensions

File Extension	Description
.mvgl	VGMETROLOGY project file. Includes references to all imported objects, modifications (e.g., to rotation and transparency settings), and analysis results. Do not edit these files.

File Extension	Description
.preset	Preset file. Presets are available for various areas of the application. Each preset combines parameters of a specific area. You can transfer these files to another computer, but be aware that presets of the same name will be overwritten on that computer. Do not edit these files.
.vgarchive	VGSTUDIO MAX/VGSTUDIO archive file in a compact, single-file format created by the **Pack and go** function, which can be used for exchanging or forwarding projects. Do not edit these files.
.vgl	VGSTUDIO MAX or VGSTUDIO project file. Project files include references to all imported objects, modifications (e.g., to rotation and transparency settings), and analysis results. Do not edit these files. A *.vgl* file is combined to a project folder and—optionally—with a data folder of the same name to a project. Neither can be used without the other.
.vgrf	VG report directory containing a subdirectory structure with a complete collection of all data relevant for reporting. This data can be used for further processing by other applications.
.vgrl	User-defined default report layout file created by using the **Reporting** tool. You can reuse a default report layout to create similar reports of other content.
.vgrt	User-defined specific report layout file created by using the **Reporting** tool. You can use a specific report layout to create similar reports for exactly the same content structure.
.xvgt	Indicator template file. Do not edit these files.

License Conditions of 3rd Party Libraries

For a complete list of the 3rd party libraries used in our software, see the documents “License_Conditions_of_3rd_Party_Libraries” in the installation directory.

Q-DAS Export Fields

The following table lists the default fields used for exporting evaluation results with the Q-DAS export function. In addition to the default fields, you can define your own fields. In myVGL, you can add custom fields on the **Component** tab of the **Object properties** dialog by prefixing the corresponding tag with a K number. Custom fields are always written on component level and cannot be characteristic-specific.

Table 50-4: Header Data

Control	Description
K0100	Number of characteristics

Control	Description
K8500	Subgroup size
K8501	Subgroup type
K1001	Part number (serial number from the metainformation of volume component)
K1002	Part description (scene name of the volume)
K1004	Part amendment (currently always 0)
K1202	Test facility description (name, device name, acquisition software from the scanner manufacturer metainformation of the volume)
K1231	Measurement program number (version number of Hexagon software)
K1232	Measurement program version (name of Hexagon software, e.g., myVGL)
K1900	Remark (description from the metainformation of the volume component)
K0004	Time/date (production date/time from the metainformation of the volume component)
K0006	Batch number (lot number from the metainformation of the volume component)
K0007	Cavity number (cavity number from the metainformation of the volume component)

Table 50-5: Characteristic data

Control	Description
K2001	Characteristic number
K2002	Characteristic description (name of the feature in the scene, or tolerance name for analyses)
K2004	Characteristic type
K2005	Characteristic class (critical by default)
K2009	Measured quantity
K2022	Decimal places
K2030	Grouping field
K2031	Grouping field
K2101	Nominal value
K2110	Lower specification limit

Control	Description
K2111	Upper specification limit
K2112	Lower allowance
K2113	Upper allowance
K2142	Unit description
K2900	Remark (comment of the feature in case of CM results)
K8500	Subgroup size
K0001	Actual value
K0002	Actual value attribute