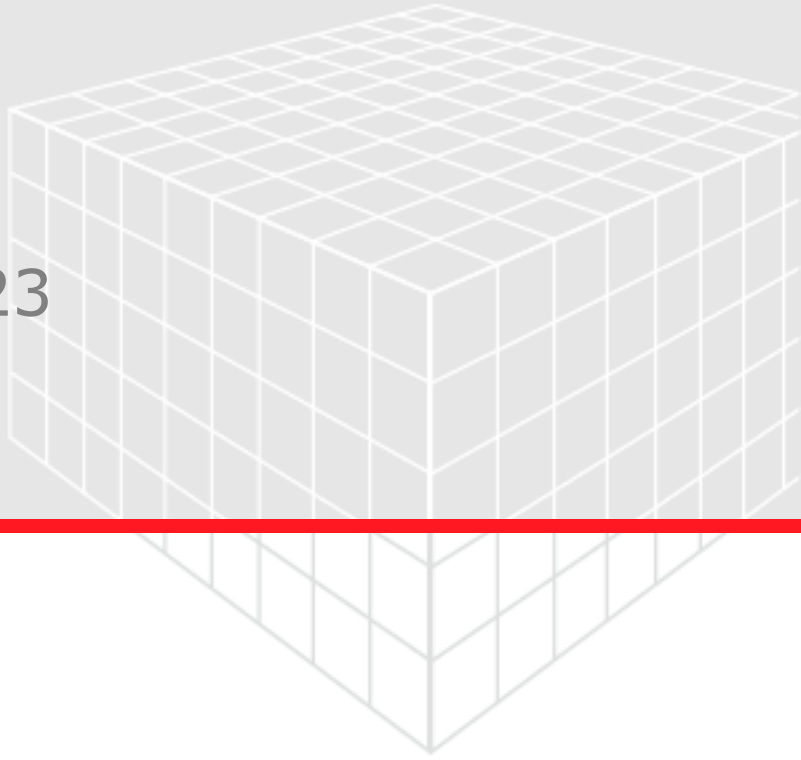
PleatGeo



User Guide

GeoDict release 2023

Published: January 14, 2023

GeoDict

https://doi.org/10.30423/userguide.geodict

Citation:
Janine Hilden, Liping Cheng, Barbara Planas. GeoDict 2023 User Guide. PleatGeo handbook. Math2Market GmbH, Germany, doi.org/10.30423/userguide.geodict

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MODELING AND DESIGNING PLEATS

Pleating refers to the practice of folding a material into homogenous parallel strips – known as pleats. Pleats are widely used in filtration applications because pleating of the filter media results in an increase of filtration surface area for a given filter volume. A well-designed pleated filter medium achieves a lower pressure drop for any given flow rate.

Pleated media are indispensable for the removal of suspended solids during air/gas and liquid filtration for a multiplicity of industrial applications, such as aerospace, pharmaceutical processing, hospitals, health care, nuclear fuels, nuclear power, and electronic micro-circuitry (computer chips).

The design of a pleated filter for a particular application needs to address crucial parameters such as flow rate (usually in cubic meter or feet per second), filter efficiency (percentage of reduction of micron particles), and filter life span.

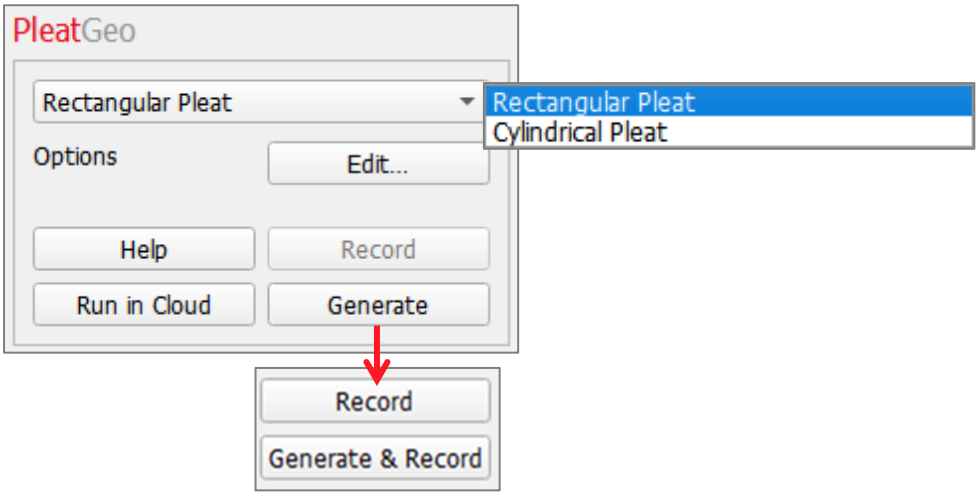
These filter specifications depend to a great extent on the type of filtering media (paper, polypropylene - PP, polyethylene - PE, polyester - PET, fiberglass, nonwoven textile, etc.). When the filter media material cannot be pleated or easily collapses when subjected to high pressures, it is possible to laminate one or both sides of the media with wire to prevent pleat collapse under high pressures and maintain consistent flow.

Cylindrical pleated filter elements are widely used because they provide a lot of filter area in limited space, with the well-known benefits of low pressure drop and high filter capacity. As one cannot simply predict the behavior of a pleated filter from experiments on flat sheet media, GeoDict additionally provides the option to model cylindrical pleated filter elements. These models permit the design of filters that use such cylindrical filter elements based on the simulation of the pressure drop, filter efficiency and filter lifetime. Compared to the methodologies of Computer-Aided-Design (CAD), our 3d image-based approach works completely automatic and requires no manual meshing steps before the simulations can run.

PLEATGEO SECTION

A pleat is a folded filter medium that can be of rectangular or cylindrical shape and sandwiched between an inner and an outer support structure. These support structures can be welded-netted or woven. The support structure can be missing altogether.

Open PleatGeo by choosing **Model** → **PleatGeo** in the Menu bar. The heading PleatGeo appears above the module section, on the bottom left of the GeoDict GUI.



PleatGeo can be used to:

- Create a **Rectangular Pleat**, for a straight or rectangular pleat filter.
- Create a **Cylindrical Pleat** filter element. The models are not only available in the usual GDT format, but also as CAD data in the STL file format for use in third party simulations tools such as Fluent, CFX or Star-CD.

The results of every PleatGeo run are saved in a *.gdr file (GeoDict Results file) containing the data about the structure generation. Enter a suitable name for the *.gdr file or click the **Browse...** button to select one from the chosen project folder.

To use any of these options, select the mode from the pull-down menu and then enter the necessary parameters through the **Edit ...** button located in its panel.

Clicking **Generate** in the **PleatGeo** section generates a pleat or pleat medium using the entered pleat **Options**. View the pleat structure in 3D by selecting **View** → **3D Rendering** in the Menu bar.

Macro files containing all steps of the pleat generation process can be recorded and saved in the project folder when selecting **Macro** → **Start Macro Recording...** in the Menu bar. When recording a macro, **Record** becomes active and **Generate** changes to **Generate & Record**.

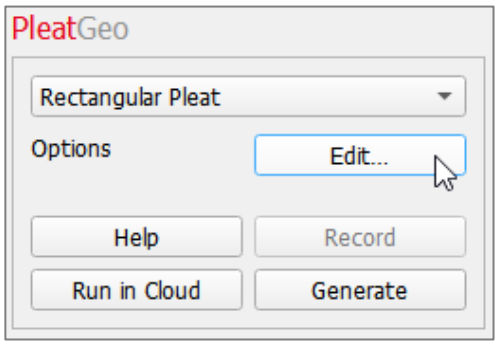
Click **Run in Cloud** to run it in the Kaleidosim cloud, see the High Performance Computing chapter of the GeoDict User Guide for details.

At the end of the pleat generation process, a *.gdr result file is saved in the project folder. Besides the result file, a results folder with the same base name is created. This results folder contains a *.gdt (GeoDict Structure) file of the generated pleat.

If you save the parameters in the **Options** dialog boxes into *.gps files, you can reload them at will.

Remember to restore and reset your (or GeoDict's) default values through the icons at the bottom of the dialog boxes when needed and/or before every PleatGeo run. Rest the mouse pointer over an icon to see a Tooltip showing the icon's function.

RECTANGULAR PLEAT



After clicking the pleat **Options' Edit...** button, the **Rectangular Pleat Options** dialog opens.

A **Result File Name (*.gdr)** must be entered. The **Result File Name** is applied to both the results file (*.gdr), and to the results folder that are saved in the project folder. The ***.gdr** (GeoDict result) files contain the complete information on the current structure generation.

At the top right of the **Rectangular Pleat Options** dialog, the available **units** (m, mm, and µm) are selectable from the pull-down menu.

The parameters for the pleat generation are organized into **Pleat Shape**, **General**, **Domain, Inner Support Netting** (or **Inner Support Weave**), **Outer Support Netting** (or **Outer Support Weave**), and **Expert**, accessible through tabs.

When creating pleats without inner or outer support, only the **Pleat Shape**, **General**, and **Domain** tabs appear.

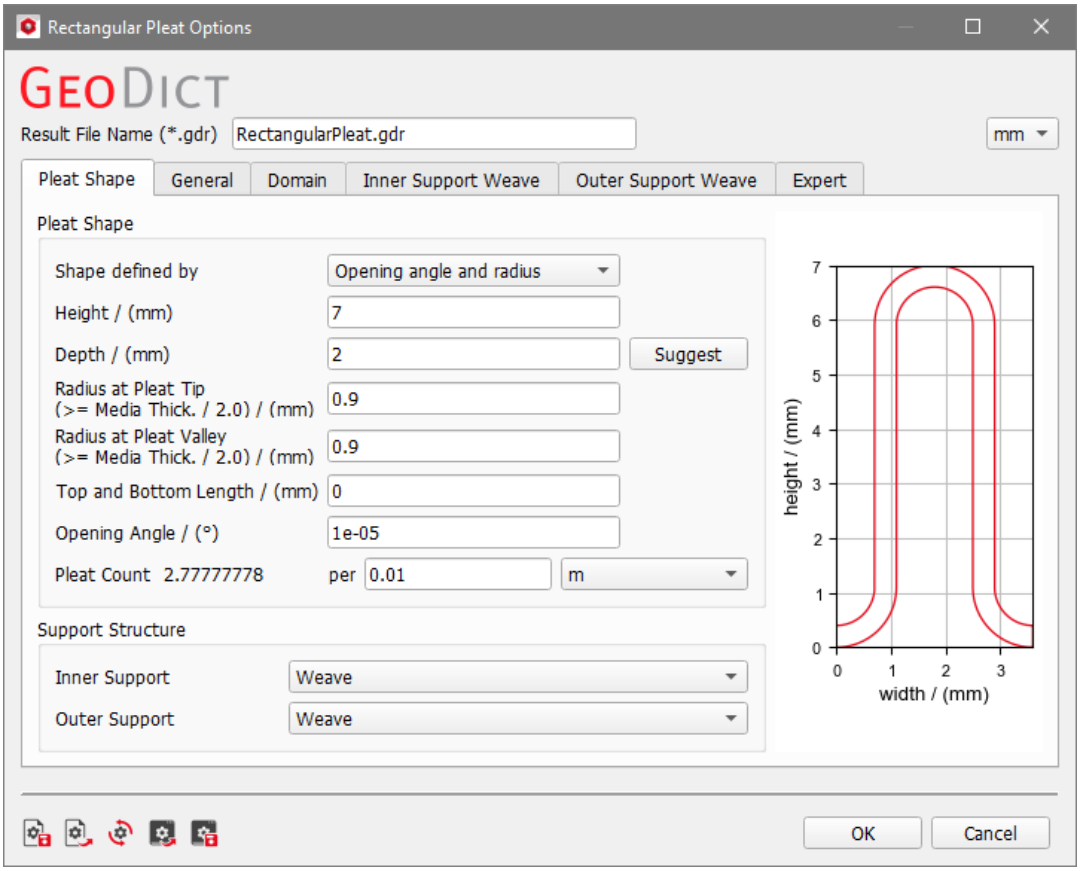
Clicking **OK** confirms the entered pleat options and clicking **Cancel** closes the **Rectangular Pleat Options** dialog and discards the current modifications.

Pleat Shape parameters

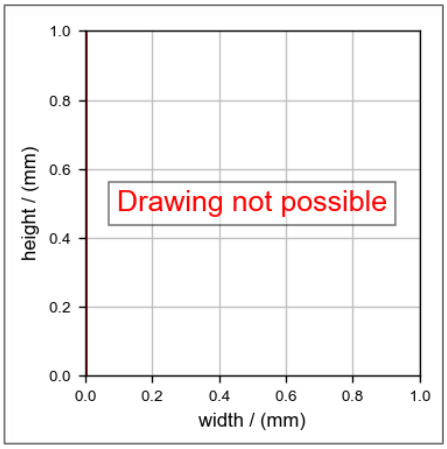
The shape properties of the pleat structure are entered under the **Pleat Shape** tab. These parameters are grouped into the panels **Pleat Shape** and **Support Structure**.

Pleat Shape

When entering **Pleat Shape** parameter values, the pleat graph at the right of the panel changes interactively and displays the effect of these adjustments on the pleat shape.



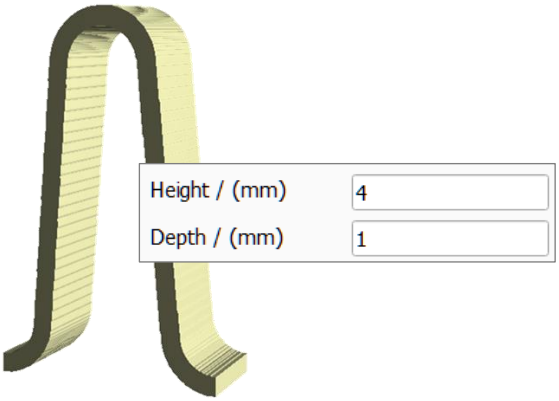
If invalid values are entered, the graph contains the error message "**Drawing not possible**" and no pleat is shown.

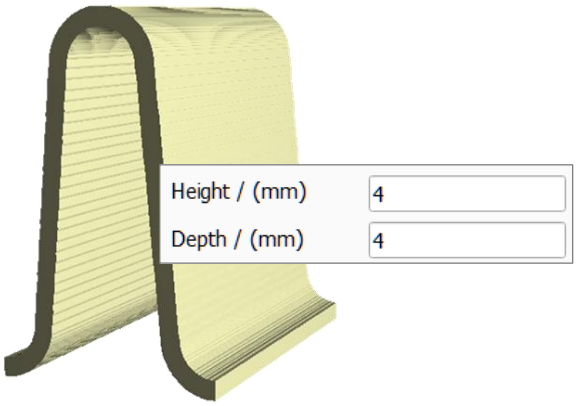


There are three different options to define the pleat's shape. The combinations **Opening angle and radius**, **Pleat count and opening angle** or **Pleat count and radius** can be chosen from the pull-down menu. As the three parameters **Opening Angle**, **Radius** and **Pleat Count** are not independent, the respective third parameter is computed automatically from the others.

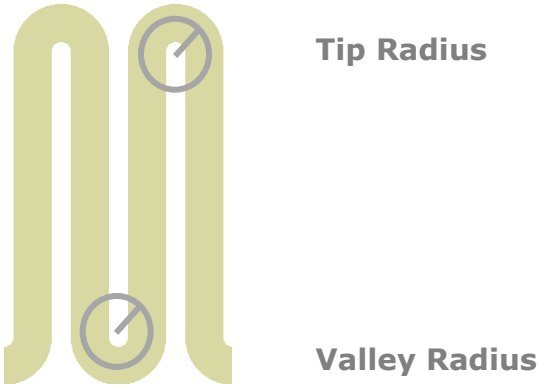
Pleat **Height** and pleat **Depth** are the physical dimensions of a single pleat in the Z- and Y-directions, respectively. Clicking the **Suggest** button shows the pleat **Depth** value that is recommended for the inner and outer support parameters. The suggested value is the minimum to generate one netting (or weave) unit cell in Y-direction. If no inner and outer support is chosen, **Suggest** is grayed out.

Only a short segment of the length of the pleat is modeled. This length in X-direction, or pleat width, is calculated automatically from the mesh parameters so that it corresponds to the period length of the mesh. This choice gives the smallest possible representative structure of the pleat that is usable for property computations.





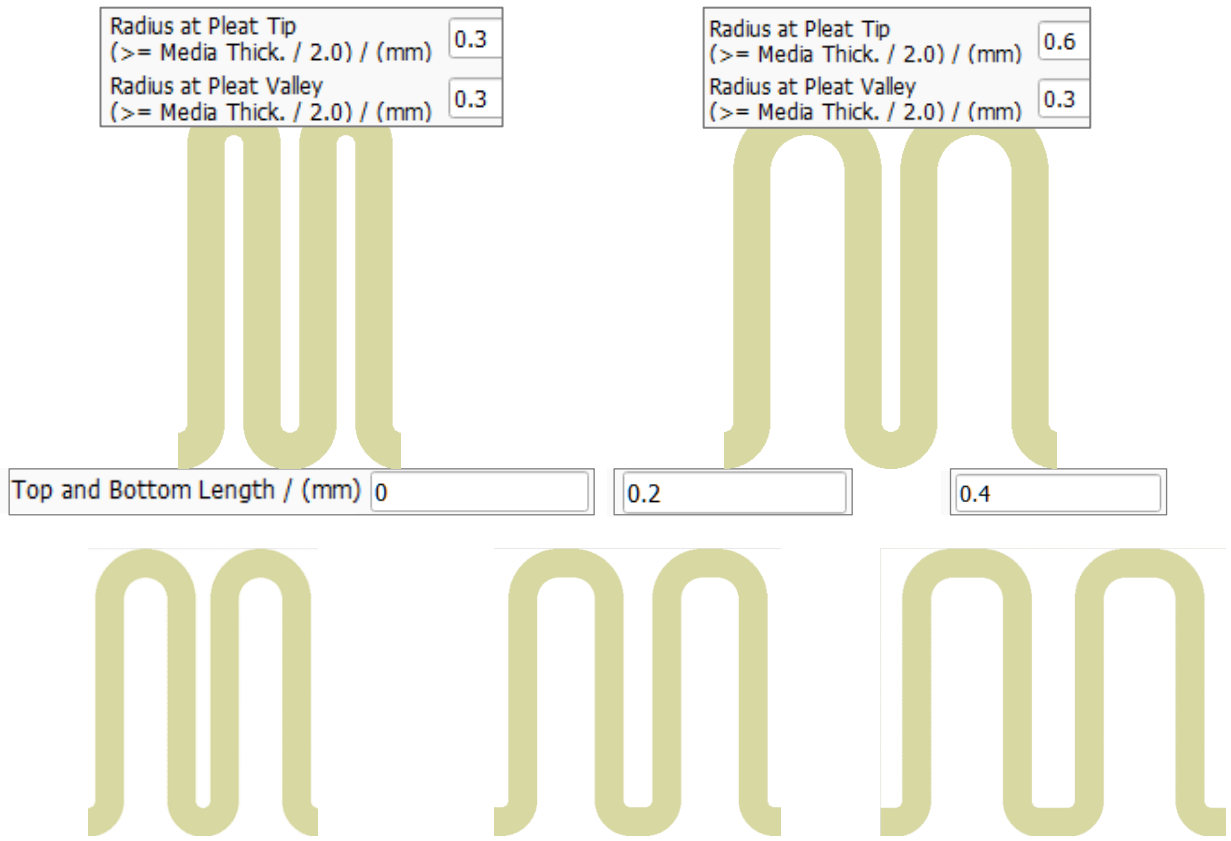
The values of **Radius at Pleat Tip** and **Radius at Pleat Valley** determine the upper pleat radius and lower pleat radius measured at the upper or the lower folds of the pleat.



If **Pleat count and radius** is chosen for defining the pleat's shape, only the top radius can be edited, as the bottom radius is set to the same value.

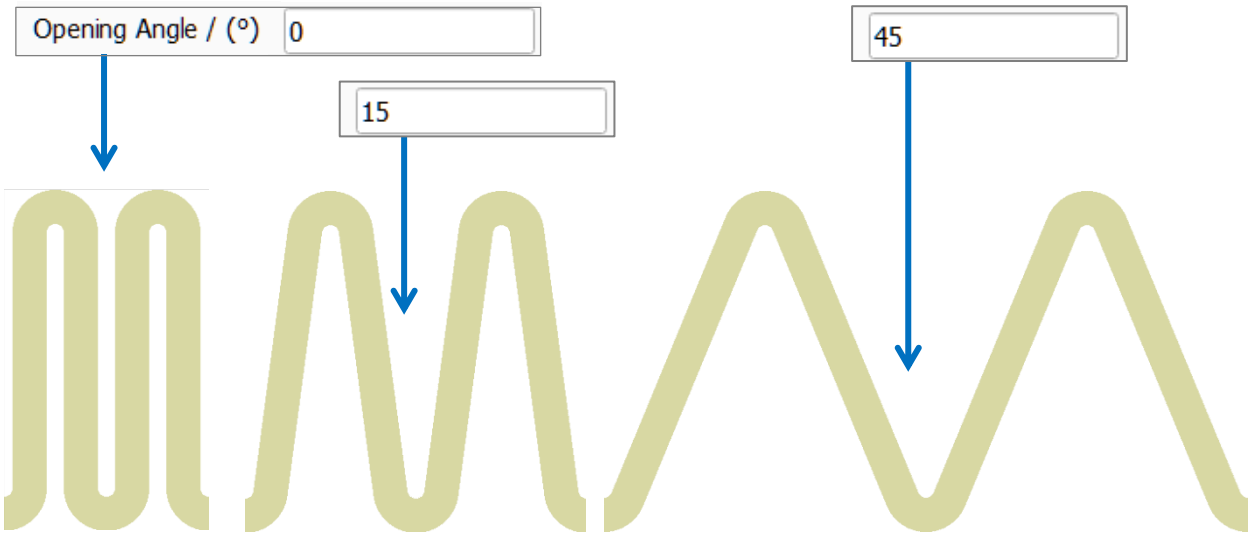
Defining the shape by **Pleat count and Opening Angle** also leads to same values for Radius at Pleat Top and Radius at Pleat Valley, but then both cannot be edited.

Otherwise, if **Opening angle and radius** is chosen, the values of radius at pleat tip and radius at pleat valley can be different. Observe how the pleat (repeated using the ProcessGeo module) achieves a different form when the pleat radii vary while other pleat parameters are kept constant.

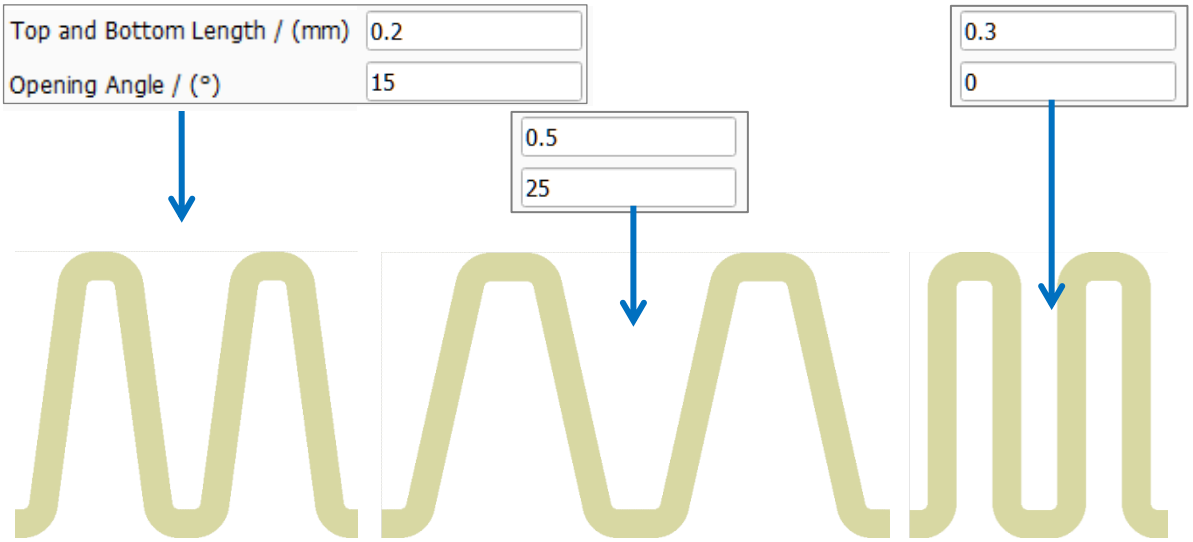


Pleat **Top and Bottom Length** controls the distance between two folds of the pleat medium in X-direction. A straight piece in the defined length is inserted both in the top and in the bottom crest.

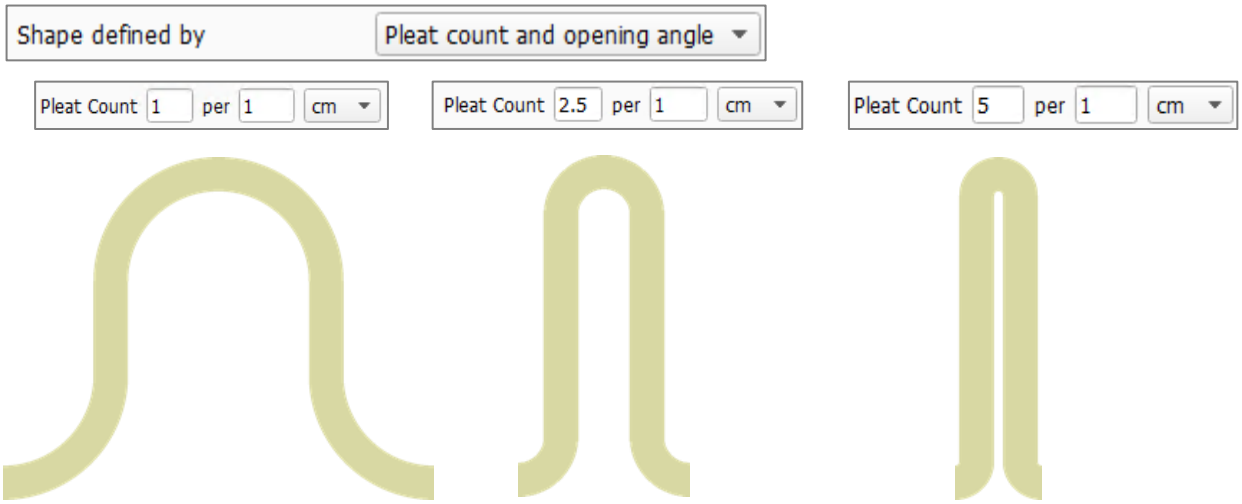
The **Opening Angle** determines the angle between the pleats in the ZX-plane.



Variations of the **Top and Bottom Length** and the **Opening Angle** allow many different pleat geometries.



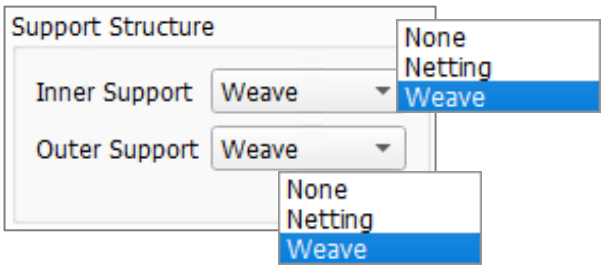
Pleat Count defines the number of pleats in the specified distance. The values for number and distance can be entered in the boxes. The available units are m, cm, or inch. Observe the variation in pleat shape for different pleat counts after selecting **Pleat count and opening angle** (for **Shape defined by**).



Support Structure

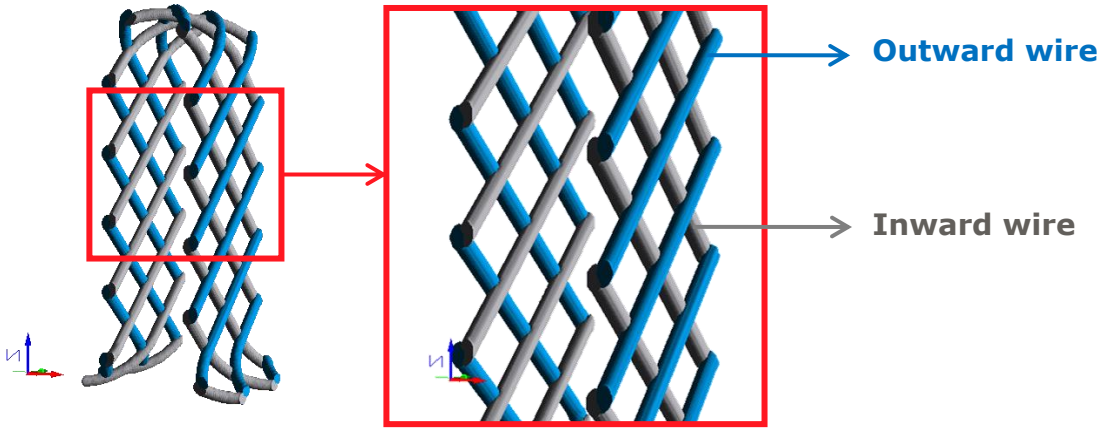
The two pull-down menus display the available choices for the support structure.

The generated pleated structures may be supported by an **Inner Support** and **Outer Support**. This can be **Weave**, **Netting** or no support (**None**).

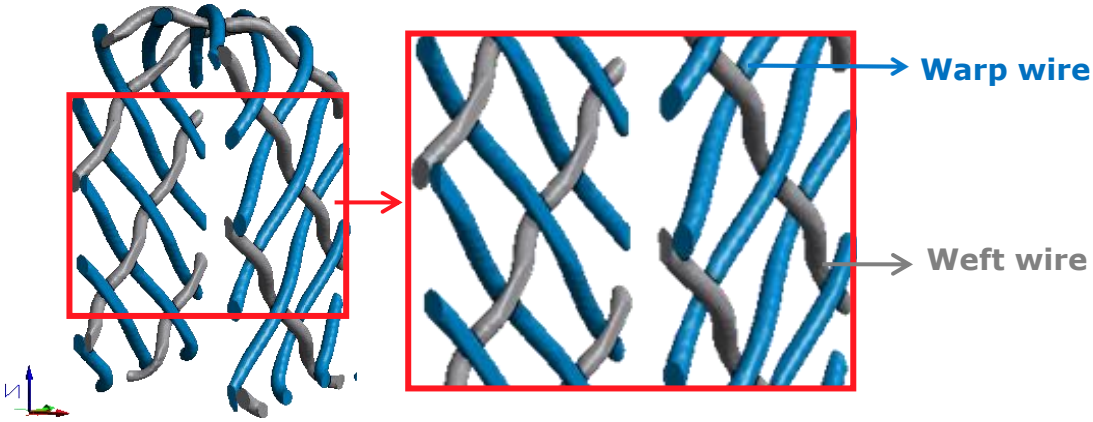


The outer and inner **Netting** are welded-melted structures consisting of inward and outward wires crossing each other at regular intervals without going over or under each other.

Inner, outer, inward, and outward are defined in PleatGeo assuming that the "inside" is on the upstream side of the pleat and its "outside" on the downstream side.

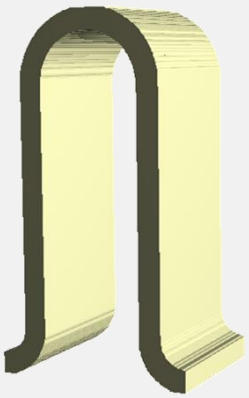
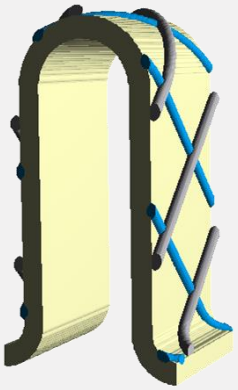
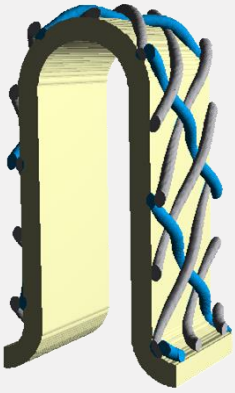
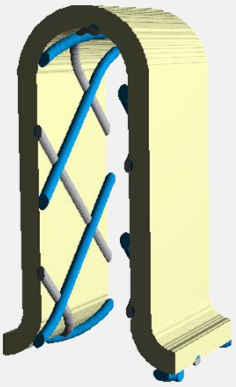
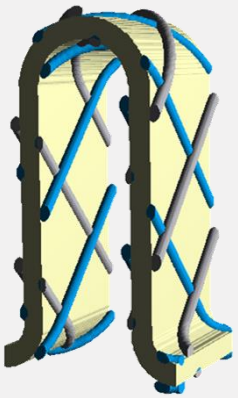
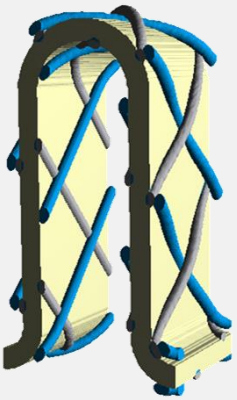
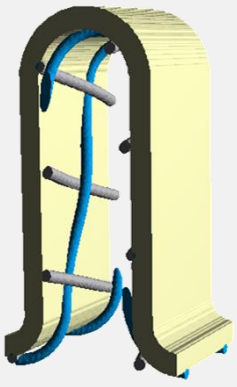
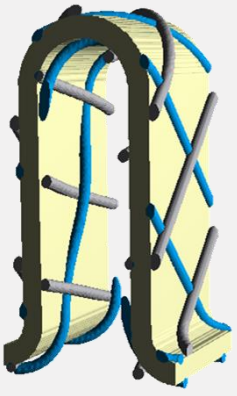
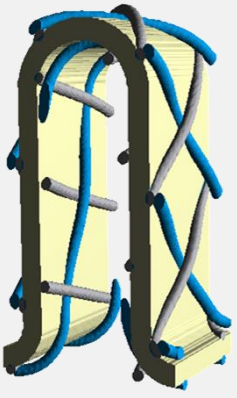


The **Inner Weave** and the **Outer Weave** are support structures made of woven warp and weft wires which interlace over-and-under each other in given weave pattern (Plain weave, Twill 2/1 Weave, Twill 2/2 Weave).



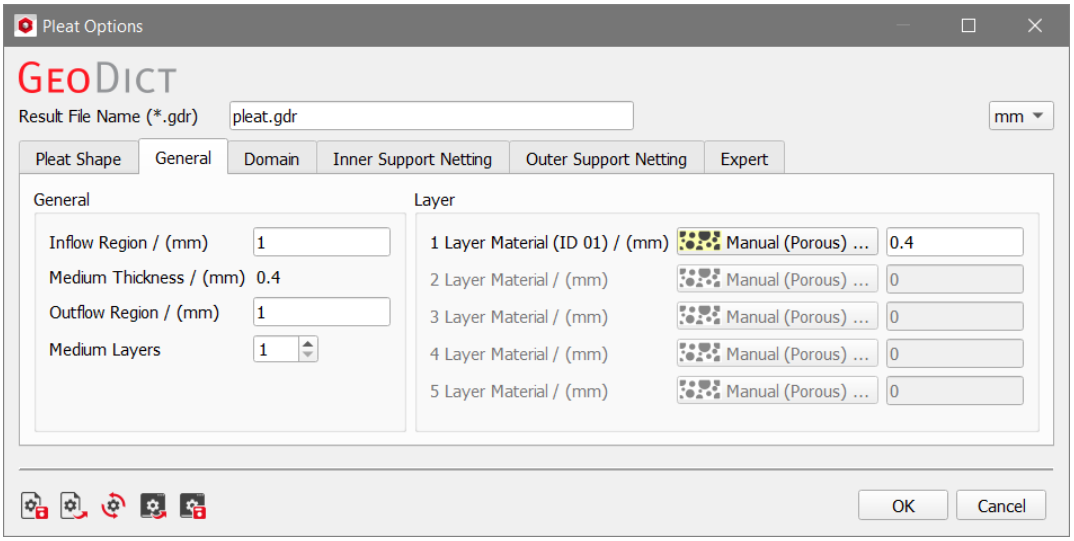
Define the weave and netting parameters in the corresponding tabs described starting on page 16.

The nine combinations of these choices are shown below in a pleat with one layer:

No inner Support No outer Support	No inner Support Outer Netting	No inner Support Outer Weave
		
Inner Netting **No outer Support**	**Inner Netting** **Outer Netting**	**Inner Netting** **Outer Weave**
		
Inner Weave **No outer Support**	**Inner Weave** **Outer Netting**	**Inner Weave** **Outer Weave**
		

General parameters

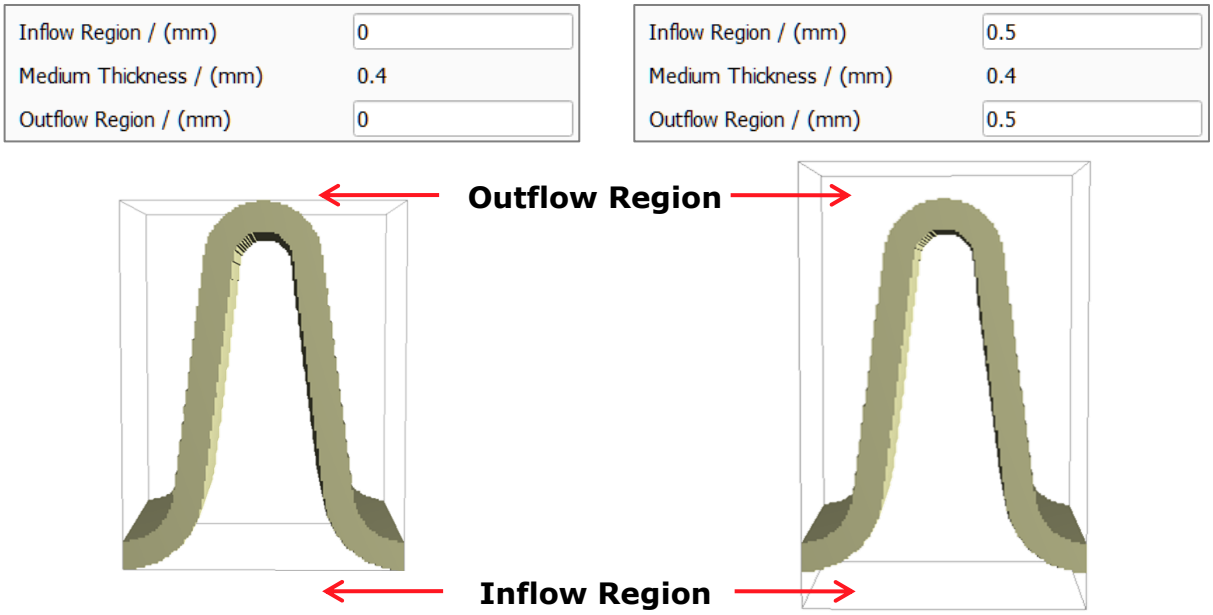
The general parameters are organized into the **General** panel and the **Layer** panel.



General

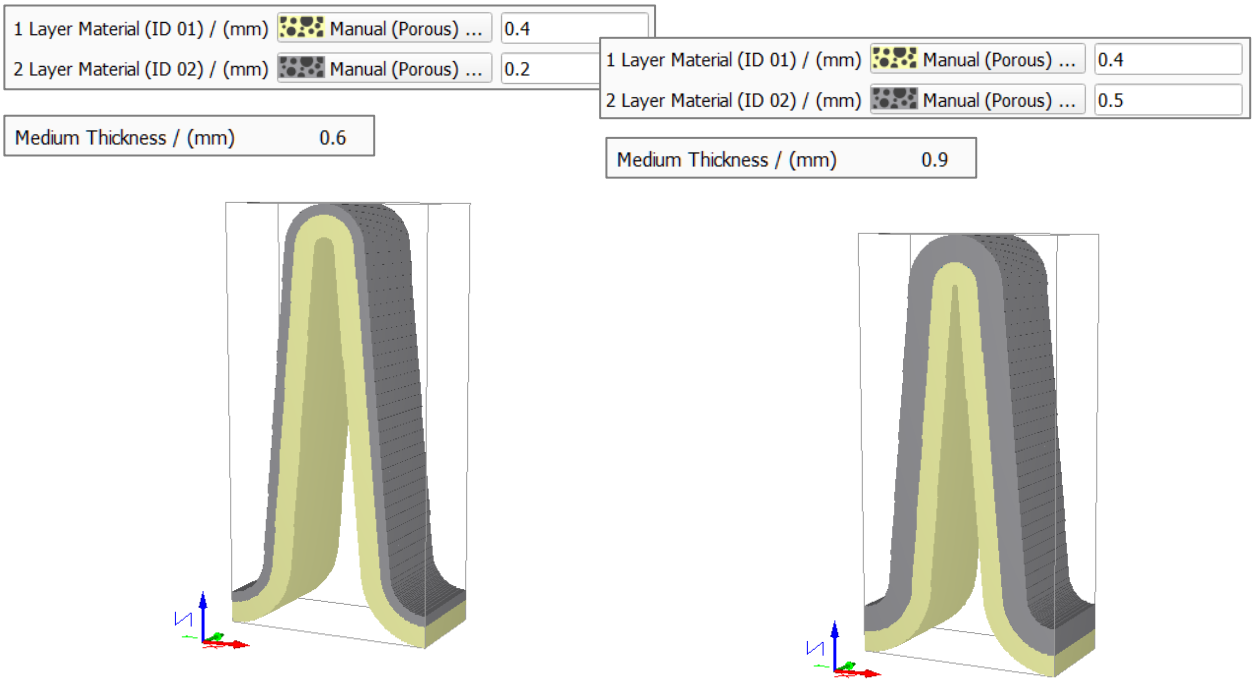
Inflow Region and **Outflow Region** of the pleat are the empty regions above and below the pleat in Z-direction.

The inflow region (large Z-values, high pressure region) and outflow region (small Z-values, low pressure region) should be chosen large enough so that the influence of boundary conditions in flow direction is reduced in flow simulations.

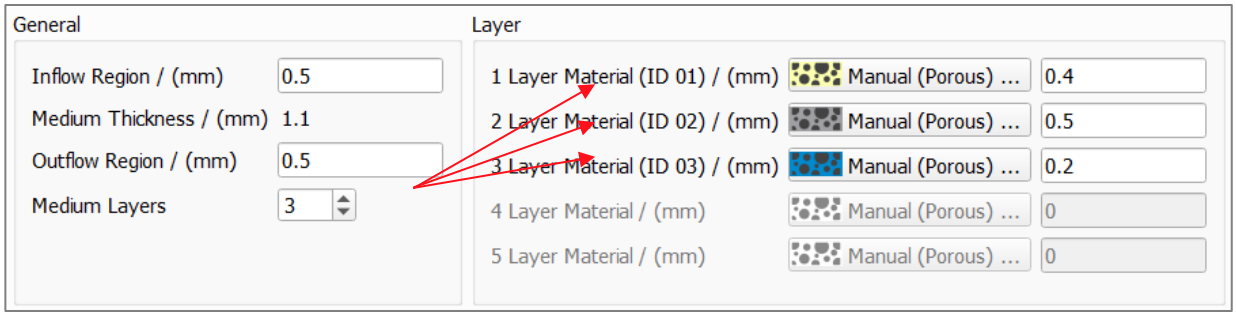


Medium Thickness defines the total thickness of the pleat medium and corresponds to the sum of the thickness of all layers.

The value of **Medium Thickness** changes automatically when modifying the thickness of the layers.

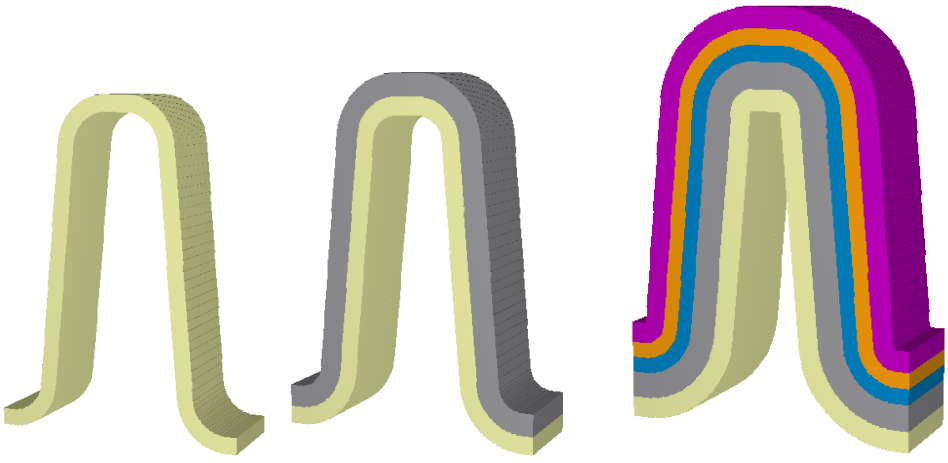


The value entered in **Medium Layers** determines the number of layers that form the pleat medium. Up to five layers of varying thickness may form the pleat.



LAYER

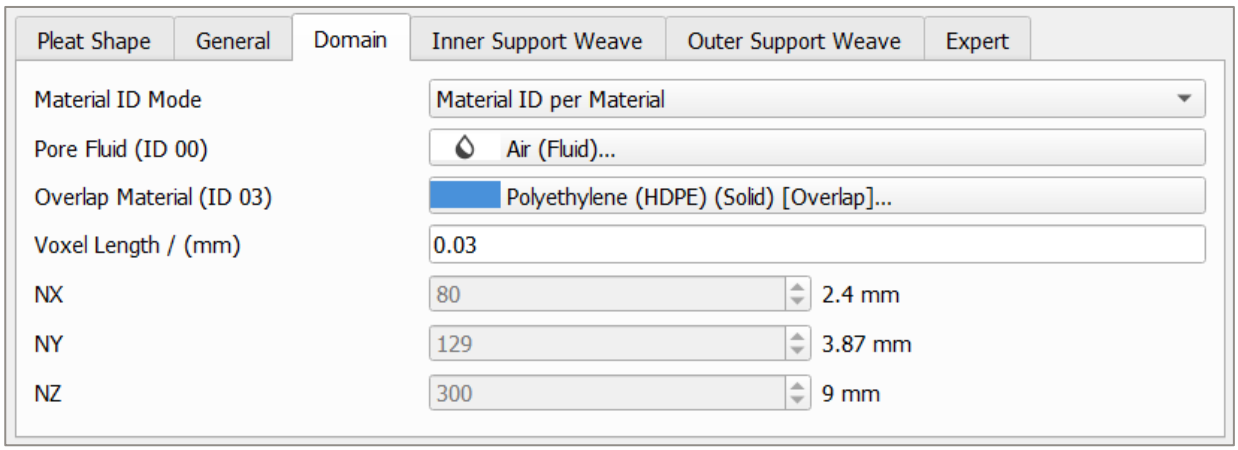
1, **2**, **3**, **4**, and **5 Layer Material** define the material and the thickness of each layer material forming the pleat medium.



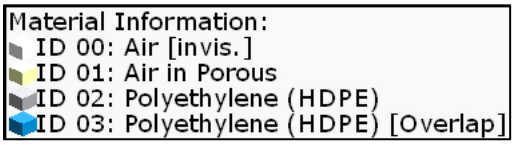
DOMAIN PARAMETERS

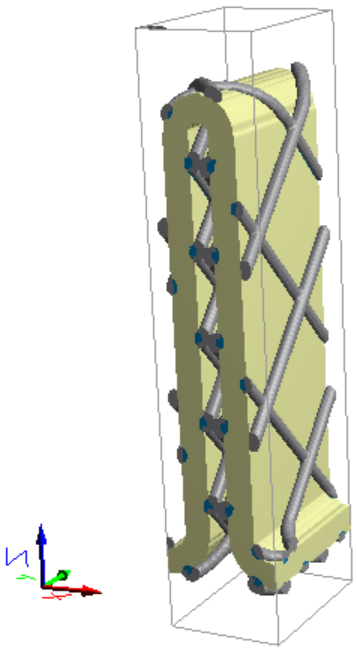
Material ID Mode allows choosing between:

- **Material ID per Material**: each constituent material gets a material ID
- **Material ID per Object-Type**: each object type gets a material ID.



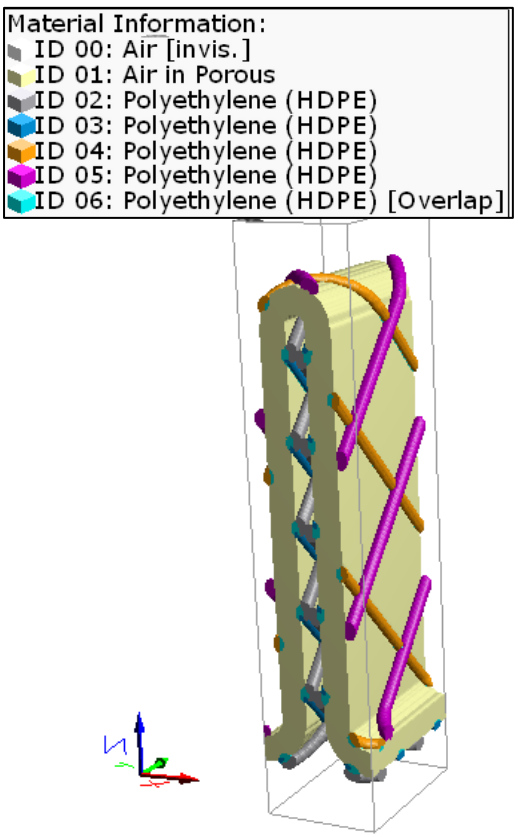
Here, **Material ID per Material** has been chosen to create a pleat with inner netting and outer netting.





The materials for the inner and outer nettings are the same. We obtain a pleat with the following Material IDs:

- ID 00 for air (invisible)
- ID 01 for the porous layer
- ID 02 for all netting material
- ID 03 for overlapping material

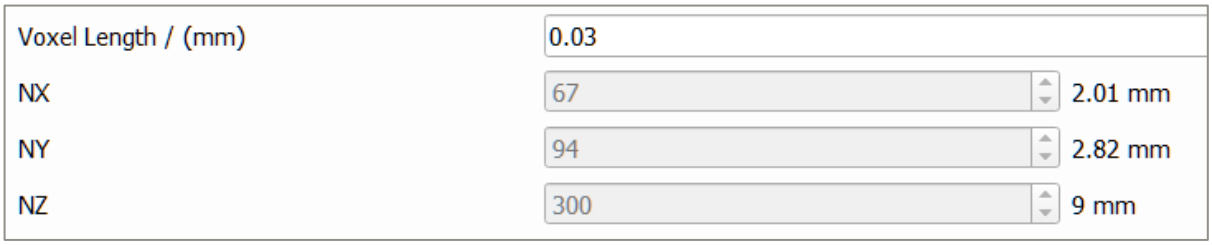


With **Material ID per Object-Type** chosen, more material IDs are present.

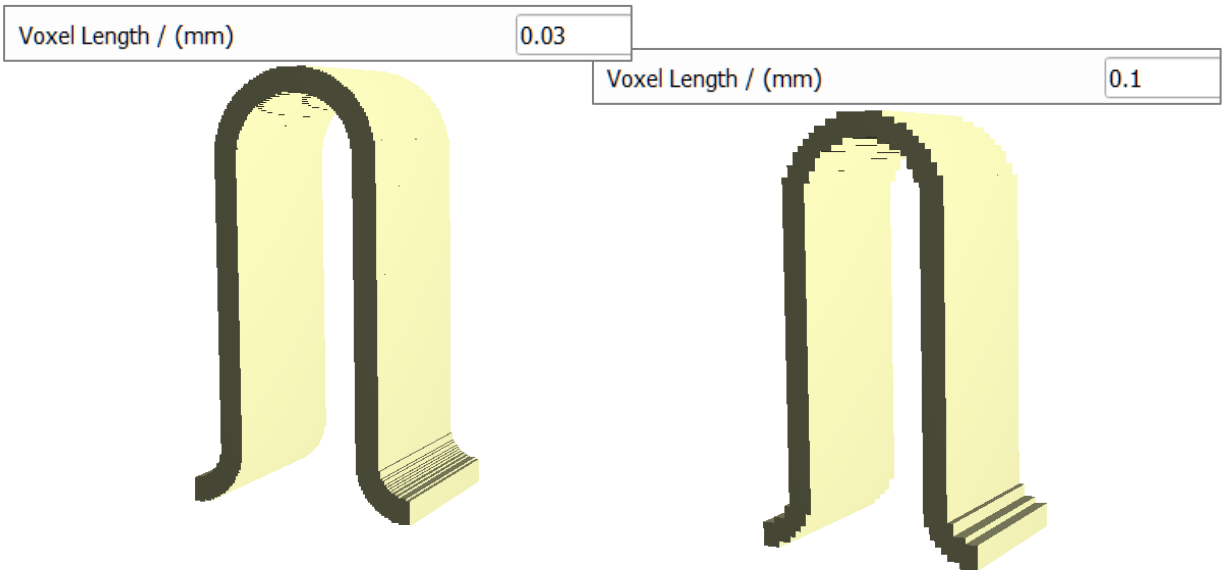
The pleat consists of the following Material IDs:

- ID 00 for air (invisible)
- ID 01 for the porous layer
- ID 02 for the inward wire of inner netting
- ID 03 for the outward wire of inner netting
- ID 04 for the inward wire of outer netting
- ID 05 for the outward wire of outer netting
- ID 06 for the overlap material.

The internal representation of a structure in GeoDict consists of rectangular 3D arrays of equally sized boxes, called volume elements or **Voxels**. The **Voxel Length** is the size of the voxels in the chosen units.



Low values for the **Voxel Length** result in a higher resolution but lead also to longer computational times.



The values for **NX**, **NY** and **NZ** indicate the number (N) of voxels in **X**, **Y** and **Z**-direction. Although it is possible to see the structure size values, they cannot be directly changed in the **Domain** panel.

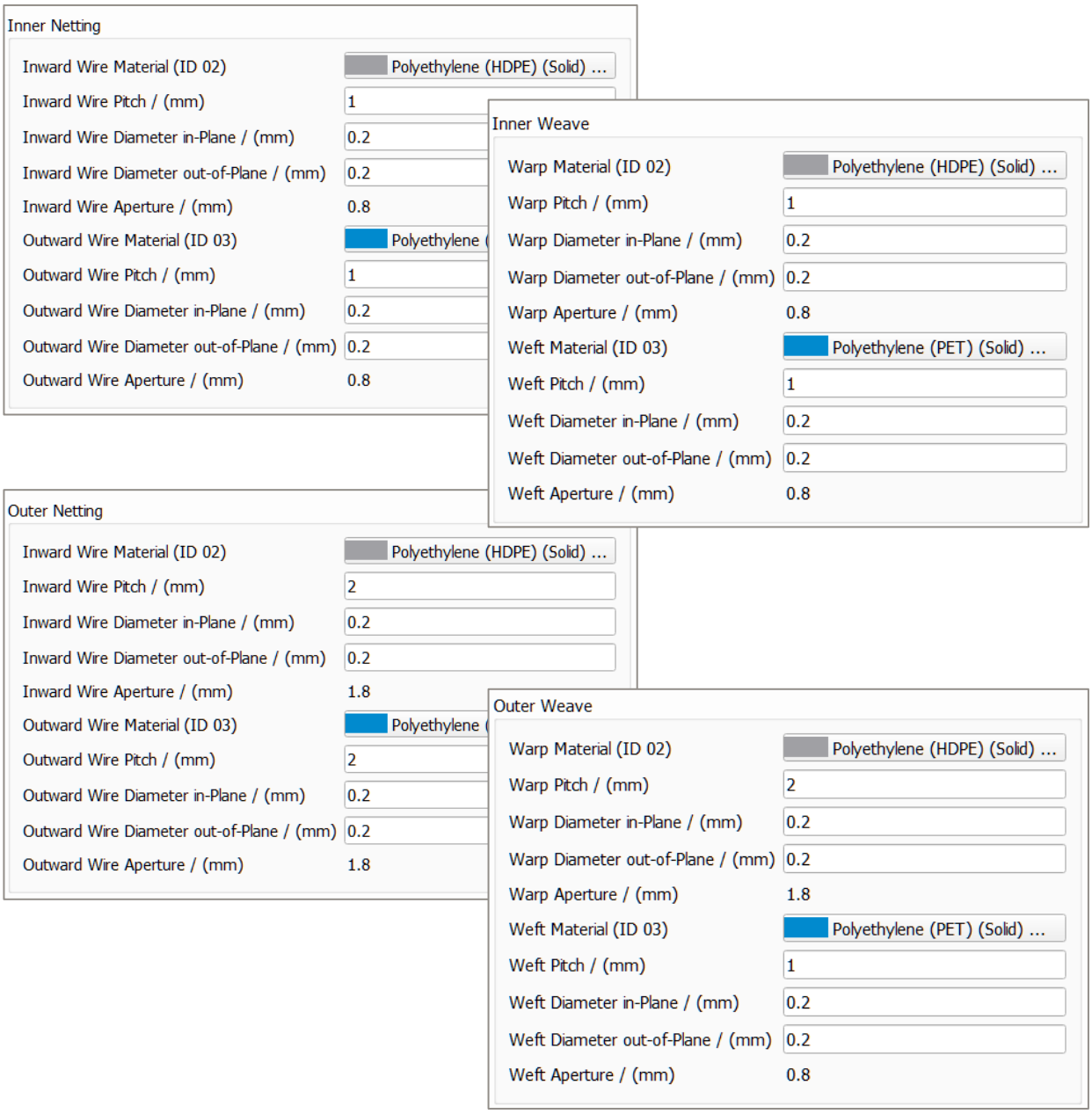
When entering a **Voxel Length**, the number of voxels corresponding to the pleat size in the three spatial dimensions (**NX**, **NY** and **NZ**) is calculated automatically, and displayed in the **Domain** panel. As a guideline, the smallest wire diameter and the media thickness should be resolved by at least 5 voxels.

Inner (and Outer) Support Netting and Weave parameters

After selecting **Netting** or **Weave** for **Inner Support** or **Outer Support** from the pull-down menus in the **Pleat Shape** tab, two tabs appear in the **Pleat Options** dialog. In these tabs, you can enter the parameters for the supporting net or woven structures. Find an overview of all support combinations on page 10.

Inner (or Outer) Netting and Inner (or Outer) Weave

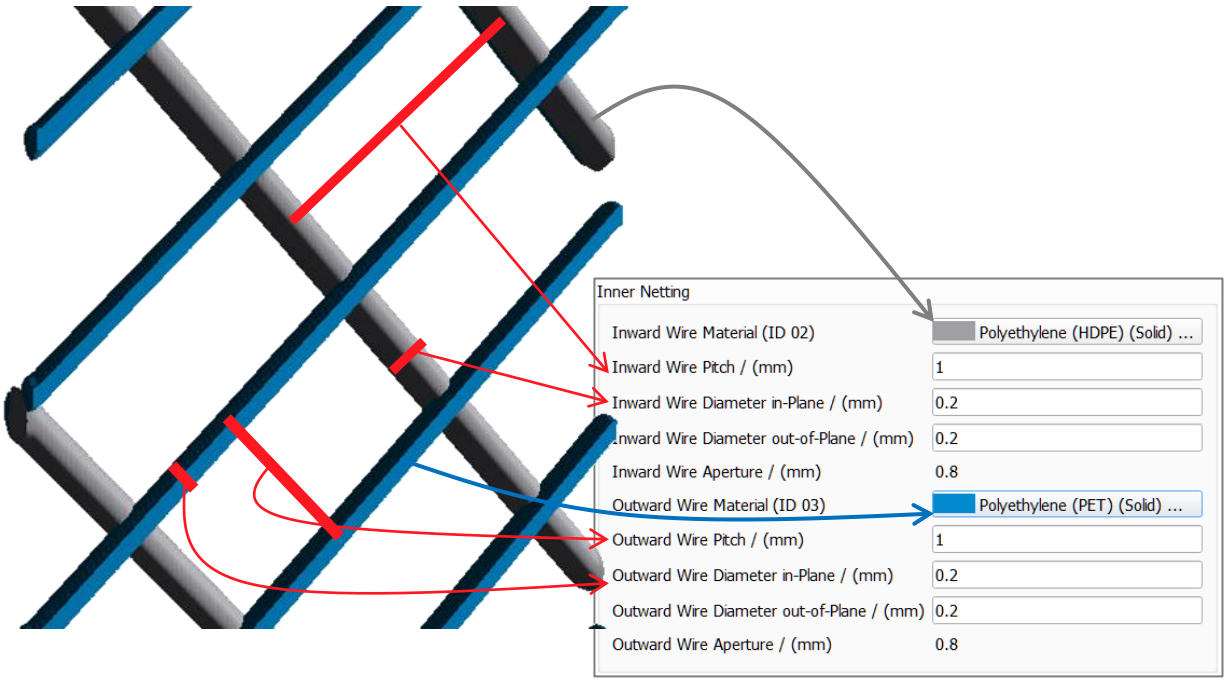
In the Inner or Outer Netting and/or the Inner or Outer Weave panels, click on the material button for the **Inward Wire Material**, **Outward Wire Material**, **Warp Material**, and **Weft Material** to select the desired material from the material data base.

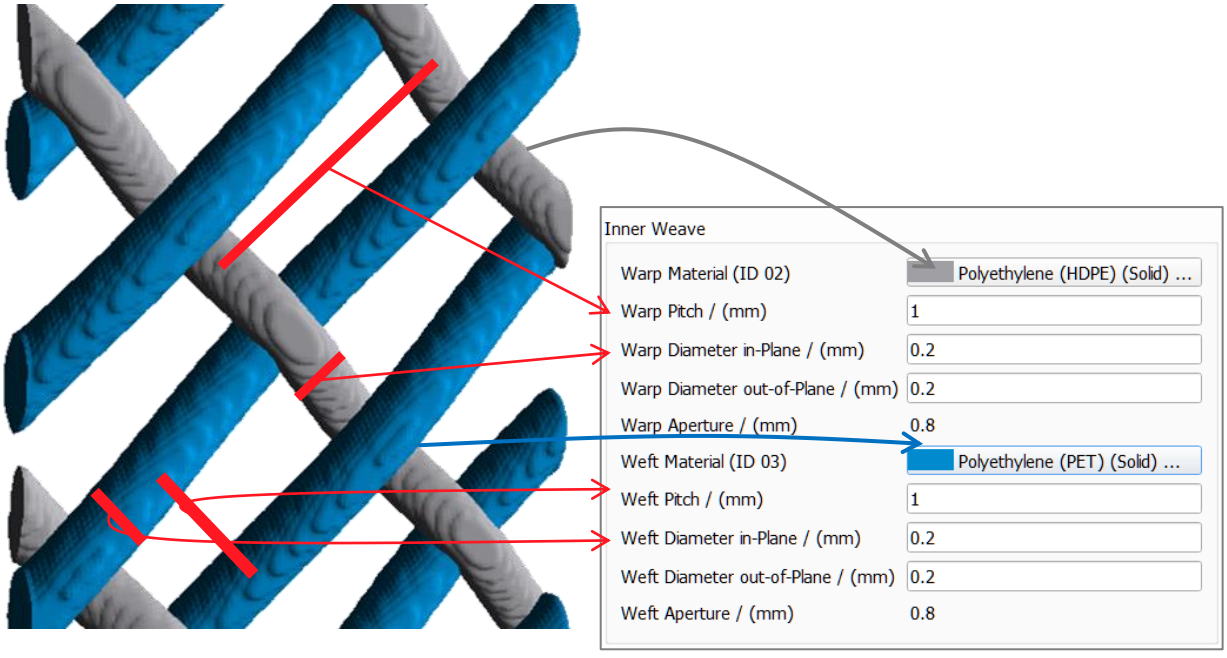


Inward Wire Pitch, **Outward Wire Pitch**, **Warp Pitch**, and **Weft Pitch** correspond, respectively, to the distance between the middle points (centers) of the inward wires, the outward wires, the warp wires, or the weft wires. The pitch is equivalent to the sum of the wire **Aperture** and the wire **Diameter in-Plane**.

Inward, outward, warp, and weft wires do not necessarily have a circular cross section. When the wires have an ellipsoid cross-section, one of the axes is oriented with the plane of the pleat (in-plane), while the other is perpendicular to the pleat and, therefore, out-of-plane. In mesh wire, **Diameter in-Plane** and **Diameter out-of-Plane** determines the wire thickness.

Inward Wire Aperture, **Outward Wire Aperture**, **Warp Aperture**, and **Weft Aperture** describe the distance between two neighboring wires, measured in the center of the aperture. The aperture is automatically calculated from the entered pitch and diameter in-Plane values.

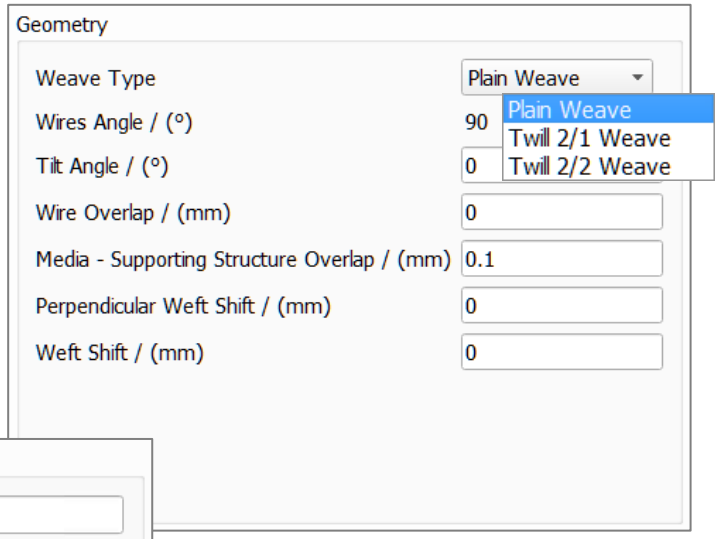


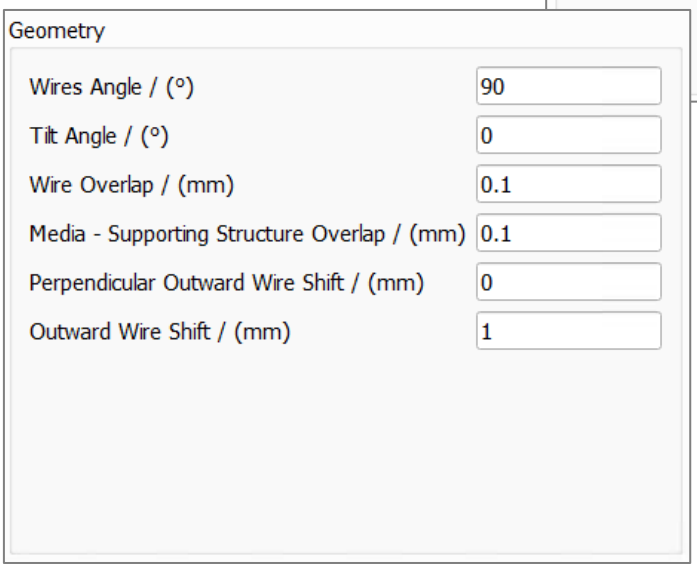


GEOMETRY

For **Inner Support Weave** or **Outer Support Weave**, one of the available **Weave Type**s can be chosen from the pull-down menu:

Plain Weave, Twill 2/1 Weave, or Twill 2/2 Weave. See the WeaveGeo handbook for more information on weave types.

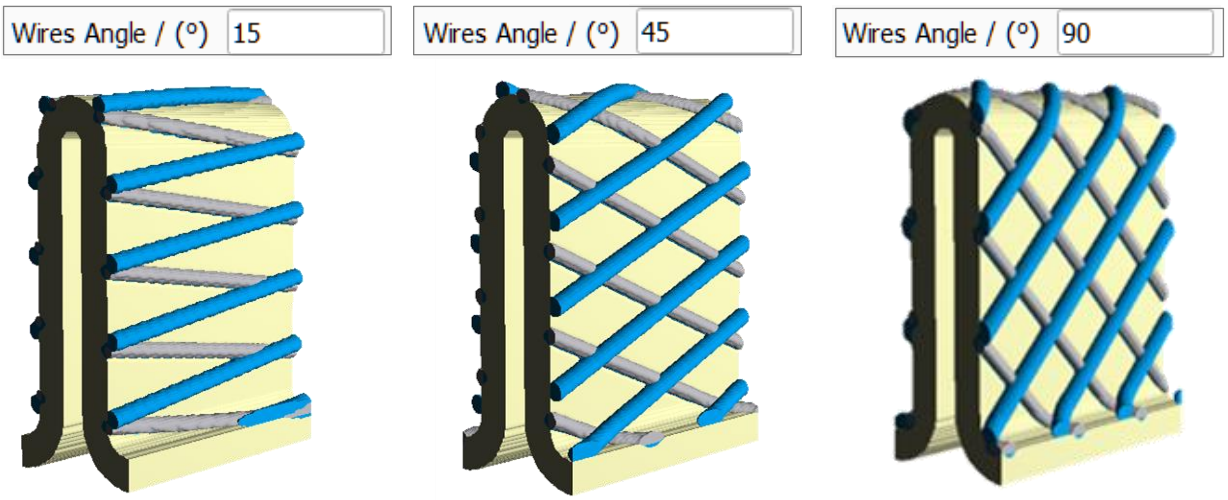




For **Inner Support Netting** or **Outer Support Netting**, the **Wires Angle** is the angle between the inward and the outward wires or the warp and the weft wires.

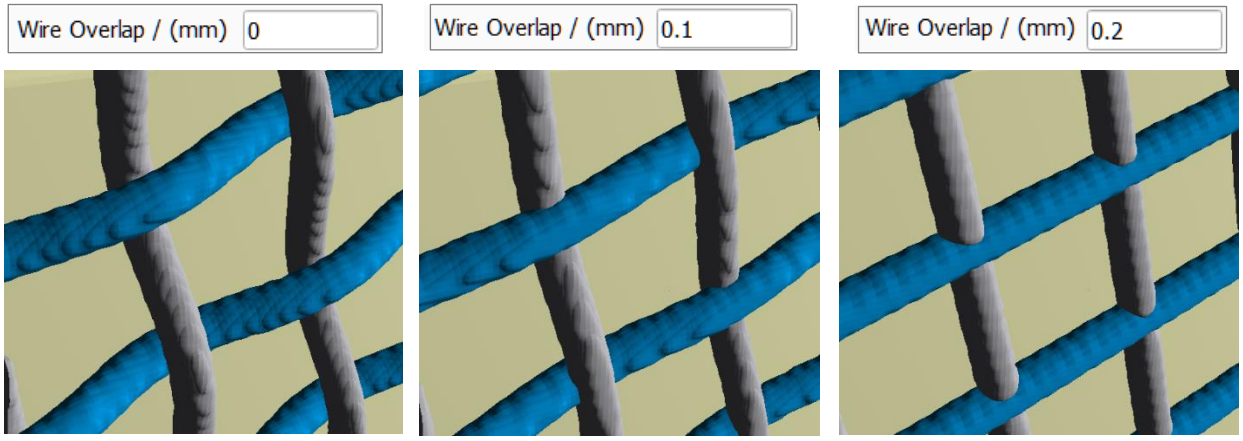
The **Wires Angle** can only be chosen for support nettings, not for support weaves.

For weaves, the wires angle is always 90º.

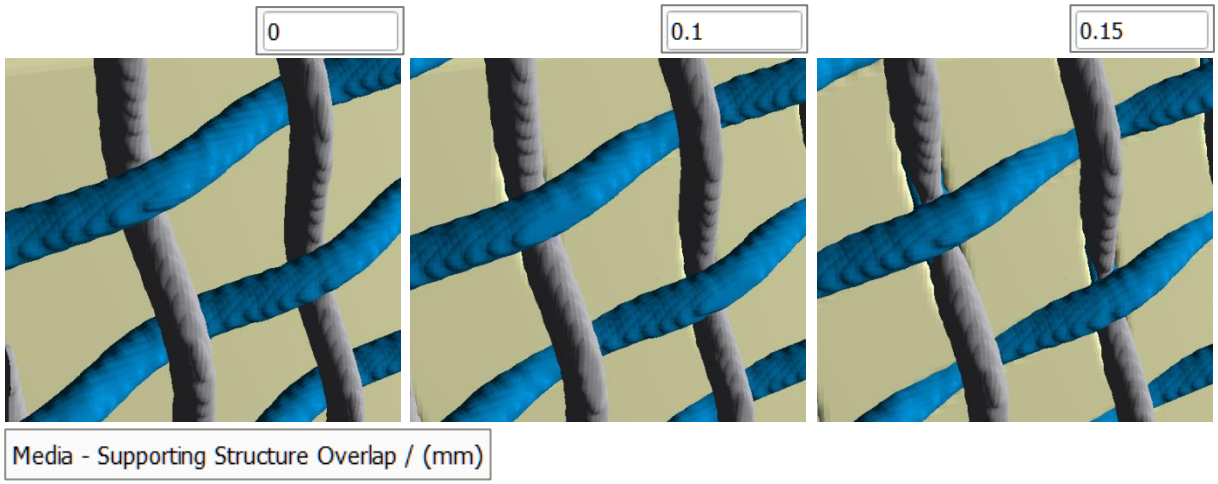


The netting or weave **Tilt Angle** is the angle of incline of the netting or the weave supporting structure with respect to the pleat medium along the pleat depth. The valid tilt angle values range from 0º to 45º.

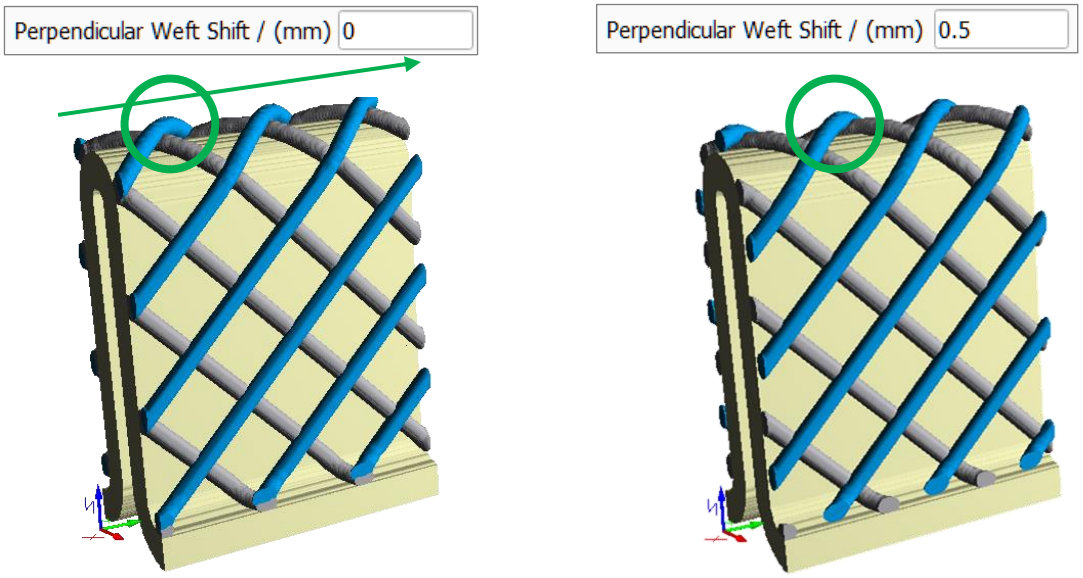
Wire Overlap establishes the percentage of overlap of the inward wire with the outward wire, or the warp wire with the weft wire. In the model, the wires of the netting (or weave) may be generated to partly cover each other to account for plastic deformations during the welding or the weaving. Observe how the warp and the weft wires increasingly overlap in the figure below.



Media–Supporting Structure Overlap is the amount of overlap between the pleated media, and the netting or weave supporting structure. Observe how increasing the **Media–Supporting Structure Overlap** from 0 mm to 0.1 mm, and to 0.15 mm gradually embeds the support structure into the pleated media.



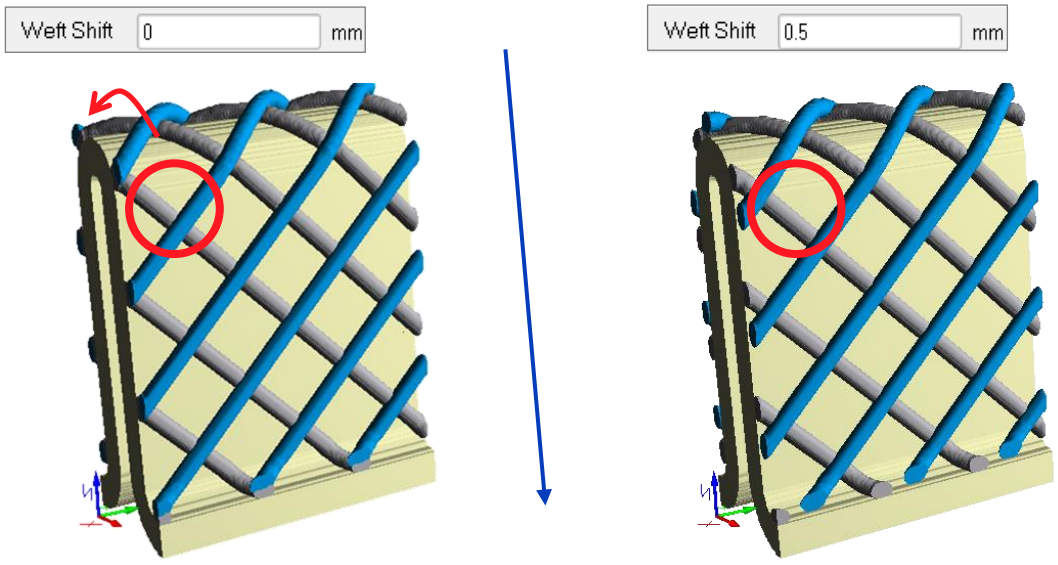
Perpendicular Outward Wire Shift and **Perpendicular Weft Shift** are, respectively, the shift of the outward wire and the weft wire on the pleat surface, perpendicular to the XZ plane, i.e. in Y-direction.



The shift in position of the blue weft wire along the Y-direction can be observed on the crest of the pleat when increasing the value of **Perpendicular Weft Shift**. The grey warp wires remain at the initial position.

Outward Wire Shift and **Weft Shift** are, respectively, the shift of the outward wire and the weft wire on the pleat surface in the XZ-plane.

Observe how the blue weft wires shift in position along the crest of the pleat when setting the **Weft Shift** value to 0.5mm (half the weft pitch). The grey warp wires remain at the initial position.

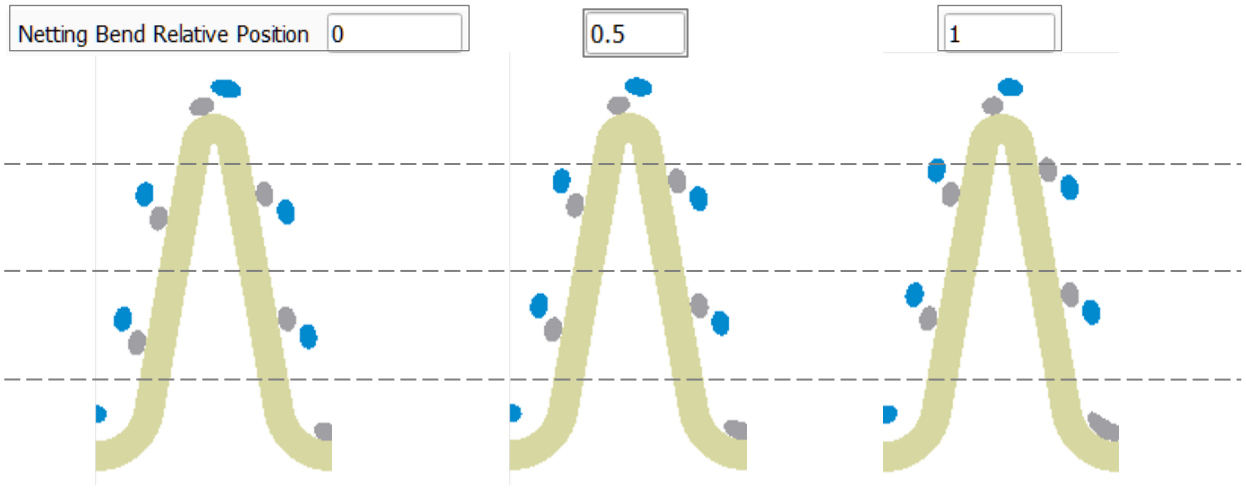


EXPERT PARAMETERS

The **Expert** tab is present in the **Pleat Options** dialog whenever the pleat has an inner or outer support structure. The expert tab may include panels for inner supporting structure parameters (netting or weave), for outer supporting structure parameters (netting or weave), or for both.

NETTING (OR WEAVE) BEND RELATIVE POSITION

At the sharp folds of the pleat, the wires of the supporting structure kink and deform during the pleating process. The **Bend Relative Position** models the effect of this support structure deformation. The bending relative position value must be between 0 and 1. Observe how the wires of the outer netting structure glide up on the right- and the left-side of the pleat, with increasing values of **Bend Relative Position**.



PLEAT TOP INWARD WIRE (OR WARP) DEFORMATION

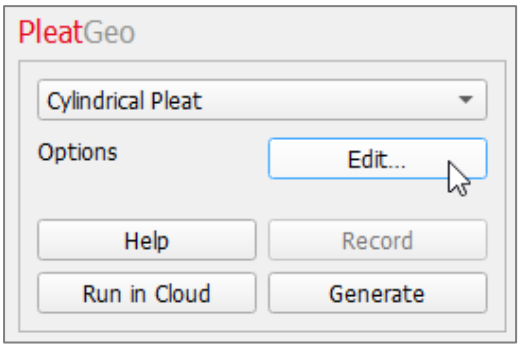
The **Pleat Top Inward wire (or Warp) Deformation** simulates the distortion of the inward or the warp wire at the crest of the pleat during welding (or weaving) in the pleating process. The deformation values can be positive or negative and are entered in the chosen length values.

The effect of the deformation can be observed in the following examples, where the Inward wire (grey) at the top of the pleat runs increasingly vertical with increasing positive values of **Pleat Top Inward Wire Deformation** or horizontal with increasing negative values of **Pleat Top Inward Wire Deformation**.

Cylindrical Pleat

Cylindrical pleated filter elements are widely used because they provide a lot of filter area in limited space, with the well-known benefits of low pressure drop and high filter capacity. As one cannot simply predict the behavior of a pleated filter from experiments on flat sheet media, GeoDict provides the option to model cylindrical pleated filter elements. These models permit the design of filters that use such cylindrical filter elements based on the simulation of the pressure drop, filter efficiency and filter lifetime.

The models are not only available in the usual GDT format, but also as CAD data in the STL file format for use in third party simulations tools such as Fluent, CFX or Star-CD. And the models are also available as volume meshes in GeoDict. The latter also contain the orientation of the computational cells to be able to account for anisotropic properties of the filter media in the individual layers of the filter element.

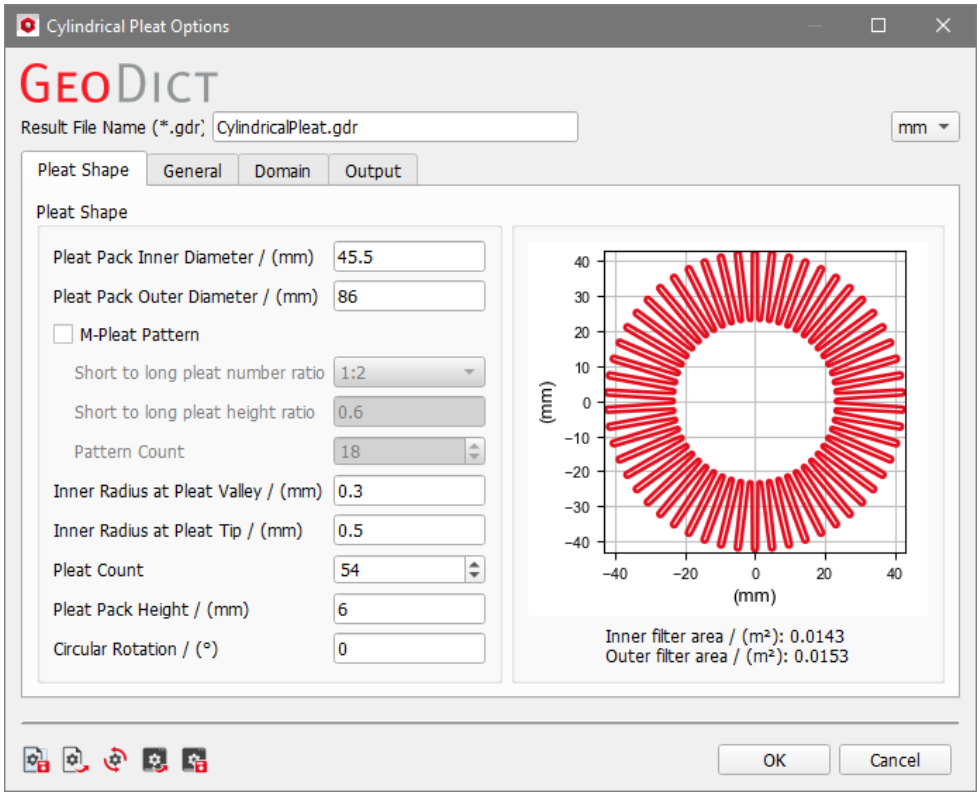


After clicking the pleat **Options' Edit...** button, the **Cylindrical Pleat Options** dialog opens.

A **Result File Name (*.gdr)** must be entered. The **Result File Name** is applied to both the results file (*.gdr), and to the results folder that are saved in the project folder. The ***.gdr** (GeoDict result) files contain the complete information on the current structure generation.

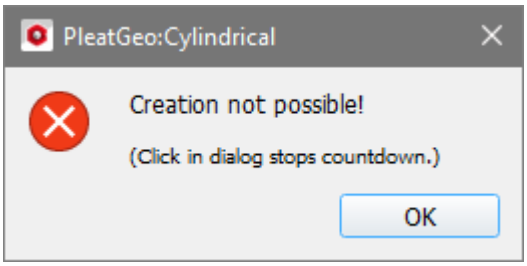
At the top right of the **Cylindrical Pleat Options** dialog, the available **units** (m, mm, and µm) are selectable from the pull-down menu.

The parameters for the pleat generation are organized into **Pleat Shape**, **General**, **Domain,** and **Output**, accessible through tabs.



Clicking **OK** confirms the entered pleat options and clicking **Cancel** closes the **Cylindrical Pleat Options** dialog and discards the current modifications.

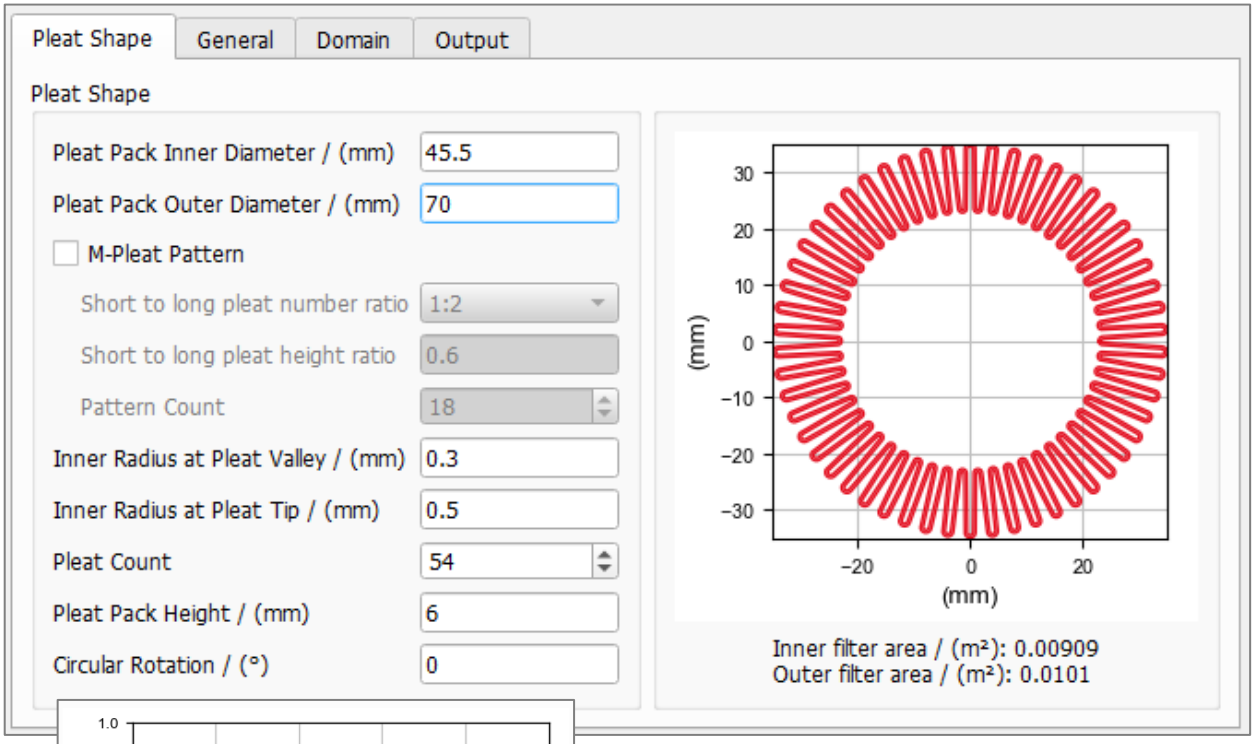
In the PleatGeo section click **Generate** to generate the cylindrical pleat medium with the entered parameters. If invalid values are entered, an error message appears.

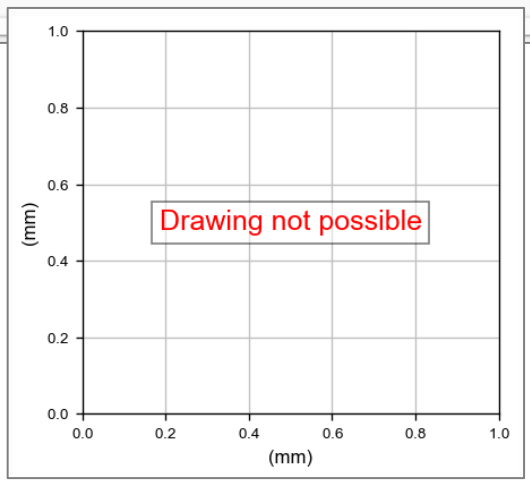


PLEAT SHAPE PARAMETERS

The shape properties of the pleat structure are entered under the **Pleat Shape** tab.

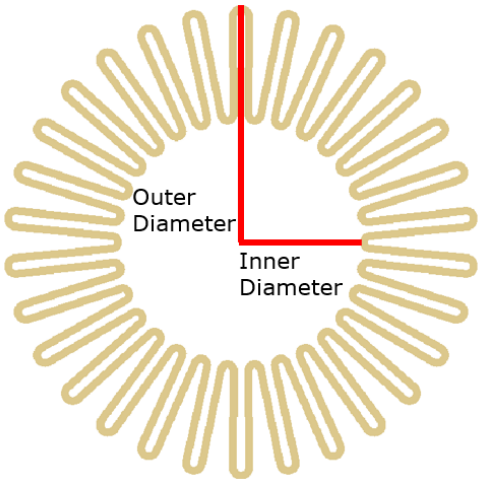
When entering **Pleat Shape** parameter values, the pleat graph at the right of the panel changes interactively and displays the effect of these adjustments on the pleat shape.

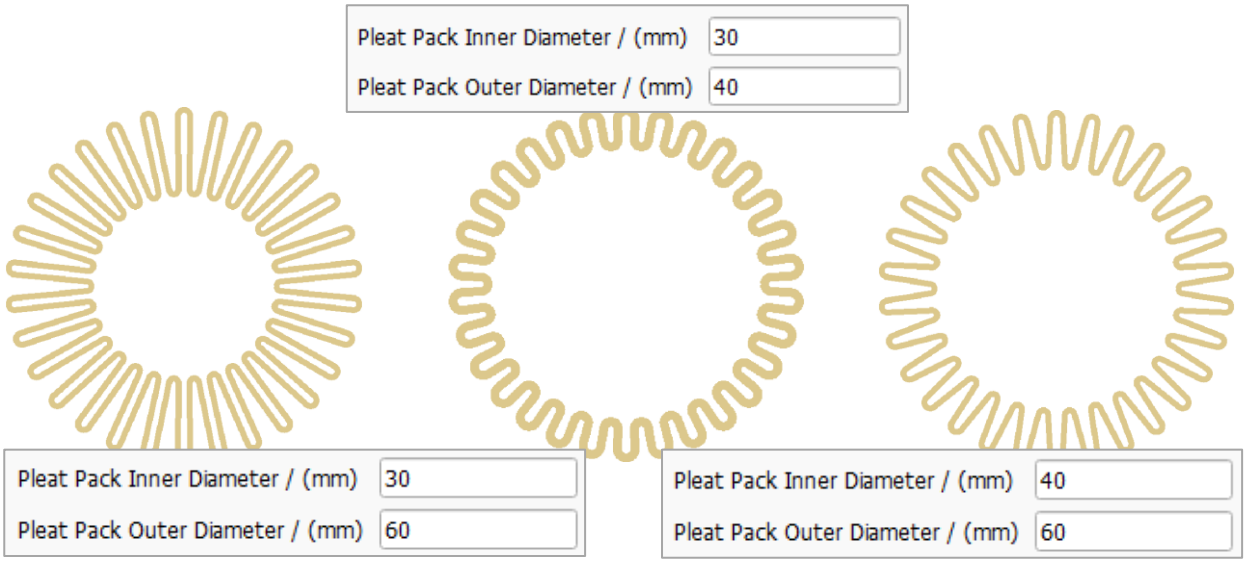




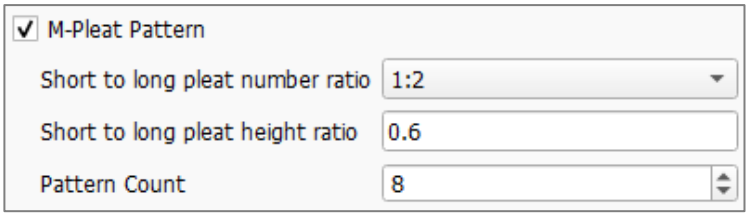
If invalid values are entered, the graph contains the error message "**Drawing not possible**" and no pleat medium is shown.

The parameters **Pleat Pack Inner Diameter** and **Pleat Pack Outer Diameter** define the pleat height and the distance to the center point of the cylindrical pleat medium.

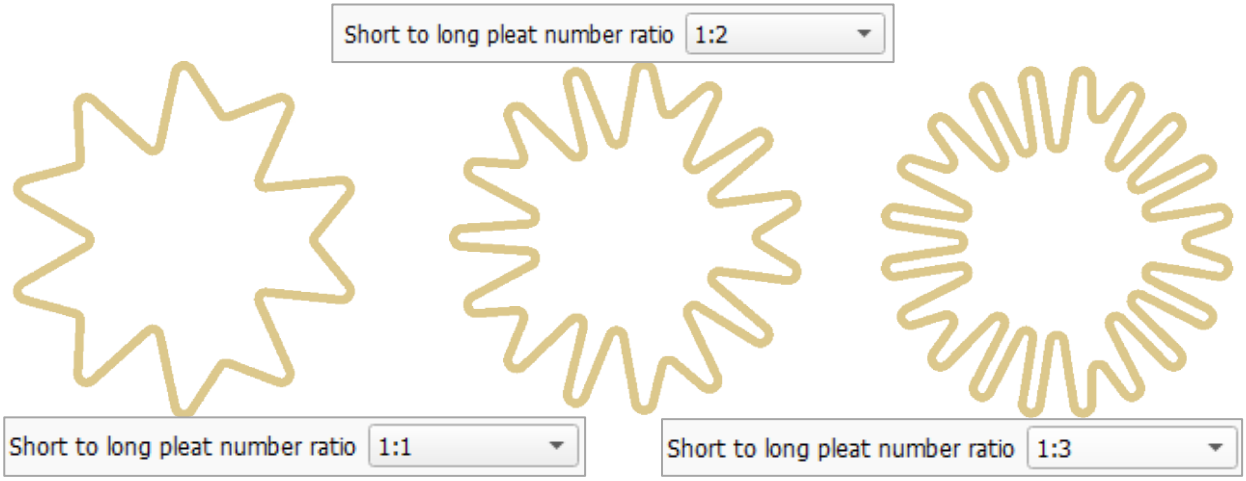




Checking **M-Pleat Pattern** applies an M-like shape on the pleats. Three parameters define the M-Pleat Pattern.

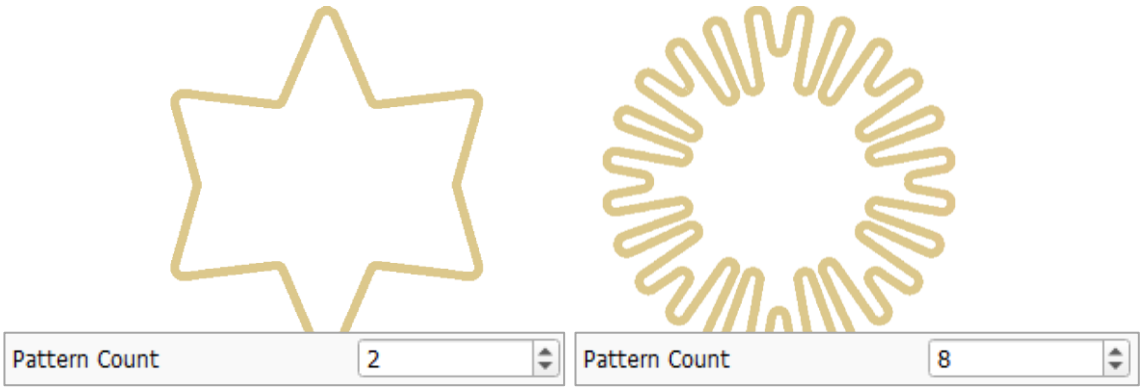


For **short to long pleat number ratio** select between **1:1**, **1:2** and **1:3**. For example 1:2 means, that for each short pleat two long pleats are found in the pleat medium.

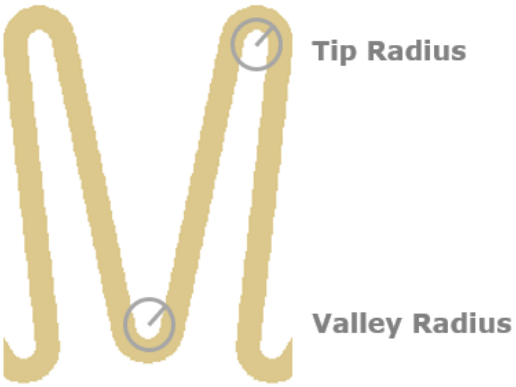


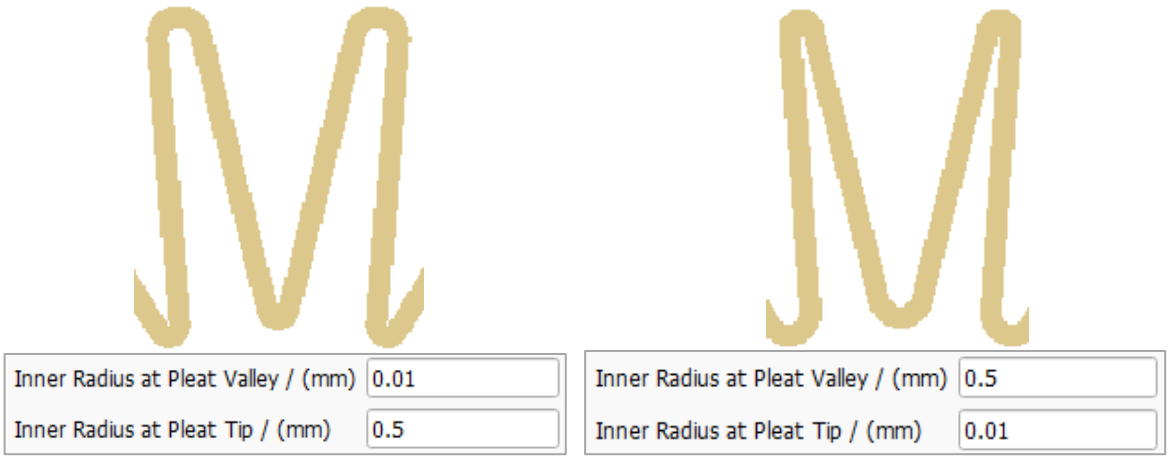
For **Short to long pleat height ratio** enter a number between 0 and 1. The smaller the number the shorter the short pleats. For a height ratio of 1 short and long pleats will have the same height.

The value entered for **Pattern Count** is the number of pattern repetitions. A pattern consists of one short pleat and the number of long pleats defined by the short to long pleat number ratio. For M-shaped pleats, the **Pattern Count** replaces the **Pleat Count**.

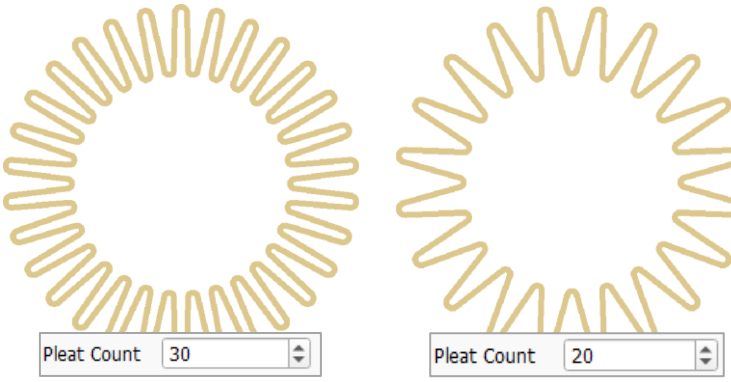


Define the **Inner Radius at Pleat Valley** and the **Inner Radius at Pleat Tip** to change the valley and tip shape of the pleats.

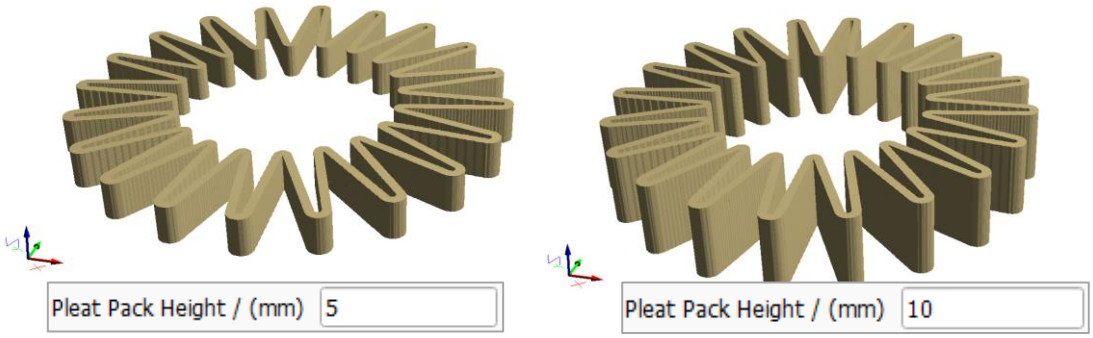




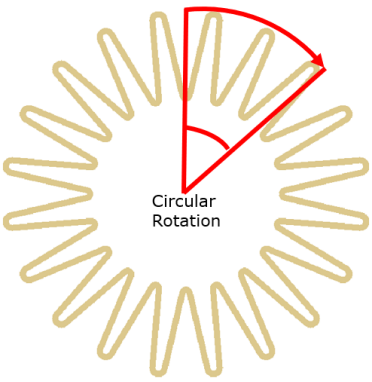
Pleat Count defines the total number of pleats that build the cylindrical pleat medium, if **M-Pleat Pattern** is not selected. Otherwise, it becomes unchoosable but calculated automatically by the M-Peat pattern mode and patter count.

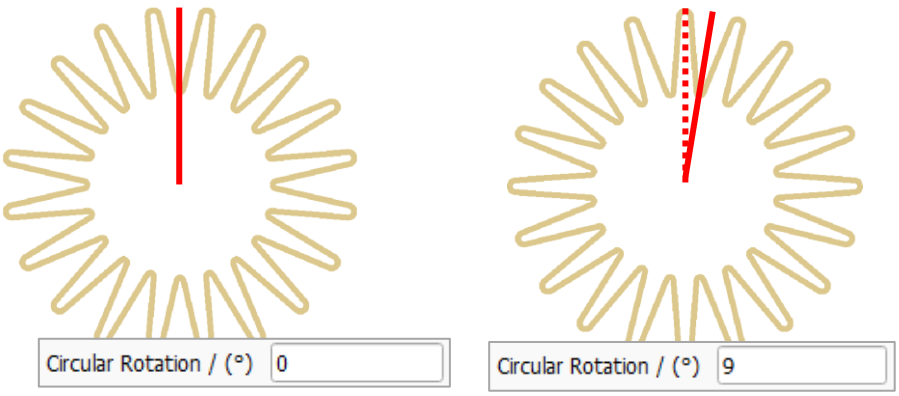


The **Pleat Pack Height** defines the height of the cylindrical pleat medium in Z-direction.



Define an angle for the **Circular Rotation**. Positive values rotate the cylindrical pleat medium in clockwise direction and negative values rotate it in anticlockwise direction.

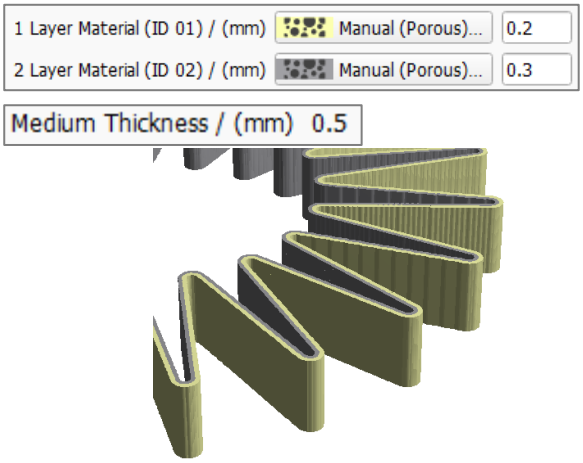


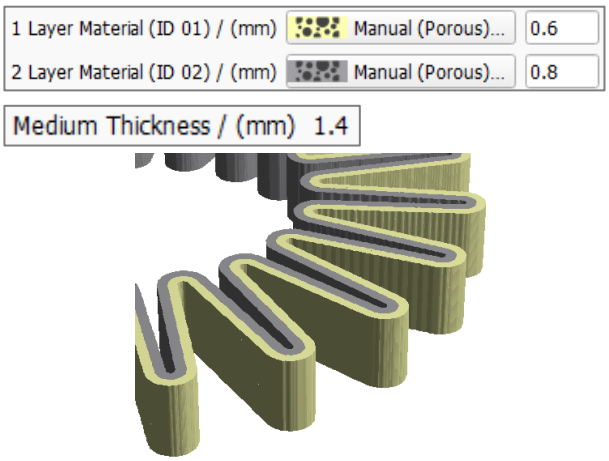


GENERAL PARAMETERS

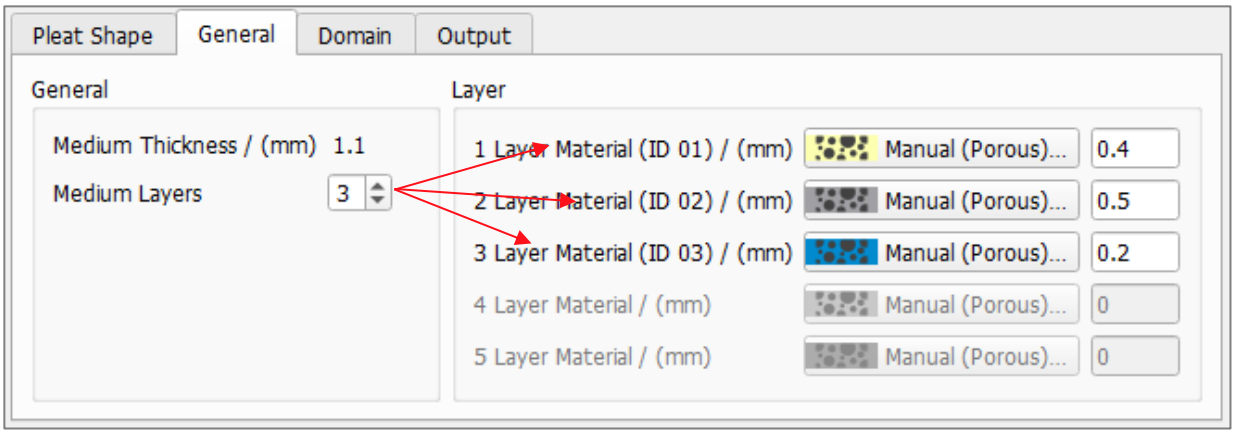
Medium Thickness defines the total thickness of the pleat medium and corresponds to the sum of the thickness of all layers.

The value of **Medium Thickness** changes automatically when modifying the thickness of the layers.

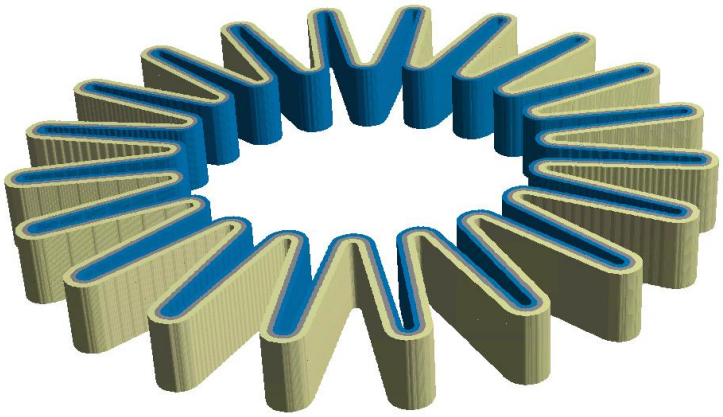




The value entered in **Medium Layers** determines the number of layers that form the pleat medium. Up to five layers of varying thickness may form the pleat.

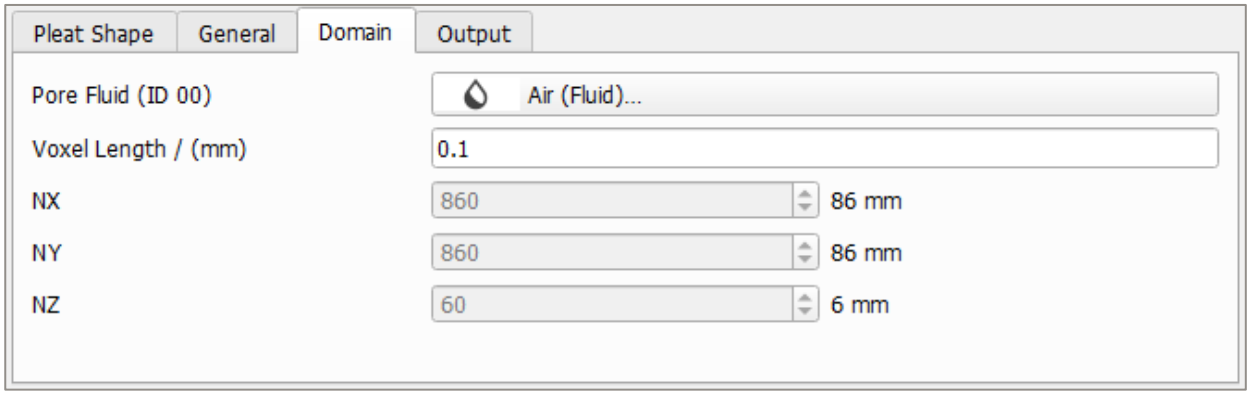


1, **2**, **3**, **4**, and **5 Layer Material** define the material and the thickness of each layer material forming the pleat medium.



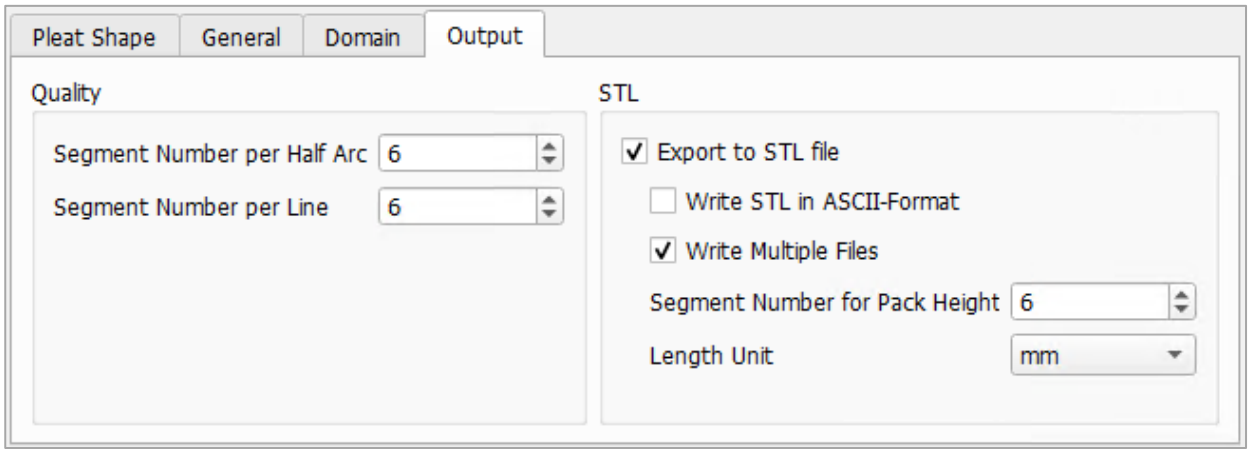
Domain parameters

The parameters under the **Domain** tab are the same as for the **Rectangular Pleat** described starting at page 13.



Output parameters

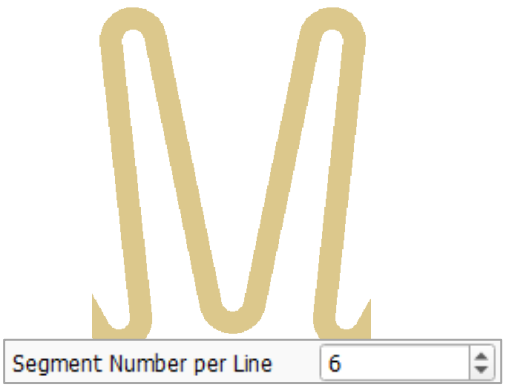
The parameters in the **Output** tab are grouped into the two panels **Quality** and **STL**.

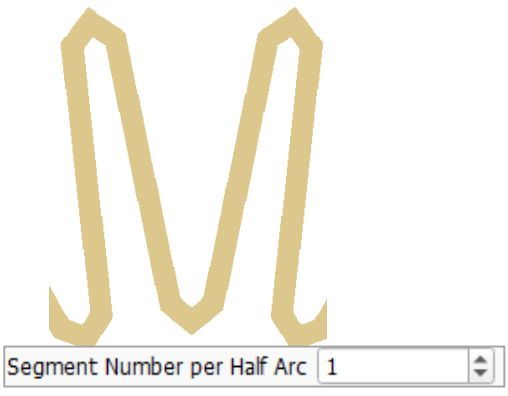


Quality

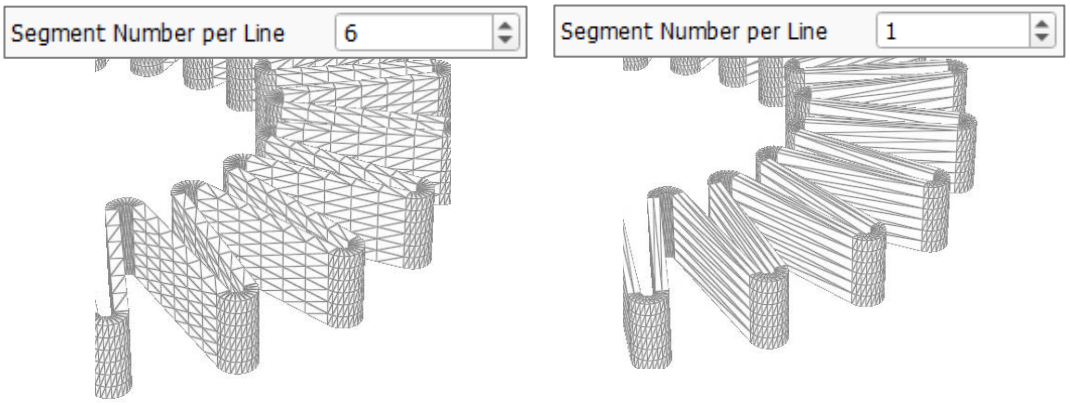
Enlarge the number of segments in a pleat to smoothen the pleat's curvature.

The **Segment Number per Half Arc** defines how many segments the half valley or half tip in a pleat consists.





The **Segment Number per Line** defines how many segments are used to build the straight pleat part between the two arcs. This only affects the STL format of the pleat. The voxel structure (*.gdt) will not change with varying line segment numbers.



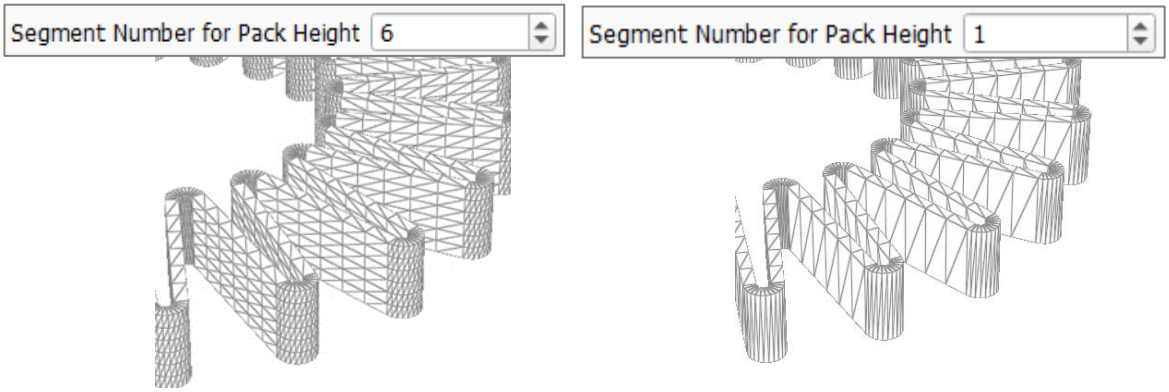
STL

Enable **Export to STL File** if the pleat structure should also be saved as *.stl.

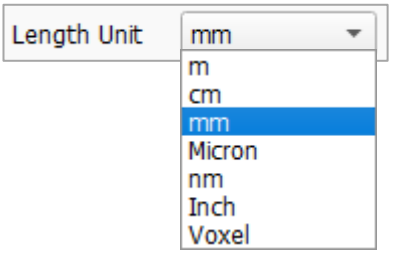
Decide whether to **Write STL in ASCII-Format** or as a binary format.

If multiple layers are defined in the **General** tab, checking **Write Multiple Files** produces an STL for each layer.

The **Segment Number for Pack Height** defines how many segments are used to build the pleat medium height in Z-direction. Larger numbers produce more triangles for the STL in Z-direction.



Determine the **Length Unit** used in the STL file.



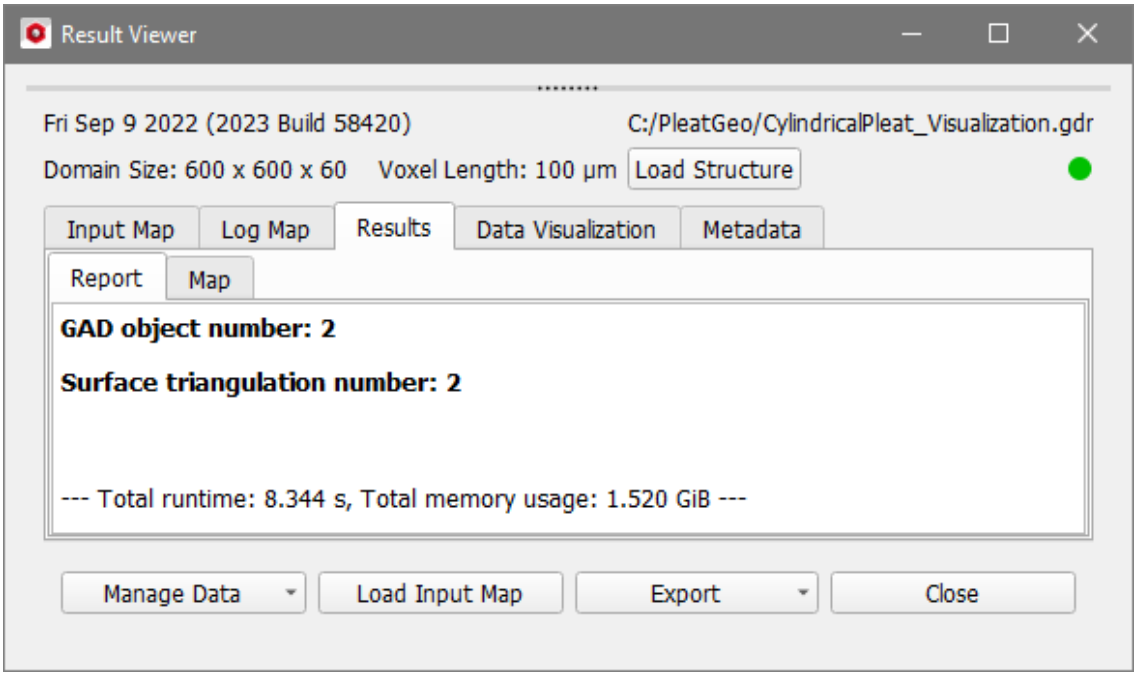
RESULTS

Generating a pleat medium produces a GeoDict result file (*.gdr) and a result folder with the same name. Both are saved in the chosen project folder (**File** → **Choose Project Folder...** in the menu bar).

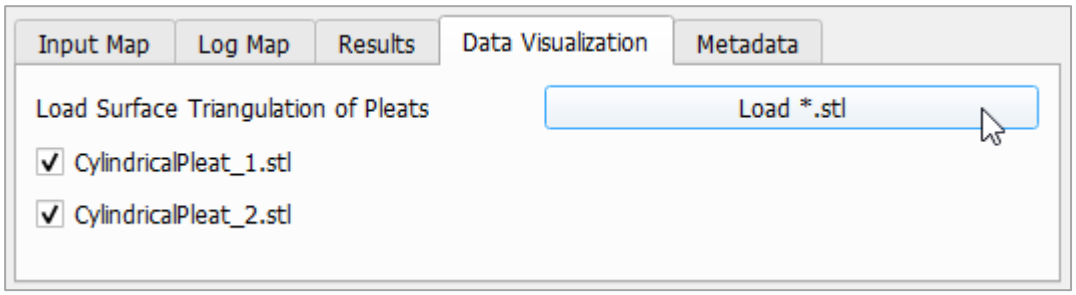
The GeoDict **Result Viewer** opens for the result file and in the **Results – Report** subtab find some information about the resulting structures.

The **GAD object number** is the number of layers in the pleat medium. Each of the layers is a different GAD-object. To learn more about analytical objects in GeoDict refer to the GadGeo handbook.

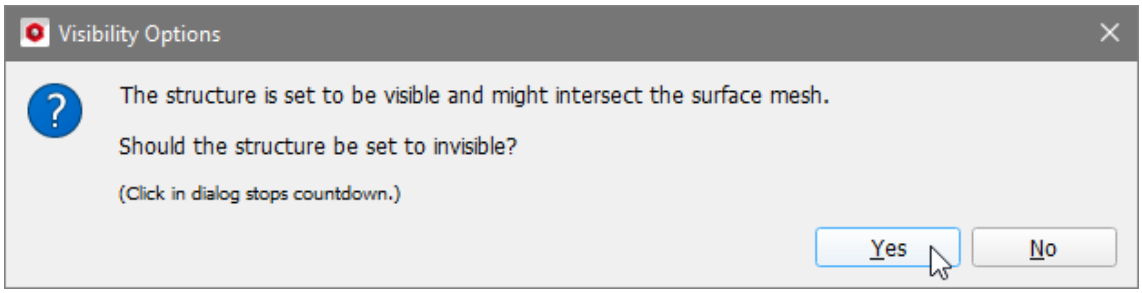
The **Surface triangulation number** is either 1 or the number of pleat layers, depending on whether **Write Multiple Files** is selected in the **Output** tab of the **Cylindrical Pleat Options** dialog.

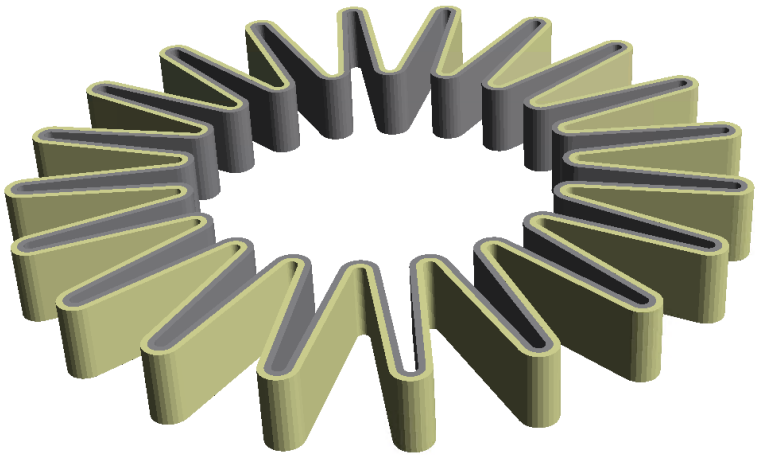


To load the STL files move to the **Data Visualization** tab. Select which layers should be loaded and click **Load *.stl**.

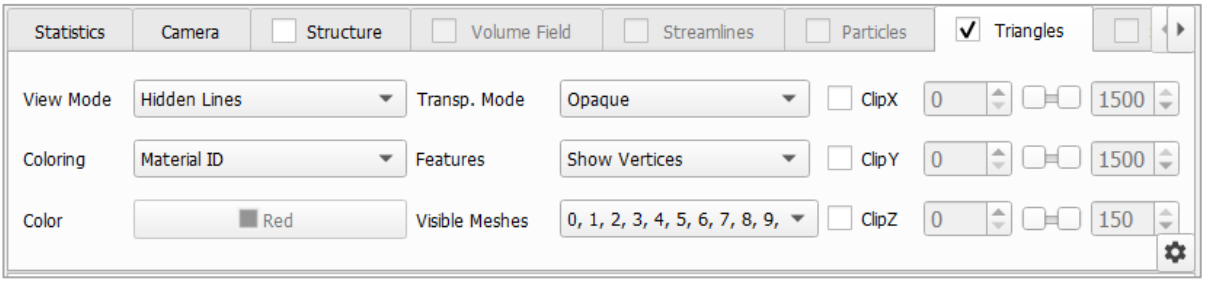


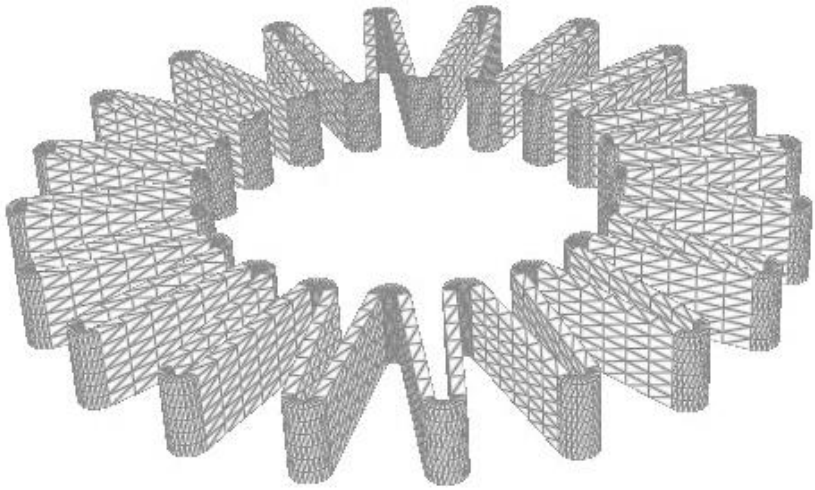
A dialog asks if the structure should be set to invisible. Click **Yes** to only visualize the triangles. The structure visualization can be turned on and off at any time by checking or unchecking the **Structure** tab in the Visualization panel.





In the Visualization panel use the options in the **Triangles** tab to change the visualization of the triangle mesh. For example, set the **View Mode** to **Hidden Lines** to view the triangles building the structure.





For more detailed information about the STL format and its visualization refer to the ImportGeo-CAD User Guide. To learn more about the general visualization settings in GeoDict refer to the Visualization User Guide.

https://doi.org/10.30423/userguide.geodict

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