# WeaveGeo

## User Guide

GeoDict release 2024

Published: February 14, 2024

Updated: July 2, 2024

GeoDict

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

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Citation:
Anne Blumer, Sebastian Rief, Barbara Planas. GeoDict 2024 User Guide. WeaveGeo handbook. Math2Market GmbH, Germany, doi.org/10.30423/userguide.geodict

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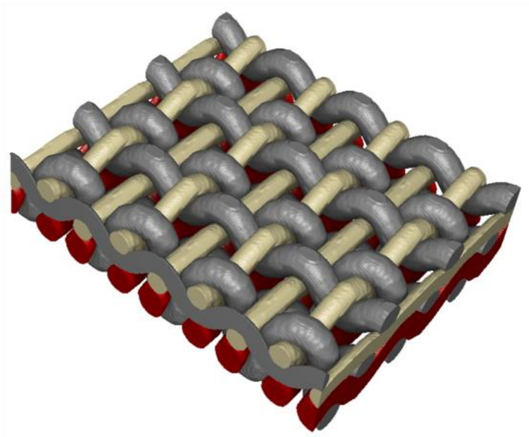
# WOVEN STRUCTURES GENERATED WITH WEAVEGEO

WeaveGeo is GeoDict's generator for woven structures. WeaveGeo contains generators for the three basic single-layer weaving patterns plain weave, twill weave, and satin weave. Additionally, user-defined weaving patterns can be created with the complex multi-layer weave command.

**Input:**
Desired weave properties: weaving pattern, weave type, warp and weft pitch, thread types, thread stiffness, materials...

WeaveGeo

**Output:**
Weave structure



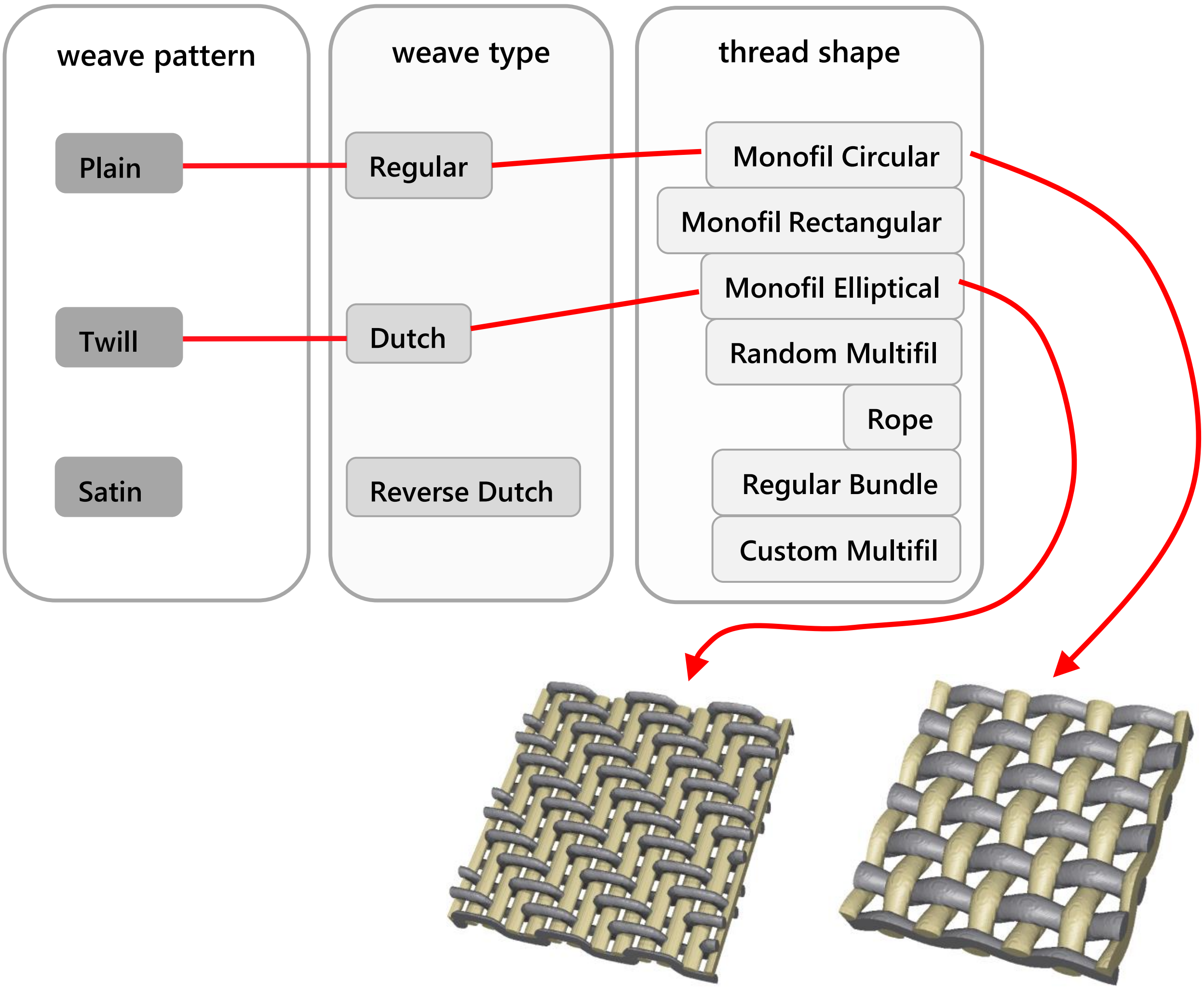
The origins of WeaveGeo lie in the industrial filtering sector. For example, simulations were conducted to improve the pressure drop of oil filters [1] or of components in paper dewatering felts [2] and forming fabrics. Furthermore, in several projects, weaves for sand control applications in oil and gas extraction and wastewater filtration ([3],[4],[5],[6]) were modelled and optimized. Many other applications are possible, such as investigations of high-density multifilament fabrics with CFD simulations [7].

Material properties like pore-size distribution, flow resistivity (permeability, pressure drop), effective thermal and electrical conductivity, effective elasticity, effective diffusion, filter efficiency, filter capacity, and many more, can be computed directly on the geometry models, using other GeoDict modules, e.g. PoroDict, ConductoDict, FlowDict, ElastoDict, DiffuDict, or FilterDict-Media.

## ESSENTIAL WEAVING TERMINOLOGY

In general, weaving involves the interlacing of two sets of threads at right angles to each other: the **warp** and the **weft**. The warp is the set of lengthwise threads that are held under tension on a weaving machine. The thread inserted above and below the warp threads is called weft. In GeoDict the weft threads are oriented in the X-direction and the warp threads are oriented in the Y-direction.

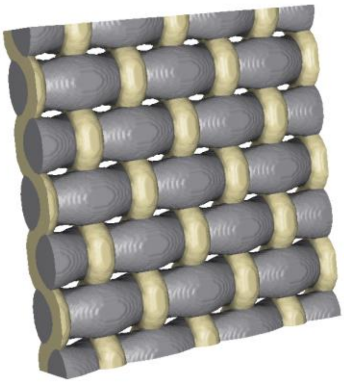
WeaveGeo allows to generate a large variety of different weaving structures by combining the available options. These options include different weaving patterns, weaving types, thread types and thread parameters (e.g. shape, size and material). Additionally, the weaving structure can be completely user-defined with the **Complex Multi-Layer Weave** option.




The choice of weave style (pattern and type) and thread material determines the final properties of the woven structure, such as weight, wettability, stability, flexibility, porosity, or smoothness.

## Weave Patterns and Weave Types

The way the warp and weft threads interlace with each other is known as the weave pattern. The basic weave patterns are **plain** weave, **twill** weave, and **satin** weave, and the majority of woven products are created using one of these three.



The **Plain** weave is the simplest weave pattern. Each weft is alternately placed above and below a warp thread, creating the characteristic cross (or checkerboard) pattern. Each unit cell contains two warp and two weft threads.

**Twill** has a characteristic pattern with a diagonal rib. The weft thread runs (floats) over at least one, and then under at least one warp thread. The characteristic pattern is created by the offset (or weft shift) between successive weft threads.

In a **Satin** (or atlas) weave, the weft thread runs (floats) over at least four warp threads before it passes under one. This leads to a very smooth structure whose appearance is dominated by the weft threads. Usually, an offset (weft shift) greater than 1 is chosen between the individual weft threads, so that no binding points lie next to each other.

In WeaveGeo, all three basic weaves can be generated according to three weave types: Regular, Dutch weave, and Reverse Dutch weave.

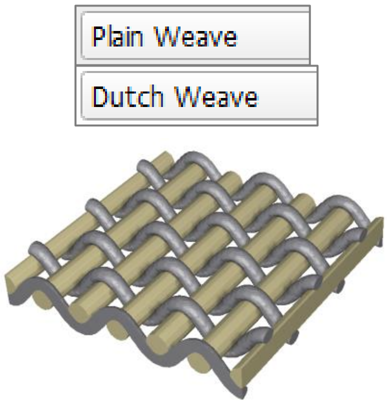
### Regular

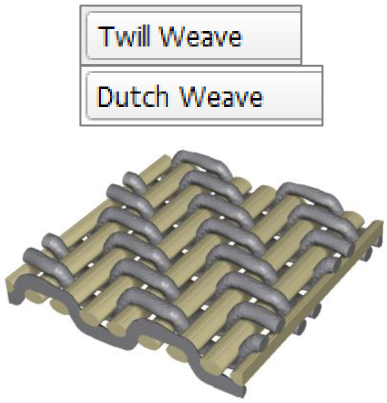
In the **Regular** (or square) weave, warp, and weft are bent around each other, resulting in a characteristic structure with rectangular meshes. Examples for all three weave patterns using the regular weave type are shown above.

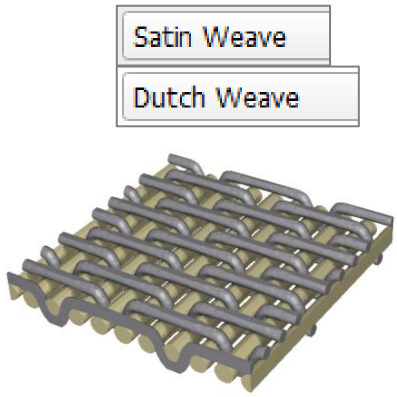
## Dutch Weave

In a **Dutch Weave**, the warp threads are straight and do not deform. The weft threads bend around the warp threads. In this way, they can be placed close together giving a very dense, firm mesh with great strength in the weft direction. Usually, the warp threads are thicker than the weft threads.

Generally, **Twill Dutch Weaves** are more rigid than **Plain Dutch Weaves** and can carry higher loads. This weave type has smaller pores and lower permeability (flow velocity) than other Dutch weaves and allows to filter particles of fine diameter. It is thus widely used for industrial filtration.

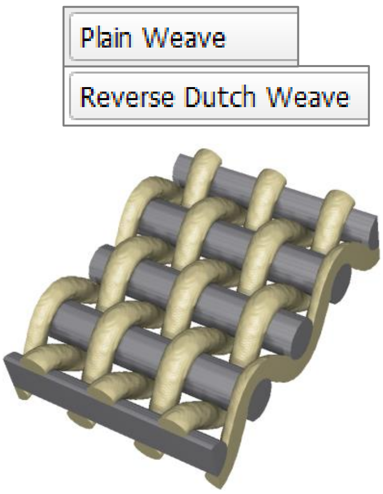


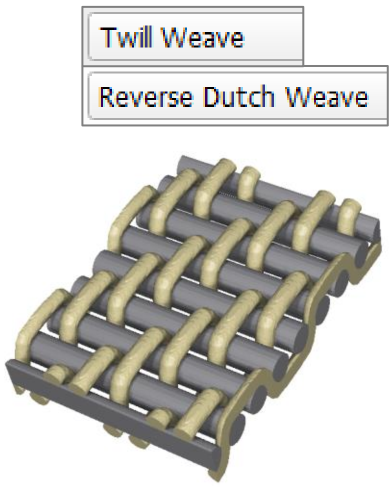



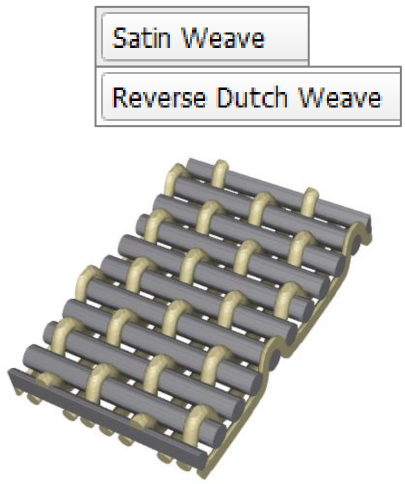




## Reverse Dutch Weave

In the **Reverse Dutch Weave**, the warp threads bend around the straight weft threads. The pattern is reversed compared to **Dutch** weaves. The result is a strong weave in the warp direction. Due to the differences in the manufacturing processes, different technical properties can be achieved. Accurate and uniform pore sizes can be realized. It is used in applications requiring specific acoustic properties, mechanical robustness (petroleum industry) and high throughput for filtration (chemical, food, and pharmaceutical industry).



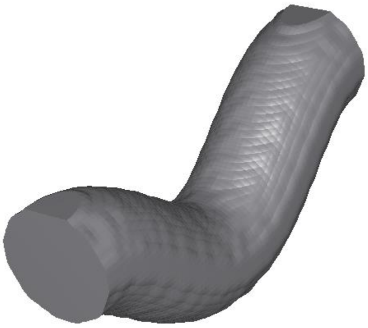
# Thread Profile Types

A thread is an object, natural or manufactured, with a high enough length-to-width ratio that it can be woven. The smallest component that can be separated from a thread is a filament. The choice of filament and the way the thread is composed of the individual filaments has a major impact on the properties of the weave.

## Monofil and Multifil

The threads of a weave can often be modelled as compact objects without an inner structure, for example, as in metal wire meshes. Such threads are called **Monofilament** or **Monofil** threads.

Three monofilament profiles are available in WeaveGeo: **Circular**, **Elliptical**, and **Rectangular**.



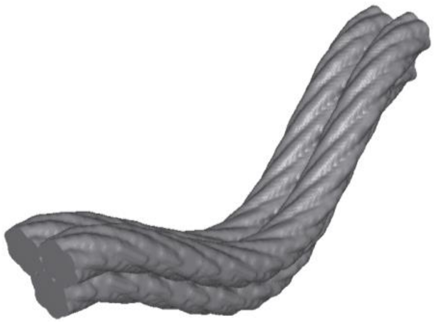
A thread which is composed of many filaments is called **Multifilament** or **Multifil** thread. For multifilament threads it is necessary to model the position of the center of the filament profiles in the threads, and the geometry of the filaments.

For the **Random Multifil** model, the filament positions are chosen randomly.

## Rope

A **Rope** is a strong, thick string made of strands of filaments (fibers, wires) twisted together.

For example, here, a 3x7 rope is shown. The rope is made of 3 strands and each strand is made of 7 filaments. WeaveGeo already contains the most common rope types, additional rope types can be implemented upon request if necessary (contact Math2Market for further information).

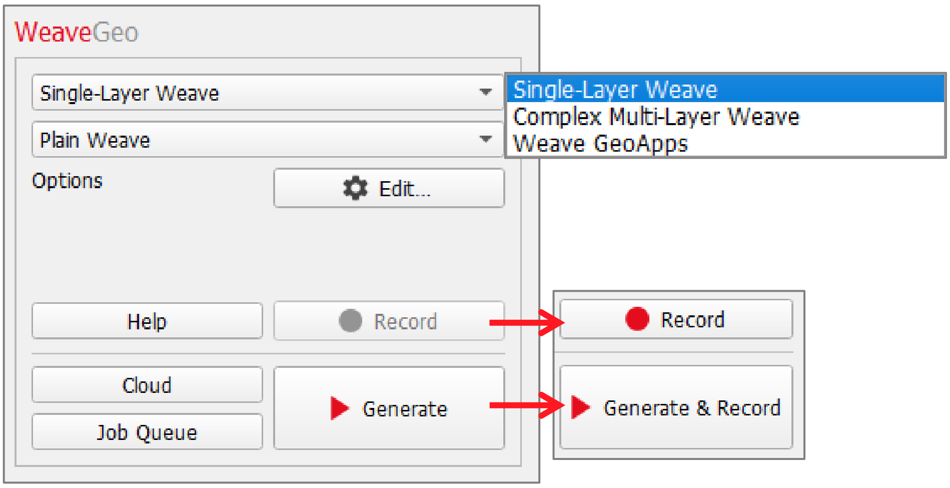


## Regular Bundle

In a **Regular Bundle**, the positions of the filaments form a regular grid. Filaments of equal size are arranged next to each other.

## WeaveGeo Section

WeaveGeo starts when selecting **Model → WeaveGeo** in the menu bar. The WeaveGeo section pull-down menu offers the commands:




- **Single-Layer Weave:** Available to model are **Plain Weave**, **Twill Weave**, **Satin Weave**. For these weave patterns (see above page 3), different styles (Plain, Dutch and Reverse Dutch) and thread types (Monofil, Multifil, Rope and Regular Bundle) are chosen, and numerous textile parameters are entered through the **Options**' **Edit ...** button.
- **Complex Multi-Layer Weave** allows to define other weave patterns and styles than the predefined ones from the single-layer weave options. Additionally, the weft and warp system can each contain up to 7 different thread types (Monofil, Multifil, Rope and Regular Bundle).
- **Weave GeoApps**, with examples of representative woven structures.

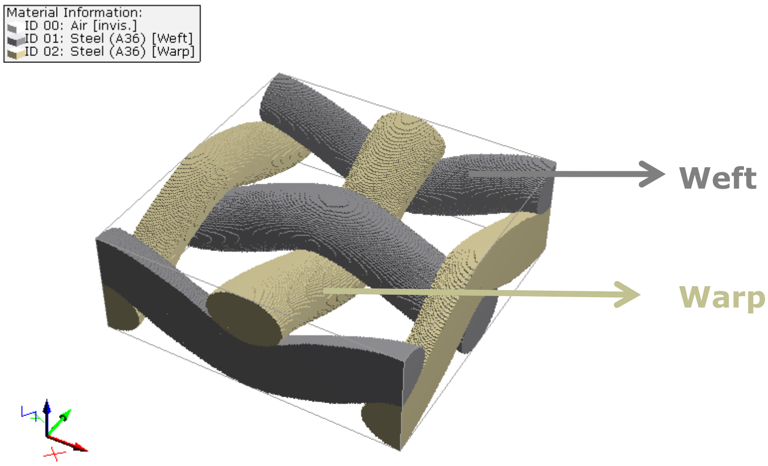
For each of the selectable weave patterns, a weave options dialog opens, containing some default textile parameters necessary to construct the unit cell. User-defined values can be entered (and saved) to modify the default structures.

The weft thread is always oriented in the X-direction and the warp thread is always oriented in the Y-direction. Thus, the weaving plane is always the X-Y-plane.

Each structure is composed of unit cells. For the plain weave, e.g., a unit cell has two weft threads and two warp threads. In the X- and Y-direction, a unit cell starts at the middle of one thread and ends at the middle of the second next thread. This means there are two meshes in each the X- and Y-direction. The size of the unit cell in the X-, Y-, and Z-direction is determined based on the entered parameters for the thread types and weaving patterns and cannot be determined by the user. However, it is possible to enter the number of unit cells which form the structure.

Every structure in WeaveGeo is generated periodically. This means a thread leaving on one side of a unit cell re-enters it on the other side.

Clicking the **Generate** button at the bottom of the WeaveGeo section starts the generation of the structure. Below, an example structure which consists of one unit cell is given. Throughout this WeaveGeo handbook (except for the complex multi-layer weaves), the weft thread is always grey and the warp thread is always beige.

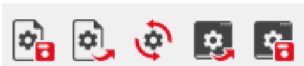



Macro files are recorded and saved when selecting **Macro** → **Start Macro Recording...** in the Menu bar. When recording a macro, **Record** becomes active and **Generate** changes to **Generate & Record**.

The results of every WeaveGeo generation run are saved in the chosen project folder. A customized **Result File Name (*.gdr)** can be entered to differentiate the results of sets of WeaveGeo generations. The result file contains all information about the current WeaveGeo run. Additionally, a result folder with the same name is created which contains the generated structure. The parameters used for the generation of the structures can be re-loaded to GeoDict directly from the results file. For this, open the results file and click the **Load Input Parameters** button at the bottom of the Result Viewer.

When running projects worth archiving, it is useful to save many files with information about the generation process, such as the structure in *.gdt and/or *.gad format (through **File** → **Save Structure as...**), and *.gps (GeoDict Project Settings file).

If you save the parameters in the **Options** dialogs into *.gps (GeoDict Project Settings) 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 dialogs when needed. Rest the mouse pointer over an icon to see a Tool Tip showing the icon's function.

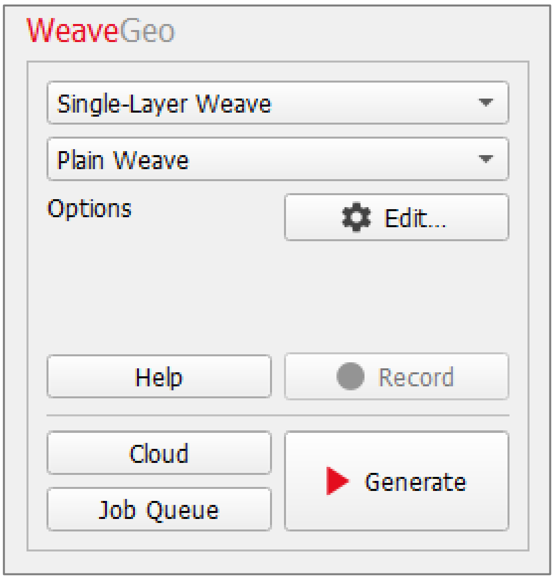


## Single-Layer Weave

When selecting **Single-Layer Weave** in the WeaveGeo section, one of the three most common weave patterns **Plain Weave**, **Twill Weave**, and **Satin Weave** must be selected from the pull-down menu.


### Plain Weave

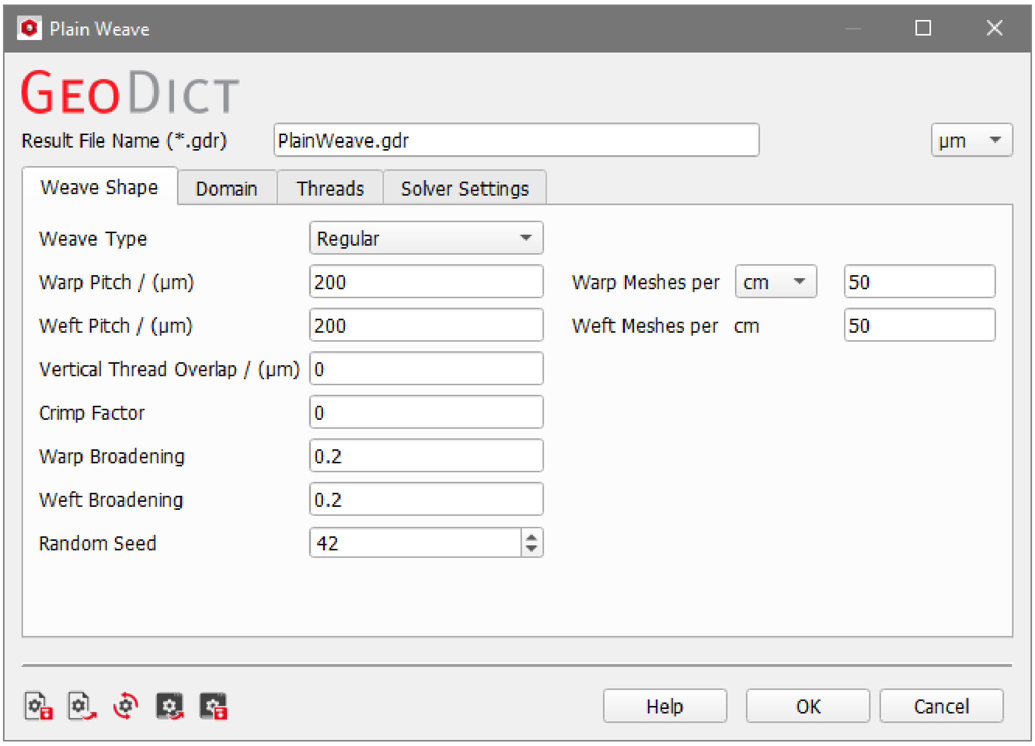
Choose **Plain Weave** and click the **Options' Edit...** button to open the **Plain Weave** dialog.




At the top of the dialog, the name for the files containing the generation results can be entered in the **Result File Name (*.gdr)** box. The default name can be kept, or a new name can be chosen fitting to the current project.

On the top right, the available **units** (m, cm, mm, µm, nm, and Inch) are selectable from the pull-down menu. When the units are changed, the entered values are adjusted automatically.

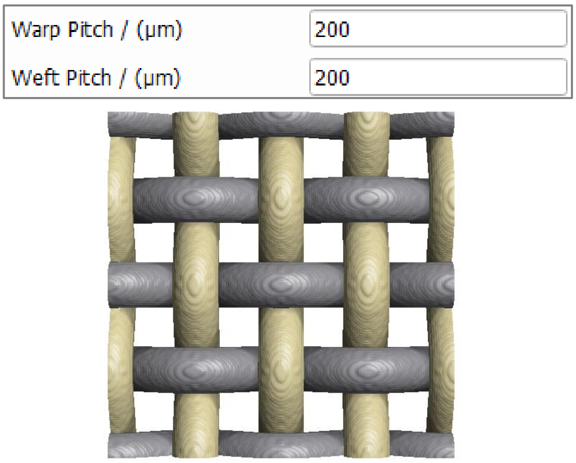
The weave parameters are organized under the tabs **Weave Shape**, **Domain**, **Threads**, and **Solver Settings**.

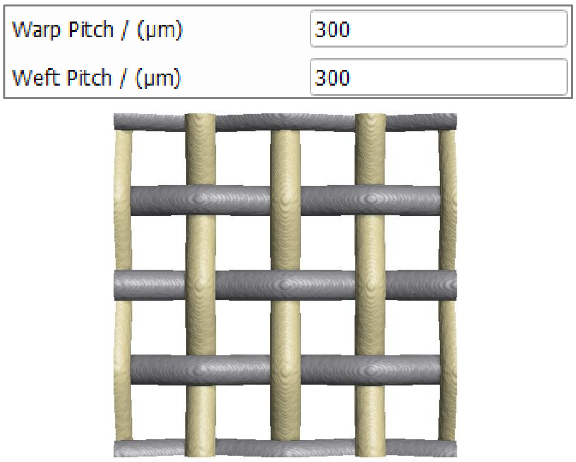



## Weave Shape

The plain weave types can be selected from the **Weave Type** pull-down menu. See pages 3ff. for explanations on these three types of weaves (**Regular**, **Dutch Weave**, and **Reverse Dutch Weave**).

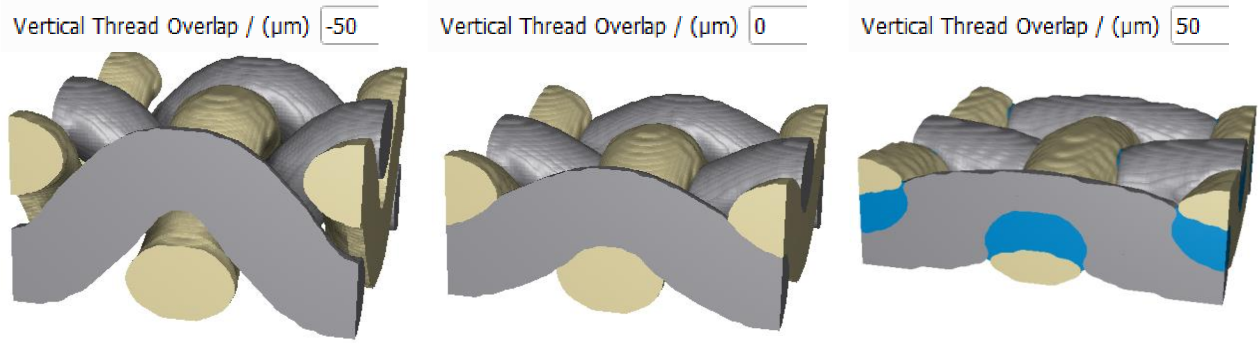
**Warp** (and **Weft**) **Pitch** is the distance between the center lines of two adjacent warp (or weft) threads. This corresponds to the sum of the aperture and the thread width. The aperture is equal to the pore space between two consecutive threads. It is not explicitly entered in the dialog, but implicitly defined by the warp (or weft) pitch. The thread width is specified in the **Threads** tab of the dialog, which is explained later on page 13ff. The warp (or weft) threads touch if the entered pitch is equal to the width of the warp (or weft) thread.



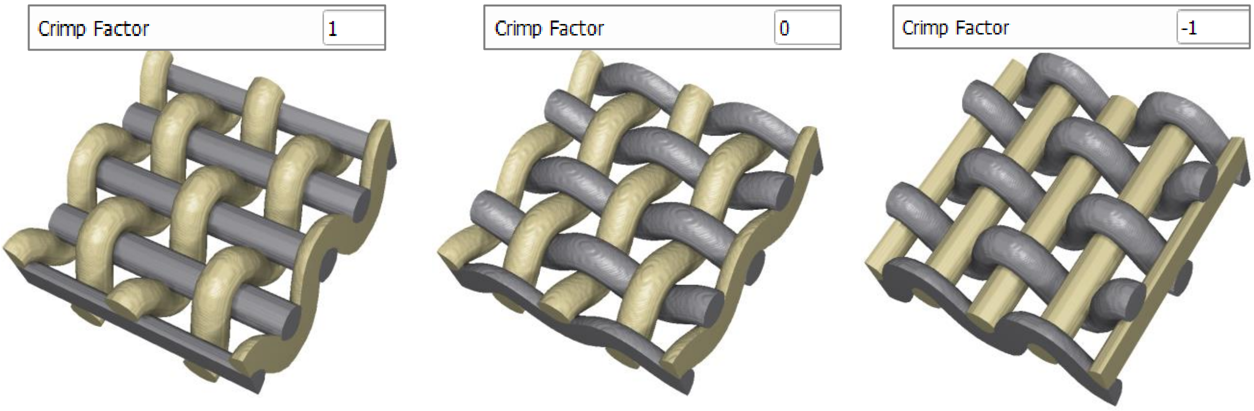

The warp pitch and weft pitch can also be entered as **Warp Meshes per Inch** or **Warp Meshes per cm** and **Weft Meshes per Inch** or **Weft Meshes per cm**. This is equivalent to the number of threads of warp or weft per inch or cm in the structure. These values are changed automatically when modifying the values for **Warp Pitch** or **Weft Pitch**, and vice versa.
The amount of overlap that the threads show at their crossing points is determined by the amount of **Vertical Thread Overlap**. Negative values can be used to enforce

distance. The overlap, corresponding to the entered value of vertical overlap, is shown blue in the figure below (for the chosen color settings for warp and weft). The thread overlap has no physical equivalent, but it is helpful to simulate the deformation of threads at their touching points.

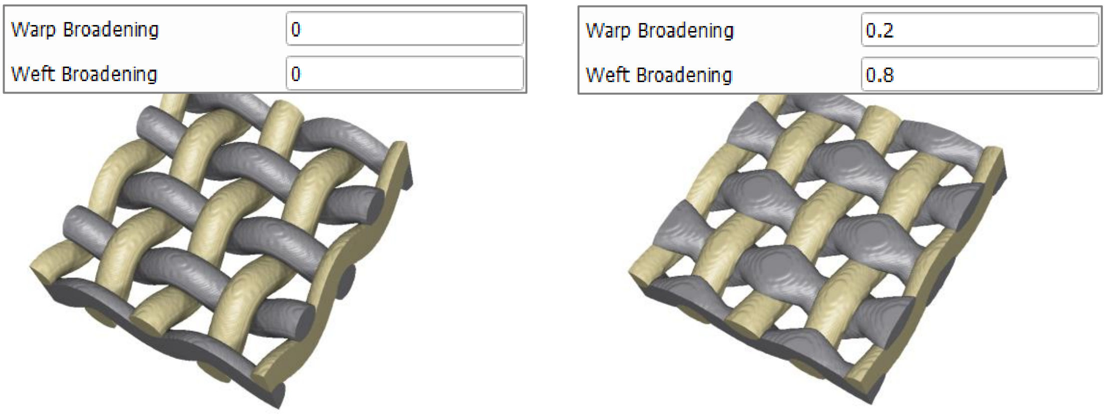



The **Crimp Factor** defines the straightness of the warp and weft threads. It varies between -1 and 1. A value of 1 for the **Crimp Factor** results in straight weft threads, which is equal to the weave type Reverse Dutch Weave. A value of -1 results in straight warp threads, which is equal to the weave type Dutch Weave.

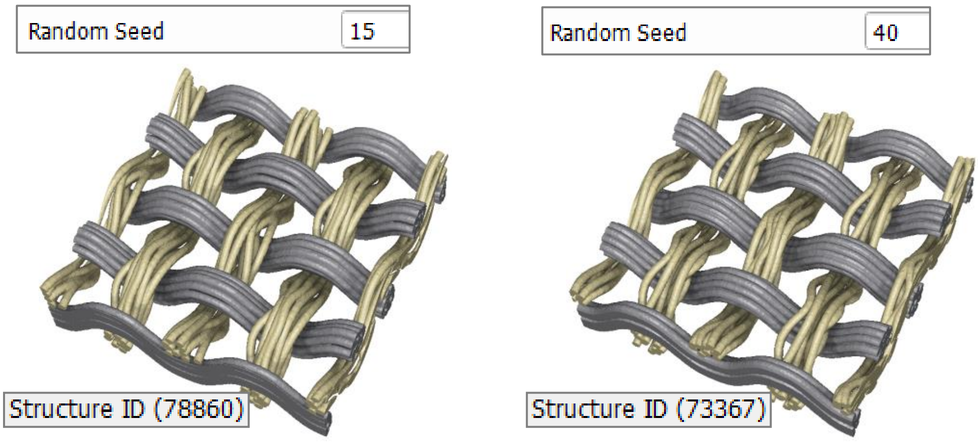
When the crimp factor is set to 0, both thread types are bent around each other, leading to a thinner structure in Z-direction. Consequently, for the weave types **Dutch Weave** and **Reverse Dutch Weave**, the Crimp Factor cannot be changed. For the weave type **Regular**, the **Crimp Factor** allows to model all possible gradations between the extremes Dutch Weave and Reverse Dutch Weave.



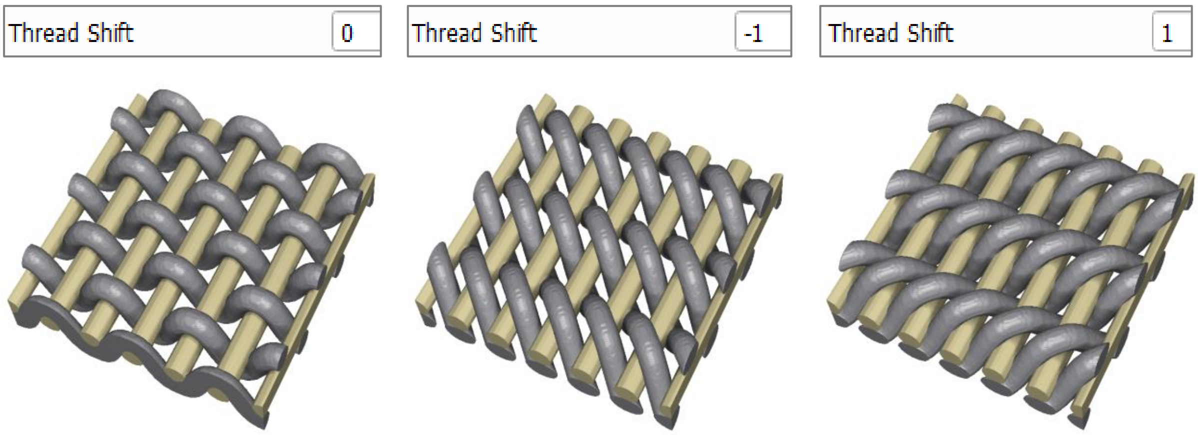

**Warp** and **Weft Broadening** are the widening of the threads at the crossing points of weft and warp threads. This simulates the bending and deformation of the threads during the weaving process. Values of broadening vary between 0 (no broadening) and 1 (maximum broadening). When Dutch Weave is chosen, the Warp Broadening is fixed to 0, because the corresponding threads are straight and do not deform. Analogously, for Reverse Dutch Weave the Weft Broadening is fixed to 0



**Random Seed** initializes the random number generator behind the structure generator. Changing its value produces different sequences of random numbers and hence, different realizations of the specified structure. If all settings are equal, generating with the same **Random Seed** value produces exactly the same structure. The **Random Seed** is a non-negative integer number. It affects the structure generation, if for example **Random Multifil** threads are used (see page 5) or **Weft/Warp Lateral Deformation** is applied (see page 24). For twill weave and satin weave, the realization of other parameters is also influenced by the chosen random seed. This is mentioned when the corresponding parameters are explained.



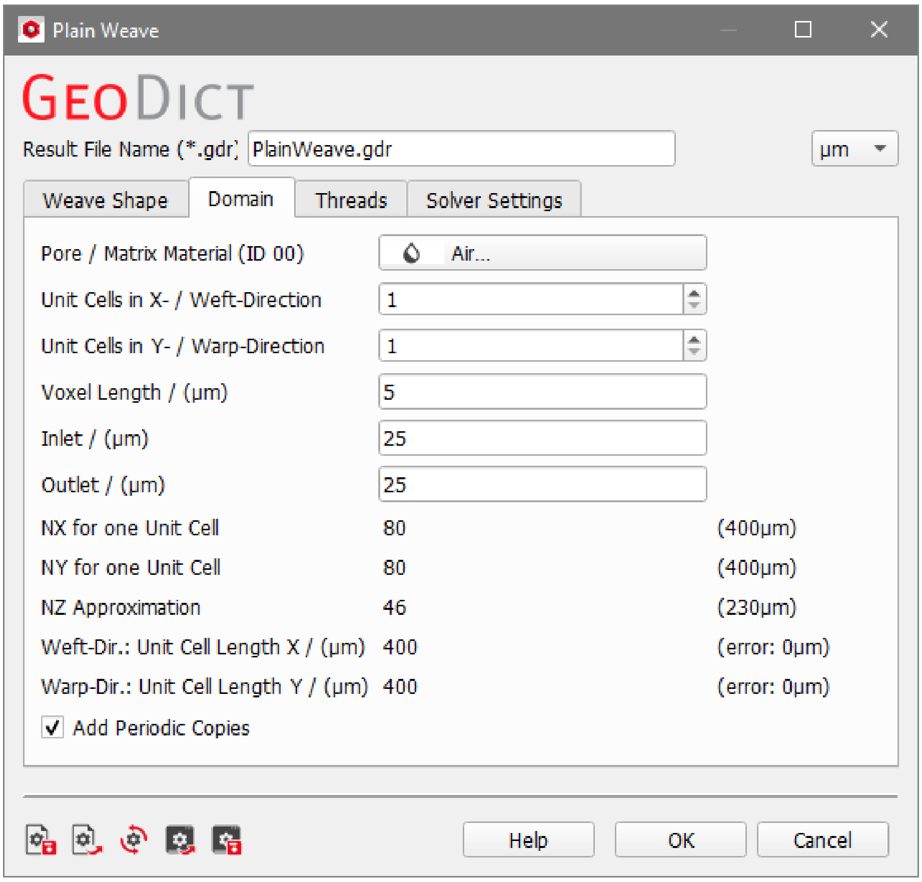

The option to choose the **Thread Shift** is only available when choosing **Dutch Weave** or **Reverse Dutch Weave.** With the default value of 0, the weft threads (or warp threads, in case of Reverse Dutch Weave) run perpendicular to the warp (or weft) threads. When choosing a value of -1 or 1, they run diagonally.



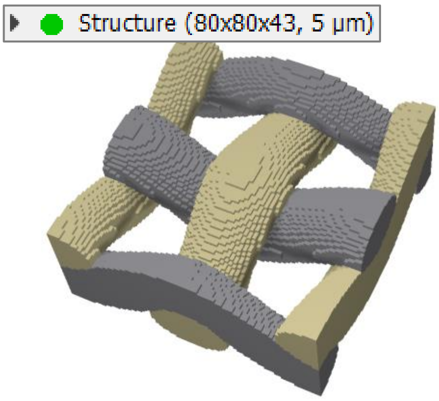

## Domain

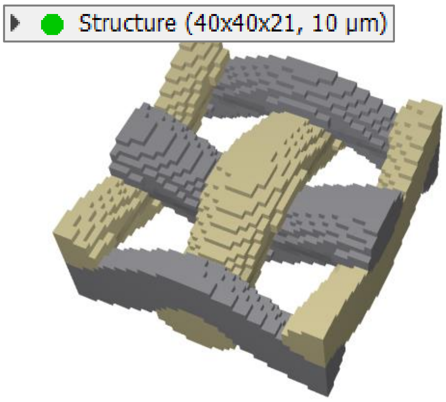
By clicking the **Pore/Matrix Material (ID 00)** button, the Material Selector opens to select the material which occupies the space surrounding the threads (e.g. Air) from the GeoDict Material Database (see also the Material Database handbook of the User Guide).

The values in **Unit Cells in X-/Weft Direction** and **Unit Cells in Y-/Warp Direction** set the number of repetitions of the generated unit cell. Thus, a large number of unit cells leads also to a larger structure.

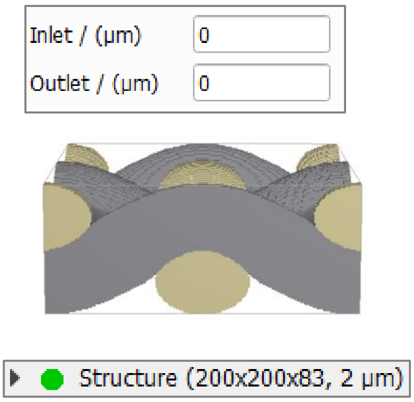


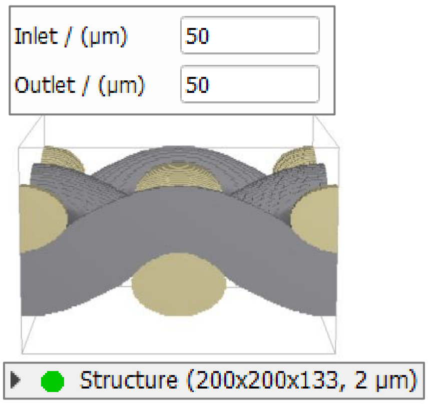

The **Voxel Length** is the size of a voxel in the chosen units. To observe the effect of increasing voxel length, select **Box renderer** under **View** → **3D Structure Renderer** → **Box**, instead of **Smooth** renderer (since this option softens the visualization).




The values of **Inlet** (-Z direction) and **Outlet** (+Z direction) determine the size of the void regions in the chosen unit below and above the created woven structure.



The values for **NX for one Unit Cell**, **NY for one Unit Cell**, and **NZ Approximation** indicate the number (N) of voxels in **X**, **Y** and **Z**-direction for the unit cell. Analogously, **Weft-Dir.: Unit Cell Length X** and **Warp-Dir.: Unit Cell Length Y** show the length of the unit cell in the chosen length unit.

These values are not editable, since they are depending on the defining parameters of the structure, as for example the thread widths and pitches and the thread broadening.

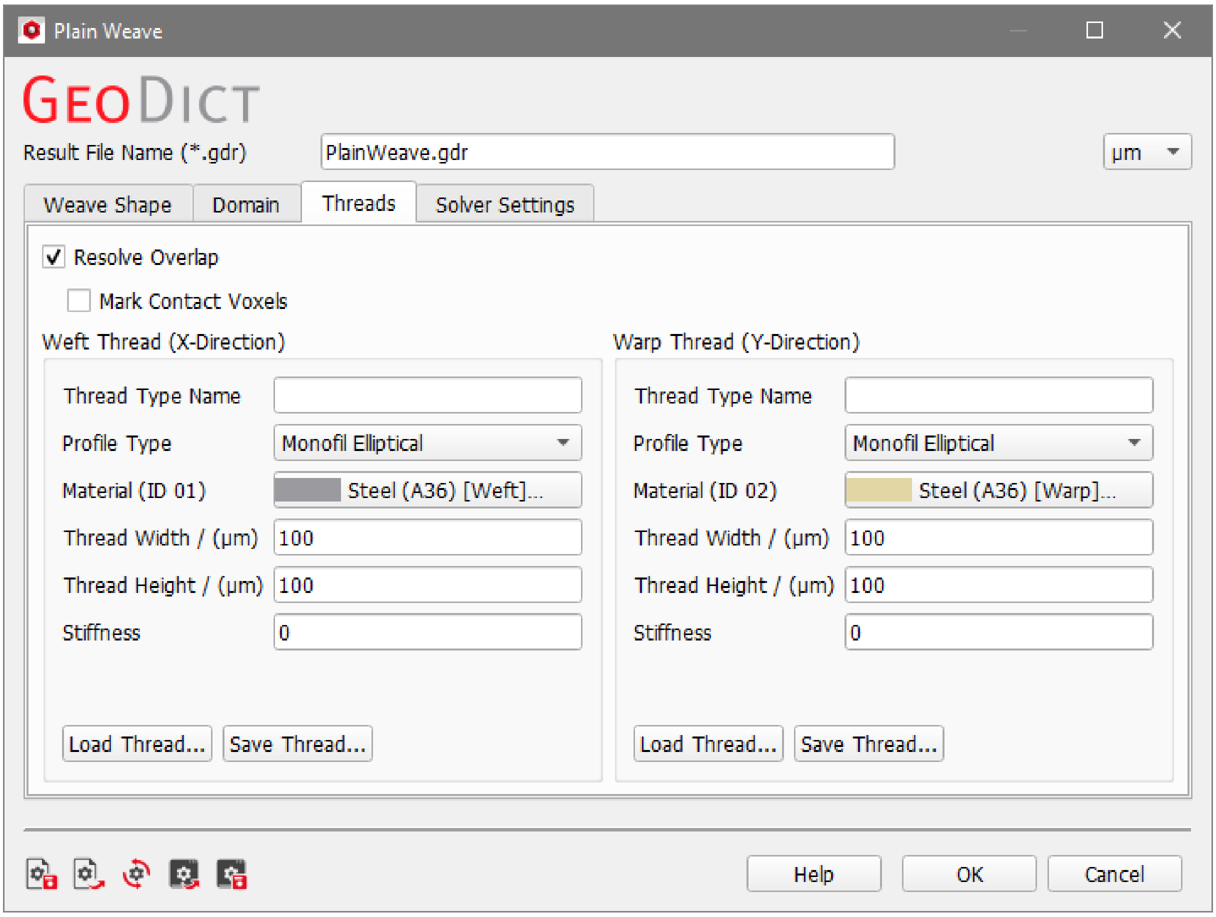
The option **Add Periodic Copies** helps to prevent problems when exporting a mesh of the structure. If this option is enabled, periodic copies of one unit cell are added in each direction of the X-Y-plane. The periodic copies are only stored as GAD information (analytical object information) and have no influence on the voxelized geometry. It is not necessary to check this option when the structure is used only in GeoDict. If the structure should be exported to a mesh (with ExportGeo-CAD of MeshGeo), this option should be enabled to prevent artefacts at the domain boundary.

## THREADS

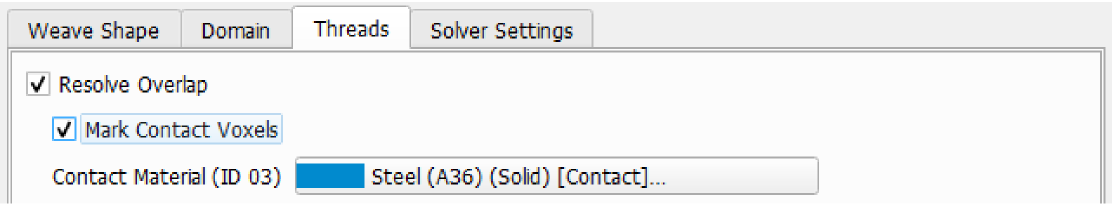
All parameters defining the shape of the threads, the size, and the number and shape of the filaments are entered under the **Threads** tab.

Different threads might overlap in the generated structure, e.g. due to Vertical Thread Overlap (see page 9). This might be unintuitive, but it leads to realistic thread shapes at contact points. Therefore, the thread overlap allows to create realistic weave structures without the need for simulating the physical effect of the thread contacts.

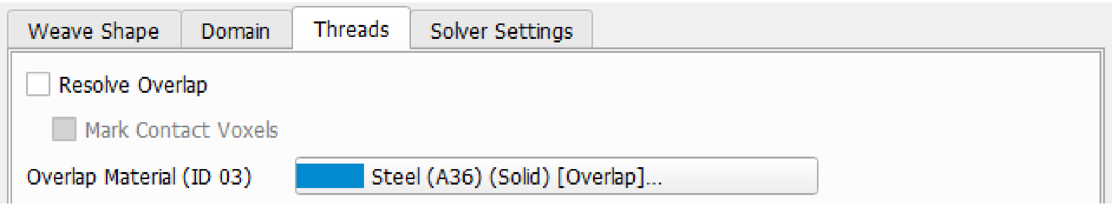
By default, **Resolve Overlap** is enabled. With this option, the overlapping regions are assigned to the materials of the threads which are in contact. This leads to a realistic weave structure.



**Mark Contact Voxels** allows to define a separate material for the contact areas. In this way, even contacting threads with the same material ID can be clearly distinguished. Using **Resolve Overlap** needs more time to compute, therefore we recommend disabling this option for large structures where the information about the overlap is not relevant (e.g. for flow simulations).

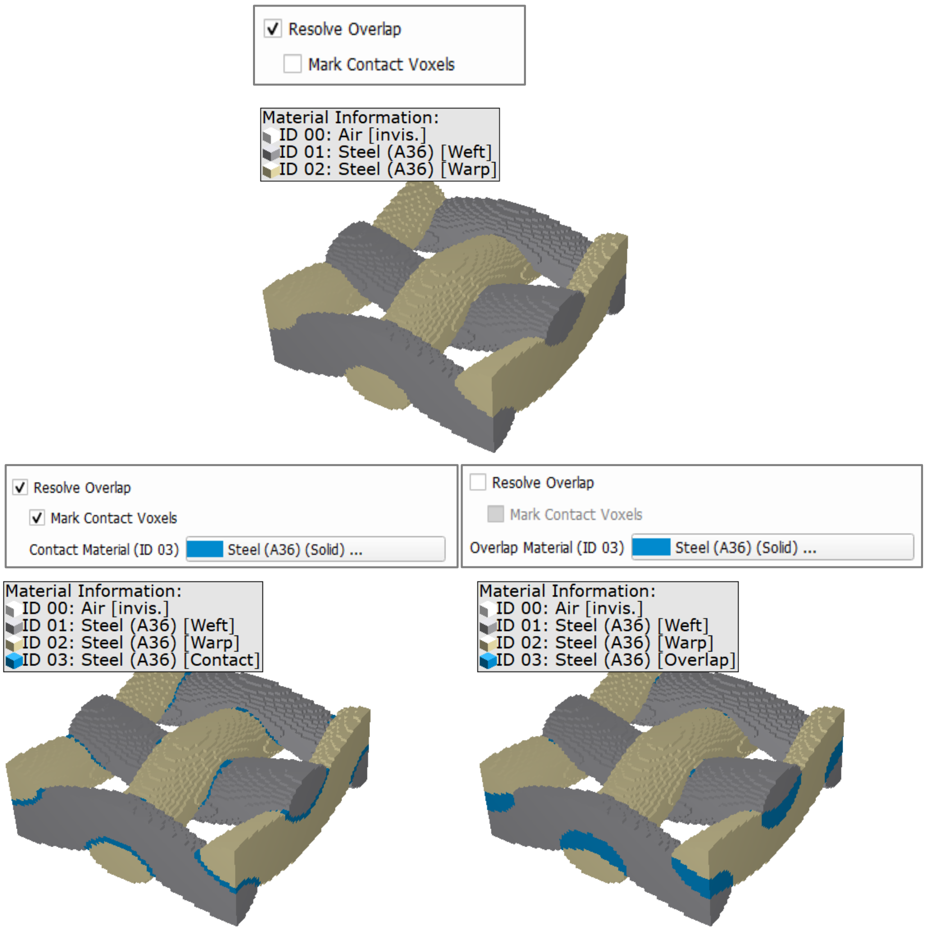



Alternatively, an **Overlap Material** can be selected for the regions where threads overlap.

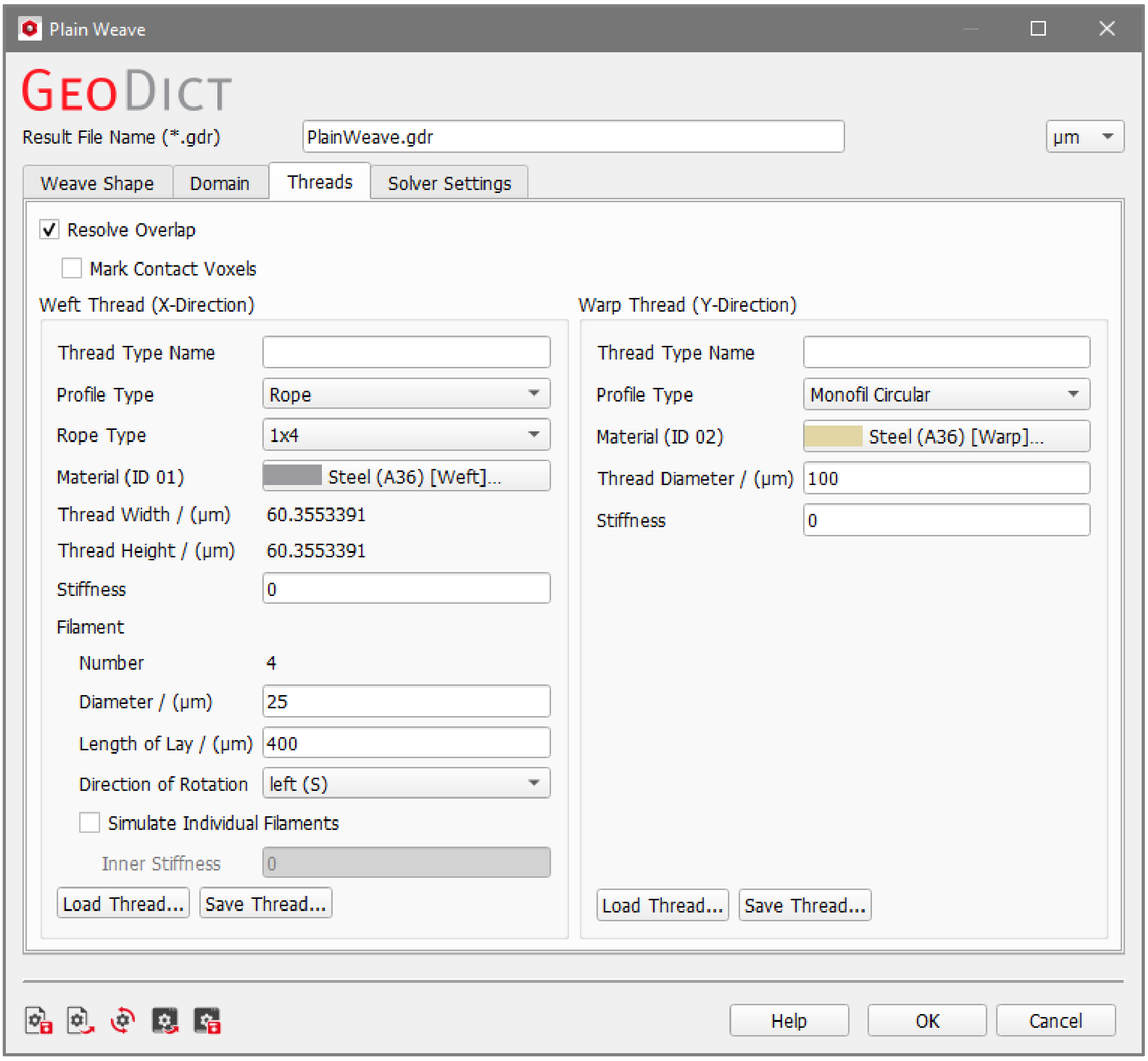


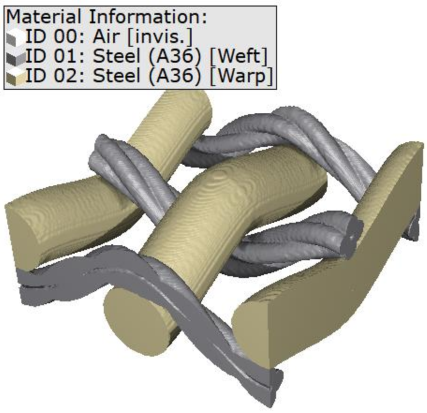

In the figure below, observe the effect of **Resolve Overlap**, **Resolve Overlap** with **Mark Contact Voxels**, and the use of an **Overlap Material**.

The vertical thread overlap was set to 30 µm.



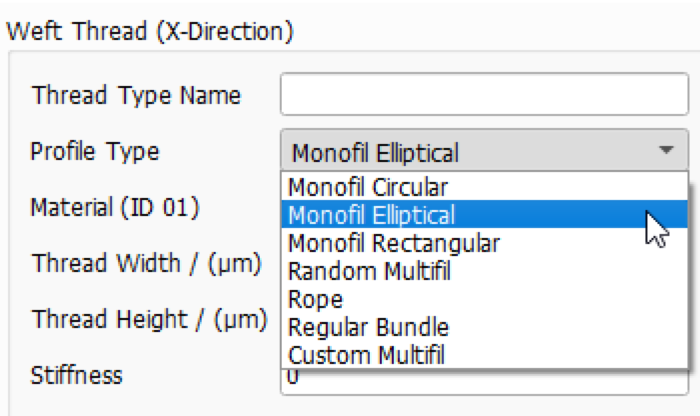
There are two panels next to each other, one for the settings of the **Weft Thread** and one for the settings of the **Warp Thread**. Each thread can be modelled individually with different parameters.



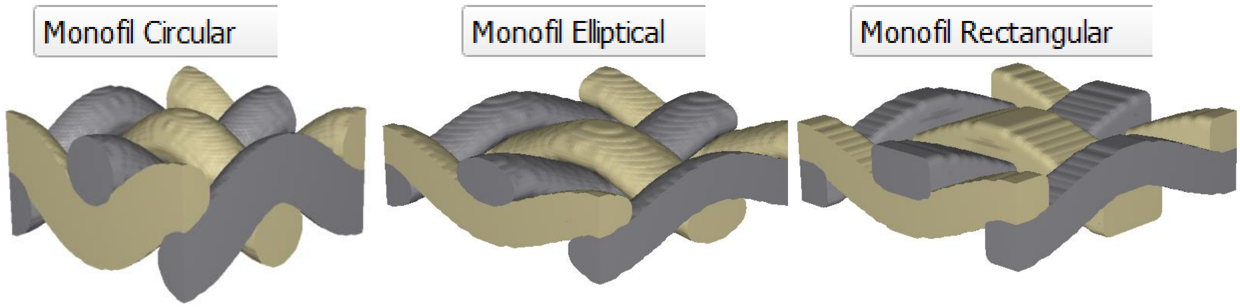




In the **Thread Type Name** field, a name can be given to the warp or the weft thread generated with the current parameters, respectively. Additionally, the thread settings can be saved by clicking **Save Thread** and later be reused for other weave structures. The parameters are saved to a Thread Type Settings (*.gps) file. Previously saved threads can be imported by clicking **Load Thread**.

Seven **Profile Types** for the threads can be selected from the pull-down menu.




Refer to page 5 for explanations on **Monofil**, **Multifil**, **Rope**, and **Regular Bundle** profile types. **Monofil** threads can have a **Circular**, **Elliptical**, or **Rectangular** cross-section.

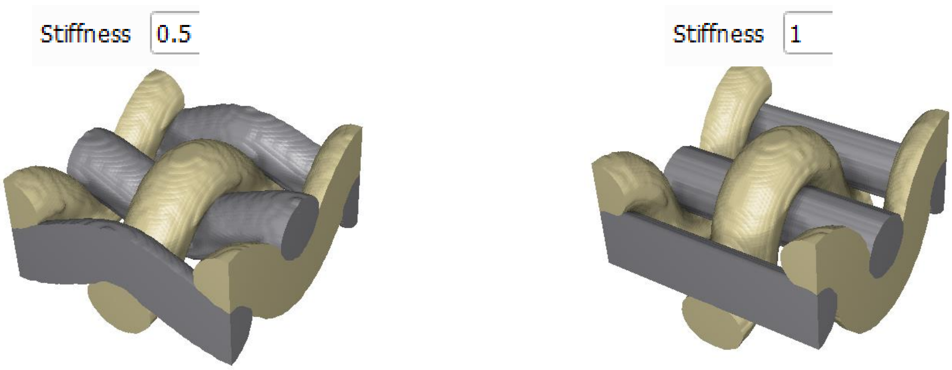



For the **Multifil** threads, **Random Multifil** and **Custom Multifil** are available.

For all profile types, **Material** determines the material assigned to the thread. Also the Material ID is given here. The **Weft Thread** has always **Material ID 01**, and the **Warp Thread** is always assigned to **Material ID 02**.

**Thread Width** and **Thread Height** determine the cross-section area of the thread. For the **Monofil Circular** profile type, width and height are equal, so only the **Thread Diameter** can be entered.

A high **Stiffness** indicates a rigid thread that only bends in small angles. Values for Stiffness can vary from 0 to 1. For plain weaves, this option has only effects when using the **FreeWeave Solver**, see page 21. Below an example is shown, where the **Stiffness** of the weft thread was varied.



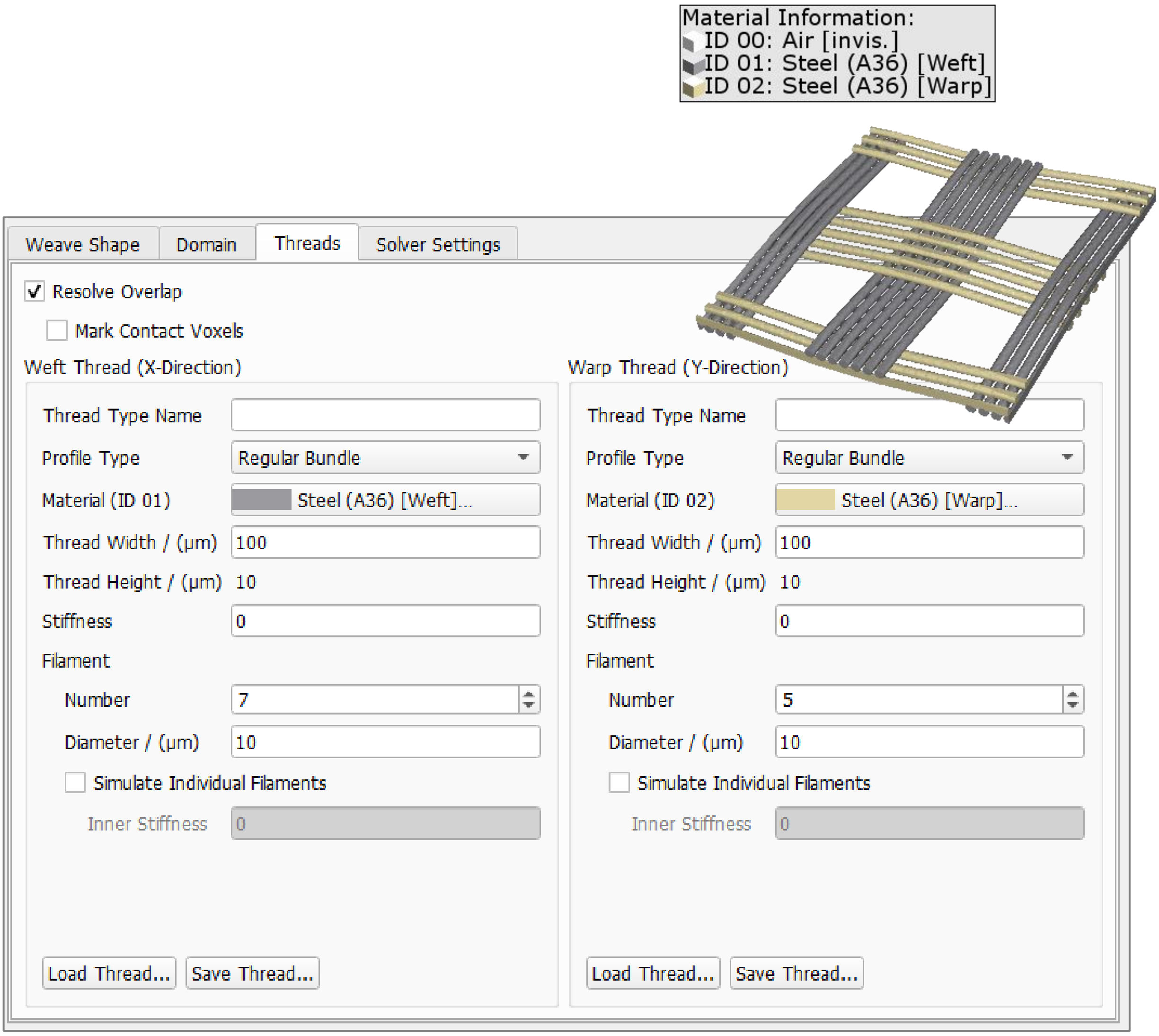
## Regular Bundle Filament settings

For **Regular Bundle** threads, the **Thread Height** cannot be entered. It is computed based on the number of individual filaments and the filament diameter.

Under **Filament,** enter the **Number**, which specifies the number of filaments per thread in regular bundles (and also in multifilament threads). The **Diameter** determines the diameter of the filaments in the thread.

If the FreeWeave Solver (see page 38) is chosen, check **Simulate Individual Filaments** to simulate interactions between the single filaments. Setting **Inner Stiffness** to a non-zero value allows to give the filaments a stiffness value, that is different to the one of the whole thread. When **Inner Stiffness** is set to zero the regular Stiffness value for the thread is used. If Simulate Individual Filaments is not activated, the thread is modelled as a single circular thread and then the filaments are placed at their computed positions.

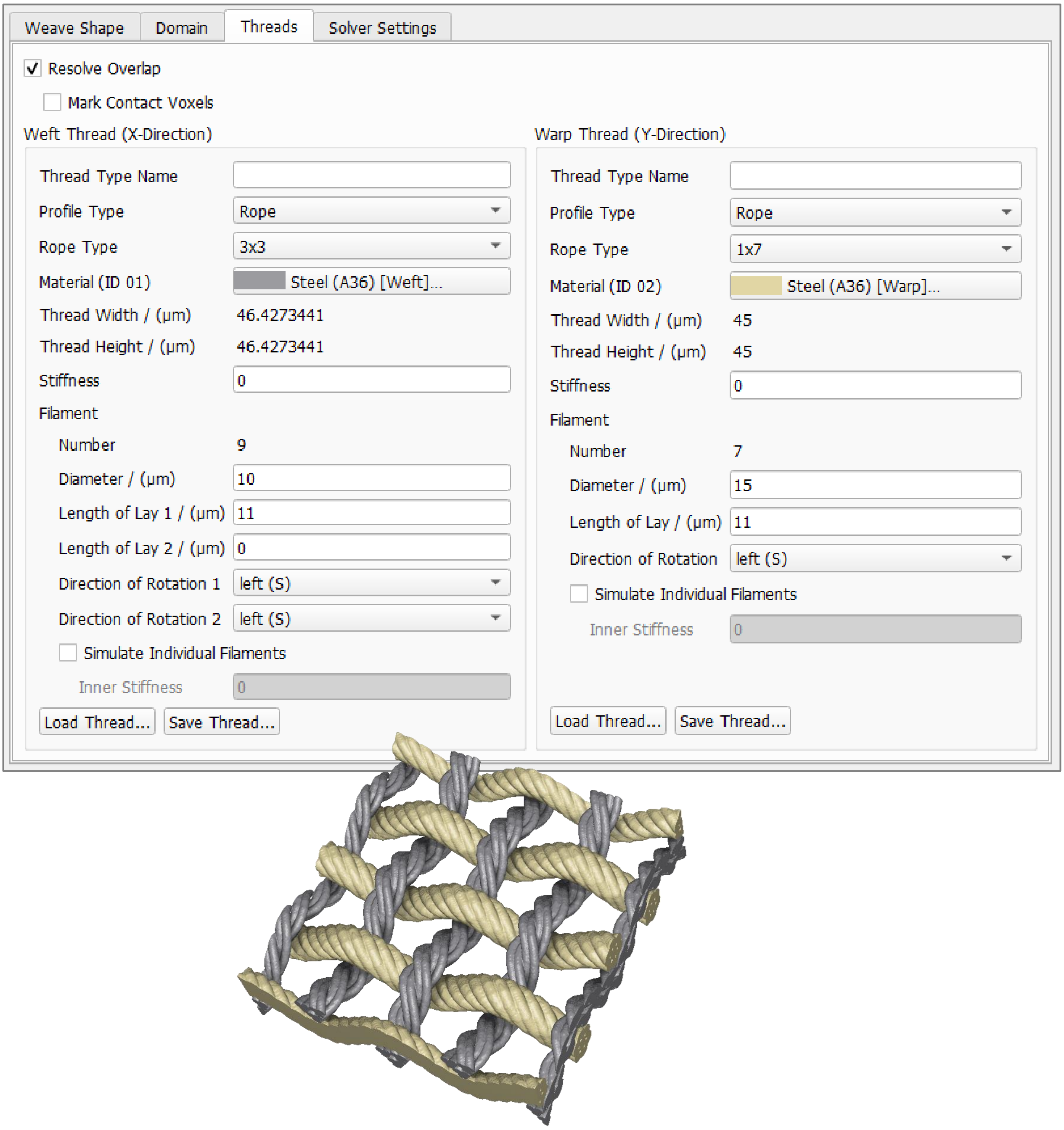
The following settings produce this structure when selecting **Regular Bundle** as the profile type.




## Rope and Random Multifil Filament Settings

For the profile type **Rope**, the filament **Number** depends on the **Rope Type** and cannot be changed manually.

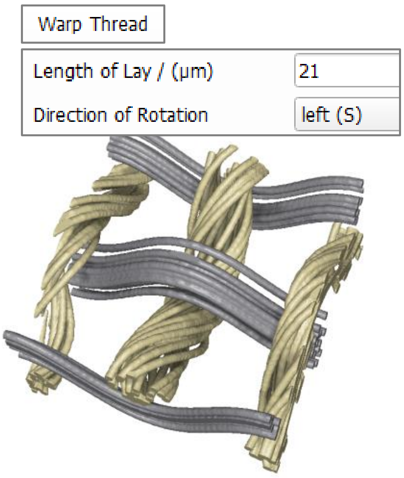
In the example below, the **warp** is a 1x7 rope. This means that it consists of one strand which contains 7 filaments. Thus, the filament number is set to 7. The **weft** is a 3x3 rope, made of 3 strands of 3 filaments, which sets 9 as the filament number.

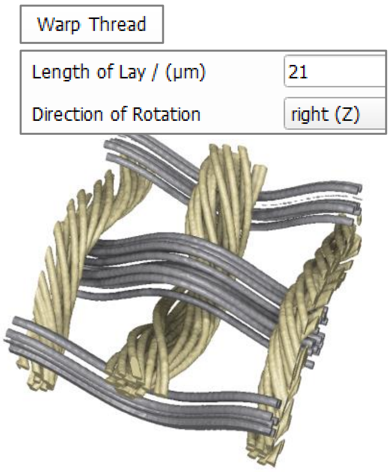



In this example structure, the number of Unit Cells in warp and weft direction (under the Domain tab) was set to 2. Note that the **Thread Width** and **Thread Height** cannot be entered since these parameters depend on the other rope parameters.

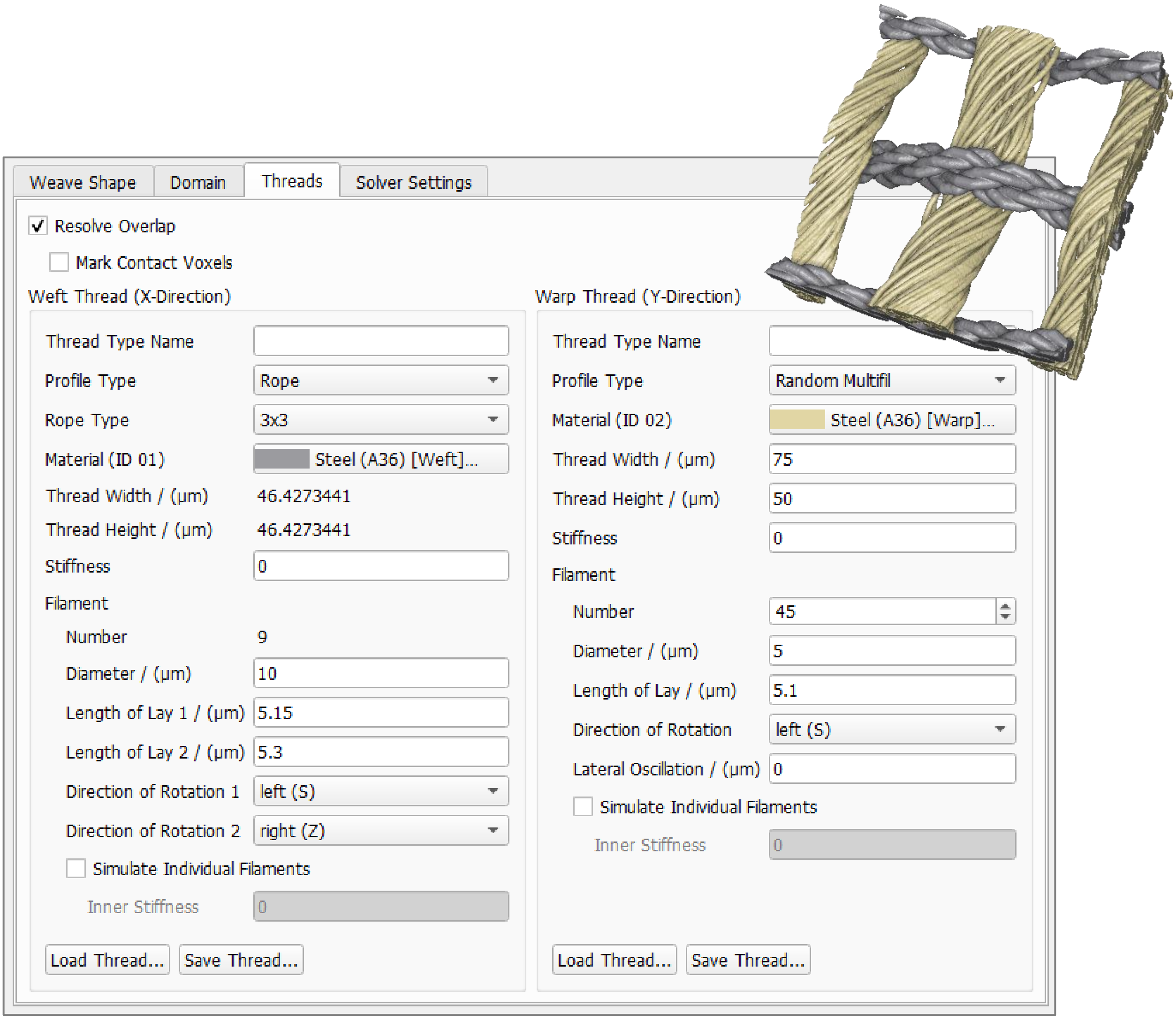
**Length of Lay** gives the distance (in the chosen unit) that is needed for the thread to perform a full 360° rotation around itself (twist). Since a unit cell must be periodic, the **Length of Lay** must be chosen accordingly. This means that in general the size of a unit cell must be a multiple of the length of lay. This ensures that the thread makes an integer number of 360° rotations. It is also possible to make e.g. only 180° twists if the filaments of the thread are arranged in a way that the structure stays periodic in the unit cell. If the entered length of lay does not allow to generate the unit cell periodically, a warning message appears, and the parameter is adjusted automatically. The choice of unrealistically short values might lead to artifacts in the generation and, therefore, to unrealistic structures. If the **Length of Lay** is set to zero, the filaments are not rotated around themselves.

**Direction of Rotation** sets the direction – **right** (Z-twist rope) or **left** (S-twist rope) - in which the thread is rotated around itself (here, the **warp** thread).




For ropes with several strands (here, the **weft** thread), the **Length of Lay 1** is the length for one rotation of the rope (thread) and **Length of Lay 2** is the length for one rotation of the strands in the rope.



**Direction of Rotation 1** controls the direction of rotation of the strand corresponding to **Length of Lay 1**: **right** (Z-twist strand) or **left** (S-twist strand). **Direction of Rotation 2** controls the direction of rotation of the strand corresponding to **Length of Lay 2.**

For Random Multifil threads the same settings as mentioned above are available. **Lateral Oscillation** is only available for **Random Multifil** threads. It is the degree of random waviness of the filaments in the X-Y-plane. A different structure with the same Lateral Oscillation can be generated by changing the **Random Seed** (see page 11).



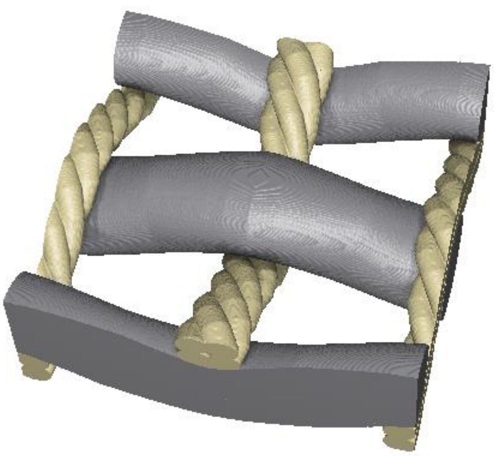
## Custom Multifil Settings

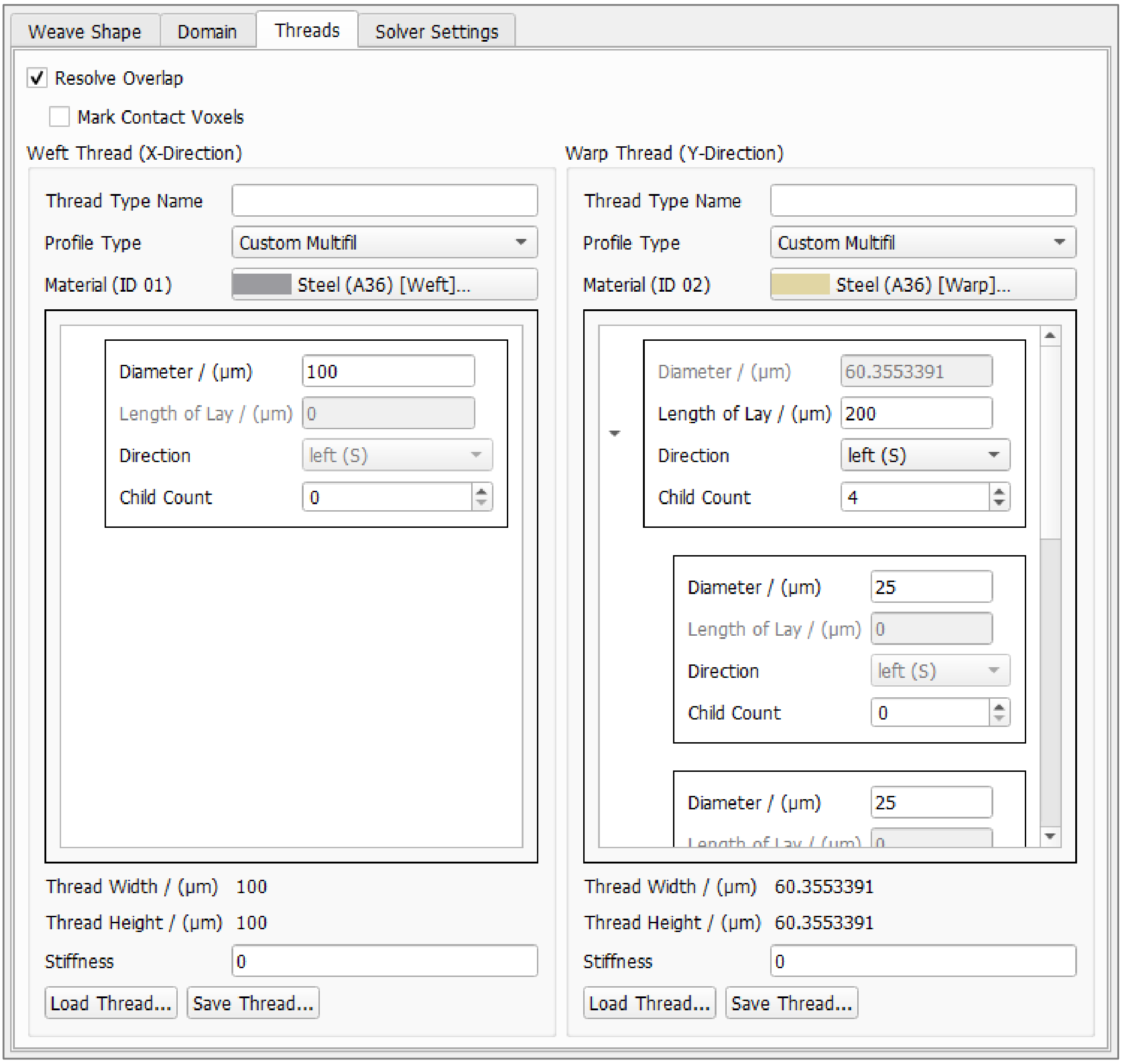
For **Custom Multifil**, the settings panel is structured hierarchically. On the first layer the settings for the whole thread can be made.

The **Thread Width** and **Thread Height** cannot be edited since they are computed from the settings of the single filaments. **Stiffness**, **Simulate Individual Filaments**, and **Inner Stiffness** were explained above on page 16ff.

The **Diameter** entered equals the **Thread Width**. **Length of Lay** and **Direction** are the same as described above on page 17. They are only active if **Child Count** is not zero. **Child Count** defines in how many filaments the thread is subdivided. The settings panel for each filament is displayed indented on the next layer. All lower layers can be folded in by clicking on the small black triangle.

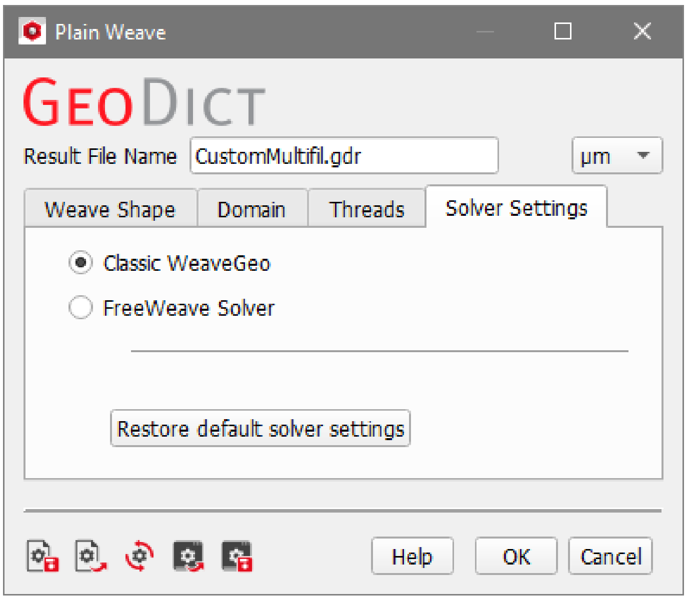
Below, a **Custom Multifil** structure is shown, generated with the settings shown on the left and below. The length in X- and Y-direction is 400 voxels, respectively.






## Solver Settings

In the **Solver Settings** tab, the default **Classic WeaveGeo** solver directly creates the structure without considering the thread contacts by a physics-based iterative solver and leads to good results in most cases.



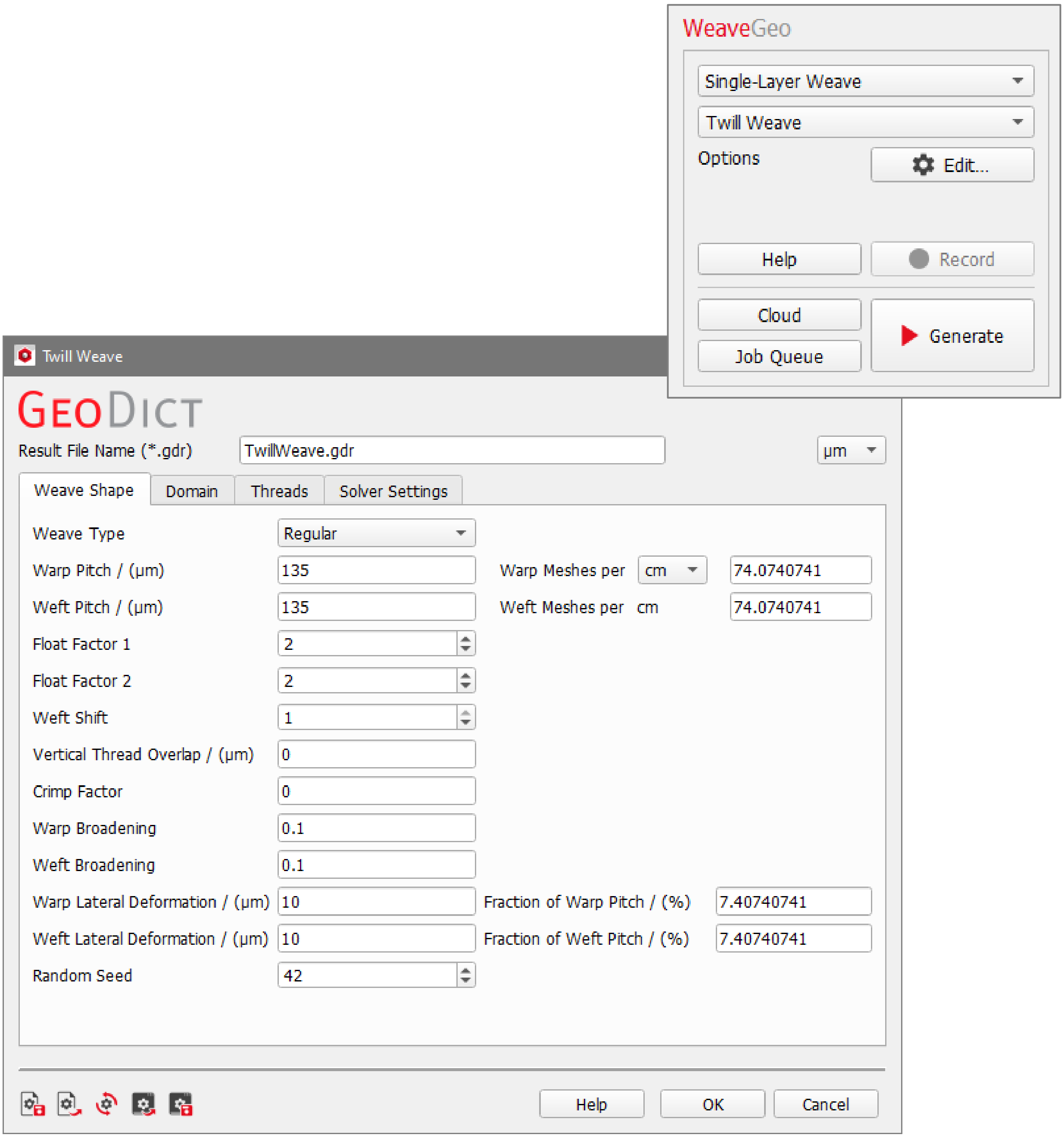
Alternatively, the **FreeWeave Solver** can be selected. With this option, the structure generation is performed by an iterative physics-based solver. This can be used to enhance the realism of the structure but might also lead to higher runtimes for the generation.

The parameters for the **FreeWeave Solver** are explained in the Free Weave section on pages 38ff.

# Twill Weave

Choose **Twill Weave** in the WeaveGeo section and click the **Edit...** button to open the **Twill Weave** dialog.

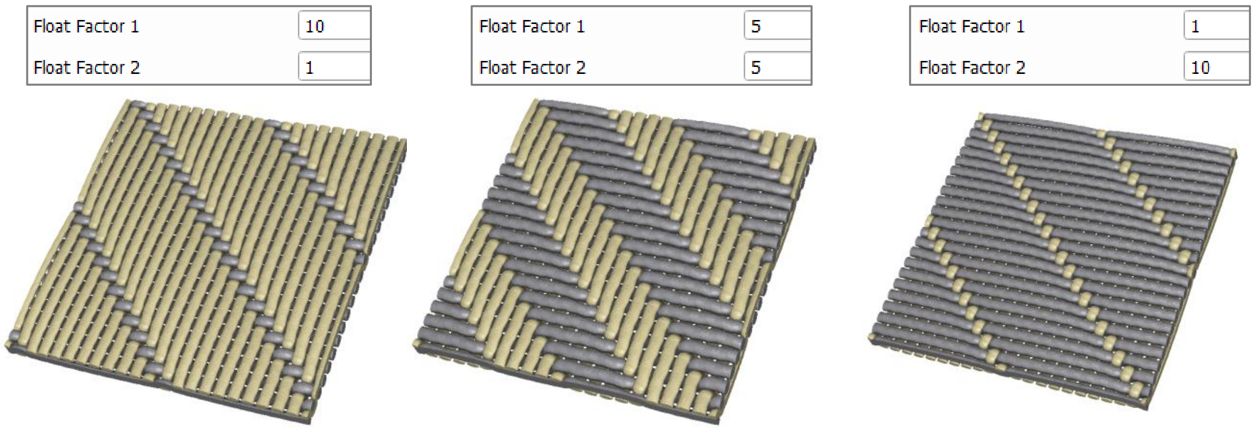
The layout of the dialog and the tabs that it contains are similar to those for the Plain Weave dialog, seen on page 8. The parameters that differ from the parameters for plain weaves are explained below.



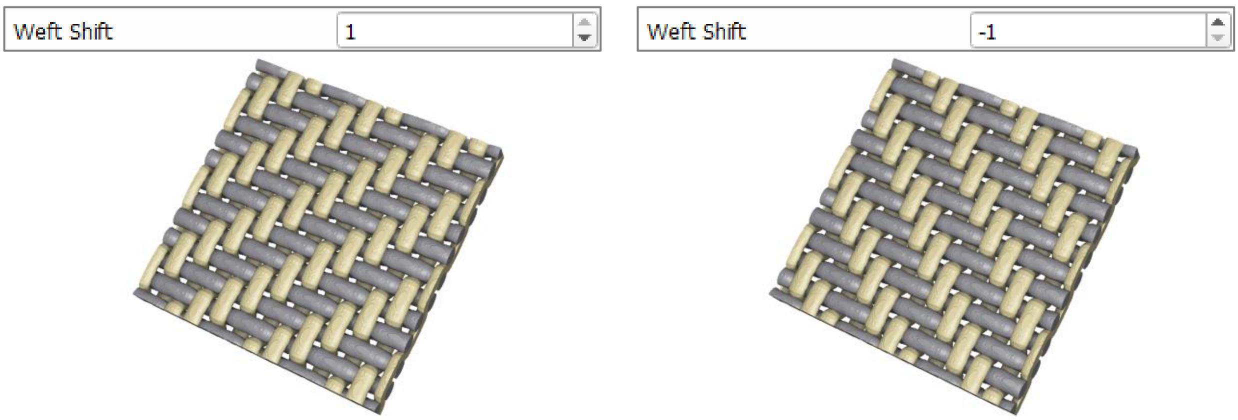

## Weave Shape

For the twill weave, the **Weave Type** pull-down menu, the **Warp Pitch**, and the **Weft Pitch** are as explained for the plain weave (pages 9ff.).

**Float Factor 1** and **Float Factor 2** values are only available for the **Twill Weave**, where their values may vary from 1 to 10. **Float Factor 1** controls the number of warp threads “floating” over the weft threads. Analogously, **Float Factor 2** controls the number of weft threads “floating” over the warp threads.

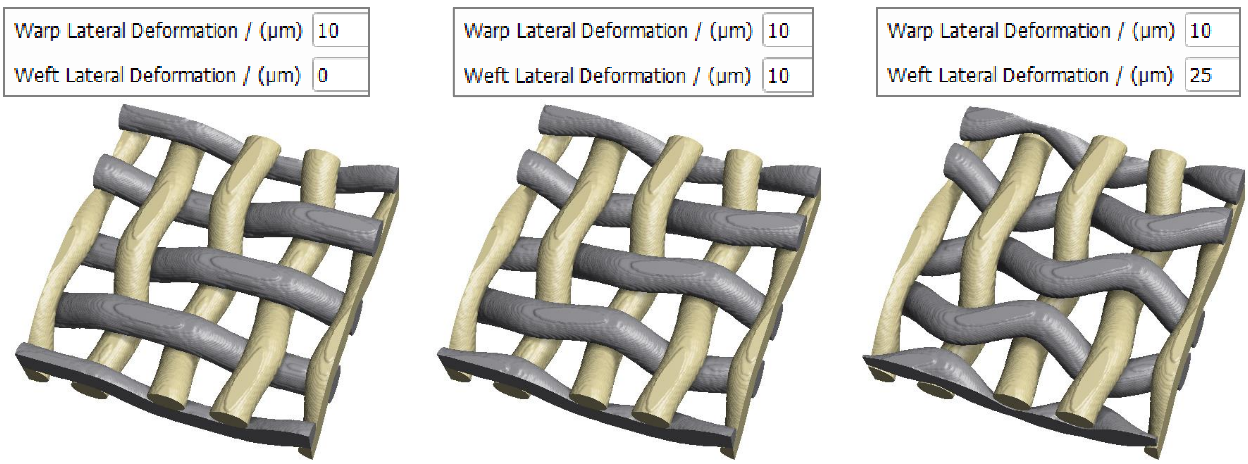


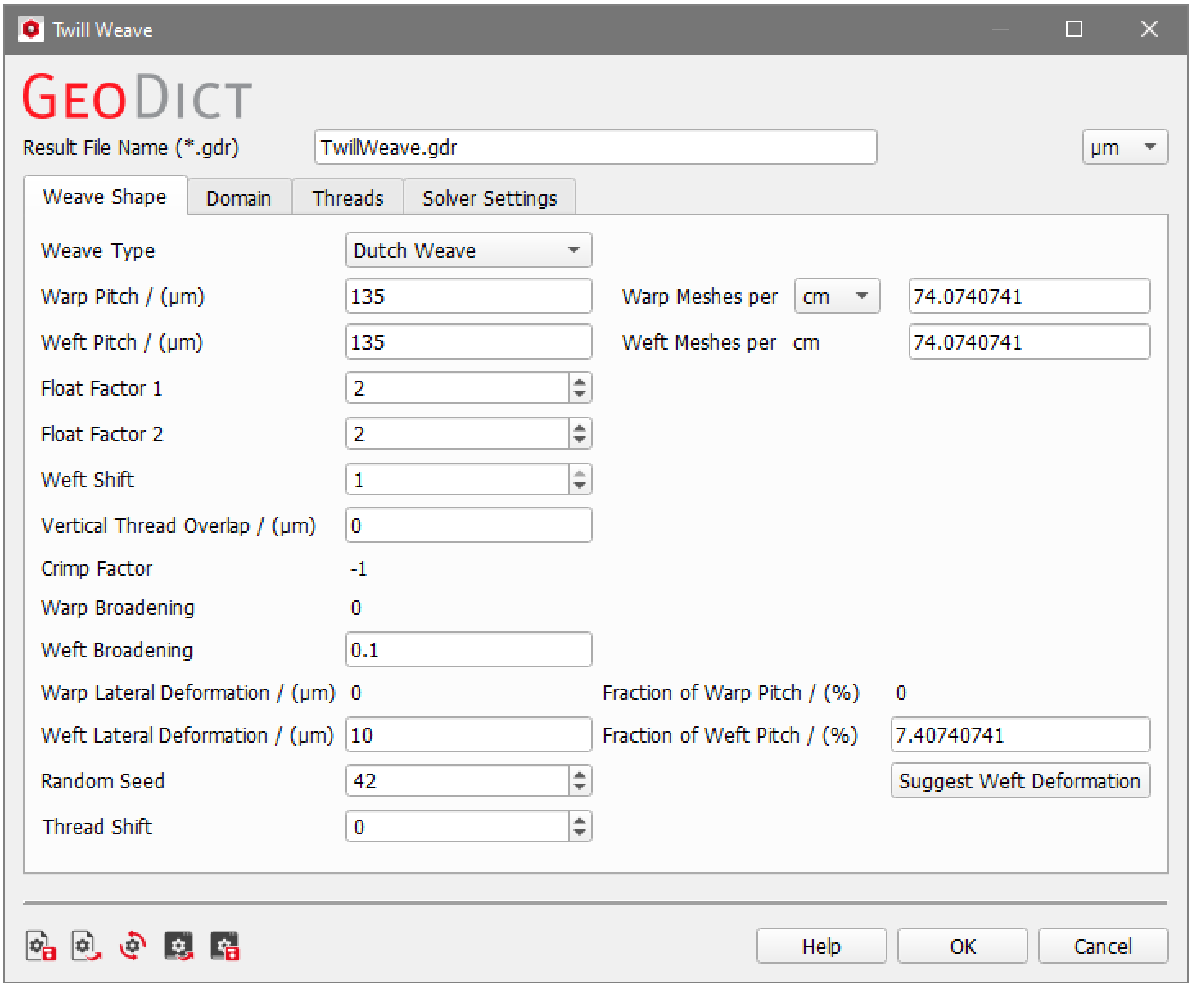

The **Weft Shift** defines the offset between successive weft threads. Choosing between the available values of -1 or 1 controls the direction of the characteristic diagonal pattern of twill weaves.




**Vertical Thread Overlap**, **Crimp Factor**, and **Warp-** and **Weft Broadening** are as explained above for the **Plain Weave** (see page 9).

**Warp Lateral Deformation** and **Weft Lateral Deformation** model the change in thread shape in the X-Y-plane during the process of weaving. They can either be set directly, or as percentage of the warp or weft pitch (**Fraction of Warp Pitch** or **Fraction of Weft Pitch**). Such deformations might occur for example through imperfections during the weaving process. The realization of the lateral deformation is influenced by the current **Random Seed** (see page 11).






If **Dutch Weave** is chosen as weave type, the button **Suggest Weft Deformation** appears. Similar, if **Reverse Dutch** is selected, the button **Suggest Warp Deformation** is shown. The suggested deformation depends on the settings made under **Weft Pitch (**or **Warp Pitch)** and **Thread Diameter**. If the pitch size is chosen such that neighboring threads do not overlap (pitch size ≥ thread diameter), the suggested lateral deformation is zero and the threads run straight. If the threads would overlap, the lateral deformation is set to half of the differential distance when clicking the button.

When choosing the **FreeWeave solver** in the Solver Settings tab, the lateral deformation cannot be defined. The solver finds this value automatically.

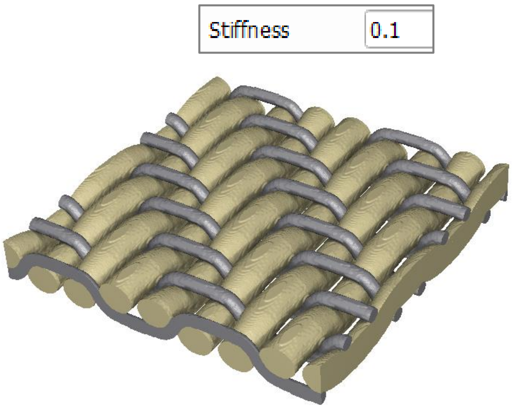
## Domain

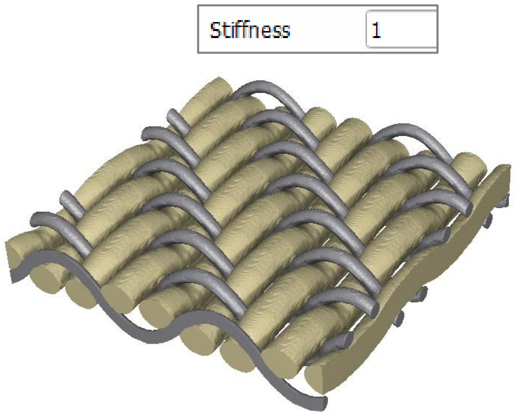
All parameters under the **Domain** tab are the same as explained on page 11 for the plain weave.

## Threads

All parameters under the **Threads** tab are the same as explained on pages 13ff. for the plain weave.

The influence of the stiffness can be easily observed in the twill weave example below when changing the stiffness of the **weft** thread and using the **Classic WeaveGeo** solver.



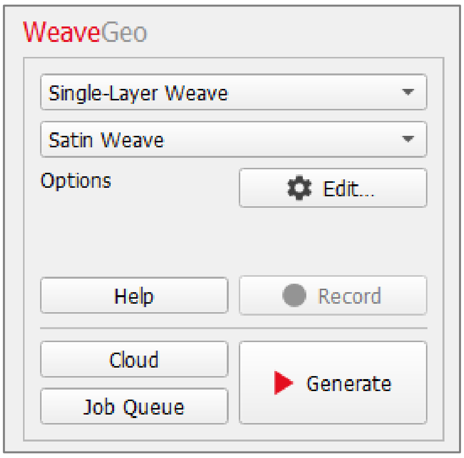

### SOLVER SETTINGS

The **Solver Settings** tab is the same as for plain weaves (see page 21). The **FreeWeave Solver** is explained on page 38ff.

## Satin Weave

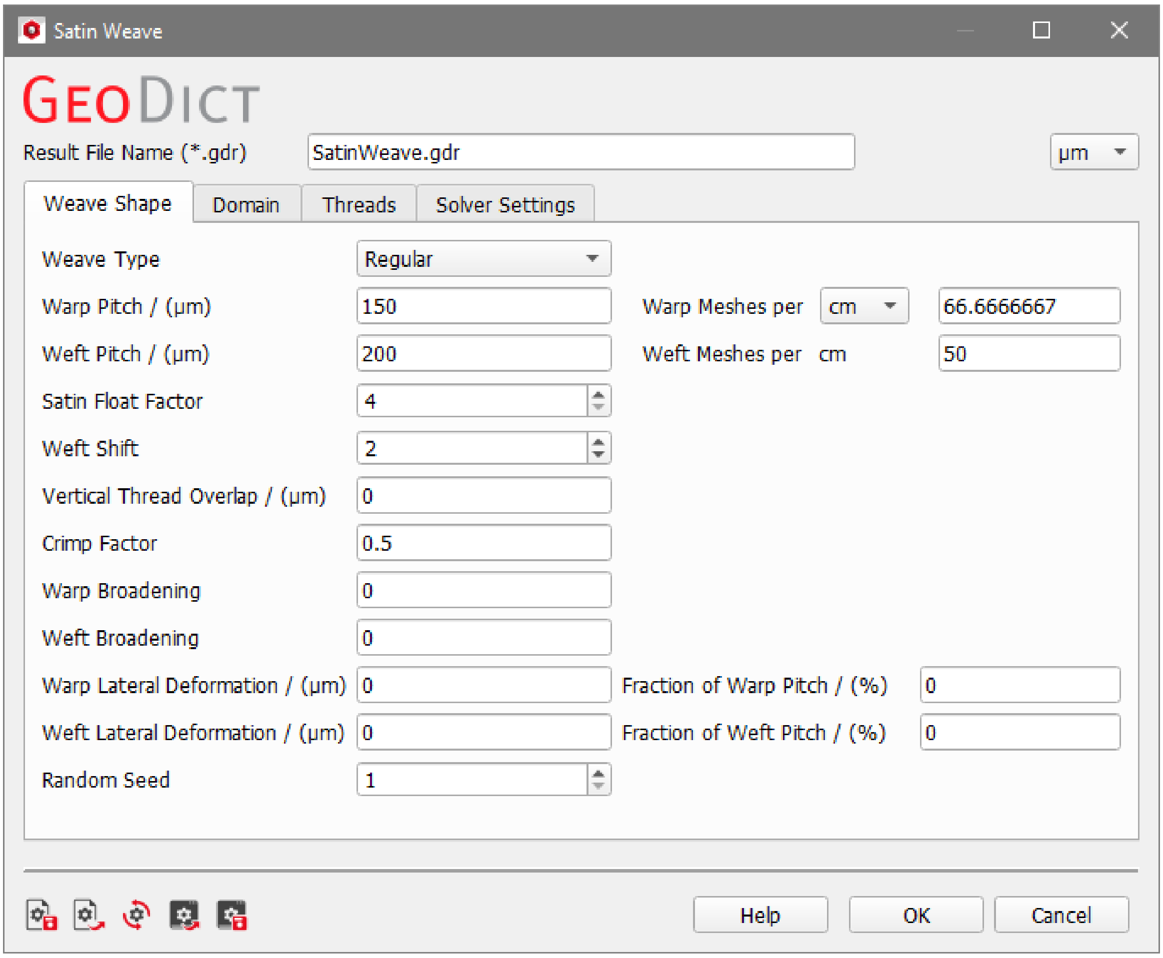
Choose **Satin Weave** and click the **Options' Edit...** button to open the **Satin Weave** dialog.

The layout of the Satin Weave dialog is similar to the Plain Weave dialog, seen on page 8. The parameters that differ from the parameters for the weave types listed before are explained below.

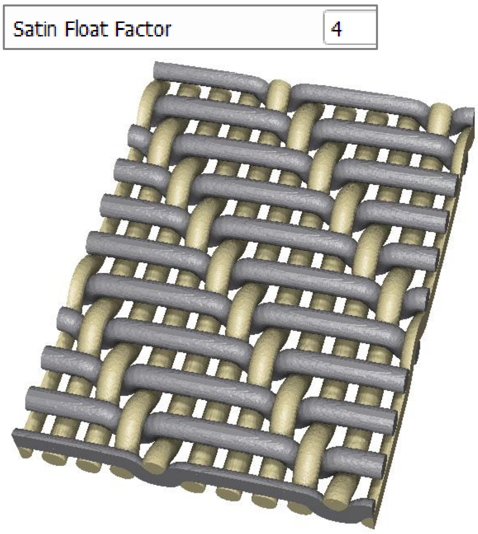



### Weave Shape

For the satin weave, the **Weave Type** pull-down menu and the **Warp** (and **Weft**) **Pitch** are as explained for the plain weave (see page 9ff.).

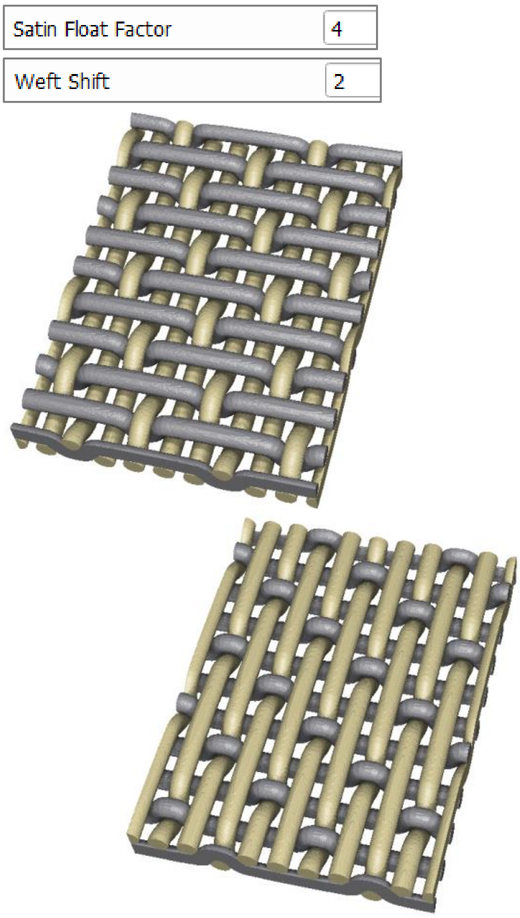


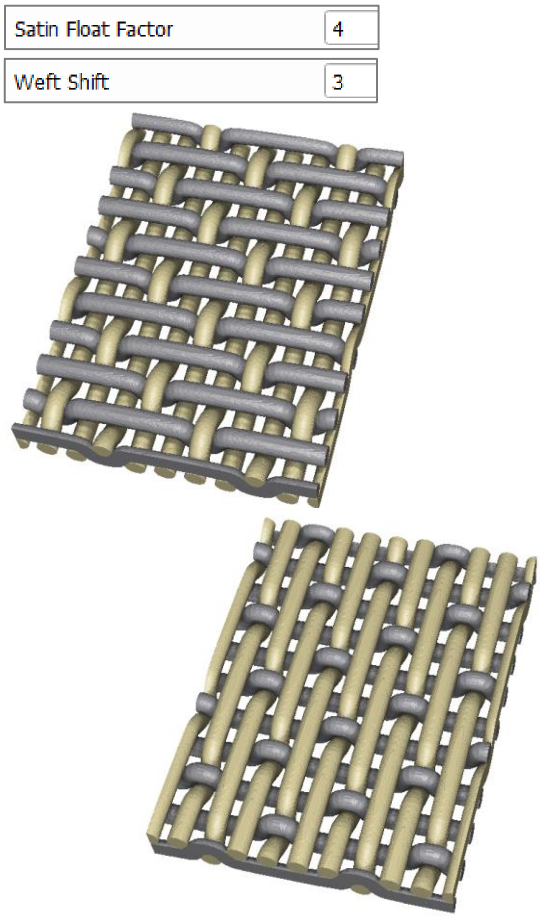
The **Satin Float Factor** value, special to the satin weave, may vary from 4 to 10. It controls the number of weft threads floating over the warp threads. Typical satin weaves are the Satin 4/1 and the Satin 7/1, corresponding to satin float factors of 4 and of 7.





The available options for the **Weft Shift** for **Satin weaves** differ from those available for **Twill weaves**. In twill weaves, the offset is limited to 1 or -1, while for satin weaves it is at least 1 and the maximal value depends on the chosen float factor. The **Weft Shift** is an integer number and is at most one lower than the **Satin Float Factor**. For example, for a **Satin Float Factor** of 4 the feasible values for the **Weft Shift** are 1, 2 and 3. In the figures below, for a satin 4/1, observe the effect of choosing a weft shift of 2 or 3. The figures show the same structure, once viewed from above and once from below.



**Vertical Thread Overlap**, **Crimp Factor**, and **Warp-** and **Weft Broadening** are as explained above for the plain weave (see pages 9ff.). The same holds for **Warp** and **Weft Lateral Deformation**, **Fraction of Warp Pitch** and **Fraction of Weft Pitch** (see page 24), and **Random Seed** (page 11).

### Domain

All parameters under the **Domain** tab are the same as explained on page 11 for the plain weave.

### Threads

All parameters under the **Threads** tab are the same as explained on pages 13ff. for the plain weave.

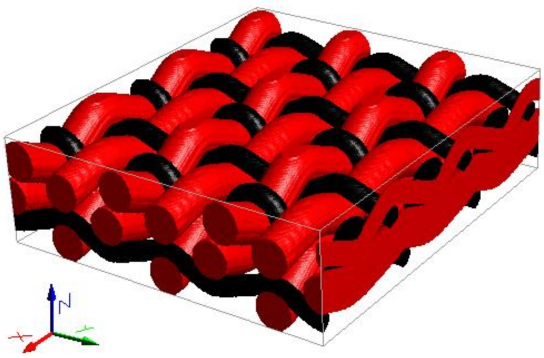
### Solver Settings

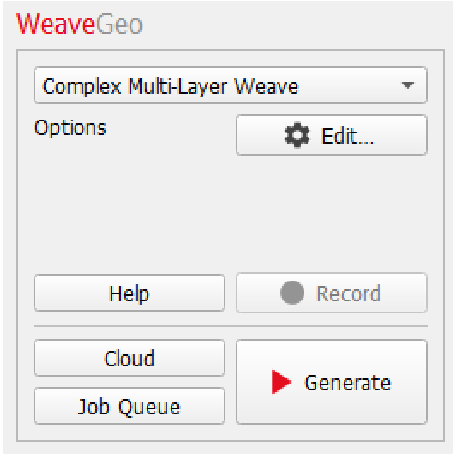
The **Solver Settings** tab is the same as for plain weaves (see page 21). The **FreeWeave Solver** is explained on page 38ff.

## Complex Multi-Layer Weave

Since GeoDict 2024, this command, previously named FreeWeave, is called **Complex Multi-Layer Weave**. The options menu has not changed and will be explained in the following.

**Complex Multi-Layer Weave** allows to generate sophisticated multilayered weaves and gives the user full control over the weave generation. Thus, the graphical user interface contains more options than those for the weave types shown before. For the structure generation, the physical contact between the threads is simulated by an iterative physics-based solver, the **Free Weave** solver.






Choose **Complex Multi-Layer Weave** from the pull-down menu in the WeaveGeo section and click the **Options**' **Edit...** button to open the **Complex Multi-Layer Weave** dialog. It is organized in the four tabs **Global**, **Materials and Thread Types**, **Binding**, and **Solver Settings**.

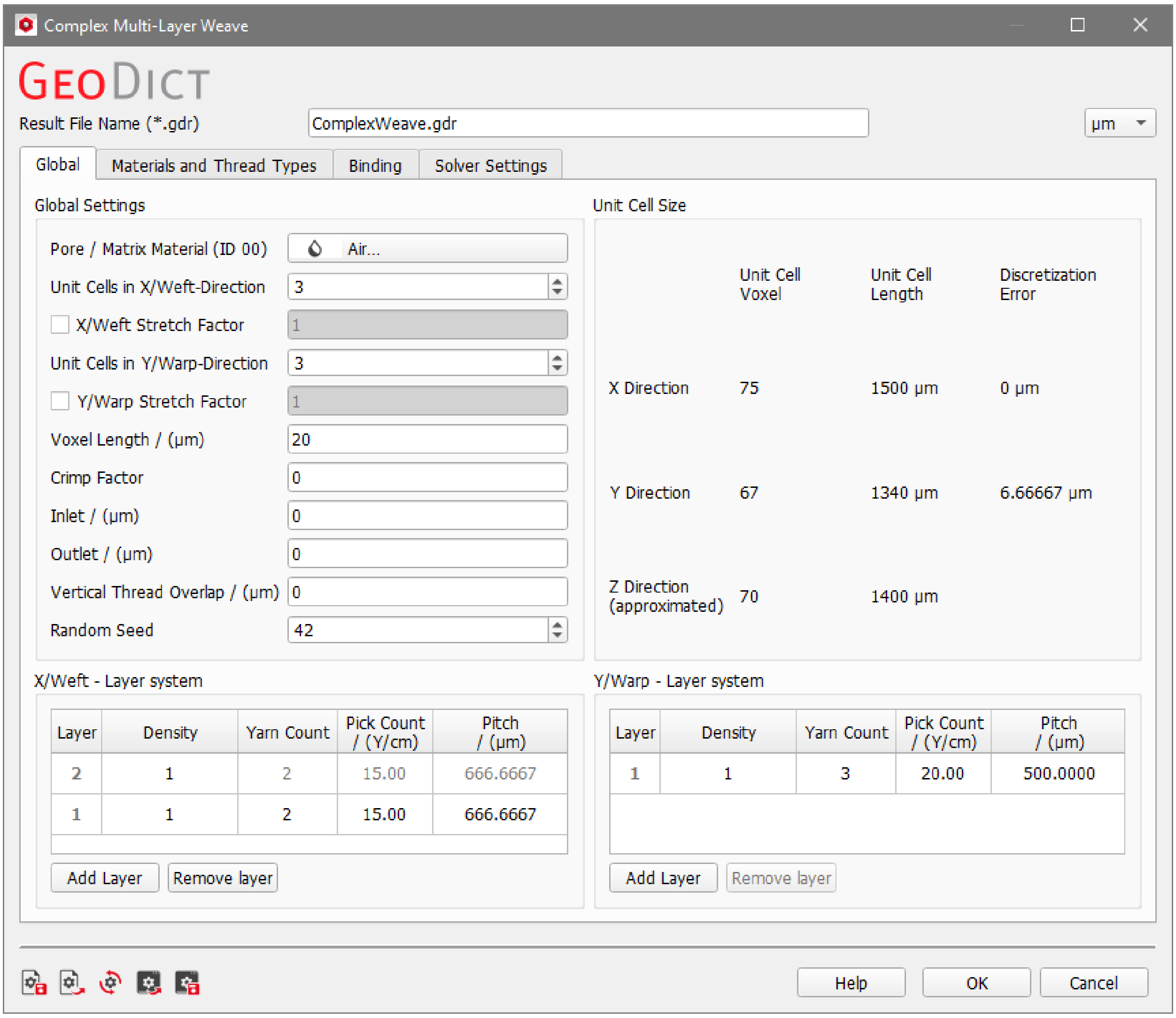
### Global

In the **Global** tab, the **Global Settings** for the domain can be made. The **Unit Cell Size** is computed based on these settings and shown to the user. Also, the setup of the **Weft-** and **Warp-Layer System** can be made here.

Through the **Pore / Matrix Material (ID 00)** button, select the material which occupies the space surrounding the threads (e.g. Air) from the GeoDict Material Database.

The values in **Unit Cells in X/Weft-Direction** and **Unit Cells in Y/Warp-Direction** set the number of repetitions of the generated unit cell. If a GeoDict simulation with periodic boundary conditions will be performed on the structure later on, one unit cell is sufficient. It is also possible to activate and enter a **X/Weft Stretch Factor** and a **Y/Warp Stretch Factor** respectively, which should be close to 1. If the Stretch Factor is enabled, the simulation is done in two passes. First a simulation without this option is done, then a stretching is done and the final position of the threads is determined. If the X/Weft Stretch Factor is e.g. 1.05, the domain is enlarged by 5% in X-Direction before the second pass of simulation. In the second pass the threads are tightened to reach again their initial length. In the Result File a table shows the remaining error of this process.

**Voxel Length**, **Inlet,** and **Outlet** are as explained on page 11ff., **Crimp Factor**, **Vertical Thread Overlap** and **Random Seed** are as explained above for the plain weave (see pages 9ff.).




For the **Weft-Layer System** (as well as for the **Warp-Layer System**), any number of layers can be defined. Layers are added by **Add Layer** and removed by **Remove Layer**. The parameters can be edited by double clicking on a value.

The **Density** is the ratio between the **Yarn Counts** (i.e. the number of threads) in the different layers. It must be a positive whole number.

The **Yarn Count** is the absolute number of yarns in the unit cell and is defined in **Layer 1**. The **Yarn Counts** in the subsequent layers are defined by the **Density** values. Therefore, the **Yarn Count** for Layer 1 must be divisible by the **Density** for Layer 1. The number of threads in a layer can later be adapted by hiding threads. For this, see page 34.

## EXAMPLE:

Layer 1 consists of 4 yarns and Layer 2 contains 8 yarns:

| Layer | **Density** | Yarn Count | Pick Count / (Y/cm) | Pitch / (µm) |
|---|---|---|---|---|
| 2 | 2 | 8 | 30.00 | 333.3333 |
| 1 | 1 | 4 | 15.00 | 666.6667 |

Layer 1 consists of 4 yarns and Layer 2 contains 2 yarns:

| Layer | Density | Yarn Count | Pick Count / (Y/cm) | Pitch / (µm) |
|---|---|---|---|---|
| 2 | 1 | 2 | 7.50 | 1333.3333 |
| 1 | 2 | 4 | 15.00 | 666.6667 |

The **Pick Count** is the number of Yarns per cm and the **Pitch** is the distance between the midpoints of two adjacent yarns. The **Pitch** is the reciprocal value of the **Pick Count**. When one of those two values is changed in the user interface, the other one is updated automatically.

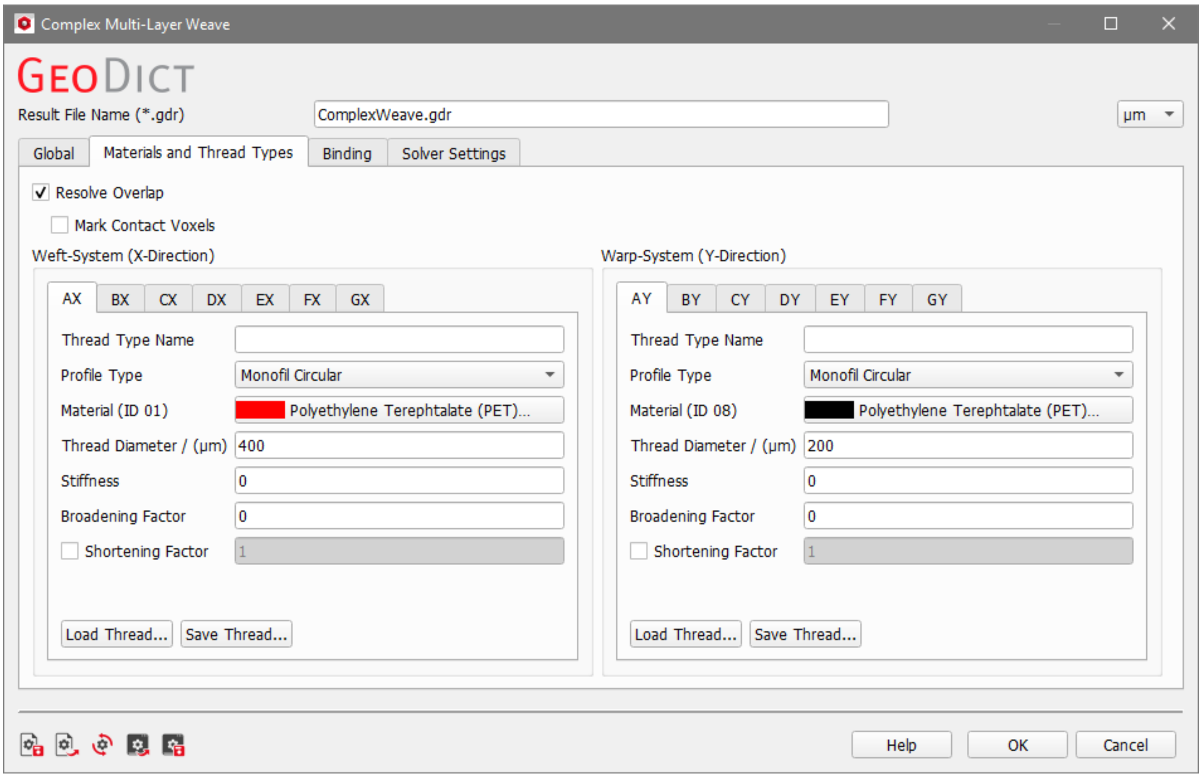
The values for the **Unit Cell Size** are not editable since they depend on the definition of the parameters of the structure. For example, the thread widths and pitches and the chosen number of unit cells determine the width and height of the weave.

The **Unit Cell Size** is displayed as the number of voxels (**Unit Cell Voxels**) in **X Direction, Y Direction** and **Z Direction (approximated)** and the corresponding **Unit Cell Length is shown** in the chosen unit. The weave generation in **FreeWeave** is based on an iterative solver, therefore the number of voxels in Z Direction can only be approximated here.

In the third column, the **Discretization Error** is shown. It is the length difference between the defined weave and the voxelized (discretized) weave and can be minimized by adjusting the **Voxel Length.**

## Materials and Thread Types

Under the Materials and Thread Types tab, up to seven different thread types can be defined for each the **Weft-System** and the **Warp-System**. The **Thread** definition works analogously to all the other WeaveGeo modules and is described on page 13ff.

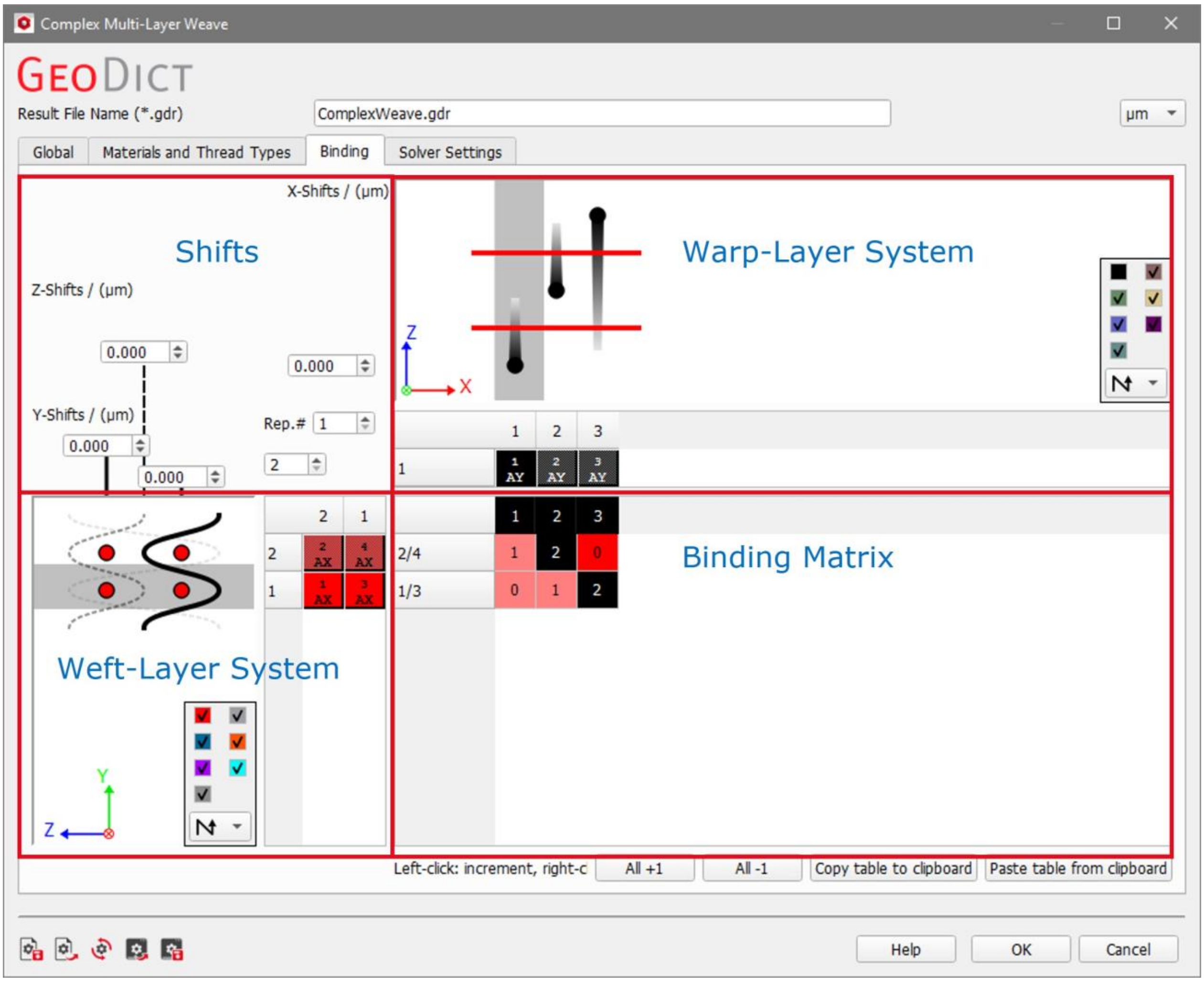


The **Shortening Factor** can be defined for each thread individually. At the beginning of the generation process, a thread is much longer than the domain size in its direction. During the generation process the threads are tightened (see also page 38), thus they get shorter in each iteration.

The **Shortening Factor** determines how long the thread is allowed to be in relation to the domain length. If the shortening factor is 1.05 the thread can be shortened to 105% of the domain length. Thus, the **Shortening Factor** must be larger or equal than 1.

## Binding

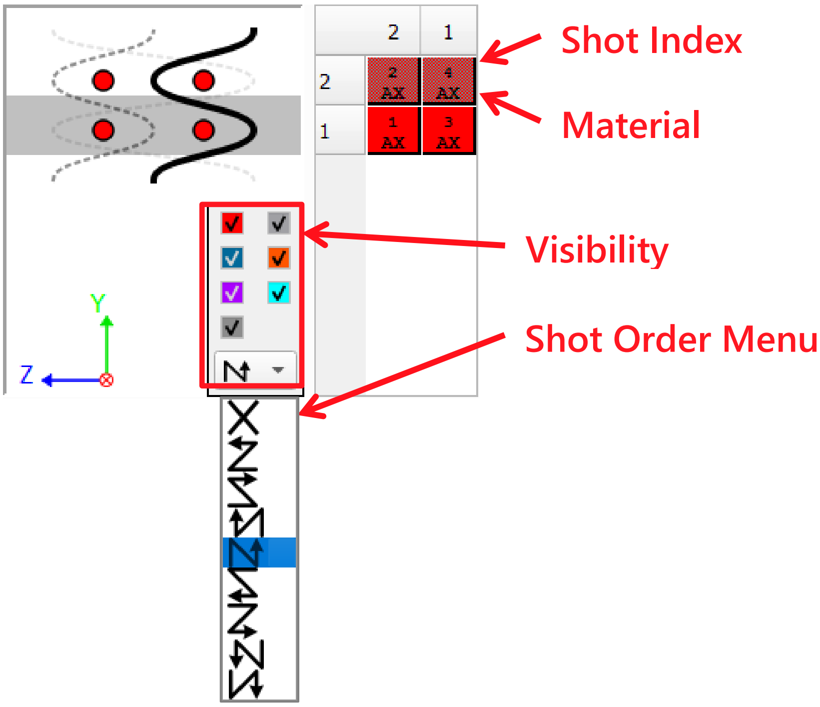
The **Binding** tab shows a 2D preview of the weave and the binding matrix. The 2D preview of the **Weft-Layer System** is located at the bottom left of the window, the **Warp-Layer System** at the top right. The **Binding Matrix** is located at the bottom right.




### Weft-Layer System

The preview of the **Weft-Layer System** shows all weft layers in vertical direction. The first layer is in the first column from the right. Each layer is displayed in a 2D preview and a table.

The weft threads are represented by colored circles, the warp threads as lines. The color of both corresponds to the color of the cells in the table and to the color of the threads in the structure and stands for the **Material** of the thread.

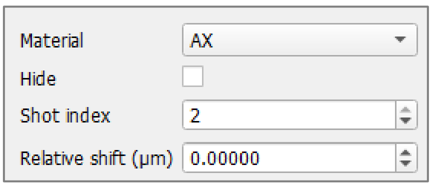



In the **Visibility Settings**, the different **Materials** can be activated/deactivated by clicking on the corresponding color. All threads with a deactivated material are invisible in the preview but will be generated, unlike hidden threads (see below, page 34). This functionality gives the user a better overview during the generation of complex weaves.

The number in each cell stands for the **Shot Index**. The **Shot Order** can be changed from a dropdown menu and assigns a **Shot Index** to each thread following the chosen pattern.

If X is chosen from the menu, the **Shot Index** can be assigned manually for each thread. This can be done in the **Property Menu** of the thread, which can be accessed by clicking on the corresponding cell in the table. However, the **Shot Index** and **Shot Order** *do not affect the structure generation* in GeoDict. These parameters are only relevant for setting up a real weaving machine.

In the **Property Menu**, several other properties can be defined.

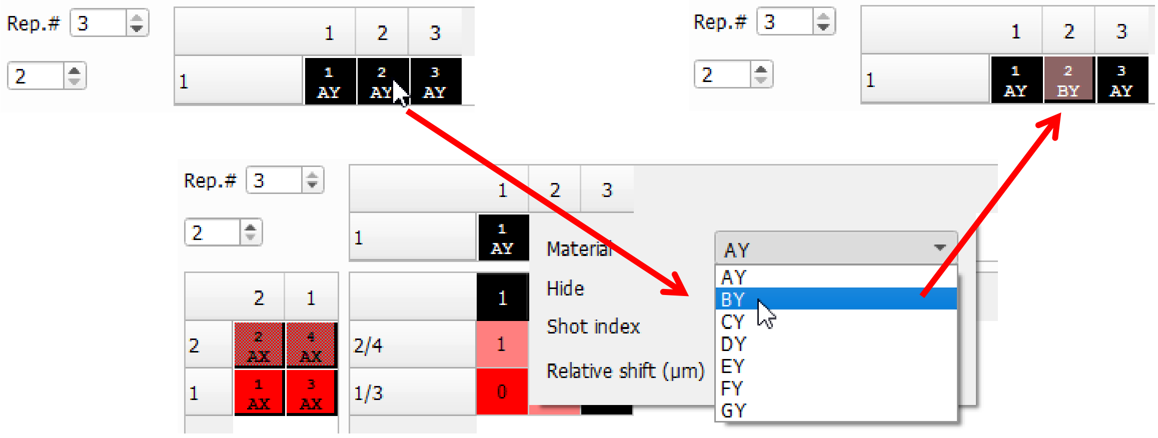



Property Menu

The **Material** can be changed, and the thread can be hidden (Select **Hide**), that means it is not included in the weave after generation. By changing the **Relative Shift**, the thread can be moved in Y-direction. This value is added to the value of the **Y-Shift** of the corresponding layer, see below page 36.

The properties of the threads can be defined for each thread individually or they can be repeated after a certain number of threads. This number is defined under **Rep.#** (Repetition). The number below **Rep.#** corresponds to the repetition of the weft threads and the number on the right corresponds to the repetitions of the warp threads. If the **Rep.#** is smaller than the number of threads in the corresponding system (weft or warp), the material color for the repeated threads is greyed out. This is shown below where Rep.# = 1 for the warp system. If the repetition number is set to the number of threads, individual thread types can be assigned for each thread. (See below for Rep.# = 3).

To assign a thread type to a thread, open the Property Menu and select a thread type from the drop-down menu under Material. The available thread types are defined under the Materials and Thread Types tab (see page 32).




## Warp-Layer System

The preview of the **Warp-Layer System** shows all weft layers in horizontal direction, the first layer is in the first row from the bottom. The warp threads are represented by colored circles with trails that indicate whether the threads come from top or bottom. The weft threads are represented as lines. This represents the weaving process: The weft threads are present at first in the weaving machine and are therefore straight in the beginning. The warp threads are woven around the weft threads.

The color of both corresponds to the color of the cells in the table and stands for the **Material** of the thread. All other elements of the **Warp-Layer System** are identical to the **Weft-Layer System.**

## Binding Matrix

In the **Binding Matrix**, there is a column for each individual warp thread, while the row count is defined by the maximal yarn count of all weft layers.

| | 1 | 2 | 3 |
|---|---|---|---|
| 2/4 | 1 | 2 | 0 |
| 1/3 | 0 | 1 | 2 |

The numbers and colors in the first row show the shot index and material color of the warp threads, respectively. The first column only shows the shot index of the weft threads. Each cell stands for the intersection of a warp and a weft thread. The numbers in the cells determine the position of the warp thread in Z-direction relative to the weft thread layers at that location. Value 0 means that the thread is located at the bottom of the weave, below the first layer of weft threads. Setting the maximum value – which equals the number of weft layers – means that the thread lies on top of the weave. The color of each cell of the binding matrix corresponds to the material color of the thread which lays on top. The color pattern of the binding matrix corresponds to the color pattern of the top view of the weave.

When clicking in a cell, the related column and row of the **Binding Matrix** are highlighted. In the previews, the thread position is marked grey, and the previews switch to the corresponding position in the weave. Threads lying in this weft/warp position are shown as bold lines while threads lying behind this position are shown as dotted lines. In the weft preview the intensity of the dotted lines indicates the distance to the thread. The previews represent the geometry of the weave as one would see it when slicing through the model in 2D mode. Refer to the example below on page 38 for further explanation.

Left-click on a highlighted cell to increase the number by 1 and thereby change the position in Z-direction by one layer up. The previews are updated, and the color of the cell may change depending on the material ID which is on top of the weave. The position can be lowered again by a right click.


With the buttons below the Binding Matrix, the complete matrix can be edited. This is especially helpful when editing larger binding matrices. With **All +1** and **All -1**, all entries in the matrix are incremented by 1 (or decremented). With **Copy table to clipboard** and **Paste table from clipboard**, the complete table can be copied or pasted.

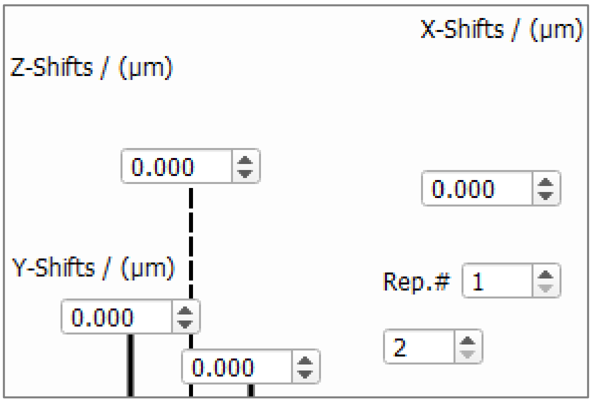
## Shifts

If two warp threads overlap, they are marked with a yellow attention sign (triangle) with exclamation mark in the preview of the **Warp-Layer System**. The overlap is not checked in Z-direction.

This initial overlap can be resolved by either adjusting the binding or using **Shifts**.

- **Shifts** in **X-direction** are defined for all **Warp-Layers**.
- **Shifts** in **Y-direction** can be defined for each **Weft-Layer** individually.
- **Shifts** in **Z-direction** are performed for all warp threads between two weft layers (threads with same number in binding matrix). The number of layers

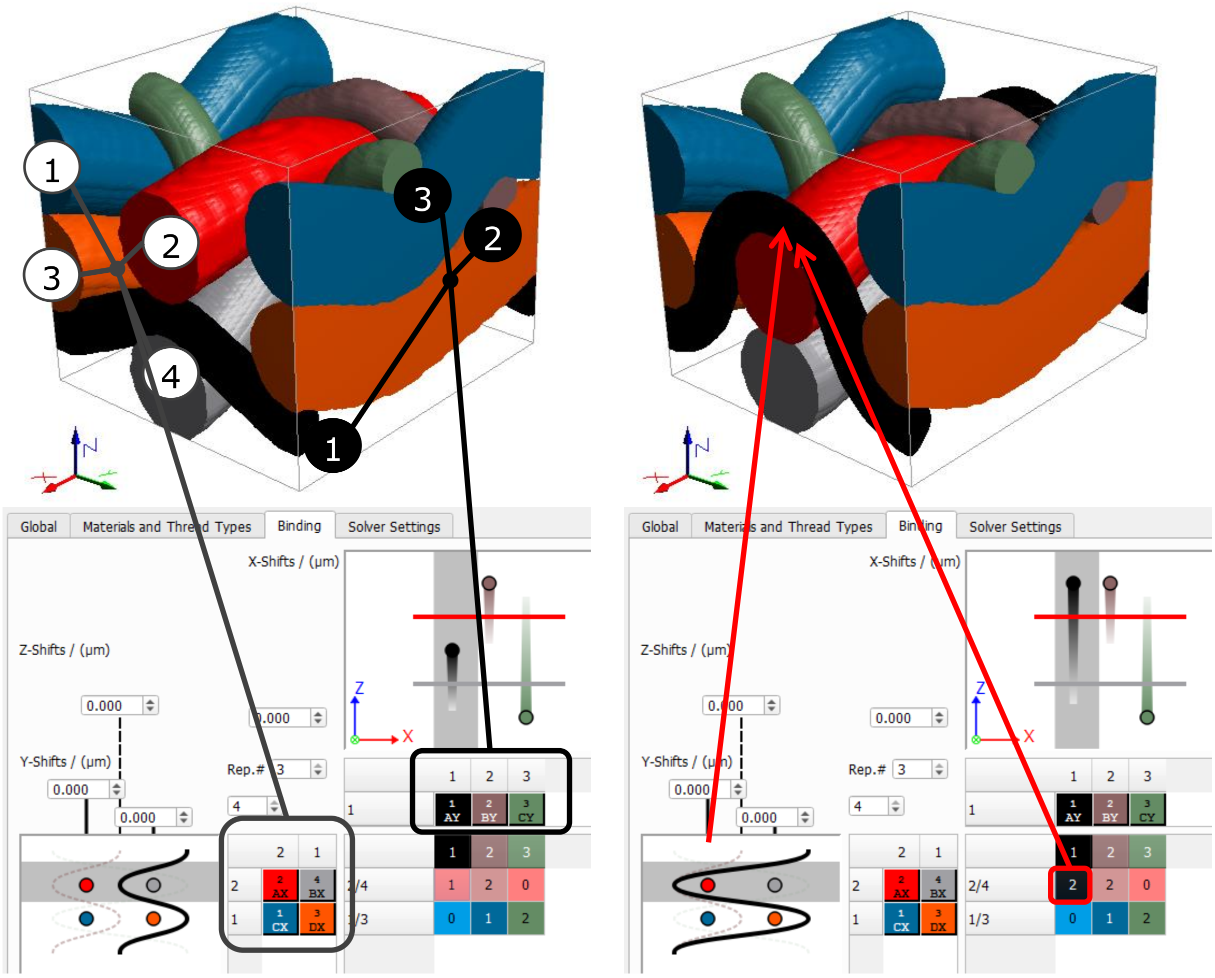
where such a shift is possible is one less than the number of weft layers, because the shifts in z direction affect the distances between the single weft layers.




**X-** and **Y-Shifts** are shown in the previews while **Z-Shifts** are not. Please note that in case of **Shifts** in **X- and Y-direction**, all threads belonging to the same layer will be shifted. In case of the **Z-Direction**, the distance between two layers is increased or decreased. For a **Z-Shift** of 0, the threads of the layers touch. That does not necessarily correspond to the position in Z-direction at which they are currently displayed in the preview.

Since the structure generation is performed with an iterative physics-based simulation, the distances between threads might change during the generation.

## Example



In the above example, the default parameters are kept: Only the repetition and the thread types are changed to better visualize the connection between the **Free Weave** user interface and the generated structure.

The structure on the left shows one unit cell of the **Complex Multi-Layer Weave** default structure. For better understanding, the **Rep.#** is set to 3 (see page 34) and a different thread type with a different color is assigned to each thread.

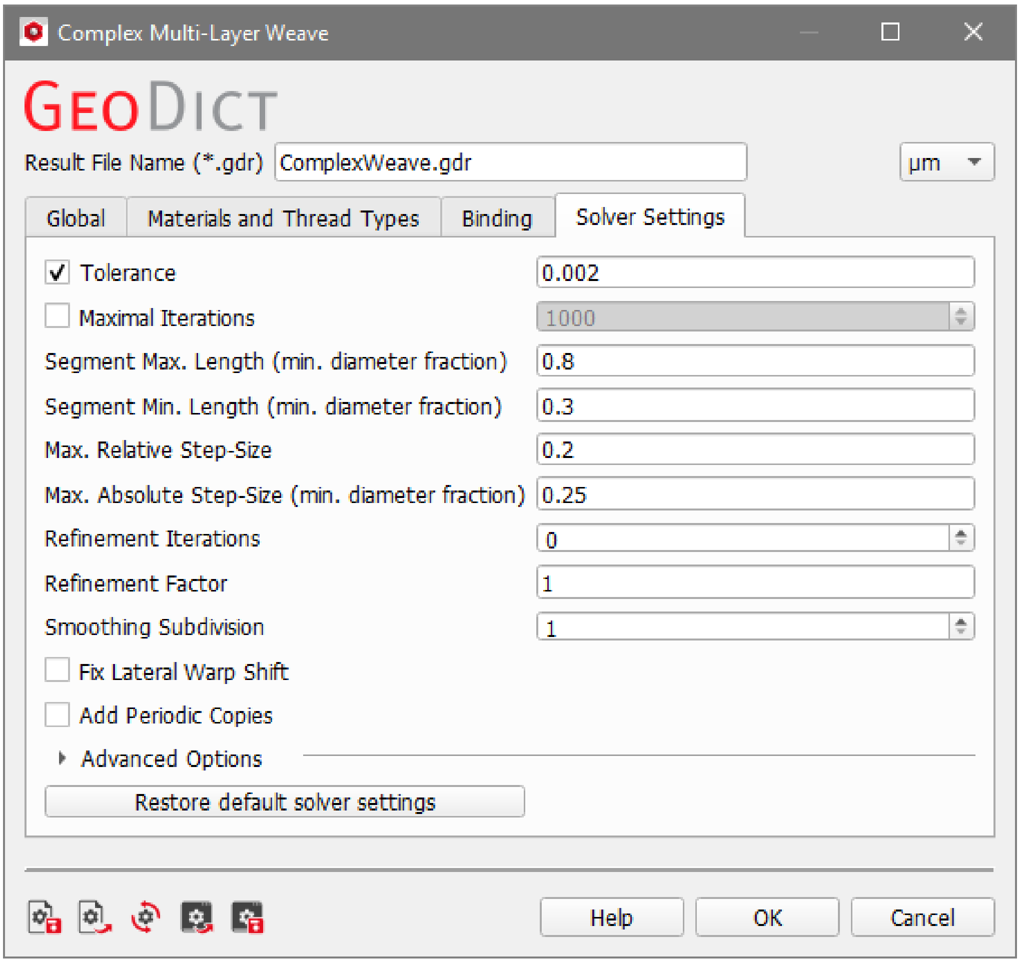
On the right, warp thread #1 (black) is moved up one layer: The binding matrix now shows its color since it is now laying on top of the weave. This can be observed in the 2D-diagram to the left and in the generated 3D-structure.

## Solver Settings

**Complex Multi-Layer Weave** performs a physical simulation to generate the weave in an iterative process. After defining the weave parameters, the threads are tightened while the interaction between the threads is considered, such as collisions. The parameters for this simulation are defined in the **Solver Settings** tab.

The **Tolerance** stands for the height reduction of the weave due to the simulated tightening between subsequent iteration steps. The simulation stops if the height reduction is below this threshold for several iterations. This does not work for all kind of weaves. Thus, another stopping criterion is the **Maximal Iterations**, where the solver stops once the entered number of iterations is reached. Both criteria can be selected at once and the solver run stops when one of the two is satisfied.

Threads are divided into linear segments and their **Segment Length** is relative to the minimum thread diameter. The **Segment Min. Length** should be less than half of the **Segment Max. Length**.



The **Max. Relative Step-Size** and **Max. Absolute Step-Size** define how much a thread may be moved in an iteration. The **Max. Absolute Step-Size** is defined by the given value multiplied with the smallest fiber diameter. It should be smaller than 0.5, to avoid fibers "jumping over" other fibers with which they collide. The value for the **Max. Relative Step-Size** is multiplied with the length on which two fibers overlap and should be smaller than 1 for a stable simulation. In case of overlap, the smaller value of **Max. Absolute Step-Size** and **Max. Relative Step-Size size** is used.

After either **Tolerance** or **Maximal Iterations** stopping criteria are fulfilled, the fibers are subdivided into smaller segments over several iterations given by **Refinement Iterations**. These iterations are done in an additional solver run pass.

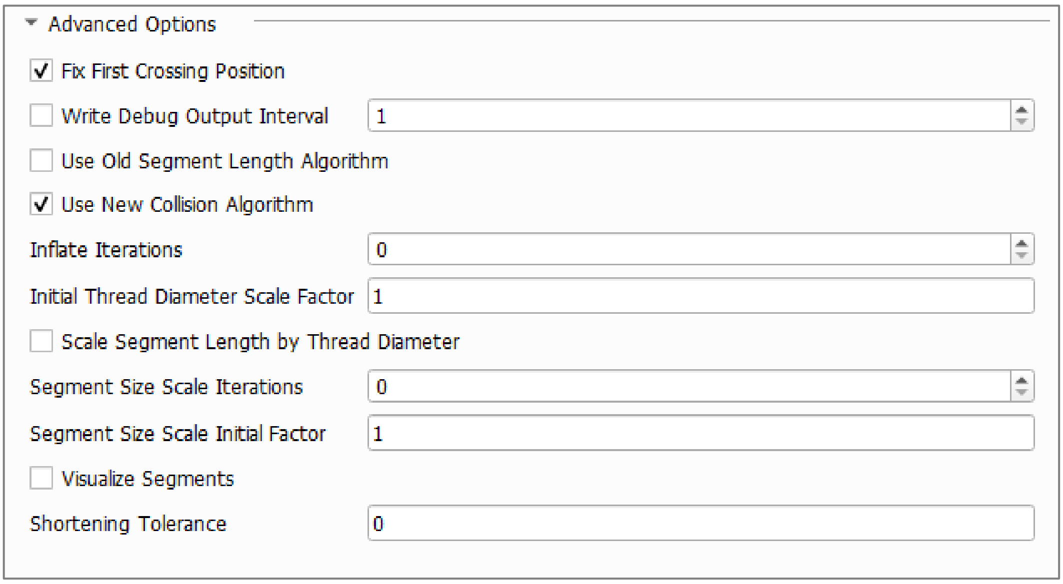
The **Refinement Factor** defines to which extent the **Minimum** and the **Maximum Segment Length** are reduced at the end of the refinement iterations. A value of 0.1 means that the **Minimum** and the **Maximum Segment Length** are reduced to 10% of their start values. The **Refinement Factor** is a number that is larger or equal than 0.1 and less or equal than 1. If the Refinement Factor is set to 1, this feature is disabled and no Refinement Iterations are performed.

**Smoothing Subdivision** performs a subdivision and spline interpolation as a postprocessing step after the simulation. The primary use for this is in visualization to make the structure appear smoother. As it happens only once at the end of the simulation, it is not computationally expensive to use. The number given here is the number of subdivisions to perform and it is thus a positive integer number. A value of 1 will perform no subdivision. A value of 2 will split each segment into two segments etc. In most situations, increasing the value beyond 3 will not give a noticeable improvement.

If **Fix Lateral Warp Shift** is activated, the entered lateral deformation of the warp threads is fixed during the creation of the weave. This means the warp threads cannot move along the lateral direction.

The option to **Add Periodic Copies** is described on page 13.

Clicking on **Advanced Options** unfolds many more settings. For most of the simulations they need not to be changed. If they need to be adjusted, tooltips describe how they can be used.

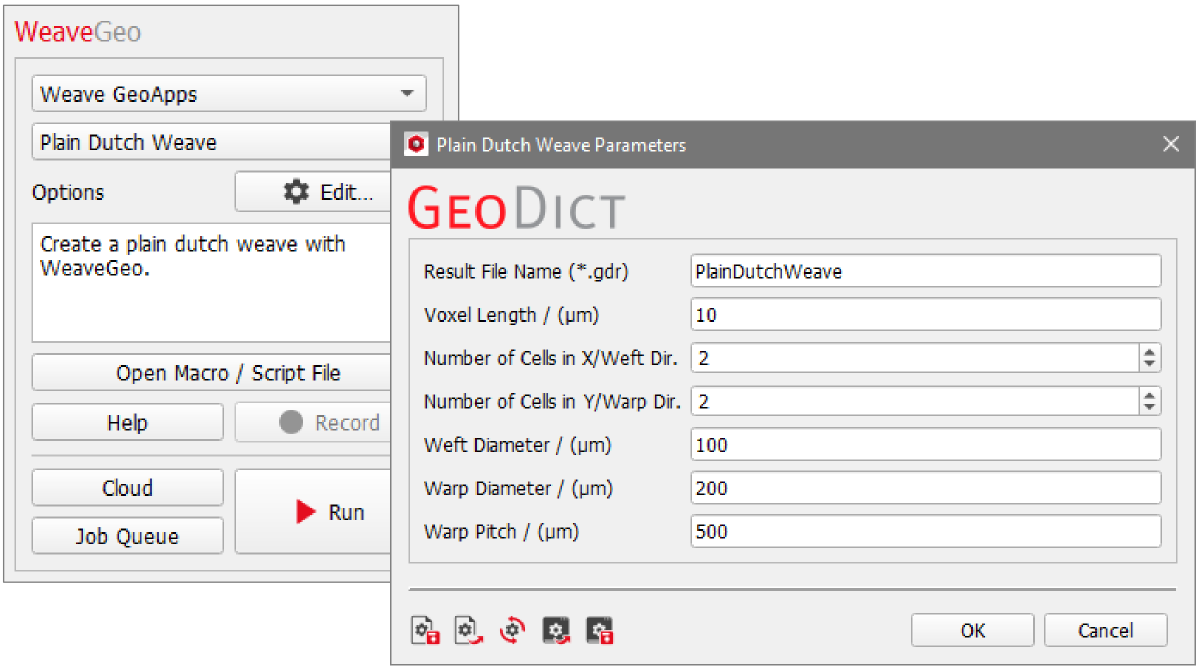


## WEAVE GEOAPPS

When **Weave GeoApps** is selected in the WeaveGeo section, several representative structures can be chosen from the pull-down menu.

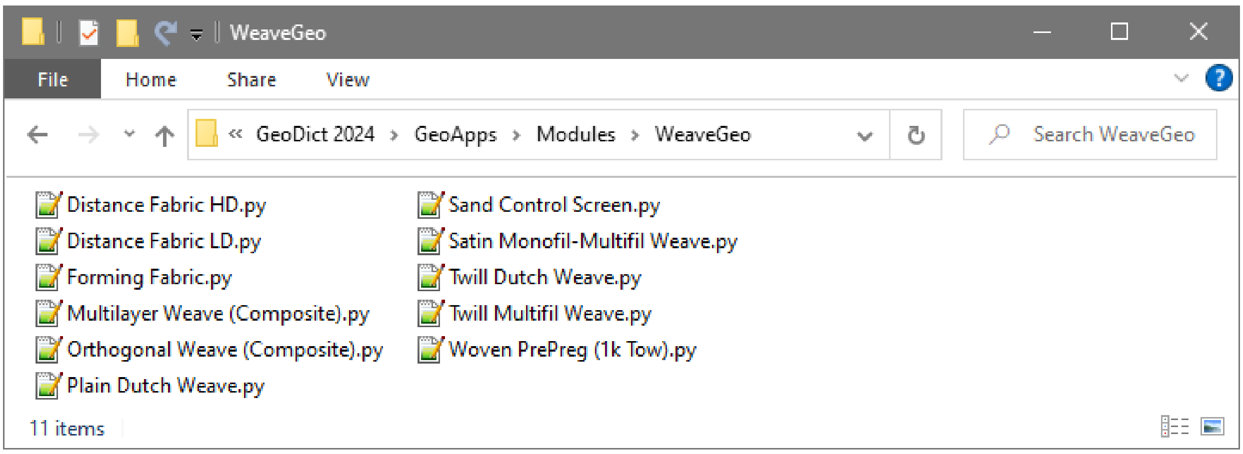
For each of these structures, a macro in Python format exists, that is executed if the generation process is started. The macros are delivered within the WeaveGeo folder in the GeoDict installation folder. These macros can be used as basis for new structures by modifying parameters to generate user-defined weaves.

Various parameters define each of the structures generated by the macros, such as resolution parameters (**Voxel Length**), **Number of Cells in X** and **Y** direction, **Weft** and **Warp Diameter**, or **Warp Pitch**.




By clicking the **Options' Edit...** button, the corresponding parameter dialog is opened and the main parameters defining the weave can be changed.

Clicking **Open Macro / Script File** opens the macro file for the selected weave in a text editor. The syntax and the steps involved in the generation can be observed. Macros from the WeaveGeo folder can also be modified and saved as a local, customized macro in the user's project folder. More on macro creation can be found in the GeoPy Scripting handbook of the User Guide. The GeoApps handbook of the User Guide explains how a macro can be added as user-defined GeoApp.



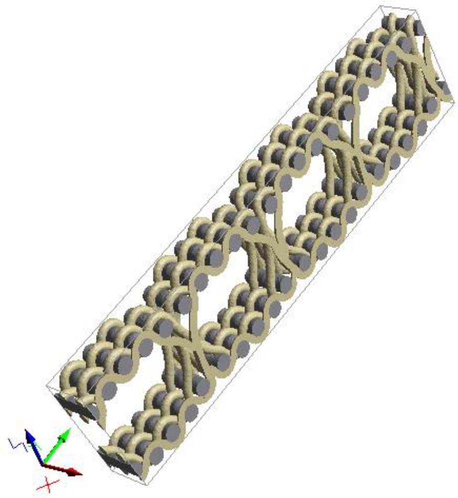
Any custom macro added to this WeaveGeo folder appears as **Weave GeoApp** in the pull-down menu list in the WeaveGeo GUI.

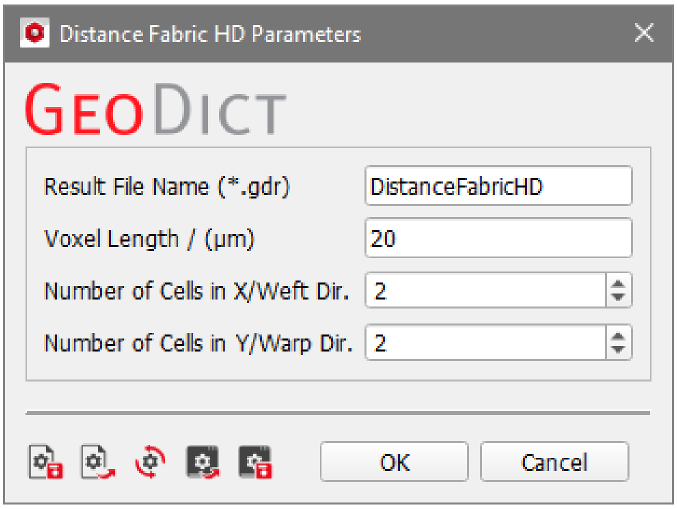
When all parameters are defined, create the structure by clicking **Run**.

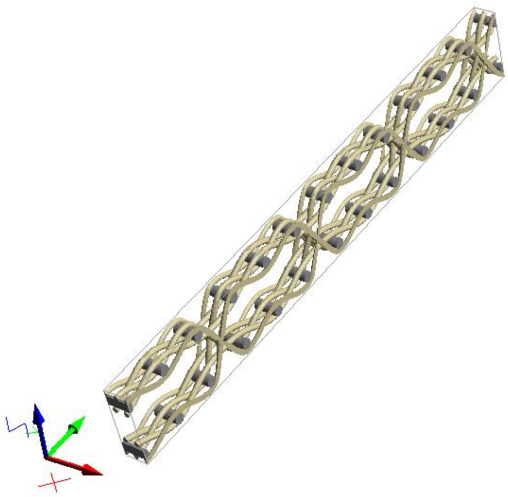
In the project folder, a result file (*.gdr) and a folder with the same name containing the generated structure, are automatically saved. After the generation has finished, the **Result Viewer** opens automatically and displays the result file (*.gdr). The generated structure is shown in the visualization area and can be rendered in 3D. More information on the Result Viewer can be found in the Result Viewer handbook of the User Guide.

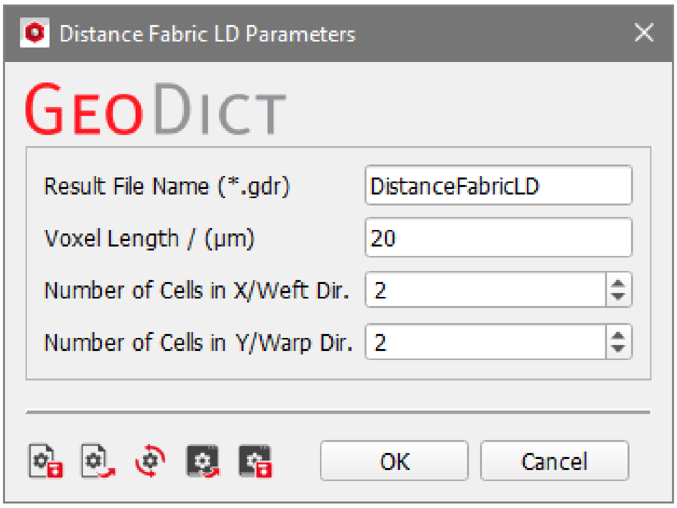
## Weave GeoApps Gallery

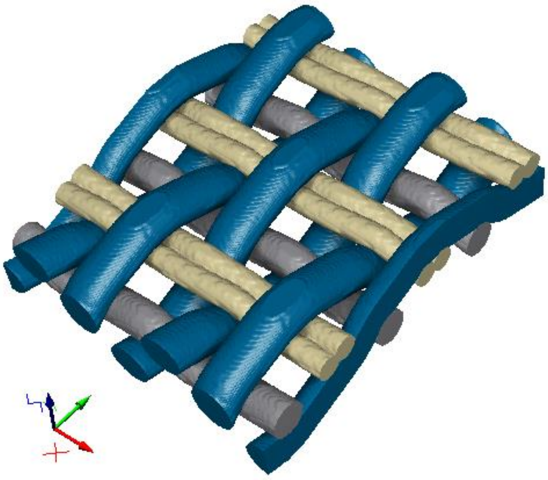
In the following, the resulting structures of all WeaveGeo – Weave GeoApps are shown together with the default settings for each GeoApp.

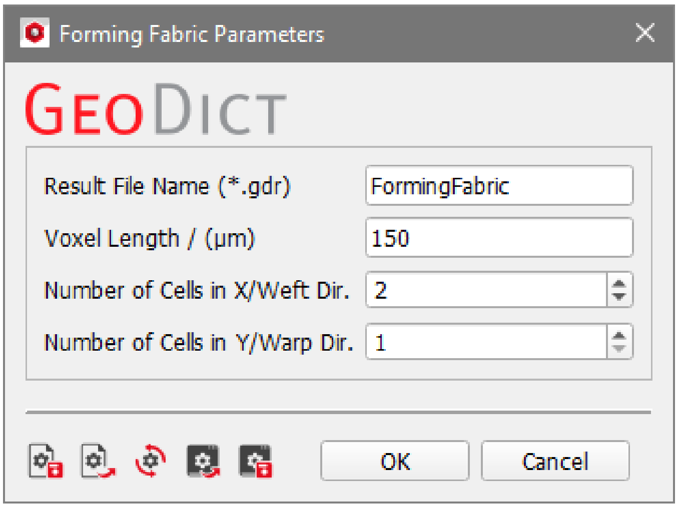


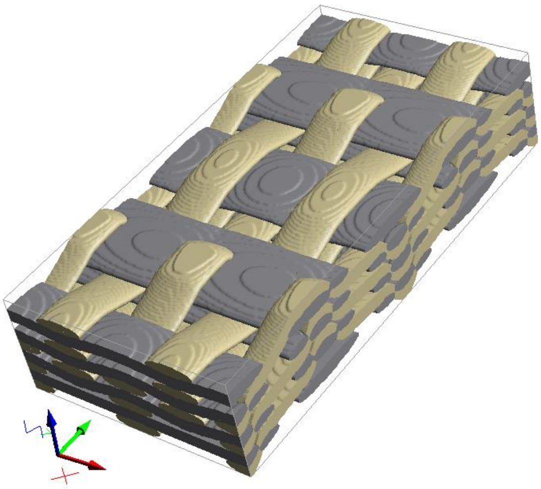


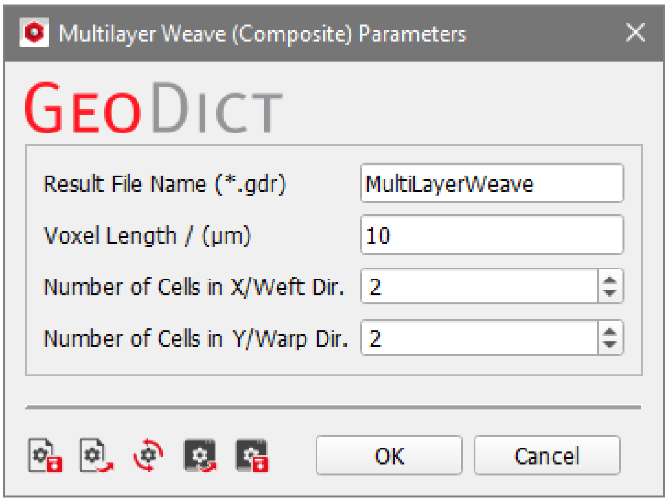



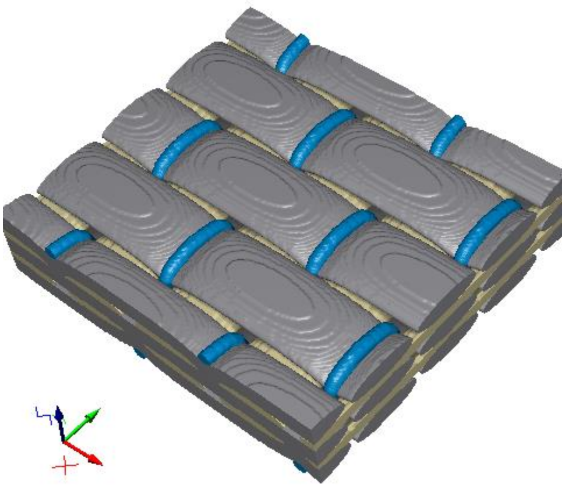


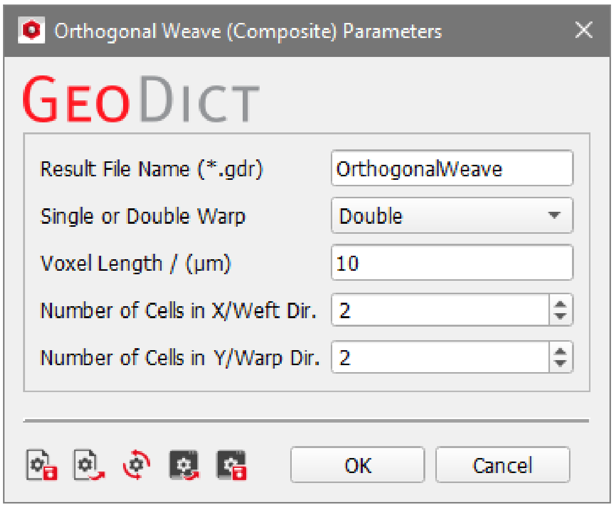


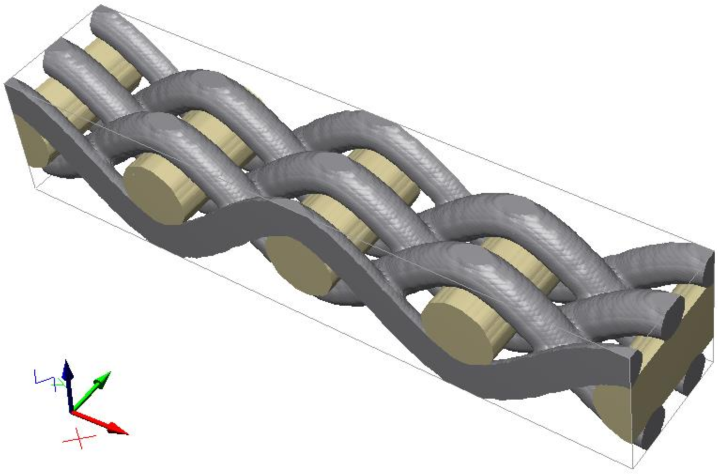

Forming Fabric Parameters
GeoDict
Result File Name (*.gdr)
FormingFabric
Voxel Length / (µm)
150
Number of Cells in X/Weft Dir.
2
Number of Cells in Y/Warp Dir.
1
OK
Cancel

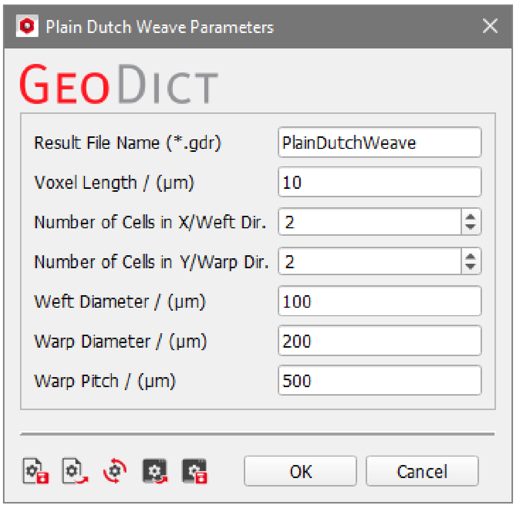


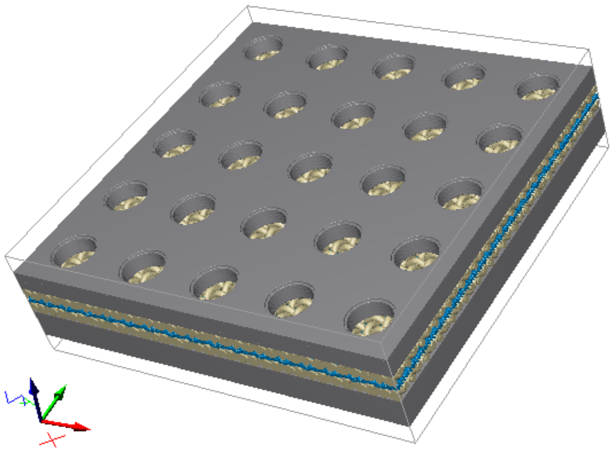

Multilayer Weave (Composite) Parameters
GeoDict
Result File Name (*.gdr)
MultiLayerWeave
Voxel Length / (µm)
10
Number of Cells in X/Weft Dir.
2
Number of Cells in Y/Warp Dir.
2
OK
Cancel

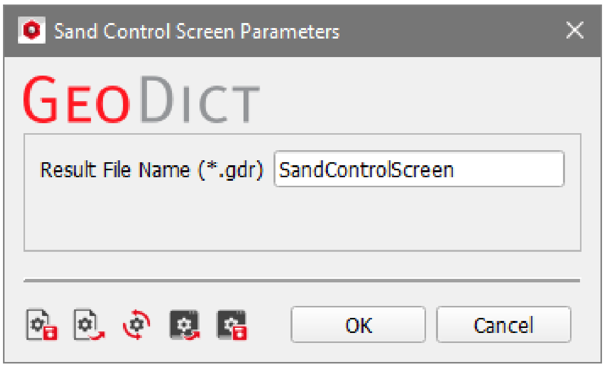



Orthogonal Weave (Composite) Parameters
GeoDict
Result File Name (*.gdr)
OrthogonalWeave
Single or Double Warp
Double
Voxel Length / (µm)
10
Number of Cells in X/Weft Dir.
2
Number of Cells in Y/Warp Dir.
2
OK
Cancel

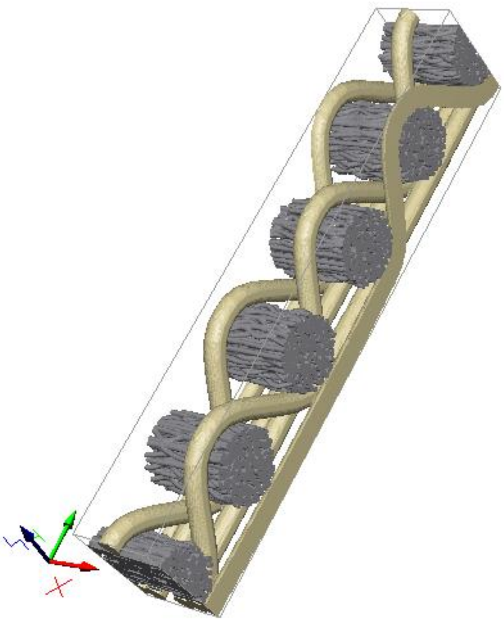


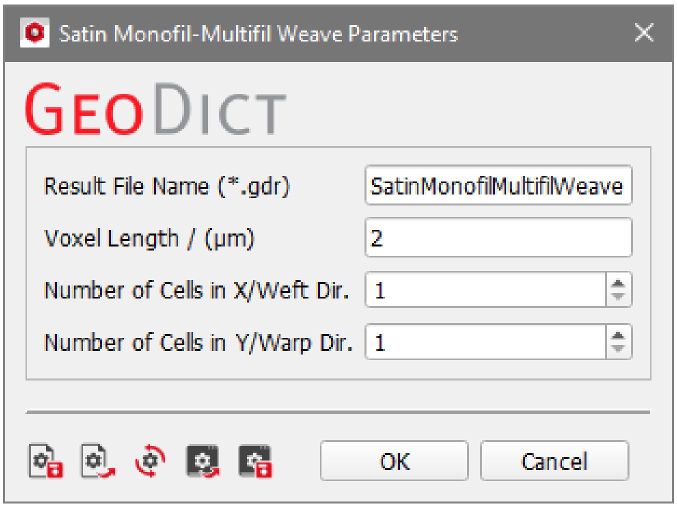


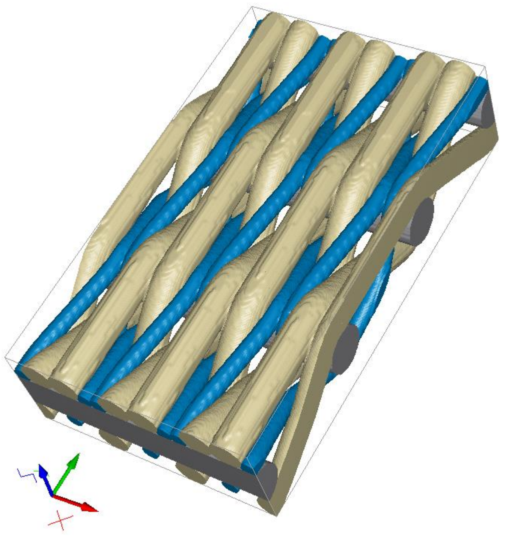



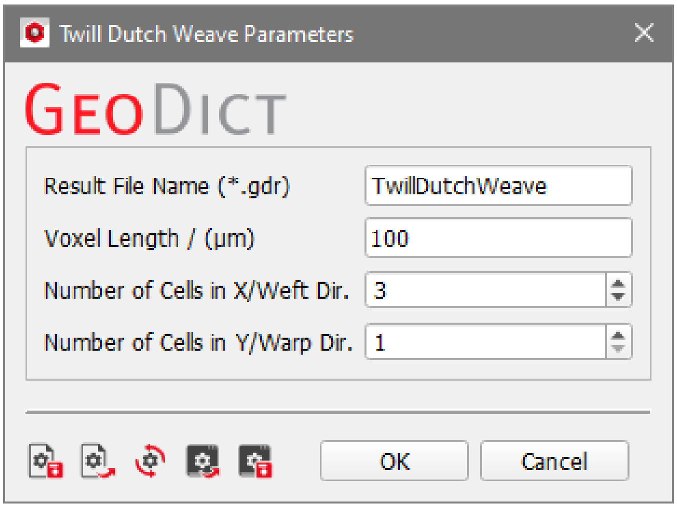


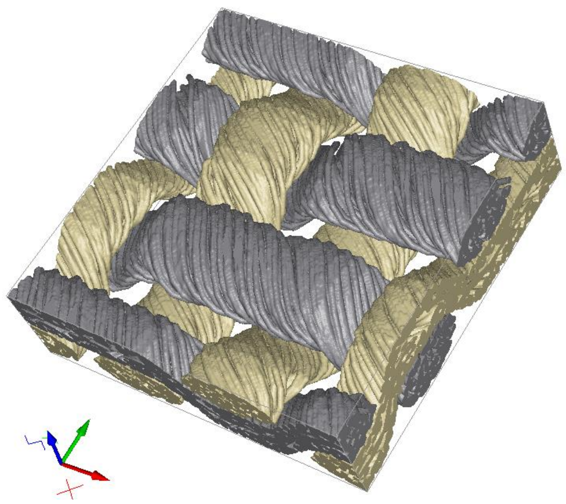

To generate the Sand Control Screen structure, a license for the GridGeo module is also needed. Be aware that the generated structure is very large (2000 x 2000 x 600) and the generation might take around 10 minutes.

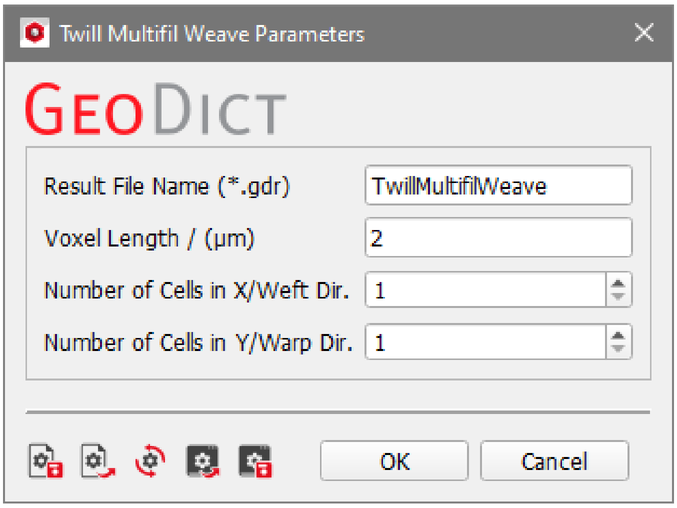


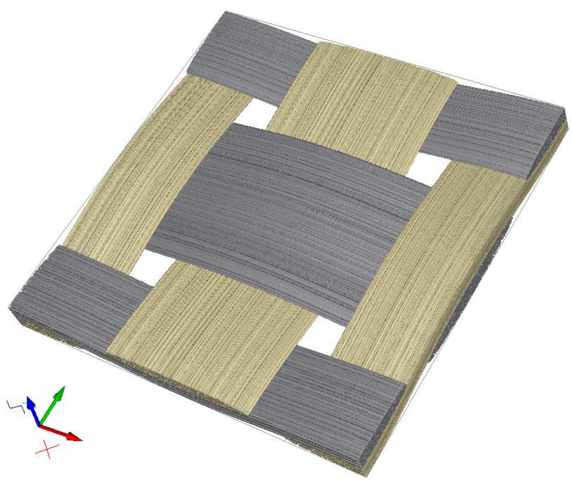


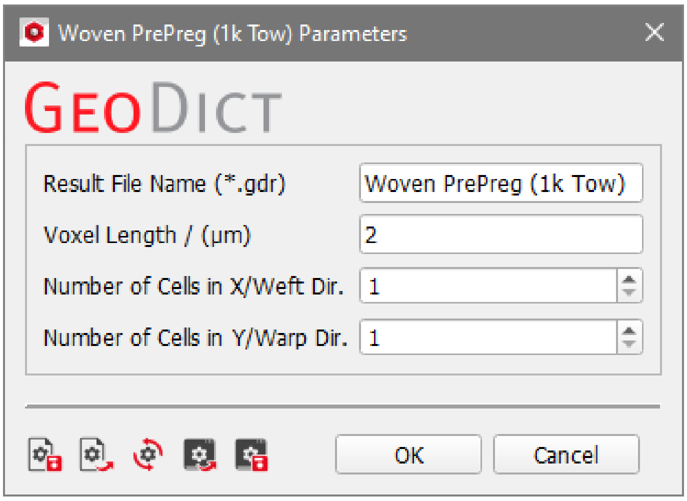



Twill Dutch Weave Parameters
GeoDict
Result File Name (*.gdr)
TwillDutchWeave
Voxel Length / (µm)
100
Number of Cells in X/Weft Dir.
3
Number of Cells in Y/Warp Dir.
1
OK
Cancel




Twill Multifil Weave Parameters
GeoDict
Result File Name (*.gdr)
TwillMultifilWeave
Voxel Length / (µm)
2
Number of Cells in X/Weft Dir.
1
Number of Cells in Y/Warp Dir.
1
OK
Cancel




Woven PrePreg (1k Tow) Parameters
GeoDict
Result File Name (*.gdr)
Woven PrePreg (1k Tow)
Voxel Length / (µm)
2
Number of Cells in X/Weft Dir.
1
Number of Cells in Y/Warp Dir.
1
OK
Cancel

## References

[1] A. Wiegmann, O. Iliev, A. Schindelin; 2010; Computer Aided Engineering of Filter Materials and Pleated Filters; Global Guide of the Filtration and Separation Industry by E. von der Luehe. VDL – Verlag, pp 191-198.

[2] S. Probst-Schendzielorz, M. W. Schmitt, S. Rief, A. Wiegmann and H. Andrae; 2011; Simulation of Press Dewatering; Progress in Paper Physics Seminar 2011, Graz.

[3] M. Knefel; 2011; Advances in Simulation of Technical Meshes; Industrial Equipment News.

[4] M. Knefel; 2011; CFD Simulation of Woven Sand Control Screens; AFS Annual Conference, Louisville, KY.

[5] M. Knefel, P. Wirtz; 2009; Auswahl und Optimierung technischer Gewebe mittels GeoDict; 2. Fest-Flüssig-Trenntage, Potsdam.

[6] E. Glatt, S. Rief, A. Wiegmann, M. Knefel, E. Wegenke; 2009; Structure and pressure drop of real and virtual metal wire meshes (in German); F&S Filtrieren und Separieren, Jahrgang 23, Nr. 2, pp 61-65.

[7] S. Rief, E. Glatt, E. Laourine, D. Aibibu, C. Cherif, A. Wiegmann; 2011; Modeling and CFD-Simulation of woven textiles to determine permeability and retention properties; AUTEX Research Journal, Vol. 11, No 3, pp 78-83.

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

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