WeaveGeo

User Guide

GeoDict release 2022

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GeoDict

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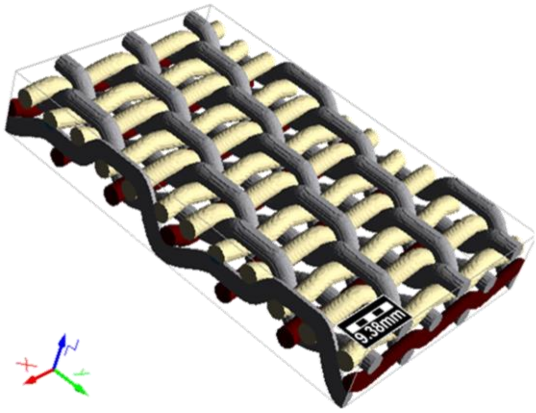
Generating weave structures with WeaveGeo

WeaveGeo is GeoDict's generator for woven structures. WeaveGeo contains generators for the three basic weaving patterns plain weave, twill, and satin. Additionally, Free Weave is a tool to create user-defined weaving patterns up to complex multilayered structures.

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.

References

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

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

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

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

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

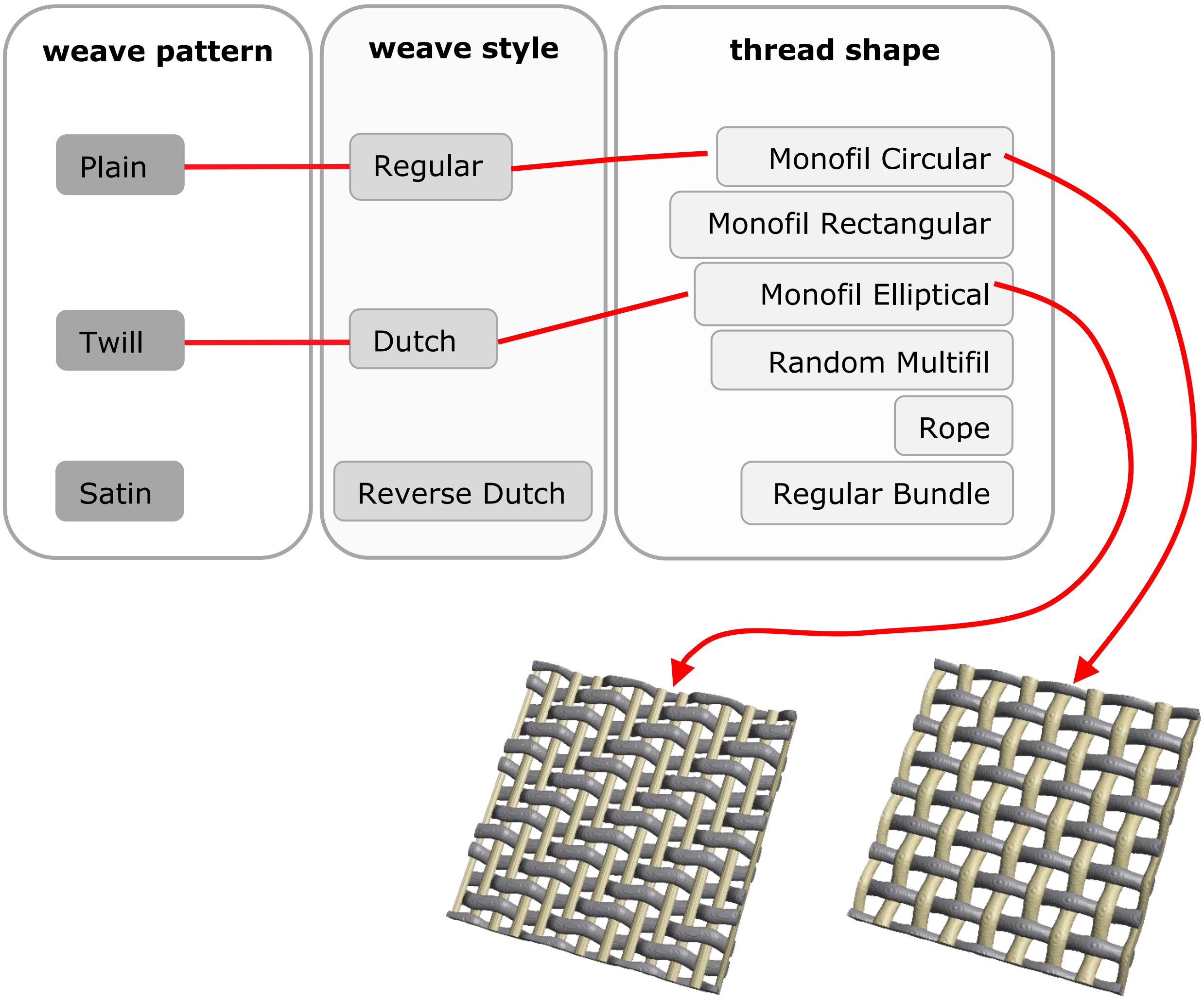
[6] Structure and pressure drop of real and virtual metal wire meshes, E. Glatt, S. Rief, A. Wiegmann, M. Knefel and E. Wegenke, (in German), F&S Filtrieren und Separieren, Jahrgang 23, Nr. 2, 2009, pp 61-65.

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

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.

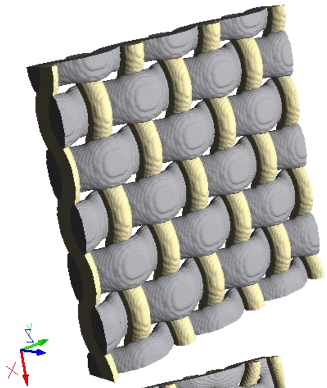
WeaveGeo allows to generate a large variety of different weaving structures by combining the available options. These options include different weaving patterns, weaving styles, thread types and thread parameters (e.g. shape, size and material). Additionally, the weaving structure can be completely user-defined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



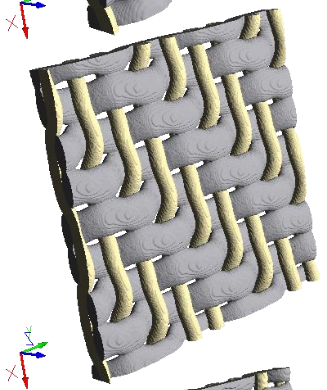
The choice of weave type (and material) determines the final properties of the woven structure, such as weight, wettability, stability, flexibility, porosity, or smoothness.

Weave Types by Crossing Pattern

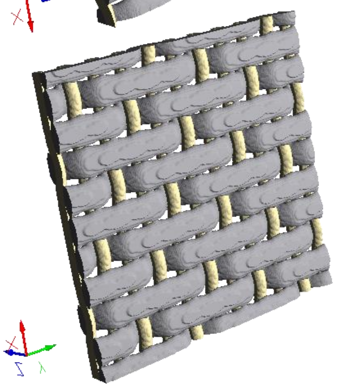
The way the warp and weft threads interlace with each other is known as the weave type. The three basic weave types are **plain** weave, **twill** weave, and **satin** weave, and the majority of woven products are created with one of these weaving patterns.



The **Plain** weave is the simplest weave type. 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 methods of weaving: regular, Dutch weave, and Reverse Dutch weave.

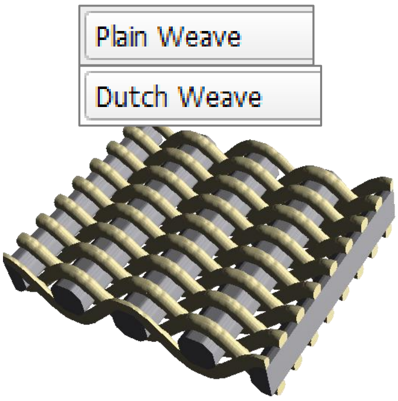
Regular

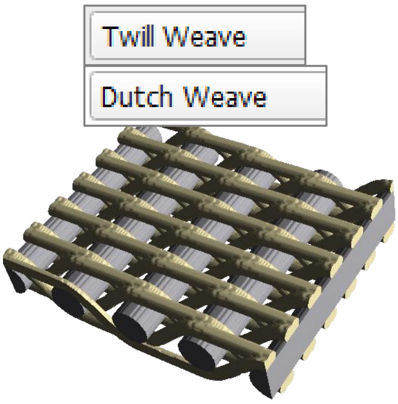
In the **Regular** (or square) weave, warp, and weft are bent around each other, resulting in a characteristic structure with rectangular meshes.

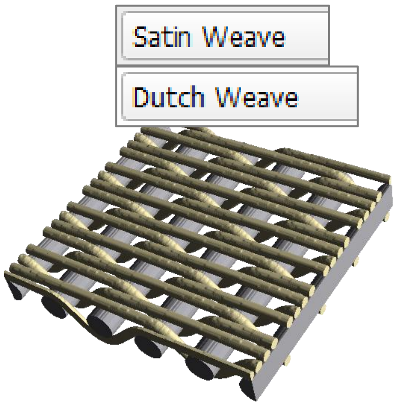
Dutch Weave

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.

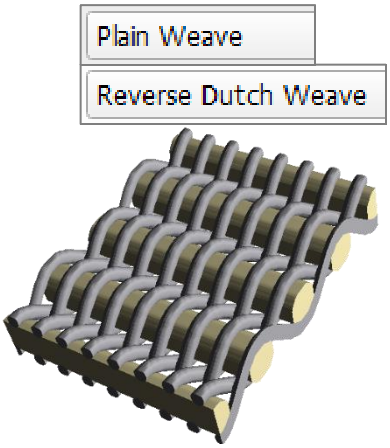


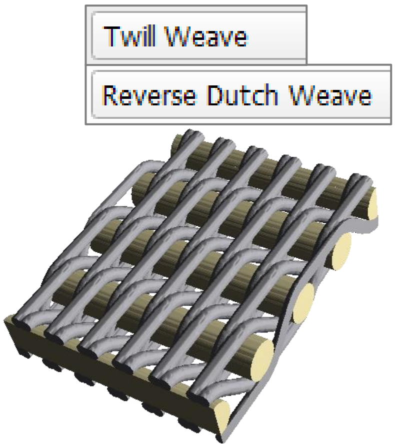


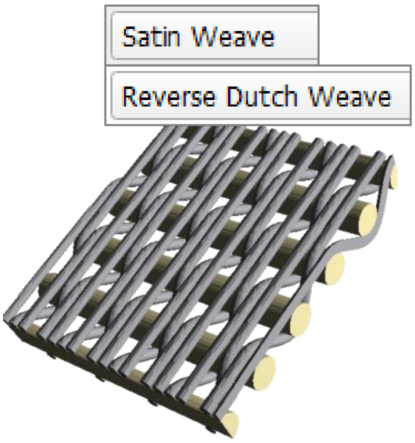


Reverse Dutch Weave

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).







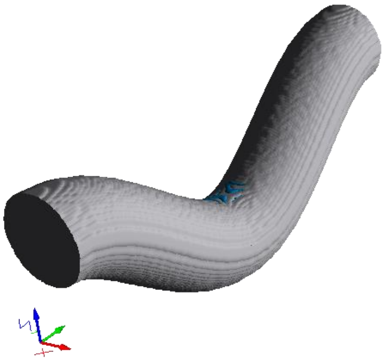
Weave Profile Types

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

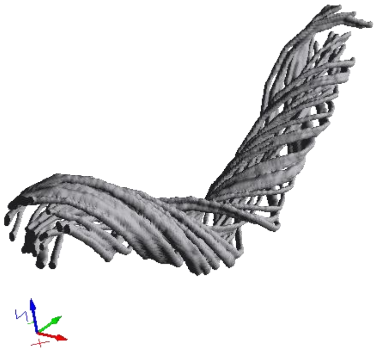
The threads of a weave can often be modelled as compact objects without an inner structure, for example, as in metal wire meshes. Such threads are called **Monofilament** or **Monofil** threads.

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.

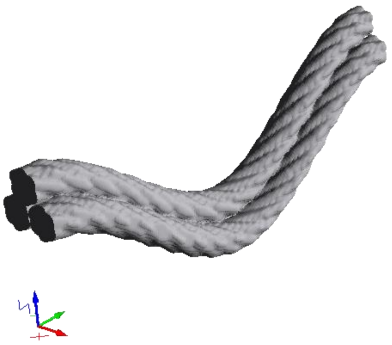
For the **Random Multifil** model, the filament positions are chosen randomly.



Rope

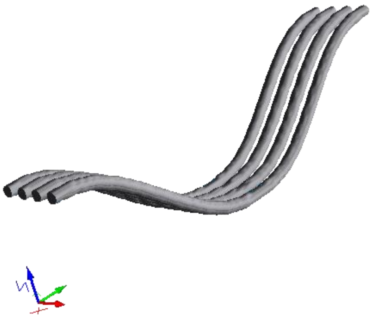
A **Rope** is a strong, thick string made of strands of filaments (fibers, wires) twisted together.

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

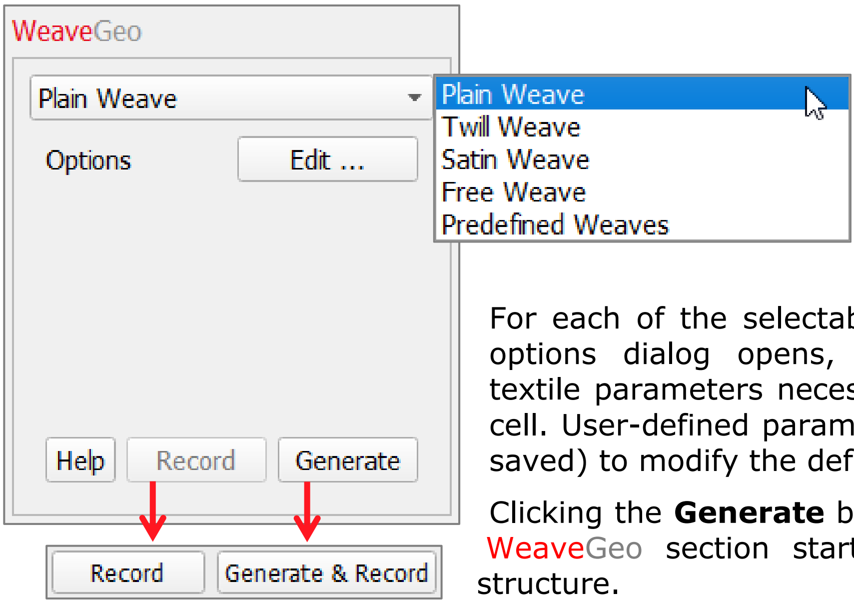
In a **Regular Bundle**, the positions of the filaments form a regular grid.



WEAVEGEO SECTION

WeaveGeo starts when selecting **Model** → **WeaveGeo** in the Menu bar. The following commands are available in the **WeaveGeo** section pull-down menu:

- Weave Types: **Plain Weave**, **Twill Weave**, **Satin Weave**, and **Free Weave**. For these weave patterns (see above page 4), different styles (Plain, Dutch and Reverse Dutch) and thread types (Monofil, Random Multifil, Rope and Regular Bundle) can be chosen, and numerous textile parameters can be entered through the **Options**' **Edit ...** buttons located in their panels.
- **Predefined Weaves** contains examples for representative woven structures.



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

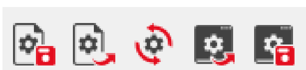
Clicking the **Generate** button at the bottom of the WeaveGeo section starts the generation of the structure.

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 Map** 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.

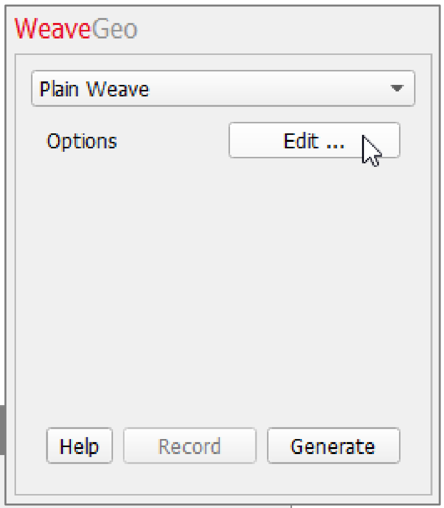


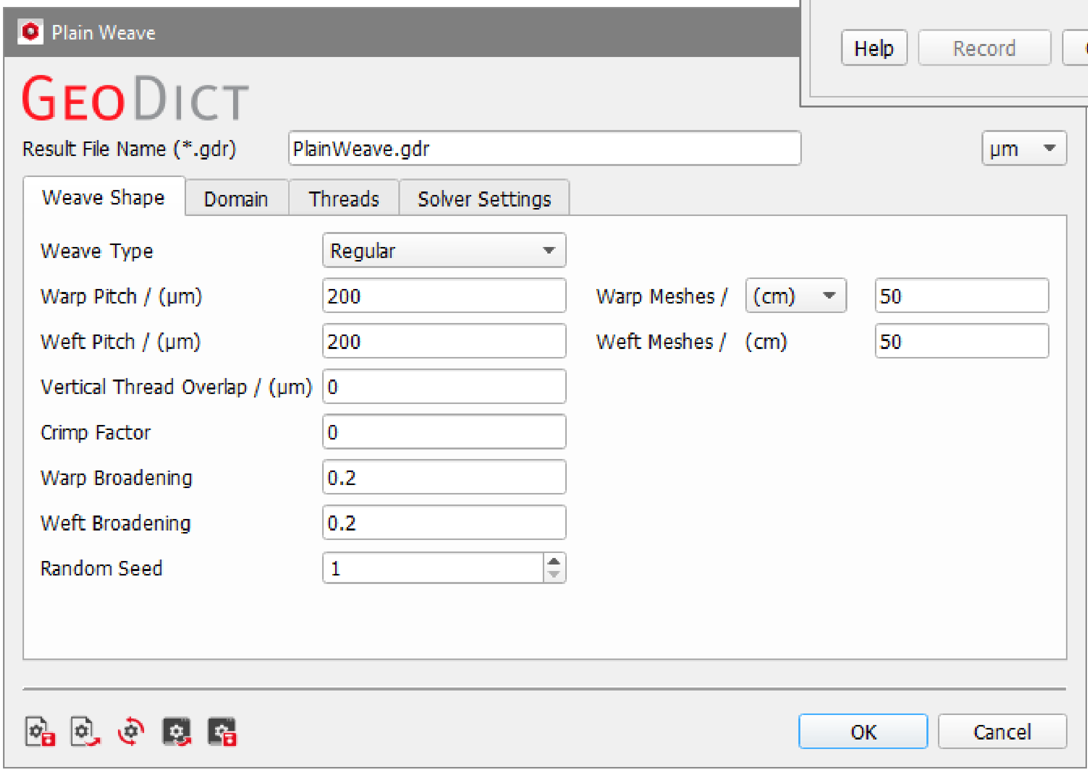
Plain Weave

Choose **Plain Weave** from the pull-down menu in the WeaveGeo section 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 the current project.

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





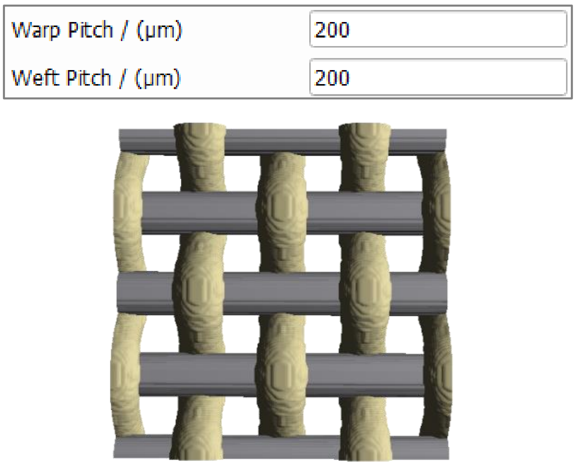
The weave parameters are organized under the tabs **Weave Shape**, **Domain**, **Threads**, and **Result Options**.

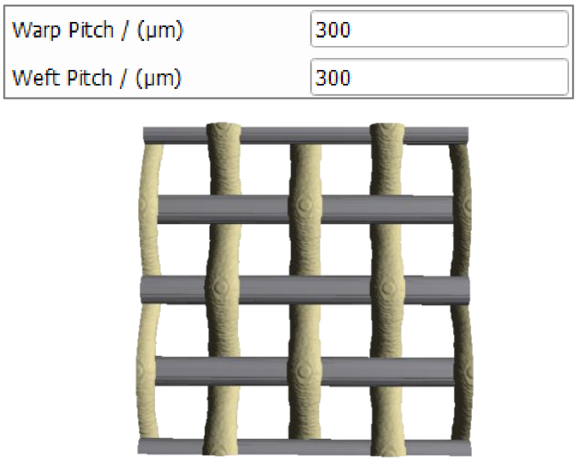
Weave Shape

The plain weave types can be selected from the **Weave Type** pull-down menu. See pages 4 ff. for explanations on these three types of weaves (Regular, Dutch Weave, and Reverse Dutch Weave).

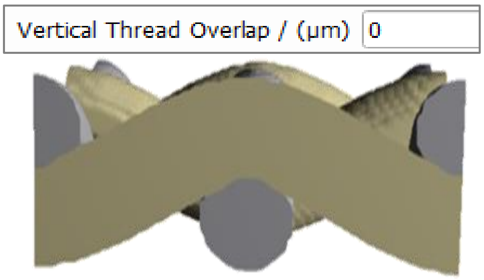
Warp (and **Weft**) **Pitch** is the distance between the center lines of two adjacent threads. This corresponds to the sum of the aperture and the thread diameter. The threads touch if the entered pitch is equal to the warp (or weft) thread width (diameter of the threads in the X or Y direction).

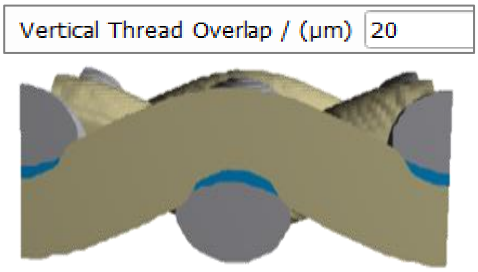
The warp pitch and weft pitch can also be entered as **Warp Meshes / Inch** and **Weft Meshes / Inch**. This is equivalent to the number of threads of warp or weft per inch in the structure. These values are changed automatically when modifying the values for **Warp Pitch** or **Weft Pitch**, and vice versa. Together with the **Voxel Length** and the number of **Unit Cells**, they determine the total size of the domain (NX, NY, NZ).



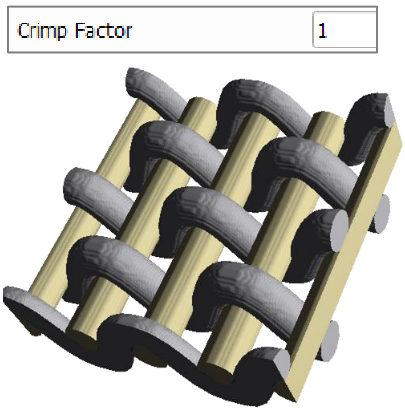


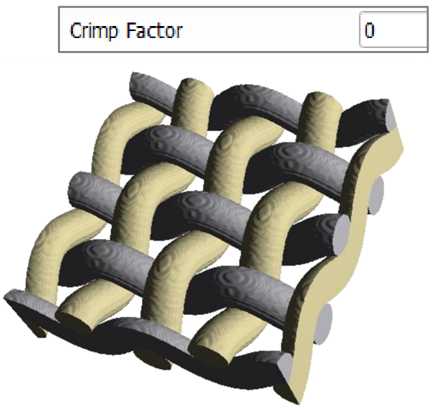
Vertical Thread Overlap is the amount of overlap that the threads show at their crossing points. The overlap, corresponding to the entered value of vertical overlap, is shown blue in the figure below (for the chosen color settings for warp and weft). The thread overlap has no physical equivalent, but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

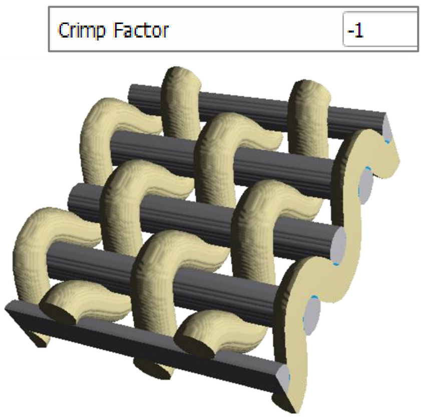




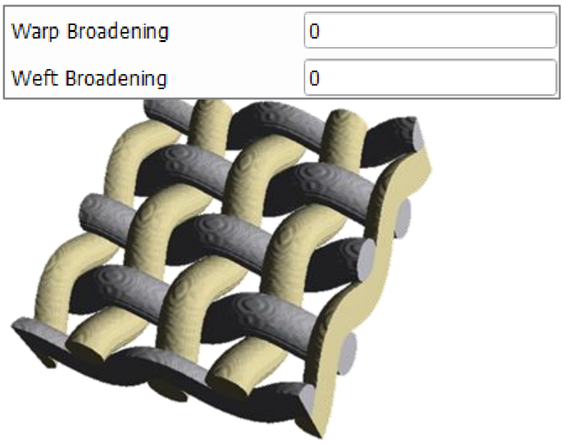
The **Crimp Factor** defines the straightness of the warp and weft threads. It varies between -1 and 1. A value of 1 for the **Crimp Factor** results in straight weft threads, while a value of -1 results in straight warp threads. When it is set to 0, both thread types bent around each other, leading to a thinner structure. With the **Crimp Factor**, all possible gradations between the extremes Dutch Weave and Reverse Dutch Weave can be achieved.

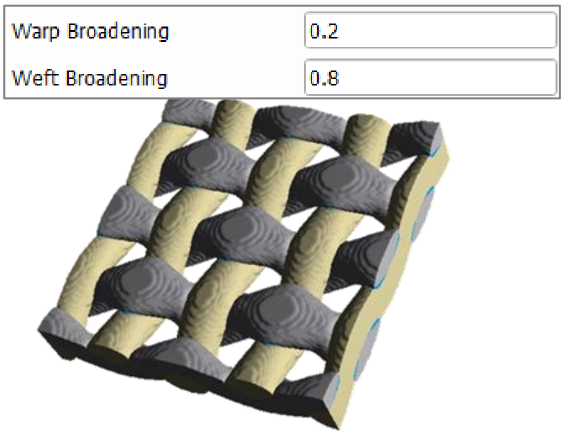




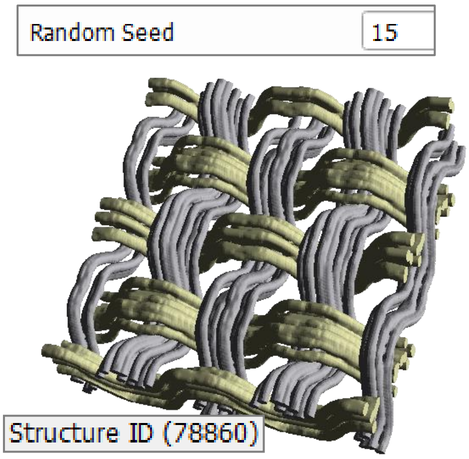


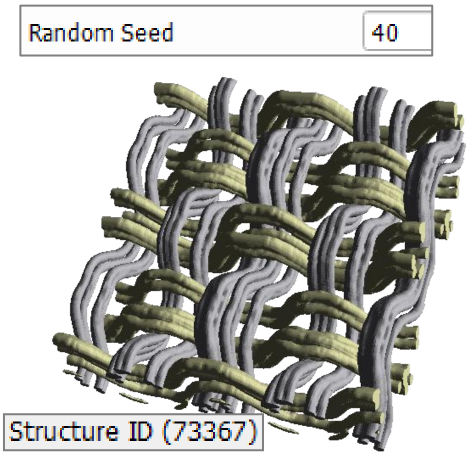
Warp and **Weft Broadening** are the relative spreading of the threads at the interlacing points of weft and warp threads. This spreading simulates the bending and deformation of the threads during the weaving process. Values of broadening vary between 0 (no broadening) and 1.



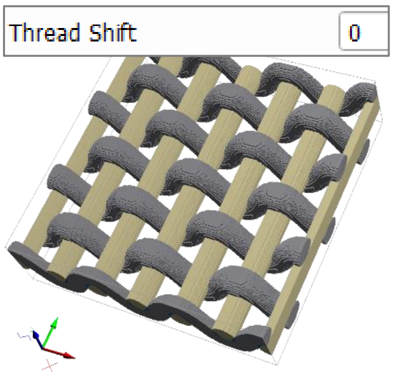


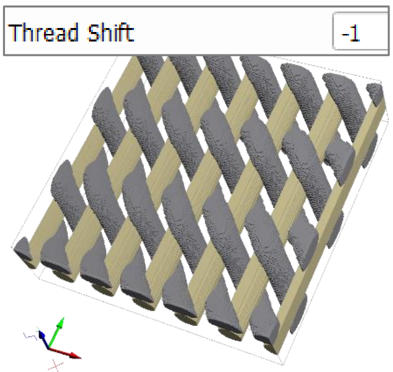
Random Seed initializes the random number generator behind the structure generator. Changing its value produces different sequences of random numbers and hence, different realizations of the specified structure. If all settings are equal, generating with the same **Random Seed** value produces exactly 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 6) or **Weft/Warp Lateral Deformation** is applied (see page 21).

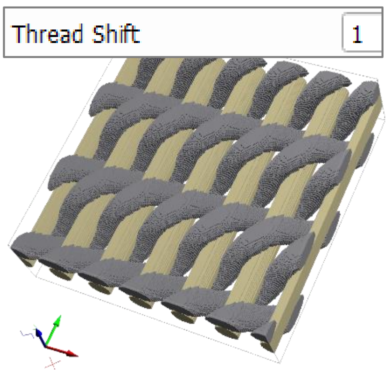




The option to choose the **Thread Shift** is only available when using **Dutch Weave** or **Reverse Dutch Weave.** With the default value of 0, the weft threads (or warp threads, in case of Reverse Dutch Weave) run perpendicular to the warp (or weft) threads. When choosing a value of -1 or 1, they run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



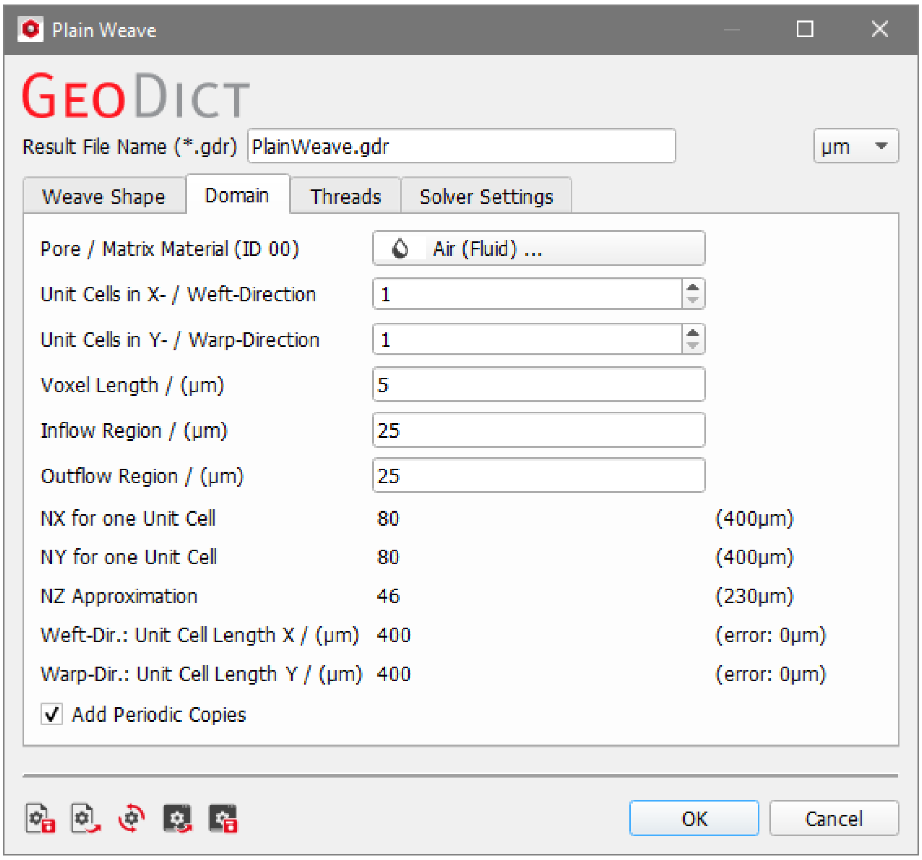




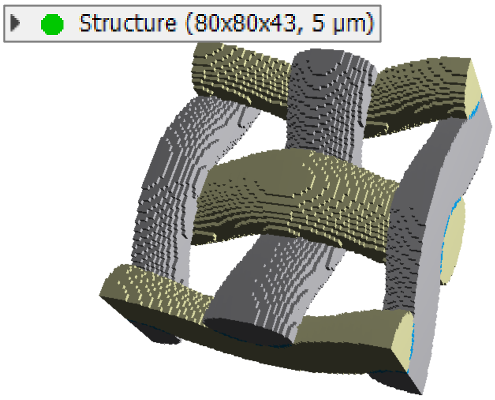
DOMAIN

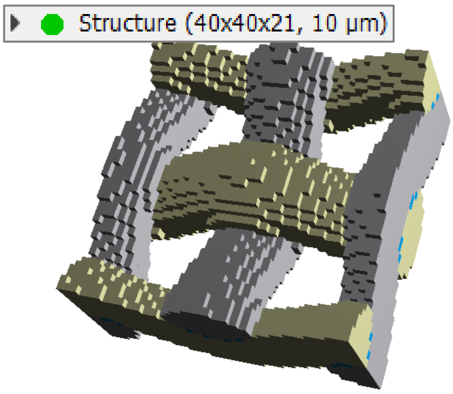
Through the **Pore / Matrix Material (ID 00)** button, select the material which occupies the space surrounding the threads (e.g. Air) from the GeoDict Material Database.

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. Thus, a large number of unit cells leads also to a larger structure.

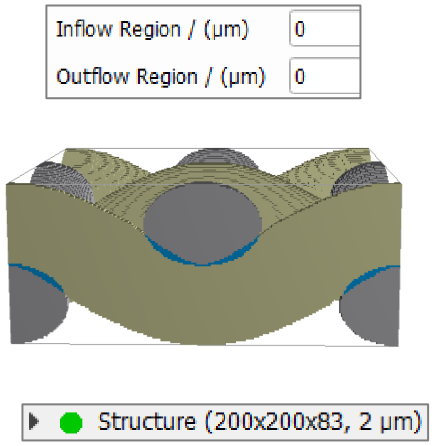


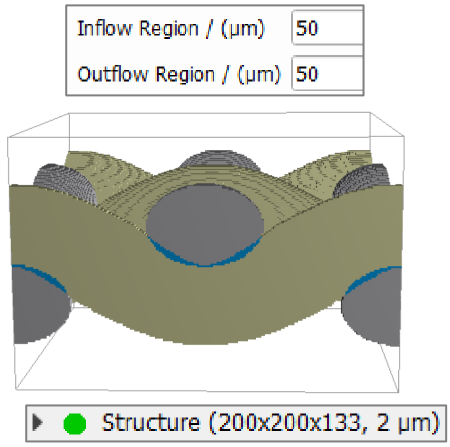
The **Voxel Length** is the size of a voxel in the chosen units. To see the difference that the increase in voxel length produces, select the **Box renderer** under **View → 3D Structure Renderer → Box**, and not the **Smooth** renderer (since this option softens the visualization).





The values entered for **Inflow Region** and **Outflow Region** determine the size of the void regions below (-Z direction) and above (+Z direction) the generated woven structure.





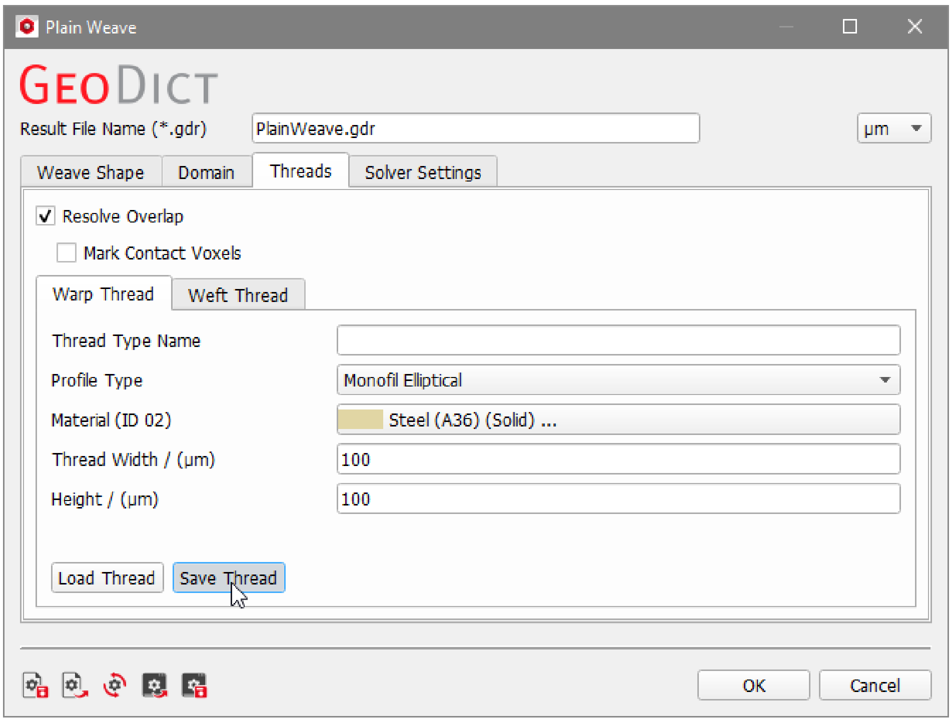
The values for **NX for one Unit Cell**, **NY for one Unit Cell**, and **NZ Approximation** indicate the number (N) of voxels in **X**, **Y** and **Z**-direction for the unit cell. Analogously, **Weft-Dir.: Unit Cell Length X** and **Warp-Dir.: Unit Cell Length Y** show the length of the unit cell.

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 chosen number of unit cells.

The option **Add Periodic Copies** is new in GeoDict 2021 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 XY-plane. This leads to a larger GAD information (i.e. the analytical information about the objects in the structure) and the domain is not periodic anymore. It is not necessary to check this option when the structure is used only in GeoDict. If this option is disabled, the threads end at the domain boundary and the domain is periodic. In this case, artefacts might occur when exporting the structure to a mesh (with ExportGeo-CAD of MeshGeo).

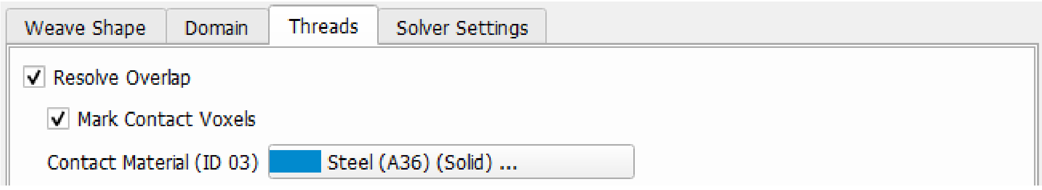
Threads

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

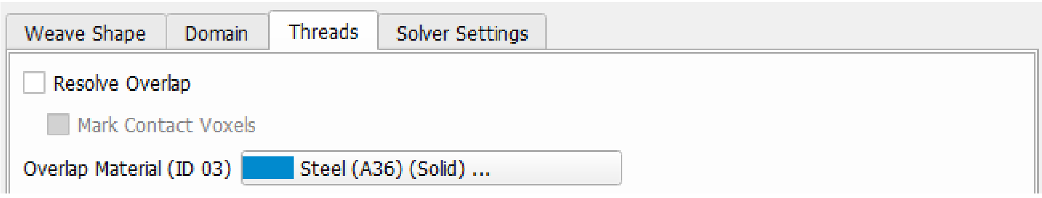


Different threads might overlap in the generated structure. This might be unintuitive, but it leads to realistic thread shapes at contact points. Therefore, the thread overlap allows to create realistic weave structures without the need for simulating the physical effect of the thread contacts.

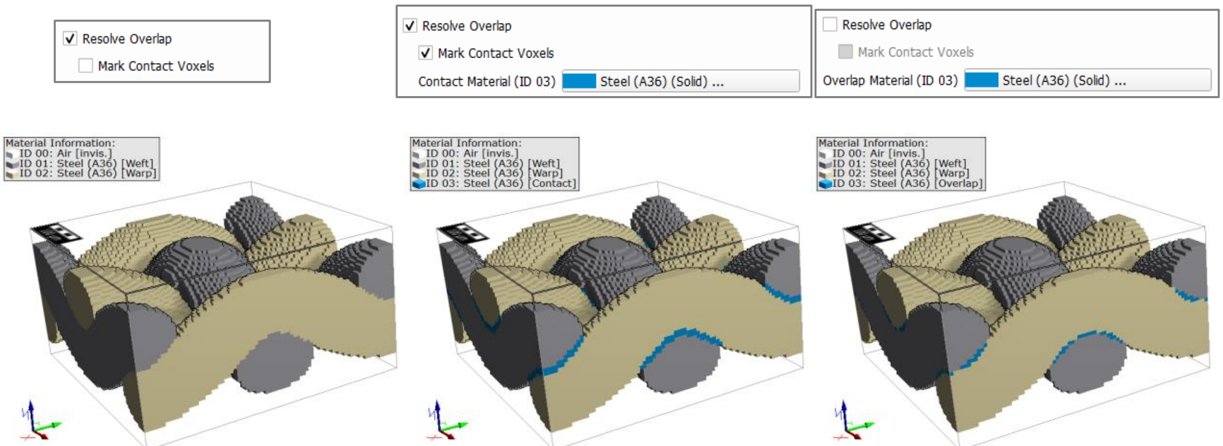
By default, **Resolve Overlap** is enabled. With this option, the overlapping regions are assigned to the materials of the threads which are in contact. This leads to a realistic weave structure. **Mark Contact Voxels** allows to define a separate material for the contact areas. In this way, even contacting 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.

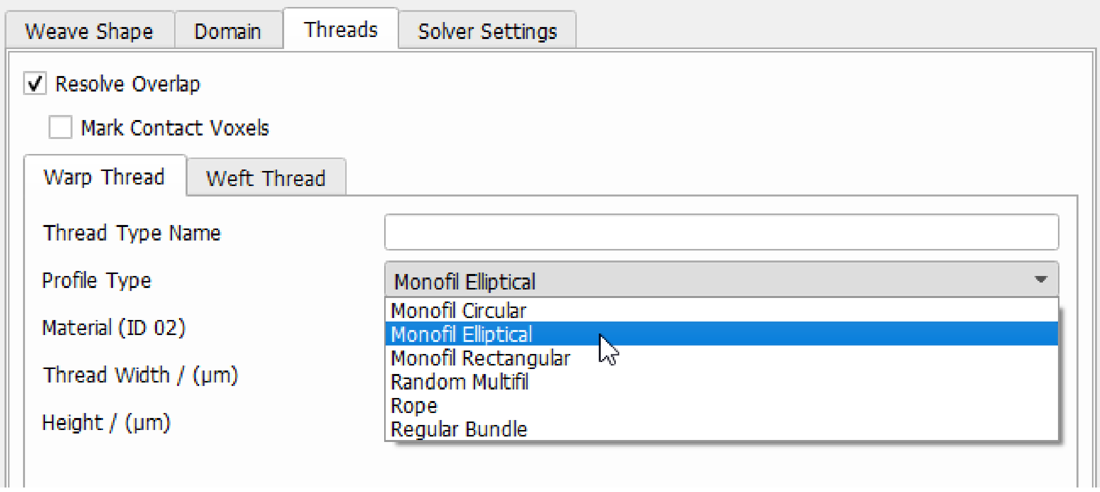


In the figure below, observe the effect of **Resolve Overlap**, **Resolve Overlap** with **Mark Contact Voxels**, and the use of an **Overlap Material**.

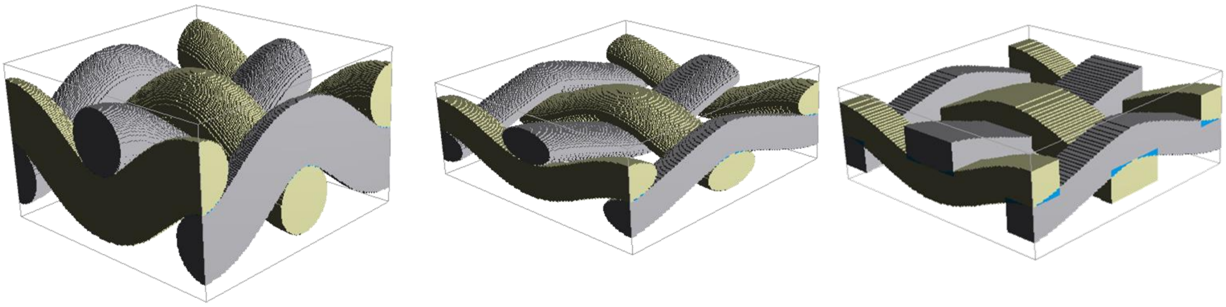


In the **Thread Type Name** field, a name can be given to the warp or the weft thread generated with the current parameters. Additionally, the thread settings can be saved by clicking **Save Thread** and later be reused for other weave structures. The parameters are saved to a Thread Type Settings (*.gps)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

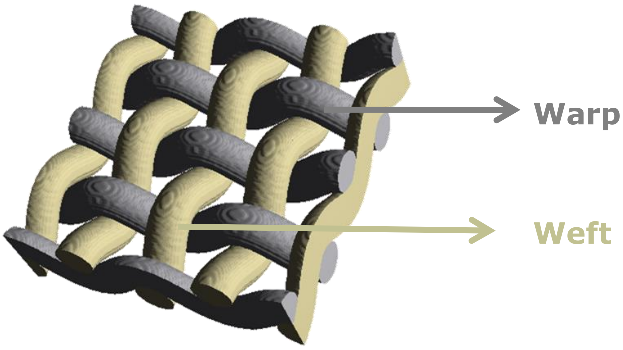
Six **Profile Types** for the threads can be selected from the pull-down menu. Warp and weft thread can differ in their profile type.



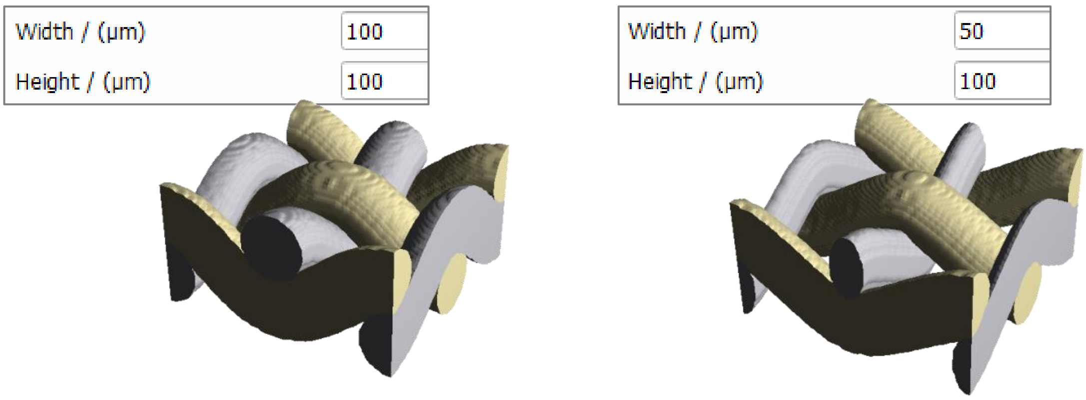
Refer to page 6 for explanations on **Monofil**, **Multifil**, **Rope**, and **Regular Bundle** profile types. **Monofil** threads can have a **Circular**, **Elliptical**, or **Rectangular** cross-section.



For all profile types, **Material** designates the Material assigned to the thread. **Width** and **Height** determine the cross-section area of the thread. For the **Monofil Circular** profile type, only the **Width** can be entered.

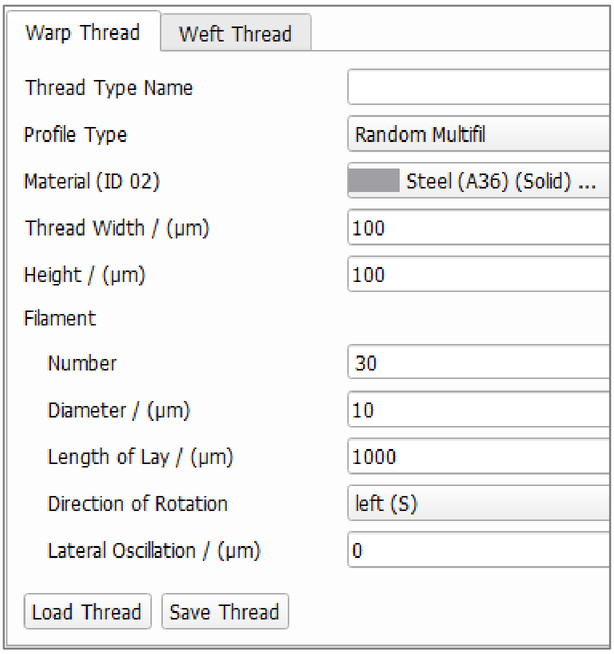


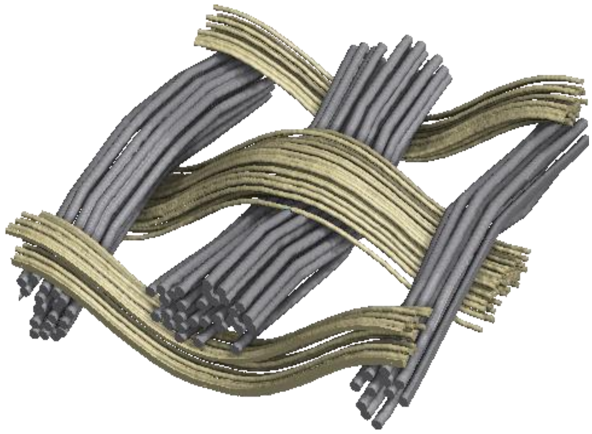
Different settings can be chosen for the warp and weft threads. Here below, a **Monofil** elliptical thread has been selected for the **warp** (and different width and height entered) whereas the **weft** is a **Monofil** circular thread.



Random Multifil, Rope, and Regular Bundle Filament settings

Filament - Number specifies the number of filaments per thread in multifilament threads and in regular bundles.

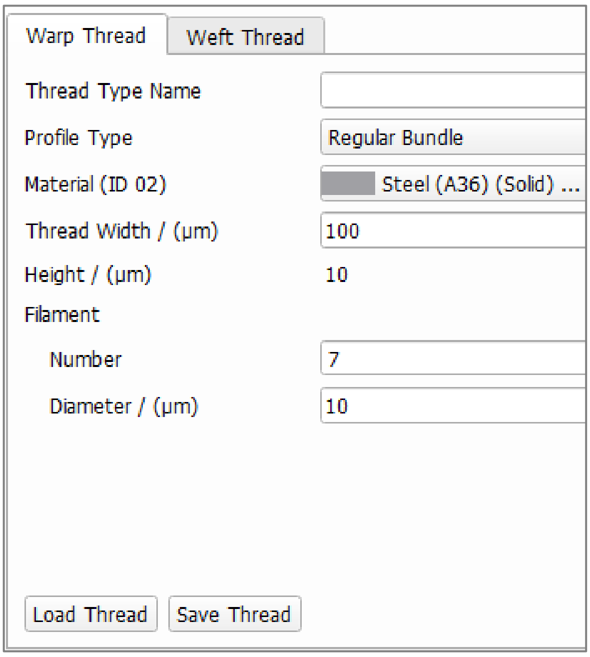


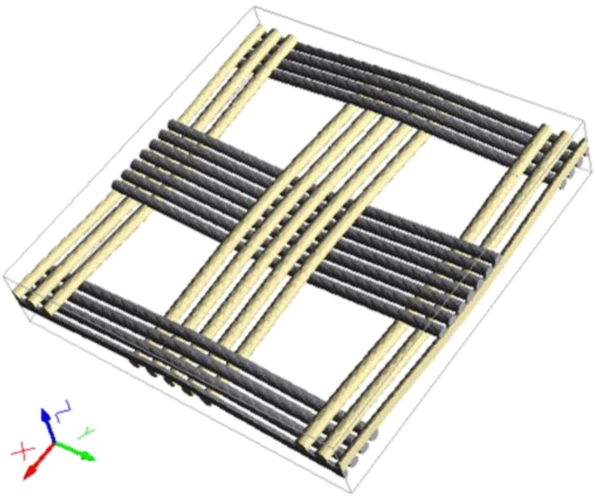


Filament - Diameter determines the diameter of the filaments in a multifilament thread.

Length of Lay, **Direction of Rotation** and **Lateral Oscillation** are explained under Rope below (see page 15).

The following settings produce this structure when selecting **Regular Bundle** as the profile type. Note that the thread **Height** cannot be entered: It is computed based on the filament diameter, filament number and the properties of the chosen multifilament type.



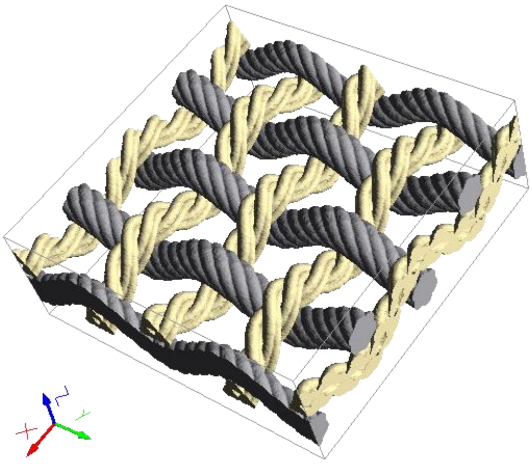


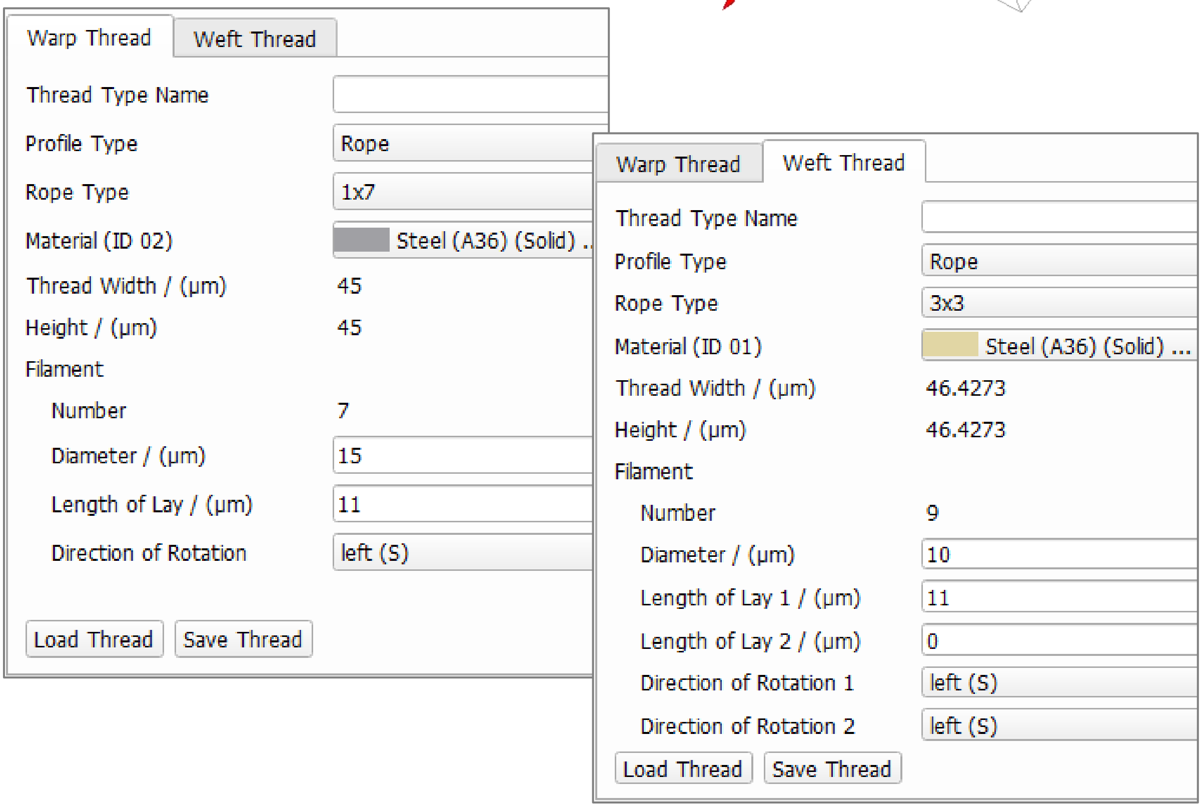
For **Rope**, the filament **Number** depends on the **Rope Type** and cannot be changed manually.

For example, here the **warp** is a 1x7 rope. This means 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.

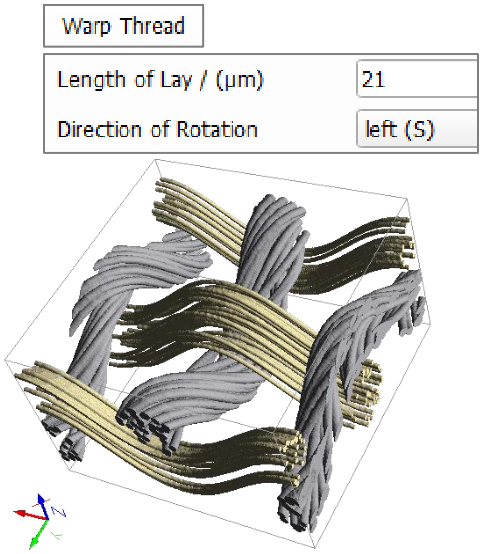
In the figure on the right, the number of Unit Cells in warp and weft direction (under the Domain tab) was set to 2. Note that the thread **Width** and **Height** cannot be entered since these parameters depend on the other rope parameters.

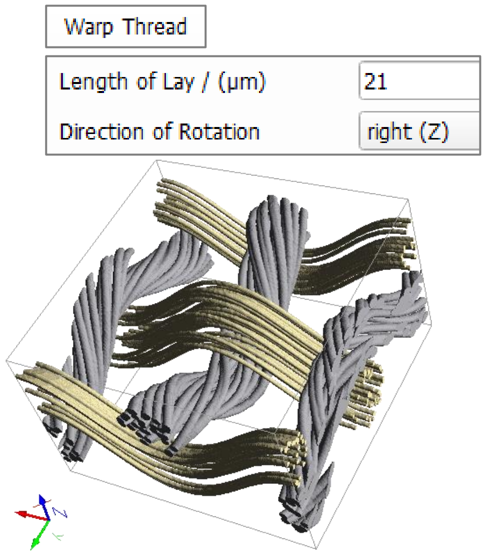




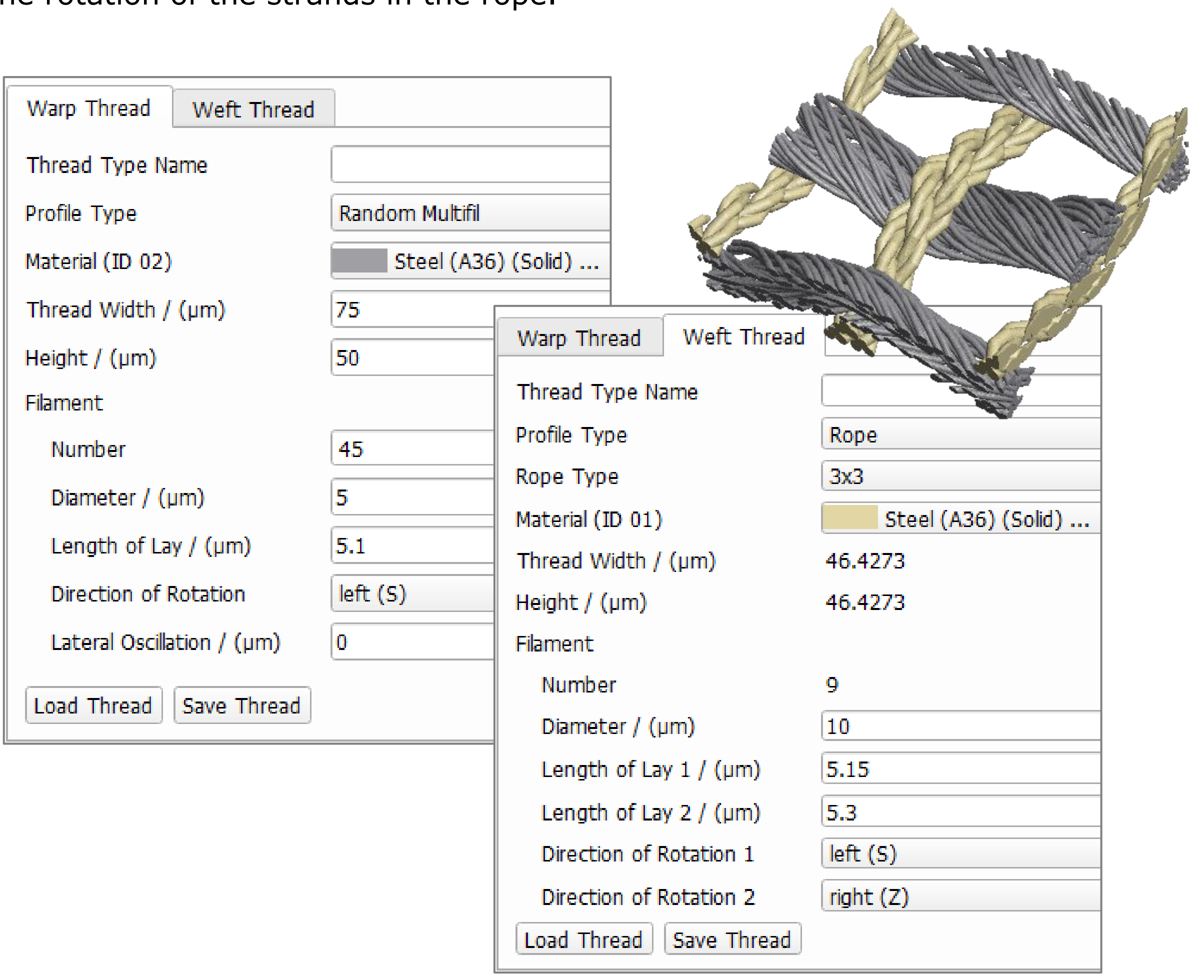
Length of Lay is the distance in which the thread (and its filaments) is rotated 360° around its axis. The **Length of Lay** must be chosen so that the unit cell is periodic. In other words: The unit cell length must be a multiple of the **Length of Lay**. Otherwise, a warning message appears, and the parameter is adjusted automatically. The choice of unrealistically short values might lead to artifacts in the generation and, therefore, to unrealistic structures.

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).



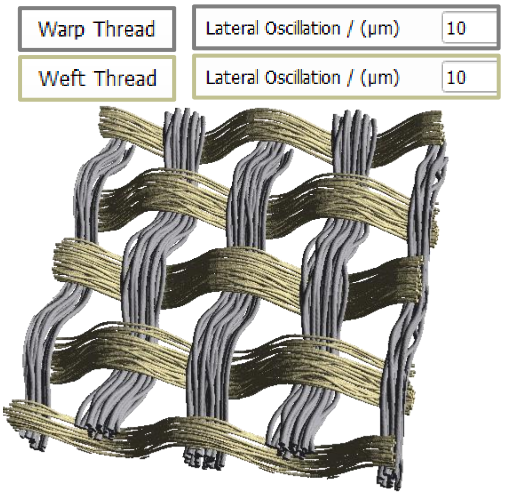


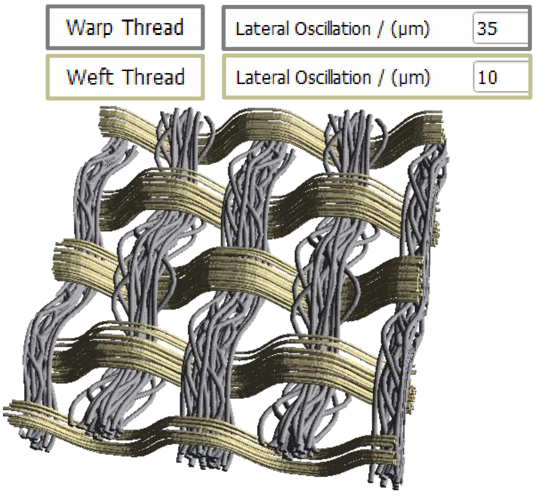
For ropes with several strands (here the **weft** thread), the **Length of Lay 1** is the length for one rotation of the rope (thread) and **Length of Lay 2** is the length for one rotation of the strands in the rope.



Direction of Rotation 2 controls the direction of rotation of the strands: **right** (Z-twist strand) or **left** (S-twist strand).

Lateral Oscillation is the degree of random waviness of the filaments in the XY plane. **Lateral Oscillation** is only available for **Random Multifil** threads. A different structure with the same Lateral Oscillation can be generated by changing the **Random Seed** (see page 10).

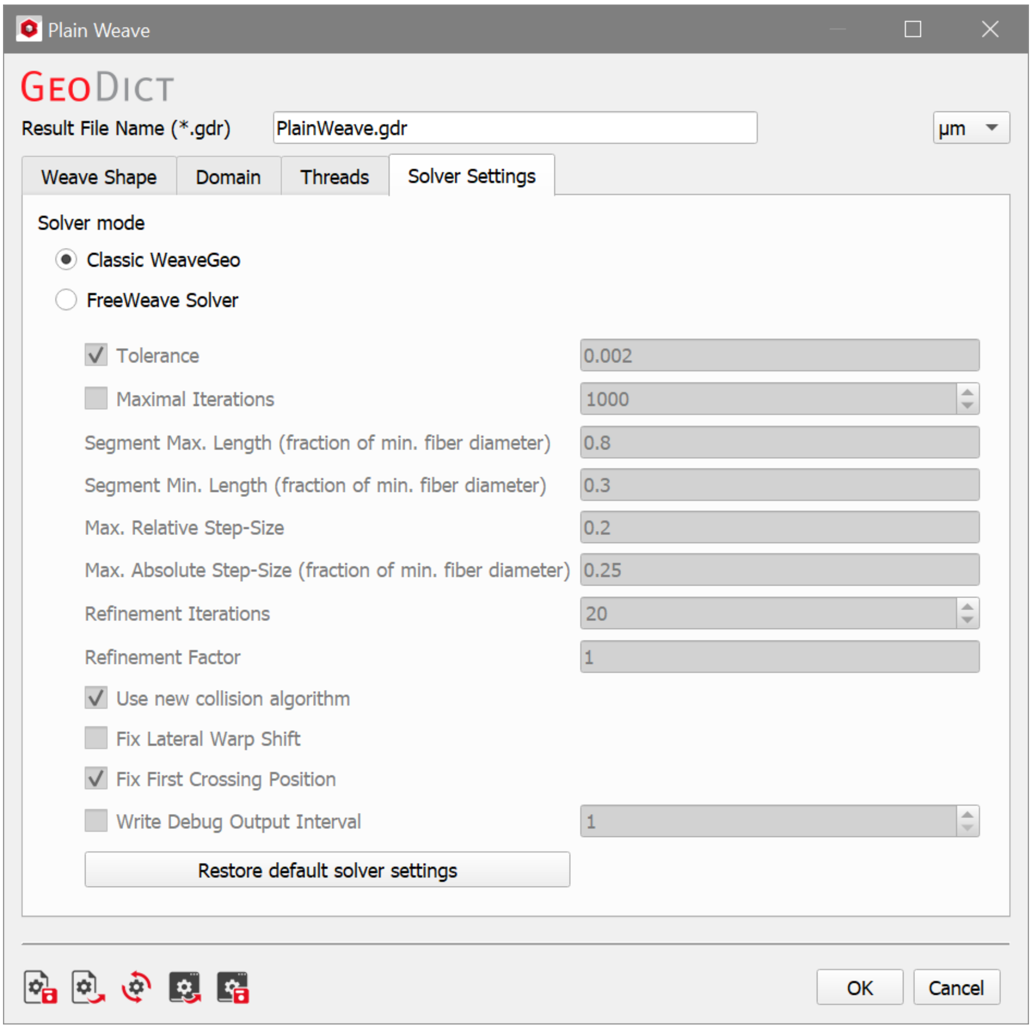




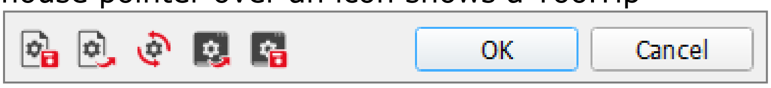
Solver Settings

In the **Solver Settings**, the default Classic WeaveGeo directly creates the structure without considering the thread contacts by a physics-based iterative solver. This option leads to good results in most cases and was the only available option prior to GeoDict 2021.

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 33 f.



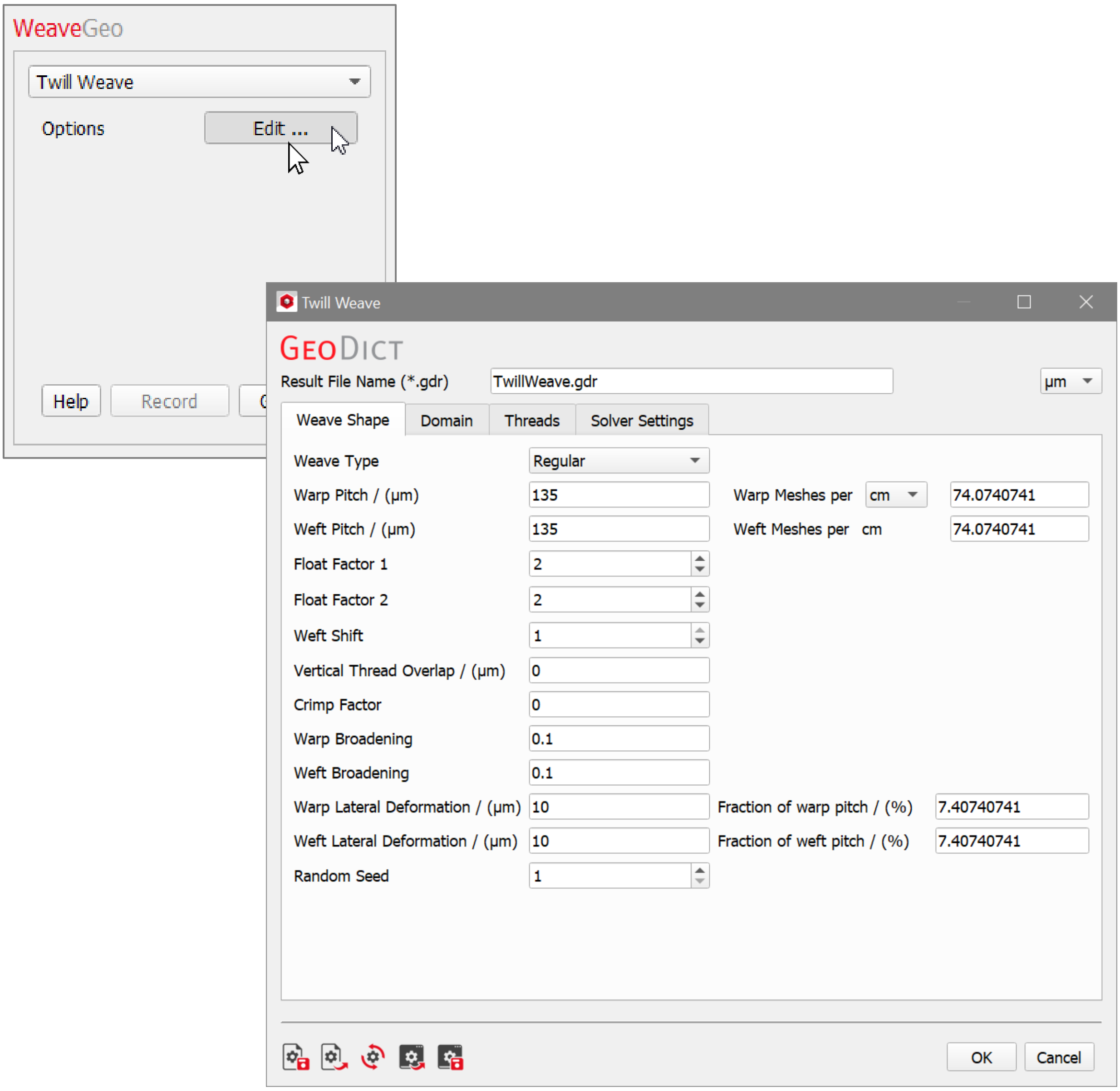
The parameters entered in most GeoDict dialogs, here especially in the **Plain Weave**, **Twill Weave**, **Satin Weave**, or **Free Weave** dialogs can be saved into *.gps (GeoDict Project Settings) files and/or loaded from them. Remember to restore and reset your (or GeoDict's) default values through the icons at the bottom of the dialog when needed and/or before every WeaveGeo run.
Resting the mouse pointer over an icon shows a ToolTip



Twill Weave

Choose **Twill Weave** from the pull-down menu in the WeaveGeo section and click the **Edit…** button to open the **Twill Weave** dialog.

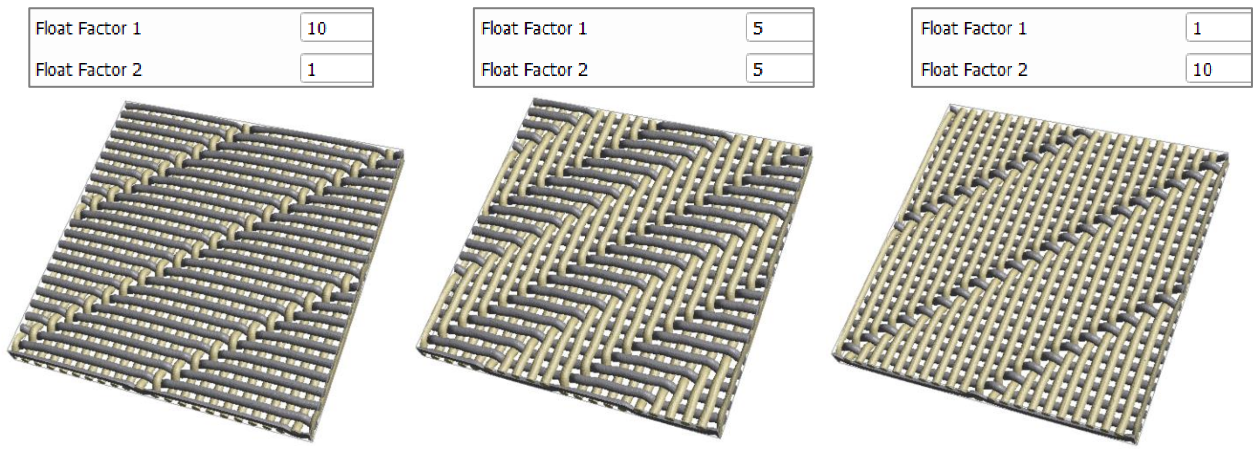
The layout of the dialog and the tabs that it contains are similar to those for the Plain Weave dialog, seen in page 8. The parameters that differ from the parameters for plain weaves are explained below.



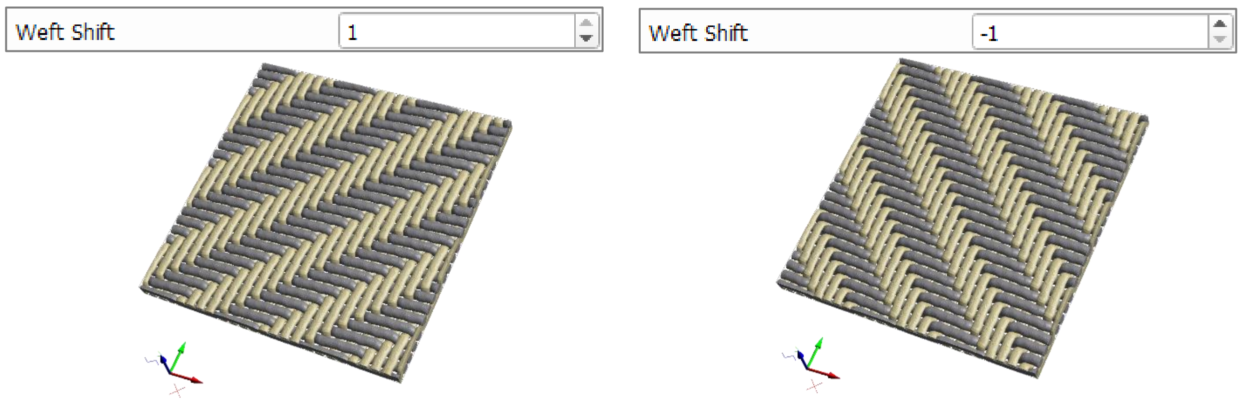
Weave Shape

For the twill weave, the **Weave Type** pull-down menu and the **Warp** (and **Weft**) **Pitch** are as explained for the plain weave (pages 8 ff.).

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.

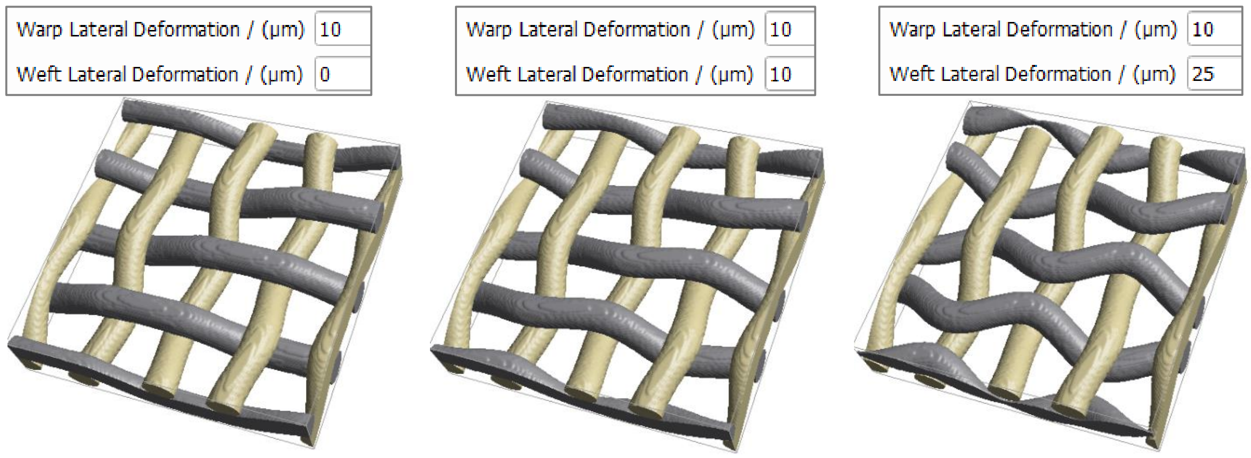


The **Weft Shift** defines the offset between successive weft threads. Choosing between the available values of -1 or 1 controls the direction of the characteristic diagonal pattern of twill weaves. This parameter is only available for **Twill** and **Satin** weaves.



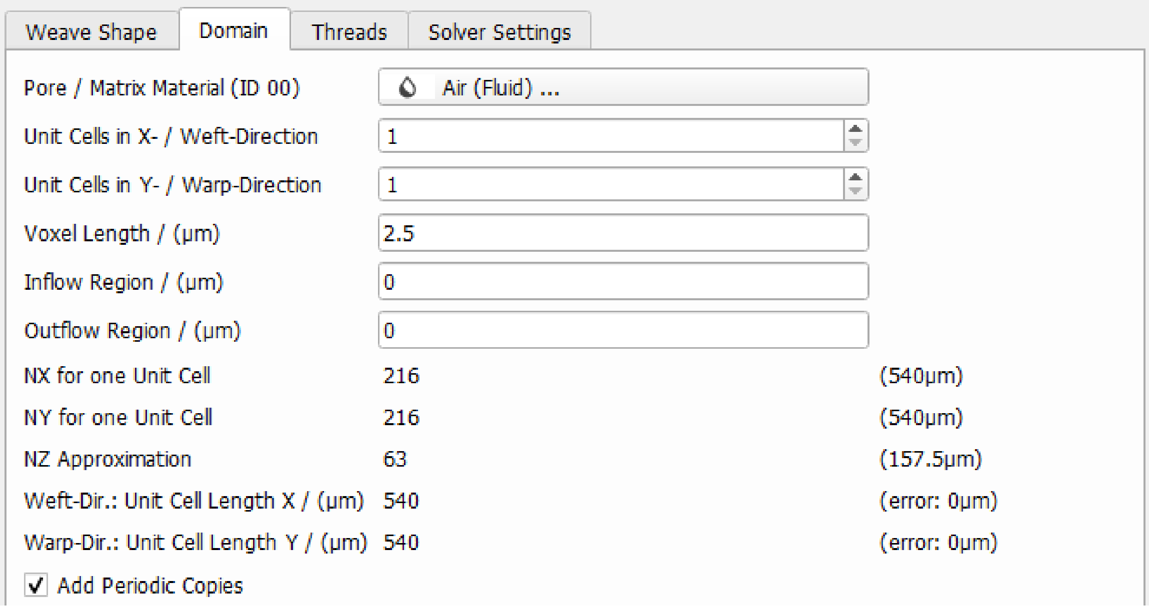
Vertical Thread Overlap, **Crimp Factor**, and **Warp-** and **Weft Broadening** are as explained above for the **Plain Weave** (see page 9).

Warp Lateral Deformation and **Weft Lateral Deformation** model the change in thread shape in the XY 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 lateral deformation is also influenced by the current Random Seed (see page 10).



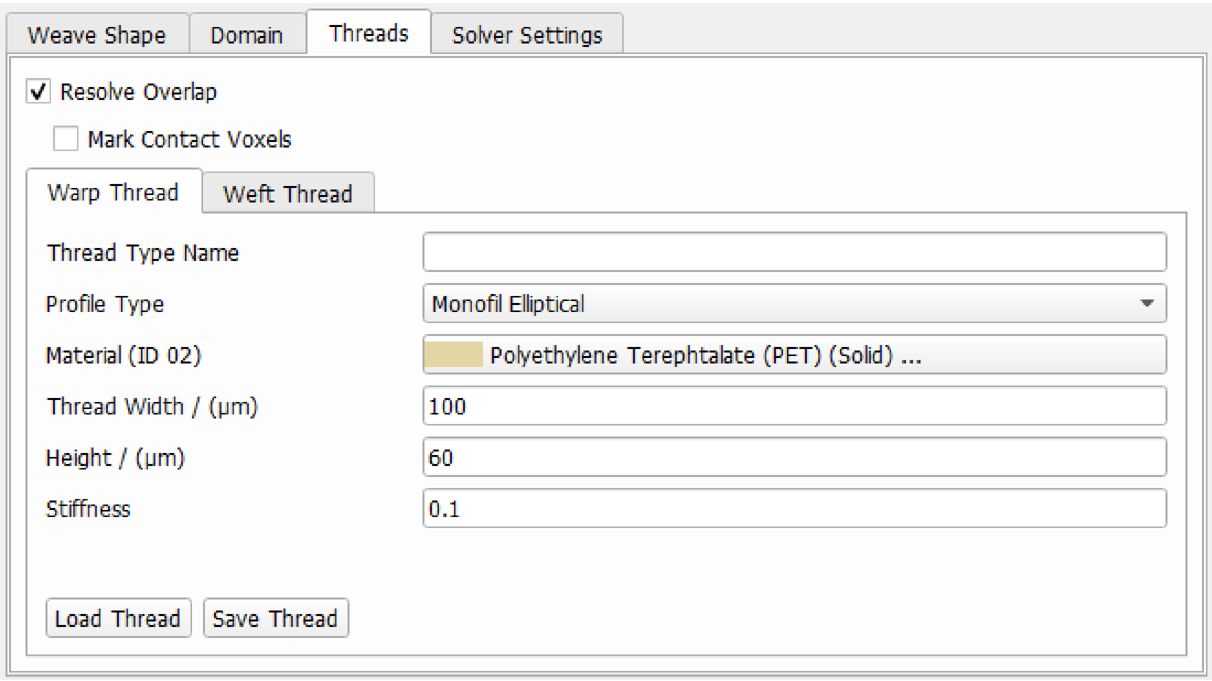
Domain

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



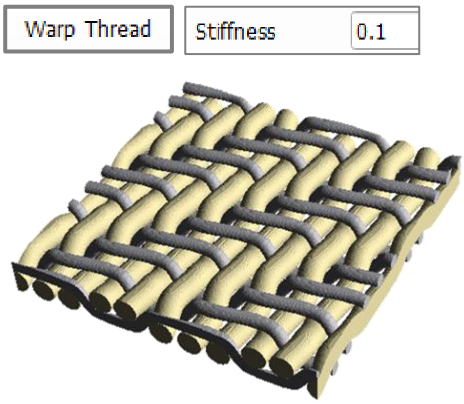
Threads

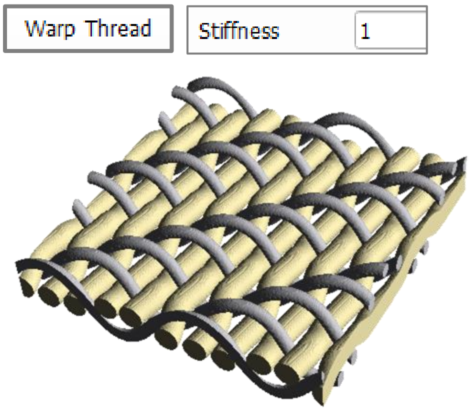
All parameters under the **Warp Thread** and the **Weft Thread** subtabs are the same as in pages 12 ff. for the plain weave, except for the additional **Stiffness** parameter.



A high **Stiffness** indicates a rigid thread that only bends in small angles. Values for Stiffness can vary from 0 to 1.

The influence of this setting can be easily observed in the following twill weave when changing the stiffness of the **warp** thread.





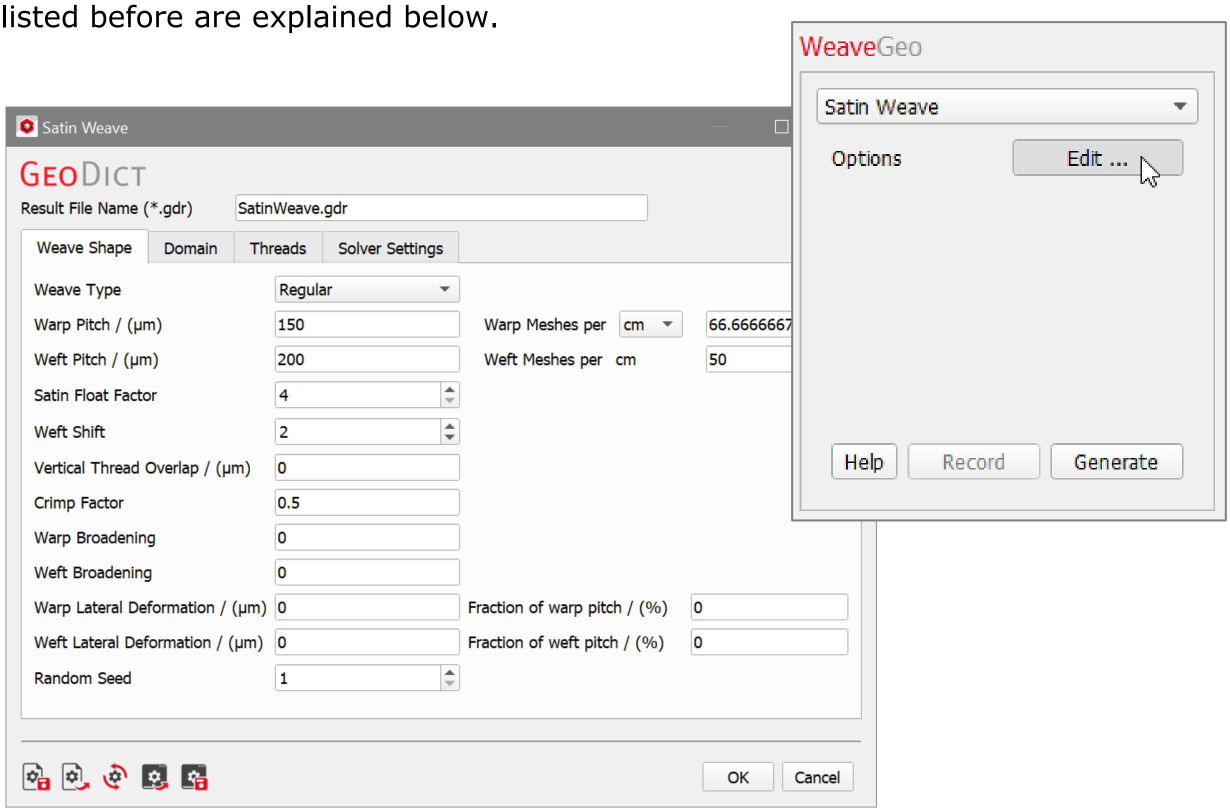
Solver Settings

All parameters under the **Solver Settings** tab are explained on page 19 for the plain weave.

Satin Weave

Choose **Satin Weave** from the pull-down menu in the WeaveGeo section and click the **Options**' **Edit...** button to open the **Satin Weave** dialog.

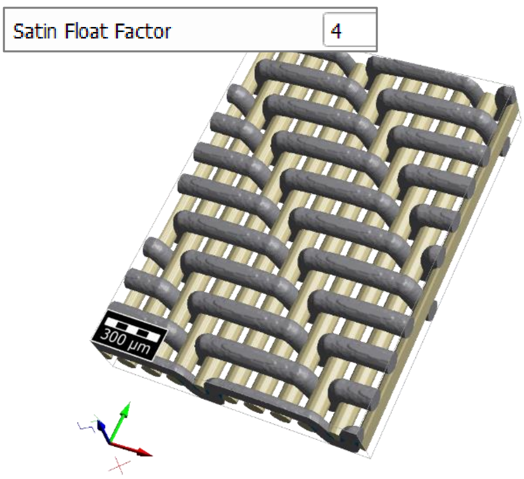
The layout of the dialog and its tabs are similar to those for the Plain Weave dialog, seen on page 8. The parameters that differ from the parameters for the weave types listed before are explained below.

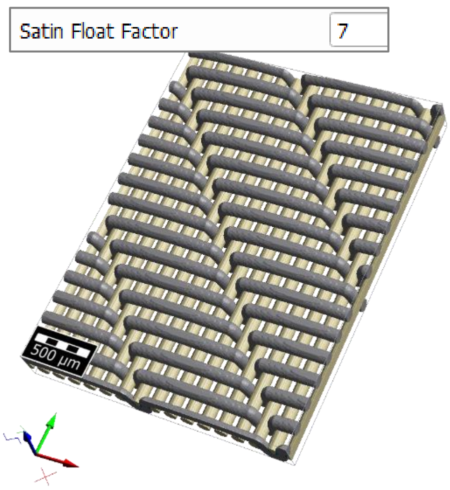


Weave Shape

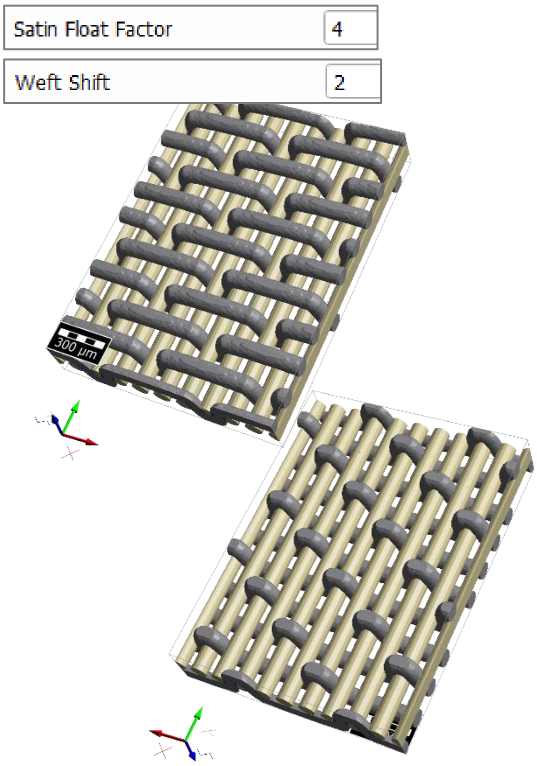
For the satin weave, the **Weave Type** pull-down menu and the **Warp** (and **Weft**) **Pitch** are as explained for the plain (pages 8 ff.) and the twill weave.

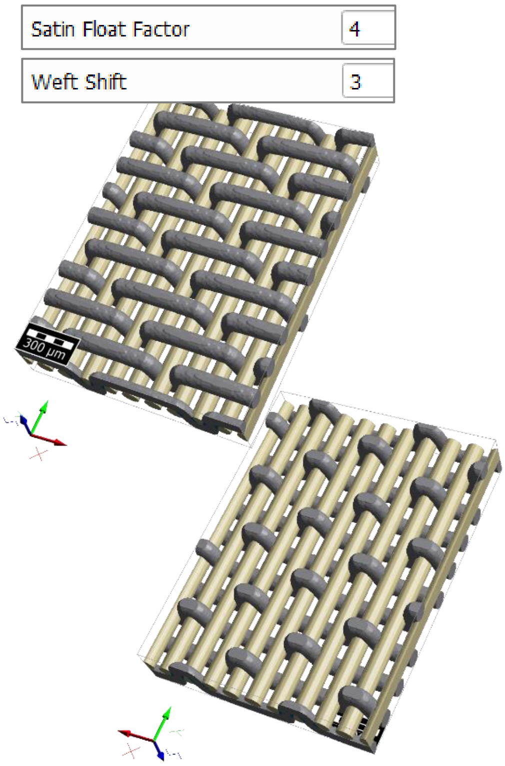
The **Satin Float Factor** value, special to the satin weave, may vary from 4 to 10. It controls the number of weft threads floating over the warp threads. Typical satin weaves are the Satin 4/1 and the Satin 7/1, corresponding to satin float factors of 4 and of 7.





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, while for satin weaves it can be chosen depending on the chosen float factor. For example, for a **Satin Float**

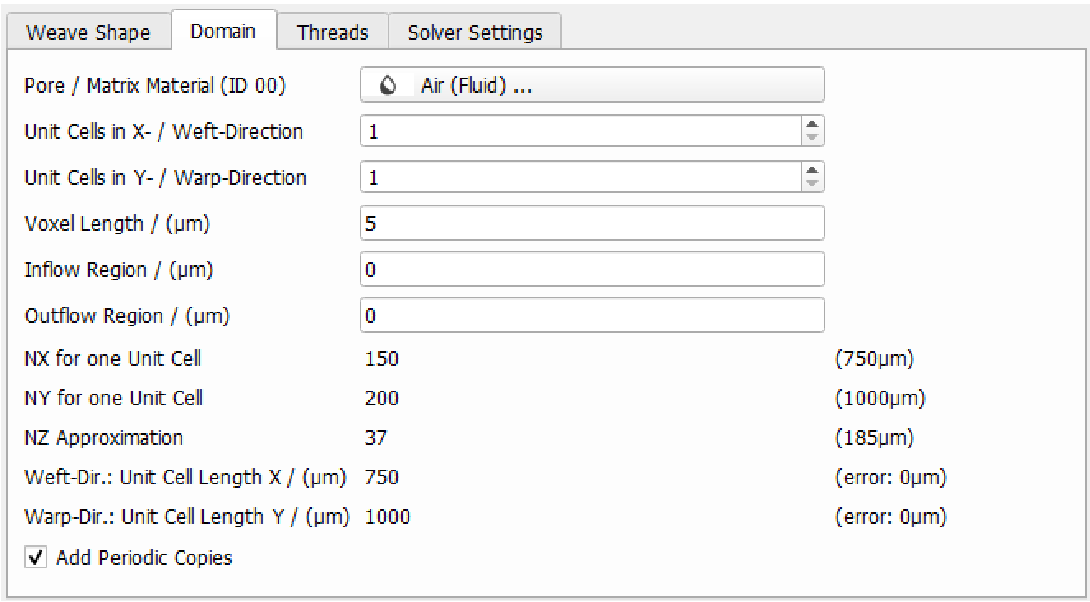




Factor of 4 the feasible values for the **Weft Shift** are 1,2 and 3. In the figures below, for a satin 4/1, observe the effect of choosing a weft shift of 2 or 3.
Vertical Thread Overlap, **Crimp Factor**, and **Warp-** and **Weft Broadening** are as explained above for the plain weave (see pages 9 f.). The same holds for **Warp** and **Weft Lateral Deformation**, **Fraction of warp pitch** and **Fraction of weft pitch** (see page 21), and Random Seed (page 10).

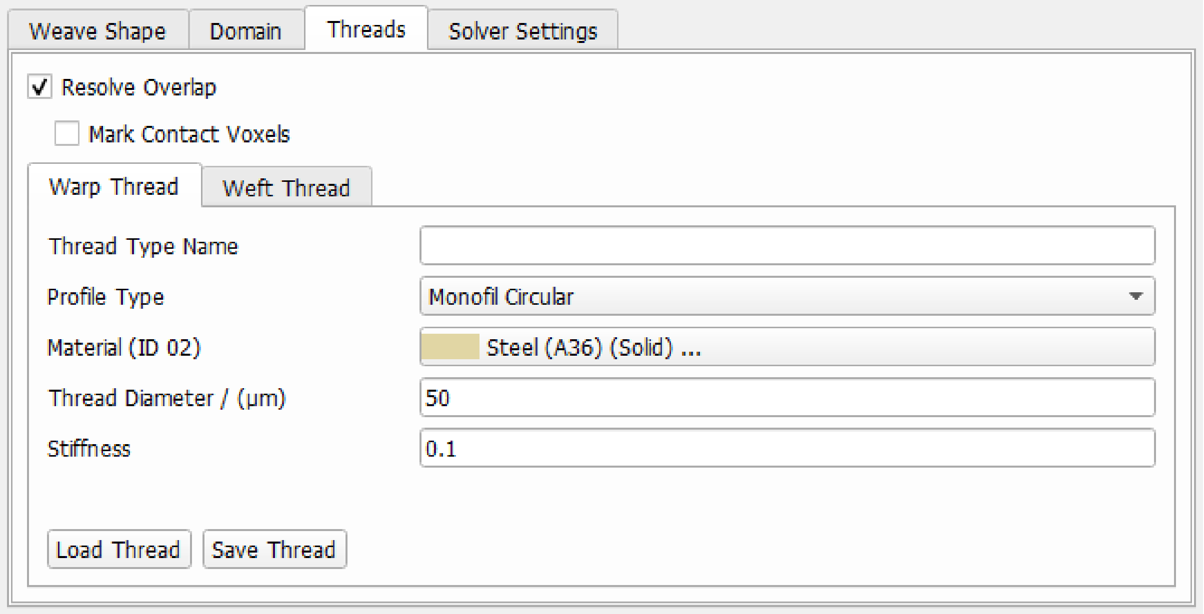
Domain

All parameters under the **Domain** tab are the same as in pages 11 f. for the plain weave.



Threads

All parameters under the **Warp Thread** and the **Weft Thread** subtabs are the same as in pages 12 ff. for the plain weave, except for the additional **Stiffness** parameter, which is explained in the **Twill Weave** section (page 22).



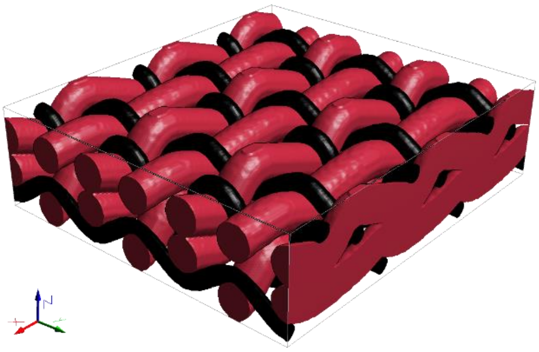
Solver Settings

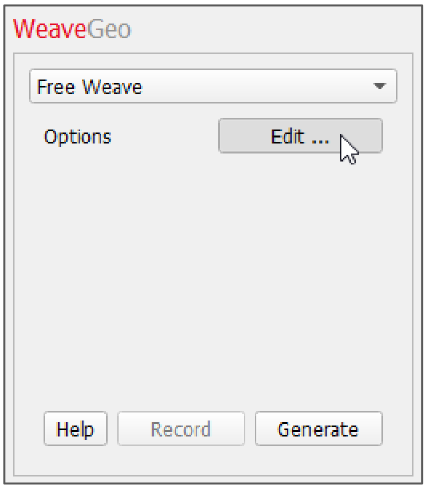
All parameters under the **Solver Settings** tab are explained on page 19 for the plain weave.

FREE WEAVE

Free 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. Those options are explained in detail in the following sections. For the structure generation, the physical contact between the threads is simulated by an iterative physics-based solver.

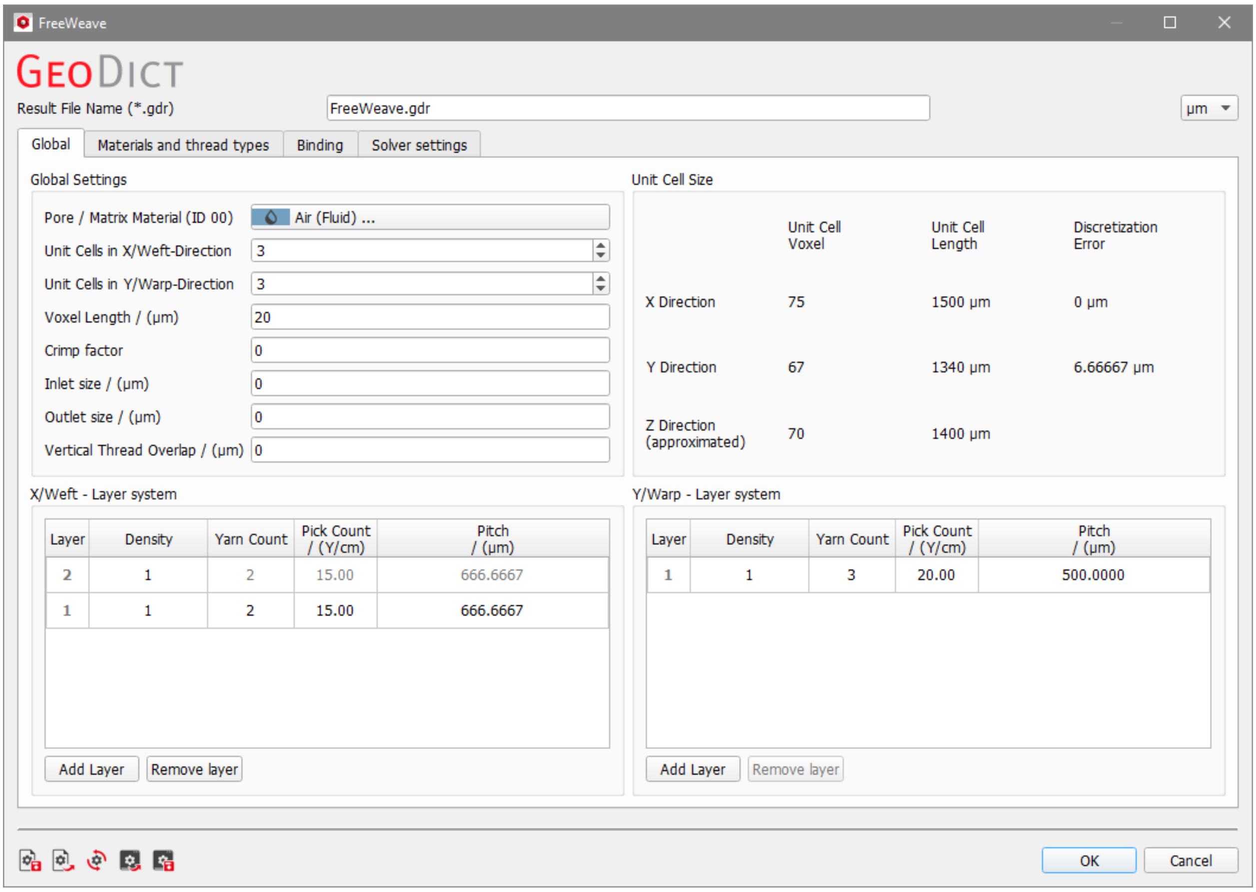
Choose **Free Weave** from the pull-down menu in the WeaveGeo section and click the **Options' Edit...** button to open the **Free Weave** dialog.





GLOBAL

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. For periodic simulations, one unit cell is sufficient.

Voxel Length, **Inflow Size,** and **Outflow Size** are as explained on page 11f and **Vertical Thread Overlap** and **Crimp Factor** are as explained above for the plain weave (see pages 9f.).

The **Unit Cell Size** is determined by the number of voxels (Unit Cell Voxels) in **X Direction, Y Direction** and **Z Direction (approximated)** and the corresponding **Unit Cell Length.** The weave generation in **FreeWeave** is based on an iterative solver, therefore the number of voxels in Z Direction can only be approximated here. These values are not editable since they depend on the definition of the structure's parameters. For example, the thread widths and pitches and the chosen number of unit cells will determine the weave width and height.

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

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 **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 30.

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:

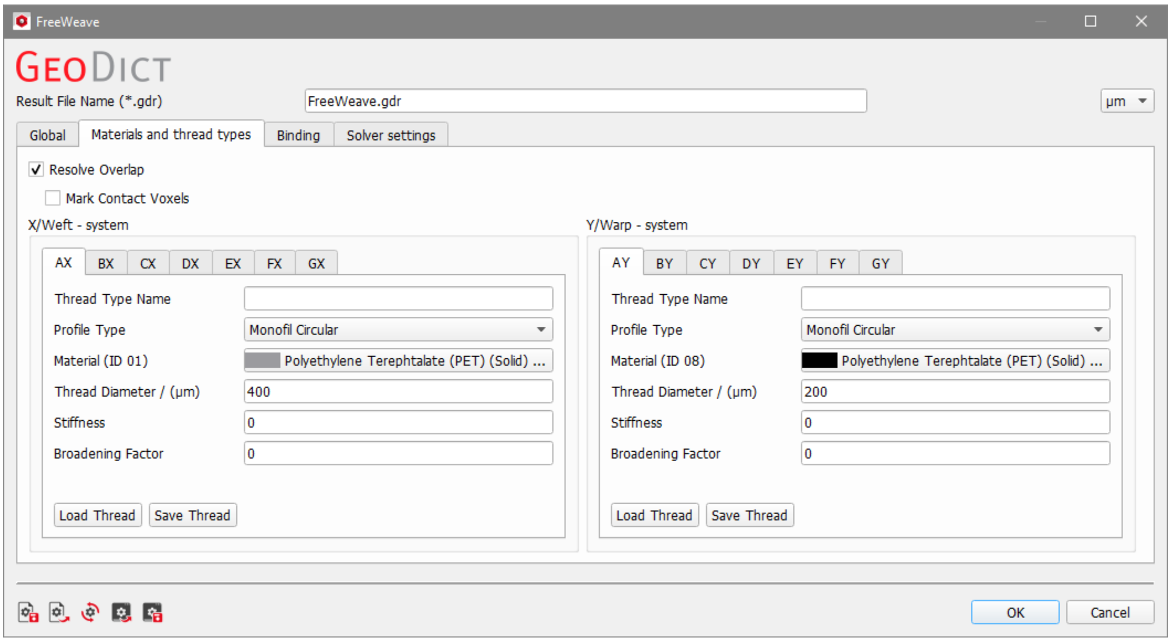
Layer	Density	Yarn Count	Pick Count / (Y/cm)	Pitch / (µm)
2	1	2	7.50	1333.3333
1	2	4	15.00	666.6667

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 **Yarn Count**. When one of those two values is changed in the user interface, the other one is updated automatically.

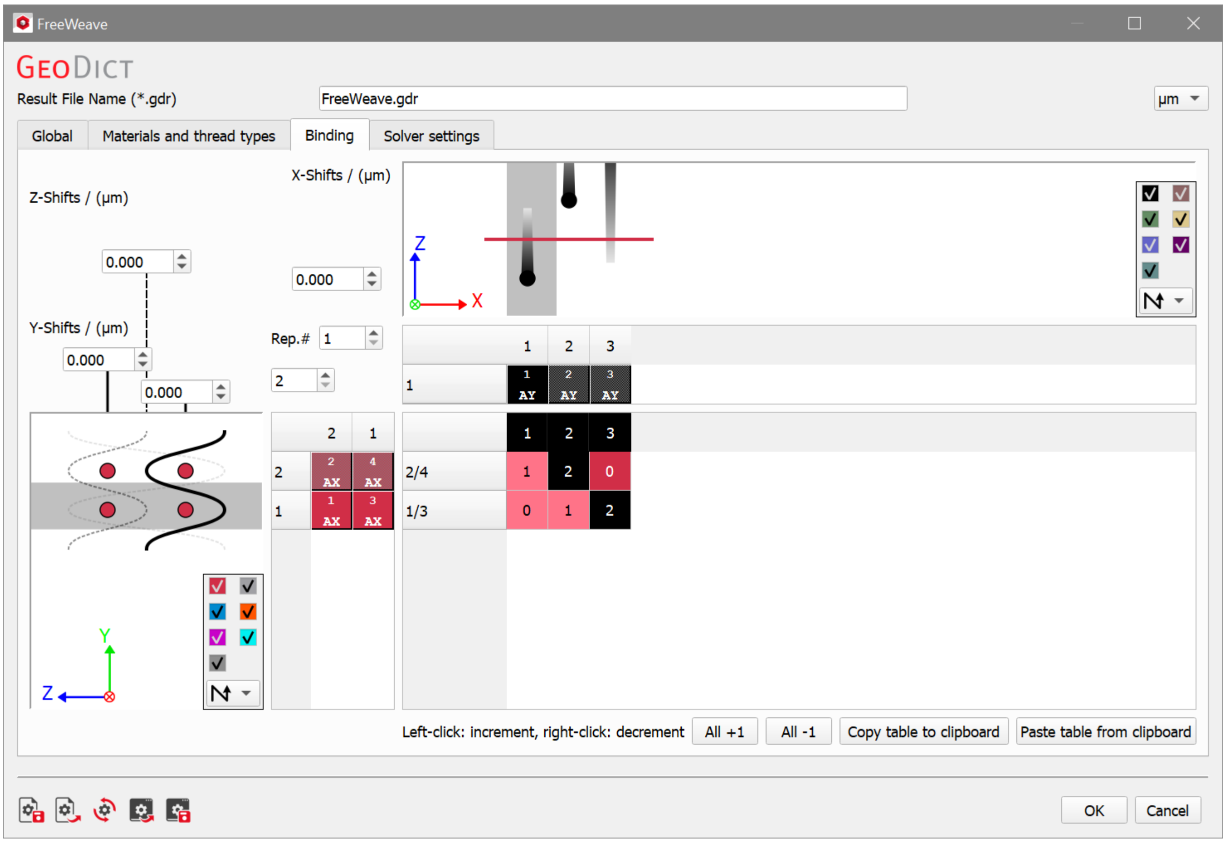
Materials and Thread Types

Under the Materials and Thread Types tab, up to seven different thread types can be defined for the **Weft-system** and the **Warp-system**. The **Thread** definition works analogously to all the other WeaveGeo modules and is described on page 12f.

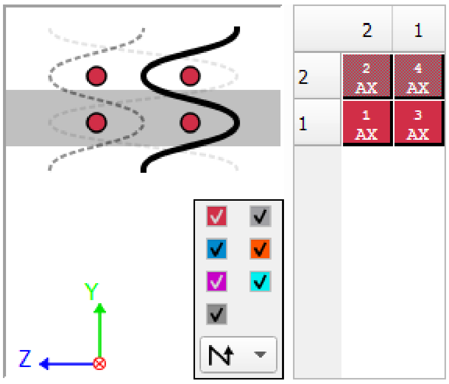


Binding

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.

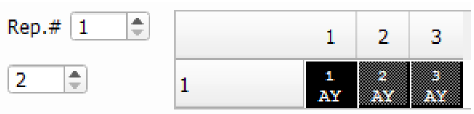
The weft threads are represented by colored circles, the warp threads as lines. The color of both corresponds to the color of the cells in the table and to the color of the threads in the structure and stands for the **Material** of the thread.

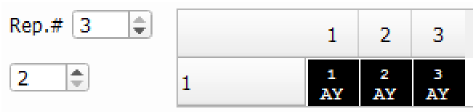
The number in each cell stands for the **Shot Index**. The **Shot Order** can be changed from a dropdown menu and assigns a **Shot Index** to each thread following the chosen pattern.

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.

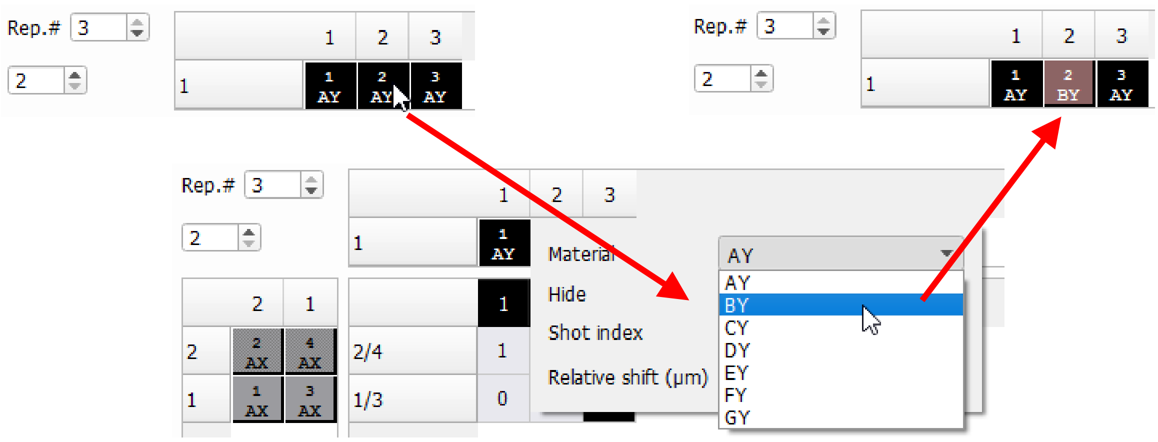
In the **Visibility Settings**, the different **Materials** can be activated/deactivated. All threads with a deactivated material are invisible in the preview but will be generated, unlike hidden threads (see below, p. 30). This functionality gives the user a better overview during the generation of complex weaves.

In the **Property Menu** (reachable by clicking on the thread type, see below), several other properties can be defined. The **Material** can be changed, and the thread can be hidden (Select **Hide**), that means that it is not included in the weave after generation. By changing the **Relative Shift**, the thread can be moved in y-direction. 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). If the **Rep.#** is smaller than the number of threads, the material color for the repeated threads is greyed out (See below for Rep.# = 1). Otherwise, other thread types can be assigned for the other threads (See below for Rep.# = 3).





To assign a thread type to a thread, click on the box and select a thread type from the list. The available thread types are defined under the Materials and Thread Types tab (see page 29).



Warp-Layer System

	1	2	3
1	1 AY	2 AY	3 AY

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

	1	2	3
2/4	1	2	0
1/3	0	1	2

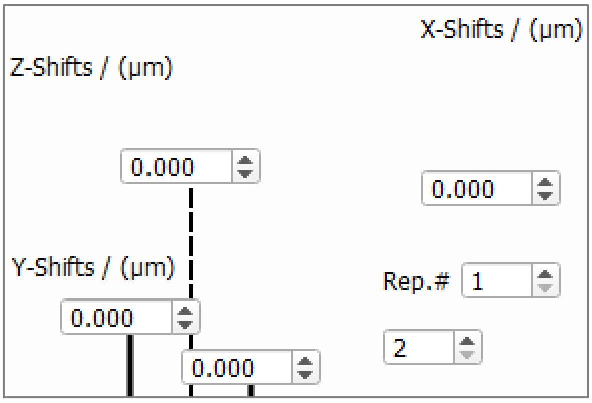
In the **Binding Matrix**, each cell stands for the intersection of a warp and a weft thread. The numbers in the cells determine the position of the warp thread in z-direction relative to the weft threads at that location. Value 0 means that the thread is located at the bottom of the weave. Setting the maximum value – which equals the number of weft layers – means that the thread lies on top of the weave. There is a column for each individual warp thread while the row count is defined by the number of weft threads. 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 for further explanation (see page 32)

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 and Repetition



If two warp or weft threads overlap, they are marked with a yellow sign 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**.

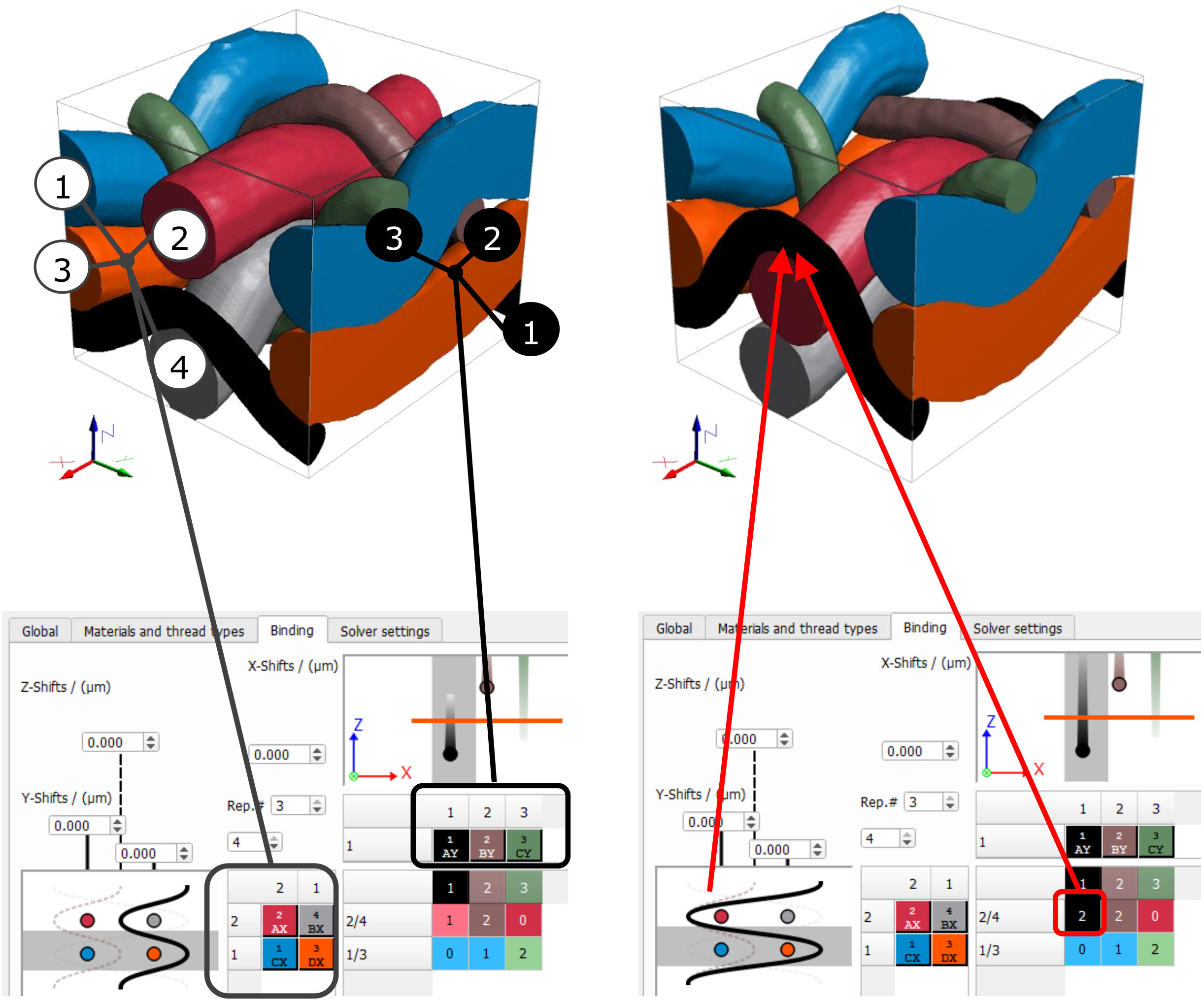
- **Shifts** in **x-direction** can be defined for each **Warp-Layer**
- **Shifts** in **y-direction** can be defined for each **Weft-Layer**
- **Shifts** in **z-direction** move all threads of a binding layer (threads with same number in binding matrix).

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. The table of the **Warp-Layer System** shows the layers with their threads.

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

Example

In this 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 **Free Weave** default structure. For better understanding, the **Rep.#** is set to 3 (see page 30) and a different thread type with a different color is assigned to each thread. On the right, weft thread #2 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.



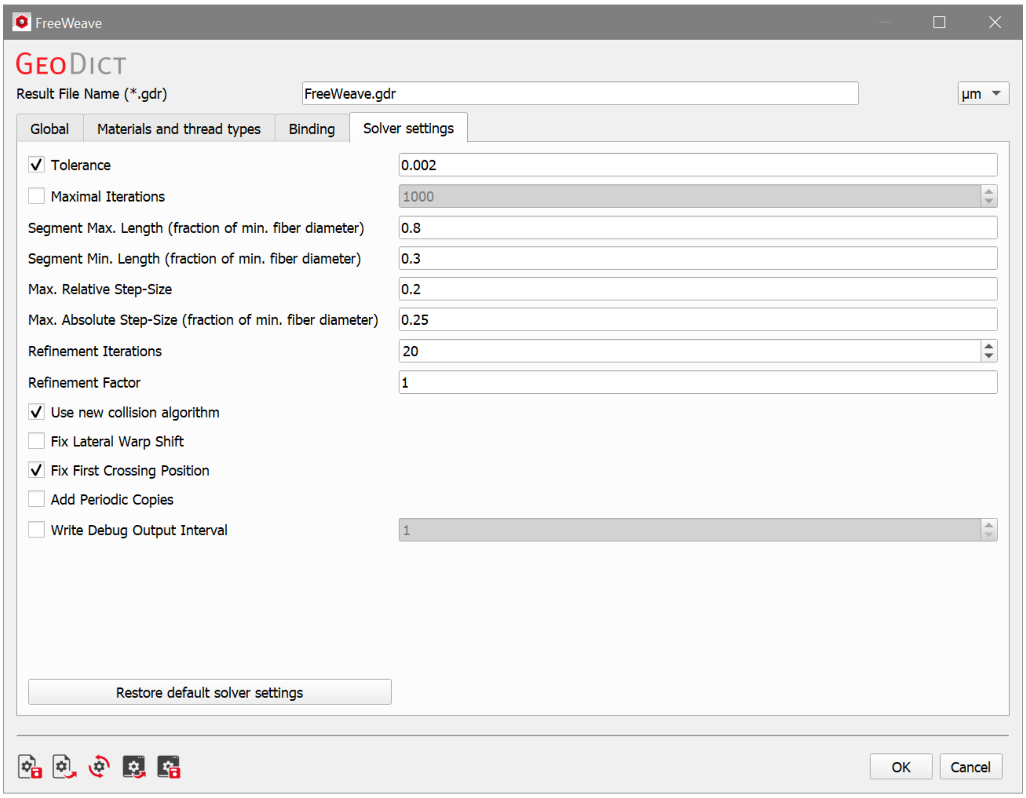
SOLVER SETTINGS

Free 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**.

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. Another stopping criterion is the **Maximum Number of Iterations**.

Fibers are divided into linear segments and their **Segment Length** is relative to the minimum fiber diameter. The minimum **Segment Length** should be less than half of the maximum **Segment 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 smallest fiber diameter. It should not be too large to avoid that fibers "jump over" other fibers with which they collide. The value given for the **Max relative step-size** is multiplied with the length on which two fibers overlap. In case of overlap, the smaller value of **Max absolute step-size** and **Max relative step-size** is used.



At the beginning of the **Solver** run, the fibers are subdivided into smaller segments over several iterations given by **Refinement Iterations**, which are part of the solver iterations. This is also the minimum number of iterations. Other stopping criteria are only considered when the **Refinement Iterations** are exceeded.

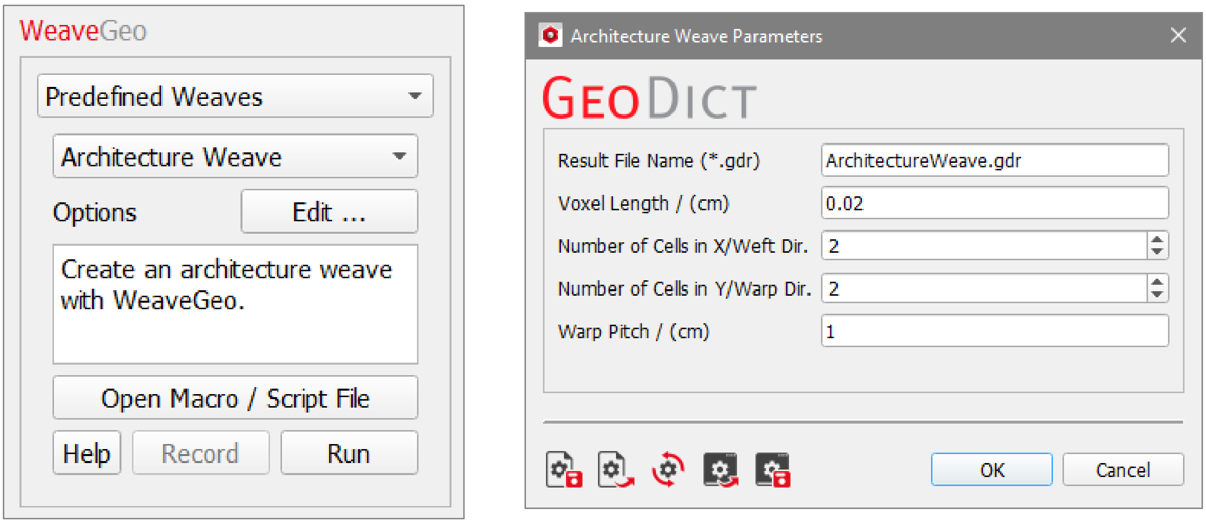
The **Refinement Factor** defines to which extent the **Minimum** and the **Maximum Segment Length** are reduced at the end of the refinement iterations. A value of 0.1 means that the **Minimum** and the **Maximum Segment Length** are reduced to 10% of their start values. The **Refinement Factor** is a number that is larger than 0 and less than or equal to 1.

Since GeoDict 2022, a new collision algorithm is implemented which provides a more precise collision detection. This algorithm is activated with **Use new collision algorithm**. If **Fix Lateral Warp** shift is activated, the warp threads cannot move along longitudinal direction of the weft threads. By checking **Fix First Crossing Position**, the first crossing point of the weave is fixed at the x-y-position (0,0). This ensures that the weave structure does not move in the domain. Thus, it is suggested to keep this option enabled.

If the option **Write Debug Output Interval** is chosen, a *.gad-file is saved in the specified interval. This allows to understand the structure generation process, but it saves more data to the disk. It is recommended to keep this option disabled.

PREDEFINED

When **Predefined Weaves** is selected in the WeaveGeo section, several representative structures can be chosen from the pull-down menu. For each of these structures, the generation process is saved as a Python macro. These macros can be modified and used as basis to generate user-defined materials.



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 File** opens the macro file for the selected weave. The macro files are in Python format (*.py) and can be modified.

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

In the project folder, a result file (*.gdr) and a folder with the same name which contains the generated structure, are automatically saved.

This result file can be opened in GeoDict through **File** → **Open Results (*.gdr)...** in the Menu bar. Then, the parameters used for the generation of the structures can be loaded to GeoDict by clicking the **Load Input Map** button at the bottom of the Result Viewer.

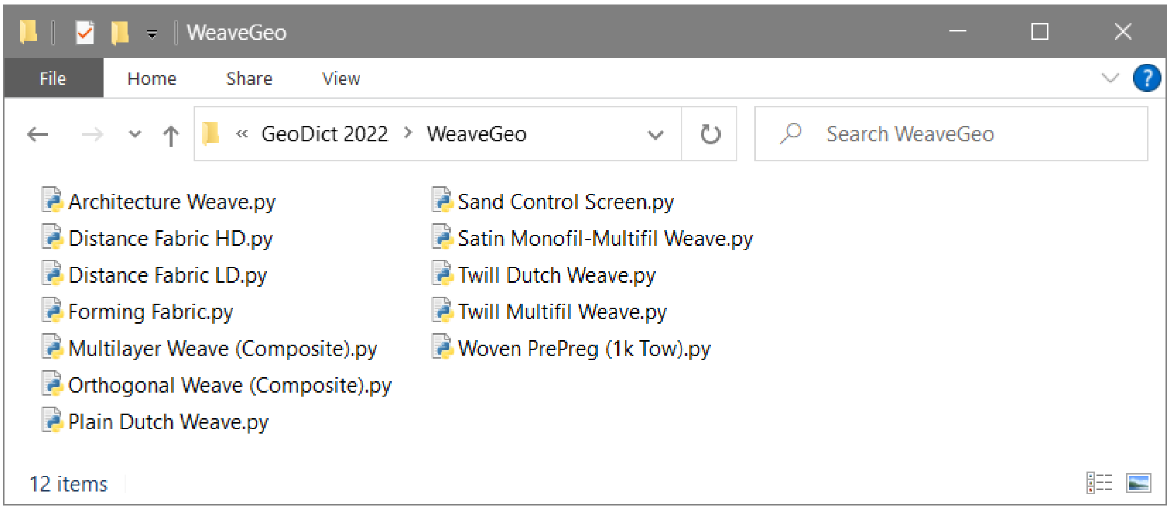
The parameters that were used in the generation are loaded in the corresponding dialogs and can be examined in detail. Various parameters define each of the predefined structures, such as resolution parameters (**Voxel Length**), **Number Cells in X** and **Y** direction, **Weft** and **Warp Diameter**, or **Warp Pitch**

PREDEFINED WEAVES GALLERY

All predefined weaves can be edited through the **Options' Edit...** button. The parameters for these predefined materials are shown in the opening dialogs.

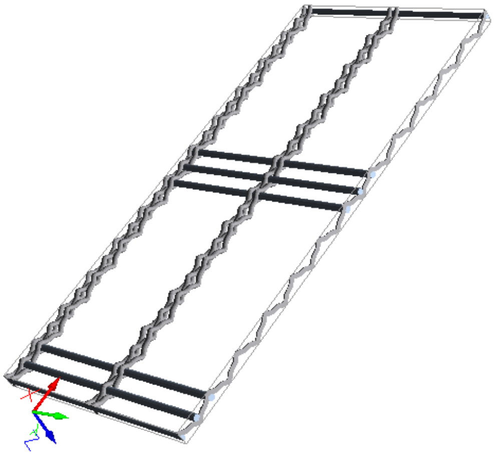
When the user clicks **Generate**, the corresponding macro is executed. As mentioned above, these macros are Python scripts (*.py). After generation, the structures can be rendered in 3D.

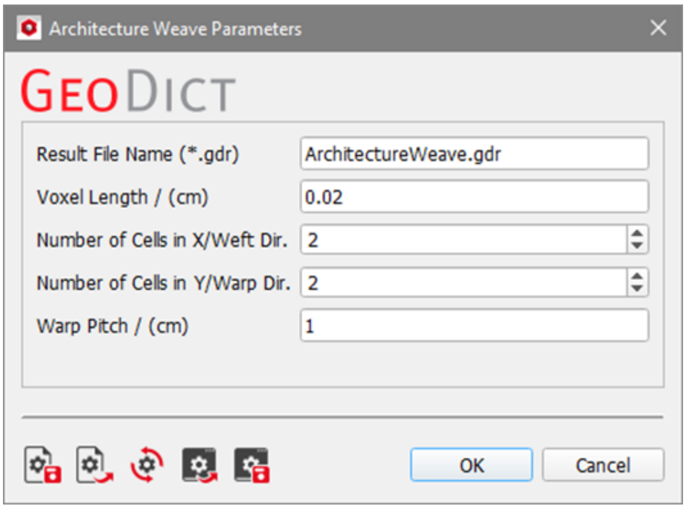
The macro files can be found in the WeaveGeo folder in the GeoDict installation folder. The macros can be opened with a text editor to observe their syntax and the steps involved in the generation. They can also be edited, but it is recommended to save a copy in a different folder before doing so.

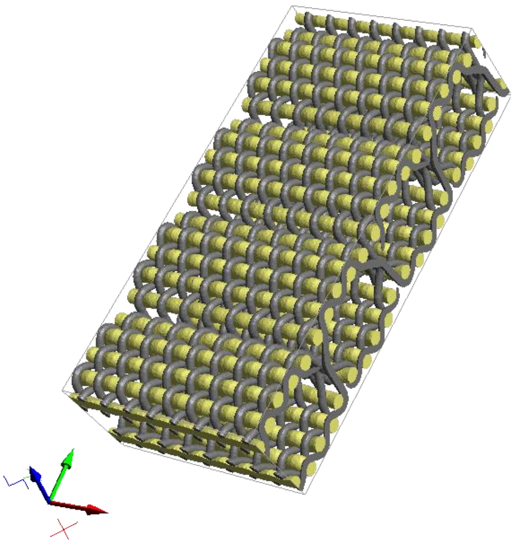


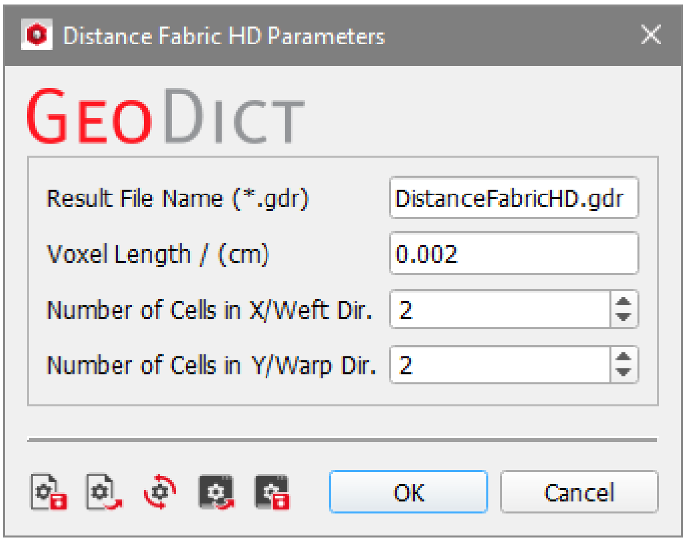
Any custom macro added to this WeaveGeo folder appears as predefined weave in the pull-down menu list in the WeaveGeo GUI.

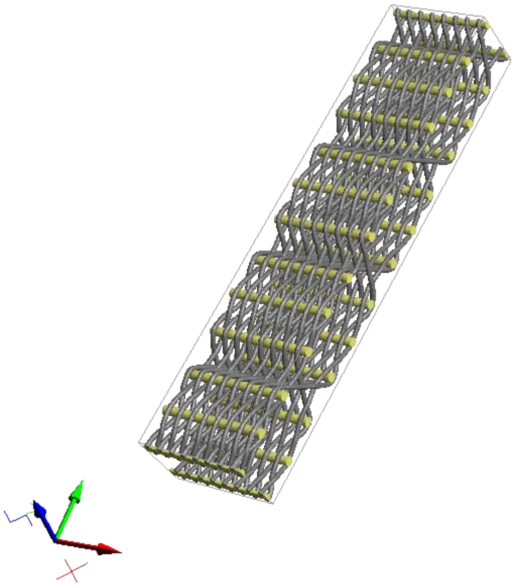
Macros from the WeaveGeo folder can be modified and saved as a local, customized macro in the user's project folder.

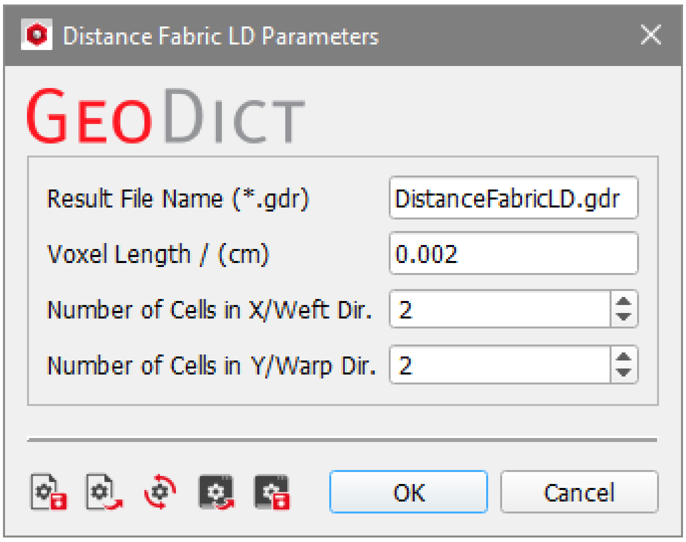


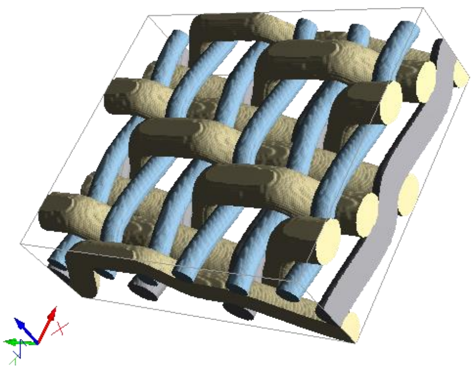


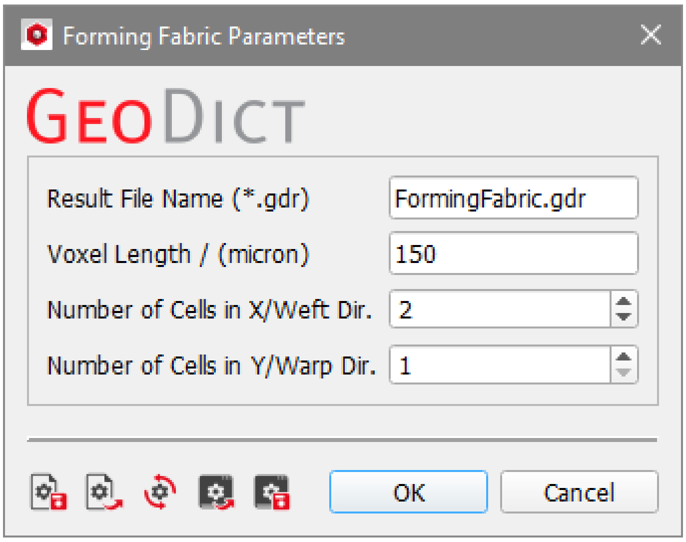


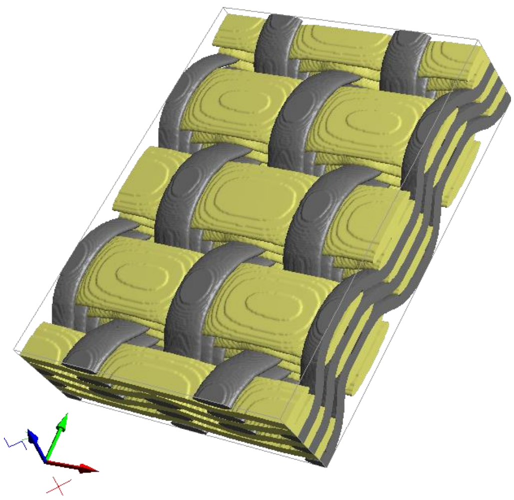


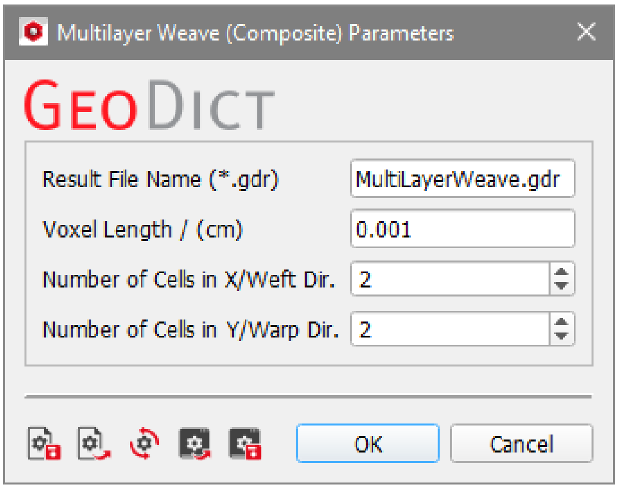


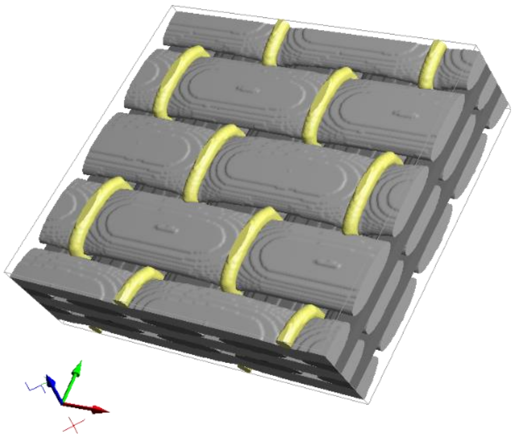

Distance Fabric LD Parameters
GeoDict
Result File Name (*.gdr)
DistanceFabricLD.gdr
Voxel Length / (cm)
0.002
Number of Cells in X/Weft Dir.
2
Number of Cells in Y/Warp Dir.
2
OK
Cancel

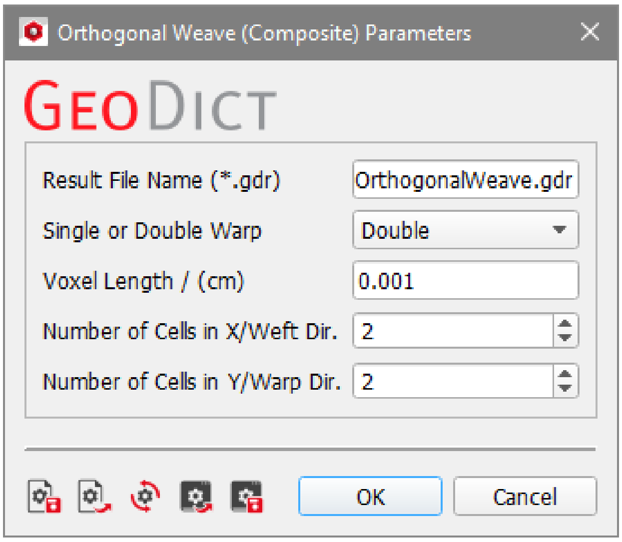


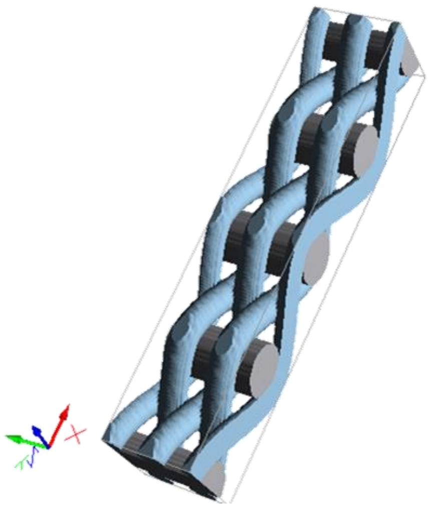

Forming Fabric Parameters
GeoDict
Result File Name (*.gdr)
FormingFabric.gdr
Voxel Length / (micron)
150
Number of Cells in X/Weft Dir.
2
Number of Cells in Y/Warp Dir.
1
OK
Cancel

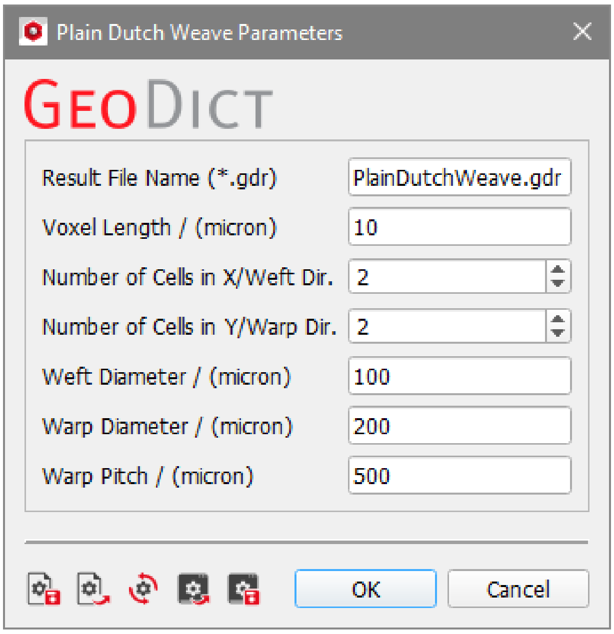


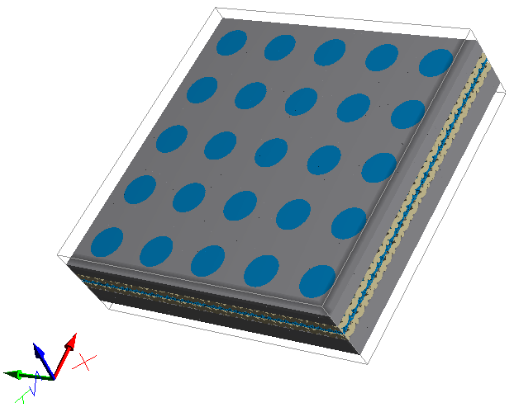

Multilayer Weave (Composite) Parameters
GeoDict
Result File Name (*.gdr)
MultiLayerWeave.gdr
Voxel Length / (cm)
0.001
Number of Cells in X/Weft Dir.
2
Number of Cells in Y/Warp Dir.
2
OK
Cancel





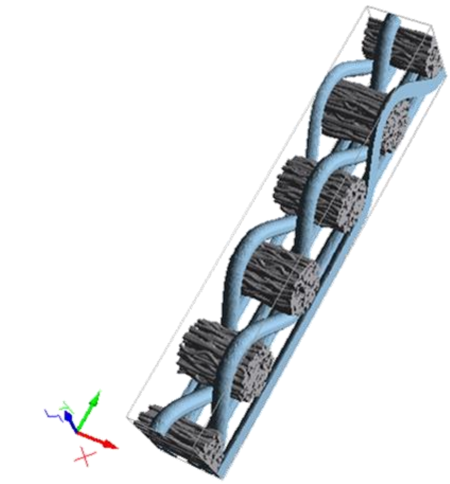


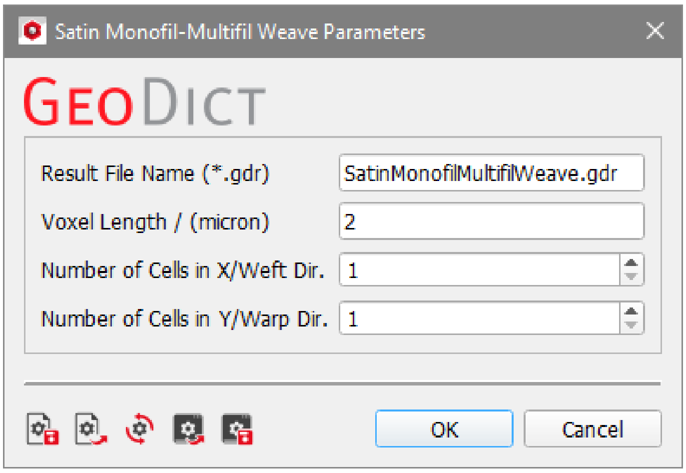


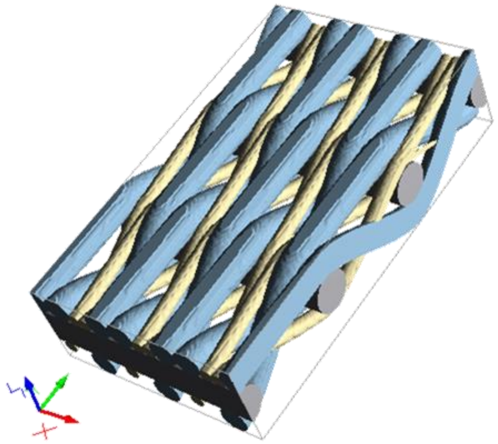


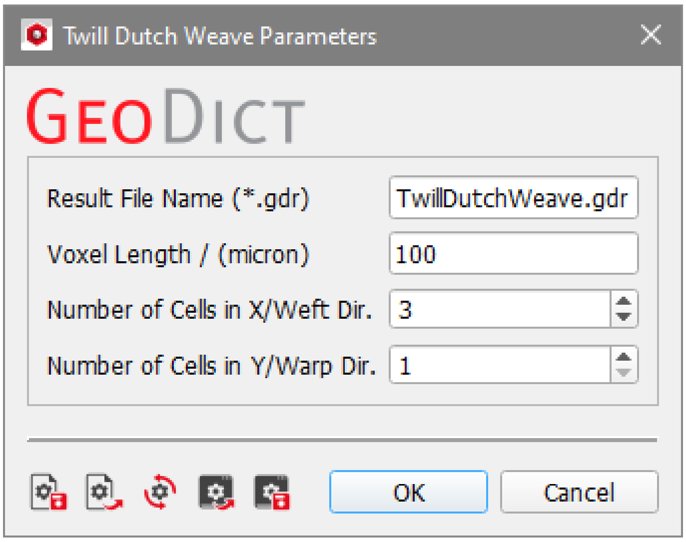
Sand Control Screen – No editable options

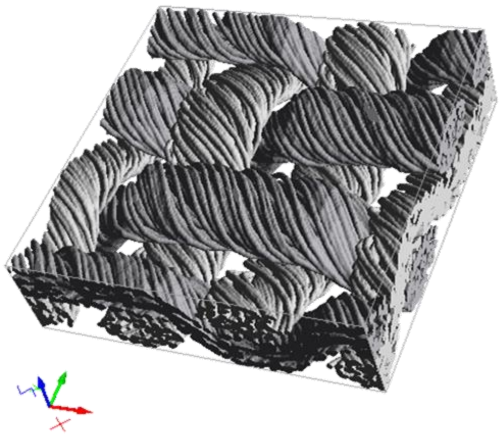
To generate the Sand Control Screen structure, also a GridGeo license is needed. Be aware that the generated structure is very large (2000x2000x600) and the generation might take long (ca. 2 hours).

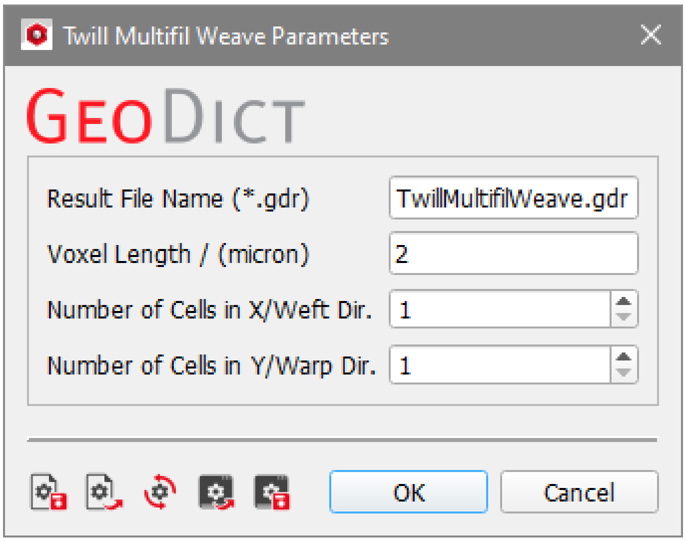


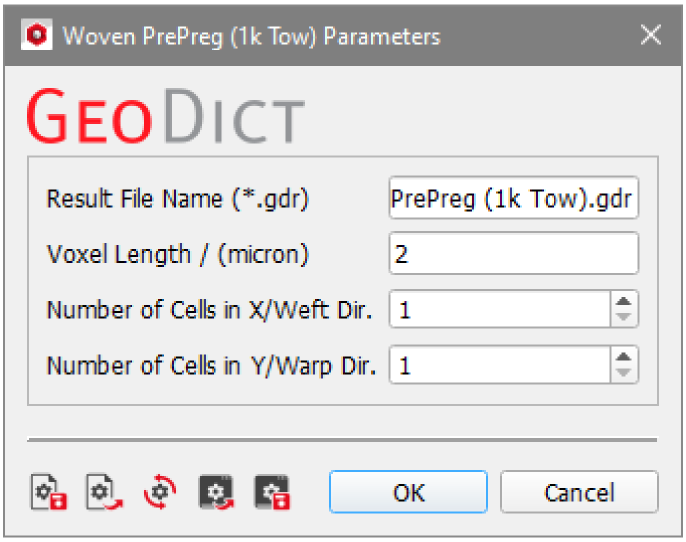

Satin Monofil-Multifil Weave Parameters
GeoDict
Result File Name (*.gdr)
SatinMonofilMultifilWeave.gdr
Voxel Length / (micron)
2
Number of Cells in X/Weft Dir.
1
Number of Cells in Y/Warp Dir.
1
OK
Cancel




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

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