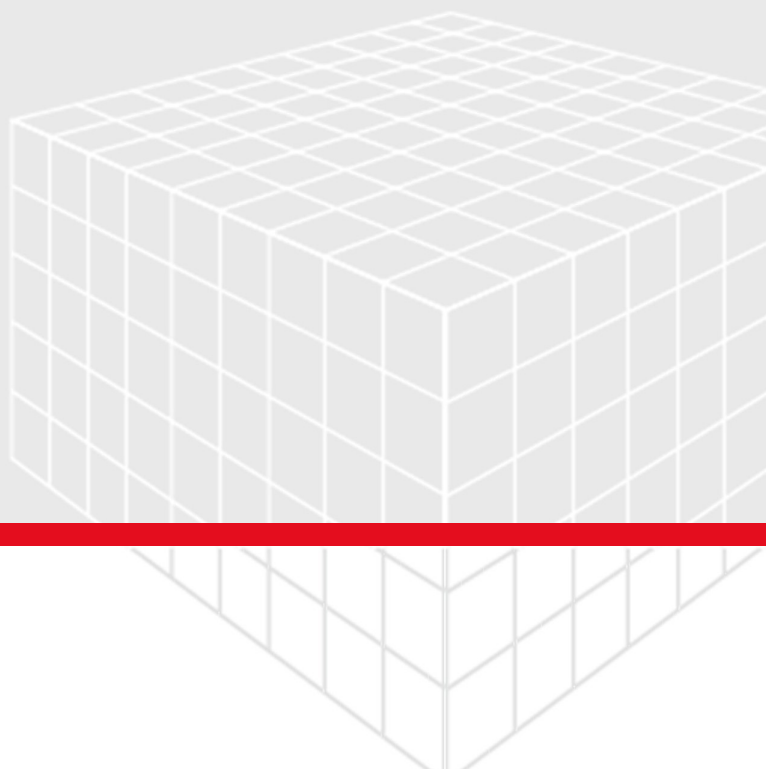


WeaveGeo

User Guide

GEODICT Release 2026

Published: June 2026



GEO DICT

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

WeaveGeo

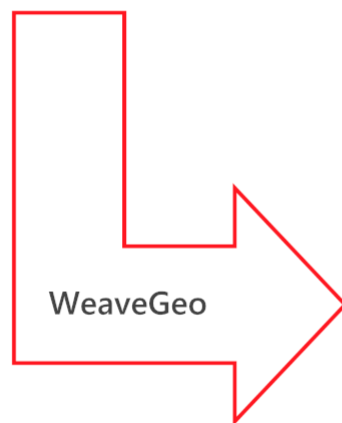
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1 WeaveGeo

WeaveGeo is GeoDict's generator for woven structures. It 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.

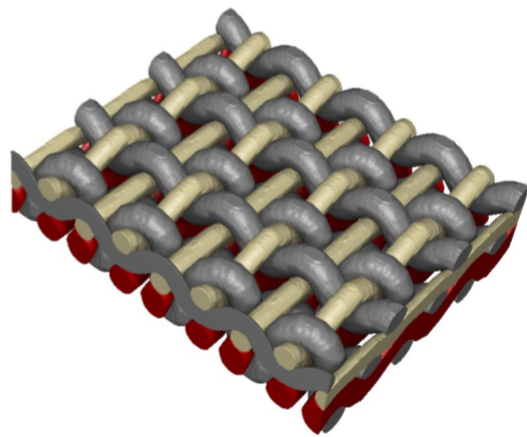
Input:

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



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 ([Wiegmann et al., 2010](#)^[117]) or of components in paper dewatering felts ([Probst-Schendzielorz et al.](#))^[117] and forming fabrics. Furthermore, in several projects, weaves for sand control applications in oil and gas extraction and wastewater filtration ([Knefel 2011](#)^[117], [Knefel, 2011](#)^[117], [Knefel and Wirtz 2009](#)^[117], [Glatt et al., 2009](#)^[117]) were modeled and optimized. Many other applications are possible, such as investigations of high-density multifilament fabrics with CFD simulations ([Rief et al., 2011](#))^[117].



New in GeoDict 2026

- Significant improvement in speed when handling weaves with multi-filament threads in non-periodic domains.
- Improvement of multi-filament thread packing for woven geometries.
- Rectangular fiber profiles can now be chamfered or rounded.
- Fiber segment length can now be scaled by cross-sectional area instead of diameter to improve the stiffness model.
- Implemented a new scaling scheme for broadening and overlap.

- The FreeWeave solver now accounts for fiber diameter and/or cross-sectional area when calculating broadening and overlap.
- Introduction of iterative broadening in the FreeWeave solver. Broadening is now gradually increased during the first iterations until the target value is reached.

Learn to use WeaveGeo:

- [Essential Weaving Terminology](#)⁵
Familiarise yourself with the terminology used in WeaveGeo. You will learn the different weave patterns, weave types, and thread types.
- [Single-Layer Weave](#)¹¹
Dive into the single-layer weave patterns Plain Weave, Twill Weave, and Satin Weave.
- [Complex Multi-Layer Weave](#)⁸⁹
Learn more about the Complex Multi-Layer Weaves created with the FreeWeave solver.
- [Weave GeoApps](#)¹¹⁵
Find out which WeaveGeo GeoApps are available.
- [References](#)¹¹⁷
The WeaveGeo references are listed here.



Join the conversation

Visit the Community on [GeoDict Forum](#) to be inspired and get answers to top questions.

Find illustrative application examples on the [website](#).

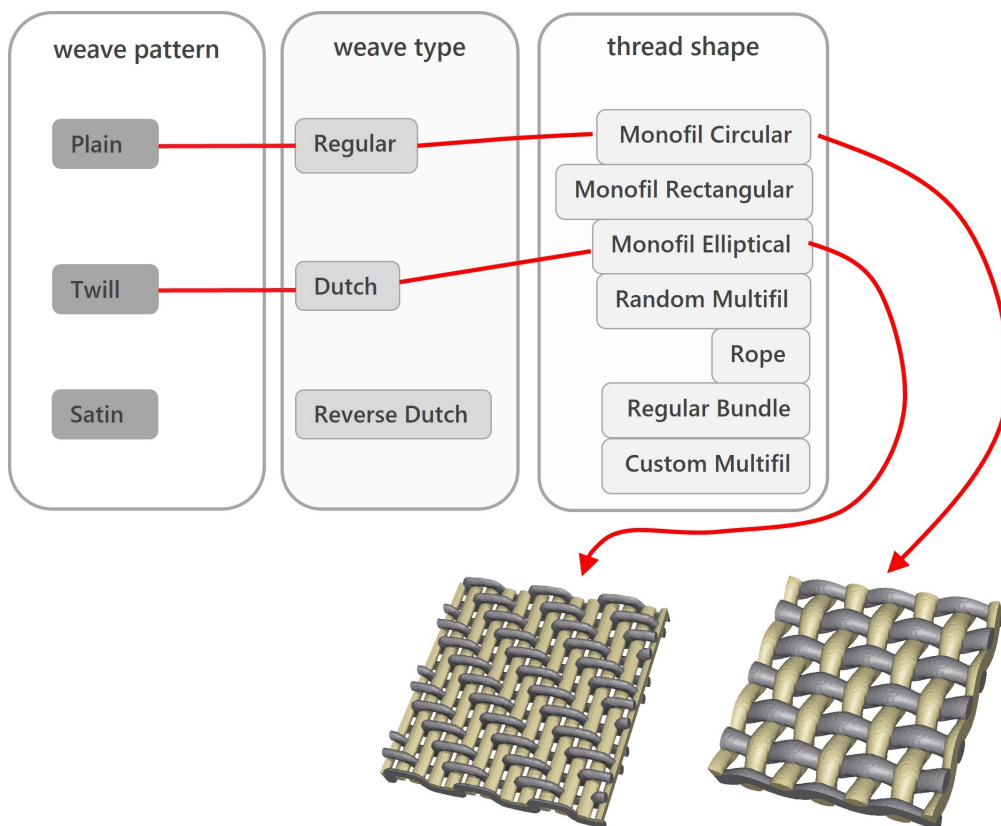
Our tutorials and seminar videos give you a first hands-on experience. They are collected in the [Learning Center](#).

Send your [Support Request](#) to our technical Support.

1.1 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 threads 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 you 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](#)^[89] 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.

Topics of Essential Weaving Terminology

- [Weave Patterns and Weave Types](#)^[6]
Description of available weaves.
- [Thread Profile Types](#)^[8]
Description of threads.

1.1.1 Weave Patterns and Weave Types

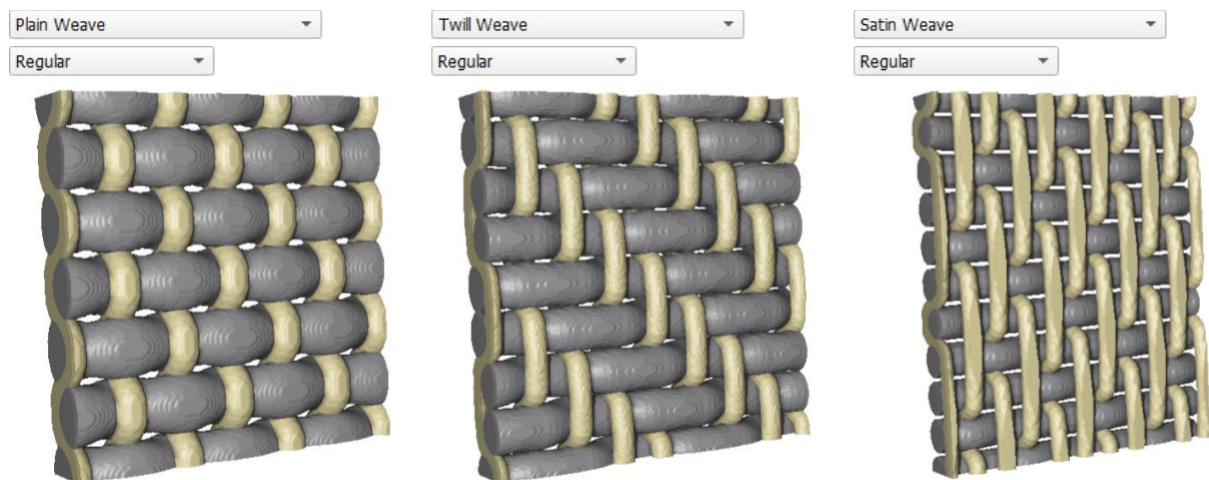
Weave Patterns

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 Weave 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.



Note! 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.

Weave Types

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

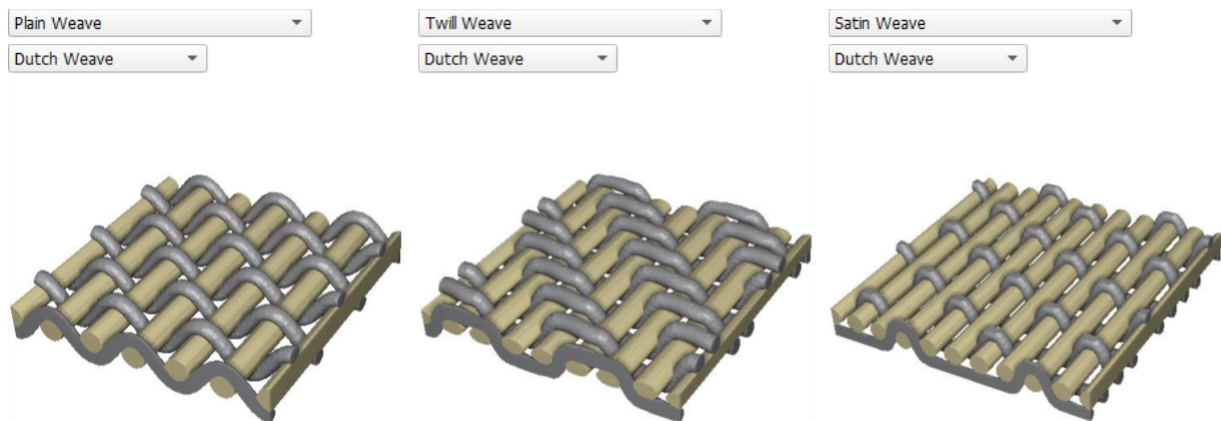
✓ Regular

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

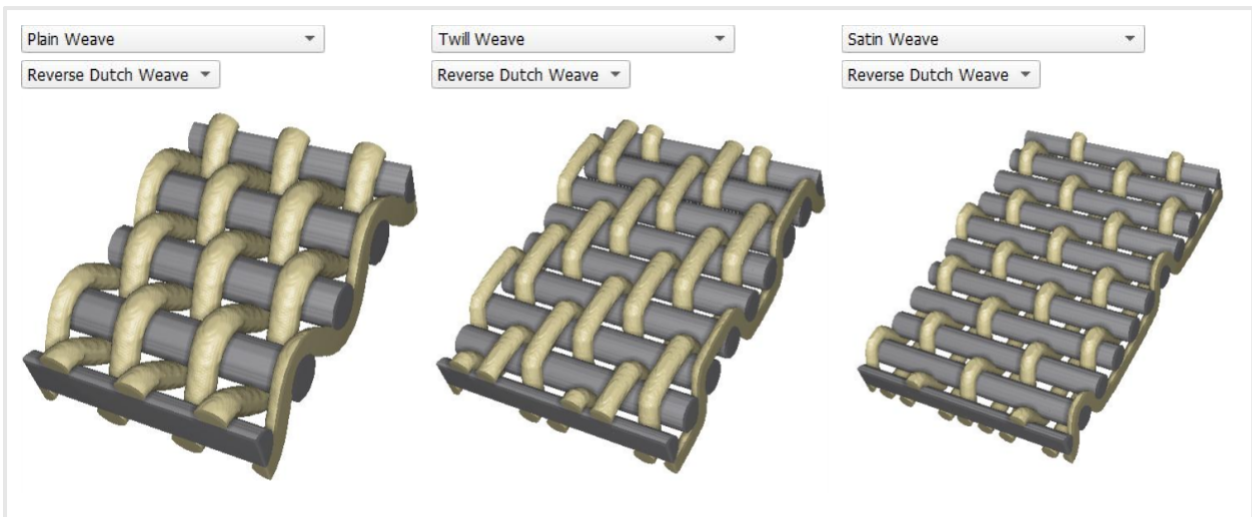
In a **Dutch Weave**, the warp threads are straight and do not deform. The weft threads bend around the warp threads. In this way, they can be placed close together giving a very dense, firm mesh with great strength in the weft direction. Usually, the warp threads are thicker than the weft threads.

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).



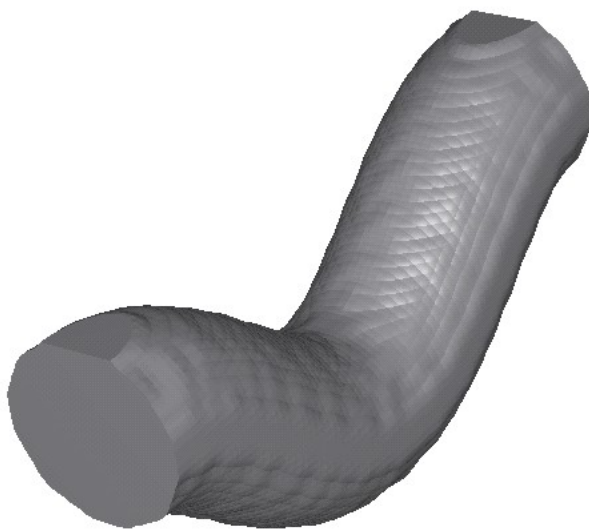
1.1.2 Thread Profile Types

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.

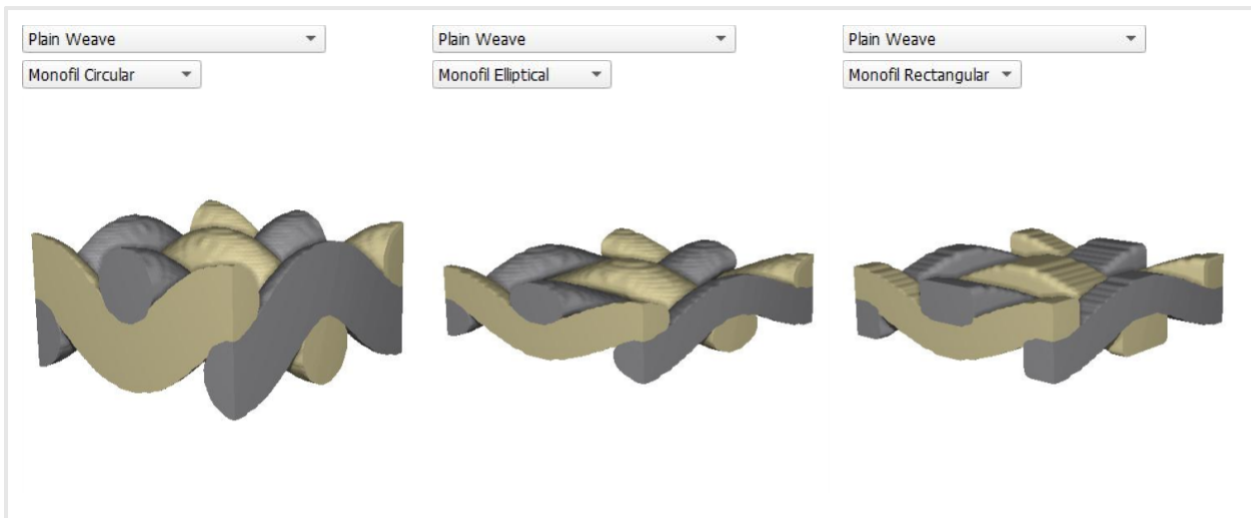
✓ Monofil

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**.



|



✓ Multifil

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.

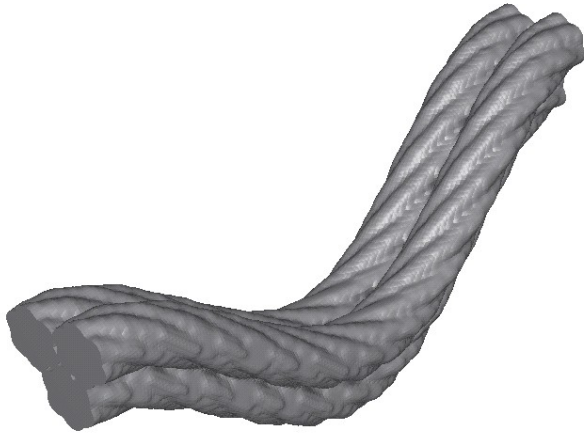


For the **Random Multifil** model, the filament positions are chosen randomly.

✓ Rope

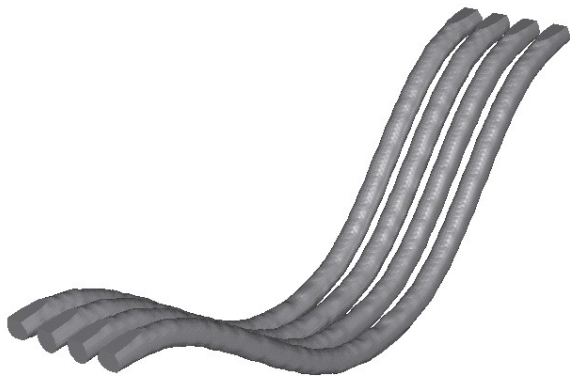
A **Rope** is a strong, thick string made of strands of filaments (fibers, wires) twisted together. For example, here, a 3x7 rope is shown. The rope is made of 3 strands and each strand is made of 7 filaments. WeaveGeo already contains the most common rope types, additional

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. They are not twisted and do not have deformations in lateral direction.



1.2 Single-Layer Weave

When selecting **Single-Layer Weave** in the WeaveGeo section, one of the three most common weave patterns [Plain Weave](#)^[12], [Twill Weave](#)^[35], and [Satin Weave](#)^[61] can be selected from the pull-down menu.

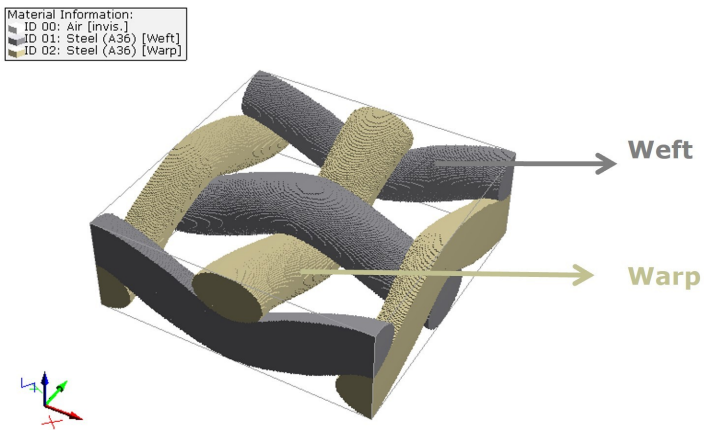


Each structure is composed of unit cells. For the plain weave, e.g., a unit cell has two weft threads and two warp threads. In the X- and Y-direction, a unit cell starts at the middle of one thread and ends at the middle of the second next thread. This means there are two meshes in each the X- and Y-direction. 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.



Know how! 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 User Guide (except for the complex multi-layer weaves), the weft thread is always grey and the warp thread is always beige.

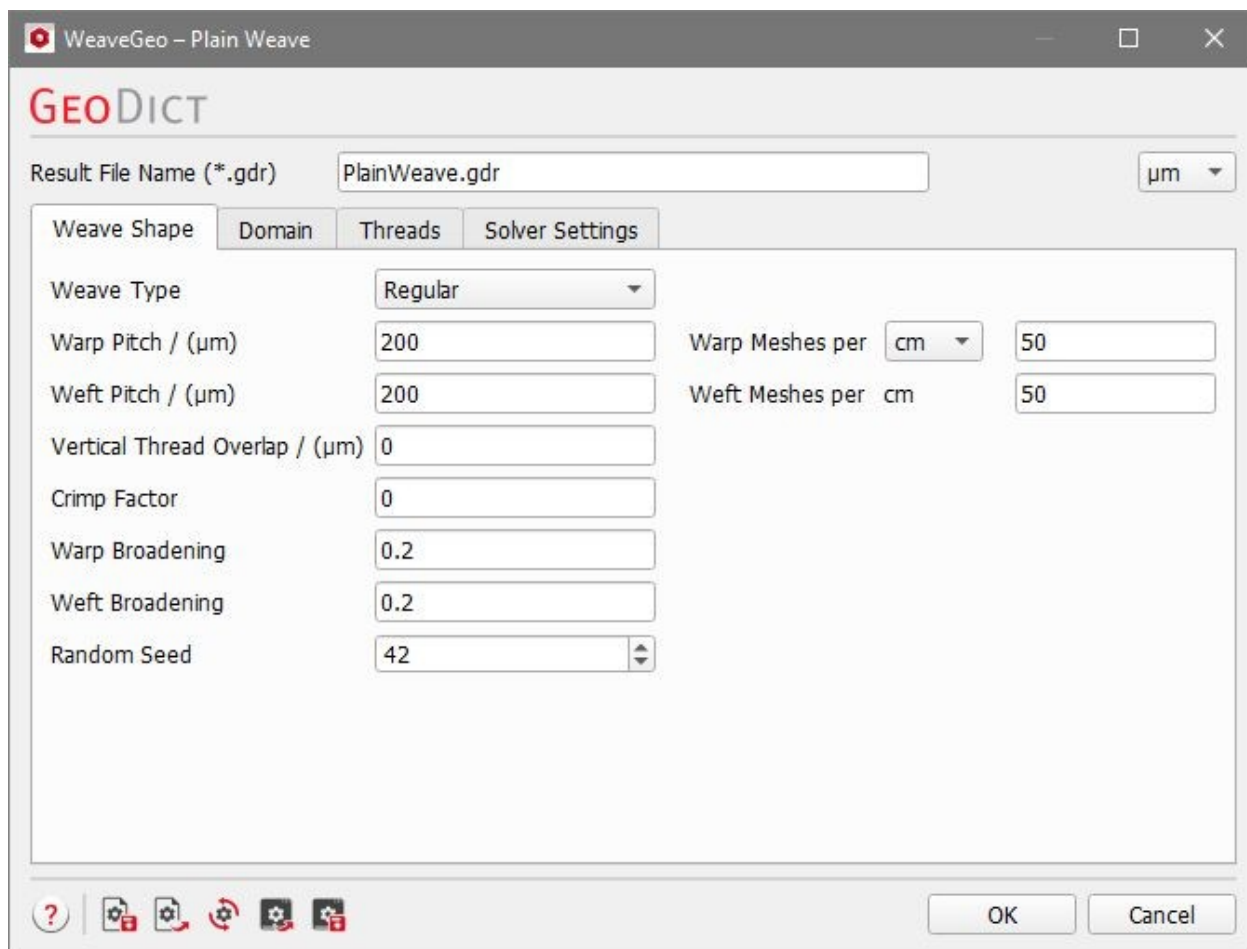


Learn how to create single-layer weave structures:

- [Plain Weave](#) ¹²
Create a simple weave pattern, where the threads are alternately placed above and below each other.
- [Twill Weave](#) ³⁵
Create a weave with a diagonal rib pattern, created by the offset between successive weft threads.
- [Satin Weave](#) ⁶¹
Create a weave with a smooth pattern where the weft thread runs over at least four warp threads before it passes under one.

1.2.1 Plain Weave

Plain Weave creates a simple weaving pattern in which the threads are alternately placed above and below each other.



At the top of the **Edit...** dialog, the name for the folder containing the generation results can be entered in the **Result File Name (*.gdr)** box. You can either keep the default name or choose a new one that fits 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**.

The Plain Weave parameters:

- [Weave Shape](#)¹⁴
Set the weave shape parameters.
- [Domain](#)¹⁸
Set the parameters for the domain in which the weave is created.
- [Threads](#)²¹
Set all parameters defining the shape of the threads, the size, and the number and shape of the filaments are entered under the Threads tab.
- [Solver Settings](#)³⁰
Choose the solver in this tab and define settings if available.

Weave Shape

Select the parameters for generating the weave under the **Weave Shape** tab.

WeaveGeo – Plain Weave

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Result File Name (*.gdr) µm ▾

Weave Shape | Domain | Threads | Solver Settings

Weave Type Regular ▾

Warp Pitch / (µm) Warp Meshes per cm ▾

Weft Pitch / (µm) Weft Meshes per cm

Vertical Thread Overlap / (µm)

Crimp Factor

Warp Broadening

Weft Broadening

Random Seed ▴ ▾

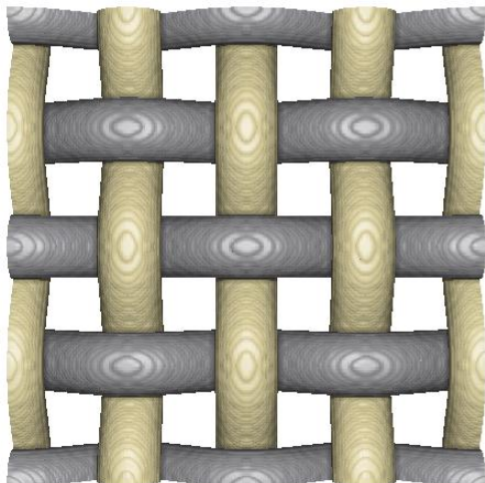
? 📁 ↶ ↷ 🔍 🔍 OK Cancel

The weave type can be selected from the [Weave Type](#) ⁶ drop-down menu. The available weave types are Regular, Dutch Weave, and Reverse Dutch Weave.

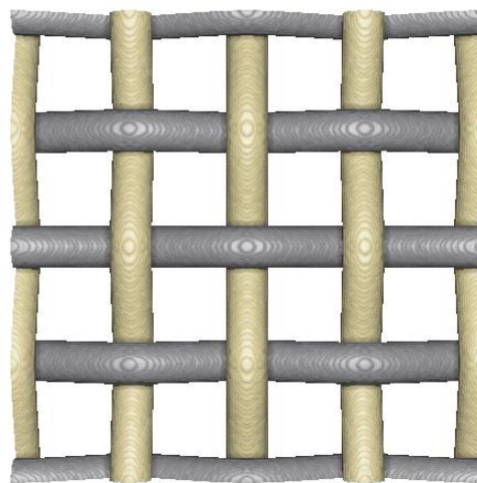
✓ Pitch and Meshes

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. The warp (or weft) threads touch if the entered pitch is equal to the width of the warp (or weft) thread.

Warp Pitch / (μm)
 Weft Pitch / (μm)



Warp Pitch / (μm)
 Weft Pitch / (μm)



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.

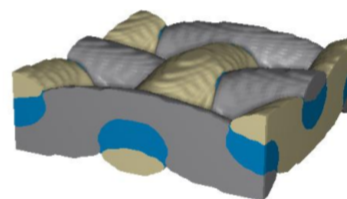
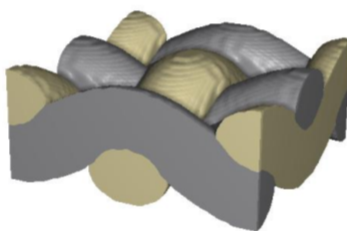
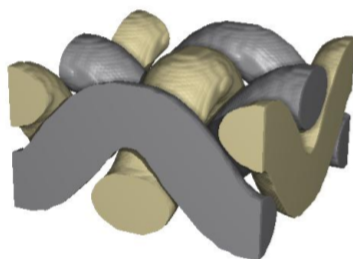
✓ Vertical Thread Overlap

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.

Vertical Thread Overlap / (μm)

Vertical Thread Overlap / (μm)

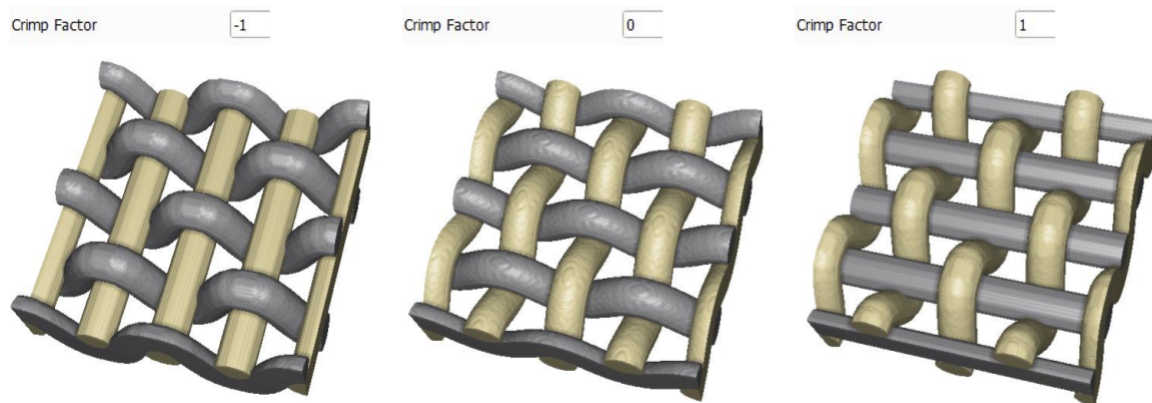
Vertical Thread Overlap / (μm)



✓ Crimp Factor

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.

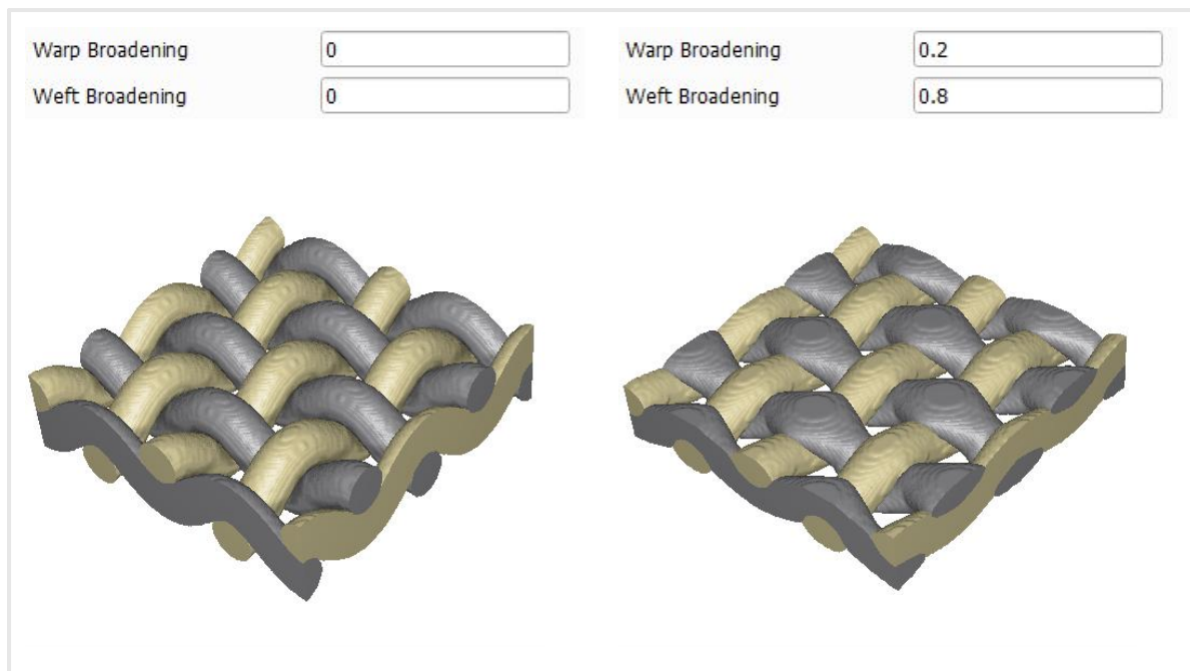


✓ Broadening

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). This means the new thread width is between 100% and 200% of the original thread width. 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.



Important! If the FreeWeave solver is chosen, the effect of the broadening is different compared to the result from the Classic solver.



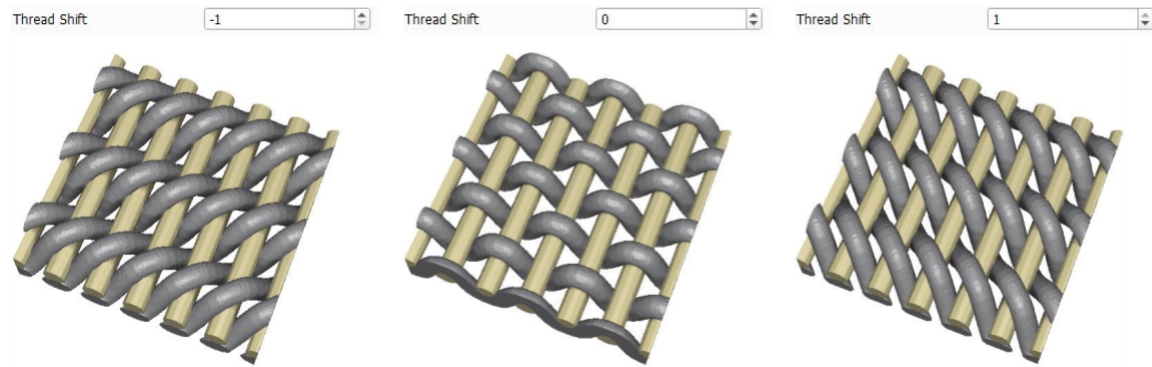
✓ Random Seed

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](#)^[8] threads are used and [Weft/Warp Lateral Deformation](#)^[41] is applied (as for the **warp** thread in the example below). 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 parameter is explained.



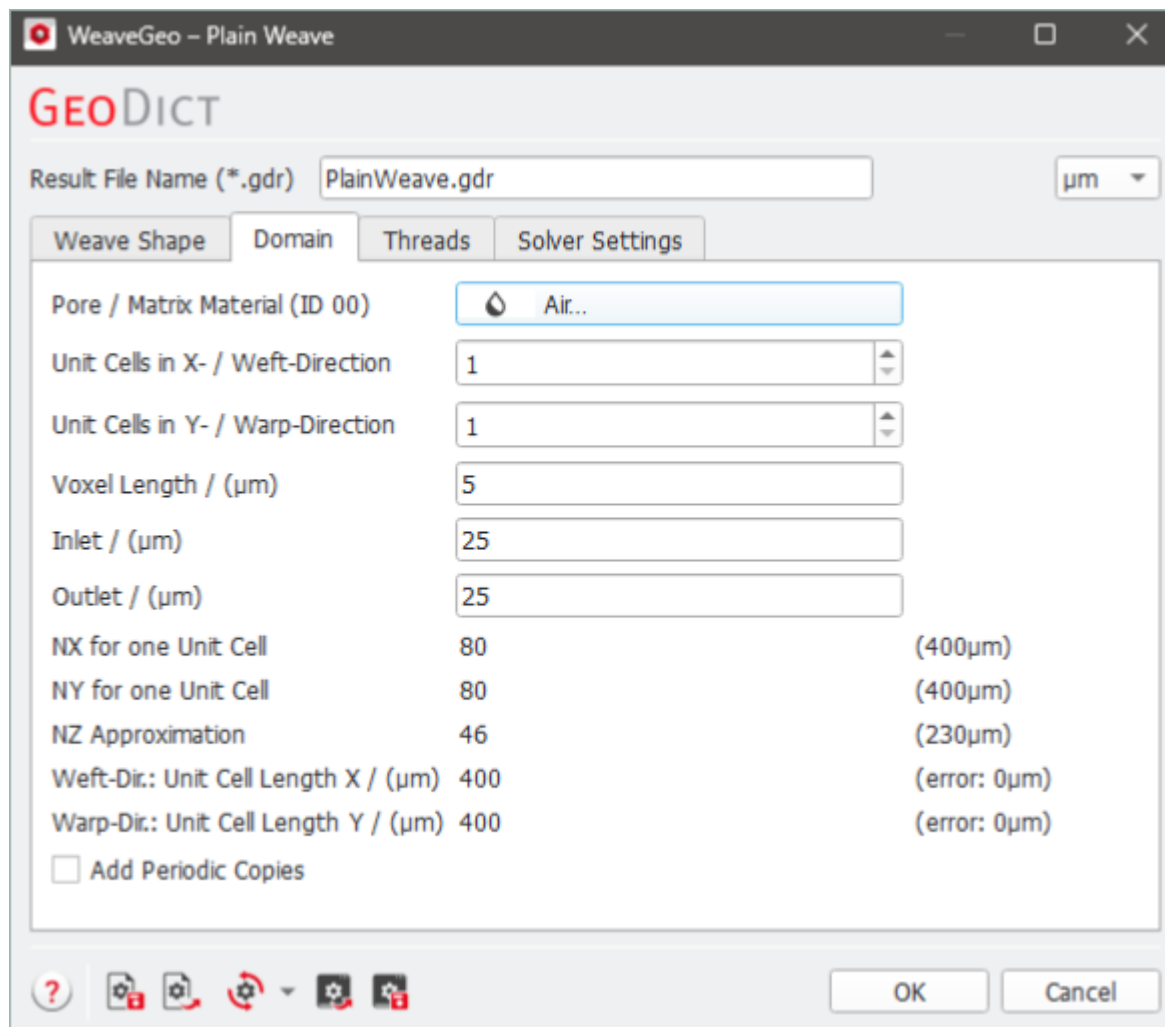
✓ Thread Shift

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.

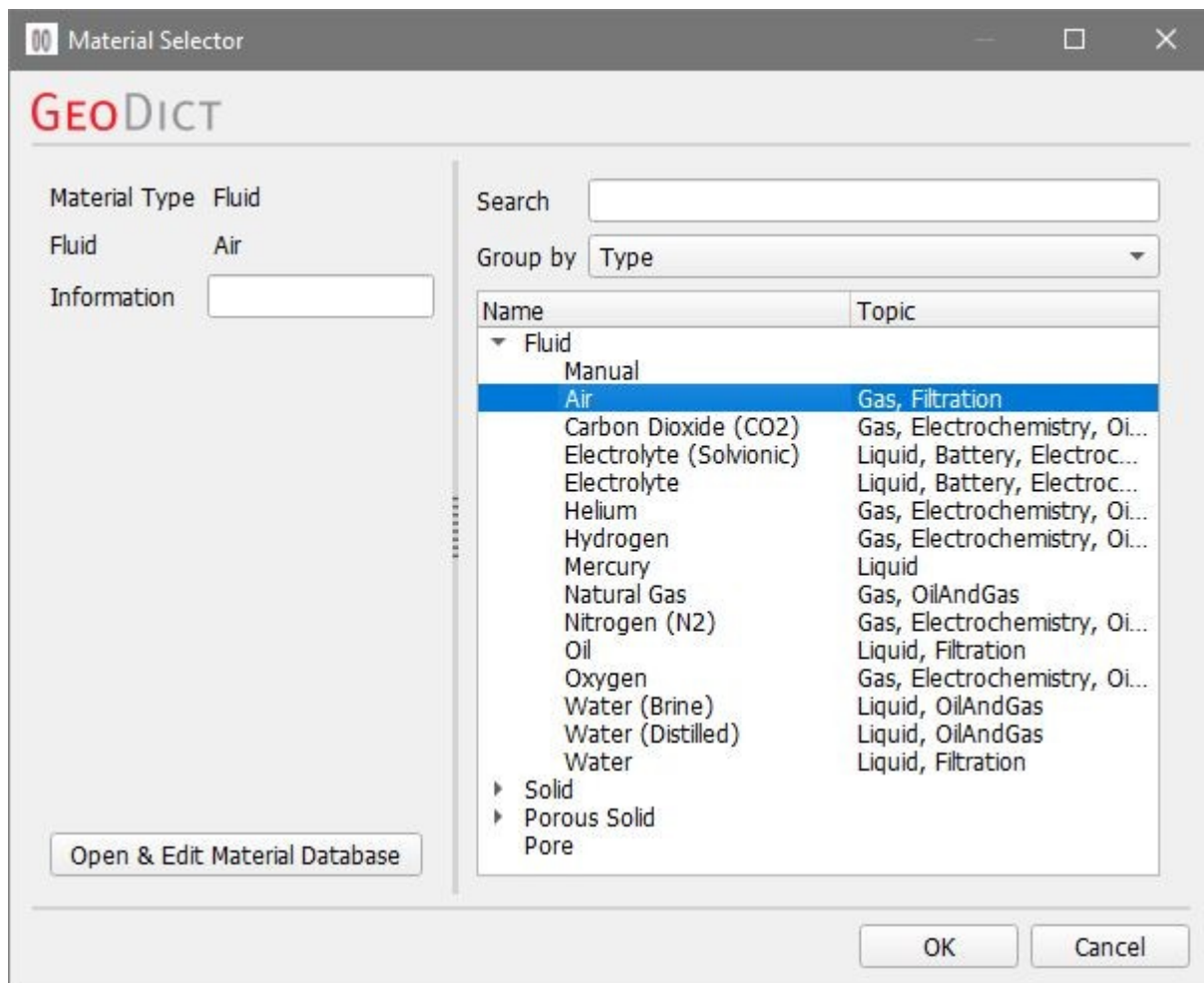


Domain

Edit the parameters for the domain in which the weave is created under the **Domain** tab.



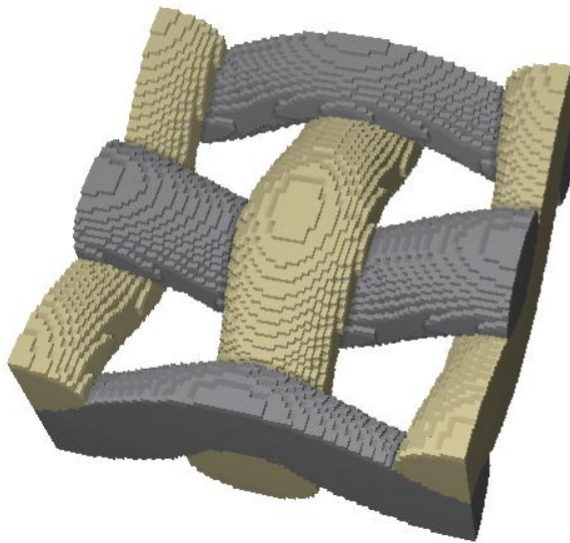
Click the **Pore/Matrix Material (ID 00)** button to open the Material Selector to select the material which occupies the space surrounding the threads (e.g., Air) from the GeoDict Material Database. The surrounding material always has **Material ID 00**.



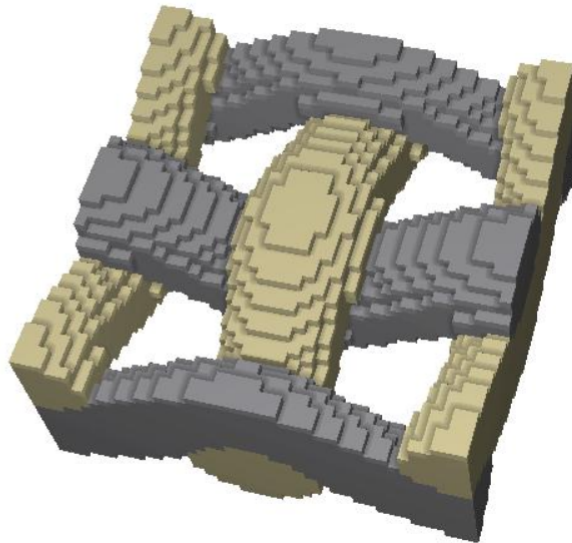
The values in **Unit Cells in X-/Weft Direction** and **Unit Cells in Y-/Warp Direction** set the number of repetitions of the generated unit cell. Thus, a large number of unit cells also leads to a larger structure.

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

▶ ● Structure (80x80x43, 5 μm)



▶ ● Structure (40x40x21, 10 μm)

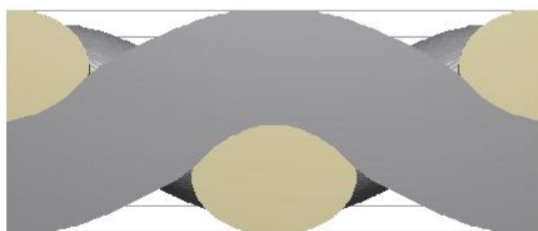


The values of **Inlet** (-Z direction) and **Outlet** (+Z direction) determine the size of the void regions in the chosen unit below and above the created woven structure.

Inlet / (μm)

Outlet / (μm)

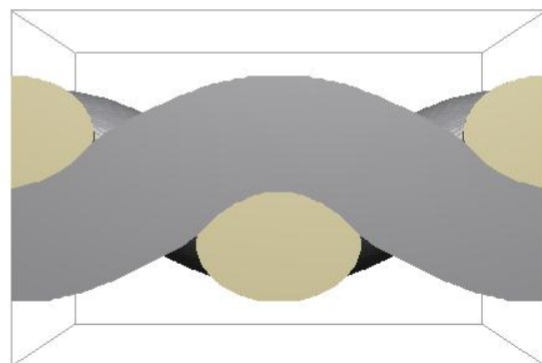
▶ ● Structure (200x200x83, 2 μm)



Inlet / (μm)

Outlet / (μm)

▶ ● Structure (200x200x133, 2 μm)



The values for **NX for one Unit Cell**, **NY for one Unit Cell**, and **NZ Approximation** indicate the number 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 depend on the defining parameters of the structure, such as the thread widths, pitches, and 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 or MeshGeo), this option should be enabled to prevent artifacts at the domain boundary.

Threads

In the **Threads** tab, select the parameters that define the shape of the threads, their size, and the number and shape of the filaments.

This tab is divided into three main parts. At the top select how overlapping threads should be treated. Below, 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**. Both contain the same parameters for the different thread types. Each thread can be modeled individually with different parameters.

✓ How to handle thread overlap?

Different threads might overlap in the generated structure, e.g., due to **Vertical Thread Overlap** (see [Weave Shape tab](#)). 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 more realistic structure.

☒ Resolve Overlap

☒ Mark Contact Voxels

Contact Material (ID 03)

Steel (A36) (Solid) [Contact]...

Additionally checking **Mark Contact Voxels** allows to define a separate material for the contact areas. This means, for each overlapping object a one voxel thick layer is reassigned to the **Contact Material**. In this way, even contacting threads with the same material ID can be clearly distinguished.



Know how! 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.

☐ Resolve Overlap

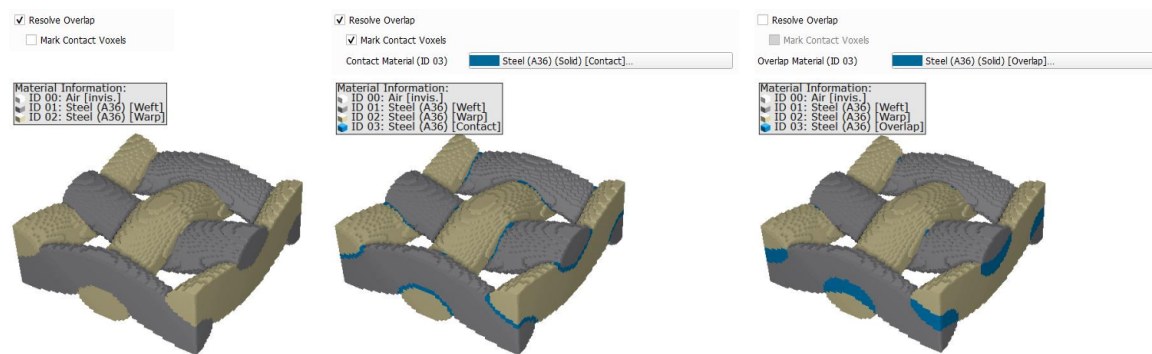
☐ Mark Contact Voxels

Overlap Material (ID 03)

Steel (A36) (Solid) [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 , while the threads have a height of 100 μm .



✓ Can I save and reload settings for a thread?

Yes, this is possible. At the bottom of the Weft and the Warp Thread panel, respectively, there is a **Save Thread** button. Click it to enter a name and save the parameters to a ***.gps** file. This is a GeoDict settings file.

File name:

Save as type:

Previously saved threads can be imported by clicking **Load Thread**.

Thread panels

Thread Type Name

Profile Type

Rope Type

Material (ID 01)

Thread Width / (µm)

Thread Height / (µm)

Stiffness

Filament

Number

Diameter / (µm)

Length of Lay / (µm)

Direction of Rotation

Thread Type Name

Profile Type

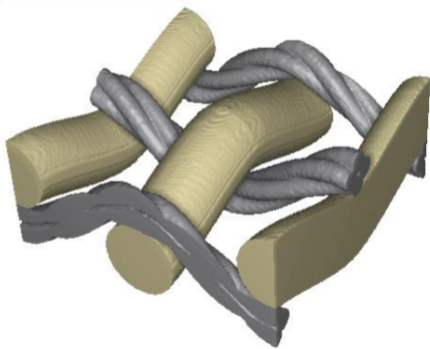
Material (ID 02)

Thread Diameter / (µm)

Stiffness

Material Information:

- ID 00: Air [Invis.]
- ID 01: Steel (A36) [Weft]
- ID 02: Steel (A36) [Warp]



Parameters for all profile types

✓ Thread Type Name

In the **Thread Type Name** field, a name can be given to the warp or the weft thread generated with the current parameters, respectively. The name is not shown in the generated structure, only in the dialog. Giving the thread a name can support to easily recognize a loaded thread in the dialog.

✓ Profile Type

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

Profile Type

- Monofil Circular
- Monofil Elliptical
- Monofil Rectangular
- Random Multifil
- Rope
- Regular Bundle
- Custom Multifil

Monofil threads can have a **Circular**, **Elliptical**, or **Rectangular** cross-section. For the **Multifil** threads, **Random Multifil** and **Custom Multifil** are available.

See the [Thread Profile types](#) section for explanations on **Monofil**, **Multifil**, **Rope**, and **Regular Bundle** profile types.

✓Material

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**.

Click on the material name to open the Material Selector and select the material for the corresponding thread from the GeoDict Material Database.

✓Thread Width / Thread Height / Thread Diameter

Thread Width and **Thread Height** determine the size of the cross-section area of the thread. The thread height is the extent in Z-direction. As the weft thread has its longitudinal direction in X-direction, the thread width determines the extent in Y-direction. For the warp thread the thread width determines the extent in X-direction.



Note! For **Ropes** and **Custom Multifils**, the Thread Width and Thread Height cannot be entered since these parameters depend on the other rope parameters. They are only shown as information. Find more information below in the profile type specific parameters section.

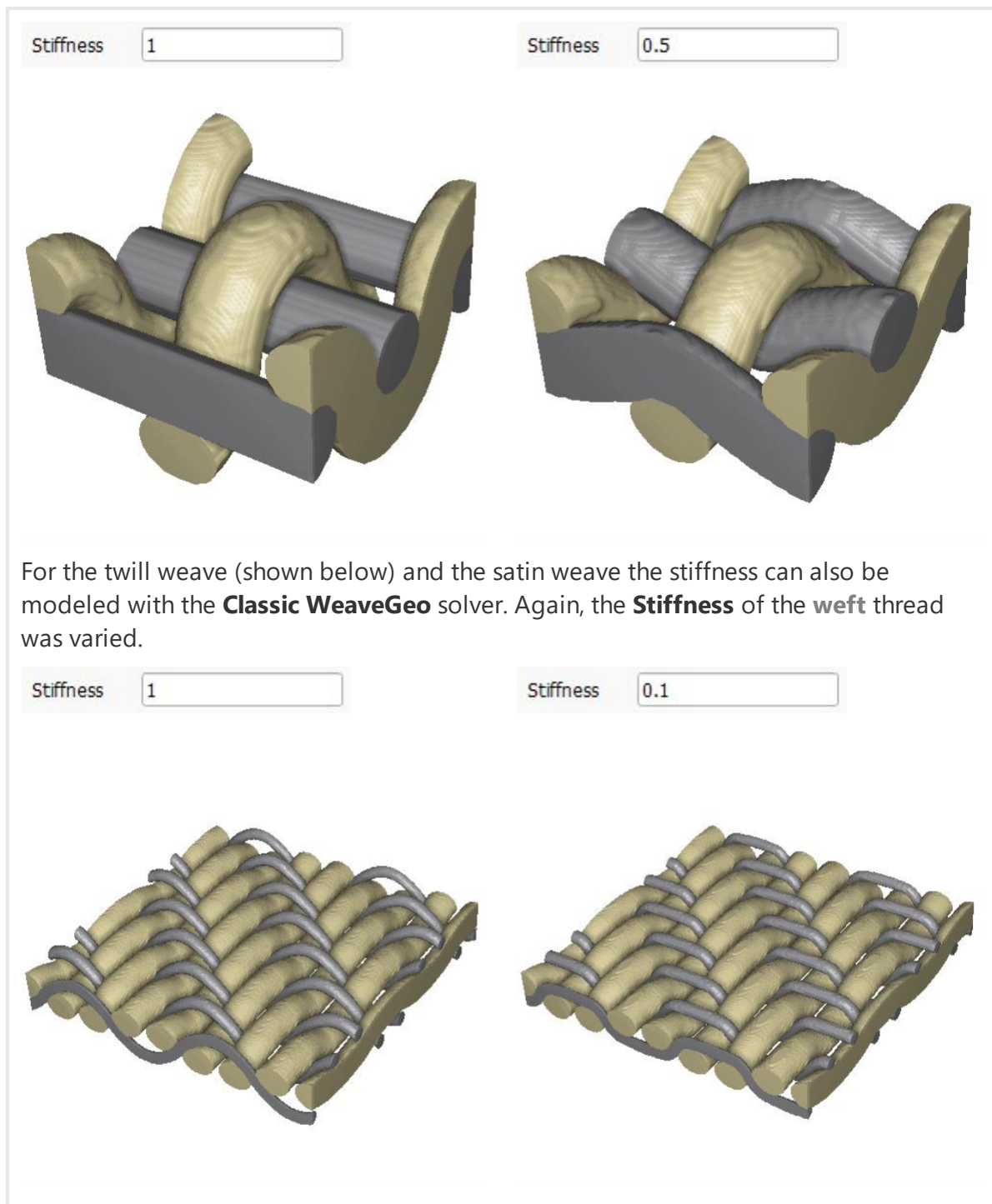


Note! For **Regular Bundle** threads, the Thread Height cannot be entered and is only shown as information. It is computed based on the number of individual filaments and the filament diameter.

In case of a **Monofil Circular** profile type, width and height are equal, so only the **Thread Diameter** can be entered.

✓Stiffness

The **Stiffness** parameter controls the bending behavior of the threads. A high stiffness indicates a rigid thread that only bends in small angles. Values for stiffness can vary from 0 to 1. This option only has an effect on plain weaves when using the FreeWeave Solver (in the [Solver Settings tab](#)). Below, an example of a plain weave is shown, where the **Stiffness** of the **weft** thread was varied.



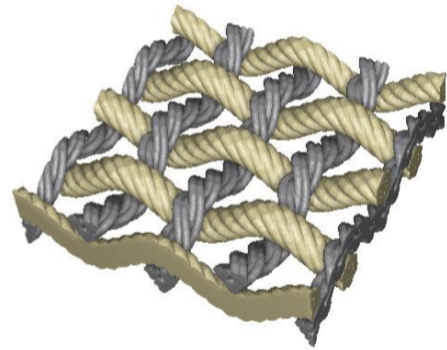
Parameters for Random Multifil, Rope, and Regular Bundle

✓ Number for Ropes

For the profile type **Rope**, one of the predefined **Rope Types** must be selected from the drop-down menu. The selected **Rope Type** determines the filament **Number** which cannot be changed manually.

In the example below, the **warp** thread 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** thread is a 3x3 rope, made of 3 strands of 3 filaments, which sets 9 as the filament number. The number of **Unit Cells** in warp and weft direction (under the Domain tab) was set to 2.

Weft Thread (X-Direction)		Warp Thread (Y-Direction)	
☒ Resolve Overlap		☐ Mark Contact Voxels	
Thread Type Name		Thread Type Name	
Profile Type	Rope	Profile Type	Rope
Rope Type	3x3	Rope Type	1x7
Material (ID 01)	Steel (A36) [Weft]...	Material (ID 02)	Steel (A36) [Warp]...
Thread Width / (μm)	46.4273441	Thread Width / (μm)	45
Thread Height / (μm)	46.4273441	Thread Height / (μm)	45
Stiffness	0	Stiffness	0
Filament		Filament	
Number	9	Number	7
Diameter / (μm)	10	Diameter / (μm)	15
Length of Lay 1 / (μm)	11	Length of Lay / (μm)	11
Length of Lay 2 / (μm)	0	Direction of Rotation	left (S)
Direction of Rotation 1	left (S)	Direction of Rotation 2	left (S)
Direction of Rotation 2	left (S)		
Load Thread...	Save Thread...	Load Thread...	Save Thread...



✓ Number for Random Multifil

For **Random Multifil** profile types, an arbitrary number of filaments can be entered. The upper limit is 10,000 filaments, but keep in mind that more filaments will lead to longer structure generation times.

✓ Number for Regular Bundle

Enter the **Number** specifying the number of filaments per thread in regular bundles. Possible values are in the range from 1 to 19.

✓ Diameter

Under Diameter enter the diameter of the individual filaments, which are all equal sized.

✓ Length of Lay

Length of Lay is only available for **Random Multifil** and **Rope**. It 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.

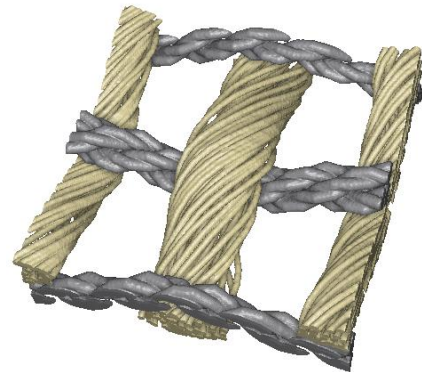
For ropes with several strands (here, the **weft** thread), the **Length of Lay 1** is the length for one rotation of the rope (thread) and **Length of Lay 2** is the length for one rotation of the strands in the rope.

☒ Resolve Overlap
☐ Mark Contact Voxels

Weft Thread (X-Direction)
 Thread Type Name:
 Profile Type: **Rope**
 Rope Type: **3x3**
 Material (ID 01): **Steel (A36) [Weft]...**
 Thread Width / (μm): 46.4273441
 Thread Height / (μm): 46.4273441
 Stiffness: 0
 Filament:
 Number: 9
 Diameter / (μm): 10
 Length of Lay 1 / (μm): 5.15
 Length of Lay 2 / (μm): 5.3
 Direction of Rotation 1: **left (S)**
 Direction of Rotation 2: **right (Z)**

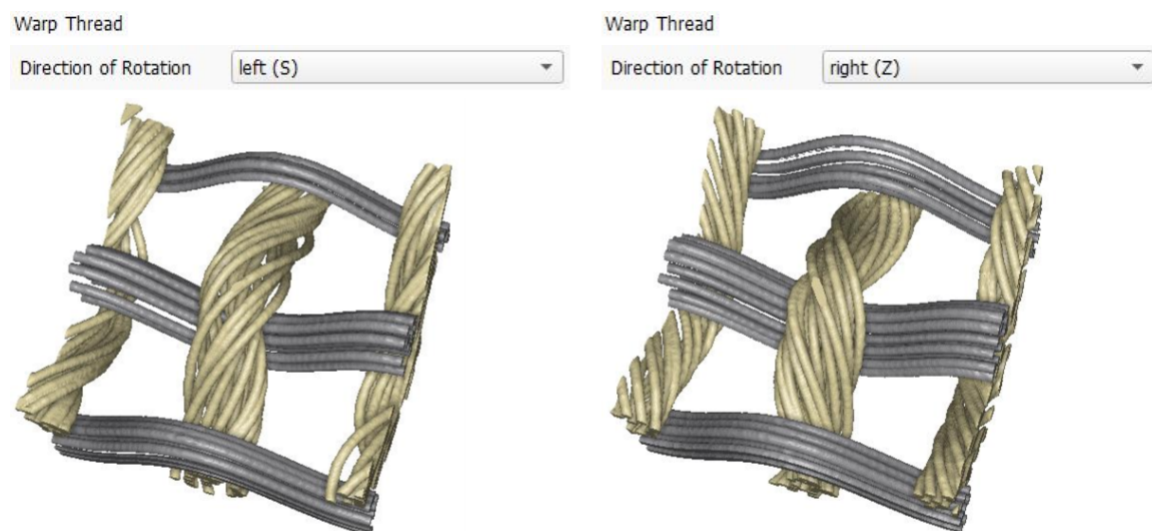
Warp Thread (Y-Direction)
 Thread Type Name:
 Profile Type: **Random Multifil**
 Material (ID 02): **Steel (A36) [Warp]...**
 Thread Width / (μm): 75
 Thread Height / (μm): 50
 Stiffness: 0
 Filament:
 Number: 45
 Diameter / (μm): 5
 Length of Lay / (μm): 5.1
 Direction of Rotation: **left (S)**
 Lateral Oscillation / (μm): 0

Load Thread... Save Thread...



✓ Direction of Rotation

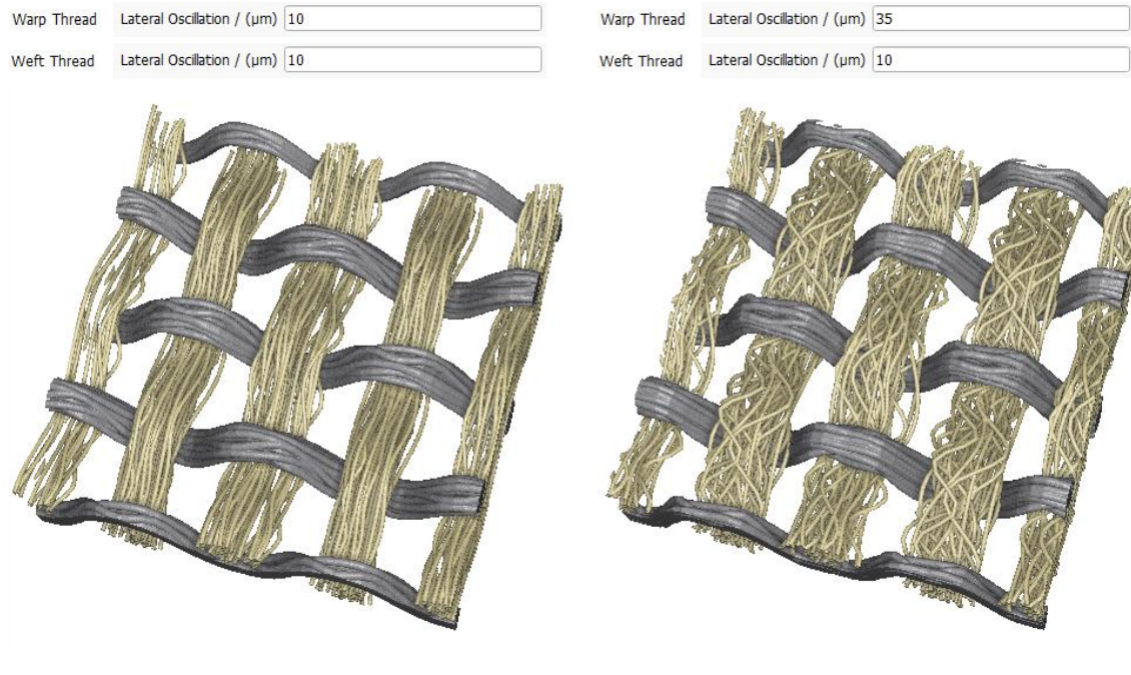
Direction of Rotation is only available for **Random Multifil** and **Rope** and sets the direction - **right** (Z-twist rope) or **left** (S-twist rope) - in which the thread is rotated around itself (here, the **warp** thread). It only has an effect if the value for **Length of Lay** is larger than zero.



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**.

✓ Lateral Oscillation

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 [Weave Shape tab](#)).



Parameters for Custom Multifil

✓ How does the Custom Multifil profile type work?

For **Custom Multifil**, the settings panel is structured hierarchically. On the first, layer the settings for the whole thread can be made. On the subsequent layers, the strands and filaments of which the thread is composed can be defined individually. At the bottom, the **Thread Width** and **Thread Height** are displayed. They cannot be edited since they are computed from the settings of the single filaments. The **Stiffness** is given for the whole thread.

On each layer the parameters **Diameter**, **Length of Lay**, **Direction**, and **Child Count** are shown. The active parameters depend on the level of the corresponding filament.

The **Diameter** is only editable for the filaments with a **Child Count** of 0 and defines their thickness. The diameter of the filament in the layer above is automatically computed based on the number of child filaments and their entered diameters.

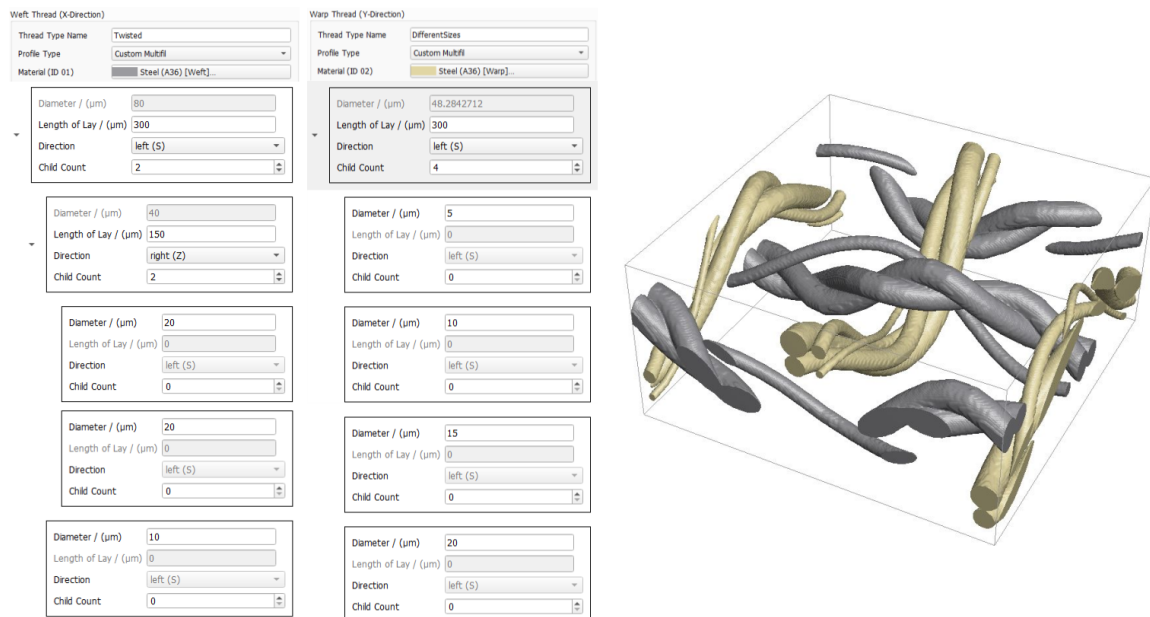


Know how! In contrast to Random Multifil threads, the filaments can have different diameters.

Length of Lay and **Direction** are the same as described above and define how a filament is twisted around itself. They are only active if **Child Count** is not zero.

Child Count defines in how many sub-filaments a filament is divided. The settings panel for each filament is displayed indented on the next layer. You can fold all lower layers by clicking on the small black triangle.

Below, a **Custom Multifil** structure is shown, generated with the shown settings. The domain length in X- and Y-direction is 300 voxels, respectively. The weft thread consists of two right (Z)-twisted filaments and a single, thinner filament twisted left (S) around them. The warp thread consists of 4 filaments with different diameters which are also twisted.



Special parameters for the FreeWeave solver

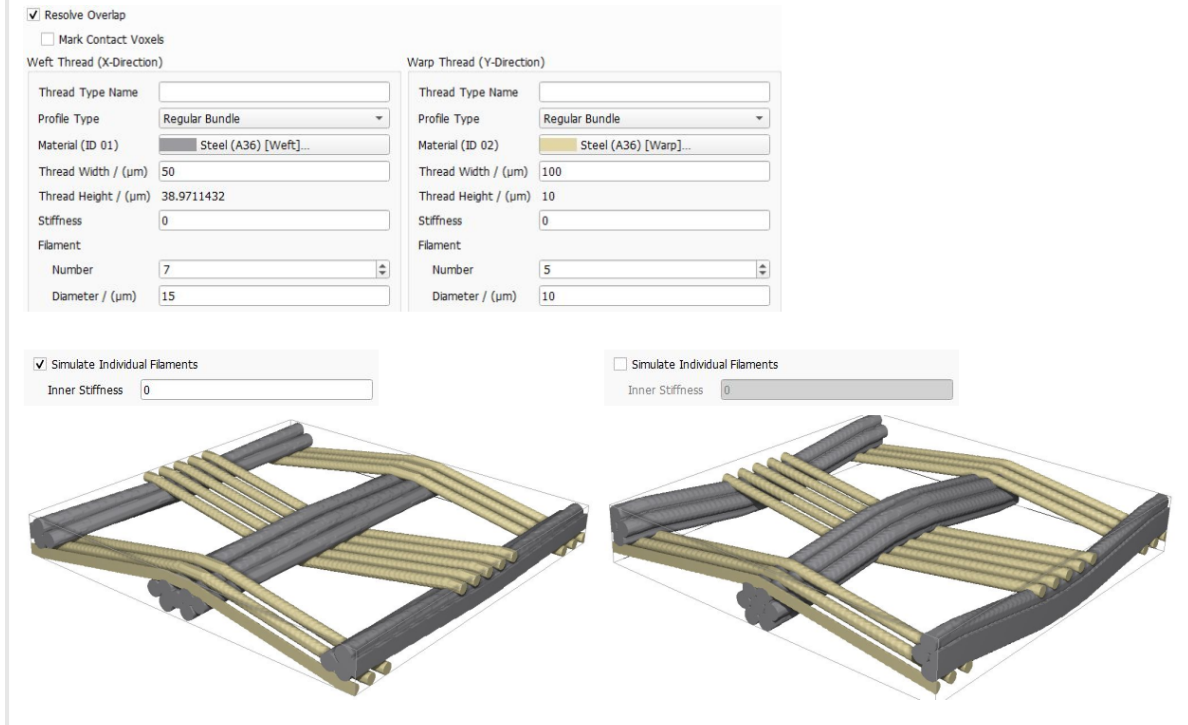
✓ Simulate Individual Filaments

If the FreeWeave Solver is chosen (in the [Solver Settings tab](#)), an additional option at the bottom of the thread panels is available. Check **Simulate Individual Filaments** to simulate interactions between the single filaments. Setting **Inner Stiffness** to a non-zero value allows you set a filament 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. When **Simulate Individual Filaments** is not active, the thread is modeled as a single circular thread. Then the filaments are placed at their computed positions.

The structure in the following example was produced with the shown settings. Observe the difference in the placement of the weft threads for **Simulate Individual Filaments**

checked and unchecked.

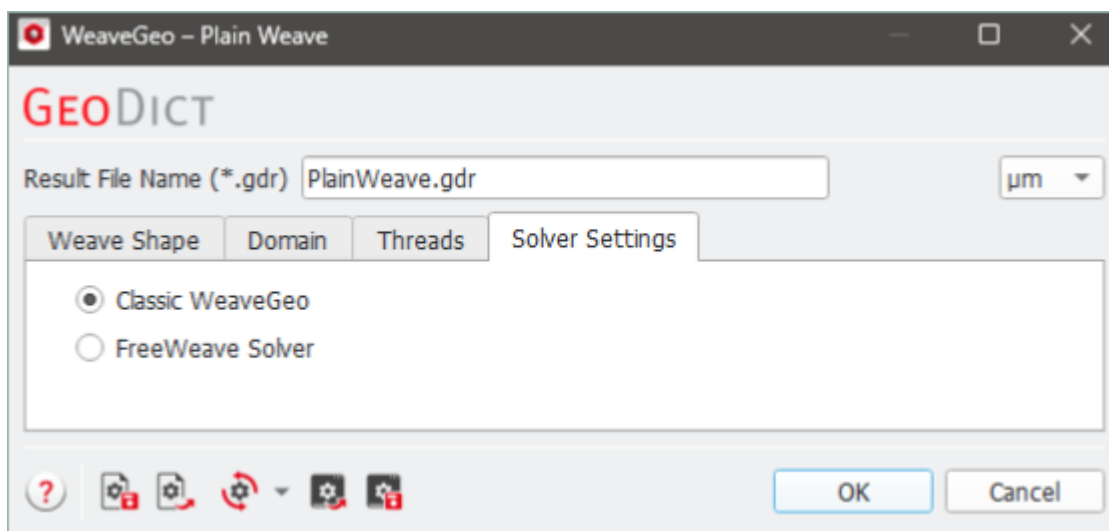
Simulate Individual Filaments is always available in the **Complex Multi-Layer Weave** command if a multifilament profile type is selected.



Solver Settings

In the **Solver Settings** tab, choose between the default **Classic WeaveGeo** solver and the **FreeWeave Solver**.

The **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. This solver has no parameters.



Alternatively, you can select the **FreeWeave Solver**, which produces more realistic structures but may also result in longer generation times.

The screenshot shows the 'WeaveGeo - Plain Weave' window with the 'Solver Settings' tab active. The 'FreeWeave Solver' is selected. The following parameters are visible:

Parameter	Value
☒ Tolerance	0.002
☐ Maximum Iterations	1000
Segment Max. Length (min. diameter fraction)	0.8
Segment Min. Length (min. diameter fraction)	0.3
Max. Relative Step-Size	0.2
Max. Absolute Step-Size (min. diameter fraction)	0.25
Refinement Iterations	0
Refinement Factor	1
Smoothing Subdivision	1
☐ Fix Lateral Warp Shift	

At the bottom of the settings area is a button labeled 'Restore default solver settings'. The bottom of the window features a toolbar with icons for help, undo, redo, and other functions, along with 'OK' and 'Cancel' buttons.

✓FreeWeave Solver parameters

The **FreeWeave Solver** performs a physical simulation when generating the weave as an iterative process. During the simulation, the threads are tightened and their interaction, such as collisions, is considered.

The **Tolerance** represents the reduction in the height 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 method is not suitable for all types of weaves. Thus, another stopping criterion is the **Maximal Iterations**, where the solver stops once the entered number of iterations is reached. These two criteria

can be selected together, and the solver will stop when either criterion 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 during one 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** 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 than or equal to 0.1 and less than or equal to 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 post-processing step after the simulation. The primary use for this is in visualization to make the structure appear smoother. As it only happens once at the end of the simulation, it is not computationally expensive. 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.

Clicking on **Advanced Options** unfolds additional solver settings. They do not need to be changed for most simulations. Tooltips describe how they can be used if they need to be adjusted.

Advanced Options

☒ Fix First Crossing Position

☐ Write Debug Output Interval

Segment length algorithm

☒ Use New Collision Algorithm

Inflate Iterations

Initial Thread Diameter Scale Factor

Height (Z) scale factor

Segment length mode

Segment length override

Segment Size Scale Iterations

Segment Size Scale Initial Factor

☐ Visualize Segments

Multifil broadening smooth factor

Overlap Scale Iterations

Broadening Scale Iterations

Restore default solver settings

When the option **Fix First Crossing Position** is enabled, the first crossing point remains fixed at its initial position, preventing drift in the XY plane during the iteration.

Enable **Write Debug Output Interval** to save the intermediate structure to the result folder every N iterations.

Choose the algorithm to regulate the segment length when approximating fiber trajectory with the **Segment length algorithm**:

- **Legacy:** this algorithm splits and merges segments during the simulation. It was called *Old Segment Length Algorithm* in previous versions.
- **Standard:** this algorithm subdivides segments once before the simulation and then normalizes the segment lengths during simulations.
- **Proportional Subdivision:** this algorithm uses the same strategy as Standard, but matches the target lengths more accurately.

Enable the option **Use New Collision Algorithm** to perform a more accurate collision detection. With this option enabled, cylinder-to-cylinder collisions are tested instead of sphere-to-cylinder collisions.

The number of initial iterations in which to gradually inflate warp threads can be set

under **Inflate Iterations**.

The **Initial Thread Diameter Scale Factor** specifies the initial fraction of the thread diameter used at the start of the simulation. For example, a value of 0.2 means that the threads start 20% of their defined diameter and gradually expand to 100%.

The Z-height will be scaled by the **Height (Z) scale factor**. It is recommended to set this factor to the same value as **Initial Thread Diameter Scale Factor**.

The **Segment length mode** determines how the target segment length varies with the fiber diameter.

- **Constant**: the segment lengths are constant and independent of the fiber diameter.
- **Relative to diameter**: the segment lengths are proportional to the fiber diameter.
- **Relative to cross-section area**: the segment length are proportional to the fiber cross-section area.

The **Segment length override** factor defines whether and how the segment length will be overridden. For non-zero values, the segment length override is enabled. The resulting behavior also depends on the chosen Segment length mode:

- For the **Constant** segment length mode, this value defines the length of segments in meters.
- For the **Relative to diameter** mode, the segment length is the fiber diameter multiplied by this value.
- For the **Relative to cross-section area** mode, the segment length is the fiber cross-sectional area multiplied by this value.

The **Segment Size Scale Iterations** defines the number of initial iterations in which the segment length is gradually increased. This option only works properly with the **Legacy** segment length algorithm.

The **Segment Size Scale Initial Factor** specifies the fraction of segment length used at the start of the simulation. For example, a value of 0.2 means that the initial segment length is 20% of the defined segment length.

If the option **Visualize Segments** is checked, control points of the segments are shown using spheres.

The **Multifil broadening smooth factor** is an integer value that controls the smoothing of the curvature computation. If this value is greater than zero, a broadening algorithm is enabled that computes broadening for the entire multifilament bundle instead of the individual filaments.

The **Overlap Scale Iterations** parameter defines the number of initial iterations during which the overlap is gradually increased to the specified maximum value. In the first iteration, no overlap is applied.

The **Broadening Scale Iterations** parameter defines the number of initial iterations during which the broadening is gradually increased to the specified maximum value. In

the first iteration, no broadening is applied.

1.2.2 Twill Weave

The **Twill Weave** command creates a diagonal rib pattern caused by the offset between successive weft threads.

Result File Name (*.gdr) µm

Weave Shape | Domain | Threads | Solver Settings

Weave Type: Regular

Warp Pitch / (µm): 135 Warp Meshes per cm: 74.0740741

Weft Pitch / (µm): 135 Weft Meshes per cm: 74.0740741

Float Factor 1: 2

Float Factor 2: 2

Weft Shift: 1

Vertical Thread Overlap / (µm): 0

Crimp Factor: 0

Warp Broadening: 0.1

Weft Broadening: 0.1

Warp Lateral Deformation / (µm): 10 Fraction of Warp Pitch / (%): 7.40740741

Weft Lateral Deformation / (µm): 10 Fraction of Weft Pitch / (%): 7.40740741

Random Seed: 42

OK Cancel

At the top of the **Edit...** dialog, the name for the folder containing the generation results can be entered in the **Result File Name (*.gdr)** box. You can either keep the default name or choose a new one that fits 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**.

The Twill Weave parameters:

- [Weave Shape](#) ³⁶

The Twill Weave parameters:

In this tab the settings for the weave are made.

- [Domain](#)^[43]

In this tab, the parameters for the domain in which the weave is created are entered.

- [Threads](#)^[47]

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

- [Solver Settings](#)^[56]

Choose the solver in this tab and define settings if available.

Weave Shape

The parameters for the Twill Weave are similar to those for the [Plain Weave](#)^[14]. First, the parameters that also appear in the Plain Weave dialog are described. Below are the descriptions for all Twill Weave specific parameters.

WeaveGeo - Twill Weave

GEO DICT

Result File Name (*.gdr) TwillWeave.gdr µm

Weave Shape Domain Threads Solver Settings

Weave Type Regular

Warp Pitch / (µm) 135 Warp Meshes per cm 74.0740741

Weft Pitch / (µm) 135 Weft Meshes per cm 74.0740741

Float Factor 1 2

Float Factor 2 2

Weft Shift 1

Vertical Thread Overlap / (µm) 0

Crimp Factor 0

Warp Broadening 0.1

Weft Broadening 0.1

Warp Lateral Deformation / (µm) 10 Fraction of Warp Pitch / (%) 7.40740741

Weft Lateral Deformation / (µm) 10 Fraction of Weft Pitch / (%) 7.40740741

Random Seed 42

OK Cancel

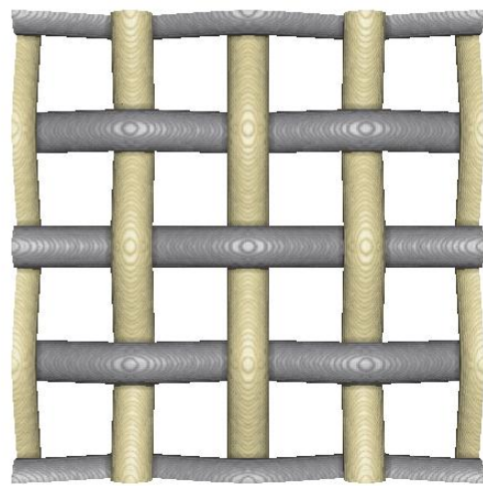
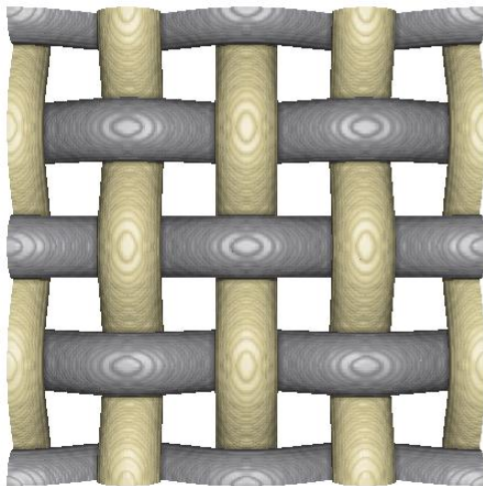
The weave type can be selected from the [Weave Type](#)^[6] drop-down menu. The available

weave types are Regular, Dutch Weave, and Reverse Dutch Weave.

✓ Pitch and Meshes

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. The warp (or weft) threads touch if the entered pitch is equal to the width of the warp (or weft) thread.

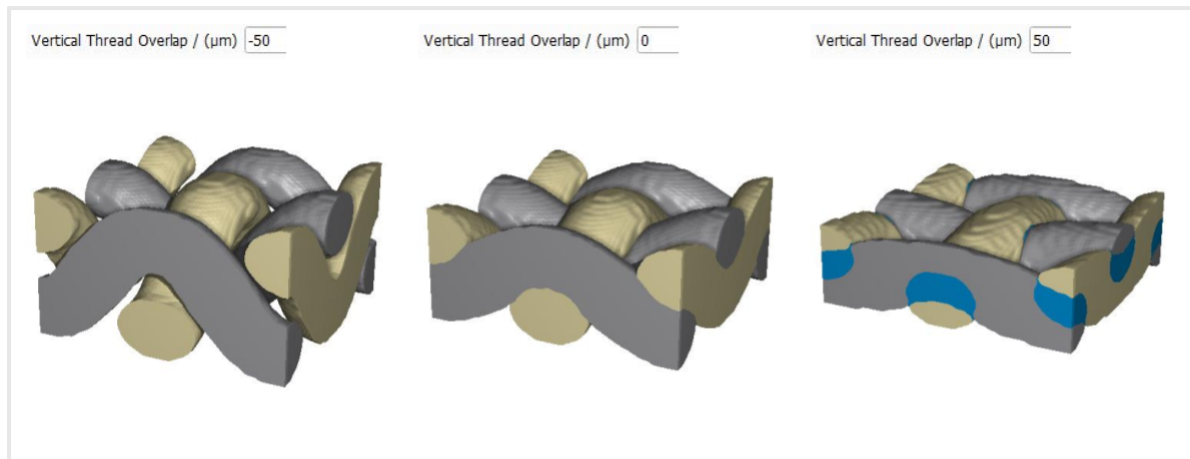
Warp Pitch / (μm)	200	Warp Pitch / (μm)	300
Weft Pitch / (μm)	200	Weft Pitch / (μm)	300



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.

✓ Vertical Thread Overlap

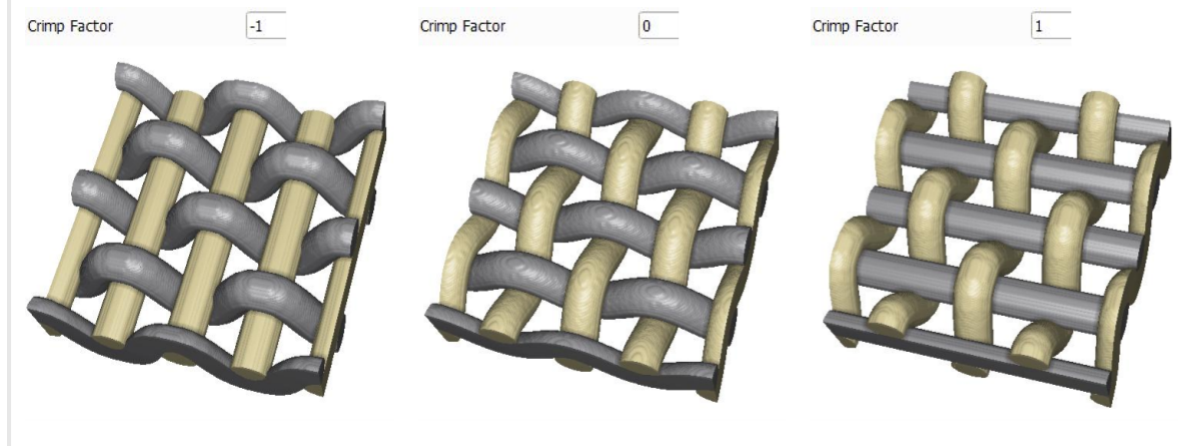
The amount of overlap that the threads show at their crossing points is determined by the amount of **Vertical Thread Overlap**. Negative values can be used to enforce distance. The overlap, corresponding to the entered value of vertical overlap, is shown blue in the figure below (for the chosen color 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.



✓ Crimp Factor

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.



✓ Broadening

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). This means the new thread width is between 100% and 200% of the original thread width. 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.



Important! If the FreeWeave solver is chosen, the effect of the broadening is different compared to the result from the Classic solver.

Warp Broadening

0

Weft Broadening

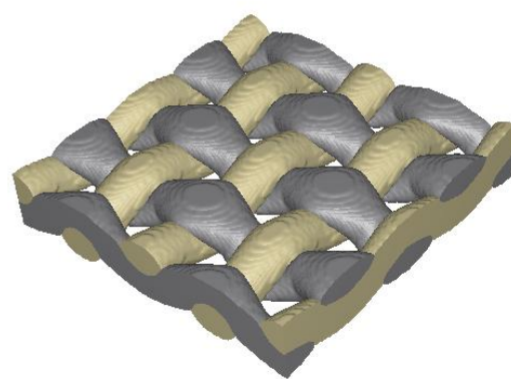
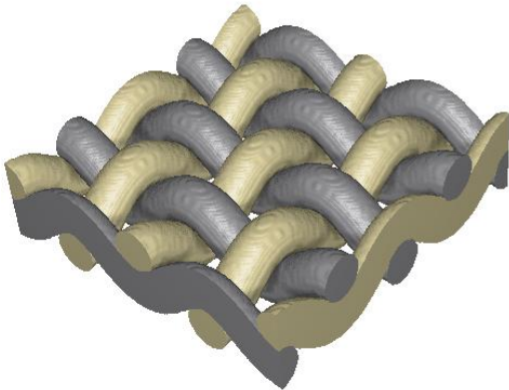
0

Warp Broadening

0.2

Weft Broadening

0.8



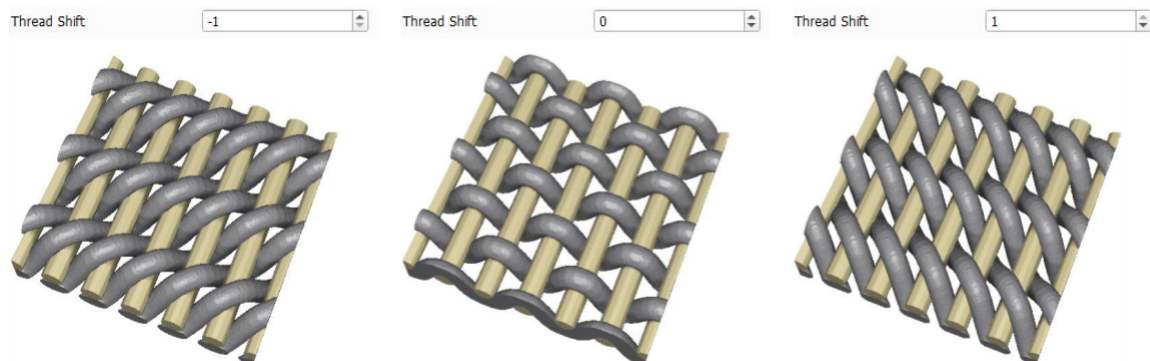
✓ Random Seed

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](#)^[8] threads are used and [Weft/Warp Lateral Deformation](#)^[41] is applied (as for the **warp** thread in the example below). 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 parameter is explained.



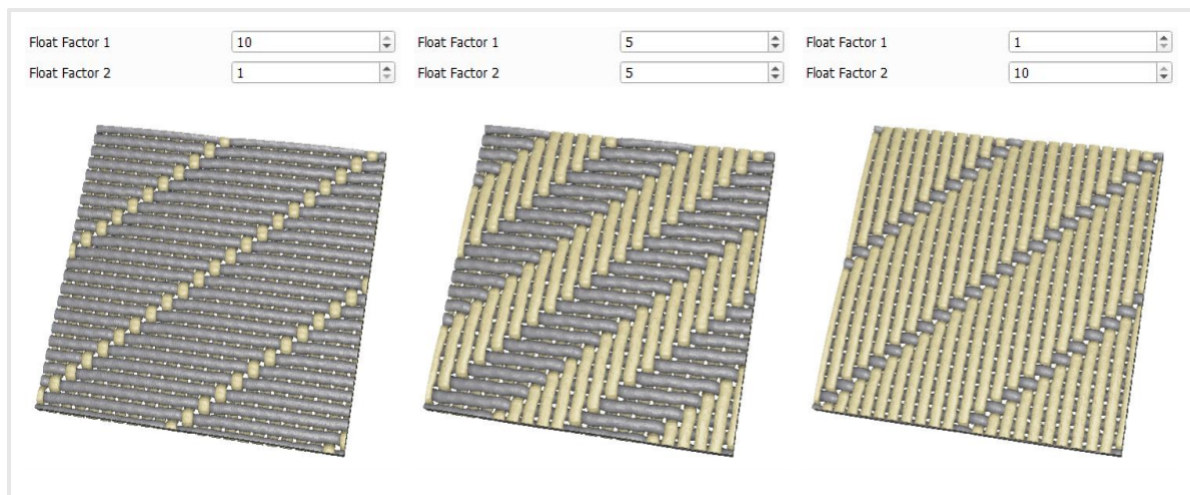
✓ Thread Shift

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.



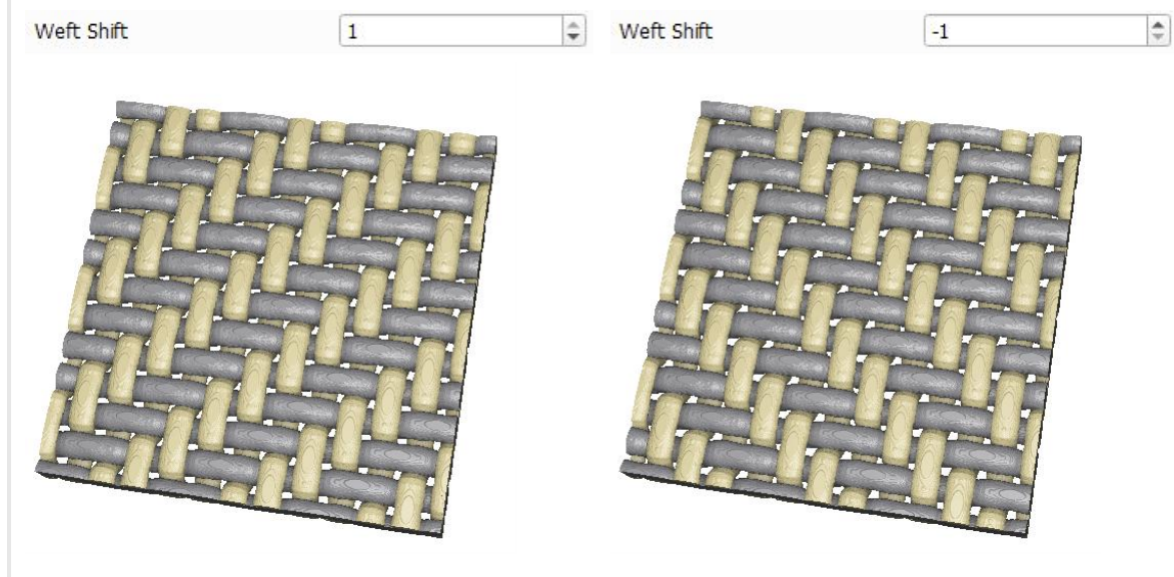
✓ Float Factors

- **Float Factor 1** and **Float Factor 2** are only available for the **Twill Weave**. Their values can vary between 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.



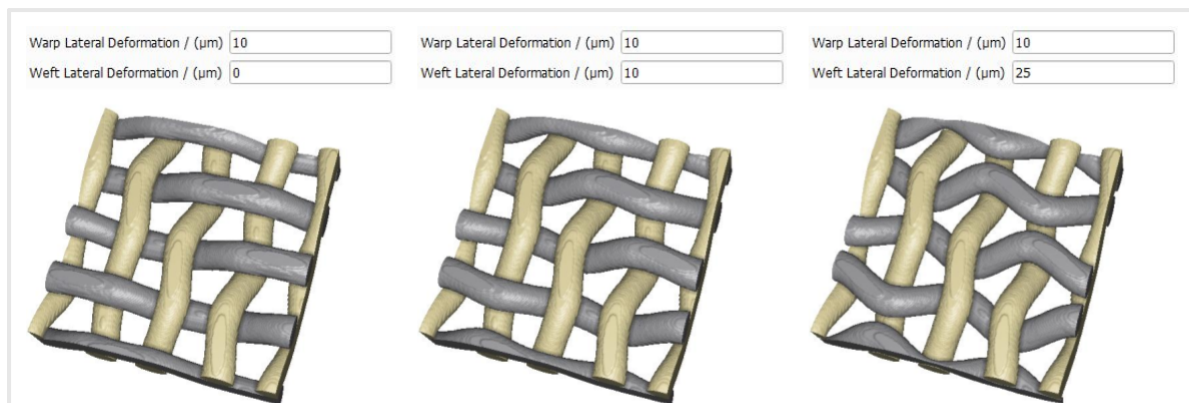
✓ Weft Shift

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.



✓ Lateral Deformation

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 **Random Seed**.



Suggest Deformation

The **Suggest Weft Deformation** button becomes available when the weave type is set to **Dutch Weave**. Similarly, if **Reverse Dutch Weave** is selected, the **Suggest Warp Deformation** button appears. 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 $\geq$ 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.

WeaveGeo - Twill Weave

GEOdict

Result File Name (*.gdr) µm ▼

Weave Shape | Domain | Threads | Solver Settings

Weave Type: Dutch Weave ▼

Warp Pitch / (µm): Warp Meshes p: cm ▼

Weft Pitch / (µm): Weft Meshes per cm:

Float Factor 1: ▼

Float Factor 2: ▼

Weft Shift: ▼

Vertical Thread Overlap / (µm):

Crimp Factor:

Warp Broadening:

Weft Broadening:

Warp Lateral Deformation / (°): Fraction of Warp Pitch / (%):

Weft Lateral Deformation / (°): Fraction of Weft Pitch / (%):

Random Seed: ▼ Suggest Weft Deformation

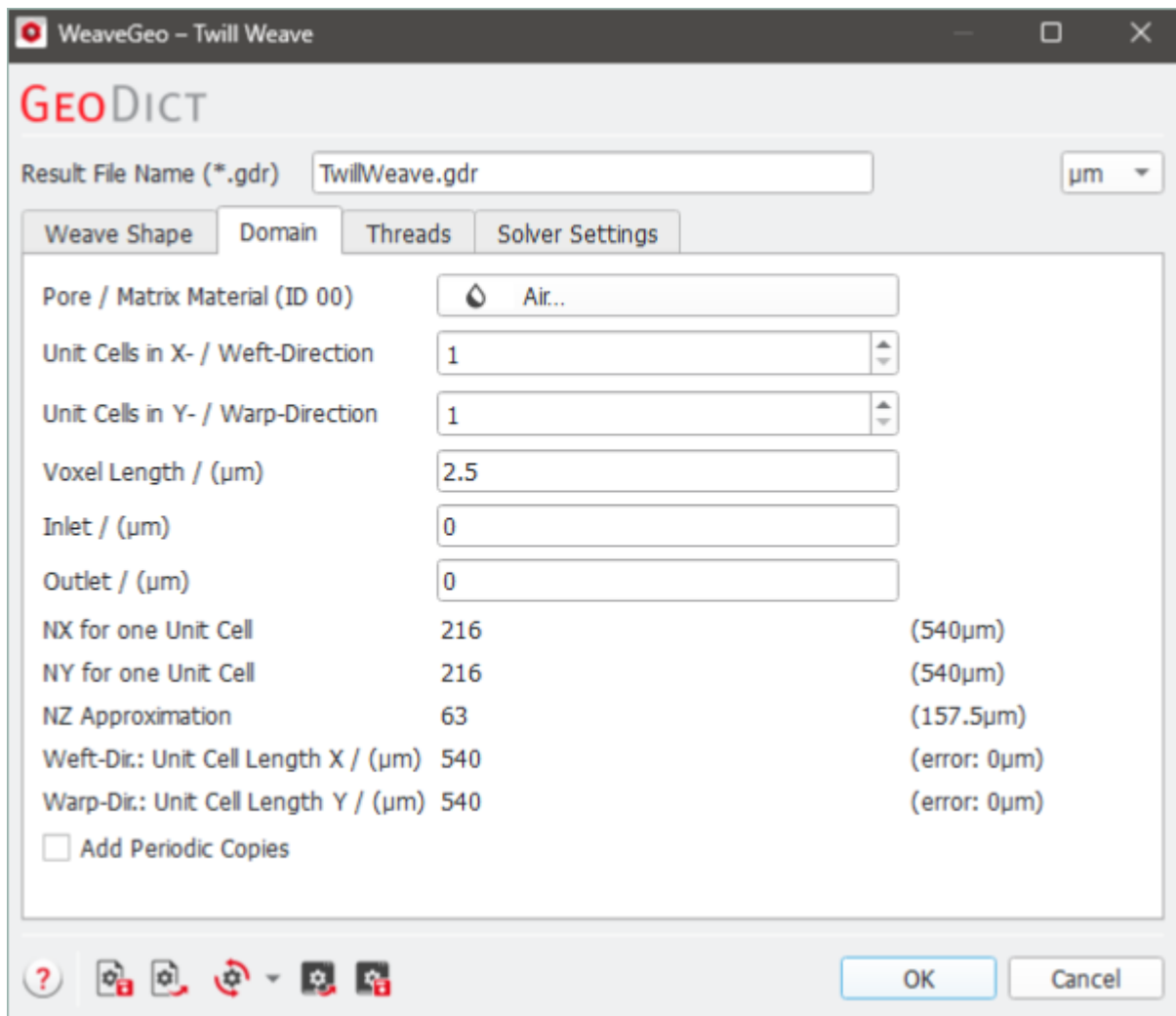
Thread Shift: ▼

? Save Undo Redo Settings Help OK Cancel

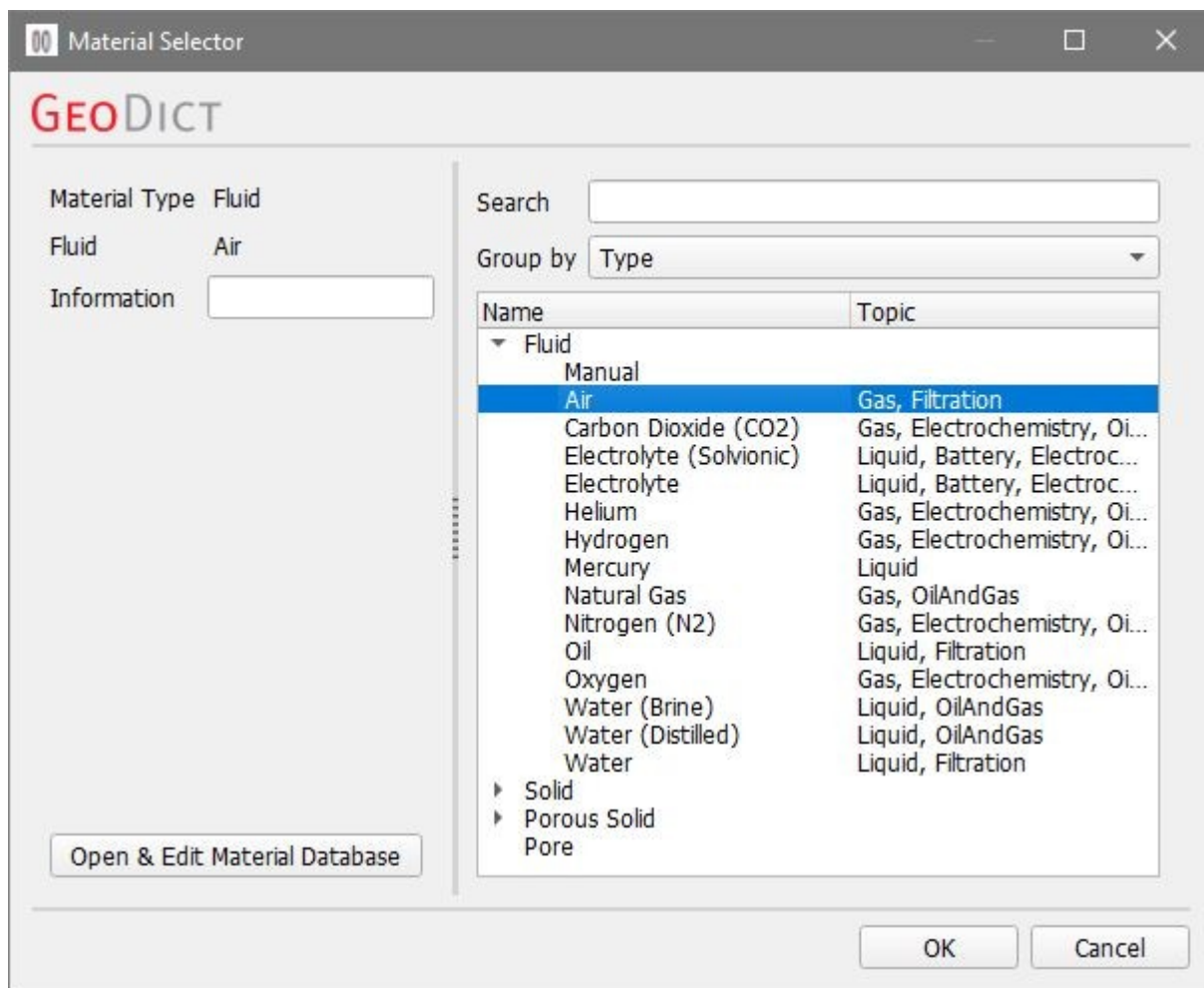
When choosing the **FreeWeave solver** in the Solver Settings tab, the lateral deformation cannot be defined. The solver finds this value automatically.

Domain

Edit the parameters for the domain in which the weave is created under the **Domain** tab.



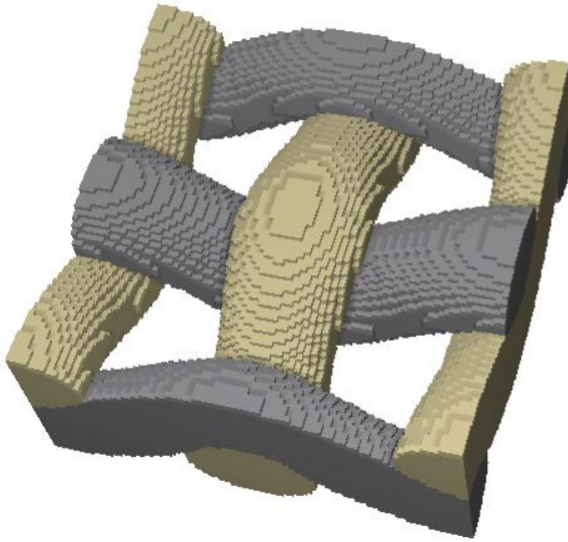
Click the **Pore/Matrix Material (ID 00)** button to open the Material Selector to select the material which occupies the space surrounding the threads (e.g., Air) from the GeoDict Material Database. The surrounding material always has **Material ID 00**.



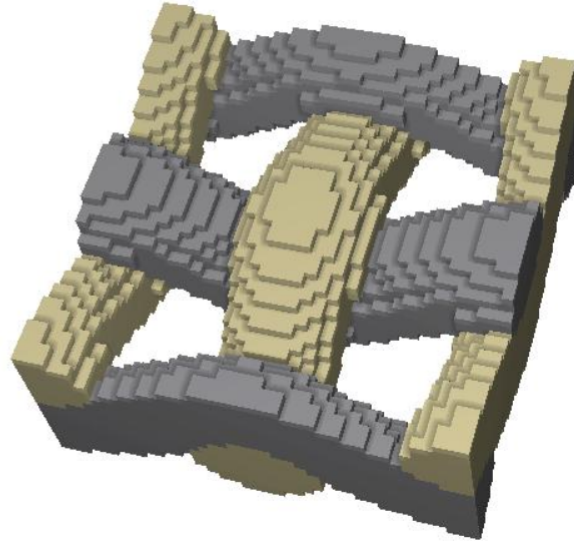
The values in **Unit Cells in X-/Weft Direction** and **Unit Cells in Y-/Warp Direction** set the number of repetitions of the generated unit cell. Thus, a large number of unit cells also leads to a larger structure.

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

▶ ● Structure (80x80x43, 5 μm)



▶ ● Structure (40x40x21, 10 μm)

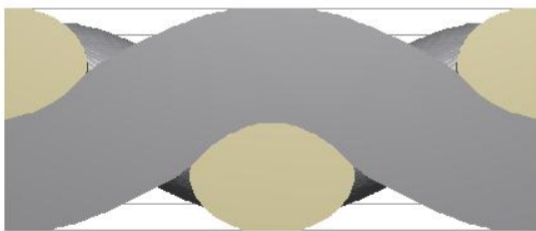


The values of **Inlet** (-Z direction) and **Outlet** (+Z direction) determine the size of the void regions in the chosen unit below and above the created woven structure.

Inlet / (μm)

Outlet / (μm)

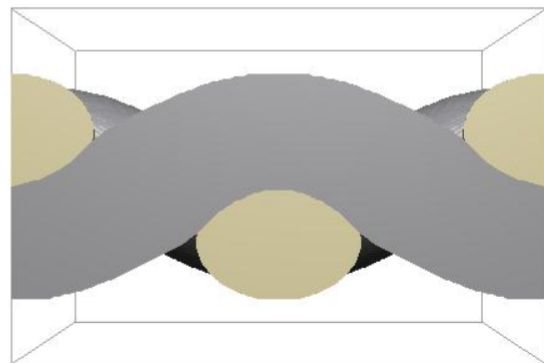
▶ ● Structure (200x200x83, 2 μm)



Inlet / (μm)

Outlet / (μm)

▶ ● Structure (200x200x133, 2 μm)



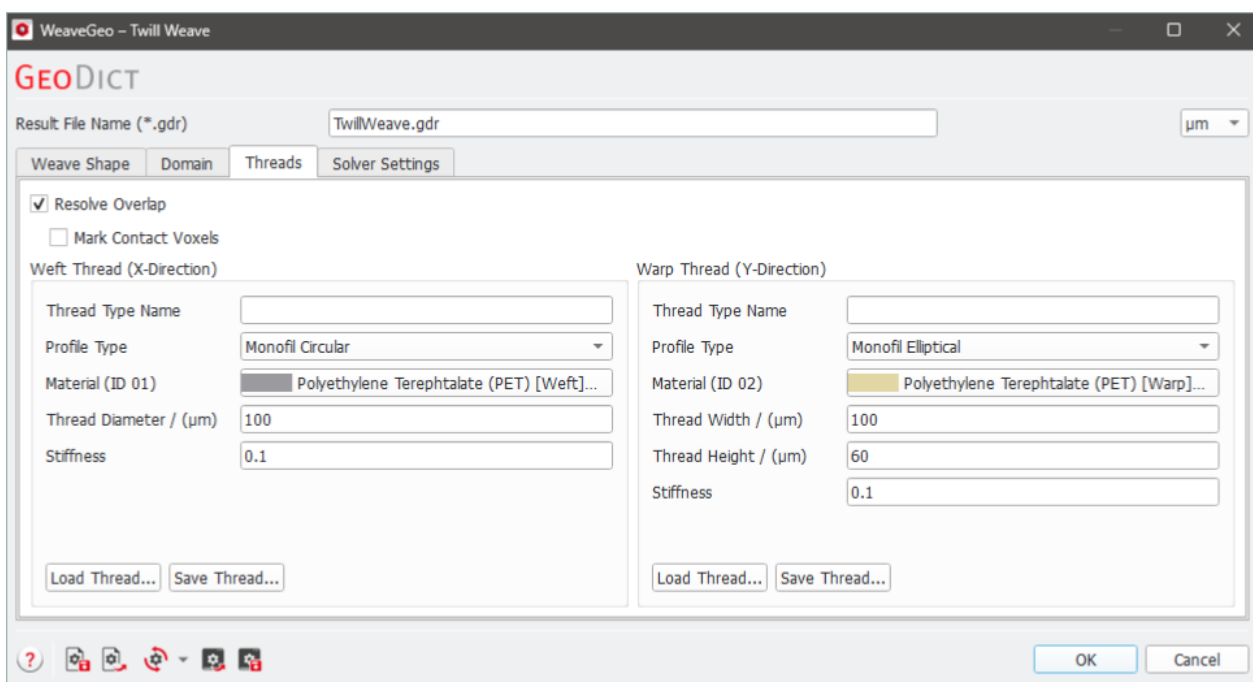
The values for **NX for one Unit Cell**, **NY for one Unit Cell**, and **NZ Approximation** indicate the number of voxels in **X**, **Y** and **Z**-direction for the unit cell. Analogously, **Weft-Dir.: Unit Cell Length X** and **Warp-Dir.: Unit Cell Length Y** show the length of the unit cell in the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

These values are not editable, since they depend on the defining parameters of the structure, such as the thread widths, pitches, and 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 or MeshGeo), this option should be enabled to prevent artifacts at the domain boundary.

Threads

In the **Threads** tab, select the parameters that define the shape of the threads, their size, and the number and shape of the filaments.



This tab is divided into three main parts. At the top select how overlapping threads should be treated. Below, 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**. Both contain the same parameters for the different thread types. Each thread can be modeled individually with different parameters.

✓ How to handle thread overlap?

Different threads might overlap in the generated structure, e.g., due to **Vertical Thread Overlap** (see [Weave Shape tab](#)). 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 more realistic structure.

☒ Resolve Overlap

☒ Mark Contact Voxels

Contact Material (ID 03)

Steel (A36) (Solid) [Contact]...

Additionally checking **Mark Contact Voxels** allows to define a separate material for the contact areas. This means, for each overlapping object a one voxel thick layer is reassigned to the **Contact Material**. In this way, even contacting threads with the same material ID can be clearly distinguished.



Know how! 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.

☐ Resolve Overlap

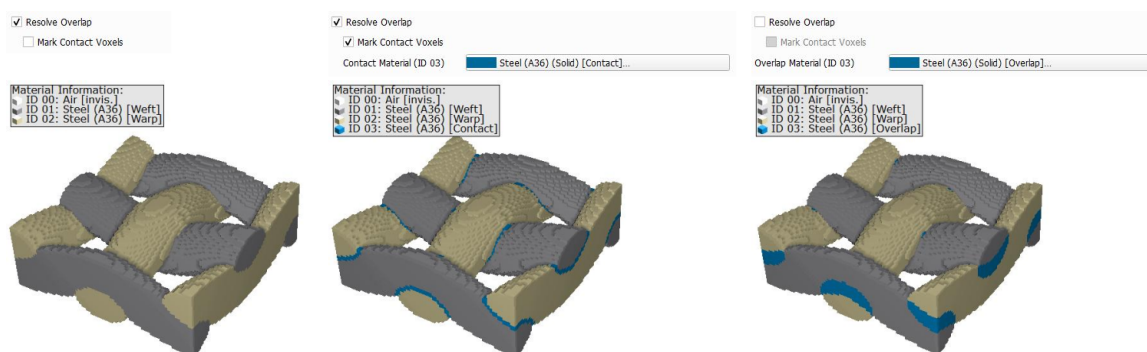
☐ Mark Contact Voxels

Overlap Material (ID 03)

Steel (A36) (Solid) [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 , while the threads have a height of 100 μm .



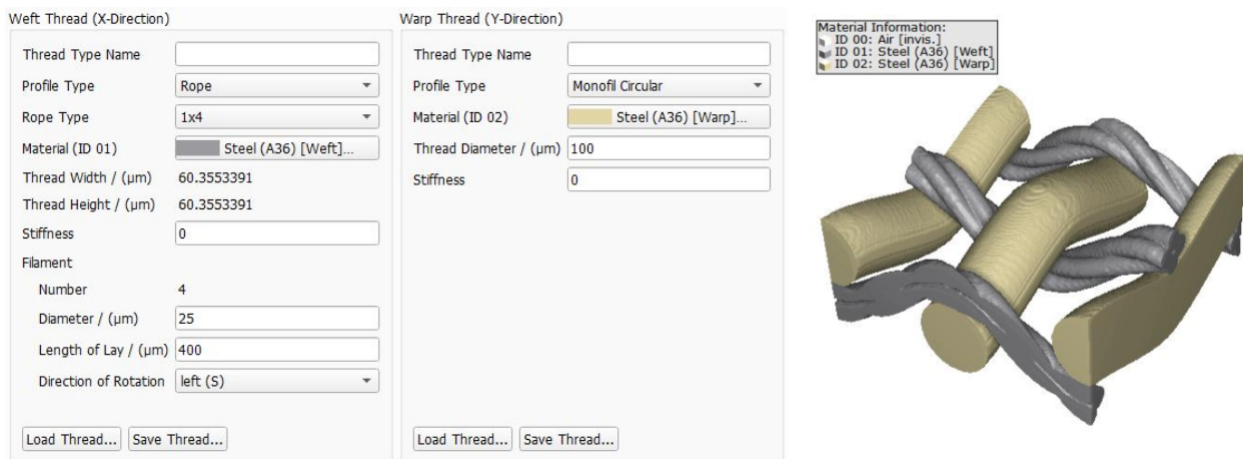
✓ Can I save and reload settings for a thread?

Yes, this is possible. At the bottom of the Weft and the Warp Thread panel, respectively, there is a **Save Thread** button. Click it to enter a name and save the parameters to a ***.gps** file. This is a GeoDict settings file.

File name: RopeThread.gps
 Save as type: Thread Type Configs::Settings (*.gps)

Previously saved threads can be imported by clicking **Load Thread**.

Thread panels



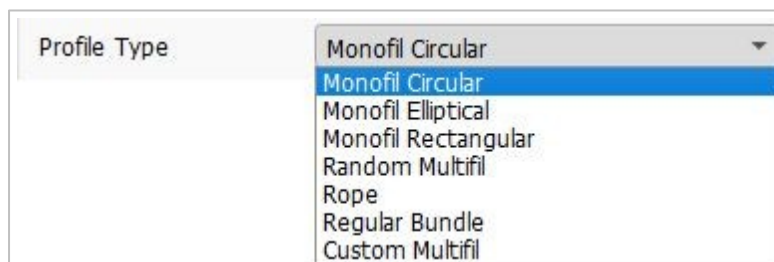
Parameters for all profile types

✓ Thread Type Name

In the **Thread Type Name** field, a name can be given to the warp or the weft thread generated with the current parameters, respectively. The name is not shown in the generated structure, only in the dialog. Giving the thread a name can support to easily recognize a loaded thread in the dialog.

✓ Profile Type

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



Monofil threads can have a **Circular**, **Elliptical**, or **Rectangular** cross-section. For the **Multifil** threads, **Random Multifil** and **Custom Multifil** are available.

See the [Thread Profile types](#) section for explanations on **Monofil**, **Multifil**, **Rope**, and **Regular Bundle** profile types.

✓Material

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**.

Click on the material name to open the Material Selector and select the material for the corresponding thread from the GeoDict Material Database.

✓Thread Width / Thread Height / Thread Diameter

Thread Width and **Thread Height** determine the size of the cross-section area of the thread. The thread height is the extent in Z-direction. As the weft thread has its longitudinal direction in X-direction, the thread width determines the extent in Y-direction. For the warp thread the thread width determines the extent in X-direction.



Note! For **Ropes** and **Custom Multifils**, the Thread Width and Thread Height cannot be entered since these parameters depend on the other rope parameters. They are only shown as information. Find more information below in the profile type specific parameters section.

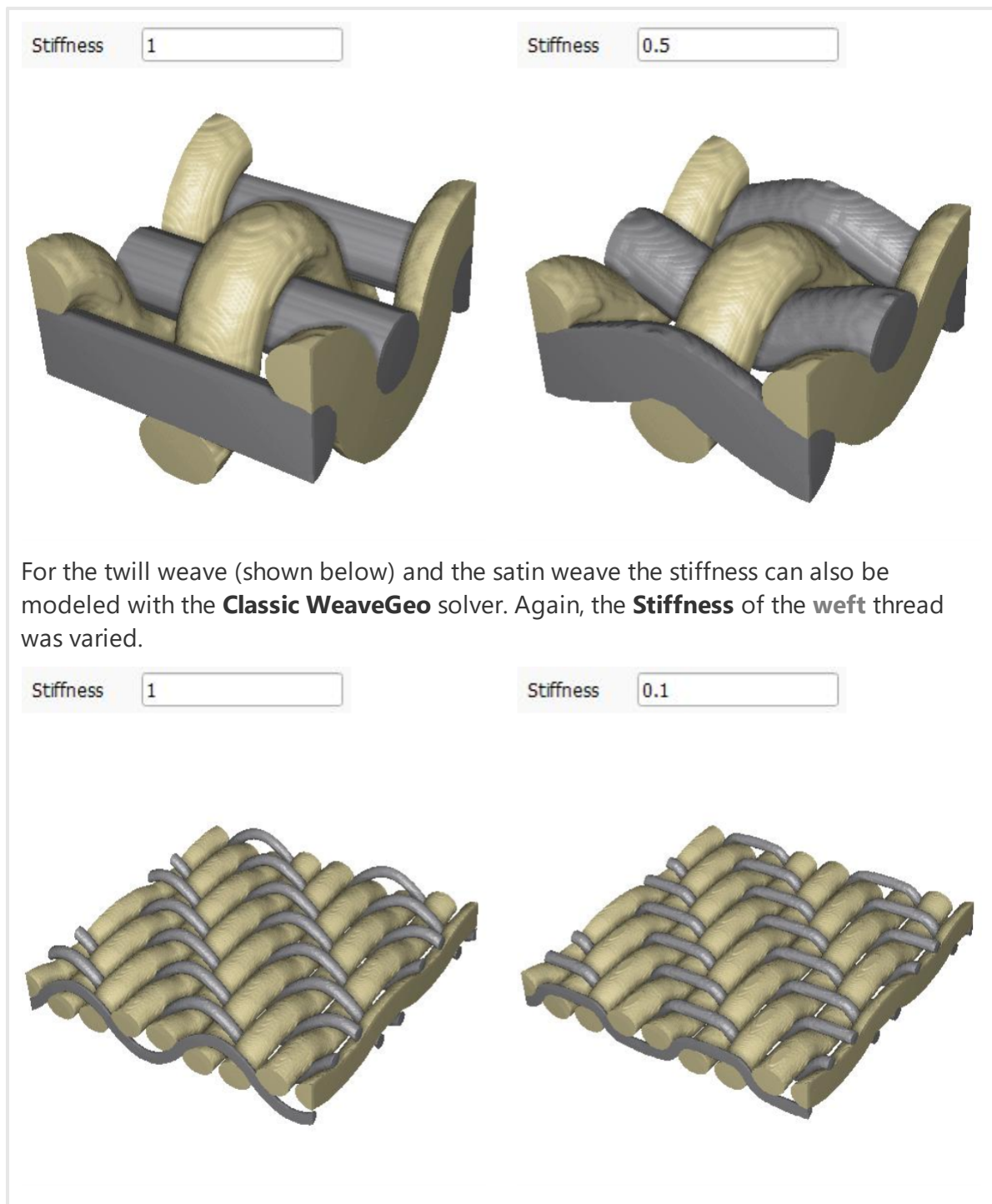


Note! For **Regular Bundle** threads, the Thread Height cannot be entered and is only shown as information. It is computed based on the number of individual filaments and the filament diameter.

In case of a **Monofil Circular** profile type, width and height are equal, so only the **Thread Diameter** can be entered.

✓Stiffness

The **Stiffness** parameter controls the bending behavior of the threads. A high stiffness indicates a rigid thread that only bends in small angles. Values for stiffness can vary from 0 to 1. This option only has an effect on plain weaves when using the FreeWeave Solver (in the [Solver Settings tab](#)). Below, an example of a plain weave is shown, where the **Stiffness** of the **weft** thread was varied.

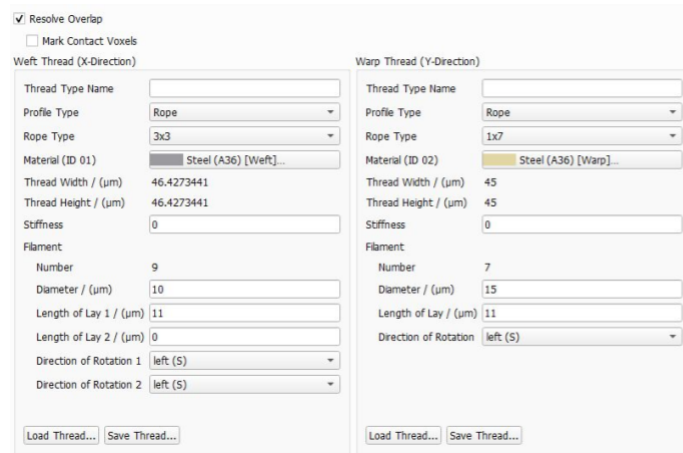


Parameters for Random Multifil, Rope, and Regular Bundle

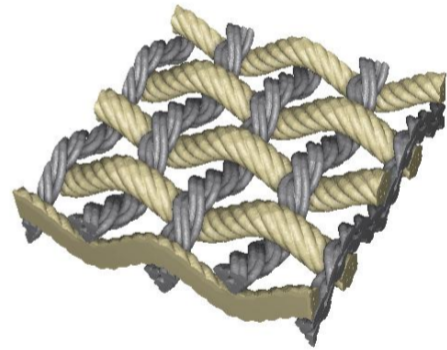
✓ Number for Ropes

For the profile type **Rope**, one of the predefined **Rope Types** must be selected from the drop-down menu. The selected **Rope Type** determines the filament **Number** which cannot be changed manually.

In the example below, the **warp** thread 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** thread is a 3x3 rope, made of 3 strands of 3 filaments, which sets 9 as the filament number. The number of **Unit Cells** in warp and weft direction (under the Domain tab) was set to 2.



The screenshot shows the 'Thread' configuration window in WeaveGeo. It is divided into two panels: 'Weft Thread (X-Direction)' and 'Warp Thread (Y-Direction)'. Both panels have identical settings for 'Thread Type Name' (empty), 'Profile Type' (Rope), 'Rope Type' (3x3 for Weft, 1x7 for Warp), 'Material (ID 01)' (Steel (A36) [Weft]), 'Thread Width / (μm)' (46.4273441), 'Thread Height / (μm)' (46.4273441), 'Stiffness' (0), and 'Filament' settings (Number: 9 for Weft, 7 for Warp; Diameter: 10 μm for Weft, 15 μm for Warp; Length of Lay: 11 μm for both; Length of Lay 2: 0 μm for both; Direction of Rotation 1 and 2: left (S) for both). At the bottom of each panel are 'Load Thread...' and 'Save Thread...' buttons.



✓ Number for Random Multifil

For **Random Multifil** profile types, an arbitrary number of filaments can be entered. The upper limit is 10,000 filaments, but keep in mind that more filaments will lead to longer structure generation times.

✓ Number for Regular Bundle

Enter the **Number** specifying the number of filaments per thread in regular bundles. Possible values are in the range from 1 to 19.

✓ Diameter

Under Diameter enter the diameter of the individual filaments, which are all equal sized.

✓ Length of Lay

Length of Lay is only available for **Random Multifil** and **Rope**. It 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,

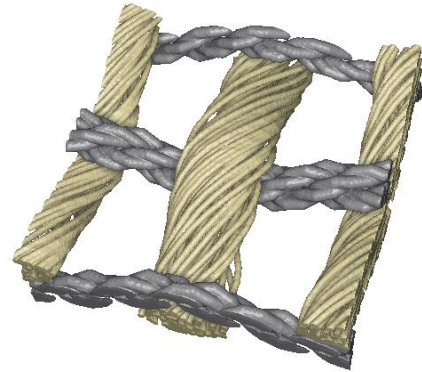
and the parameter is adjusted automatically. The choice of unrealistically short values might lead to artifacts in the generation and, therefore, to unrealistic structures. If the **Length of Lay** is set to zero, the filaments are not rotated around themselves.

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.

☒ Resolve Overlap
☐ Mark Contact Voxels

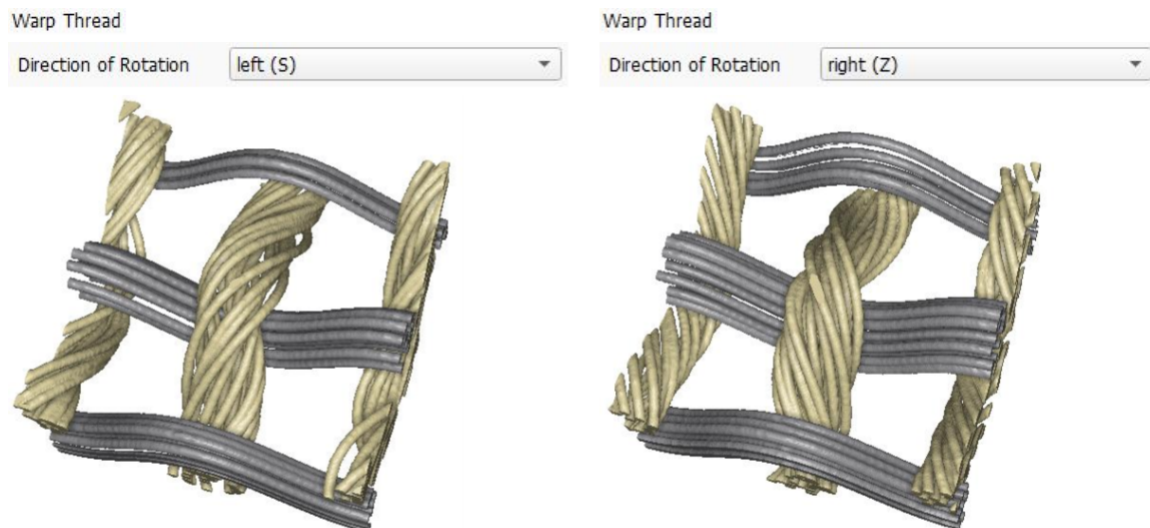
Weft Thread (X-Direction)
 Thread Type Name:
 Profile Type: **Rope**
 Rope Type: **3x3**
 Material (ID 01): **Steel (A36) [Weft]...**
 Thread Width / (μm): 46.4273441
 Thread Height / (μm): 46.4273441
 Stiffness: 0
 Filament:
 Number: 9
 Diameter / (μm): 10
 Length of Lay 1 / (μm): 5.15
 Length of Lay 2 / (μm): 5.3
 Direction of Rotation 1: **left (S)**
 Direction of Rotation 2: **right (Z)**

Warp Thread (Y-Direction)
 Thread Type Name:
 Profile Type: **Random Multifil**
 Material (ID 02): **Steel (A36) [Warp]...**
 Thread Width / (μm): 75
 Thread Height / (μm): 50
 Stiffness: 0
 Filament:
 Number: 45
 Diameter / (μm): 5
 Length of Lay / (μm): 5.1
 Direction of Rotation: **left (S)**
 Lateral Oscillation / (μm): 0



✓ Direction of Rotation

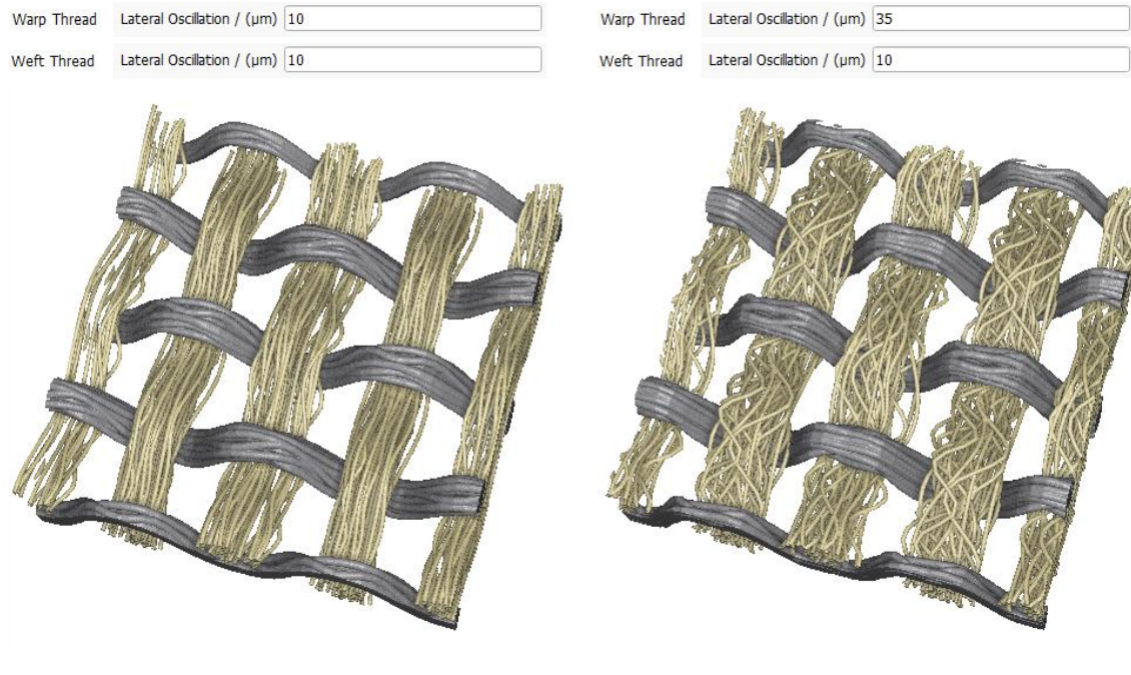
Direction of Rotation is only available for **Random Multifil** and **Rope** and sets the direction - **right** (Z-twist rope) or **left** (S-twist rope) - in which the thread is rotated around itself (here, the **warp** thread). It only has an effect if the value for **Length of Lay** is larger than zero.



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**.

✓ Lateral Oscillation

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 [Weave Shape tab](#)).



Parameters for Custom Multifil

✓ How does the Custom Multifil profile type work?

For **Custom Multifil**, the settings panel is structured hierarchically. On the first, layer the settings for the whole thread can be made. On the subsequent layers, the strands and filaments of which the thread is composed can be defined individually. At the bottom, the **Thread Width** and **Thread Height** are displayed. They cannot be edited since they are computed from the settings of the single filaments. The **Stiffness** is given for the whole thread.

On each layer the parameters **Diameter**, **Length of Lay**, **Direction**, and **Child Count** are shown. The active parameters depend on the level of the corresponding filament.

The **Diameter** is only editable for the filaments with a **Child Count** of 0 and defines their thickness. The diameter of the filament in the layer above is automatically computed based on the number of child filaments and their entered diameters.

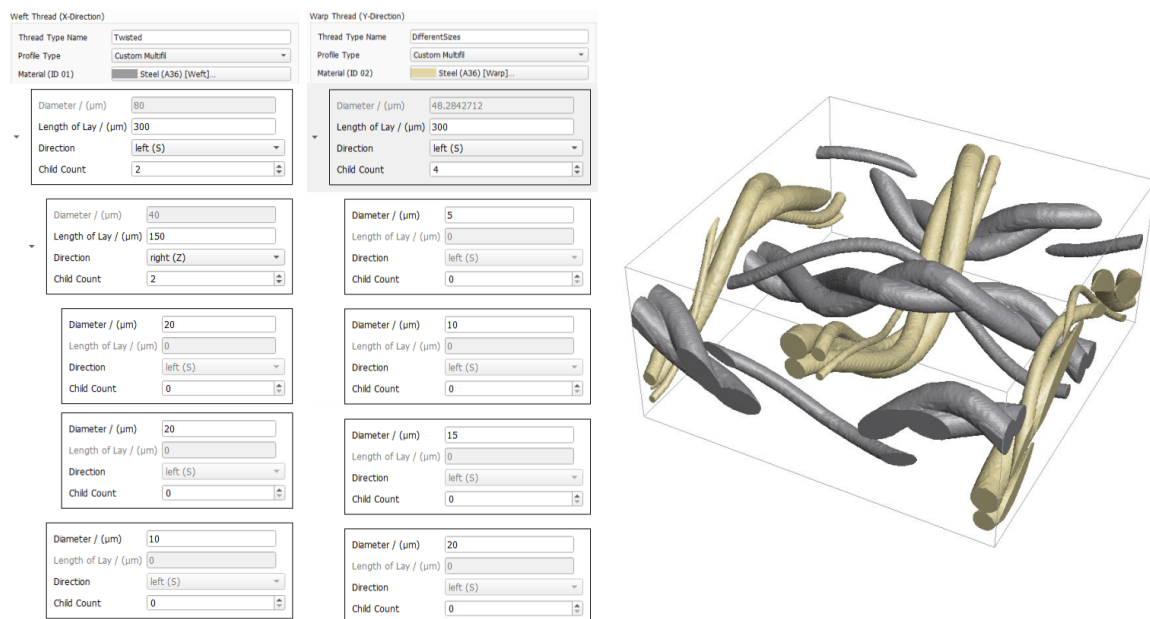


Know how! In contrast to Random Multifil threads, the filaments can have different diameters.

Length of Lay and **Direction** are the same as described above and define how a filament is twisted around itself. They are only active if **Child Count** is not zero.

Child Count defines in how many sub-filaments a filament is divided. The settings panel for each filament is displayed indented on the next layer. You can fold all lower layers by clicking on the small black triangle.

Below, a **Custom Multifil** structure is shown, generated with the shown settings. The domain length in X- and Y-direction is 300 voxels, respectively. The weft thread consists of two right (Z)-twisted filaments and a single, thinner filament twisted left (S) around them. The warp thread consists of 4 filaments with different diameters which are also twisted.



Special parameters for the FreeWeave solver

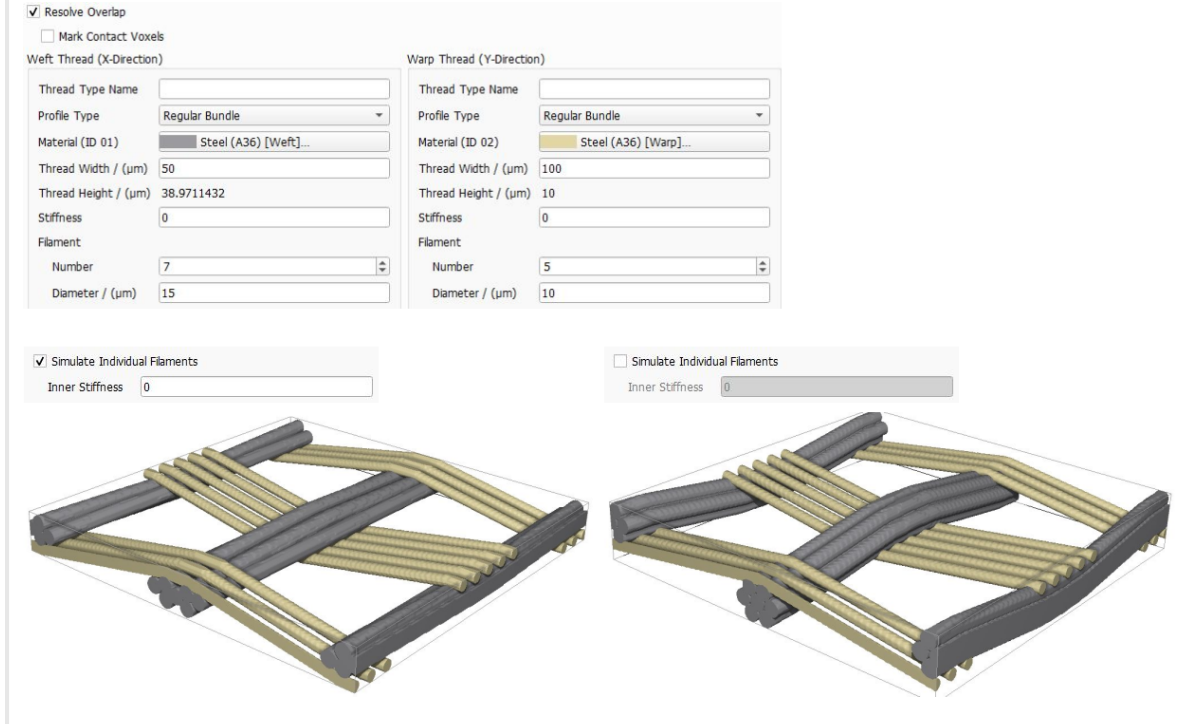
✓ Simulate Individual Filaments

If the FreeWeave Solver is chosen (in the [Solver Settings tab](#)), an additional option at the bottom of the thread panels is available. Check **Simulate Individual Filaments** to simulate interactions between the single filaments. Setting **Inner Stiffness** to a non-zero value allows you set a filament 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. When **Simulate Individual Filaments** is not active, the thread is modeled as a single circular thread. Then the filaments are placed at their computed positions.

The structure in the following example was produced with the shown settings. Observe the difference in the placement of the weft threads for **Simulate Individual Filaments**

checked and unchecked.

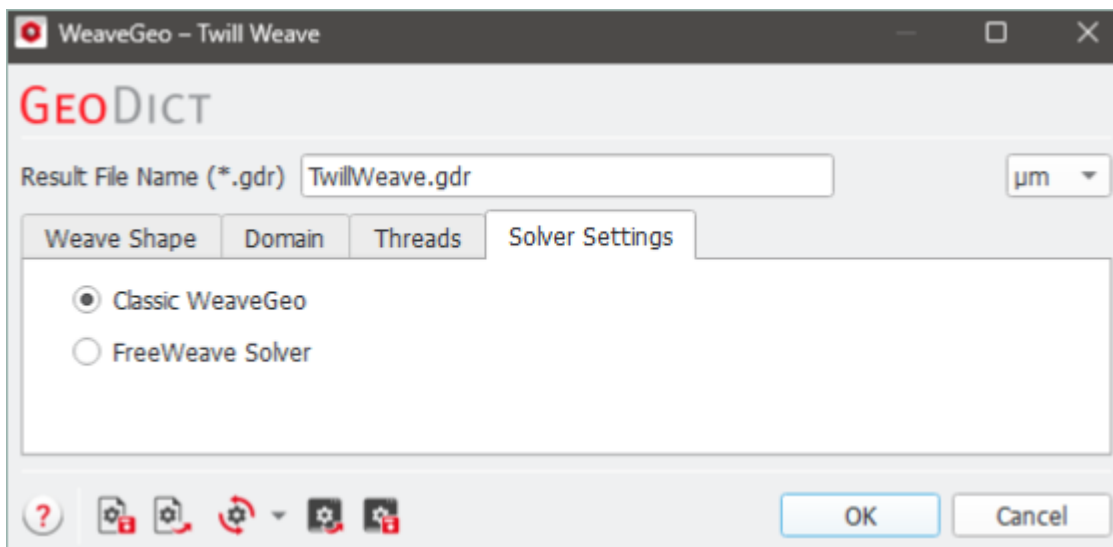
Simulate Individual Filaments is always available in the **Complex Multi-Layer Weave** command if a multifilament profile type is selected.



Solver Settings

In the **Solver Settings** tab, choose between the default **Classic WeaveGeo** solver and the **FreeWeave Solver**.

The **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. This solver has no parameters to be set.



Alternatively, you can select the **FreeWeave Solver**, which produces more realistic structures but may also result in longer generation times.

WeaveGeo - Twill Weave

GEODICT

Result File Name (*.gdr) µm

Weave Shape **Domain** **Threads** **Solver Settings**

☐ Classic WeaveGeo

☒ **FreeWeave Solver**

☒ Tolerance

☐ Maximum Iterations

Segment Max. Length (min. diameter fraction)

Segment Min. Length (min. diameter fraction)

Max. Relative Step-Size

Max. Absolute Step-Size (min. diameter fraction)

Refinement Iterations

Refinement Factor

Smoothing Subdivision

☐ Fix Lateral Warp Shift

► Advanced Options

✓ FreeWeave Solver parameters

The **FreeWeave Solver** performs a physical simulation when generating the weave as an iterative process. During the simulation, the threads are tightened and their interaction, such as collisions, is considered.

The **Tolerance** represents the reduction in the height 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 method is not suitable for all types of weaves. Thus, another stopping criterion is the **Maximal Iterations**, where the solver stops once the entered number of iterations is reached. These two criteria

can be selected together, and the solver will stop when either criterion 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 during one 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** 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 than or equal to 0.1 and less than or equal to 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 post-processing step after the simulation. The primary use for this is in visualization to make the structure appear smoother. As it only happens once at the end of the simulation, it is not computationally expensive. 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.

Clicking on **Advanced Options** unfolds additional solver settings. They do not need to be changed for most simulations. Tooltips describe how they can be used if they need to be adjusted.

▼ Advanced Options

☒ Fix First Crossing Position

☐ Write Debug Output Interval

Segment length algorithm

☒ Use New Collision Algorithm

Inflate Iterations

Initial Thread Diameter Scale Factor

Height (Z) scale factor

Segment length mode

Segment length override

Segment Size Scale Iterations

Segment Size Scale Initial Factor

☐ Visualize Segments

Multifil broadening smooth factor

Overlap Scale Iterations

Broadening Scale Iterations

1

ProportionalSubdivision

0

1

1

Constant

0

0

1

0

0

0

Restore default solver settings

When the option **Fix First Crossing Position** is enabled, the first crossing point remains fixed at its initial position, preventing drift in the XY plane during the iteration.

Enable **Write Debug Output Interval** to save the intermediate structure to the result folder every N iterations.

Choose the algorithm to regulate the segment length when approximating fiber trajectory with the **Segment length algorithm**:

- **Legacy:** this algorithm splits and merges segments during the simulation. It was called *Old Segment Length Algorithm* in previous versions.
- **Standard:** this algorithm subdivides segments once before the simulation and then normalizes the segment lengths during simulations.
- **Proportional Subdivision:** this algorithm uses the same strategy as Standard, but matches the target lengths more accurately.

Enable the option **Use New Collision Algorithm** to perform a more accurate collision detection. With this option enabled, cylinder-to-cylinder collisions are tested instead of sphere-to-cylinder collisions.

The number of initial iterations in which to gradually inflate warp threads can be set

under **Inflate Iterations**.

The **Initial Thread Diameter Scale Factor** specifies the initial fraction of the thread diameter used at the start of the simulation. For example, a value of 0.2 means that the threads start 20% of their defined diameter and gradually expand to 100%.

The Z-height will be scaled by the **Height (Z) scale factor**. It is recommended to set this factor to the same value as **Initial Thread Diameter Scale Factor**.

The **Segment length mode** determines how the target segment length varies with the fiber diameter.

- **Constant**: the segment lengths are constant and independent of the fiber diameter.
- **Relative to diameter**: the segment lengths are proportional to the fiber diameter.
- **Relative to cross-section area**: the segment length are proportional to the fiber cross-section area.

The **Segment length override** factor defines whether and how the segment length will be overridden. For non-zero values, the segment length override is enabled. The resulting behavior also depends on the chosen Segment length mode:

- For the **Constant** segment length mode, this value defines the length of segments in meters.
- For the **Relative to diameter** mode, the segment length is the fiber diameter multiplied by this value.
- For the **Relative to cross-section area** mode, the segment length is the fiber cross-sectional area multiplied by this value.

The **Segment Size Scale Iterations** defines the number of initial iterations in which the segment length is gradually increased. This option only works properly with the **Legacy** segment length algorithm.

The **Segment Size Scale Initial Factor** specifies the fraction of segment length used at the start of the simulation. For example, a value of 0.2 means that the initial segment length is 20% of the defined segment length.

If the option **Visualize Segments** is checked, control points of the segments are shown using spheres.

The **Multifil broadening smooth factor** is an integer value that controls the smoothing of the curvature computation. If this value is greater than zero, a broadening algorithm is enabled that computes broadening for the entire multifilament bundle instead of the individual filaments.

The **Overlap Scale Iterations** parameter defines the number of initial iterations during which the overlap is gradually increased to the specified maximum value. In the first iteration, no overlap is applied.

The **Broadening Scale Iterations** parameter defines the number of initial iterations during which the broadening is gradually increased to the specified maximum value. In

the first iteration, no broadening is applied.

1.2.3 Satin Weave

The **Satin Weave** command creates a smooth patterned weave. In this weave, the weft thread passes over at least four warp threads before passing under one.

The screenshot shows the 'WeaveGeo - Satin Weave' dialog box. At the top, the 'Result File Name (*.gdr)' field contains 'SatinWeave.gdr' and a unit dropdown menu is set to 'µm'. Below this are four tabs: 'Weave Shape', 'Domain', 'Threads', and 'Solver Settings'. The 'Weave Shape' tab is selected, displaying various parameters for configuring the weave. These include 'Weave Type' (set to 'Regular'), 'Warp Pitch / (µm)' (100), 'Weft Pitch / (µm)' (200), 'Satin Float Factor' (4), 'Weft Shift' (2), 'Vertical Thread Overlap / (µm)' (0), 'Crimp Factor' (0.5), 'Warp Broadening' (0), 'Weft Broadening' (0), 'Warp Lateral Deformation / (µm)' (0), 'Weft Lateral Deformation / (µm)' (0), 'Fraction of Warp Pitch / (%)' (0), 'Fraction of Weft Pitch / (%)' (0), and 'Random Seed' (42). At the bottom of the dialog are 'OK' and 'Cancel' buttons.

At the top of the **Edit...** dialog, the name for the folder containing the generation results can be entered in the **Result File Name (*.gdr)** box. You can either keep the default name or choose a new one that fits 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**.

The Satin Weave parameters:

- [Weave Shape](#) ⁶²

In this tab the settings for the weave are made.

The Satin Weave parameters:

- [Domain](#)⁷⁰
In this tab, the parameters for the domain in which the weave is created are entered.
- [Threads](#)⁷⁴
All parameters defining the shape of the threads, the size, and the number and shape of the filaments are entered under the Threads tab.
- [Solver Settings](#)⁸³
Choose the solver in this tab and define settings if available.

Weave Shape

The parameters for the Satin Weave are similar to those for the [Plain Weave](#)¹⁴. First, the parameters that also appear in the Plain Weave dialog are described. Below are the descriptions for all Satin Weave specific parameters.

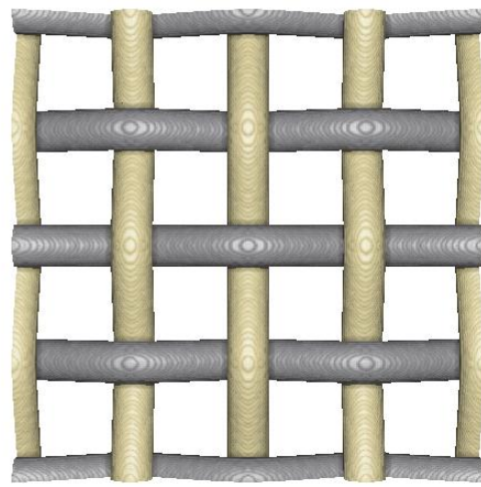
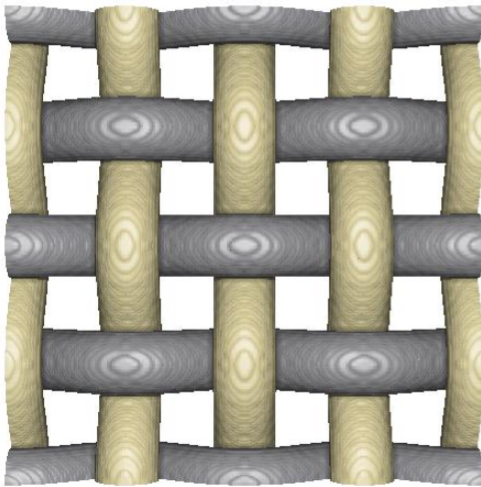
The screenshot shows the 'WeaveGeo - Satin Weave' dialog box. At the top, the 'Result File Name (*.gdr)' is 'SatinWeave.gdr' and the unit is 'μm'. The 'Weave Shape' tab is selected, showing various parameters for creating a satin weave. The 'Weave Type' is set to 'Regular'. The 'Warp Pitch' is 100 μm and 'Weft Pitch' is 200 μm. The 'Satin Float Factor' is 4 and 'Weft Shift' is 2. The 'Vertical Thread Overlap' is 0 μm, 'Crimp Factor' is 0.5, 'Warp Broadening' is 0, and 'Weft Broadening' is 0. The 'Warp Lateral Deformation' and 'Weft Lateral Deformation' are both 0 μm. The 'Fraction of Warp Pitch' and 'Fraction of Weft Pitch' are both 0%. The 'Random Seed' is 42. The dialog has 'OK' and 'Cancel' buttons at the bottom right.

The weave type can be selected from the [Weave Type](#)⁶ drop-down menu. The available weave types are Regular, Dutch Weave, and Reverse Dutch Weave.

✓ Pitch and Meshes

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. The warp (or weft) threads touch if the entered pitch is equal to the width of the warp (or weft) thread.

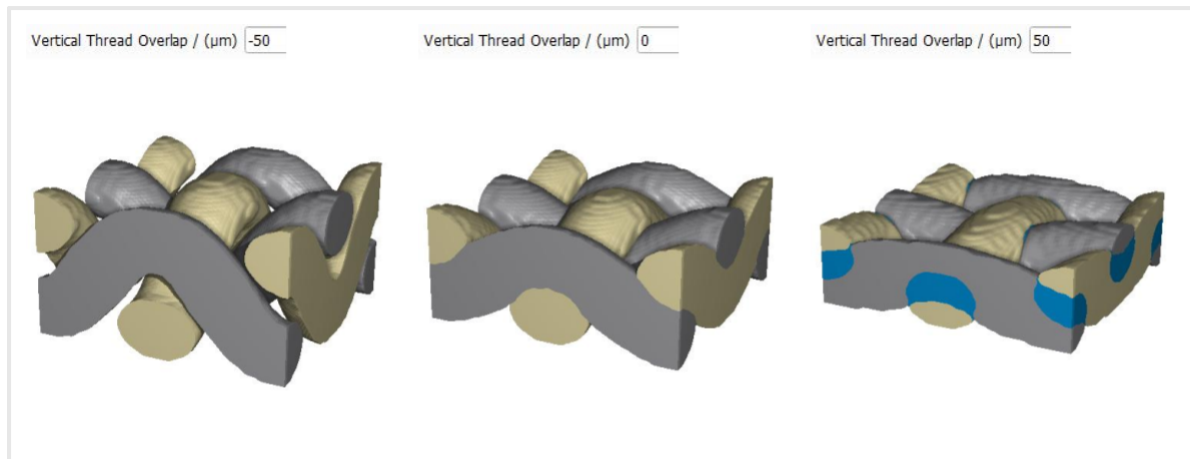
Warp Pitch / (μm)	200	Warp Pitch / (μm)	300
Weft Pitch / (μm)	200	Weft Pitch / (μm)	300



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.

✓ Vertical Thread Overlap

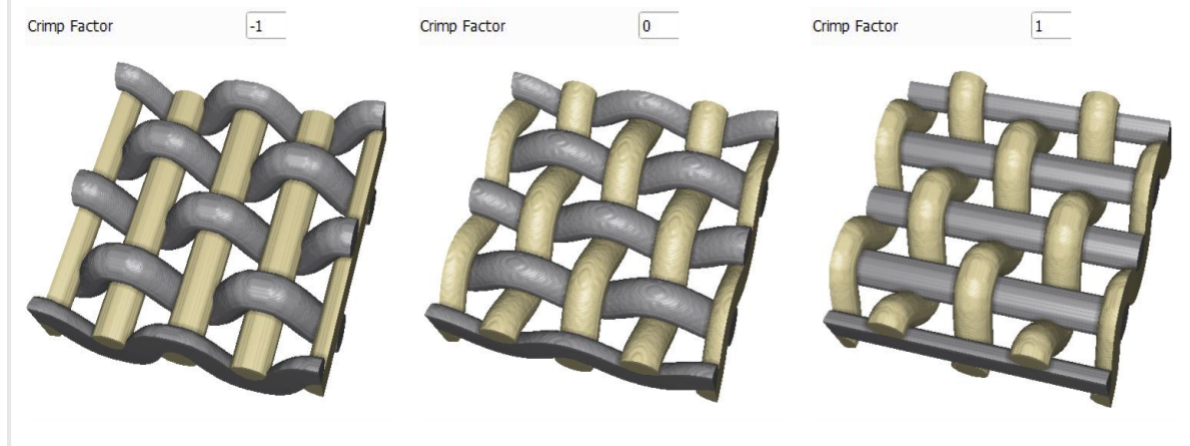
The amount of overlap that the threads show at their crossing points is determined by the amount of **Vertical Thread Overlap**. Negative values can be used to enforce distance. The overlap, corresponding to the entered value of vertical overlap, is shown blue in the figure below (for the chosen color 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.



✓ Crimp Factor

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.



✓ Broadening

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). This means the new thread width is between 100% and 200% of the original thread width. 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.



Important! If the FreeWeave solver is chosen, the effect of the broadening is different compared to the result from the Classic solver.

Warp Broadening

0

Weft Broadening

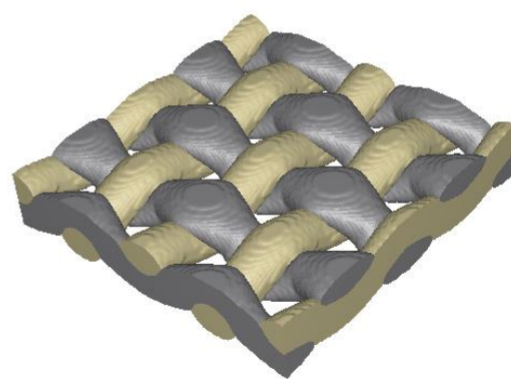
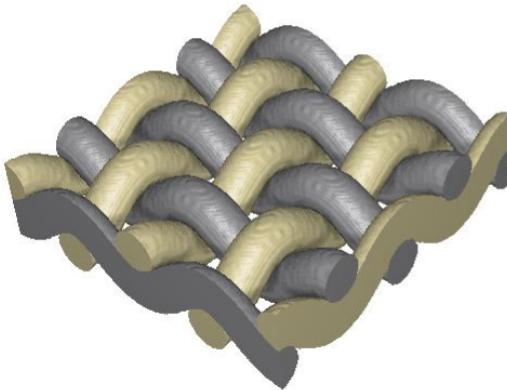
0

Warp Broadening

0.2

Weft Broadening

0.8



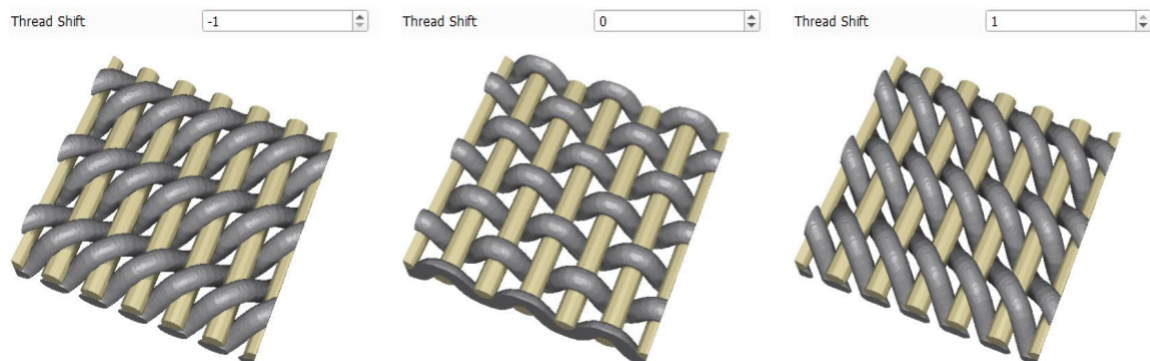
✓ Random Seed

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](#)^[8] threads are used and [Weft/Warp Lateral Deformation](#)^[41] is applied (as for the **warp** thread in the example below). 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 parameter is explained.



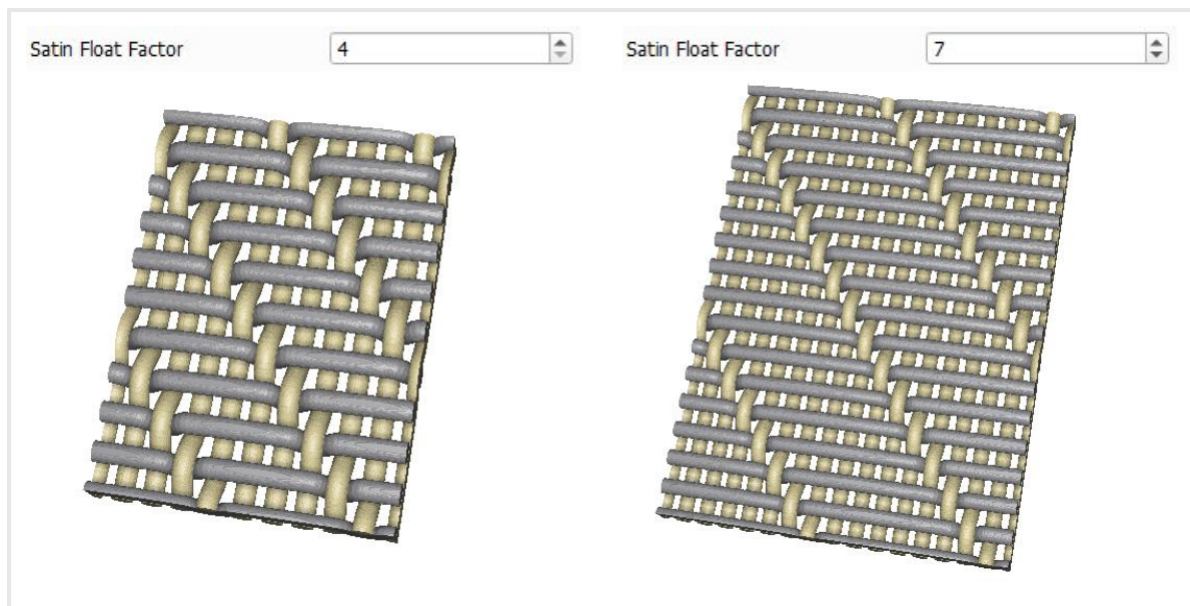
✓ Thread Shift

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.



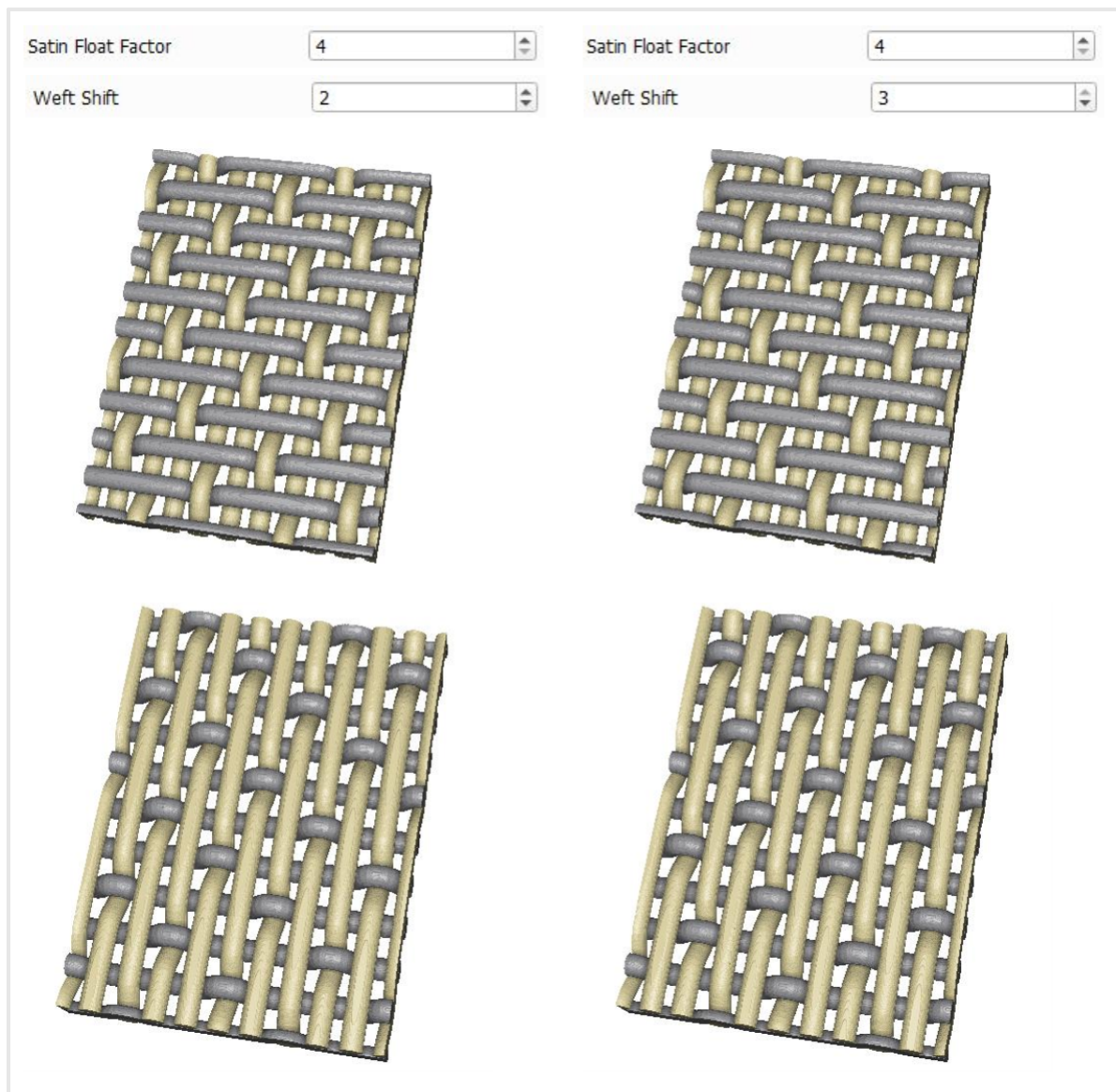
✓ Satin Float Factor

The **Satin Float Factor**, which is specific to the satin weave, can range from 4 to 10. This value controls the number of weft threads that float over the warp threads. Examples of typical satin weaves are Satin 4/1 and Satin 7/1, which correspond to float factors of 4 and 7, respectively.



✓ Weft Shift

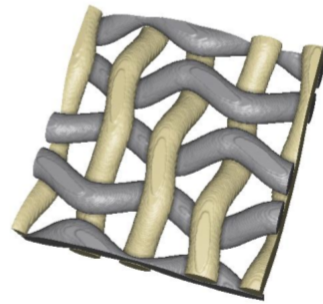
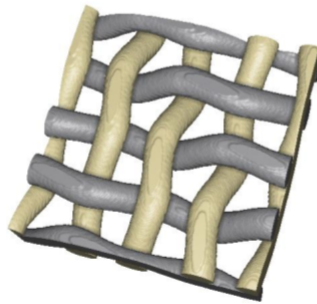
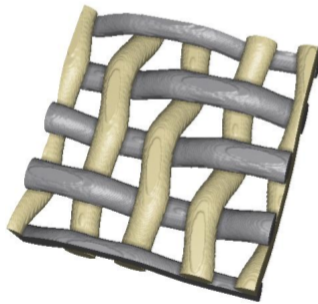
The **Weft Shift** defines the offset between successive weft threads. For **Satin Weaves** the available options differ from those available for **Twill Weaves**. In twill weaves, the offset is limited to 1 or -1, while for satin weaves it is at least 1 and the maximal value depends on the chosen float factor. The **Weft Shift** is an integer number, with a maximum value that is one less 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.



✓ Lateral Deformation

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 **Random Seed**.

Warp Lateral Deformation / (μm)	10	Warp Lateral Deformation / (μm)	10	Warp Lateral Deformation / (μm)	10
Weft Lateral Deformation / (μm)	0	Weft Lateral Deformation / (μm)	10	Weft Lateral Deformation / (μm)	25



Suggest Deformation

The **Suggest Weft Deformation** button becomes available when the weave type is set to **Dutch Weave**. Similarly, if **Reverse Dutch Weave** is selected, the **Suggest Warp Deformation** button appears. 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 $\geq$ 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.

WeaveGeo - Twill Weave

GEO DICT

Result File Name (*.gdr) μm ▼

Weave Shape | Domain | Threads | Solver Settings

Weave Type: Dutch Weave ▼

Warp Pitch / (μm): Warp Meshes p cm ▼

Weft Pitch / (μm): Weft Meshes per cm

Float Factor 1: ▲ ▼

Float Factor 2: ▲ ▼

Weft Shift: ▲ ▼

Vertical Thread Overlap / (μm):

Crimp Factor:

Warp Broadening:

Weft Broadening:

Warp Lateral Deformation / (Fraction of Warp Pitch / (%)

Weft Lateral Deformation / (Fraction of Weft Pitch / (%)

Random Seed: ▲ ▼ Suggest Weft Deformation

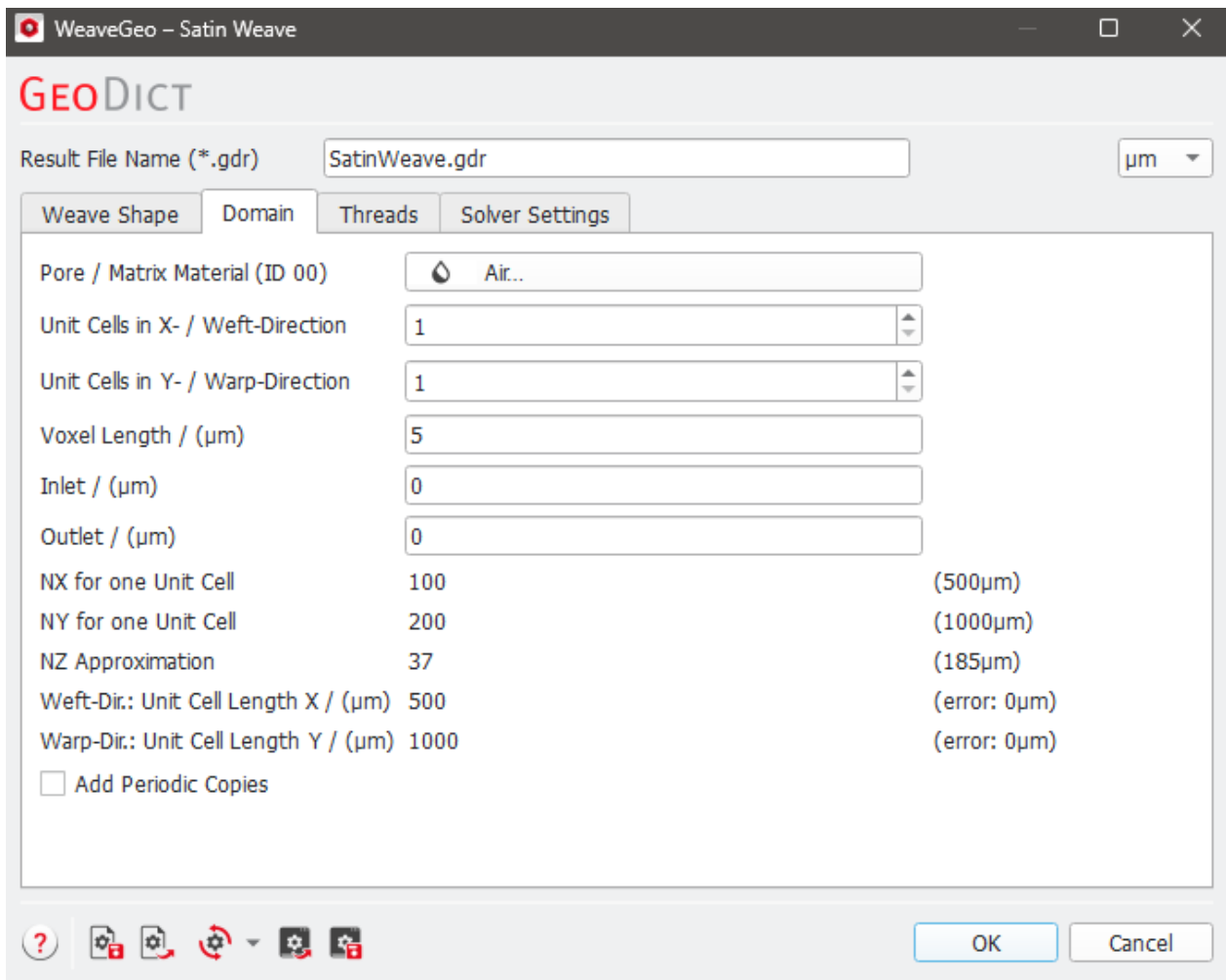
Thread Shift: ▲ ▼

? Save Undo Redo Zoom Zoom In Zoom Out OK Cancel

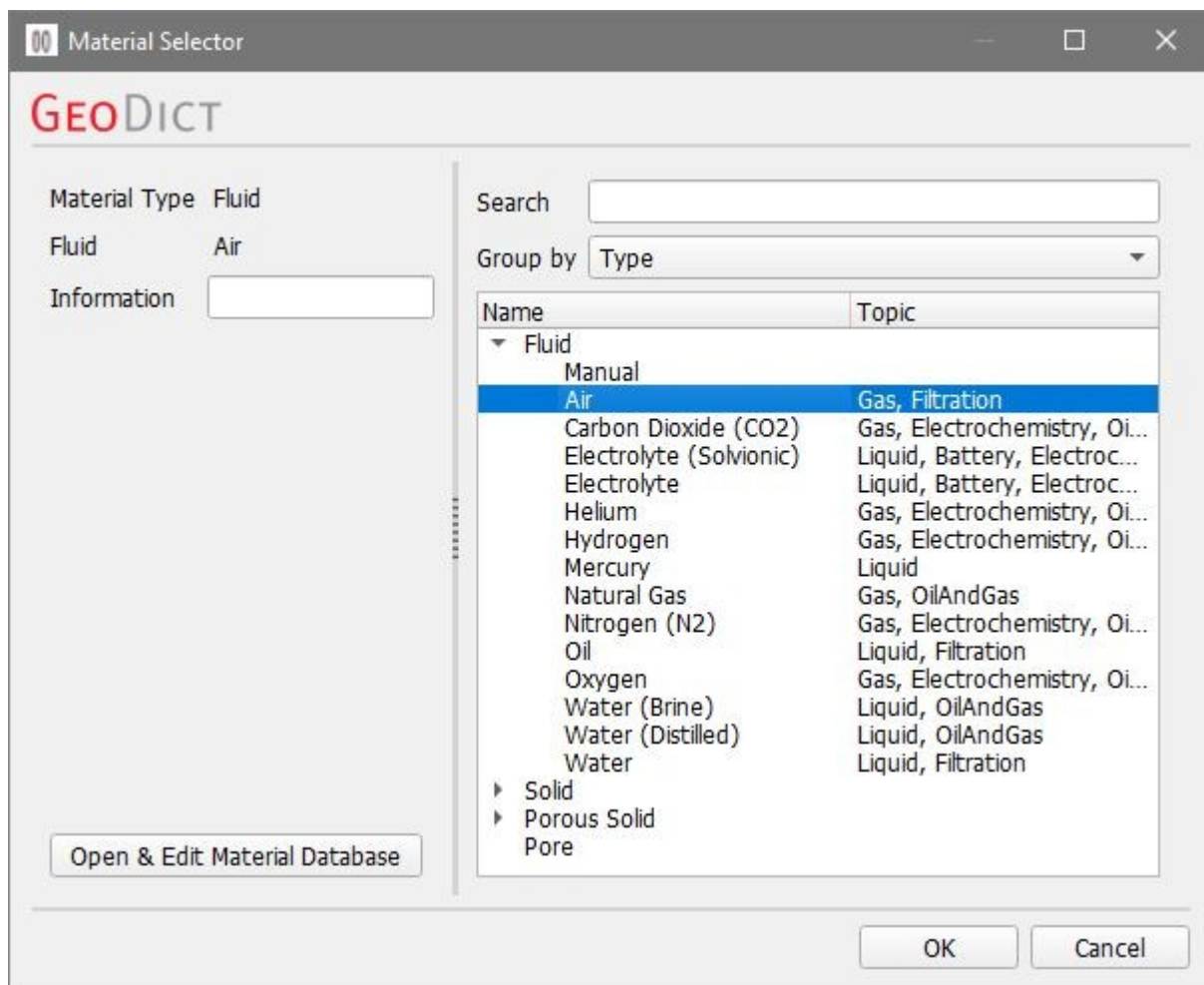
When choosing the **FreeWeave solver** in the Solver Settings tab, the lateral deformation cannot be defined. The solver finds this value automatically.

Domain

Edit the parameters for the domain in which the weave is created under the **Domain** tab.



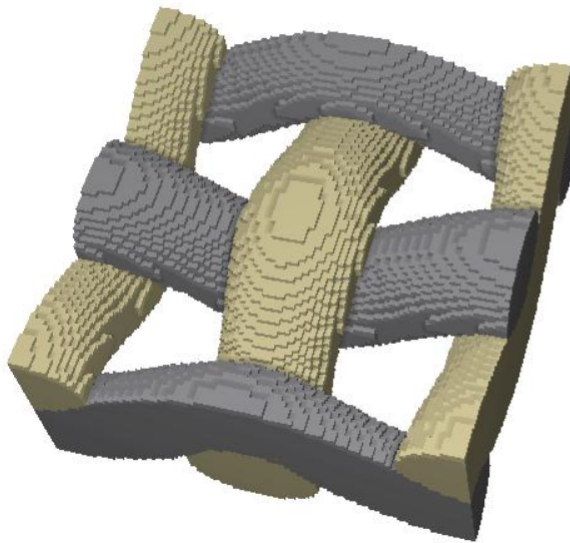
Click the **Pore/Matrix Material (ID 00)** button to open the Material Selector to select the material which occupies the space surrounding the threads (e.g., Air) from the GeoDict Material Database. The surrounding material always has **Material ID 00**.



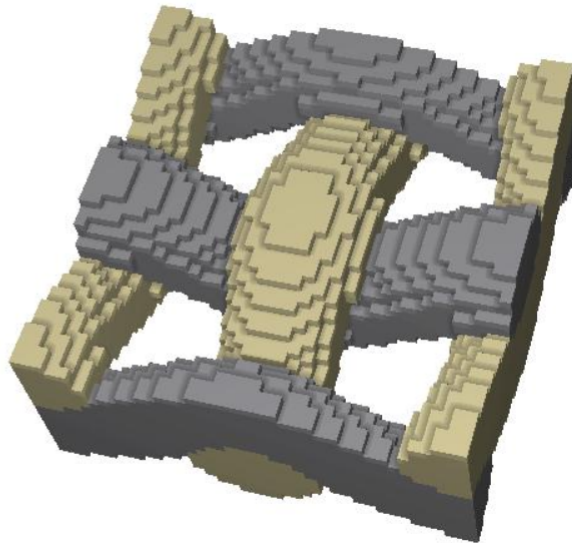
The values in **Unit Cells in X-/Weft Direction** and **Unit Cells in Y-/Warp Direction** set the number of repetitions of the generated unit cell. Thus, a large number of unit cells also leads to a larger structure.

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

▶ ● Structure (80x80x43, 5 μm)



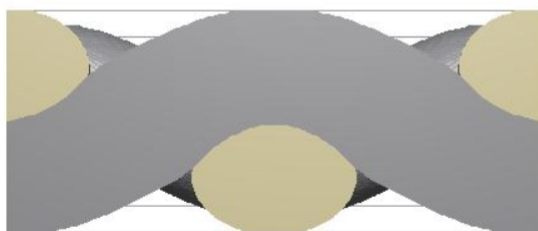
▶ ● Structure (40x40x21, 10 μm)



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.

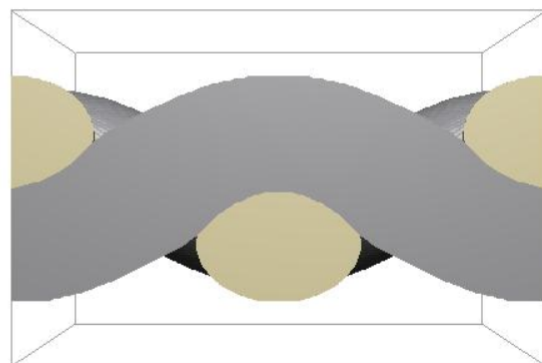
Inlet / (μm)
Outlet / (μm)

▶ ● Structure (200x200x83, 2 μm)



Inlet / (μm)
Outlet / (μm)

▶ ● Structure (200x200x133, 2 μm)



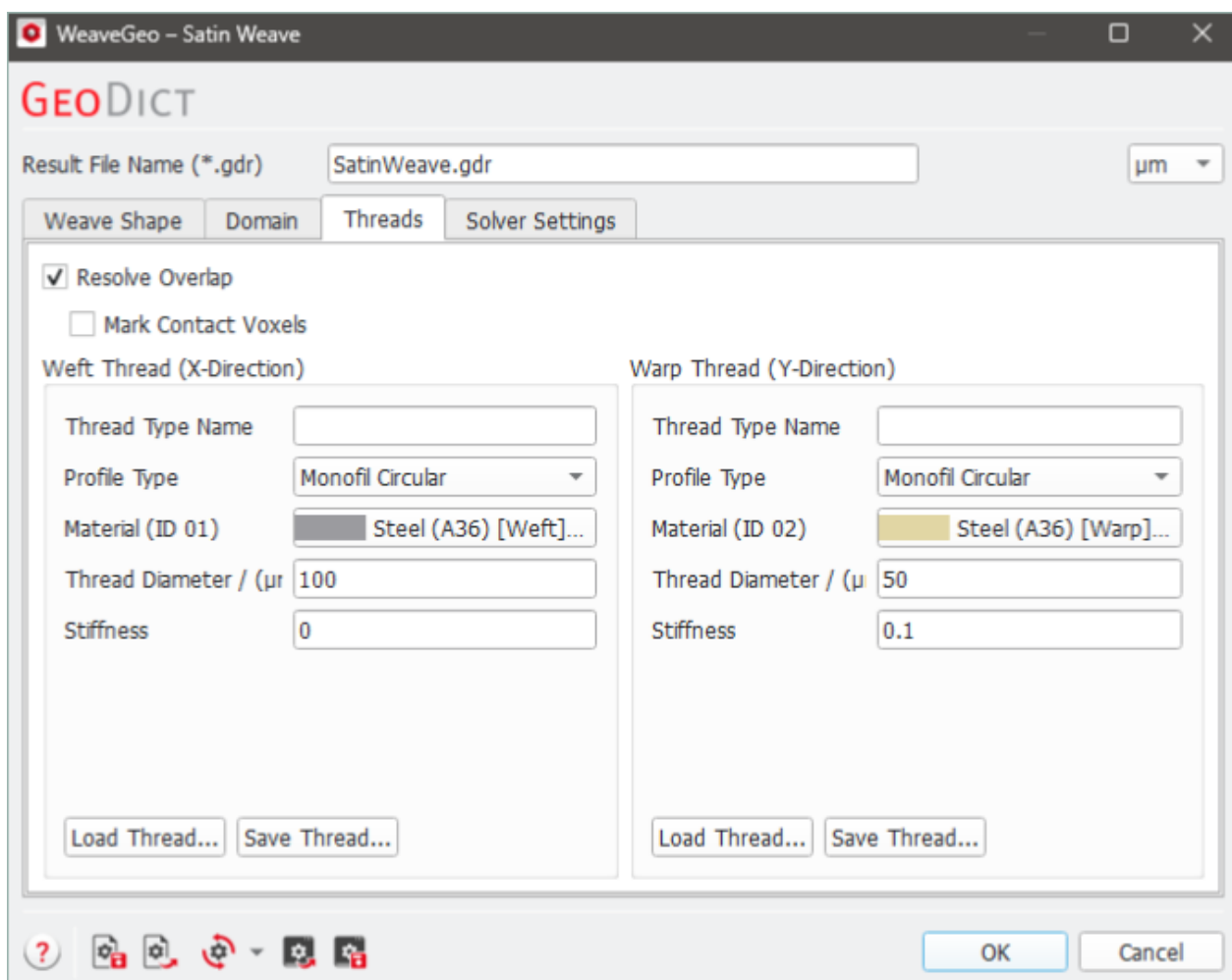
The values for **NX for one Unit Cell**, **NY for one Unit Cell**, and **NZ Approximation** indicate the number of voxels in **X**, **Y** and **Z**-direction for the unit cell. Analogously, **Weft-Dir.: Unit Cell Length X** and **Warp-Dir.: Unit Cell Length Y** show the length of the unit cell in the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

These values are not editable, since they depend on the defining parameters of the structure, such as the thread widths, pitches, and 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 or MeshGeo), this option should be enabled to prevent artifacts at the domain boundary.

Threads

In the **Threads** tab, select the parameters that define the shape of the threads, their size, and the number and shape of the filaments.



This tab is divided into three main parts. At the top select how overlapping threads should be treated. Below, 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**. Both contain the same parameters for the different thread types. Each thread can be modeled individually with different parameters.

✓ How to handle thread overlap?

Different threads might overlap in the generated structure, e.g., due to **Vertical Thread**

Overlap (see [Weave Shape tab](#)). 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 more realistic structure.

☒ **Resolve Overlap**

☒ **Mark Contact Voxels**

Contact Material (ID 03) Steel (A36) (Solid) [Contact]...

Additionally checking **Mark Contact Voxels** allows to define a separate material for the contact areas. This means, for each overlapping object a one voxel thick layer is reassigned to the **Contact Material**. In this way, even contacting threads with the same material ID can be clearly distinguished.



Know how! 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.

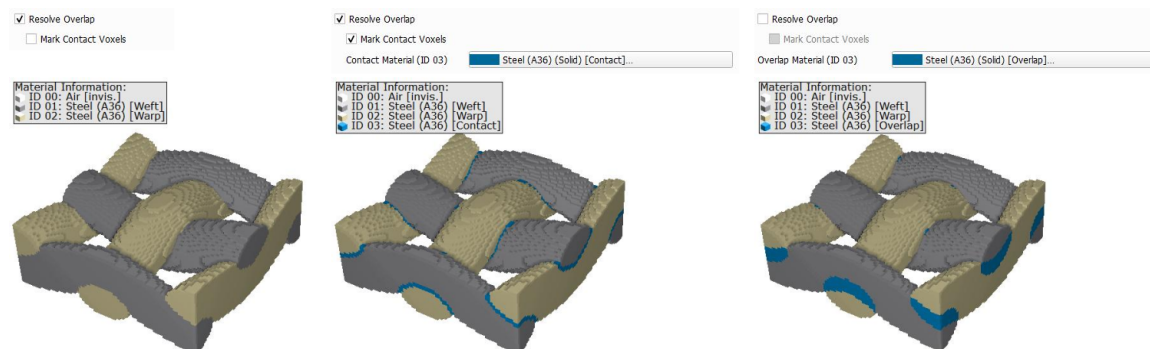
☐ **Resolve Overlap**

☐ **Mark Contact Voxels**

Overlap Material (ID 03) Steel (A36) (Solid) [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 , while the threads have a height of 100 μm .



✓ Can I save and reload settings for a thread?

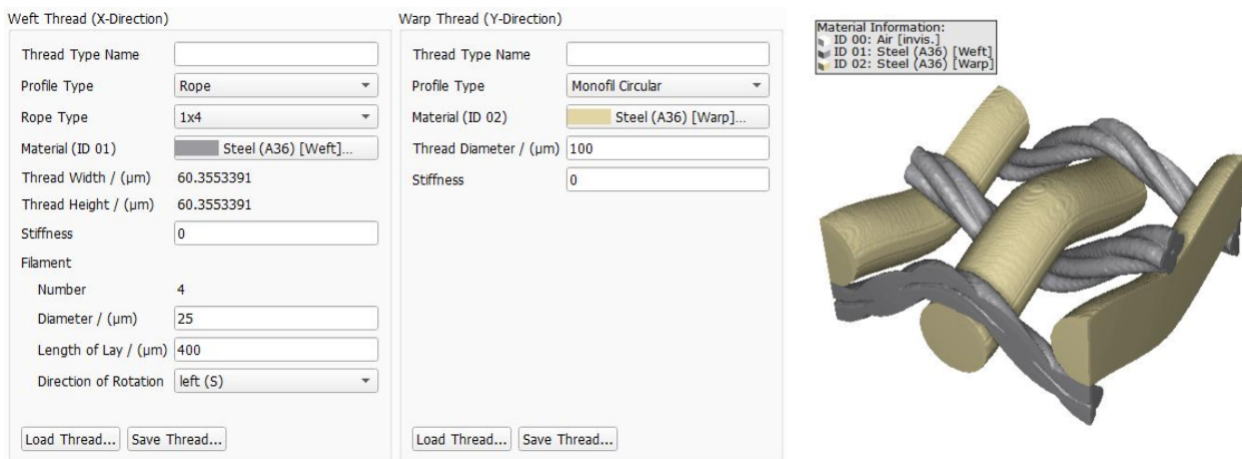
Yes, this is possible. At the bottom of the Weft and the Warp Thread panel, respectively, there is a **Save Thread** button. Click it to enter a name and save the parameters to a ***.gps** file. This is a GeoDict settings file.

File name:

Save as type:

Previously saved threads can be imported by clicking **Load Thread**.

Thread panels



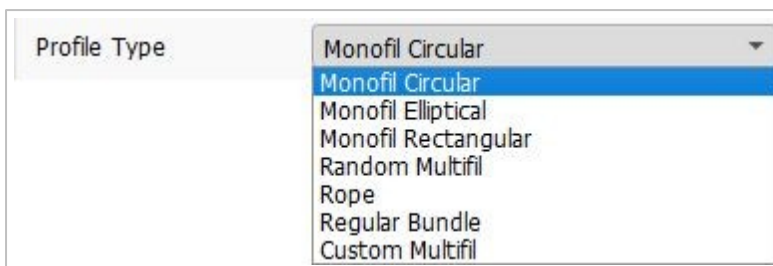
Parameters for all profile types

✓ Thread Type Name

In the **Thread Type Name** field, a name can be given to the warp or the weft thread generated with the current parameters, respectively. The name is not shown in the generated structure, only in the dialog. Giving the thread a name can support to easily recognize a loaded thread in the dialog.

✓ Profile Type

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



Monofil threads can have a **Circular**, **Elliptical**, or **Rectangular** cross-section. For the **Multifil** threads, **Random Multifil** and **Custom Multifil** are available.

See the [Thread Profile types](#) section for explanations on **Monofil**, **Multifil**, **Rope**, and **Regular Bundle** profile types.

✓ Material

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**.

Click on the material name to open the Material Selector and select the material for the corresponding thread from the GeoDict Material Database.

✓ Thread Width / Thread Height / Thread Diameter

Thread Width and **Thread Height** determine the size of the cross-section area of the thread. The thread height is the extent in Z-direction. As the weft thread has its longitudinal direction in X-direction, the thread width determines the extent in Y-direction. For the warp thread the thread width determines the extent in X-direction.

i Note! For **Ropes** and **Custom Multifils**, the Thread Width and Thread Height cannot be entered since these parameters depend on the other rope parameters. They are only shown as information. Find more information below in the profile type specific parameters section.

i Note! For **Regular Bundle** threads, the Thread Height cannot be entered and is only shown as information. It is computed based on the number of individual filaments and the filament diameter.

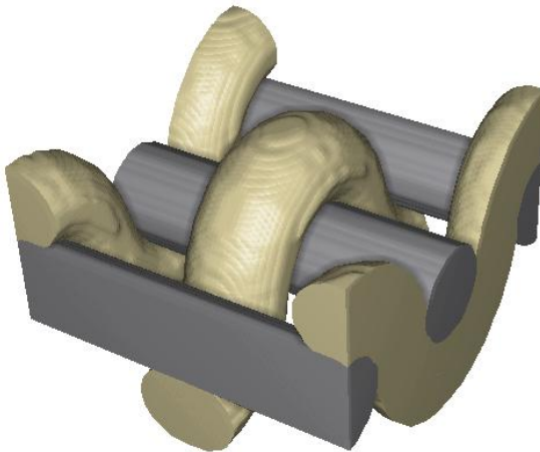
In case of a **Monofil Circular** profile type, width and height are equal, so only the **Thread Diameter** can be entered.

✓ Stiffness

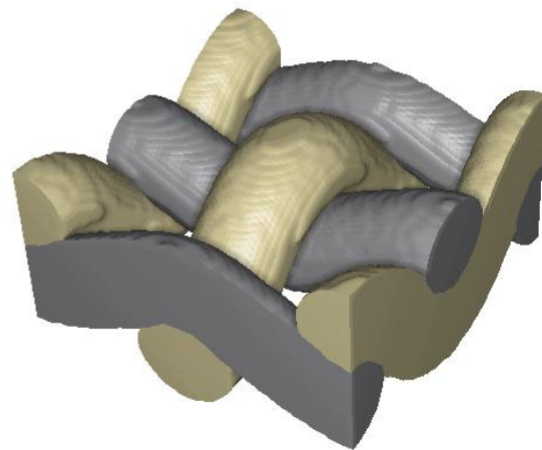
The **Stiffness** parameter controls the bending behavior of the threads. A high stiffness

indicates a rigid thread that only bends in small angles. Values for stiffness can vary from 0 to 1. This option only has an effect on plain weaves when using the FreeWeave Solver (in the [Solver Settings tab](#)). Below, an example of a plain weave is shown, where the **Stiffness** of the **weft** thread was varied.

Stiffness

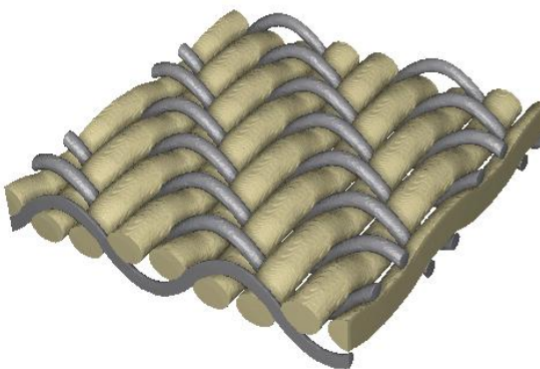


Stiffness

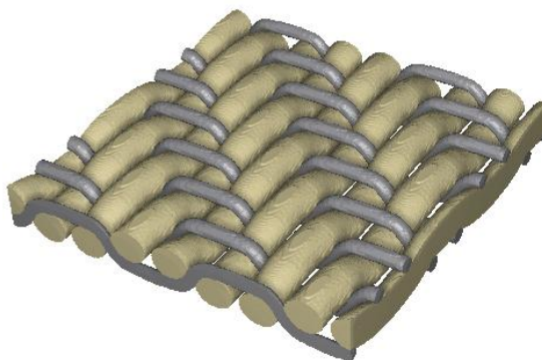


For the twill weave (shown below) and the satin weave the stiffness can also be modeled with the **Classic WeaveGeo** solver. Again, the **Stiffness** of the **weft** thread was varied.

Stiffness



Stiffness

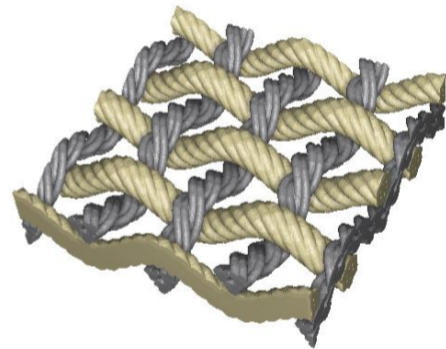


Parameters for Random Multifil, Rope, and Regular Bundle

✓ Number for Ropes

For the profile type **Rope**, one of the predefined **Rope Types** must be selected from the drop-down menu. The selected **Rope Type** determines the filament **Number** which cannot be changed manually.

In the example below, the **warp** thread 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** thread is a 3x3 rope, made of 3 strands of 3 filaments, which sets 9 as the filament number. The number of **Unit Cells** in warp and weft direction (under the Domain tab) was set to 2.



✓ Number for Random Multifil

For **Random Multifil** profile types, an arbitrary number of filaments can be entered. The upper limit is 10,000 filaments, but keep in mind that more filaments will lead to longer structure generation times.

✓ Number for Regular Bundle

Enter the **Number** specifying the number of filaments per thread in regular bundles. Possible values are in the range from 1 to 19.

✓ Diameter

Under Diameter enter the diameter of the individual filaments, which are all equal sized.

✓ Length of Lay

Length of Lay is only available for **Random Multifil** and **Rope**. It 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

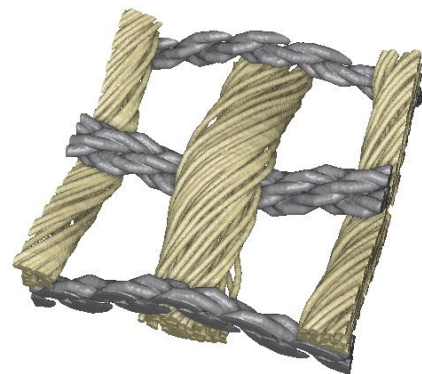
length of lay. This ensures that the thread makes an integer number of 360° rotations. It is also possible to make, e.g., only 180° twists if the filaments of the thread are arranged in a way that the structure stays periodic in the unit cell. If the entered length of lay does not allow to generate the 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.

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.

☒ Resolve Overlap
☐ Mark Contact Voxels

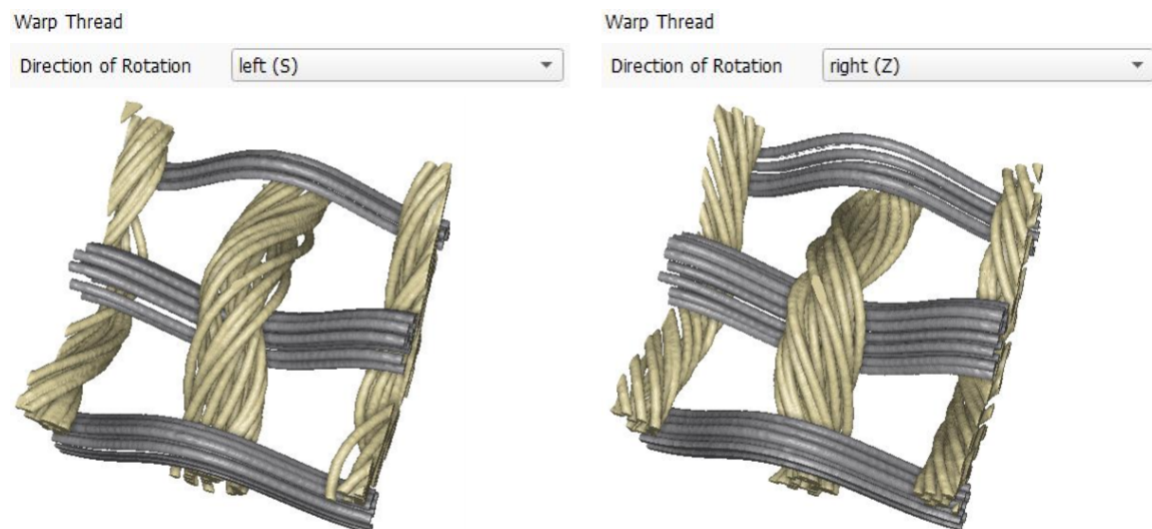
Weft Thread (X-Direction)
 Thread Type Name:
 Profile Type:
 Rope Type:
 Material (ID 01):
 Thread Width / (μm):
 Thread Height / (μm):
 Stiffness:
 Filament:
 Number:
 Diameter / (μm):
 Length of Lay 1 / (μm):
 Length of Lay 2 / (μm):
 Direction of Rotation 1:
 Direction of Rotation 2:

Warp Thread (Y-Direction)
 Thread Type Name:
 Profile Type:
 Material (ID 02):
 Thread Width / (μm):
 Thread Height / (μm):
 Stiffness:
 Filament:
 Number:
 Diameter / (μm):
 Length of Lay / (μm):
 Direction of Rotation:
 Lateral Oscillation / (μm):



✓ Direction of Rotation

Direction of Rotation is only available for **Random Multifil** and **Rope** and sets the direction - **right** (Z-twist rope) or **left** (S-twist rope) - in which the thread is rotated around itself (here, the **warp** thread). It only has an effect if the value for **Length of Lay** is larger than zero.

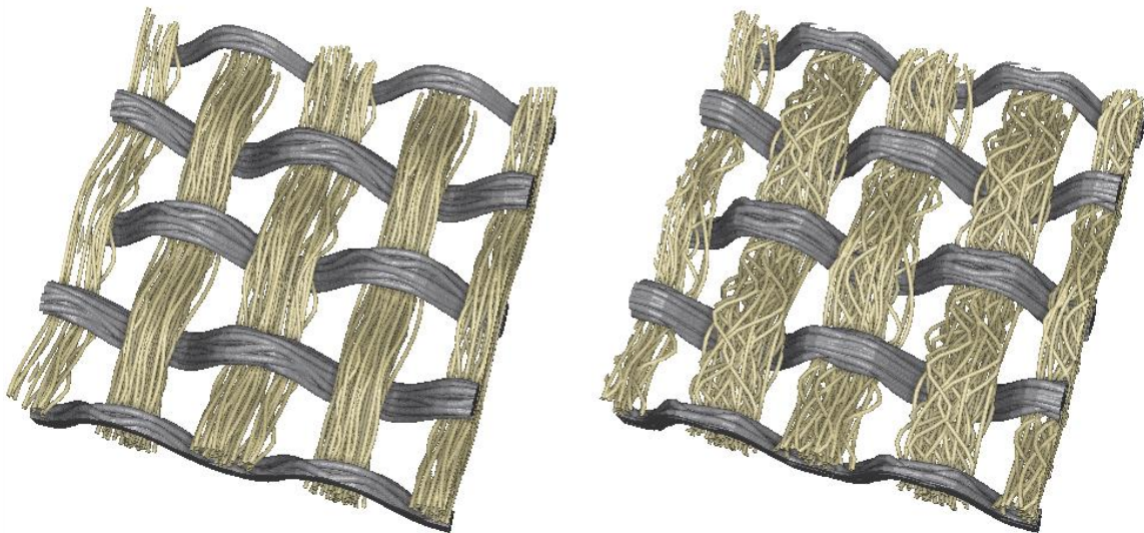


Direction of Rotation 1 controls the direction of rotation of the strand corresponding to **Length of Lay 1**: **right** (Z-twist strand) or **left** (S-twist strand). **Direction of Rotation 2** controls the direction of rotation of the strand corresponding to **Length of Lay 2**.

✓ Lateral Oscillation

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 [Weave Shape tab](#)).

Warp Thread	Lateral Oscillation / (μm)	10	Warp Thread	Lateral Oscillation / (μm)	35
Weft Thread	Lateral Oscillation / (μm)	10	Weft Thread	Lateral Oscillation / (μm)	10



Parameters for Custom Multifil

✓ How does the Custom Multifil profile type work?

For **Custom Multifil**, the settings panel is structured hierarchically. On the first, layer the settings for the whole thread can be made. On the subsequent layers, the strands and filaments of which the thread is composed can be defined individually. At the bottom, the **Thread Width** and **Thread Height** are displayed. They cannot be edited since they are computed from the settings of the single filaments. The **Stiffness** is given for the whole thread.

On each layer the parameters **Diameter**, **Length of Lay**, **Direction**, and **Child Count** are shown. The active parameters depend on the level of the corresponding filament.

The **Diameter** is only editable for the filaments with a **Child Count** of 0 and defines

their thickness. The diameter of the filament in the layer above is automatically computed based on the number of child filaments and their entered diameters.

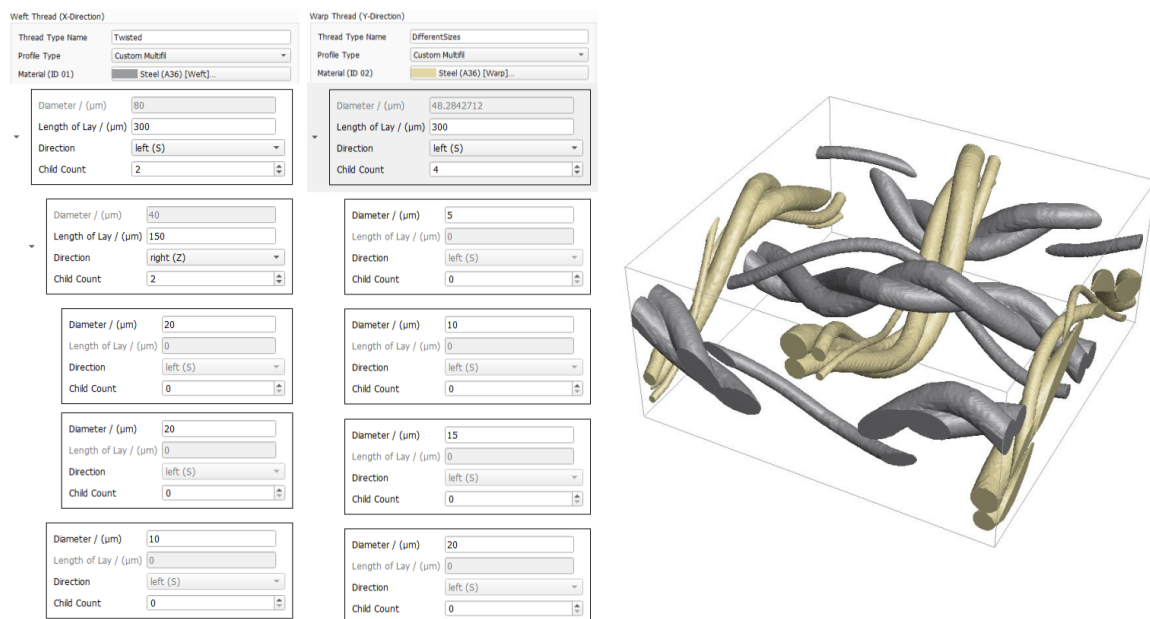


Know how! In contrast to Random Multifil threads, the filaments can have different diameters.

Length of Lay and **Direction** are the same as described above and define how a filament is twisted around itself. They are only active if **Child Count** is not zero.

Child Count defines in how many sub-filaments a filament is divided. The settings panel for each filament is displayed indented on the next layer. You can fold all lower layers by clicking on the small black triangle.

Below, a **Custom Multifil** structure is shown, generated with the shown settings. The domain length in X- and Y-direction is 300 voxels, respectively. The weft thread consists of two right (Z)-twisted filaments and a single, thinner filament twisted left (S) around them. The warp thread consists of 4 filaments with different diameters which are also twisted.



Special parameters for the FreeWeave solver

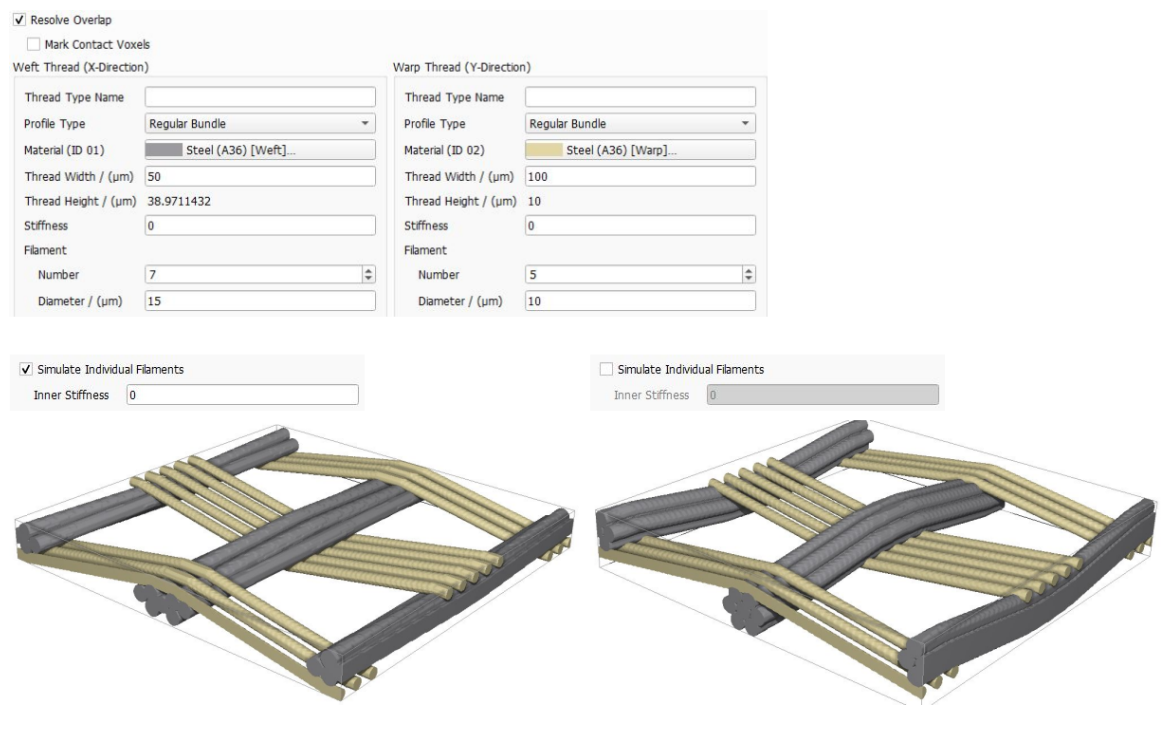
✓ Simulate Individual Filaments

If the FreeWeave Solver is chosen (in the [Solver Settings tab](#)), an additional option at the bottom of the thread panels is available. Check **Simulate Individual Filaments** to simulate interactions between the single filaments. Setting **Inner Stiffness** to a non-zero value allows you set a filament 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. When **Simulate Individual Filaments** is not active, the thread is modeled as a single circular thread. Then the filaments are placed at their computed positions.

The structure in the following example was produced with the shown settings. Observe the difference in the placement of the weft threads for **Simulate Individual Filaments** checked and unchecked.

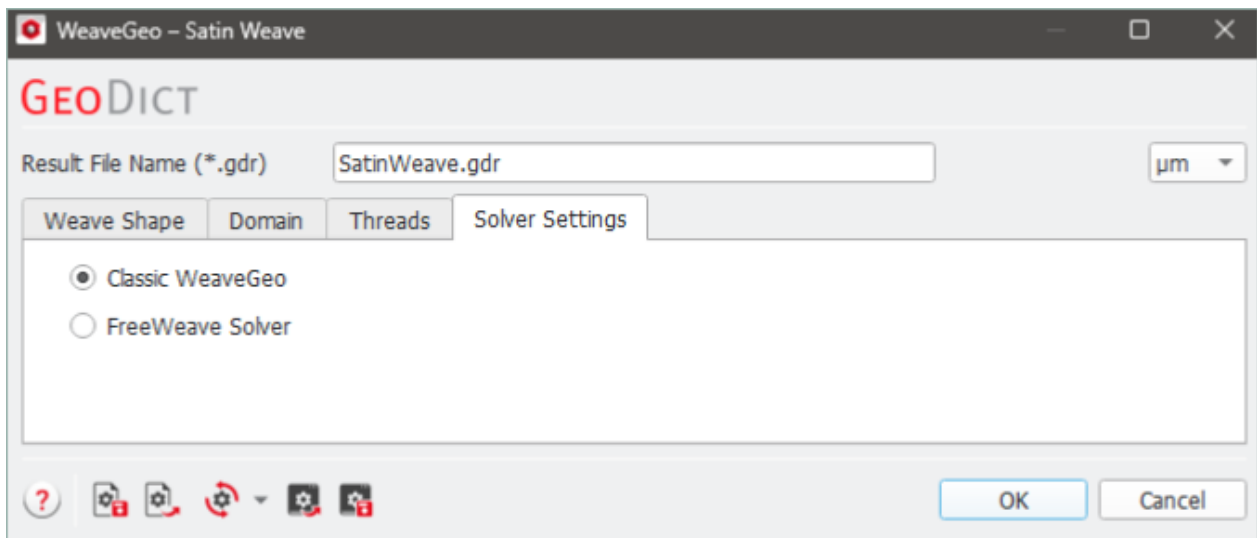
Simulate Individual Filaments is always available in the **Complex Multi-Layer Weave** command if a multifilament profile type is selected.



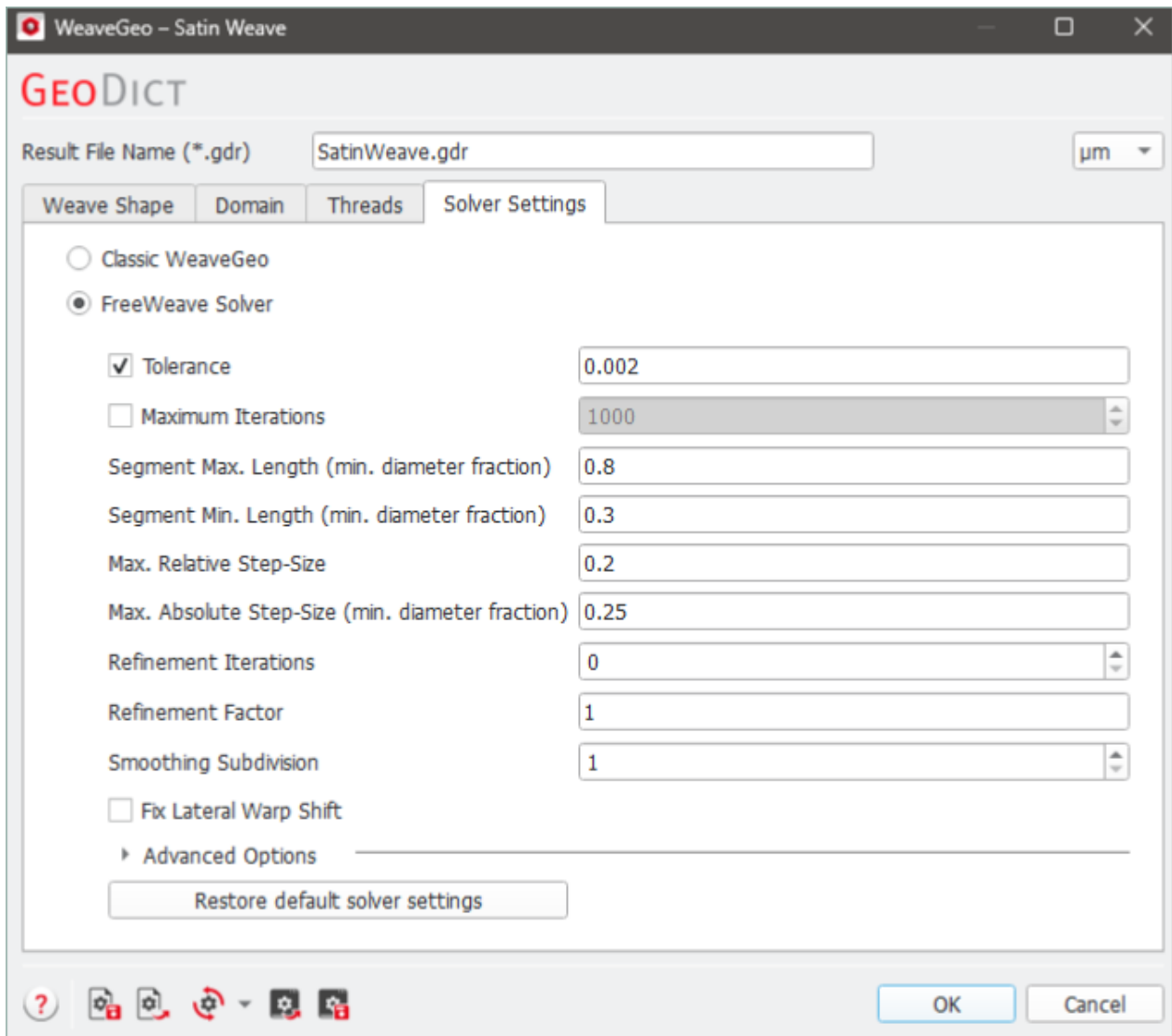
Solver Settings

In the **Solver Settings** tab, choose between the default **Classic WeaveGeo** solver and the **FreeWeave Solver**.

The **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. This solver has no parameters to be set.



Alternatively, you can select the **FreeWeave Solver**, which produces more realistic structures but may also result in longer generation times.



✓FreeWeave Solver parameters

The **FreeWeave Solver** performs a physical simulation when generating the weave as an iterative process. During the simulation, the threads are tightened and their interaction, such as collisions, is considered.

The **Tolerance** represents the reduction in the height 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 method is not suitable for all types of weaves. Thus, another stopping criterion is the **Maximal Iterations**, where the solver stops once the entered number of iterations is reached. These two criteria can be selected together, and the solver will stop when either criterion 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 during one 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** 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 than or equal to 0.1 and less than or equal to 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 post-processing step after the simulation. The primary use for this is in visualization to make the structure appear smoother. As it only happens once at the end of the simulation, it is not computationally expensive. 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.

Clicking on **Advanced Options** unfolds additional solver settings. They do not need to be changed for most simulations. Tooltips describe how they can be used if they need to be adjusted.

▼ Advanced Options

☒ Fix First Crossing Position

☐ Write Debug Output Interval

Segment length algorithm

☒ Use New Collision Algorithm

Inflate Iterations

Initial Thread Diameter Scale Factor

Height (Z) scale factor

Segment length mode

Segment length override

Segment Size Scale Iterations

Segment Size Scale Initial Factor

☐ Visualize Segments

Multifil broadening smooth factor

Overlap Scale Iterations

Broadening Scale Iterations

1

ProportionalSubdivision

0

1

1

Constant

0

0

1

0

0

0

Restore default solver settings

When the option **Fix First Crossing Position** is enabled, the first crossing point remains fixed at its initial position, preventing drift in the XY plane during the iteration.

Enable **Write Debug Output Interval** to save the intermediate structure to the result folder every N iterations.

Choose the algorithm to regulate the segment length when approximating fiber trajectory with the **Segment length algorithm**:

- **Legacy:** this algorithm splits and merges segments during the simulation. It was called *Old Segment Length Algorithm* in previous versions.
- **Standard:** this algorithm subdivides segments once before the simulation and then normalizes the segment lengths during simulations.
- **Proportional Subdivision:** this algorithm uses the same strategy as Standard, but matches the target lengths more accurately.

Enable the option **Use New Collision Algorithm** to perform a more accurate collision detection. With this option enabled, cylinder-to-cylinder collisions are tested instead of sphere-to-cylinder collisions.

The number of initial iterations in which to gradually inflate warp threads can be set

under **Inflate Iterations**.

The **Initial Thread Diameter Scale Factor** specifies the initial fraction of the thread diameter used at the start of the simulation. For example, a value of 0.2 means that the threads start 20% of their defined diameter and gradually expand to 100%.

The Z-height will be scaled by the **Height (Z) scale factor**. It is recommended to set this factor to the same value as **Initial Thread Diameter Scale Factor**.

The **Segment length mode** determines how the target segment length varies with the fiber diameter.

- **Constant**: the segment lengths are constant and independent of the fiber diameter.
- **Relative to diameter**: the segment lengths are proportional to the fiber diameter.
- **Relative to cross-section area**: the segment length are proportional to the fiber cross-section area.

The **Segment length override** factor defines whether and how the segment length will be overridden. For non-zero values, the segment length override is enabled. The resulting behavior also depends on the chosen Segment length mode:

- For the **Constant** segment length mode, this value defines the length of segments in meters.
- For the **Relative to diameter** mode, the segment length is the fiber diameter multiplied by this value.
- For the **Relative to cross-section area** mode, the segment length is the fiber cross-sectional area multiplied by this value.

The **Segment Size Scale Iterations** defines the number of initial iterations in which the segment length is gradually increased. This option only works properly with the **Legacy** segment length algorithm.

The **Segment Size Scale Initial Factor** specifies the fraction of segment length used at the start of the simulation. For example, a value of 0.2 means that the initial segment length is 20% of the defined segment length.

If the option **Visualize Segments** is checked, control points of the segments are shown using spheres.

The **Multifil broadening smooth factor** is an integer value that controls the smoothing of the curvature computation. If this value is greater than zero, a broadening algorithm is enabled that computes broadening for the entire multifilament bundle instead of the individual filaments.

The **Overlap Scale Iterations** parameter defines the number of initial iterations during which the overlap is gradually increased to the specified maximum value. In the first iteration, no overlap is applied.

The **Broadening Scale Iterations** parameter defines the number of initial iterations during which the broadening is gradually increased to the specified maximum value. In

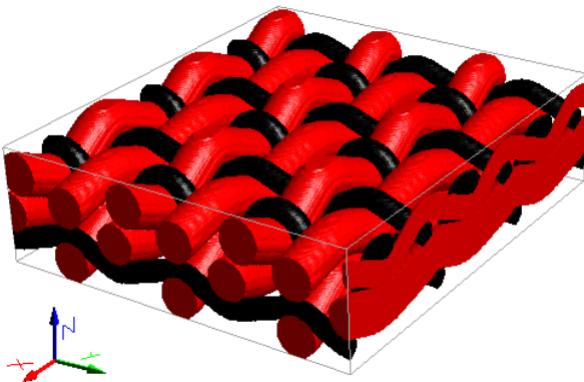
the first iteration, no broadening is applied.

1.3 Complex Multi-Layer Weave

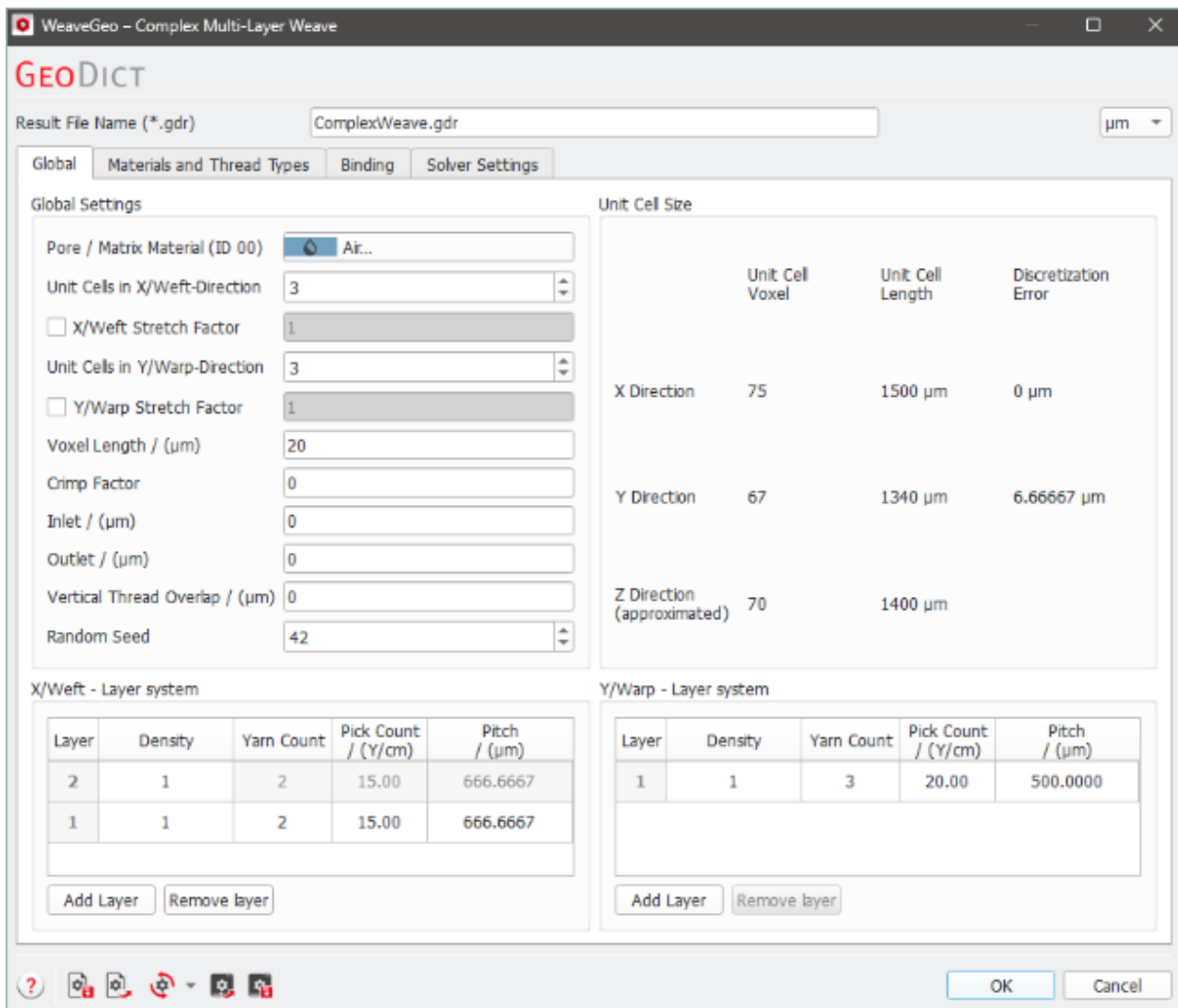
The **Complex Multi-Layer Weave** command allows to generate sophisticated multi layered weaves and gives you full control over the weave generation. Thus, the graphical user interface contains more options than those for the [single-layer weave](#) types. For the structure generation, the physical contact between the threads is simulated by an iterative physics-based solver, the **FreeWeave** solver.



Note! Until GeoDict 2023, this command was named FreeWeave. Starting with GeoDict 2024 it is named **Complex Multi-Layer Weave**. The options menu has not changed.



At the top of the **Edit...** dialog, the name for the folder containing the generation results can be entered in the **Result File Name (*.gdr)** box. You can either keep the default name or choose a new one that fits 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 **Global**, **Materials and Thread Types**, **Binding**, and **Solver Settings**.

Learn how to create Complex Multi-Layer Weave structures:

- [Global](#)^[91]
Define settings for the domain, unit cell and the weft-/warp-layer system.
- [Materials and Thread Types](#)^[93]
Define the shape and the material of the threads.
- [Binding](#)^[104]
Define how the individual threads are bent around each other.
- [Solver Settings](#)^[111]
Define the settings for the FreeWeave solver in this tab.

1.3.1 Global

The **Global** tab allows you to make **Global Settings** for the domain. The **Unit Cell Size** is computed based on these settings and displayed. You can also set up the **Weft-** and **Warp-Layer System** here.

The screenshot shows the 'WeaveGeo - Complex Multi-Layer Weave' application window. The 'Global' tab is selected, displaying various settings for the simulation. The 'Global Settings' section includes fields for material selection, unit cell dimensions, and random seed. The 'Unit Cell Size' section shows calculated values for X, Y, and Z directions. The 'X/Weft - Layer system' and 'Y/Warp - Layer system' sections contain tables for layer properties.

Global Settings

Pore / Matrix Material (ID 00): Air...

Unit Cells in X/Weft-Direction: 3

☐ X/Weft Stretch Factor: 1

Unit Cells in Y/Warp-Direction: 3

☐ Y/Warp Stretch Factor: 1

Voxel Length / (μm): 20

Crimp Factor: 0

Inlet / (μm): 0

Outlet / (μm): 0

Vertical Thread Overlap / (μm): 0

Random Seed: 42

Unit Cell Size

	Unit Cell Voxel	Unit Cell Length	Discretization Error
X Direction	75	1500 μm	0 μm
Y Direction	67	1340 μm	6.66667 μm
Z Direction (approximated)	70	1400 μm	

X/Weft - Layer system

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

Y/Warp - Layer system

Layer	Density	Yarn Count	Pick Count / (Y/cm)	Pitch / (μm)
1	1	3	20.00	500.0000

✓ Global Settings

Select the material that occupies the space surrounding the threads (e.g., air) from the GeoDict Material Database using the **Pore / Matrix Material (ID 00)** button. See the Material Database User Guide for more information. The surrounding material always has **Material ID 00**.

The values for **Unit Cells in X/Weft-Direction** and **Unit Cells in Y/Warp-Direction** determine how many times the generated unit cell is repeated. 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 **Y/Warp Stretch Factor**, which should be close to 1. If the **Stretch Factor** is enabled, the simulation is done in two stages. 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 stage of simulation. In the second stage the threads are tightened to reach again their initial length. In the Result File a table shows the remaining error of this process.

The **Voxel Length**, **Inlet**, and **Outlet** settings are explained on the [Domain tab](#)^[18] for plain weave. The **Crimp Factor**, **Vertical Thread Overlap**, and **Random Seed** are explained on the [Weave Shape tab](#)^[14] for plain weave.

✓Warp- & Weft-Layer system

Any number of layers can be defined for the **Weft-Layer System** and the **Warp-Layer System**. The layer with the lowest number is the bottom layer. Layers are added by **Add Layer** and are stacked on top (in Z+ direction). Delete the topmost layer by clicking **Remove Layer**. The parameters of each layer 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 integer.

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](#)^[108] threads.

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.

✓ Unit Cell Size

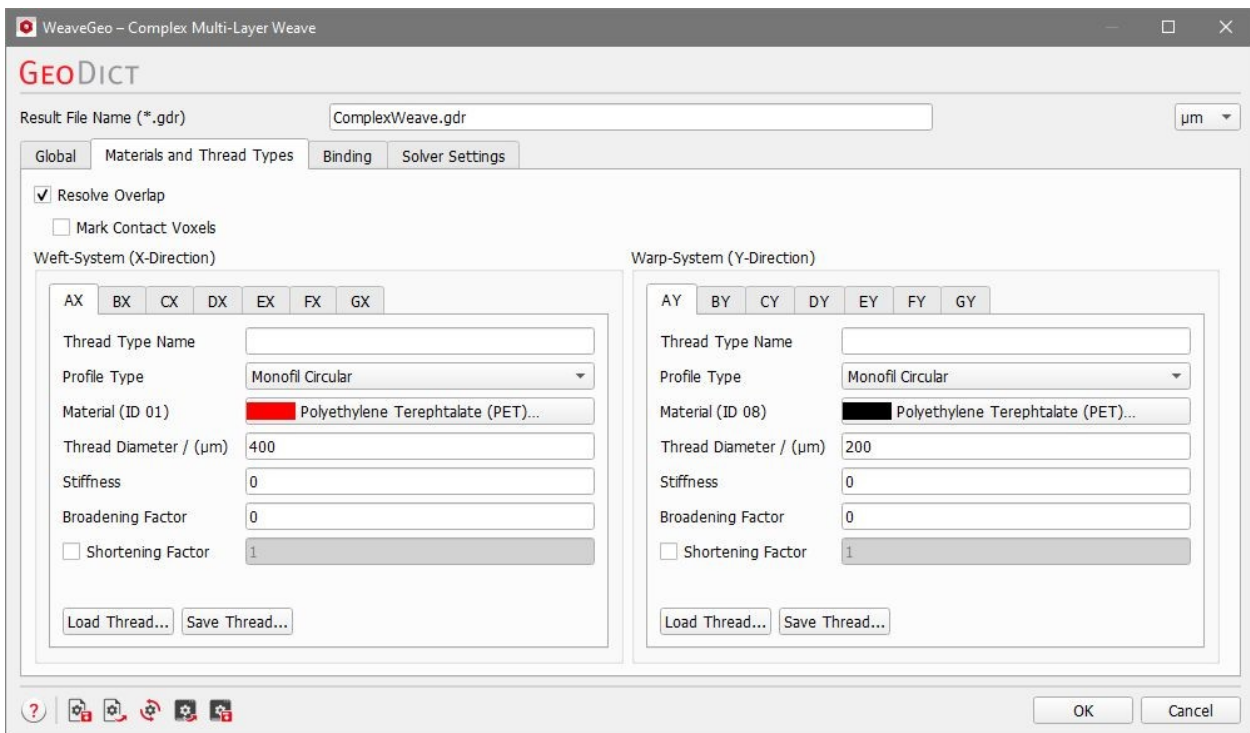
The values for the **Unit Cell Size** are not editable since they depend on the definition of the parameters of the structure. For example, the thread widths and pitches and the chosen number of unit cells determine the width and height of the weave.

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**.

1.3.2 Materials and Thread Types

The **Materials and Thread Types** tab allows you to define up to seven different thread types for both the **Weft** and **Warp-System**. The **Thread** definition works similarly to the [Threads tab](#)^[21] of all the other WeaveGeo commands. The **Weft-System** panel consists of 7 tabs named **AX** to **GX** where the parameters for each thread are entered. The seven threads of the weft-system are assigned Material IDs from 01 to 07. Similarly, the tabs for the **Warp-System** are named **AY**,...,**GY**, respectively. The warp system's threads are assigned Material IDs 08 through 14. The names AX, AY,... appear again in the [Binding tab](#)^[104].

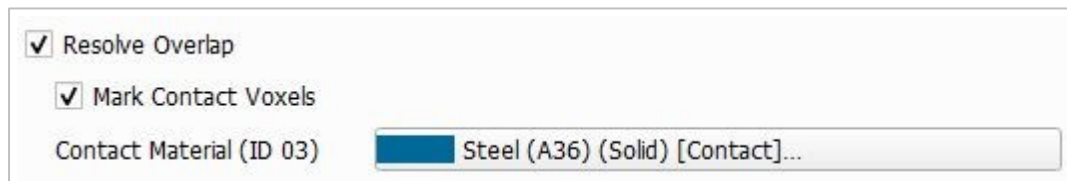


This tab is divided into three main parts. At the top select how overlapping threads should be treated. Below, there are two panels next to each other, one for the settings of the **Weft Thread** and one for the settings of the **Warp Thread**. Both contain the same parameters for the different thread types. Each thread can be modeled individually with different parameters.

✓ How to handle thread overlap?

Different threads might overlap in the generated structure, e.g., due to **Vertical Thread Overlap** (see [Weave Shape tab](#)). 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 more realistic structure.



Additionally checking **Mark Contact Voxels** allows to define a separate material for the contact areas. This means, for each overlapping object a one voxel thick layer is reassigned to the **Contact Material**. In this way, even contacting threads with the same material ID can be clearly distinguished.



Know how! 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.

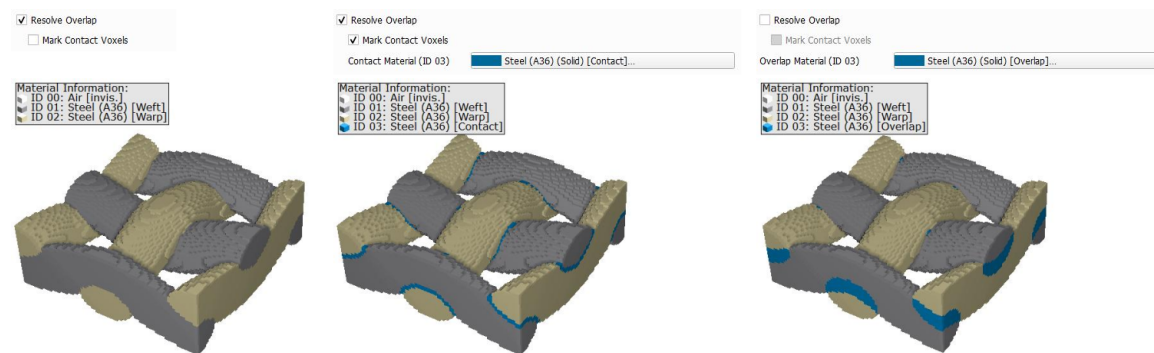
☐ Resolve Overlap

☐ Mark Contact Voxels

Overlap Material (ID 03) Steel (A36) (Solid) [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 , while the threads have a height of 100 μm .



✓ Can I save and reload settings for a thread?

Yes, this is possible. At the bottom of the Weft and the Warp Thread panel, respectively, there is a **Save Thread** button. Click it to enter a name and save the parameters to a ***.gps** file. This is a GeoDict settings file.

File name:

Save as type:

Previously saved threads can be imported by clicking **Load Thread**.

Thread panels

Weft Thread (X-Direction)

Thread Type Name:

Profile Type:

Rope Type:

Material (ID 01):

Thread Width / (μm):

Thread Height / (μm):

Stiffness:

Filament:

Number:

Diameter / (μm):

Length of Lay / (μm):

Direction of Rotation:

Warp Thread (Y-Direction)

Thread Type Name:

Profile Type:

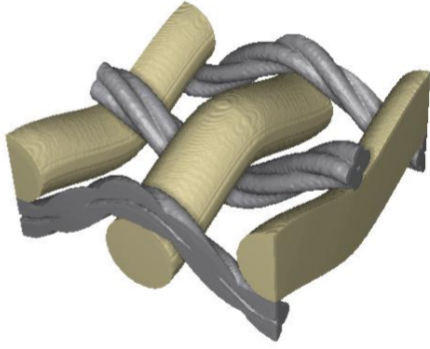
Material (ID 02):

Thread Diameter / (μm):

Stiffness:

Material Information:

- ID 00: Air [Invis.]
- ID 01: Steel (A36) [Weft]
- ID 02: Steel (A36) [Warp]



Parameters for all profile types

✓ Thread Type Name

In the **Thread Type Name** field, a name can be given to the warp or the weft thread generated with the current parameters, respectively. The name is not shown in the generated structure, only in the dialog. Giving the thread a name can support to easily recognize a loaded thread in the dialog.

✓ Profile Type

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

Profile Type	Monofil Circular - Monofil Circular - Monofil Elliptical - Monofil Rectangular - Random Multifil - Rope - Regular Bundle - Custom Multifil
--------------	---

Monofil threads can have a **Circular**, **Elliptical**, or **Rectangular** cross-section. For the **Multifil** threads, **Random Multifil** and **Custom Multifil** are available.

See the [Thread Profile types](#) section for explanations on **Monofil**, **Multifil**, **Rope**, and **Regular Bundle** profile types.

✓ Material

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**.

Click on the material name to open the Material Selector and select the material for

the corresponding thread from the GeoDict Material Database.

✓ Thread Width / Thread Height / Thread Diameter

Thread Width and **Thread Height** determine the size of the cross-section area of the thread. The thread height is the extent in Z-direction. As the weft thread has its longitudinal direction in X-direction, the thread width determines the extent in Y-direction. For the warp thread the thread width determines the extent in X-direction.

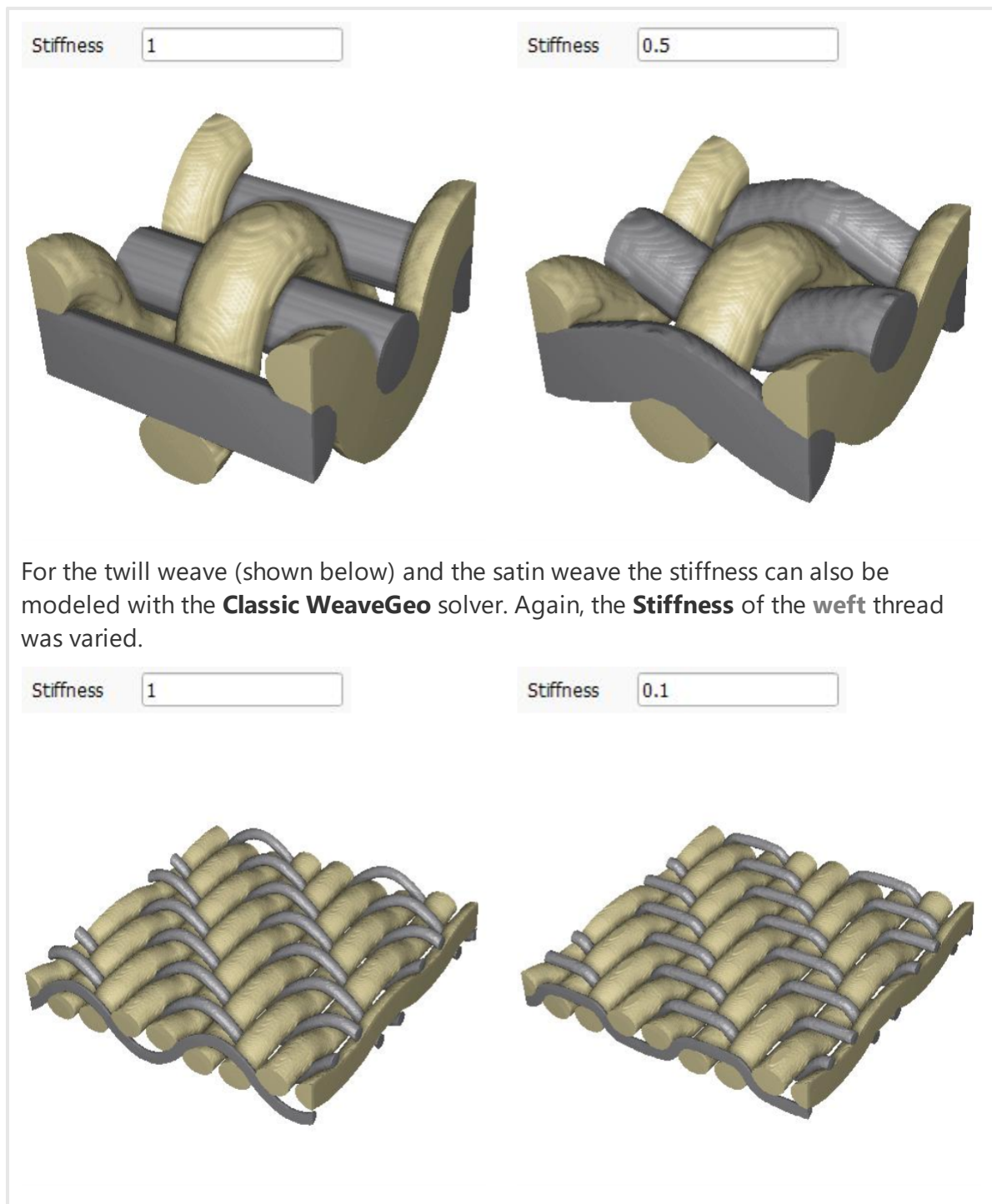
i **Note!** For **Ropes** and **Custom Multifils**, the Thread Width and Thread Height cannot be entered since these parameters depend on the other rope parameters. They are only shown as information. Find more information below in the profile type specific parameters section.

i **Note!** For **Regular Bundle** threads, the Thread Height cannot be entered and is only shown as information. It is computed based on the number of individual filaments and the filament diameter.

In case of a **Monofil Circular** profile type, width and height are equal, so only the **Thread Diameter** can be entered.

✓ Stiffness

The **Stiffness** parameter controls the bending behavior of the threads. A high stiffness indicates a rigid thread that only bends in small angles. Values for stiffness can vary from 0 to 1. This option only has an effect on plain weaves when using the FreeWeave Solver (in the [Solver Settings tab](#)). Below, an example of a plain weave is shown, where the **Stiffness** of the **weft** thread was varied.



For the twill weave (shown below) and the satin weave the stiffness can also be modeled with the **Classic WeaveGeo** solver. Again, the **Stiffness** of the **weft** thread was varied.

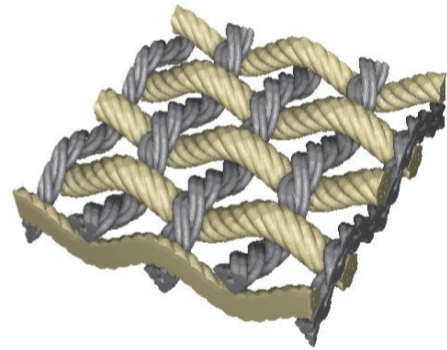
Parameters for Random Multifil, Rope, and Regular Bundle

✓ Number for Ropes

For the profile type **Rope**, one of the predefined **Rope Types** must be selected from the drop-down menu. The selected **Rope Type** determines the filament **Number** which cannot be changed manually.

In the example below, the **warp** thread 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** thread is a 3x3 rope, made of 3 strands of 3 filaments, which sets 9 as the filament number. The number of **Unit Cells** in warp and weft direction (under the Domain tab) was set to 2.

Weft Thread (X-Direction)		Warp Thread (Y-Direction)	
☒ Resolve Overlap			
☐ Mark Contact Voxels			
Thread Type Name		Thread Type Name	
Profile Type	Rope	Profile Type	Rope
Rope Type	3x3	Rope Type	1x7
Material (ID 01)	Steel (A36) [Weft]	Material (ID 02)	Steel (A36) [Warp]
Thread Width / (μm)	46.4273441	Thread Width / (μm)	45
Thread Height / (μm)	46.4273441	Thread Height / (μm)	45
Stiffness	0	Stiffness	0
Filament		Filament	
Number	9	Number	7
Diameter / (μm)	10	Diameter / (μm)	15
Length of Lay 1 / (μm)	11	Length of Lay / (μm)	11
Length of Lay 2 / (μm)	0		
Direction of Rotation 1	left (S)	Direction of Rotation	left (S)
Direction of Rotation 2	left (S)		
Load Thread...	Save Thread...	Load Thread...	Save Thread...



✓ Number for Random Multifil

For **Random Multifil** profile types, an arbitrary number of filaments can be entered. The upper limit is 10,000 filaments, but keep in mind that more filaments will lead to longer structure generation times.

✓ Number for Regular Bundle

Enter the **Number** specifying the number of filaments per thread in regular bundles. Possible values are in the range from 1 to 19.

✓ Diameter

Under Diameter enter the diameter of the individual filaments, which are all equal sized.

✓ Length of Lay

Length of Lay is only available for **Random Multifil** and **Rope**. It 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,

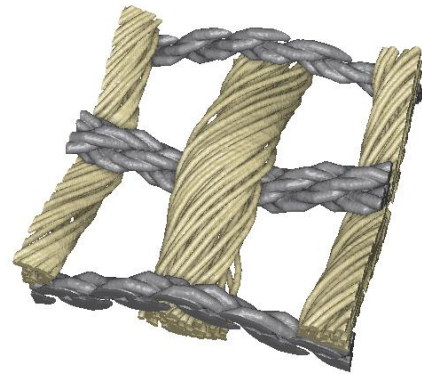
and the parameter is adjusted automatically. The choice of unrealistically short values might lead to artifacts in the generation and, therefore, to unrealistic structures. If the **Length of Lay** is set to zero, the filaments are not rotated around themselves.

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.

☒ Resolve Overlap
☐ Mark Contact Voxels

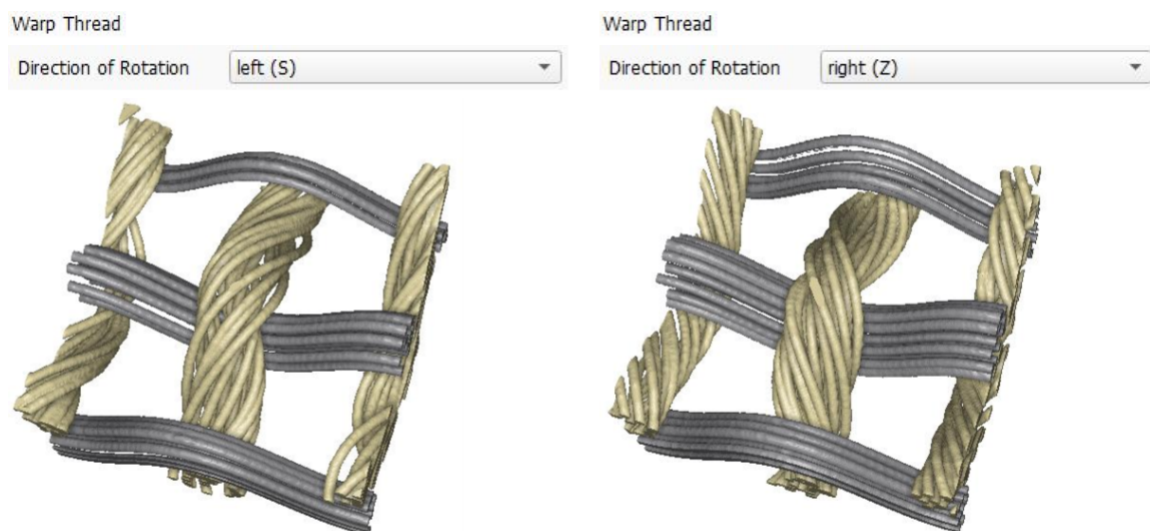
Weft Thread (X-Direction)
 Thread Type Name:
 Profile Type:
 Rope Type:
 Material (ID 01):
 Thread Width / (μm):
 Thread Height / (μm):
 Stiffness:
 Filament:
 Number:
 Diameter / (μm):
 Length of Lay 1 / (μm):
 Length of Lay 2 / (μm):
 Direction of Rotation 1:
 Direction of Rotation 2:
 Load Thread... Save Thread...

Warp Thread (Y-Direction)
 Thread Type Name:
 Profile Type:
 Material (ID 02):
 Thread Width / (μm):
 Thread Height / (μm):
 Stiffness:
 Filament:
 Number:
 Diameter / (μm):
 Length of Lay / (μm):
 Direction of Rotation:
 Lateral Oscillation / (μm):
 Load Thread... Save Thread...



✓ Direction of Rotation

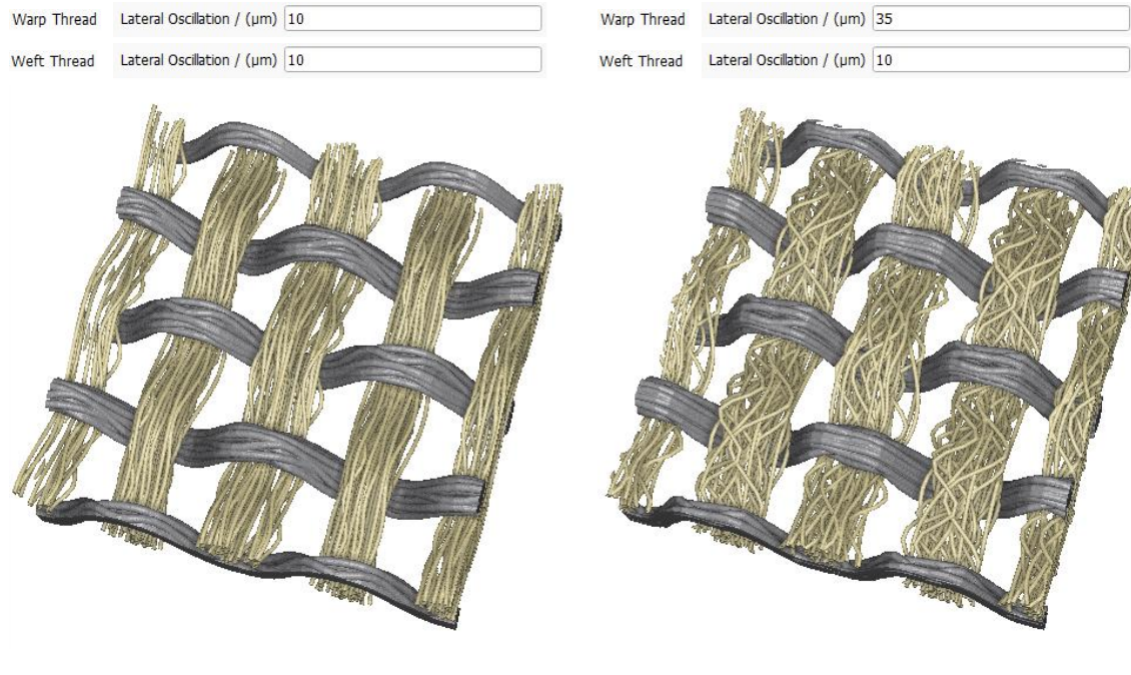
Direction of Rotation is only available for **Random Multifil** and **Rope** and sets the direction - **right** (Z-twist rope) or **left** (S-twist rope) - in which the thread is rotated around itself (here, the **warp** thread). It only has an effect if the value for **Length of Lay** is larger than zero.



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**.

✓ Lateral Oscillation

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 [Weave Shape tab](#)).



Parameters for Custom Multifil

✓ How does the Custom Multifil profile type work?

For **Custom Multifil**, the settings panel is structured hierarchically. On the first layer the settings for the whole thread can be made. On the subsequent layers, the strands and filaments of which the thread is composed can be defined individually. At the bottom, the **Thread Width** and **Thread Height** are displayed. They cannot be edited since they are computed from the settings of the single filaments. The **Stiffness** is given for the whole thread.

On each layer the parameters **Diameter**, **Length of Lay**, **Direction**, and **Child Count** are shown. The active parameters depend on the level of the corresponding filament.

The **Diameter** is only editable for the filaments with a **Child Count** of 0 and defines their thickness. The diameter of the filament in the layer above is automatically computed based on the number of child filaments and their entered diameters.

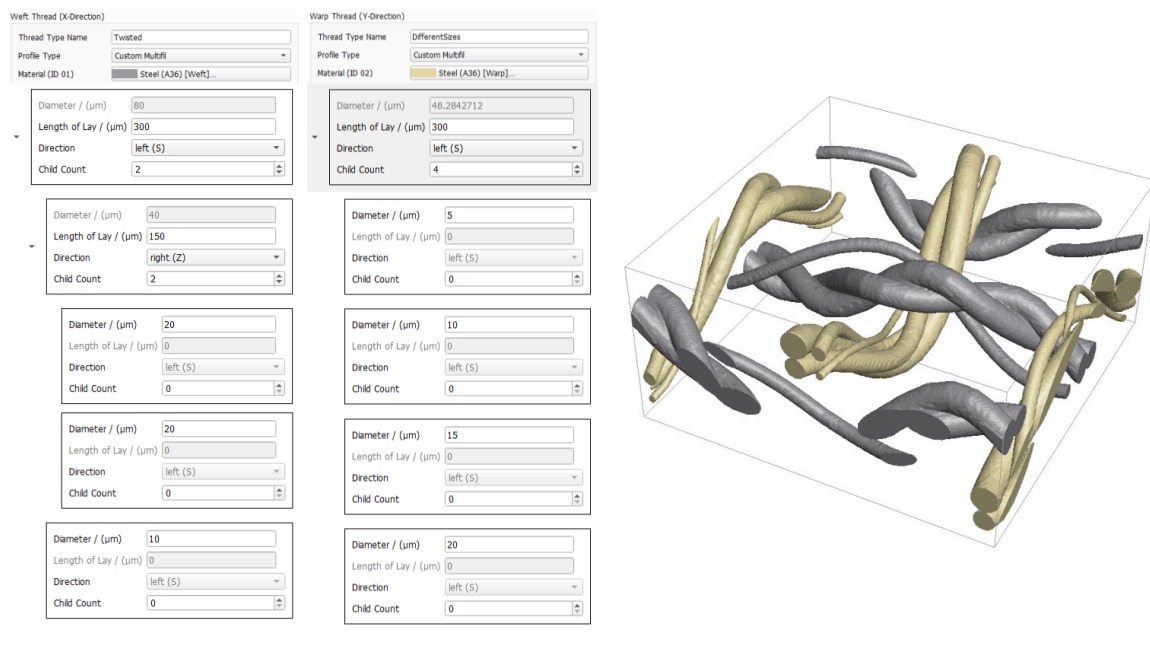


Know how! In contrast to Random Multifil threads, the filaments can have different diameters.

Length of Lay and **Direction** are the same as described above and define how a filament is twisted around itself. They are only active if **Child Count** is not zero.

Child Count defines in how many sub-filaments a filament is divided. The settings panel for each filament is displayed indented on the next layer. You can fold all lower layers by clicking on the small black triangle.

Below, a **Custom Multifil** structure is shown, generated with the shown settings. The domain length in X- and Y-direction is 300 voxels, respectively. The weft thread consists of two right (Z)-twisted filaments and a single, thinner filament twisted left (S) around them. The warp thread consists of 4 filaments with different diameters which are also twisted.



Special parameters for the FreeWeave solver

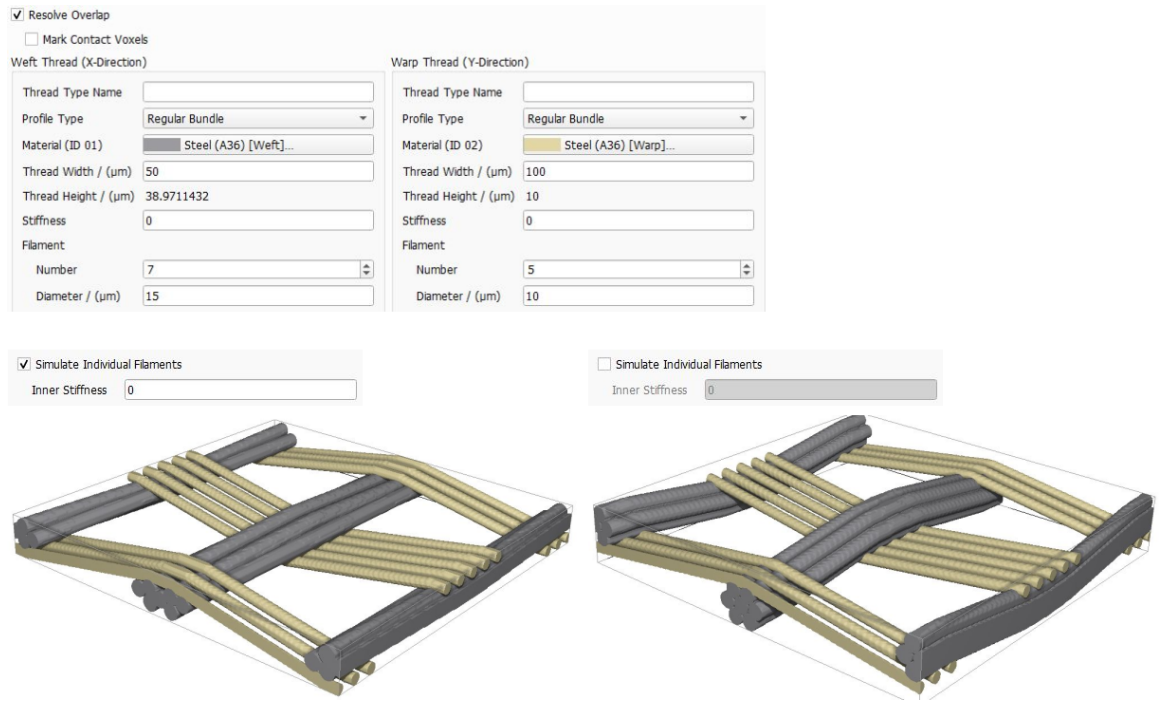
✓ Simulate Individual Filaments

If the FreeWeave Solver is chosen (in the [Solver Settings tab](#)), an additional option at the bottom of the thread panels is available. Check **Simulate Individual Filaments** to simulate interactions between the single filaments. Setting **Inner Stiffness** to a non-zero value allows you set a filament 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. When **Simulate Individual Filaments** is not active, the thread is modeled as a single circular thread. Then the filaments are placed at their computed positions.

The structure in the following example was produced with the shown settings. Observe the difference in the placement of the weft threads for **Simulate Individual Filaments**

checked and unchecked.

Simulate Individual Filaments is always available in the **Complex Multi-Layer Weave** command if a multifilament profile type is selected.



Complex Multi-Layer Weave specific parameters

✓ Broadening Factor

The **Broadening Factor** defines the behavior of bent threads. At the crossing points of two threads a thread may be widened, which means the height of the thread is reduced and the material is distributed across the width.



Important! Common values for the **Broadening Factor** range from 0 to 2. Higher values are possible, but keep in mind that the thread becomes thinner as the **Broadening Factor** increases. Extremely high values lead to long runtimes and/or unrealistic structures.

$$\text{ratio} = \frac{\text{thread radius}}{\text{bending radius}} \quad (1)$$

For threads with a non-circular cross-section, the **thread radius** is half the height (thickness in Z-direction) of the thread. The **bending radius** is the radius of the osculating circle that best approximates the curvature of the thread at the crossing point of two threads.

The cross sectional area has to be constant even if the thread is bent around other threads. Thus, the new width and height of the thread are computed as follows:

$$\text{new thread width} = \text{thread width} \cdot (1 + \text{broadening factor} \cdot \text{ratio}) \quad (2)$$

$$\text{new thread height} = \frac{\text{thread height}}{1 + \text{broadening factor} \cdot \text{ratio}} \quad (3)$$

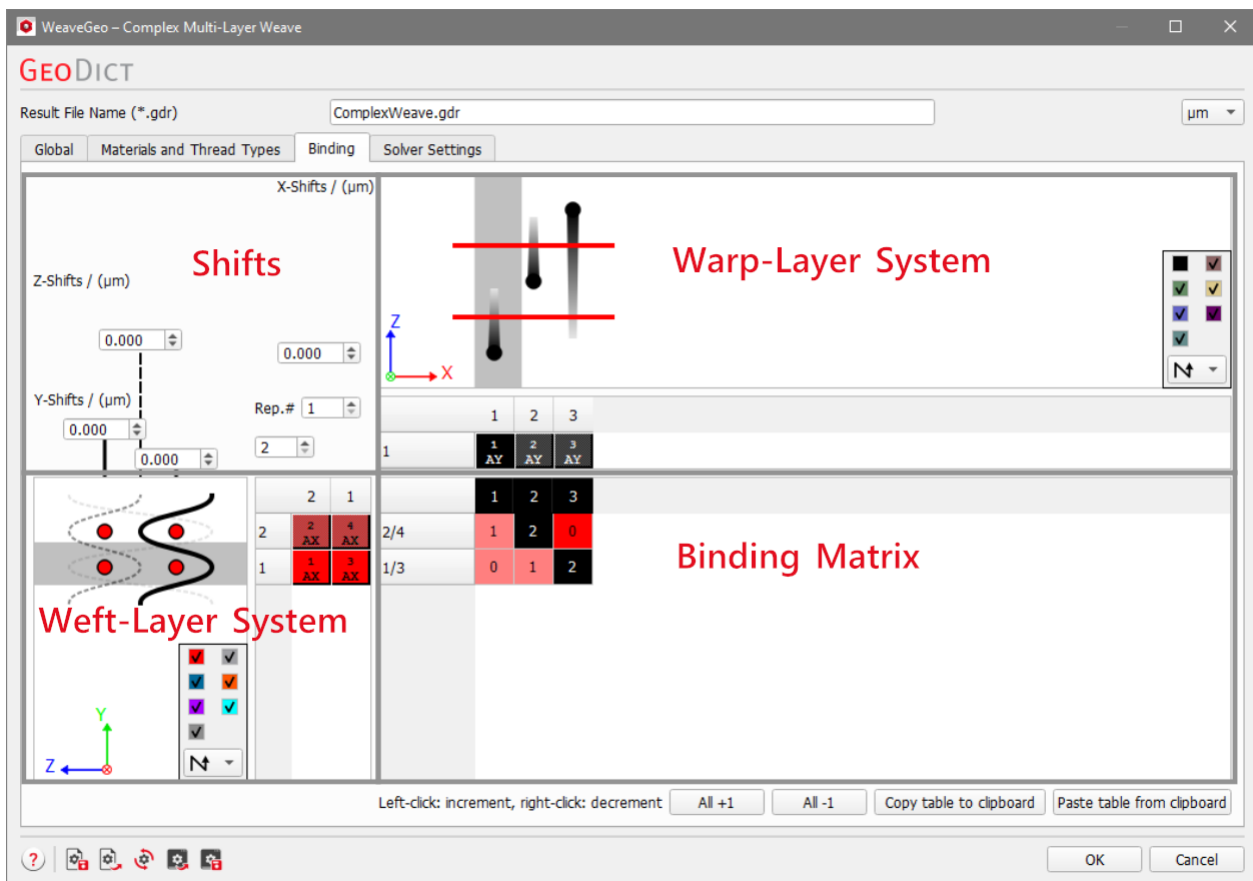
✓ Shortening Factor

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, 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.

1.3.3 Binding

The **Binding** tab shows the binding matrix and a 2D preview of the weave. 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.



✓ 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-Shifts / (μm)

Z-Shifts / (μm)

Y-Shifts / (μm)

0.000

0.000

0.000

Rep.# 1

2

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.

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 grayed out. This is shown in the example 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 where **Rep.#=3** is set).

Rep.# 1	1	2	3	Rep.# 3	1	2	3		
2	1	1 AY	2 AY	3 AY	2	1	1 AY	2 AY	3 AY

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](#).

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](#)^[108]. This functionality gives you a better overview during the generation of complex weaves.

The number in each cell represents the **Shot Index**. You can change the **Shot Order** using the drop-down menu. This assigns a shot index to each thread according to the selected pattern. If **X** is selected in the menu, the shot index can be assigned manually for each thread. This can be done in the **Property Menu** of the thread, which is accessed by clicking on the corresponding cell in the table.



Important! Index and Shot Order do not affect the structure generation in GeoDict. These parameters are only relevant for setting up a real weaving machine.

Several other properties can be defined in the **Property Menu**. The **Material** can be changed and the thread can be hidden. Selecting **Hide** means that the thread will not be included in the weave after generation. Changing the **Relative Shift** moves the thread in the Y direction. This value is added to the **Y-Shift** value of the corresponding layer, as explained under [Shifts](#)^[105].

Material	AX
Hide	☐
Shot index	2
Relative shift (µm)	0.00000

✓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, and their trails indicate whether they come from the 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

The **Binding Matrix** panel has a column for each warp thread. The number of rows is defined by the maximum 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. 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. A value of 0 indicates that the warp thread is at the bottom of the weave, beneath the first layer of weft threads. Setting the maximum value, which is equal to the number of weft layers, means that the warp thread will lie on top of the weave. The color of each cell in the binding matrix corresponds to the color of the topmost thread. The color pattern of the binding matrix matches the color pattern of the weave's top view.

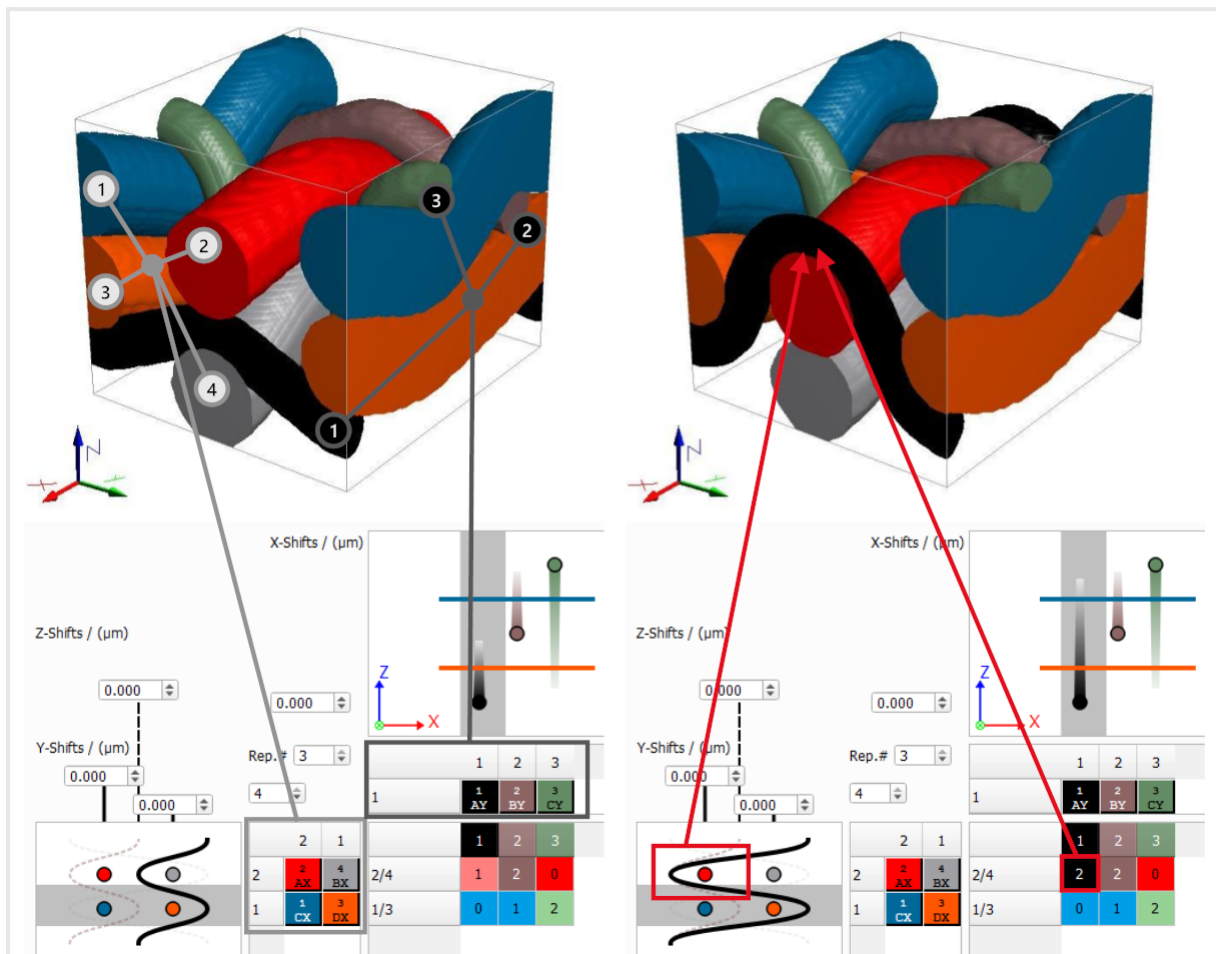
Clicking on a cell highlights the related column and row in the **Binding Matrix**. In the previews, the thread position is marked in gray. The previews switch to show the corresponding position in the weave. Threads lying in this weft/warp position are shown as bold lines while threads lying behind 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. See the [example](#)^[110] for more information.

Click on a highlighted cell with your left mouse button to increase the number by one and increase its position in the Z-direction by one layer. The previews will update, and the cell's color may change depending on the Material ID on top of the weave. You can lower the position again by right-clicking.

Left-click: increment, right-click: decrement

The buttons below the **Binding Matrix** allow you to edit the entire matrix. This is especially helpful when editing larger matrices. With **All + 1** and **All - 1**, all entries in the matrix are incremented or decremented by 1. The complete table can be copied or pasted using the **Copy table to clipboard** and **Paste table from clipboard** buttons to modify it in another program, such as a text editor.

✓ Example



In the above example, the default parameters are maintained. Only the repetition and thread types were changed to better illustrate the relationship between the **Complex Multi-Layer 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 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.

1.3.4 Solver Settings

In the **Solver Settings** tab, define the parameters for the **FreeWeave Solver**.

The screenshot shows the 'WeaveGeo - Complex Multi-Layer Weave' dialog box. The 'GEO' part of the title is in red. The 'Result File Name (*.gdr)' field contains 'ComplexWeave.gdr' and the unit is set to 'µm'. The 'Solver Settings' tab is selected, showing various parameters for the solver. The parameters are as follows:

Parameter	Value
☒ Tolerance	0.002
☐ Maximum Iterations	1000
Segment Max. Length (min. diameter fraction)	0.8
Segment Min. Length (min. diameter fraction)	0.3
Max. Relative Step-Size	0.2
Max. Absolute Step-Size (min. diameter fraction)	0.25
Refinement Iterations	0
Refinement Factor	1
Smoothing Subdivision	1
☐ Fix Lateral Warp Shift	
☐ Add Periodic Copies	
Advanced Options	

At the bottom of the dialog, there is a 'Restore default solver settings' button and 'OK' and 'Cancel' buttons.

The **FreeWeave Solver** performs a physical simulation when generating the weave as an iterative process. During the simulation, the threads are tightened and their interaction, such as collisions, is considered.

The **Tolerance** represents the reduction in the height 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 method is not suitable for all types of weaves. Thus, another stopping criterion is the **Maximal Iterations**, where the solver stops once the entered number of iterations is reached. These two criteria can be selected together, and the solver will stop when either criterion 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 during one 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** 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 than or equal to 0.1 and less than or equal to 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 post-processing step after the simulation. The primary use for this is in visualization to make the structure appear smoother. As it only happens once at the end of the simulation, it is not computationally expensive. 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 **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 or MeshGeo), this option should be enabled to prevent artifacts at the domain boundary.

Advanced Options

Clicking on **Advanced Options** unfolds additional solver settings. They do not need to be changed for most simulations. Tooltips describe how they can be used if they need to be adjusted.

Advanced Options

☒ Fix First Crossing Position

☐ Write Debug Output Interval

1

Segment length algorithm

ProportionalSubdivision

☒ Use New Collision Algorithm

Inflate Iterations

0

Initial Thread Diameter Scale Factor

1

Height (Z) scale factor

1

Segment length mode

Constant

Segment length override

0

Segment Size Scale Iterations

0

Segment Size Scale Initial Factor

1

☐ Visualize Segments

Multifil broadening smooth factor

0

Overlap Scale Iterations

0

Broadening Scale Iterations

0

Restore default solver settings

When the option **Fix First Crossing Position** is enabled, the first crossing point remains fixed at its initial position, preventing drift in the XY plane during the iteration.

Enable **Write Debug Output Interval** to save the intermediate structure to the result folder every N iterations.

Choose the algorithm to regulate the segment length when approximating fiber trajectory with the **Segment length algorithm**:

- **Legacy**: this algorithm splits and merges segments during the simulation. It was called *Old Segment Length Algorithm* in previous versions.
- **Standard**: this algorithm subdivides segments once before the simulation and then normalizes the segment lengths during simulations.
- **Proportional Subdivision**: this algorithm uses the same strategy as Standard, but matches the target lengths more accurately.

Enable the option **Use New Collision Algorithm** to perform a more accurate collision detection. With this option enabled, cylinder-to-cylinder collisions are tested instead of sphere-to-cylinder collisions.

The number of initial iterations in which to gradually inflate warp threads can be set under **Inflate Iterations**.

The **Initial Thread Diameter Scale Factor** specifies the initial fraction of the thread diameter used at the start of the simulation. For example, a value of 0.2 means that the threads start 20% of their defined diameter and gradually expand to 100%.

The Z-height will be scaled by the **Height (Z) scale factor**. It is recommended to set this factor to the same value as **Initial Thread Diameter Scale Factor**.

The **Segment length mode** determines how the target segment length varies with the fiber diameter.

- **Constant**: the segment lengths are constant and independent of the fiber diameter.
- **Relative to diameter**: the segment lengths are proportional to the fiber diameter.
- **Relative to cross-section area**: the segment length are proportional to the fiber cross-section area.

The **Segment length override** factor defines whether and how the segment length will be overridden. For non-zero values, the segment length override is enabled. The resulting behavior also depends on the chosen Segment length mode:

- For the **Constant** segment length mode, this value defines the length of segments in meters.
- For the **Relative to diameter** mode, the segment length is the fiber diameter multiplied by this value.
- For the **Relative to cross-section area** mode, the segment length is the fiber cross-sectional area multiplied by this value.

The **Segment Size Scale Iterations** defines the number of initial iterations in which the segment length is gradually increased. This option only works properly with the **Legacy** segment length algorithm.

The **Segment Size Scale Initial Factor** specifies the fraction of segment length used at the start of the simulation. For example, a value of 0.2 means that the initial segment length is 20% of the defined segment length.

If the option **Visualize Segments** is checked, control points of the segments are shown using spheres.

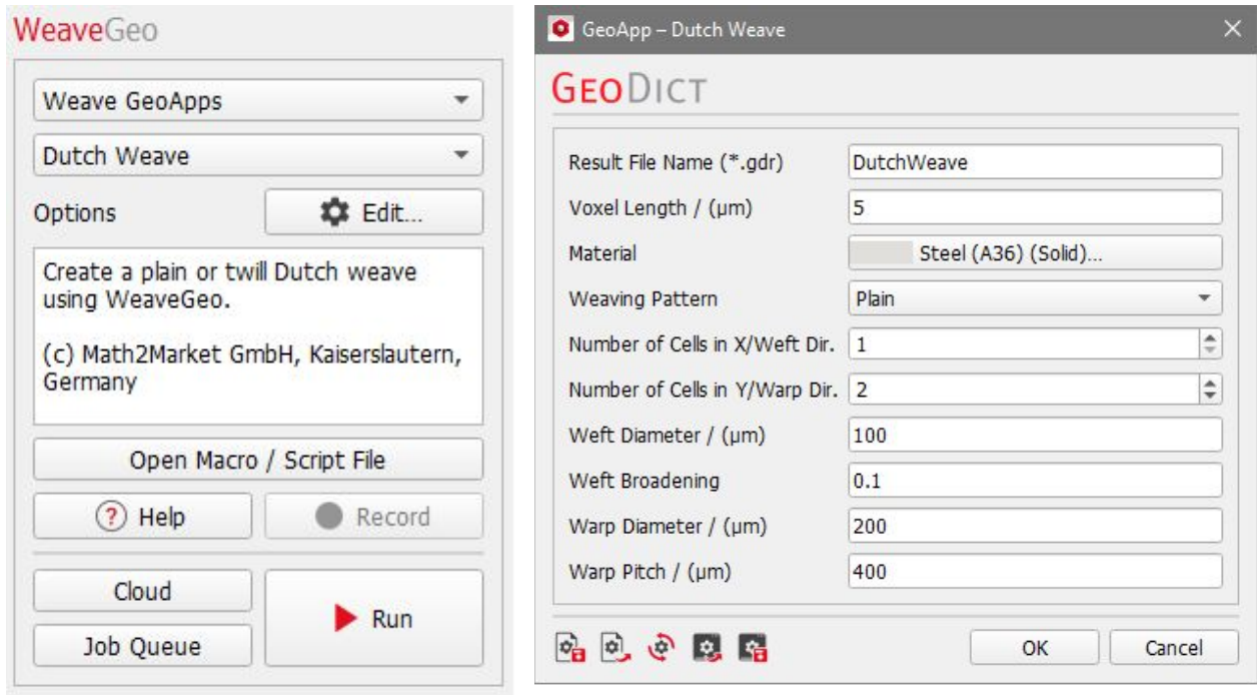
The **Multifil broadening smooth factor** is an integer value that controls the smoothing of the curvature computation. If this value is greater than zero, a broadening algorithm is enabled that computes broadening for the entire multifilament bundle instead of the individual filaments.

The **Overlap Scale Iterations** parameter defines the number of initial iterations during which the overlap is gradually increased to the specified maximum value. In the first iteration, no overlap is applied.

The **Broadening Scale Iterations** parameter defines the number of initial iterations during which the broadening is gradually increased to the specified maximum value. In the first iteration, no broadening is applied.

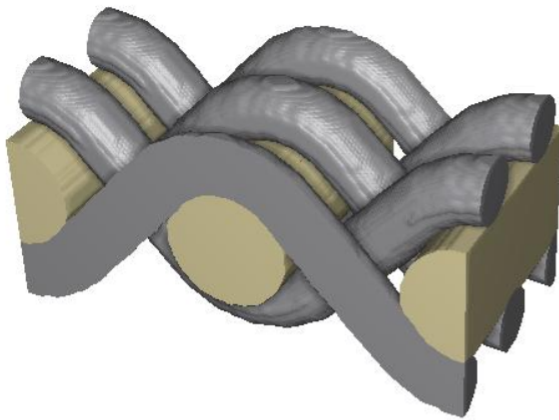
1.4 Weave GeoApps

Find the [Dutch Weave GeoApp](#)^[115] available under **Weave GeoApps**. This app is also available in the Structure Generation sections of the Woven Mesh Materials GeoApps. There, you can also add your own GeoApps.



1.4.1 Dutch Weave

With this GeoApp, you can generate Plain Dutch Weaves or Twill Dutch Weaves. Please refer to the [Plain Weave](#)^[12] and [Twill Weave](#)^[35] section for an explanation of the parameters. The resulting structures for the default parameter sets are displayed below.



GeoApp - Dutch Weave

GEODICT

Result File Name (*.gdr)

Voxel Length / (μm)

Material

Weaving Pattern

Number of Cells in X/Weft Dir.

Number of Cells in Y/Warp Dir.

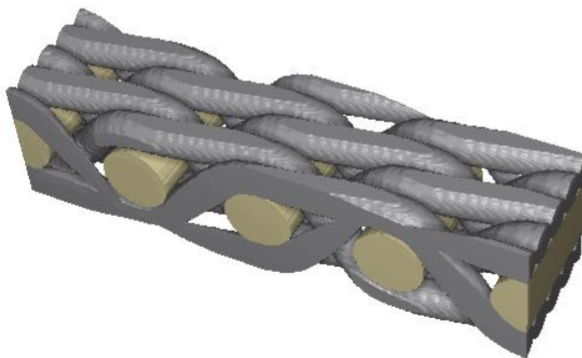
Weft Diameter / (μm)

Weft Broadening

Warp Diameter / (μm)

Warp Pitch / (μm)

OK Cancel



GeoApp - Dutch Weave

GEODICT

Result File Name (*.gdr)

Voxel Length / (μm)

Material

Weaving Pattern

Float Factor 1

Float Factor 2

Adjust Weft Pitch / (μm)

Number of Cells in X/Weft Dir.

Number of Cells in Y/Warp Dir.

Weft Diameter / (μm)

Weft Broadening

Warp Diameter / (μm)

Warp Pitch / (μm)

OK Cancel

1.5 References

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Citation: Math2Market GmbH, 2026: GeoDict 2026 User Guide, WeaveGeo, Math2Market GmbH, Germany, doi.org/10.30423/userguide.geodict



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