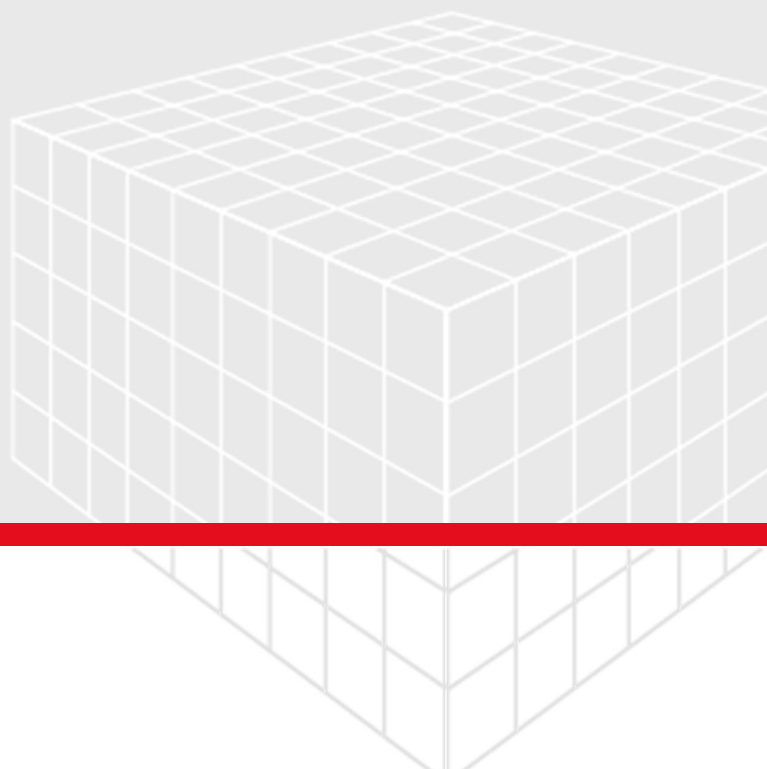


FiberGeo

User Guide

GEODICT Release 2026

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GEODICT

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FiberGeo

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1 FiberGeo

Use FiberGeo to generate and model fibrous structures. Starting from random distributions of fibers, FiberGeo creates virtual non-woven and fiber reinforced composites.

To generate fibrous material models, FiberGeo requires the input of fiber material and form, and the desired statistical properties of the resulting structure, such as size, amount of the solid phase, etc. The fibers can be straight or curved, where the profile shape can be varied (circular, elliptical, rectangular, cellulose, etc.). The orientation of fibers and the distribution of fiber parameters can be specified. It is possible, for example, to generate structures with prescribed solid volume percentage, prescribed density, or prescribed grammage.

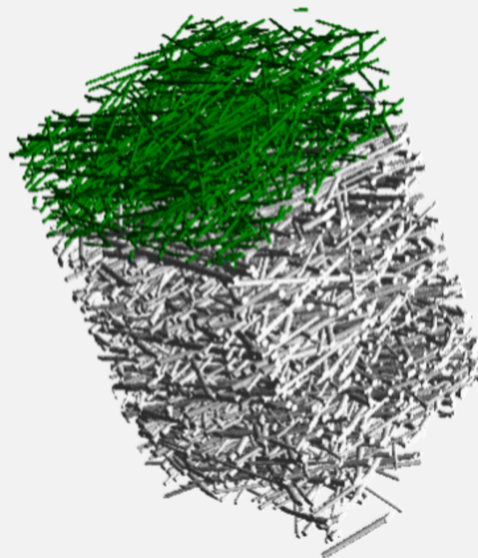
Input:

**Fiber material and desired structure properties:
sample size, solid volume fraction, orientation, ...**

FiberGeo

Output:

Fibrous Structure



FiberGeo fibrous structures are based on given statistical properties that can be estimated, e.g., from 3D images (CT-scan), from 2D images like REM, from certain material properties, or from the knowledge of the underlying production process. These properties can also be computed in GeoDict directly from the scan using the module FiberFind. The generated non-woven models are available as 3-dimensional images and as analytical data (GAD, **GeoDict analytic data**), which can be used to export surface triangulations (stl-files) for CAD-programs.

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

Important application areas are the production of glass fiber and carbon fiber reinforced composites, fibrous insulation materials, gas diffusion layers in fuel cells, filter media, dewatering felts, and many others.

Additionally, a FiberGeo license offers the possibility to generate Gaussian Random Fields, which can be segmented to structures as described here.



New in GeoDict 2026

- Curved fibers now can [bend back to media-layer](#)^[93].
- [GeoApps](#)^[163] are reorganized. The GeoApps of previous GeoDict versions are now transformed into [preset settings](#)^[6] or are moved to the Scripting Examples. Instead other GeoApps are added in the FiberGeo section.

Learn to use FiberGeo:

- [Create Fibers](#)^[5]
With Create, fibrous structures with user-defined parameters can be generated. The fibers appear randomly in the domain.
- [Pile Fibers](#)^[117]
Let the fibers fall from the top of the domain and settle in their final position after shifts and rotations.
- [Distribute](#)^[142]
If analytic object information is available, fibers can be redistributed in the given volume. Distributing the fibers is often used after a piling step to obtain a more homogeneous material.
- [Add Binder](#)^[147]
Add material in the shape of a concave meniscus in locations where fibers in that structure are close together. This models binder in fibrous structures.
- [Fiber GeoApps](#)^[163]
Several GeoApps are available in the FiberGeo section.



Join the conversation

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

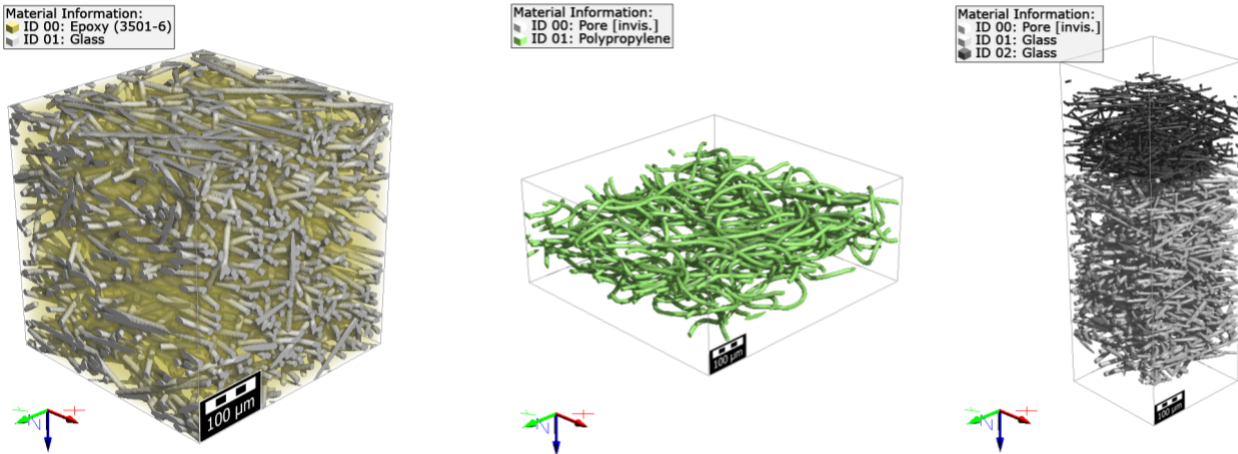
Find illustrative application examples on the [website](#).

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 Create Fibers

With **Create Fibers**, fibrous structures with user-defined parameters can be generated. Define diameters, orientations, curvature, cross-section shapes, and distribution throughout the domain. Set the size and resolution of the structure and the constituent materials. You can create the objects either in an empty domain or add them to already existing structures.



The **Create Fibers** command:

- [Options](#)⁵
Define the fiber generation parameters.
- [Results](#)¹¹²
View the fiber generation statistics in the Result Viewer.

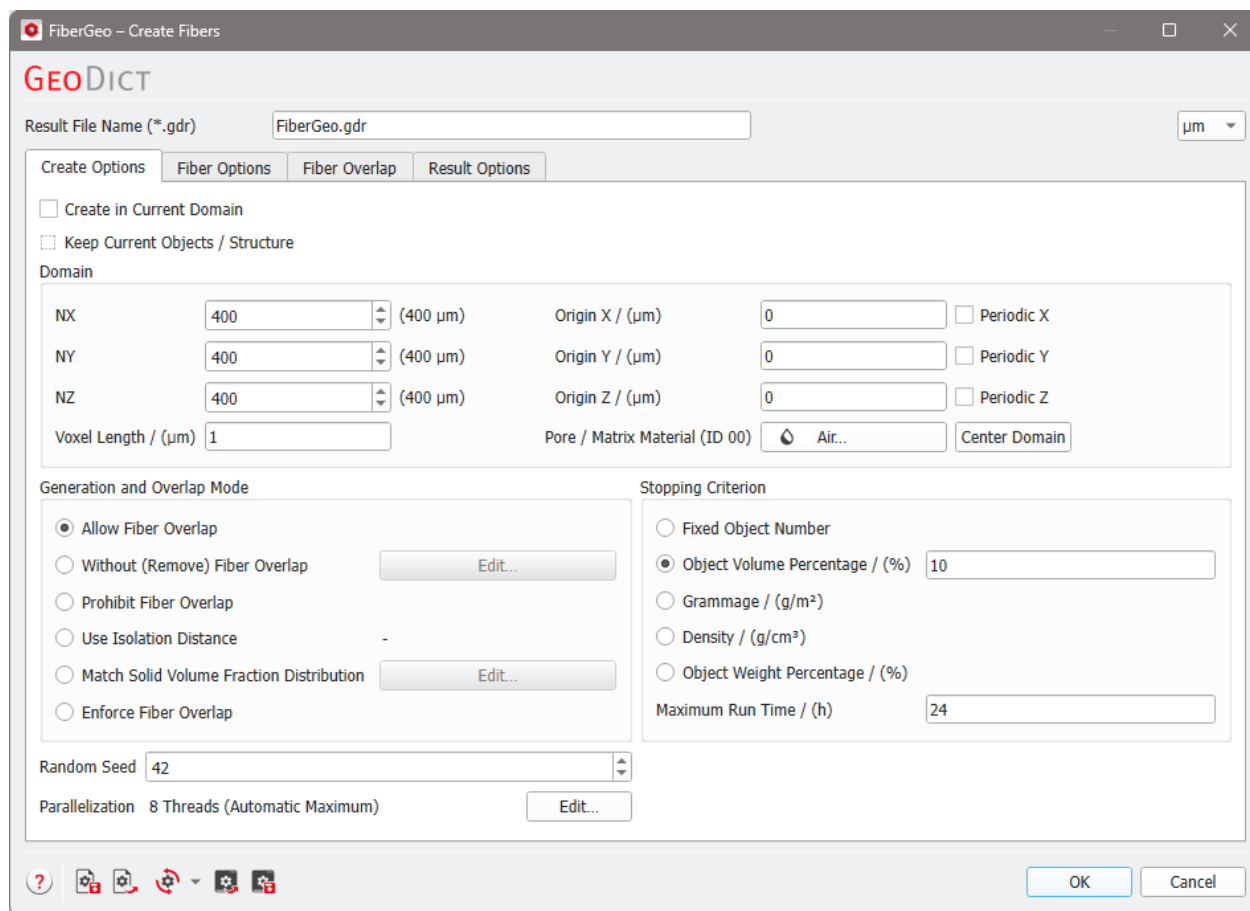
1.1.1 Options

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

The result files are saved in the chosen project folder (**File** → **Choose Project Folder**, in the **Menu bar**). If a GeoDict result file (*.gdr) with the given name already exists in the project folder, a warning message is shown at the start of the creation process. You can either decide to rename the chosen file name to a new one, to cancel the generation process, to overwrite or to back up the old file. When nothing is selected, GeoDict uses the **Back-Up** option after a waiting time.

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

The options are organized into **Create Options**, **Fiber Options**, **Fiber Overlap**, and **Result Options** accessible through tabs.



The options are organized into tabs:

- [Create Options](#)^[8]
Determine general properties of the resulting structure, such as size, position, resolution, and solid volume fraction.
- [Fiber Options](#)^[36]
Define the geometrical properties of individual fiber types such as cross-section, length, and orientation. Up to eight different fiber types can be used in one structure.
- [Fiber Overlap](#)^[107]
Choose how Material IDs are defined in positions where objects overlap.
- [Result Options](#)^[111]
Determine if intermediate geometries are saved.

Different Create Fibers Presets

In the bottom of the dialog find several helpful options.



Opens the corresponding User Guide section.

	Saves the settings to a GeoDict settings file (*.gps).
	Loads the settings from a GeoDict settings file (*.gps) or a GeoDict result file (*.gdr).
	Resets all parameter settings to the built-in default settings.
	Resets all parameter settings to the saved start-up settings.
	Saves the current parameter settings as start-up settings.

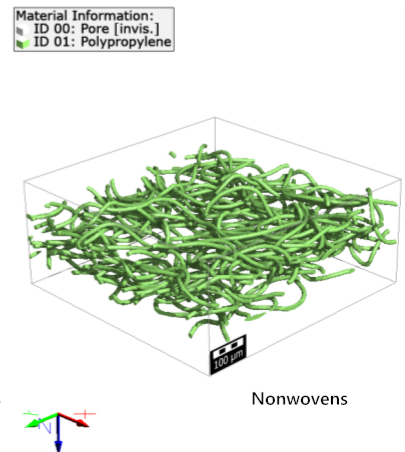
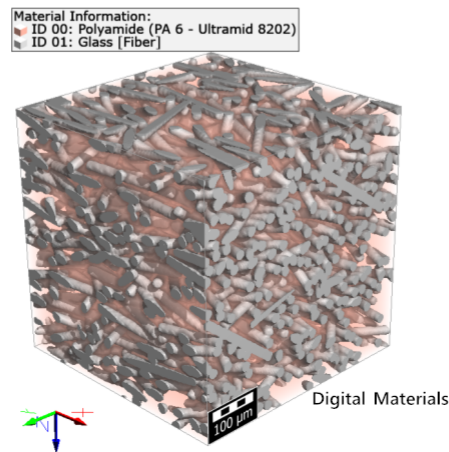
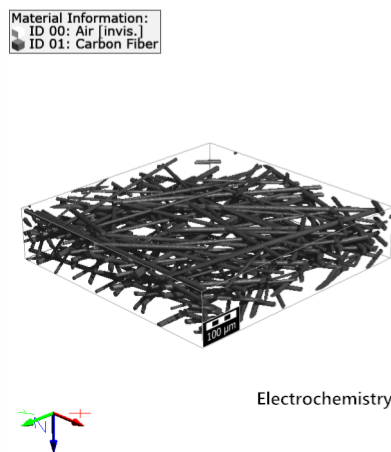
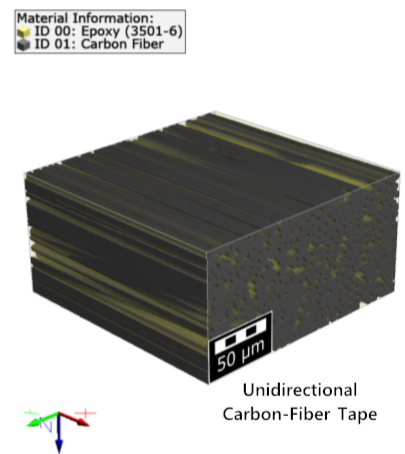
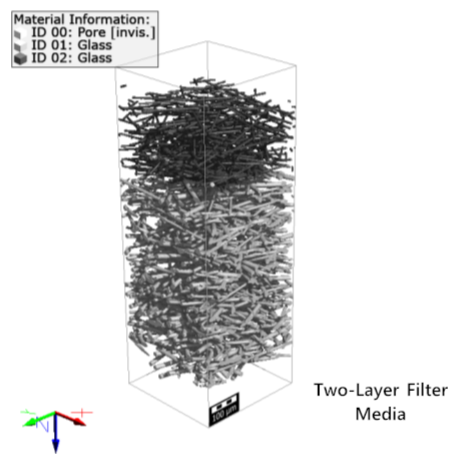
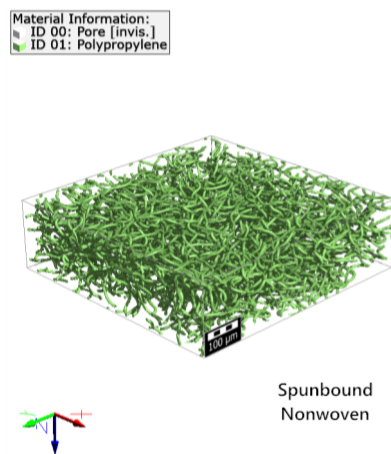
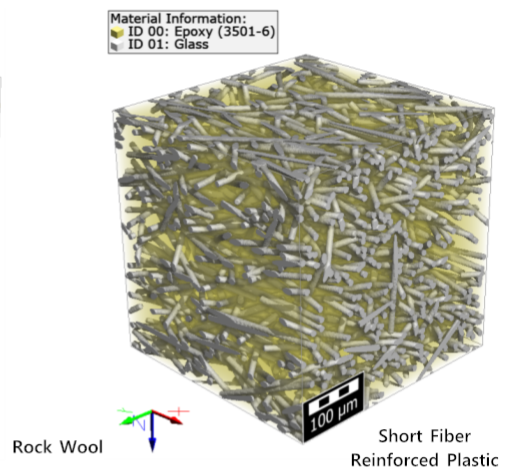
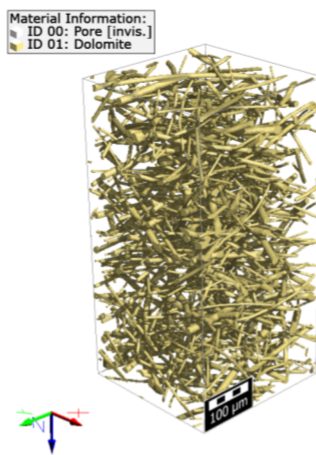
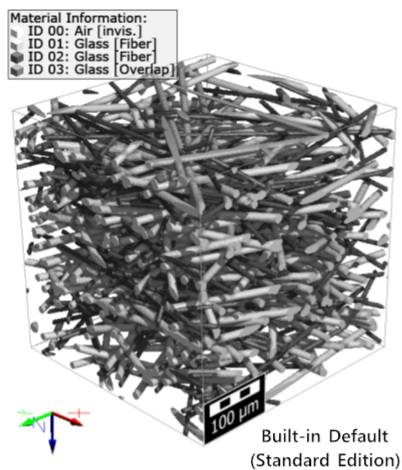
Each option is explained by a tooltip which appears when resting the mouse over the icon.

The built-in default icon comes with a selection of different presets. Clicking on the little arrow shows several additional preset options.

The usual built-in default settings will load the settings according to the current GeoDict edition. You can change the current GeoDict edition from the **Settings menu** as described in the Graphical User Interface chapter.

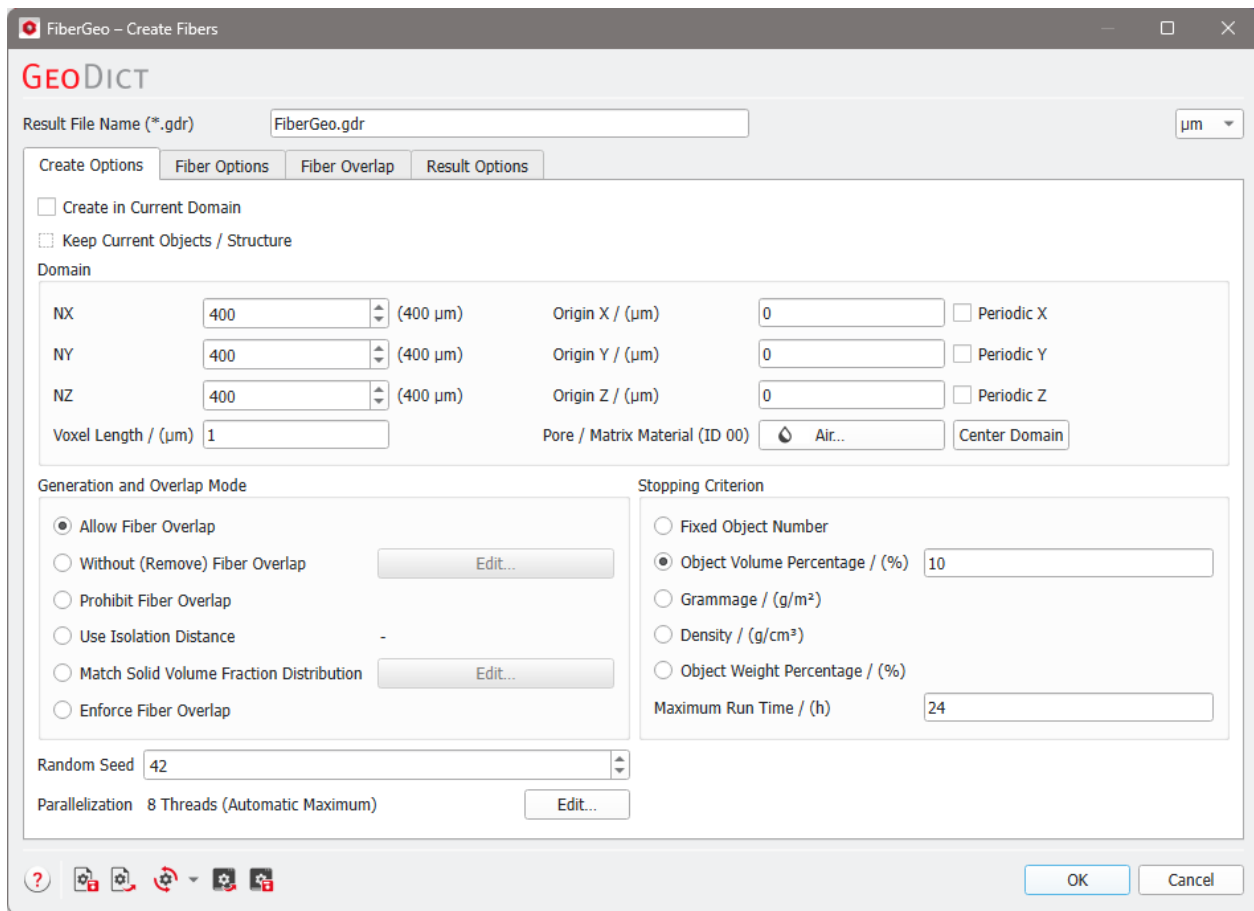
In **FiberGeo - Create** find edition-specific presets for **Electrochemistry**, **Nonwovens**, and **Digital Materials**. Additionally, find five different preset structures. Choose the presets and inspect the entered parameters in the different tabs and have a look at the following overview if they are a better base for your applications.

	Load built-in default settings
	Load predefined settings 'Rock Wool'
	Load predefined settings 'Short Fiber Reinforced Plastic'
	Load predefined settings 'Spunbond Nonwoven'
	Load predefined settings 'Two-Layer Filter Media'
	Load predefined settings 'Unidirectional Carbon-Fiber Tape'
	Load built-in default settings 'Electrochemistry'
	Load built-in default settings 'Digital Materials'
	Load built-in default settings 'Nonwovens'



Create Options

The general properties of the fibrous structure are entered under the **Create Options** tab. These parameters are grouped into the panels **Domain**, **Generation and Overlap Mode**, and **Stopping Criterion**. Additionally two groups of single parameters are available, the **Create in Current Domain** parameters at the top and the **General Options** at the bottom of the dialog.



The parameters are organized into the following groups:

- [Create in Current Domain](#)^[9]
Decide to create fibers in the current domain and whether the current structure should be kept.
- [Domain](#)^[11]
Define the domain parameters, such as resolution, periodicity, and matrix material.
- [Generation and Overlap Mode](#)^[17]
Decide about allowing, removing, or prohibiting overlap. Instead, define an isolation distance or match a certain solid volume fraction distribution.
- [Stopping Criterion](#)^[29]
Define according to which criteria the fiber generation should be stopped.
- [General Options](#)^[33]
Define the temperature, the random seed, and the number of parallel processes.

Create in Current Domain

When checking **Create in Current Domain**, the parameters of the domain currently in memory are used for the generation of a new structure. Additionally, when **Keep Current Objects / Structure** is checked, the structure in memory is kept and combined with the newly generated fibrous structure.

This feature can be used in combination with checking **Prohibit Fiber Overlap** or **Prohibit Overlap with Current Structure** in the [Generation and Overlap Mode](#)^[17] panel or with the **Center** distribution [On Current Options](#)^[72] available under the [Fiber Options](#)^[36] tab.

In this way, complex models can be created. For example, you can make fibers cover a mold that is later discarded.

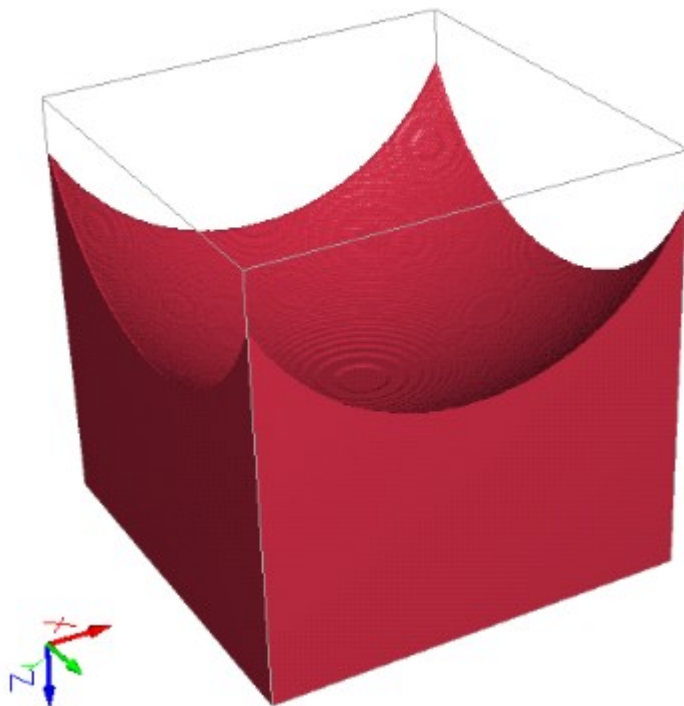
Note that the parameters grouped under the **Domain** panel, including the voxel length, cannot be modified once the **Create in Current Domain** box is checked, because they are taken from the structure already in memory.

☒ Create in Current Domain
☐ Keep Current Objects / Structure

Domain

NX	200	(200 μm)	Origin X / (μm)	0	☐ Periodic X
NY	200	(200 μm)	Origin Y / (μm)	0	☐ Periodic Y
NZ	200	(200 μm)	Origin Z / (μm)	0	☐ Periodic Z
Voxel Length / (μm) 1			Pore / Matrix Material (ID 00)  Air Center Domain		

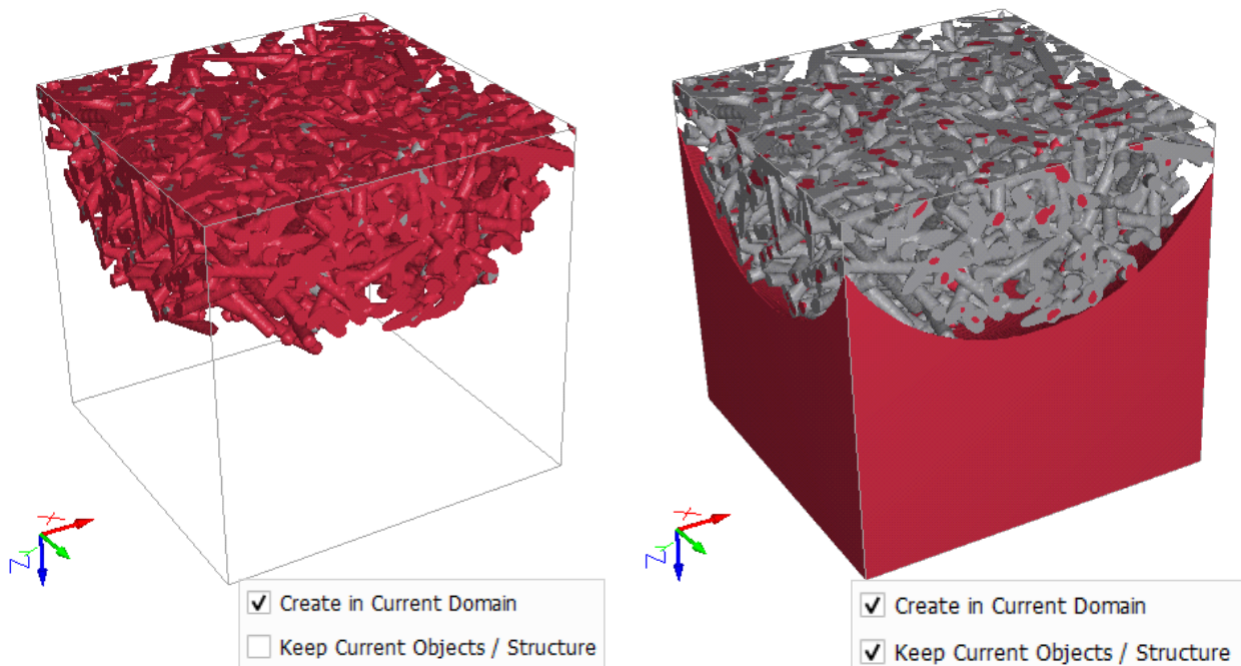
Observe the effect that **Create in Current Domain** and **Keep Current Objects / Structure** have on the generation of a fibrous structure.



Here, a mold is generated and present in memory (current structure) while polyamide PA-66 fibers are added. [Prohibit Overlap with Current Structure](#)^[28] is checked to avoid the PA-66 fibers to enter the mold, but the PA-66 fibers can overlap each other.

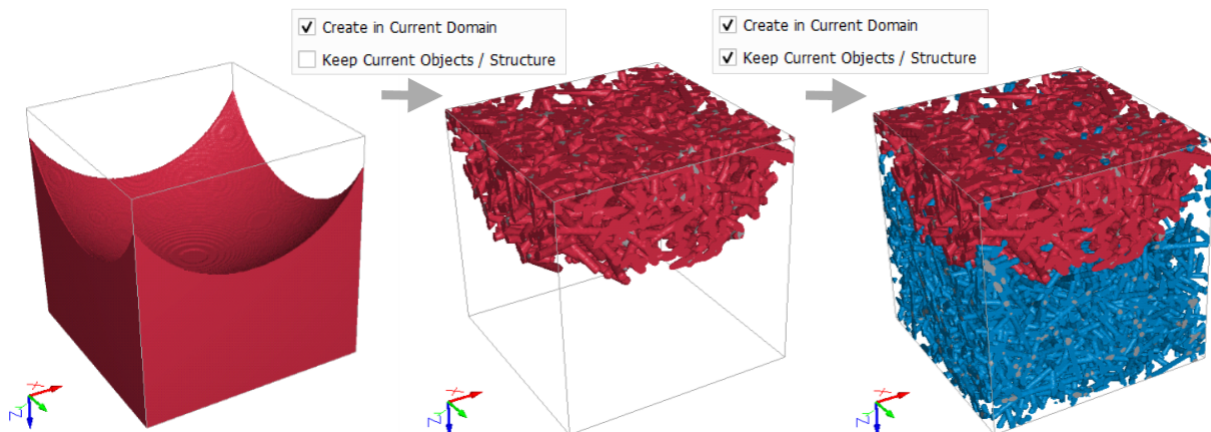
If additionally, the PA-66 fibers should not overlap each other, the more restrictive [Remove Fiber Overlap](#)^[18] should be checked instead.

The PA-66 fibers are automatically assigned the Material ID 02 when keeping the current structure (with Material ID 01).



In the following example, the same mold is made, and then PA-66 fibers are generated into the mold, which is not kept. Then, the current structure made of PA-66 fibers is kept and PET fibers are generated in the same form that the mold previously had.

In every step, overlap is prohibited with the current structure but not between the newly generated fibers.



Domain

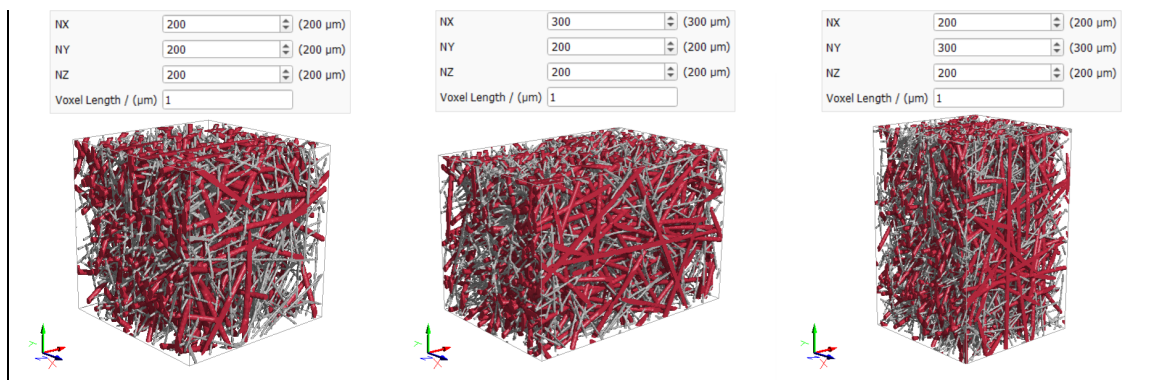
The **Domain** panel contains the parameters defining the structure size (**NX**, **NY**, and **NZ**) in combination with the resolution (**Voxel Length**), as well as the **Origin** parameters, the **Periodicity** check boxes, the **Center Domain** button, and the **Pore / Matrix Material** button.

Domain					
NX	400	(400 μm)	Origin X / (μm)	0	☐ Periodic X
NY	400	(400 μm)	Origin Y / (μm)	0	☐ Periodic Y
NZ	400	(400 μm)	Origin Z / (μm)	0	☐ Periodic Z
Voxel Length / (μm)	1		Pore / Matrix Material (ID 00)	Air...	Center Domain

✓ NX, NY, NZ, and Voxel Length

The internal representation of a structure in GeoDict consists of rectangular 3D arrays of cubes, hereafter called volume elements or voxels. **NX**, **NY**, and **NZ** are the number (N) of voxels in X, Y, and Z directions.

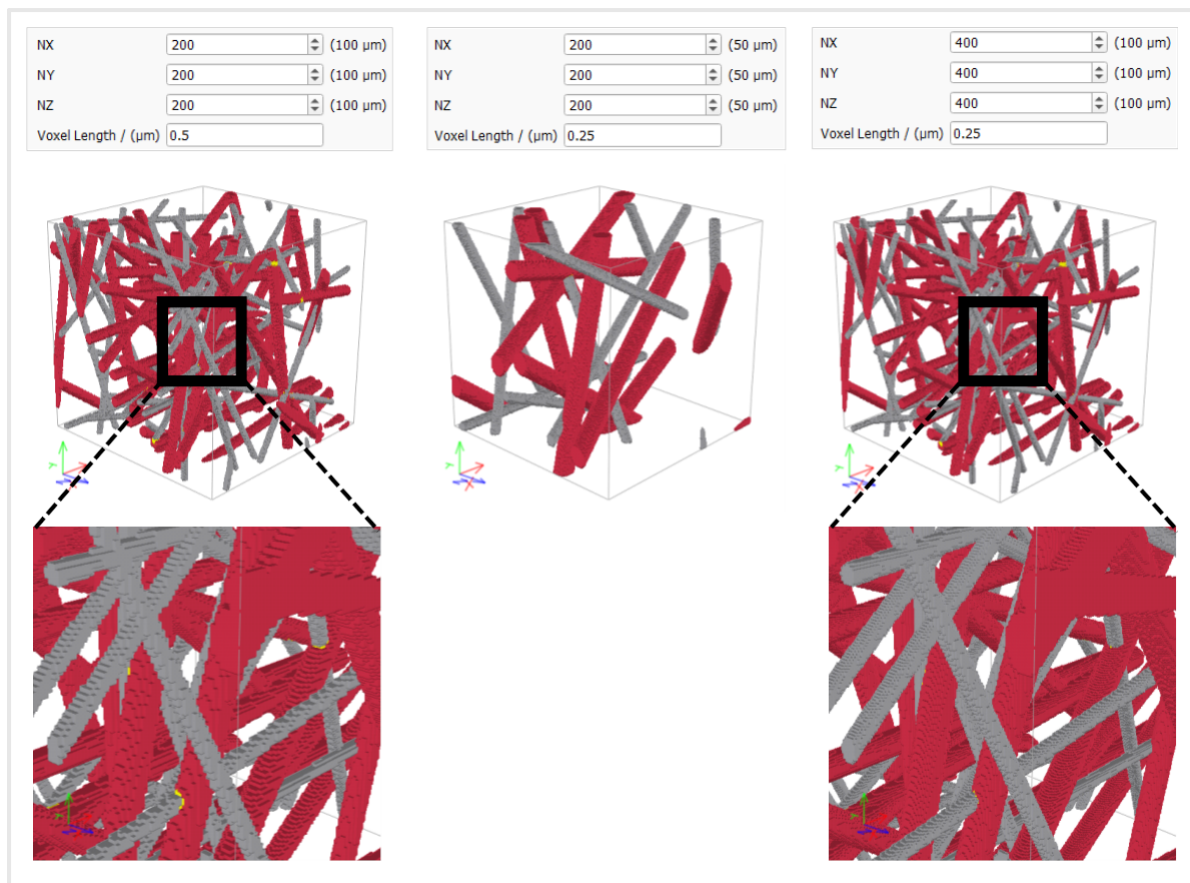
The **Voxel Length** is the size of one voxel in the chosen units. Varying the values for **NX**, **NY**, and **NZ** has the effect of changing the size of the structure in the given direction.



Low values for **Voxel Length** in combination with high values for **NX**, **NY**, and **NZ** increase the resolution, but also increase computational time. After setting the values of **NX**, **NY**, **NZ**, and **Voxel Length**, the physical structure size is automatically displayed in the chosen units (here μm).

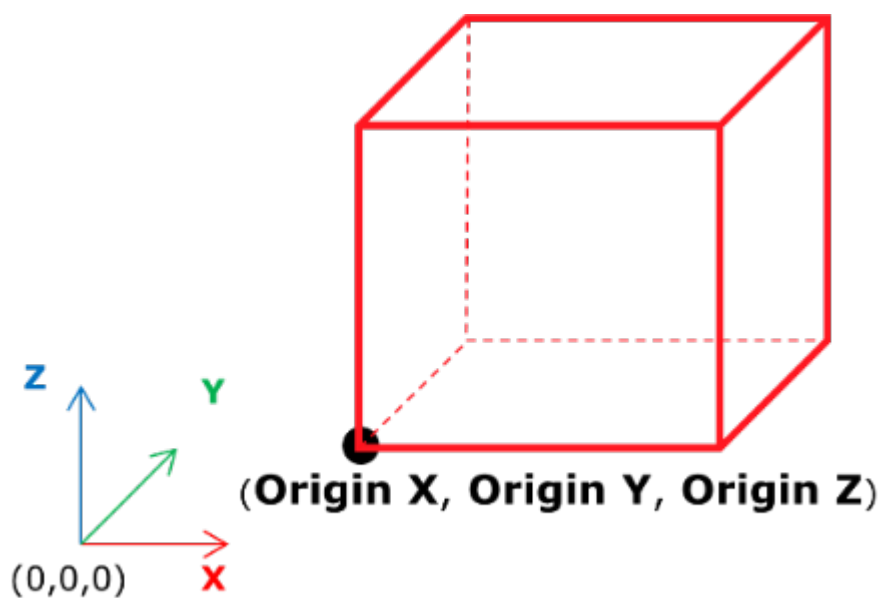
The following example shows how starting with $\text{NX} = 200$, $\text{NY} = 200$, $\text{NZ} = 200$ ($100 \times 100 \times 100 \mu\text{m}^3$, at voxel length $0.5 \mu\text{m}$), and decreasing the Voxel Length from $0.5 \mu\text{m}$ to $0.25 \mu\text{m}$ has the effect of refining the structure by increasing the resolution, while decreasing the size of the volume to $50 \times 50 \times 50 \mu\text{m}^3$.

By setting $\text{NX} = 400$, $\text{NY} = 400$, $\text{NZ} = 400$, to restore the size of the volume to the original $100 \times 100 \times 100 \mu\text{m}^3$, the structure is displayed at higher resolution.

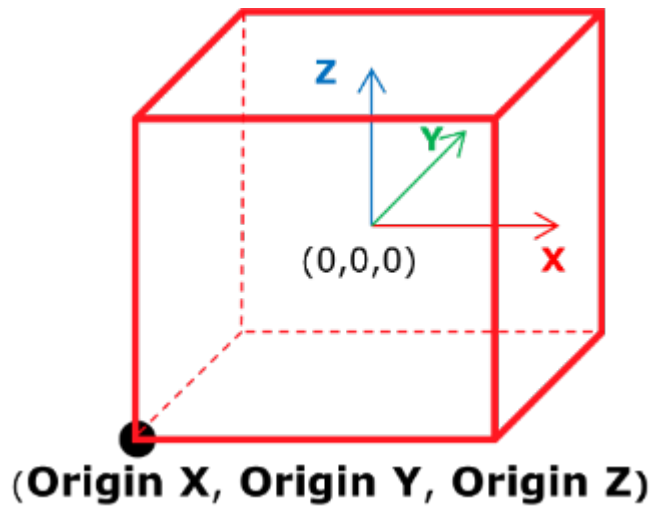


✓ Origin X, Origin Y, and Origin Z

The **Origin X**, **Origin Y**, and **Origin Z** parameters, together with the **Center Domain** button, determine the placement of the structure in the physical space. Zero values for Origin X, Origin Y, and Origin Z mean that the point with (0, 0, 0) coordinates is located at the lower left corner of the structure.



When clicking the **Center Domain** button, the (0, 0, 0)-point is set to the center of the structure as shown below.



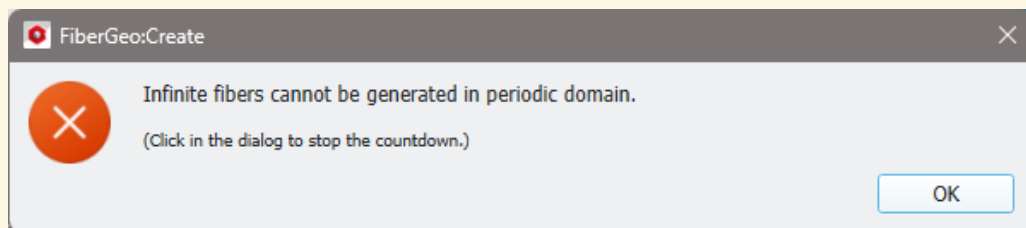
✓ Periodicity

Checking the **Periodic X**, **Periodic Y**, and **Periodic Z** boxes allows the generation of structures which are periodic in one or several directions.

Periodicity has the effect, that objects ending on one side of the volume reappear on the opposite side, so that attaching of several volumes with periodic objects results in a repetitive complex.

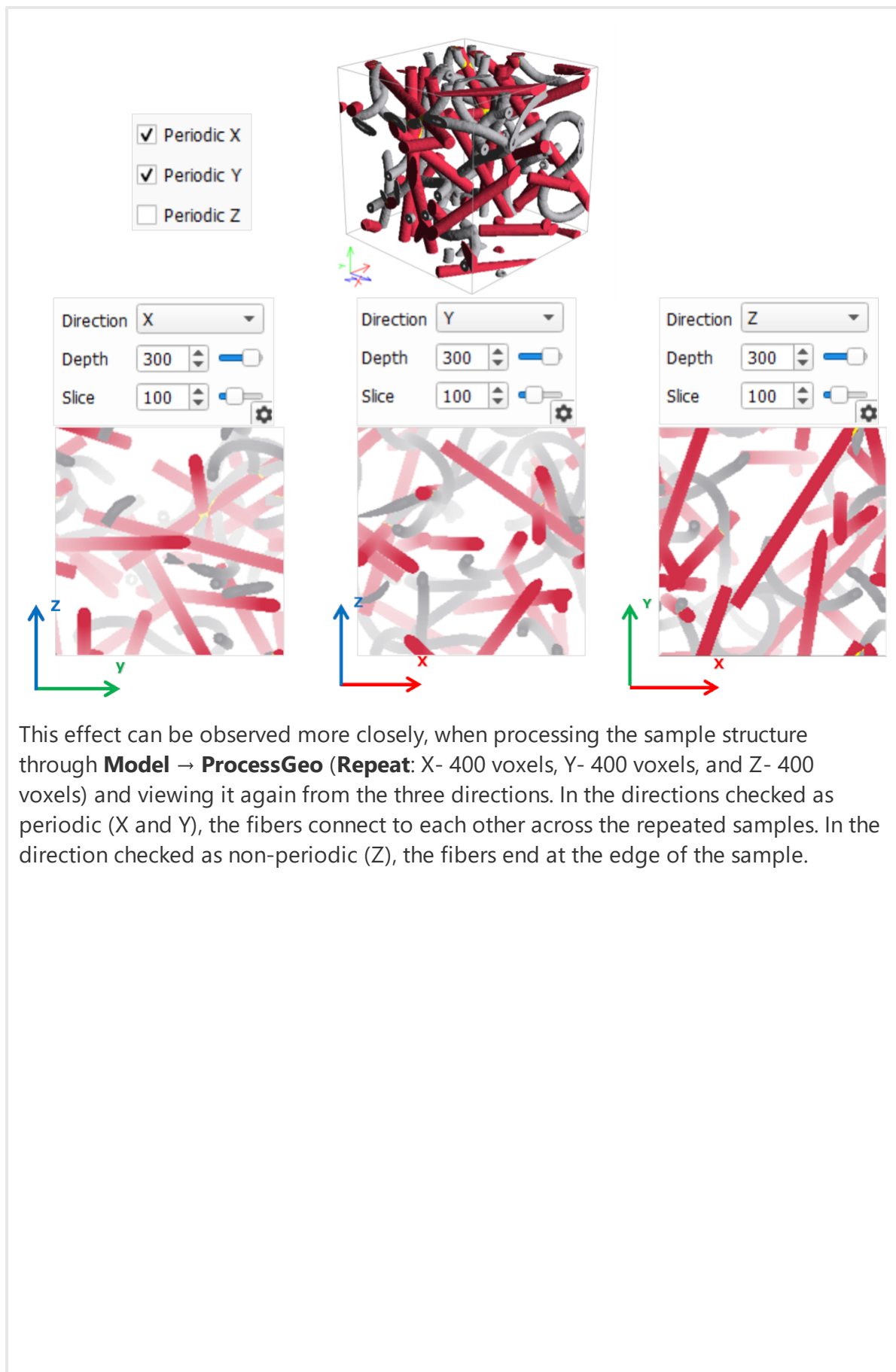


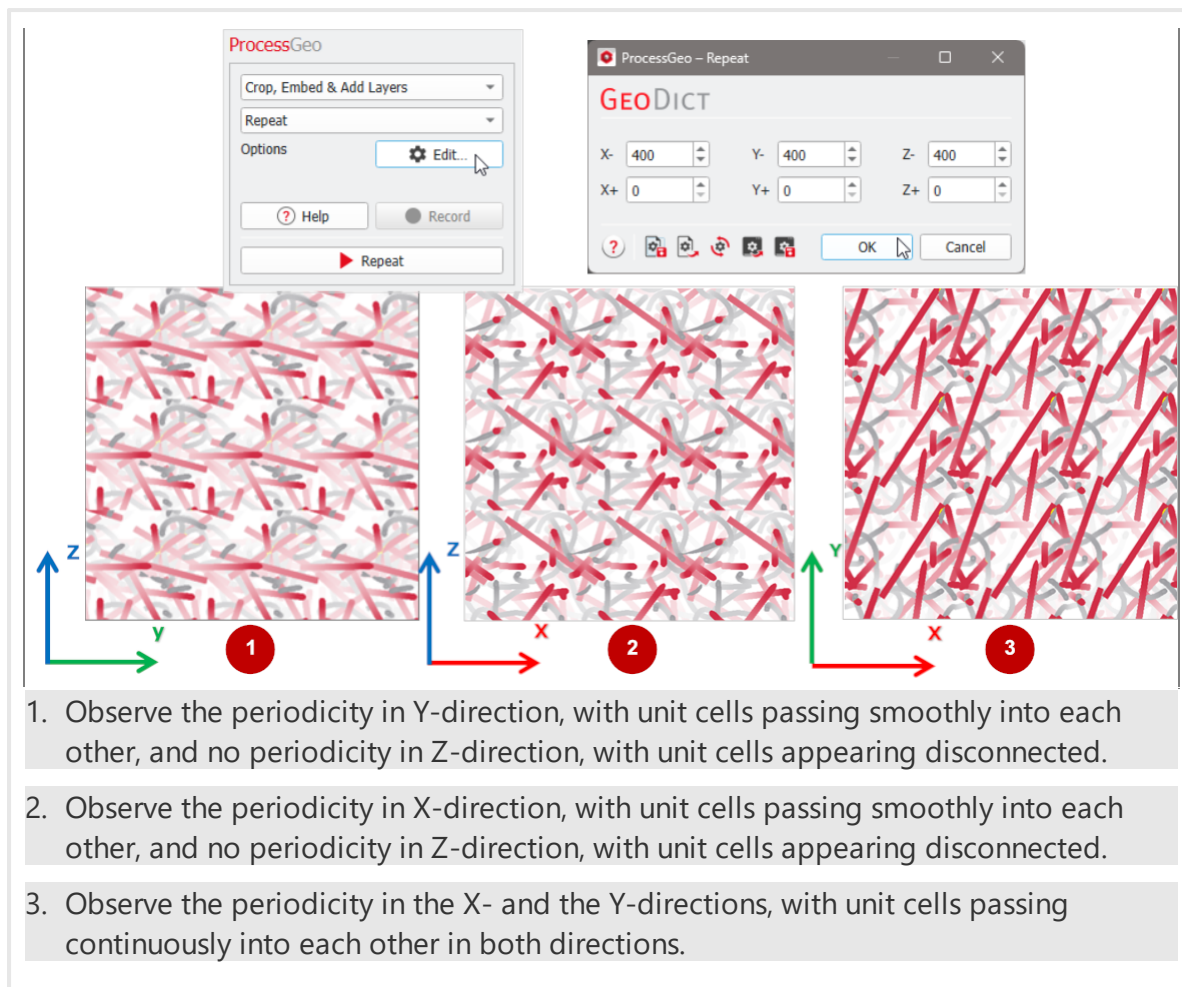
Know how! An error message appears if trying to generate a periodic structure with **Infinite fibers**.



To avoid this error, go to **Fiber Options** and remove the **Infinite** fibers and add a different fiber type, or, alternatively, do not choose to generate with periodicity.

Checking the **Periodic X** and **Periodic Y** boxes, but leaving un-checked the **Periodic Z** box, has the following effect on the periodicity of a generated fibrous structure.

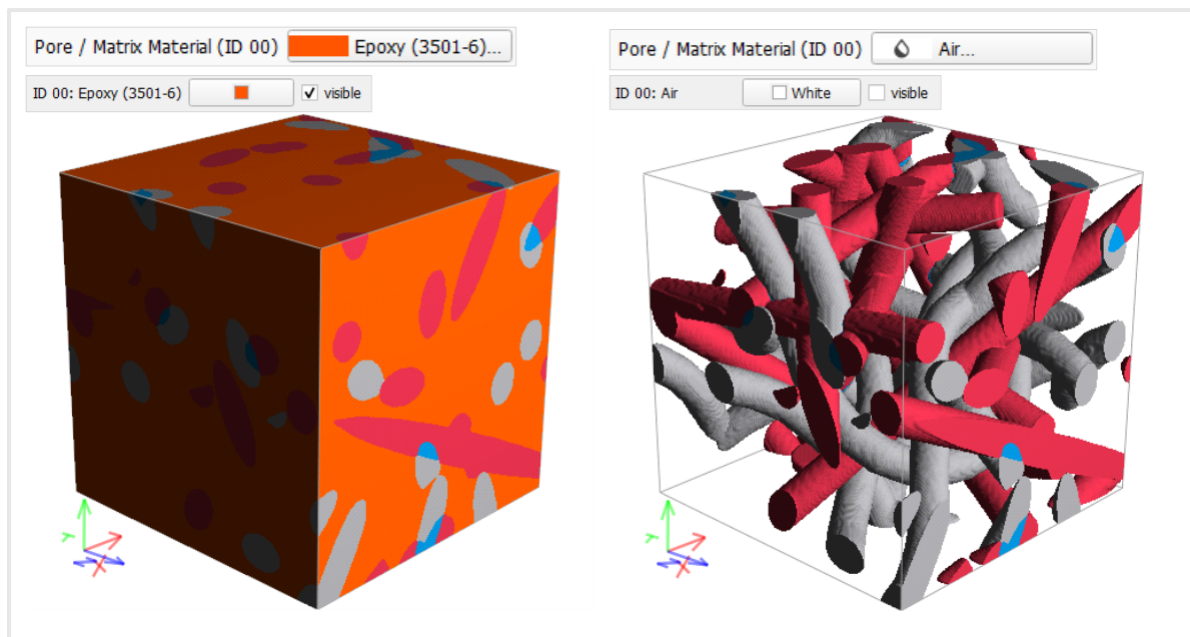




✓ Pore / Matrix Material and Density

Choose the material of the pore space or the matrix around the fibers from the pull-down menu.

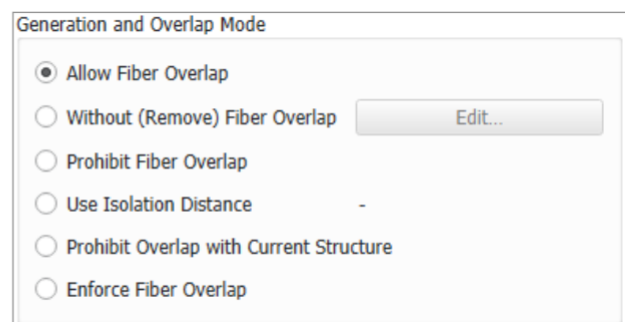
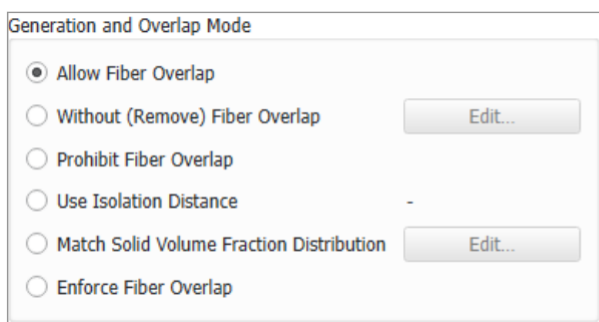
When the material is chosen to be **Pore**, the fibers are embedded in empty pore space. Otherwise, the material filling the matrix can be chosen to be a **Solid**, **Porous** medium, or **Fluid** in which the fibers are embedded. Control color and visibility of the the different Material IDs through the **Color & Visibility** tab of the side bar on the right of the GeoDict GUI.



Generation and Overlap Mode

The options in the **Generation and Overlap Mode** panel control the relative position among objects. It is possible to choose between **Allow Fiber Overlap**, **Without (Remove) Fiber Overlap**, **Prohibit Fiber Overlap**, **Use Isolation Distance**, **Match Solid Volume Fraction Distribution**, and **Enforce Fiber Overlap**.

If checking **Create in Current Domain**, **Prohibit Overlap with Current Structure** appears instead of **Match Solid Volume Fraction Distribution**. The objects in the newly generated structure can intersect with each other but not with those of the already existing structure.



Know how! The algorithm under **Allow Fiber Overlap** is fast, especially for big structures and, in most cases, leads to excellent results.

If you choose **Remove Fiber Overlap**, the generation time may be longer when generating structures with high solid volume percentages. The objects are first positioned in the structure allowing overlap. Afterwards they are moved to remove overlap as good as possible.

Prohibit Fiber Overlap or **Prohibit Overlap with Current Structure** directly position the objects one after the other without overlap. This is fast for low densities, but may

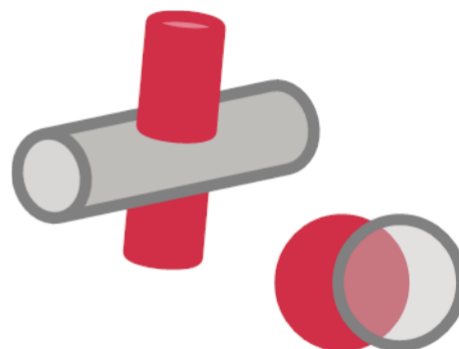
be very slow or even unfeasible when generating dense geometries since the positioning of new non overlapping objects might be geometrically impossible.

For the same reasons, with **Use Isolation Distance**, the generation time may be long, or the generation might be impossible depending on the chosen value for the isolation distance and the selected value for stopping criterion. Then, use the isolation distance option in the Remove Fiber Overlap dialog.

Generally, structures with overlapping objects can be used for processes in the pore space, as filtration and flow simulation. For simulations of mechanical properties, structures without overlap should be generated.

✓ Allow Fiber Overlap

Fibers may overlap when **Allow Fiber Overlap** is selected.

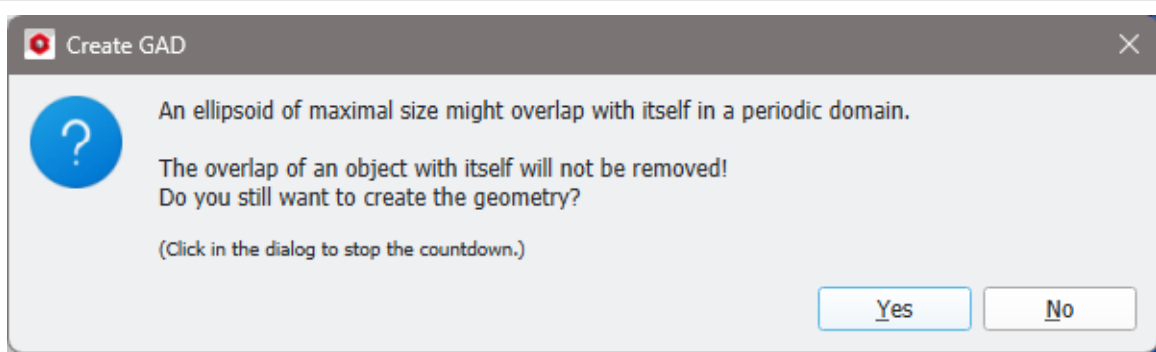


✓ Without (Remove) Fiber Overlap

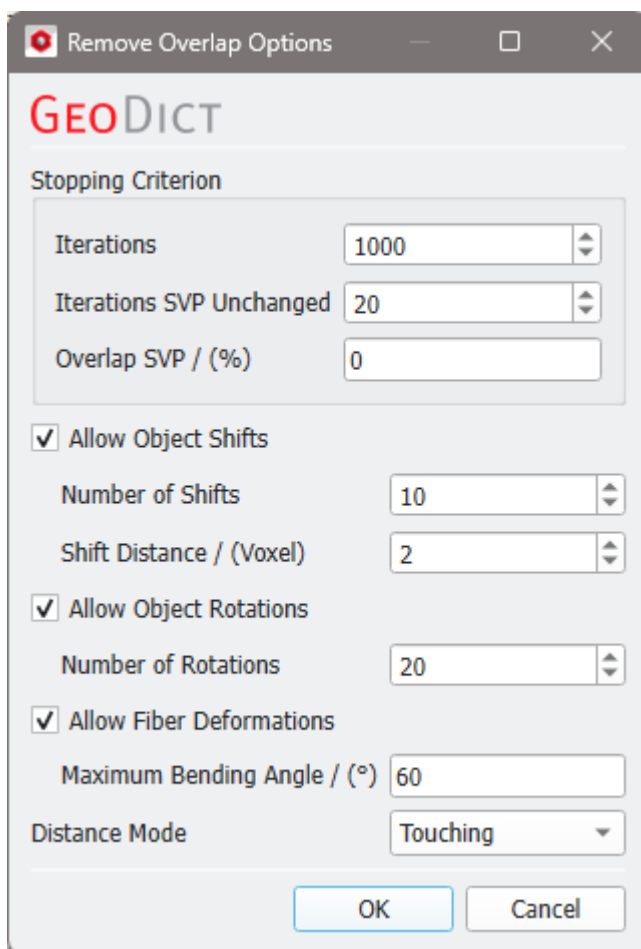
Checking **Without (Remove) Fiber Overlap** eliminates existing overlaps after the generation step.

Note! The statistical properties might change slightly after removing overlap.

Overlaps can be removed from periodic structure models with objects smaller than the domain size or non-periodic structure models with arbitrary object sizes. In a periodic domain, objects which are longer than the domain might overlap with themselves. This type of overlap cannot be removed. In this case, a message appears:



The way in which the overlap removal occurs can be controlled through the **Remove Overlap Options** accessible via the **Edit...** button.



In the **Remove Overlap Options** dialog, the following parameters can be set:

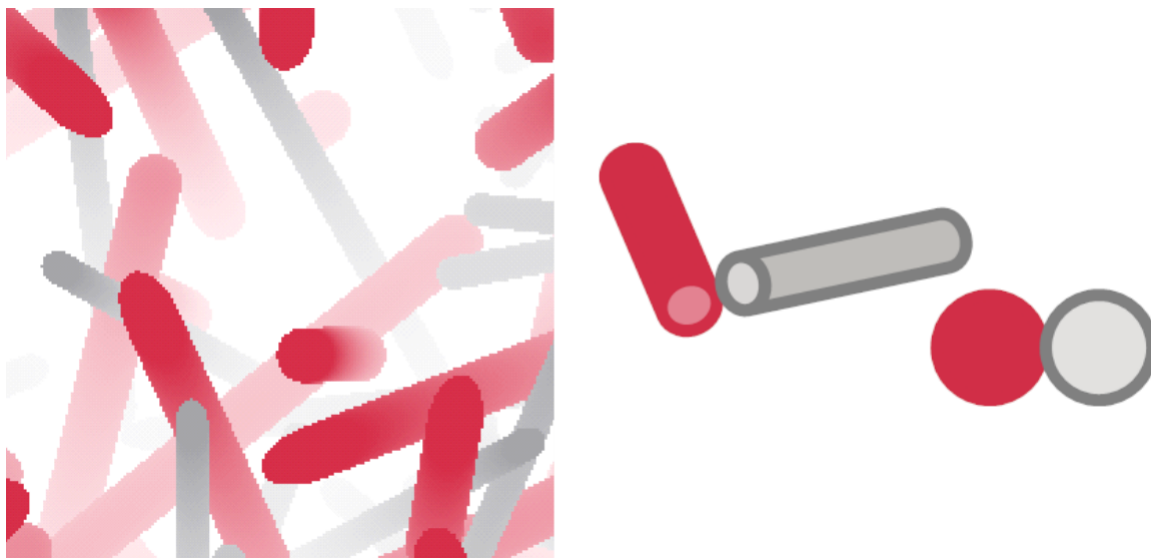
- **Iterations:** Defines after how many iterations the removal stops.
- **Iterations SVP Unchanged:** The removal stops if the SVP (Solid Volume Percentage) remained unchanged during this number of iterations.
- **Overlap SVP / (%):** Defines the final allowed Overlap SVP.
- **Allow Object Shifts:** Check if shifting the objects should be an allowed operation for

overlap removal. Define the **Number of Shifts** per iteration and the maximal **Shift Distance** in voxel per iteration.

- **Allow Object Rotations:** Check if rotating the objects should be an allowed operation for removal. Define the maximal **Number of Rotations** allowed per iteration. Objects will be rotated in all directions, where the maximal rotation angle per iteration is one degree.
- **Allow Fiber Deformations:** Check if bending fibers should be an allowed operation for overlap removal. Define the **Maximum Bending Angle** allowed between two segments. Each fiber consists of several segments. The center points of the segment connections are shifted in all directions, while the other shape parameters, as, e.g., fiber length and segment length are kept constant. The maximal point shift distance is the same as for the object shift. This option is only applied to fibers, as other objects do not consist of segments.
- **Distance Mode:** The pull-down menu offers four options:
 - The objects can be **Touching** (distance zero).
 - Enter a maximal **Defined Overlap** allowed for the objects.
 - Enter a minimal **Defined Isolation** distance for the objects.
 - **Avoid Contacts** means a defined isolation of one voxel volume diagonal.

✓ Prohibit Fiber Overlap

Fibers may touch but not overlap when **Prohibit Objects Overlap** is selected.



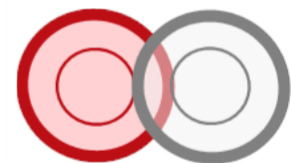
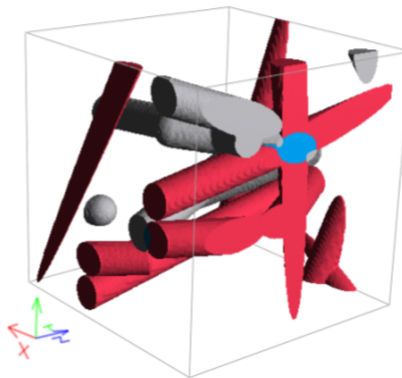
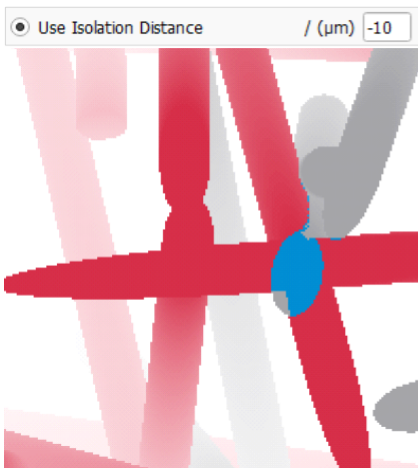
In this case, the overlap of the fibers is prohibited *during* the creation process. This option might lead to longer run times compared to **Remove Objects Overlap**. It only works for low porosity. As before, fibers longer than the domain might overlap themselves if a periodic domain is selected.

✓ Use Isolation Distance

If a positive value is inserted for **Use Isolation Distance**, the gaps between fibers have at least this preset distance.



When **Use Isolation Distance** is set to negative values (e.g., $-10\ \mu\text{m}$), the effect is that the fibers may overlap with maximally $10\ \mu\text{m}$ (showing in a different color which here is blue). Negative values of isolation distance are useful to model synthetic fibers that melt, or natural fibers that deform at touching points, during the generation of the structure. Then, the distance between the centers of the fibers is less than the sum of the two radii.



✓ Match Solid Volume Fraction Distribution

For certain applications it is necessary to create statistically distributed inhomogeneities, e.g., to generate a bimodal distribution of objects. The **Match Solid Volume Fraction (SVF) Distribution** option allows to create such structures with an inhomogeneous solid volume distribution. Objects are shifted and rotated to optimally match a SVF distribution given by a Gaussian random field. This takes place after the

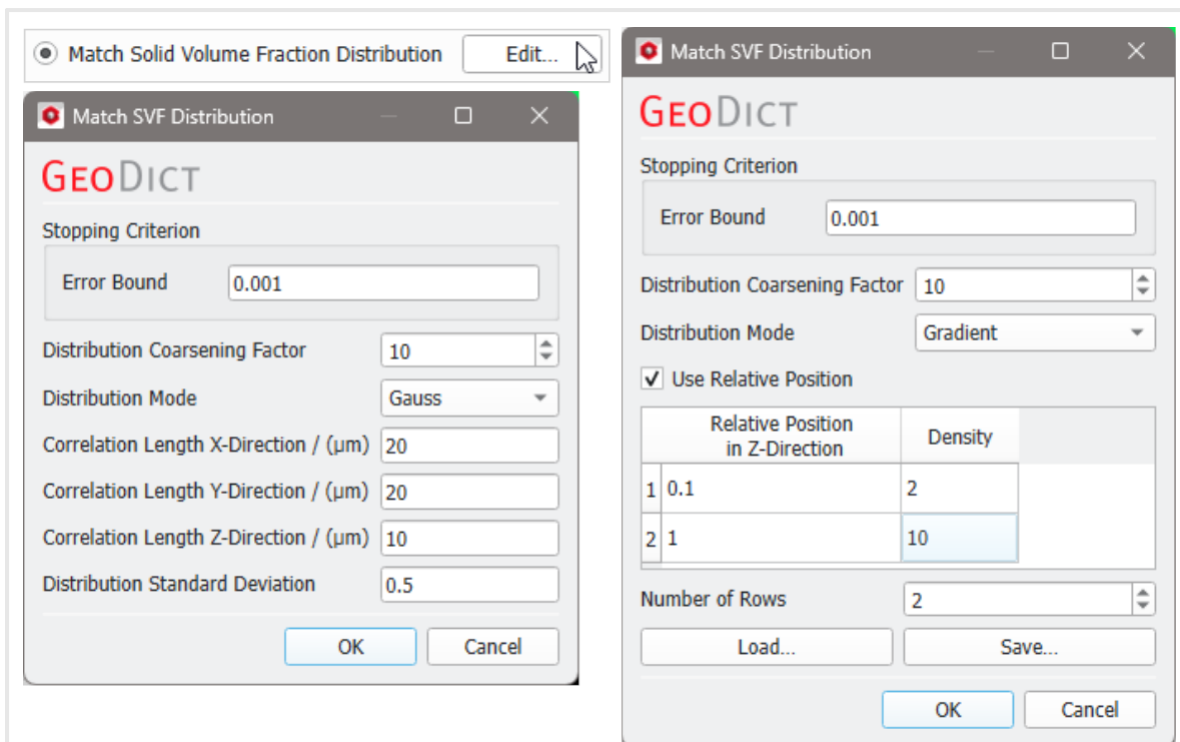
generation step. Consider that **Periodicity** is checked automatically for all directions. This is a prerequisite for the **Match Solid Volume Fraction** algorithm.



Note!

- Using this feature, overlap cannot be entirely removed during structure generation. After the solid volume fraction distribution algorithm was applied, a few steps of **Remove Overlap** are applied. The object's movement during that operation is limited such that the desired distribution is kept.
- As the SVF distribution is matched after generating the objects fitting the **Stopping Criterion**, the resulting values can differ from the inserted parameters for the **Stopping Criterion**. This is because the structure is generated with overlap and the amount of overlap can change when Fibers are shifted.
- The distribution for **Center** defined in the **Fiber Options** tab will also be affected strongly by matching the SVF distribution after generating the grain structure with the specified center distribution. The difference between the **Center Distribution** and the **Match SVF Distribution** is explained below.
- It is recommended to generate the structure without using the **Center Distribution** option under the **Fiber Options** tab when using this algorithm. The objects will be moved afterwards, matching the given SVF distribution not considering the initial center distribution anymore. The center distribution is often used to generate inlet and outlet. This can also be achieved using a Gradient distribution here. However, if you need inlet and outlet while using a Gaussian distribution, add them later either with **GadGeo - Edit Domain** or with **ProcessGeo - Embed** to avoid cropped objects.
- It is possible to reuse an existing stochastic field describing the desired SVF distribution. For this, first generate the structure with the mode **Allow Overlap** and then use the **Match SVF distribution** algorithm in GadGeo. Open the **GadGeo** section by selecting **Model** → **GadGeo** from the menu bar. Select **Algorithms** from the first pull-down menu and then **Match SVF Distribution** from the second.
- For large structures, the feature needs a large amount of memory as a volume field is loaded in GeoDict additional to the structure file.

The SVF distribution can be controlled through the **Match SVF Distribution** dialog accessible via the **Edit ...** button.



In the **Match SVF Distribution** dialog, the following parameters can be set:

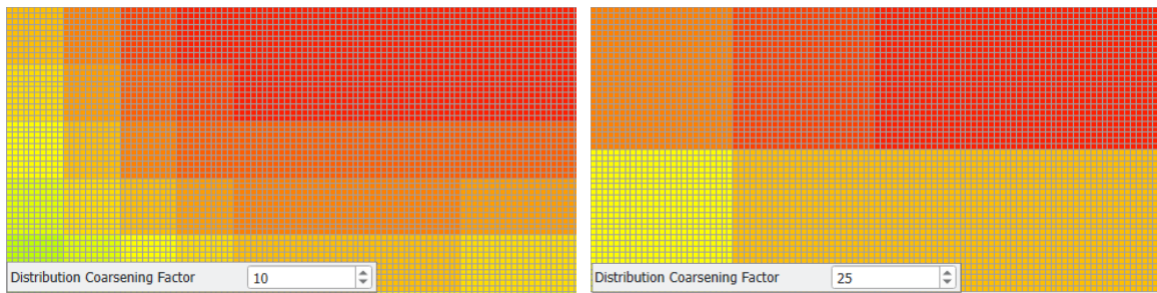
Stopping Criterion: Define the **Error Bound** to determine when the SVF matching should be stopped. When the normalized relative change of solid volume fraction is smaller than the given error bound, the algorithm is stopped.

Distribution Coarsening Factor: The SVF distribution is matched using a coarser version of the created Gaussian random field. The value must be small enough to resolve the heterogeneity of the structure. A larger value leads to a shorter run-time. If the Distribution Coarsening Factor is set to 1, the Gaussian random field is generated with the same resolution as the grain structure. The coarsening factor must be a divisor of the domain size in voxels for each of the three dimensions.

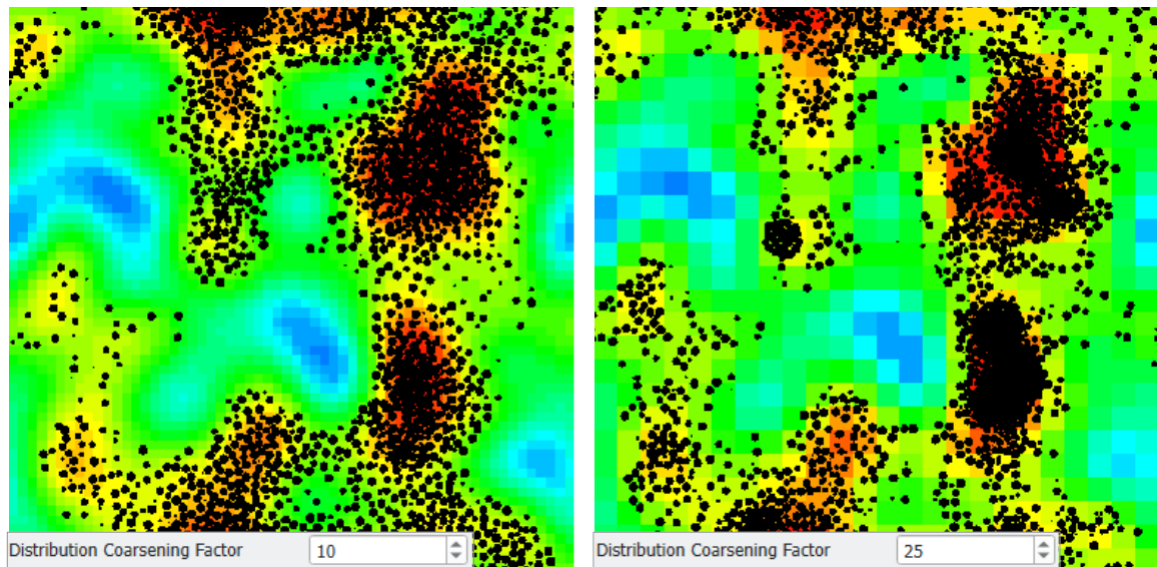
For a structure with a domain size of 2048x1024x512 voxels and a voxel length of 1 μ m a coarsening factor of 32 leads to a random field of 64x32x16 voxels with a voxel length of 32 μ m.

Keep in mind, that the coarsening factor also determines how many voxels remain to resolve the correlation lengths. The correlation length should be resolved with at least three or four voxels. Otherwise, the random field is too coarse to accurately resolve the correlation length. Consider the example above with a correlation length of 128 μ m and a coarsening factor of 32. Then, $128/32 = 4$ voxels remain to resolve one feature of the random field.

In the example below, with the grid turned on under the Camera tab in 2D view, observe the influence of the coarsening factor on the volume field. For a coarsening factor of 10, each color box has 10x10x10 voxels.



A smaller coarsening factor leads to a smoother distribution of the objects, which you can observe in the grain structure example below.



Distribution Mode: For distribution select **Gauss** or **Gradient** from the pull-down menu. The following parameters are different for these two options.

- **Gauss:**

- **Correlation Length:** The correlation length is a measure for the inhomogeneity of the material. The parameters for X-, Y- and Z-Direction determine the correlation length of the Gaussian random field, which defines the SVF distribution. It is recommended to select a value significantly smaller than the domain size in the corresponding direction to see an effect. For a constant SVF in one direction choose the corresponding domain size as correlation length.
- **Distribution Standard Deviation:** Define the relative standard deviation of the created SVF distribution. Relative means relative to the given object solid volume percentage. A larger value leads to a larger difference between the regions of low and high density. Using the relative standard deviation instead of the absolute standard deviation allows using the same Gaussian field for different solid volume percentages.

Distribution Mode	Gauss
Correlation Length X-Direction / (μm)	20
Correlation Length Y-Direction / (μm)	20
Correlation Length Z-Direction / (μm)	10
Distribution Standard Deviation	0.5

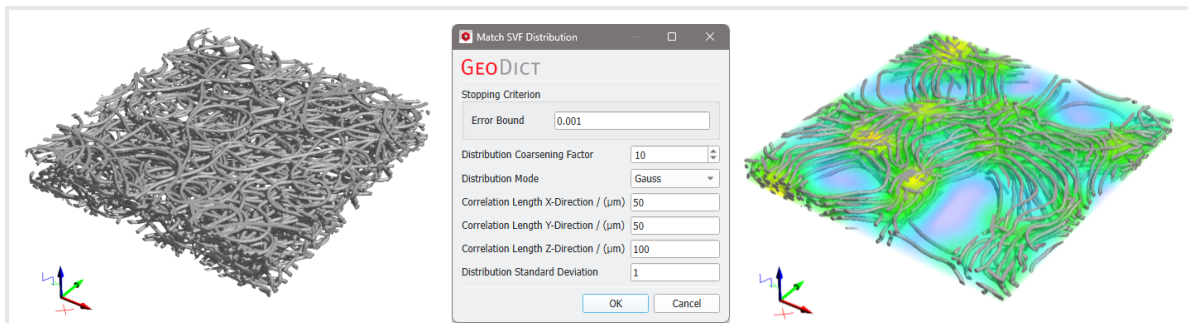
- **Gradient:**

- **Use Relative Position:** If checked, the left column values from 0 to 1 correspond to locations in the structure. In the Z-direction, the value 0 is at the origin and the value 1 is at end of the domain. If not checked, the values in the left column correspond to absolute values in the given unit.
- **Distribution Table:** The right column assigns relative density values at the locations defined in the left column, e.g., the value 10 means that there are five times more objects at $Z = 1$ than at $Z = 0.1$, with a density value of 2. The object density increases and decreases smoothly between the given locations in the Z-direction.
- **Number of Rows:** The number of rows in the distribution gradient can be increased or decreased to enter as many pairs of position and density as desired.
- **Load/Save:** The density distribution can be saved to and loaded from a .txt file.

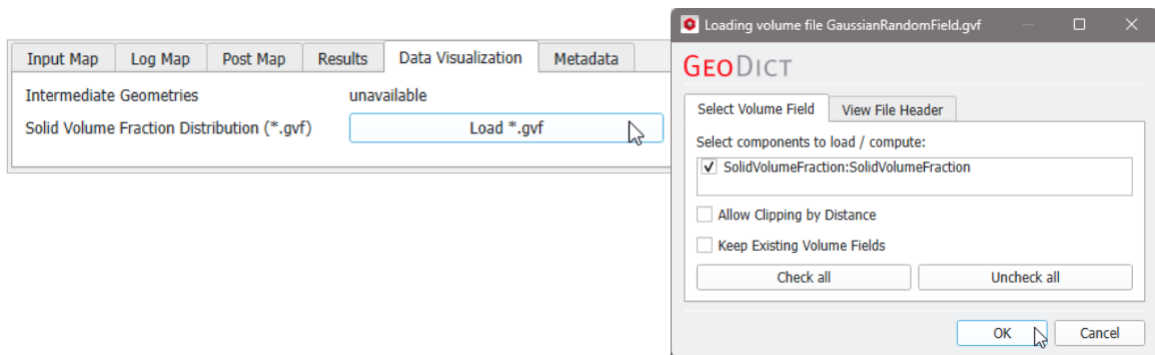
Distribution Mode	Gradient
☒ Use Relative Position	
Relative Position in Z-Direction	Density
1 0.1	2
2 1	10
Number of Rows	2
Load...	Save...

Example - Gauss

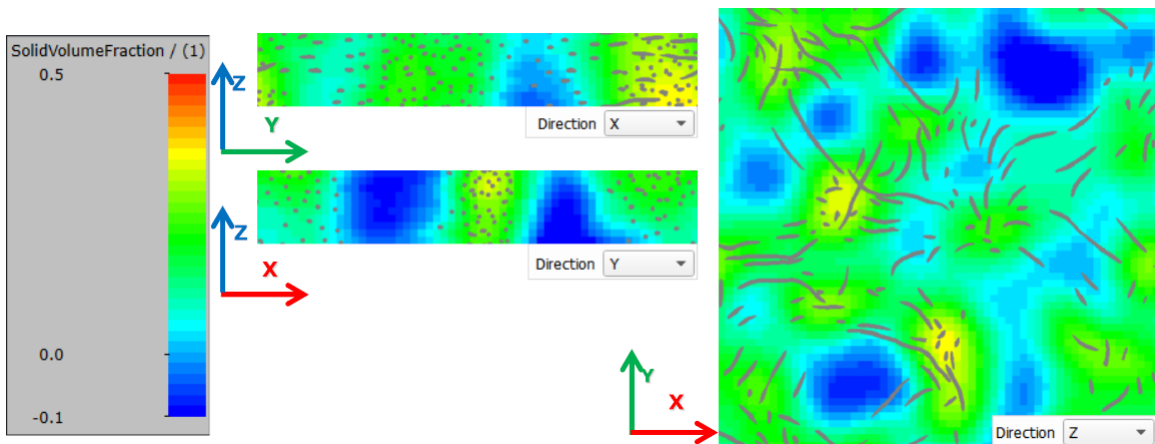
In the following example curved fibers are generated in a domain of $600 \times 600 \times 100 \mu\text{m}$. For the left structure, **Allow Fiber Overlap** is checked and no SVF distribution is matched. The structure of the right picture was generated with the same parameters except for matching the SVF distribution shown below.



A volume field describing the used gaussian random field is saved in the result folder after generating a fiber structure matching a SVF distribution. Select **File** → **Load Volume Field...** from the menu bar to load it or choose the **Data Visualization** tab in the **Result Viewer** of the result file (*.gdr) and click **Load *.gvf**. In the **Loading volume file** dialog click **OK**.



For the above example, the resulting gaussian random field is shown in 2D view from all three directions.



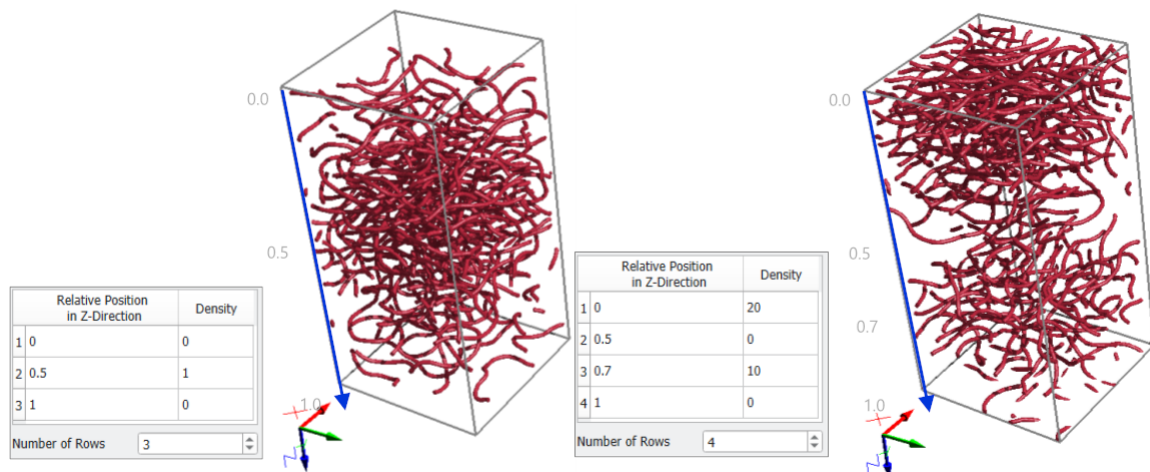
Viewed from X-direction a high correlation in Z-direction is observed, as the structure size in this direction equals the Correlation Length Z. In Y-direction a more inhomogeneous SVF distribution was generated, as the domain size in Y-direction (600 μm) is 12 times the Correlation Length Y (50 μm).

Viewed from Y-direction a similar observation can be obtained. Still the distribution in Z-direction is very homogeneous, whereas it has low correlation in X-direction.

Viewed from Z-direction, the structure is very inhomogeneous, due to small Correlation Length values for X and Y (50 μm) compared to the structure size in these directions (600 μm).

Example - Gradient

In the following example observe how the fibers are distributed corresponding to the given density distribution.

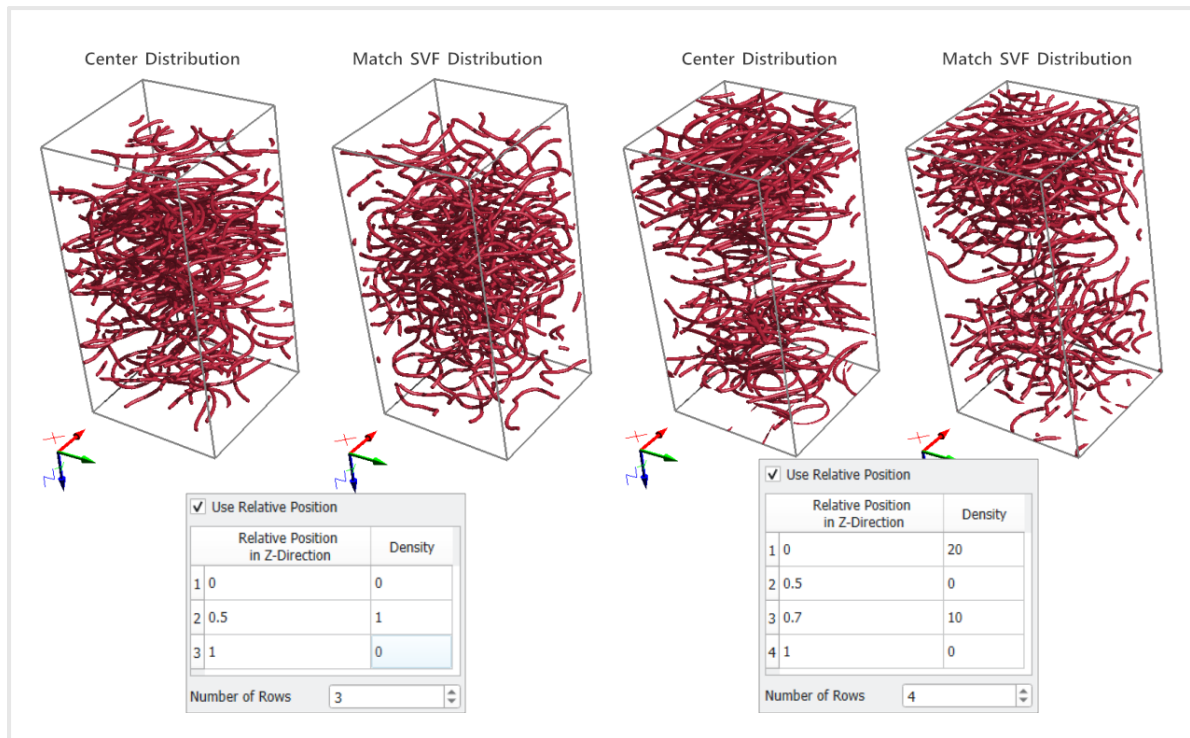


The fibers in the first example on the left have the highest density in the center of the Z-axis. Towards both ends of the domain in Z-direction the fibers become fewer. This corresponds to the density values 0 for the relative positions $Z=0$ and $Z=1$ and a density of 1 for the relative position $Z=0.5$.

The second example on the right shows a density distribution in Z-direction with 4 rows. A density of 20 for position $Z=0$ leads to twice as many fibers near the top as fibers in the lower third with a density value of 10 for position $Z=0.7$. Towards the center and the bottom, the fibers become fewer for a density value of 0.

This feature is different from the **Density Distribution** for [Center](#)^[71]. The Match SVF Distribution is a post-processing step, and the fibers are moved until they match the given solid volume fraction distribution.

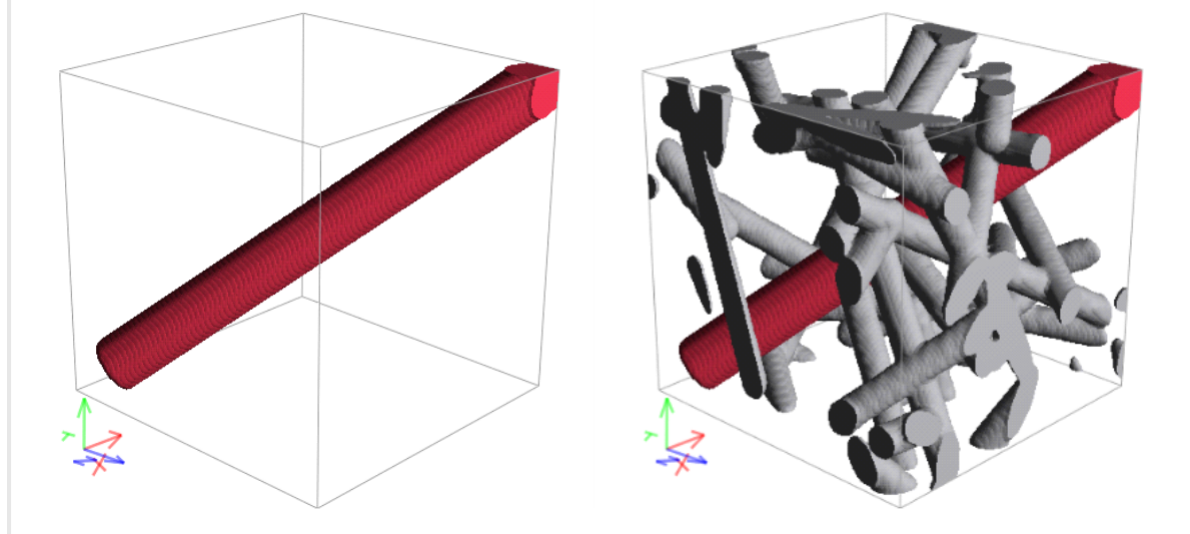
For the center distribution (in the example below shown on the left), the fiber centers are placed according to the given distribution, which is much faster and does not change the orientation of the fibers but leads to a different solid volume fraction distribution and the distribution is not as smooth as with **Match SVF Distribution**, which is shown on the right in the example below.



✓ Prohibit Overlap with Current Structure

If checking [Create in Current Domain](#) , **Prohibit Overlap with Current Structure** appears instead of **Match SVF Distribution**. The fibers in the newly generated structure can intersect with each other but not with those of the already existing structure.

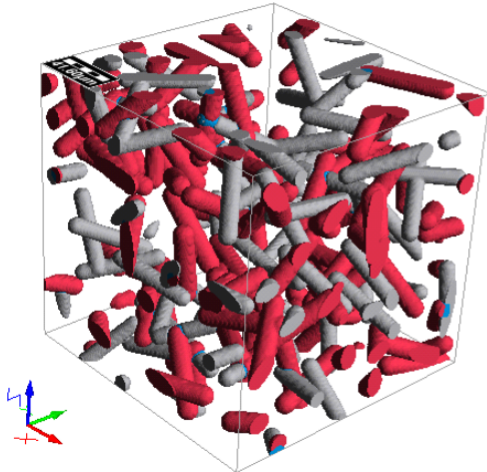
Observe this effect in a structure with one fiber (red) over which a new structure with thinner gray fibers is generated. Whereas the gray fibers overlap with each other, they do not overlap with the red fiber.



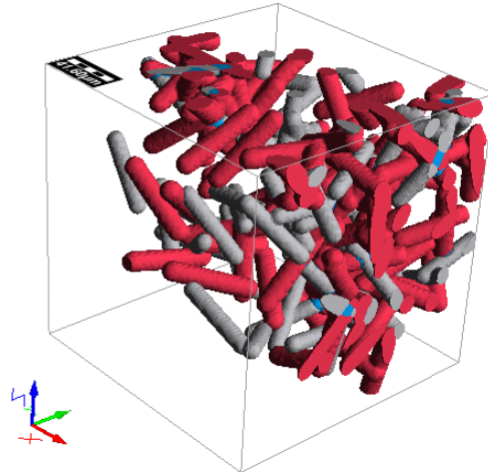
✓ Enforce Object Overlap

The structure's fibers are required to join each other, forming one large, connected component. This effect is obvious when the structure's solid volume percentage is low (here 10%), i.e., the fibers do not already form a connected component.

☐ Enforce Fiber Overlap



☒ Enforce Fiber Overlap



Stopping Criterion

The parameters in the **Stopping Criterion** panel define according to which criteria the object generation should be stopped. The available parameters are **Fixed Object Number**, **Object Volume Percentage / (%)**, **Grammage / (g/m²)**, **Density / (g/cm³)** or **Object Weight Percentage / (%)**. Additionally, when the **Maximal Run Time / (h)** is expired, the process is stopped even when the desired stopping criterion cannot be achieved.

Stopping Criterion

☐ Fixed Object Number

☒ Object Solid Volume Percentage / (%)

☐ Grammage / (g/m²)

☐ Density / (g/cm³)

☐ Object Weight Percentage / (%)

Maximum Run Time / (h)

When **Grammage**, **Density** or **Object Weight Percentage** are chosen as stopping criterion, the temperature must be set as additional parameter. The density of the constituent materials will be set with respect to the chosen temperature based on the Material Database.

When choosing **Fixed Object Number** or **Object Volume Percentage**, the temperature parameter is not available.

If checking **Create in Current** and [Keep Current Objects / Structure](#)^[9] only the criteria [Fixed Object Number](#)^[30], [Add Object Solid Volume Percentage](#)^[30] and [Maximum Run Time](#)^[32] are available.

Stopping Criterion

☐ Fixed Object Number

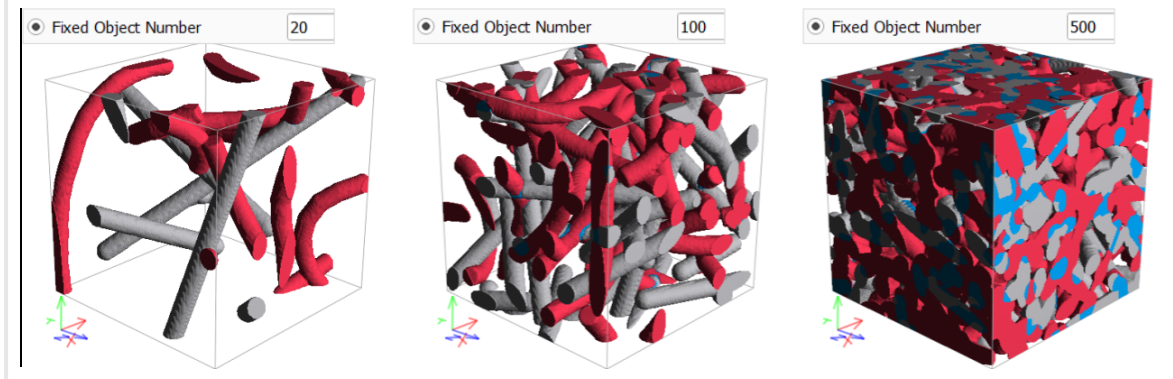
☒ Add Object Solid Volume Percentage / (%)

 Maximum Run Time / (h)

✓ Fixed Object Number

When **Fixed Object Number** is chosen as stopping criterion, FiberGeo places the given number of fibers in the structure and then the generation stops.

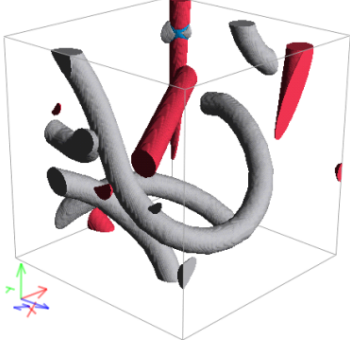
Observe the effect of setting a fixed number of objects (20, 100, or 500) as stopping criterion, for the generation of a structure with two fiber types. All other parameters are left untouched, including the default **Allow Fiber Overlap**. Note how the overlap, shown in blue, increases with the number of objects present in the structure.

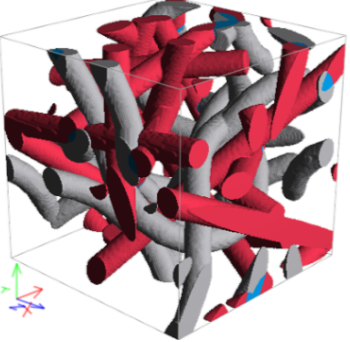


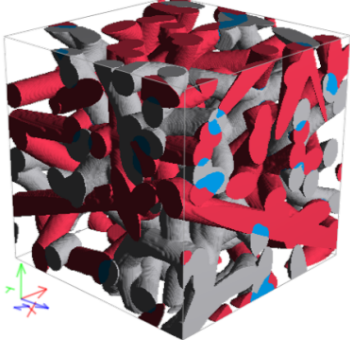
✓ (Add) Object Solid Volume Percentage

The **Object Solid Volume Percentage** (SVP) determines the fraction of the total volume in percent that the fibrous structure should have. Accepted values range from 0% to 100%. For example, a structure with an **Object Solid Volume Percentage** of 40 consists of 40% fibers and 60% void space. Porosity is defined as $1 - \text{SVP}/100$.

Observe the difference in a structure when varying the solid volume percentage from 5%, to 20%, and finally to 40%, while all other parameters are left unchanged.

☒ Object Solid Volume Percentage / (%) 5
 

☒ Object Solid Volume Percentage / (%) 20
 

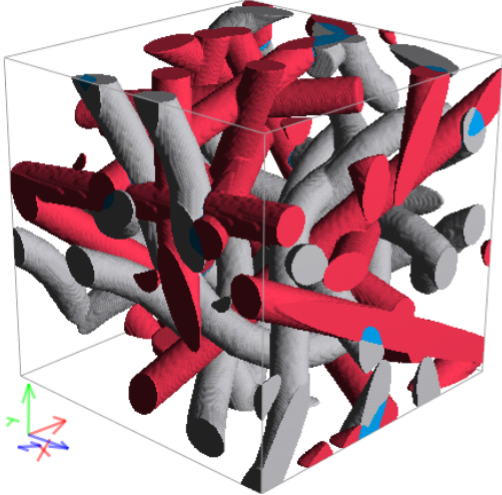
☒ Object Solid Volume Percentage / (%) 40
 

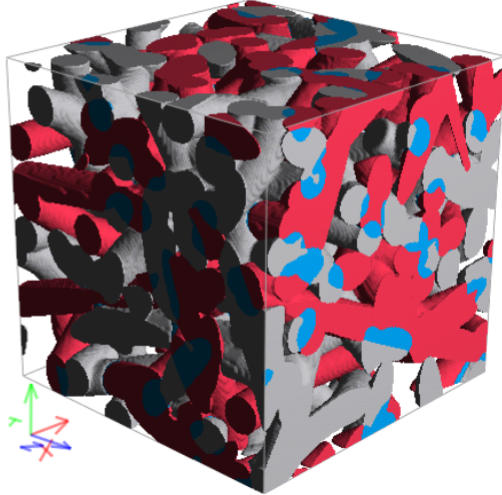
If **Create in Current** and [Keep Current Objects / Structure](#)⁹ are selected, the parameter changes to **Add Object Solid Volume Percentage**. Only the added solid volume percentage counts, i.e., only the objects not overlapping with the current structure are considered for the stopping criterion. Therefore, it is important to prevent overlap, for example by checking [Prohibit Overlap with Current Structure](#).²⁸

✓ Grammage

The **Grammage / (g/m²)** determines the mass per unit area (in the XY-Plane) of the resulting fibrous structure. When **Grammage** is chosen as stopping criterion, the [Density](#)³⁷ (g/cm³) of the fiber material(s) must be defined for each fiber type and chosen material in the fiber panels under the **Fiber Options** tab and the [temperature](#)³³ has to be set in the **Create Options** tab.

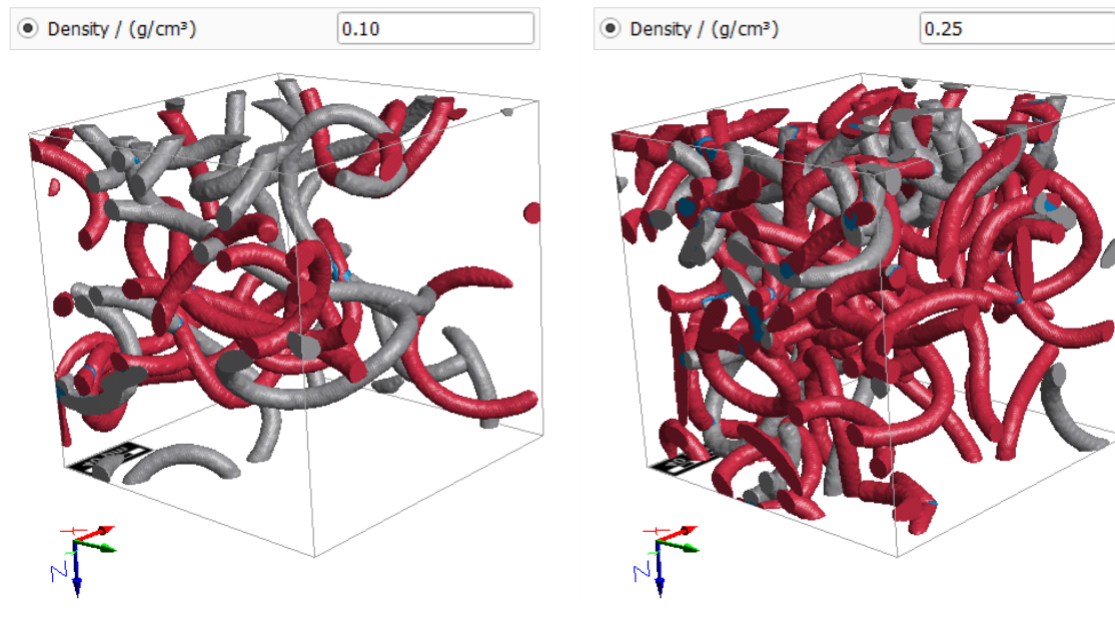
Observe the effect of increasing the **Grammage** from 15 g/m² to 40 g/m², whereas all other parameters are left unchanged.

☒ Grammage / (g/m²) 15
 

☒ Grammage / (g/m²) 40
 

✓ Density

The **Density** of the complete resulting structure depends on the densities of the constituent materials. In the following simple example, the **Matrix Density** is 0 (for Air), and the two fiber materials have densities of 1.0 g/cm³ and 3.1 g/cm³. The **Density** is set to values of 0.10 g/cm³ and to 0.25 g/cm³. The **Density** value cannot be set smaller than the lowest occurring density (here, 0 g/cm³) or larger than the highest occurring density (here, 3.1 g/cm³).



✓ Object Weight Percentage

The **Object Weight Percentage** determines the weight of the created object in relation to the weight of the whole structure (including the matrix material). The calculation is only possible when the density of the **Pore / Matrix Material** is greater than zero. Otherwise, an error message will appear.

✓ Maximum Run Time

The **Maximum Run Time (h)** becomes important when generating complex structures with elevated solid volume fraction. When **Prohibit Fiber Overlap** has been checked, the required number of objects in the structure may become unattainable. In that case, the structure generation is stopped after the time entered in **Maximum Run Time** has passed and the achieved structure is considered as the result. The analysis of the GDR result file shows any disparity between the achieved result values and the desired ones.

✓ How to know if the stopping criterion is achieved?

The relationship of the variables **Fixed Object Number**, **Object Solid Volume Percentage**, **Grammage** and **Weight Percentage** can be observed in the Result Viewer of the result file, under the **Results - Report** subtab.

In this example, a **Count** (Fixed Object Number) of 52 corresponds to a **Volume** (Object Volume Percentage) of 10.35%, a **Grammage** of 50.46 g/m² and a **Density** of 0.2523 g/cm³.

Input Map	Log Map	Post Map	Results	Data Visualization	Metadata
Report	Plots	Map			
Absolute object distribution:					
	Count	Volume / (%)	Grammage / (g/m ²)	Density / (g/cm ³)	Weight / (%)
Total	realized: 52 target: --- error: ---	realized: 10.35 target: --- error: ---	realized: 50.46 target: --- error: ---	realized: 0.2523 target: 0.2500 error: 0.0023	realized: 0.00 target: --- error: ---
Object type 1	realized: 32 target: --- error: ---	realized: 7.09 target: --- error: ---	realized: 43.94 target: --- error: ---	realized: 0.2197 target: --- error: ---	realized: 0.00 target: --- error: ---
Object type 2	realized: 20 target: --- error: ---	realized: 3.26 target: --- error: ---	realized: 6.53 target: --- error: ---	realized: 0.0326 target: --- error: ---	realized: 0.00 target: --- error: ---
Stopping criterion error: 0.93 %					

General Options

Define the general parameters temperature, random seed and parallelization.

Random Seed	42	Temperature	20	°C
Parallelization	8 Threads (Automatic Maximum)			
Edit...				

Temperature

When **Grammage** (or **Density** or **Object Weight Percentage**) is chosen as **Stopping Criterion**, a temperature can be entered. The temperature is considered for materials with temperature dependent density.

Choose the temperature in Kelvin, Celsius, or Fahrenheit.

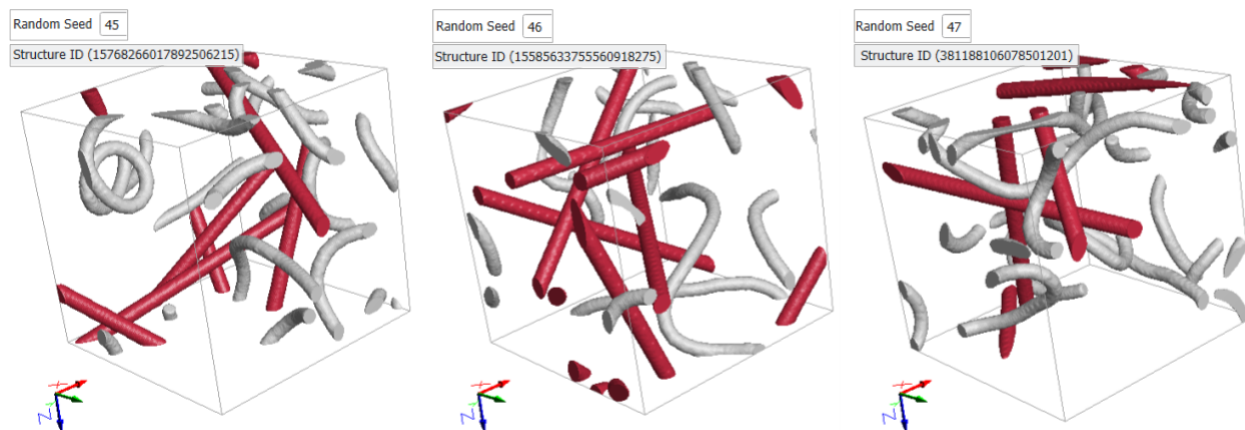
Temperature	20	°C
		K
		°C
		°F

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, as shown by the **Structure ID**

number in the Status section. The **Random Seed** is a non-negative integer number, it increases automatically with every generation run.

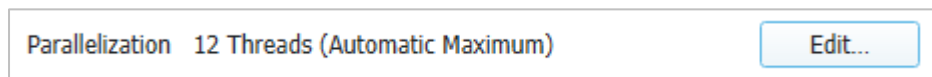
Varying the **Random Seed** allows generating different samples of the same structure for a series of experiments. In the following examples, all parameters are unchanged while the random seed is modified with every generation run.



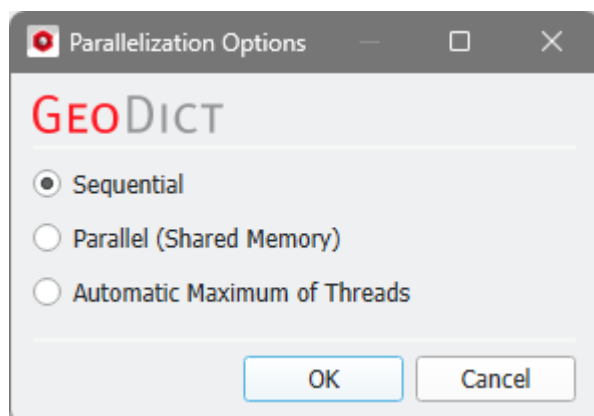
Parallelization

Control how many threads are used for the computation. Parallelization is possible if your license and hardware allow it.

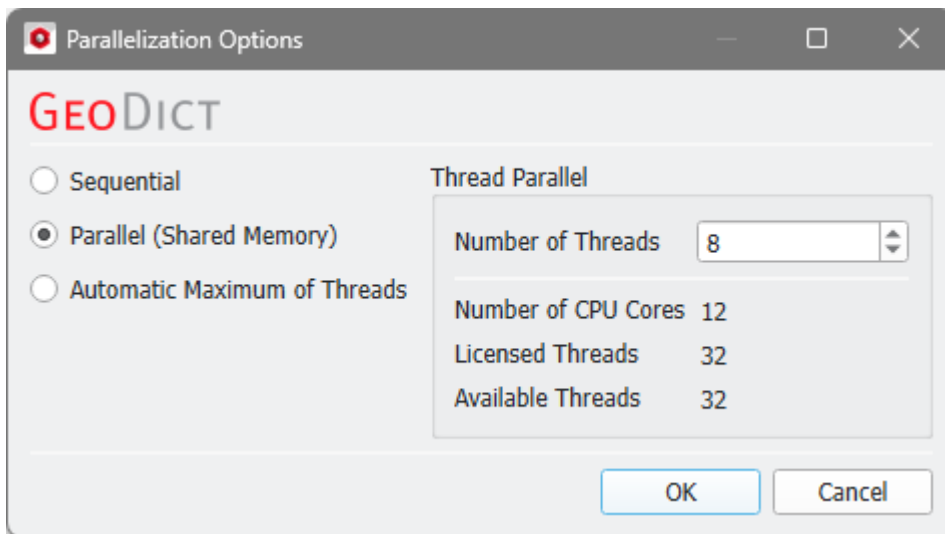
The **Parallelization Options** dialog opens when clicking the **Edit** button and you can choose between **Sequential**, **Parallel (Shared Memory)**, or **Automatic Maximum of Threads**.



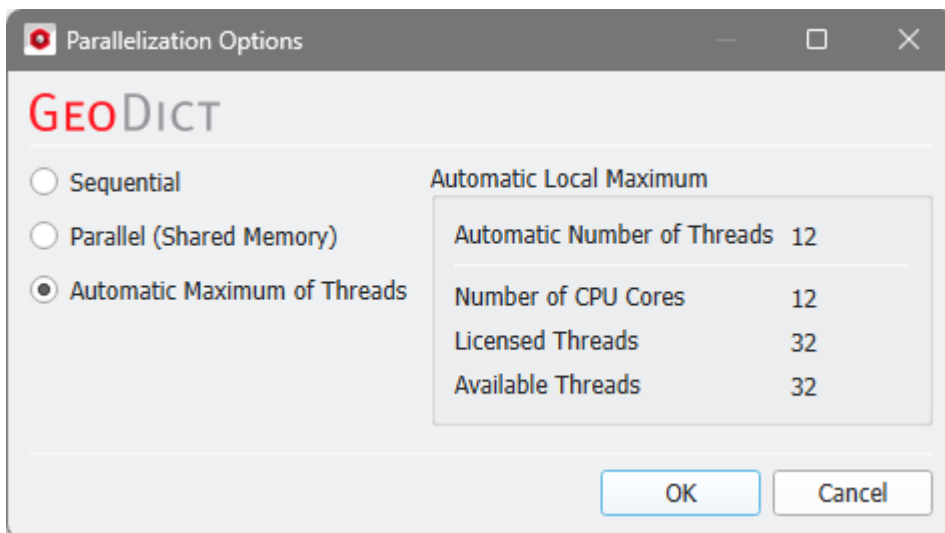
Selecting **Sequential** will not apply parallelization and only one thread is used for the computation.



When **Parallel (Shared Memory)** is selected, the **Number of Threads** can be entered. Below, the **Number of CPU Cores** that the current machine has, the maximum number of **Licensed Threads** and the number of those licensed threads that are available (**Available Threads**) are shown in the dialog. Of course, the maximal number of parallel processes you can use, is the smallest of those three numbers.



If **Automatic Maximum of Threads** is selected, the number of parallel processes is automatically selected for optimal speed, based on the CPU cores and licensed parallel processes.

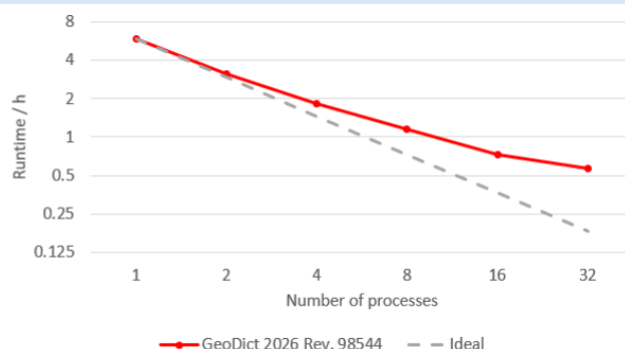
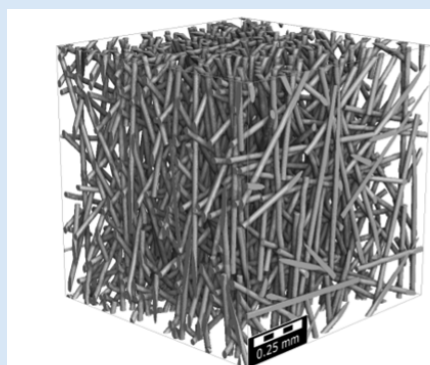


The **Automatic Local Maximum** of processes is automatically selected, which is the minimum of **Number of CPU Cores**, **Licensed Threads**, and **Available Threads**.



Parallelization Benchmark Results

As an example for the parallelization, the complete overlap in a fiber structure is removed with different number of processes. The computation is run on a server with 2 x Intel E5-2697A v4 processors with 16 cores each, running with a maximum of 3.60 GHz, and 1 TB RAM. The large fiber structure has size 1000^3 voxels and 10 % solid volume percentage. [Remove Overlap](#)¹⁸ is used with stopping criterion 0% remaining overlap.



The memory usage was 2.1 GB. As you can observe, the parallelization reduces the runtime significantly. With four processes, the runtime is already reduced by 70%.

Fiber Options

Here you can define the geometrical properties of individual fiber types. All fiber options listed here can be separately set for each fiber type. Up to eight different object types may be added to the same structure.

The fiber type parameters are organized and listed in three columns. In the left one define the [Fiber Type](#)^[37] together with its percentage and material, the center one shows a [cross-section](#)^[43] of the chosen fiber type and in the right one you can edit the [fiber parameters](#)^[47]. In the bottom you find the options to choose additional fiber types and how the fiber percentage should be given.

The fiber type parameters are organized in three columns:

- [Fiber Type and Percentage](#)^[37]
Add fibers of different types, define their percentages in the structure and their materials.

The fiber type parameters are organized in three columns:

- [Available Cross-Sections](#)^[43]
Overview of the available fiber types and preview of their cross-sections.
- [Fiber Parameters](#)^[47]
Edit the parameters that define the fiber.

Fiber Type and Percentage

For all fibers, the left column of the panel contains the name of the fiber type, the fiber percentage in the structure, and the material.

Fiber thickness given by **Diameter** **Diameter**
Dtex / (g/10000 m)

Infinite Circular	Short Elliptical	Short Rosetta
Count / (%) 40	Rel. Volume / (%) 60	Weight / (%) 60
Material (ID 01) Glass (Solid) [Fiber]...	Abs. Volume / (%) 6	Material (ID 02) Solid...
	Material (ID 02) Solid...	Density / (g/cm³) 1.5
Remove Save...	Remove Save...	Remove

Fiber Type Short Rosetta Add Load... Percentages are Weight %

✓ Fiber thickness given by

Whether the **Fiber Thickness** is given by **Diameter** or **Dtex** (decitex: textile unit of measure of fiber weight, 1 Dtex= 1 g/10000 m) is chosen from the pull-down menu. The fiber parameters in the panels are automatically adjusted depending on this choice.

The use of **Dtex** requires knowing the material density in g/cm³. For the database materials the density is automatically given. For manual materials enter the [density](#)^[41] in the fiber type panel on the left.

If the choice of **Fiber thickness given by** is changed from **Diameter** to **Dtex**, the fields Diameter, Diameter 1 and Length 1 fields transform into Dtex fields in the [Fiber parameters](#)^[47] panel on the right. The values are automatically recalculated.

Fiber thickness given by

Diameter

Diameter

Dtex / (g/10000 m)

Count / (%)

40

Material (ID 01)

Glass (Solid) [Fiber]...

Remove

Save...

Diameter / (μm)

12

Edit...

Orientation

Anisotropic Direction

Edit...

Fiber thickness given by

Dtex / (g/10000 m)

Infinite Circular

Count / (%)

40

Material (ID 01)

Glass (Solid) [Fiber]...

Density / (g/cm³)

2.58

Remove

Save...

Dtex / (g/10000 m)

1.69646

Edit...

Orientation

Anisotropic Direction

Edit...

The calculation of the Dtex value does not only depend on the diameter / diameter 1 / length 1 but also on the other parameters describing the cross-section of the fiber, for example the Inner Diameter Fraction for hollow fibers:

Fiber thickness given by

Diameter

Short Hollow

Weight / (%)

60

Material (ID 01)

Glass (Solid)...

Density / (g/cm³)

2.58

Remove

Save...

Size Mode

Aspect Ratio

Diameter / (μm)

10

Edit...

Diameter - Length Aspect Ratio

20

Edit...

Inner Diameter Fraction

0.3

Size Mode

Aspect Ratio

Dtex / (g/10000 m)

1.07207

Edit...

Diameter - Length Aspect Ratio

20

Edit...

Inner Diameter Fraction

0.3

Center / (μm)

Uniformly Distributed

Edit...

Orientation

Isotropic

Edit...

☐ Rounded Endings

Size Mode

Aspect Ratio

Dtex / (g/10000 m)

0.753983

Edit...

Diameter - Length Aspect Ratio

20

Edit...

Inner Diameter Fraction

0.6

Center / (μm)

Uniformly Distributed

Edit...

Orientation

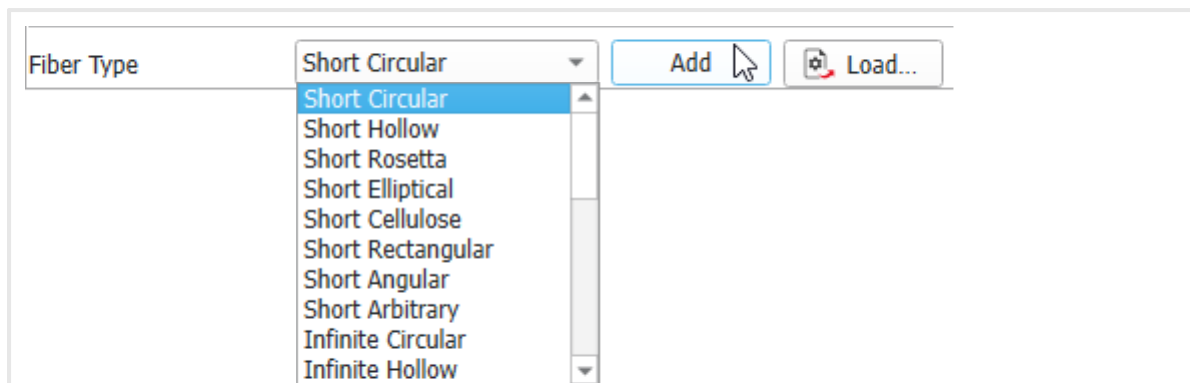
Isotropic

Edit...

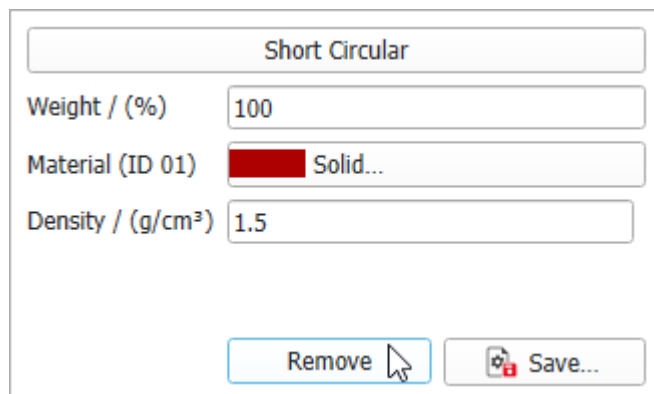
☐ Rounded Endings

✓ Adding and removing fiber types

Short Cellulose and **Short Elliptical** are the two default **Fiber Types**. At the bottom left of the dialog box, clicking **Add** inserts other fiber types chosen from the **Fiber Type** pull-down menu (Short Circular, Infinite Cellulose, Infinite Rectangular, etc.).



Fiber types can be discarded by clicking **Remove** in the left column for that fiber type.



Clicking on the fiber type name minimizes the object panel, and clicking on it again when minimized, expands it. A scroll bar at the right allows to navigate up and down in the list of chosen fiber types.



The settings for a fiber entered in the fiber type and the [fiber parameters](#)^[47] panels can be saved with all its options by clicking **Save...** and later reloaded by clicking **Load...**



✓ Percentage

The percentage of a certain fiber type can be specified as **Count %**, **Volume %**, or **Weight %**, as selected from the pull-down menu at the bottom right of the dialog box.

The screenshot shows the FiberGeo dialog box with two fiber types defined:

- Fiber Type 1: Short Circular**
 - Rel. Volume / (%): 40
 - Abs. Volume / (%): 4
 - Material (ID 01): Solid...
- Fiber Type 2: Short Rosetta**
 - Rel. Volume / (%): 60
 - Abs. Volume / (%): 6
 - Material (ID 02): Solid...

Each fiber type has a diagram showing its geometry and parameters: Diameter, Length, Center, and Direction. The 'Percentages are' dropdown menu at the bottom right is set to 'Volume %'.

Note that, if the **Weight** option is chosen, the material density must be provided (or it is taken from the GeoDict material database).

The screenshot shows the FiberGeo dialog box with two fiber types defined, where the 'Percentages are' dropdown menu is set to 'Weight %':

- Fiber Type 1: Short Circular**
 - Weight / (%): 40
 - Material (ID 01): Glass (Solid)...
 - Density / (g/cm³): 2.58
- Fiber Type 2: Short Rosetta**
 - Weight / (%): 60
 - Material (ID 02): Solid...
 - Density / (g/cm³): 1.5

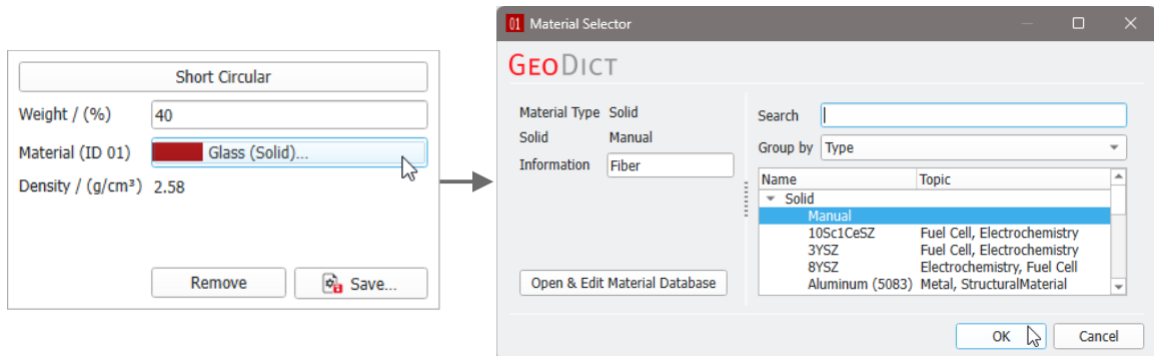
Each fiber type has a diagram showing its geometry and parameters: Diameter, Length, Center, and Direction. The 'Percentages are' dropdown menu at the bottom right is set to 'Weight %'.

If **Fixed Object Number** or **Object Volume Percentage** is chosen as **Stopping Criterion** and percentages are set to volume, the **Absolute Volume** is given below the relative volume.

✓ Material

Material designates the constituent material assigned to the fiber type used in the paper structure. Clicking on the material gives access to selecting the desired material

from the GeoDict Material Database. When none of the materials available in the database fit the preferred specifications, **Manual** should be chosen.



To match realistic material colors for visualization in a certain application, or to distinguish the constituting materials more easily, the colors of the materials can be changed through **Settings** → **Color & Visibility Settings** in the Menu bar, or by unfolding the **Color & Visibility** sidebar next to the GeoDict visualization area as described in the Visualization User Guide.

✓ Density

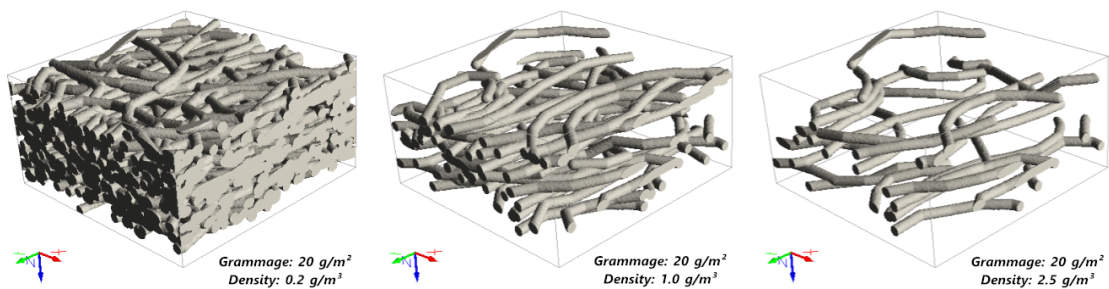
The material **Density** (g/cm³) appears for the fiber types if at least one of the following criteria is matched:

- **Stopping Criterion**^[29] is set to **Grammage**, **Density**, or **Object Weight Percentage**
- **Percentage**^[39] is set to **Weight**
- **Fiber thickness**^[37] is given by **Dtex**.

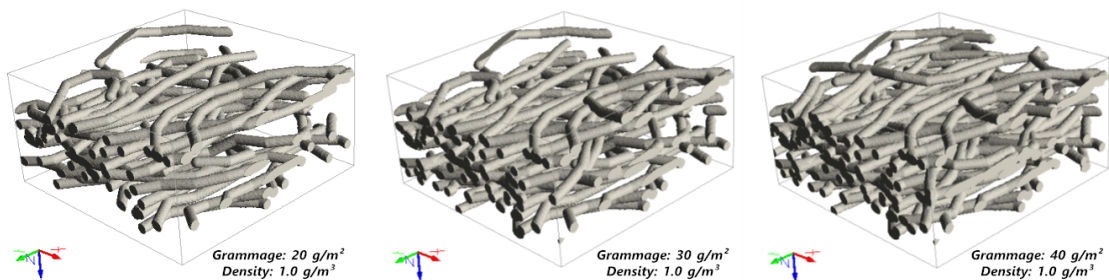
For materials included in the GeoDict Material Database, the density is automatically entered. For manual materials the density must be entered manually.

Grammage / (g/m ²)		Fixed Object Number	
40		1000	
Short Circular		Short Circular	
Rel. Volume / (%)	40	Rel. Volume / (%)	40
Material (ID 01)	Glass (Solid)...	Abs. Volume / (%)	4
Density / (g/cm ³)	2.58	Material (ID 01)	Glass (Solid)...
Remove	Save...	Remove	Save...
Short Circular		Short Circular	
Rel. Volume / (%)	40	Rel. Volume / (%)	40
Material (ID 01)	Fiber (Solid)...	Abs. Volume / (%)	4
Density / (g/cm ³)	2.58	Material (ID 01)	Fiber (Solid)...
Remove	Save...	Remove	Save...

The fiber **Density**, given in g/cm³, is an intrinsic property of the selected fiber type, affecting the final weight of the fibrous structure. The density of fiber is intimately related to the **Grammage** (g/m²) of the created fiber structure. When denser fibers are used, and the grammage is unchanged, less fibers of this type appear in the fiber structure.



Vice versa, when the same fiber type is used but an increase in grammage should be achieved, the structure must contain more fibers.



Available Cross-Sections

The **Fiber Type** is selected from the pull-down menu at the lower left under the **Fiber Options** tab. After selecting, click **Add** to include this fiber type. If the wrong fiber type has been added, discard it by clicking **Remove** as described [here](#)³⁸.

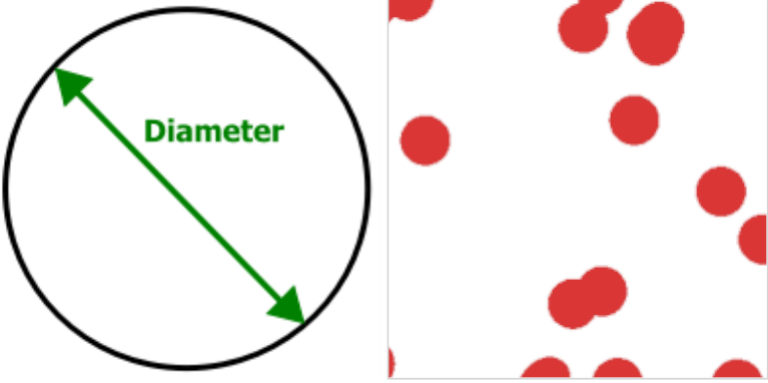
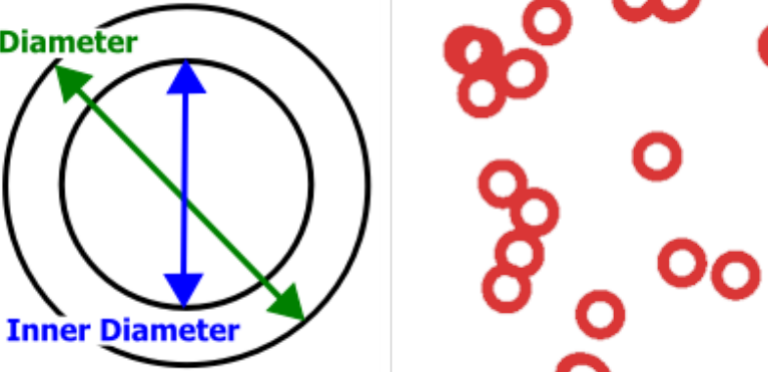
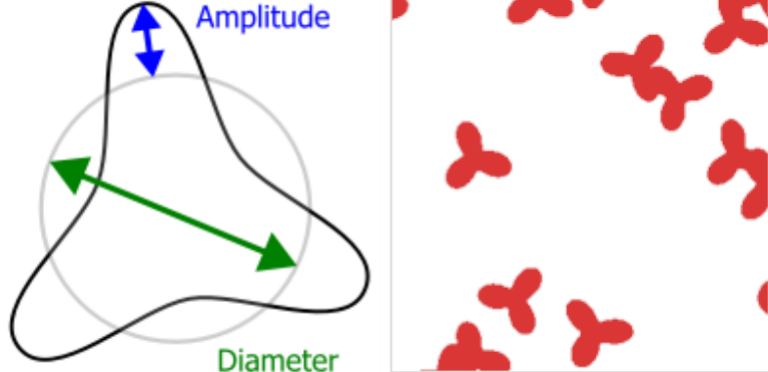
The following combinations of fiber cross-section with fiber length and fiber shape are available:

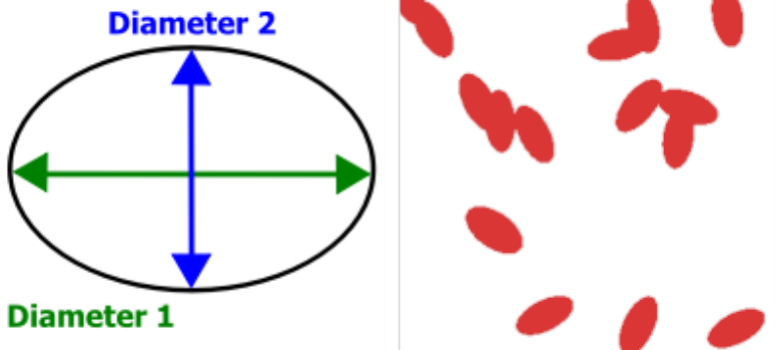
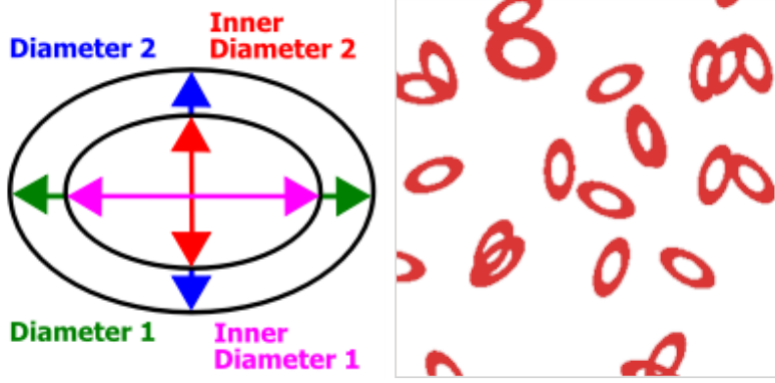
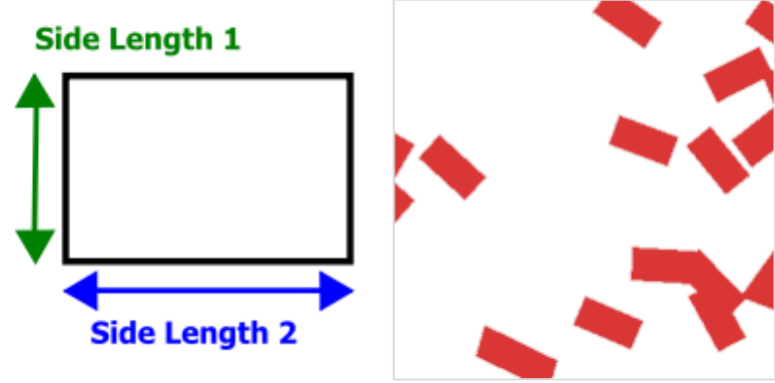
	Short	Short Bundle	Infinite	Infinite Bundle	Curved
Circular	Short Circular	Bundle Short Circular	Infinite Circular	Bundle Infinite Circular	Curved Circular
Hollow	Short Hollow		Infinite Hollow		Curved Hollow
Rosetta	Short Rosetta		Infinite Rosetta	Bundle Infinite Rosetta	Curved Rosetta
Elliptical	Short Elliptical	Bundle Short Elliptical	Infinite Elliptical	Bundle Infinite Elliptical	Curved Elliptical
Cellulose	Short Cellulose		Infinite Cellulose		Curved Cellulose
Rectangular	Short Rectangular		Infinite Rectangular		Curved Rectangular
Angular	Short Angular		Infinite Angular		Curved Angular
Arbitrary	Short Arbitrary		Infinite Arbitrary		

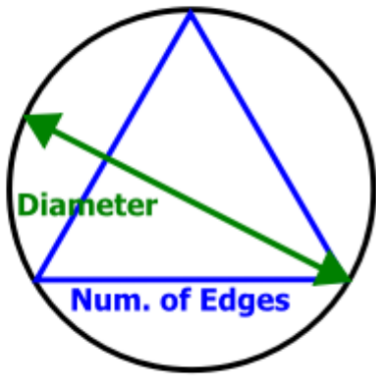
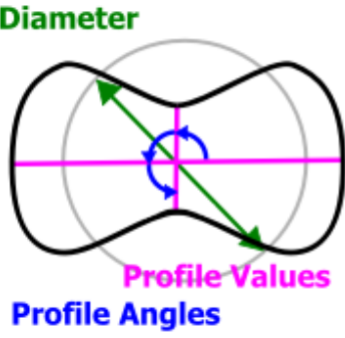
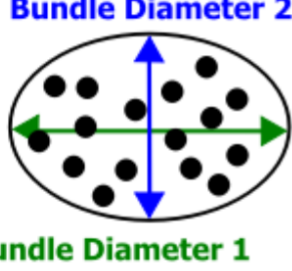
Fiber cross-section

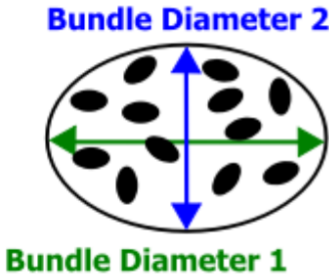
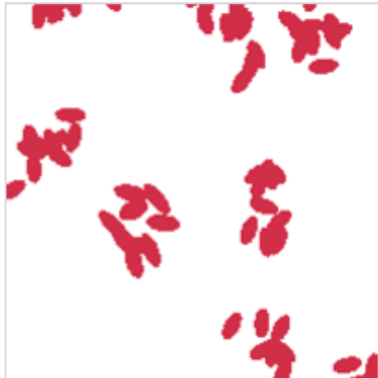
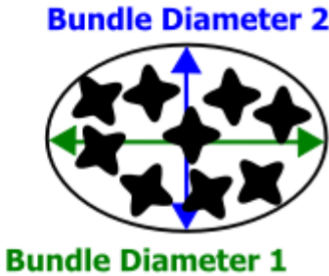
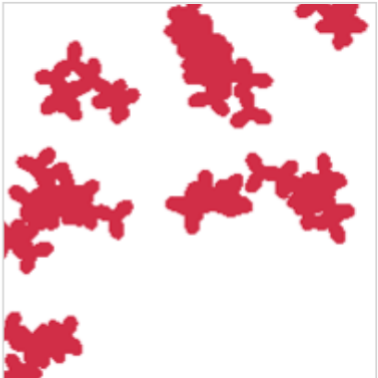
A drawing of the fiber cross-section is shown in the center column of each fiber type panel. The available fiber cross-sections and their defining parameters are:

Cross-section	Defining parameters
Circular	Diameter / (μm)

Cross-section	Defining parameters
	
Hollow 	Diameter / (μm) Inner Diameter Fraction
Rosetta 	Diameter / (μm) Amplitude Fraction Number of Leaves
Elliptical	Diameter 1 / (μm) Aspect Ratio

Cross-section	Defining parameters
	
Cellulose 	Diameter 1 / (μm) Aspect Ratio Inner Diameter Fraction
Rectangular 	Side Length 1 / (μm) Aspect Ratio
Angular	Diameter / (μm) Number of Edges

Cross-section	Defining parameters
	
Arbitrary 	Diameter / (μm) Profile Angles / ($^\circ$) Profile Values
Bundle Circular 	Bundle Diameter 1 Bundle Diameter 2 Number of Fibers Fiber Diameter Fiber Profile Angle
Bundle Elliptical	Bundle Diameter 1 Bundle Diameter 2/ Number of Fibers Fiber Diameter 1 Fiber Diameter 1 - 2 Aspect Ratio Fiber Profile Angle

Cross-section	Defining parameters	
		
Bundle Rosetta 		
	Bundle Diameter 1/(μm) Bundle Diameter 2/(μm) Number of Fibers Fiber Diameter Fiber Amplitude Fraction Fiber Number of Leaves Fiber Profile Angle	

Fiber Parameters

The right column of the fiber type panel contains the parameters controlling the geometrical and physical properties of each fiber type of the fibrous structure.

Bundle Fiber				Bundle Fiber			
Bundle Diameter 1 / (μm)		60		Edit...		Diameter / (μm)	
Bundle Diameter 2 / (μm)		30		Edit...		Amplitude Fraction	
Bundle Orientation		Isotropic		Edit...		Number of Leaves	
Number of Fibers		10		Edit...		Profile Angle / ($^\circ$)	
☒ Try to Remove Fiber Overlap in Bundle						Uniformly in [0,360]	
						Edit...	
Fiber Curl Torsion				Fiber Curl Torsion			
Curl Mode		Random				Torsion Start Angle / ($^\circ$)	
Segment Length / (μm)		30				Edit...	
☐ Isotropic		X-Direction	Y-Direction	Z-Direction			
Local Straightness [0:1]		0	0	0			
Global Straightness [0:1]		0	0	0			
Randomness		0.1	0.1	0.01			
☒ Bend Fibers Back to Media-Layer						Max Torsion Change / ($^\circ$)	
						0	

Some fiber parameters can only be set for some fiber types, such as the selections under the **Bundle** tab for fiber bundles, the **Curl** tab for curved fibers or the **Torsion** tab for Curved Elliptical, Cellulose, Rectangular, or Angular cross-section fibers. The fiber length can only be set for finite (**Short** or **Curved**) fibers but not for **Infinite** fibers.

The fiber parameters are described in the following groups:

- [Fiber Tab](#)  48
Define the fiber parameters for the different fiber types such as diameter or length.
- [Bundle Tab](#)  76
Define the bundle parameters.
- [Curl Tab](#)  80
Define the curl parameters defining a curved shape for the fiber.
- [Torsion Tab](#)  99
Define the torsion parameters such as torsion angle.
- [Distribution](#)  101
For many parameters a constant value or a distribution can be given. The different distribution options are described for the diameter of a circular fiber as an example.

Fiber Tab

Define the general fiber parameters such as diameter, fiber length, and center distribution.

The different fiber types have different options. For example, the infinite fiber types don't have a parameter to define their length, since they are infinite.

The parameters that define the fiber's position and orientation in the structure are explained in sub-topics:

- [Orientation](#)  55
Define if the fibers should have an isotropic or anisotropic orientation.
- [Center](#)  71
Define how the fiber centers should be distributed throughout the domain.

Size Mode

All non-infinite fiber types have the parameter **Size Mode**. From the pull-down menu three options can be selected. Here you can decide if the different diameter and length parameters of one fiber type should be interdependent.

✓ Independent

All diameter and length parameters are independent from each other and thus have their own values and distributions available through their **Edit...** buttons.

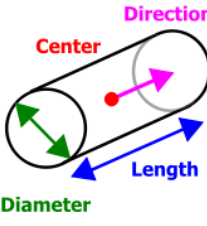
Short Circular

Rel. Volume / (%) 100

Material (ID 01) Solid...

Remove

Save...



Size Mode Independent

Diameter / (μm) 10 Edit...

Length / (μm) 100 Edit...

Center / (μm) Uniformly Distributed Edit...

Orientation Isotropic Edit...

☐ Rounded Endings

✓ Coupled

The different diameter/length parameters are coupled. Clicking the **Edit...** button for these parameters, the coupling can be defined in the distribution table.

The following structure, entirely made of short circular fibers, is generated with the coupled values for diameter and length entered in the coupled distribution table shown here. Observe the three distinct diameter-length combinations of short circular fibers:

- 50% with diameter 5 μm and length 80 μm,
- 20% with diameter 20 μm and length 120 μm, and
- 30% with diameter 10 μm and length 140 μm.

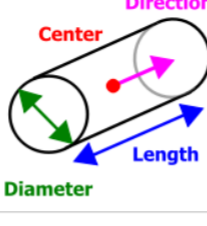
Short Circular

Rel. Volume / (%) 100

Material (ID 01) Solid...

Remove

Save...



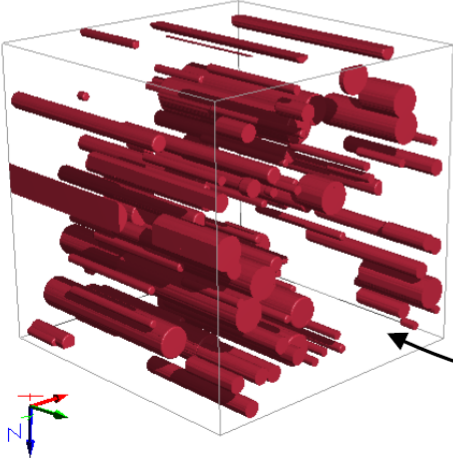
Size Mode Coupled

Diameter / (μm), Length / (μm) Edit...

Center / (μm) Uniformly Distributed Edit...

Orientation Given Directions Edit...

☐ Rounded Endings



Coupled Distribution

GEOdict

	Count	Probability	Diameter / (μm)	Length / (μm)
1	0.5	5	80	
2	0.2	20	120	
3	0.3	10	140	

Probability Sum: 1

Normalize

Number of Rows 3

Load...

Save...

OK

Cancel

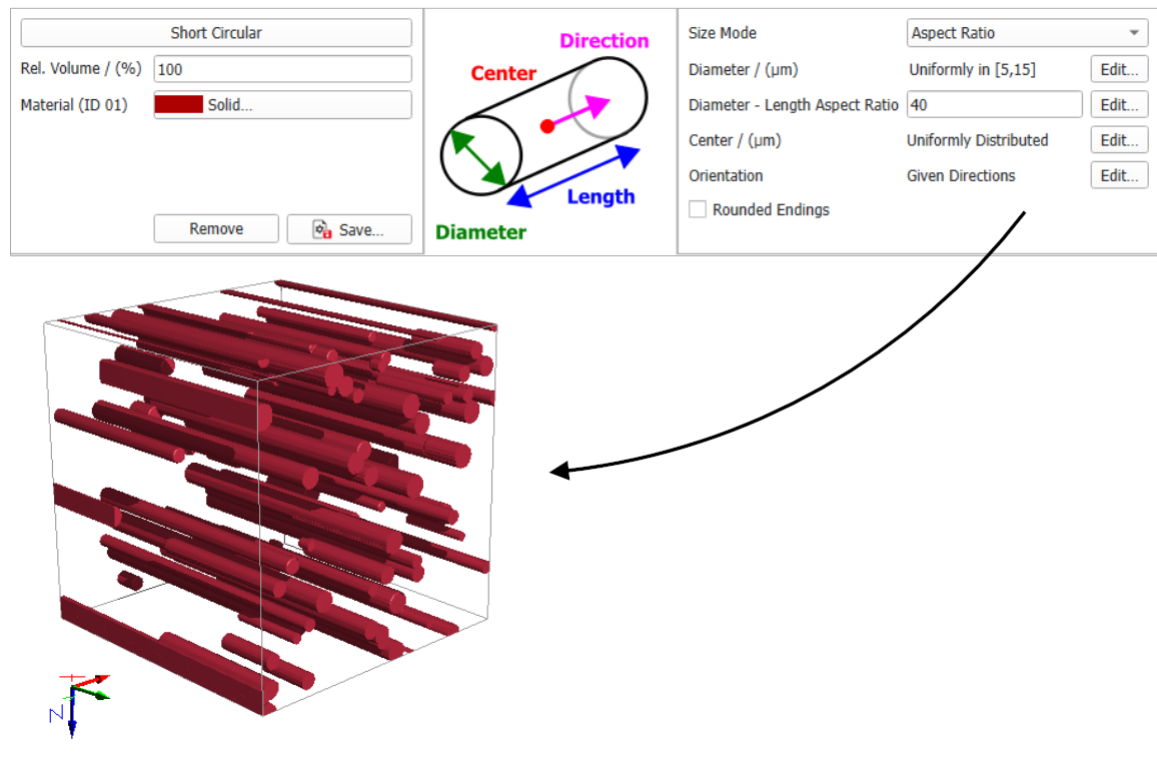
✓ Aspect Ratio

The different diameter/length parameters are given with an aspect ratio. They depend on the first [diameter](#)^[50] (given by Diameter, Diameter 1, Side Length 1, or Dtex). The resulting diameter/length value then is the aspect ratio multiplied with the first parameter value, for example:

$$\text{Length} = \text{Diameter 1} \cdot \text{Aspect Ratio} \quad (1)$$

where Aspect Ratio is short for Diameter 1 - Length Aspect Ratio.

This way you can, for example, generate fibers with a diameter [distribution](#)^[101] keeping the same aspect ratio to their length as shown below.



Diameter or Dtex

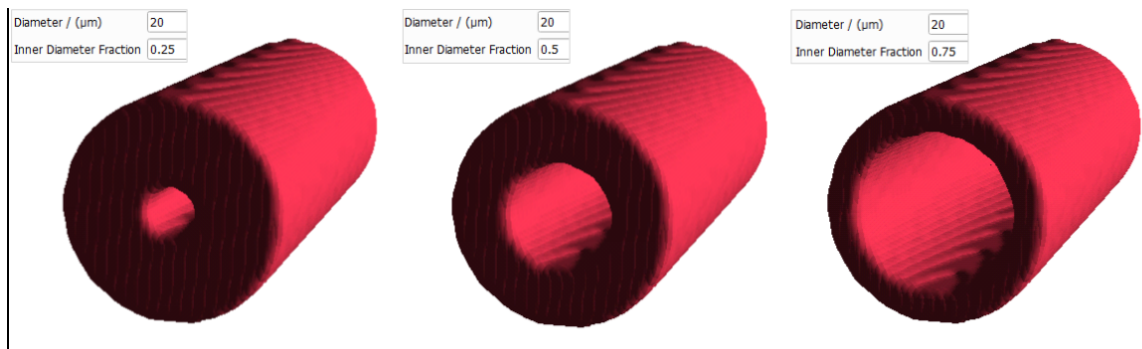
✓ Diameter or Dtex

A circular fiber has only one diameter value. The **Diameter** (or **Dtex**) value can be edited by clicking the **Edit...** button to open the **Diameter** (or **Dtex**) dialog. The circular fiber diameter can be set to have a **Constant** value, or to follow a diameter [distribution](#)^[101] (**Uniformly in interval**, **Gaussian**, **Probability Distribution**, or **Log-Normal**). Whether the parameter is given as Dtex or Diameter depends on the choice for [Fiber thickness given by](#)^[37].

✓ Inner Diameter Fraction

For a hollow fiber, the **Inner Diameter Fraction** defines which fraction of the entered (outer) diameter value is the inner diameter value. If the fiber thickness is given by [Dtex](#)³⁷, the inner and outer diameter are chosen to match the given fraction and Dtex values.

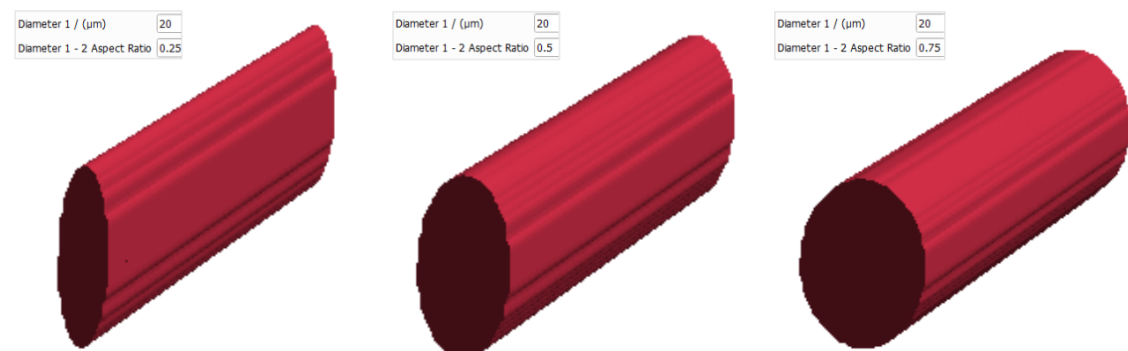
$$\text{Inner Diameter} = \text{Diameter} \cdot \text{Inner Diameter Fraction} \quad (2)$$



✓ Diameter 1 - 2 Aspect Ratio

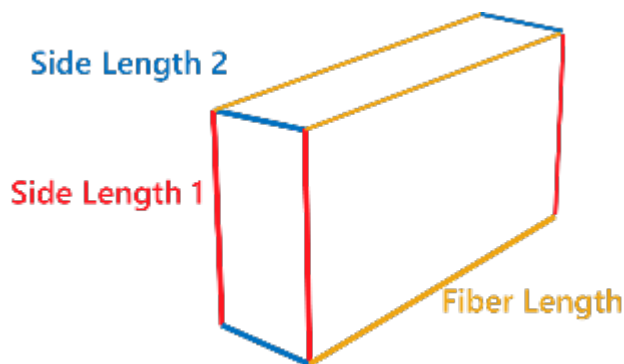
For **Elliptical** fibers, defined by two diameters, the **Aspect Ratio** is the relationship between the longer diameter (Diameter 1) and the shorter diameter (Diameter 2). If the fiber thickness is given by [Dtex](#)³⁷, the diameter 1 and 2 are chosen to match the given aspect ratio and Dtex values.

$$\text{Diameter 2} = \text{Diameter 1} \cdot \text{Aspect Ratio} \quad (3)$$



Length

Fibers can have **Finite** (Short Fibers) or **Infinite** length. For short fibers the length must be defined. Additionally, for fibers with rectangular cross-section the parameters **Length 1** and **Length 1 - 2 Aspect Ratio** define the side lengths of the cross section.



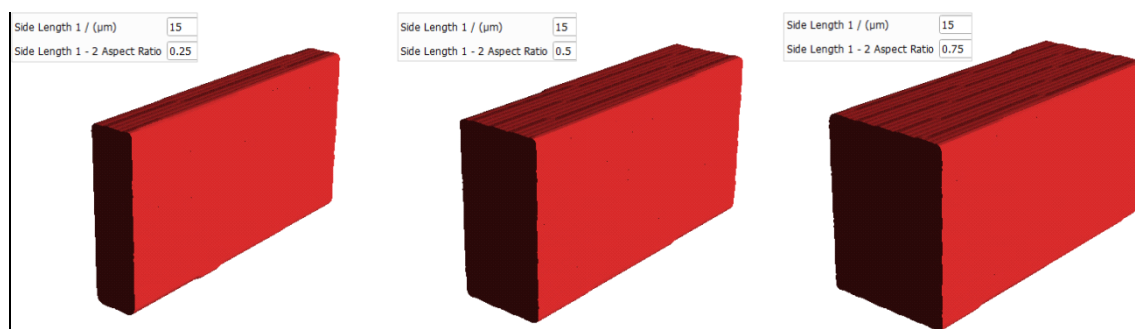
✓ Length

The length of **Short** and **Curved** fibers is editable by clicking on the **Edit...** button and choosing the desired settings in the **Length (μm)** dialog. The fiber **Length** and **Side Length** can be set to take a **Constant** value, or to follow a [distribution](#)^[101] (**Uniformly in interval**, **Gaussian**, **Probability Distribution**, or **Log-Normal**).

✓ Side Length

For fibers with rectangular cross-section, the **Side Length 1** and the **Aspect Ratio** defining **Side Length 2** can be entered. If the fiber thickness is given by [Dtex](#)^[37], the Side Length 1 and 2 are chosen to match the given aspect ratio and Dtex values.

$$\text{Side Length 2} = \text{Side Length 1} \cdot \text{Aspect Ratio} \quad (4)$$

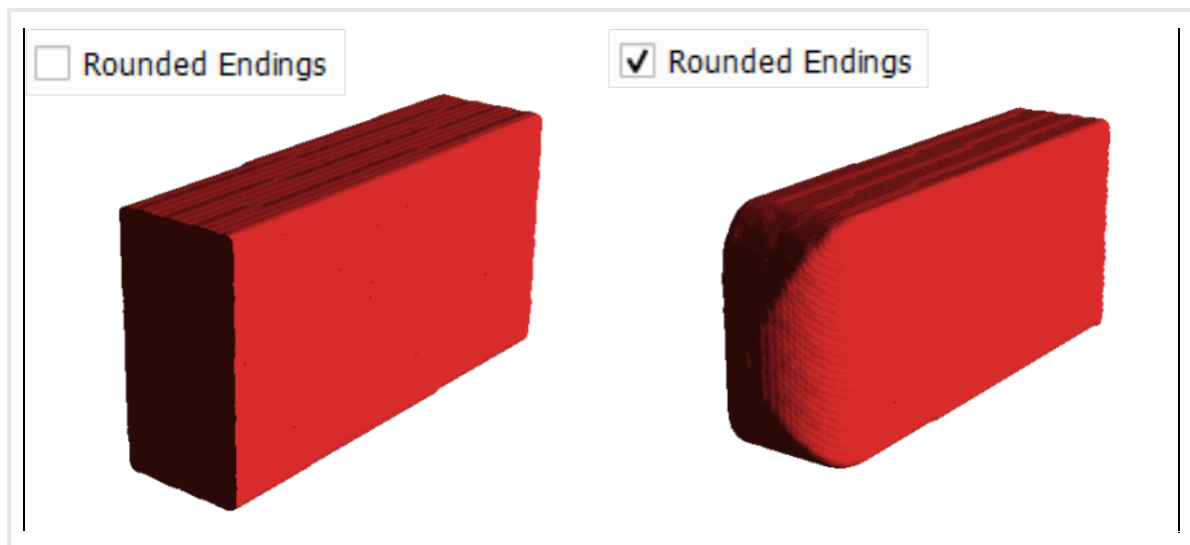


Fiber Ending

✓ Rounded Endings

Short fibers with any cross-section (Circular, Hollow, Rosetta, Cellulose, Elliptic, Rectangular, and Angular) can be created with or without rounded ends by checking or leaving un-checked the **Rounded Endings** box.

Observe the variation in the shape of the short rectangular fibers after checking the **Rounded Endings** box.

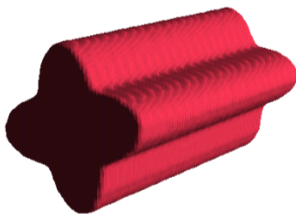


Object Specific Parameters

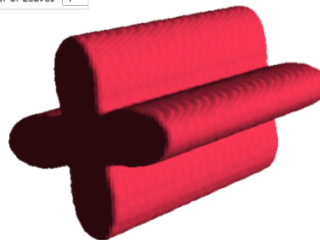
✓ Amplitude Fraction and Number of Leaves

For fibers with **Rosetta** cross-section, the **Amplitude Fraction** determines the length of the rosetta leaves, whereas the **Number of Leaves** defines how many leaves the rosetta has. The minimum number of leaves is three and the maximum is 20.

Diameter / (μm)	20
Amplitude Fraction	0.25
Number of Leaves	4



Diameter / (μm)	20
Amplitude Fraction	0.5
Number of Leaves	4



Diameter / (μm)	20
Amplitude Fraction	0.75
Number of Leaves	4



In polar coordinates, the cross-sectional shape is defined through

$$r(\phi) = \frac{\text{Diameter}}{2} (1 - \text{Amplitude Fraction} \cdot \sin(\text{Number Of Leaves} \cdot \phi))$$

(5) Rosetta Cross-Section

where ϕ in $[0, 2\pi]$ is the angle in the cross-sectional plane and the Diameter value is the average of the minimal and maximal diameter. Thus, the amplitude is given through:

$$\text{Amplitude} = \text{Amplitude Fraction} \cdot \text{Diameter}$$

(6) Rosetta Amplitude

✓ Number of Edges

For **Angular** cross sections, the **Number of Edges** defines the number of edges in the cross-section. For three edges, for example, a triangular cross-section is obtained. The minimum number of edges is three and the maximum is 20.

Number of Edges



Number of Edges



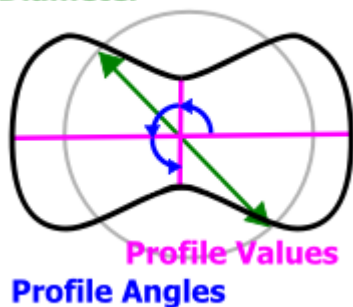
Number of Edges



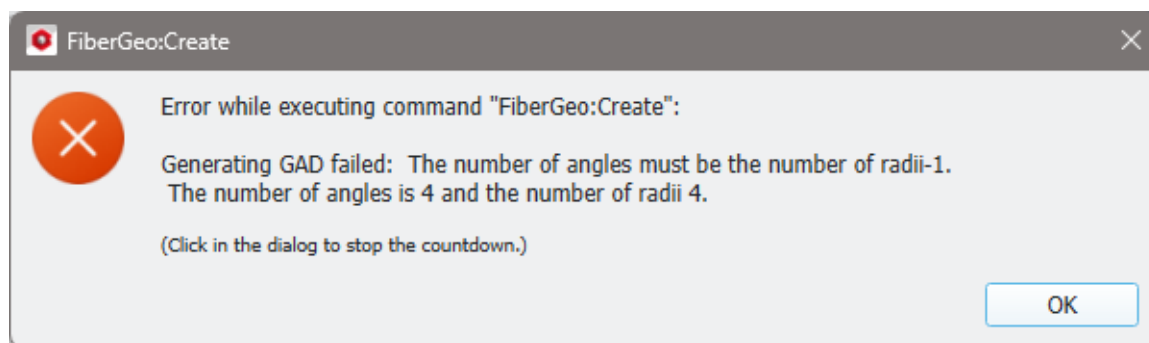
✓ Profile Angles and Profile Values

Complex cross-sections are obtained by varying the **Profile Angles** and the **Profile Values**. The **Profile Values** and the **radius** ($r = \text{Diameter}/2$) are multiplied to obtain the local radius for the corresponding **Profile Angle**. The first profile value always corresponds to a profile angle of 0° . Thus, always enter one more profile value than profile angles.

Diameter



If the entered number of angles is not number of values -1, an error message appears when clicking **Generate**.



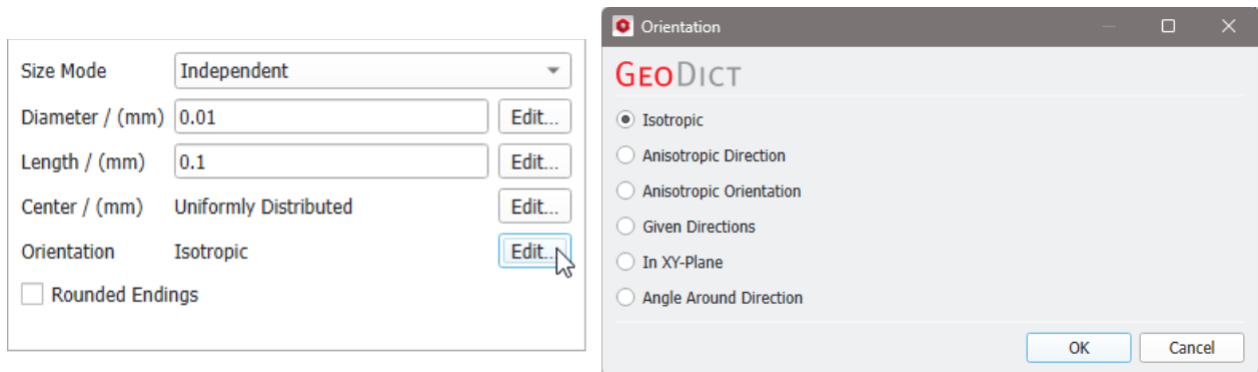
For example, with a diameter of 10 μm , the following arbitrary cross-sections can be obtained by applying the indicated profile angles and profile values:

$1 \cdot r \rightarrow r_1 = 5 \mu\text{m at } 0^\circ$ $1 \cdot r \rightarrow r_2 = 5 \mu\text{m at } 90^\circ$ $1 \cdot r \rightarrow r_3 = 5 \mu\text{m at } 180^\circ$ $1 \cdot r \rightarrow r_4 = 5 \mu\text{m at } 270^\circ$	$1.0 \cdot r \rightarrow r_1 = 5.0 \mu\text{m at } 0^\circ$ $0.5 \cdot r \rightarrow r_2 = 2.5 \mu\text{m at } 90^\circ$ $1.0 \cdot r \rightarrow r_3 = 5.0 \mu\text{m at } 180^\circ$ $0.5 \cdot r \rightarrow r_4 = 2.5 \mu\text{m at } 270^\circ$	$1.0 \cdot r \rightarrow r_1 = 5.0 \mu\text{m at } 0^\circ$ $0.5 \cdot r \rightarrow r_2 = 2.5 \mu\text{m at } 45^\circ$ $1.0 \cdot r \rightarrow r_3 = 5.0 \mu\text{m at } 120^\circ$ $0.5 \cdot r \rightarrow r_4 = 2.5 \mu\text{m at } 280^\circ$
Profile Angles / ($^\circ$) 90, 180, 270 Profile Values 1, 1, 1, 1	Profile Angles / ($^\circ$) 90, 180, 270 Profile Values 1, 0.5, 1, 0.5	Profile Angles / ($^\circ$) 45, 120, 280 Profile Values 1, 0.5, 1, 0.5
		

All objects in the generated structure have either isotropic or anisotropic orientation. The **Orientation** of an object type in a generated structure can be set by clicking the **Edit...** button. The orientation can be separately set for each object type so that differently oriented objects may coexist within the same structure.

In the **Orientation** dialog, objects can be defined to be Isotropic, have a certain **Anisotropic Direction**, **Anisotropic Orientation**, **Given Directions**, to be oriented **In XY-Plane** or have a maximum **Angle Around Direction**.

For all object types, it is possible to control the object direction (isotropic or anisotropic) and the position of the cross-section with respect to the XY-plane as well.



Isotropic

In an Isotropic orientation, all directions have the same probability.

Anisotropic Direction

When checking **Anisotropic Direction** and selecting **Anisotropy Parameter** from the **Direction Mode** pull-down menu, the **Anisotropy Parameters** (Anisotropy 1 and Anisotropy 2), as well as the **Phi**, **Theta** and **Psi** [Euler Angles](#) for the three-dimensional rotation of anisotropic objects can be defined.

In this case, the positions of cross-sections to the XY-plane are isotropic (and not entered).

☒ Anisotropic Direction

Direction Mode: Anisotropy Parameter

Anisotropy 1: 1

Anisotropy 2: 1

Euler Angles:

Phi / (°): 0

Theta / (°): 0

Psi / (°): 0

Orientation Tensor:

0.3333	0.0000	0.0000
-	0.3333	0.0000
-	-	0.3334

Normalize + Calculate Anisotropy Parameters

✓ Anisotropy Parameters

The **Anisotropy Parameters**, **Anisotropy 1** (a_1) and **Anisotropy 2** (a_2), allow to define the orientation of the objects. **Anisotropy Parameters** and the [Orientation Tensor](#)⁶³ are equivalent representations for the orientation, and GeoDict can compute one from the other automatically. The objects are created with random orientations, following a distribution defined by the given parameters.

The Algorithm

For each object, a random direction is computed

$$d = \begin{pmatrix} x \\ y \\ z \end{pmatrix}$$

which follows an isotropic distribution. Afterwards, the anisotropy parameters are used to influence these orientations. Before normalization, the resulting vector for the object orientation is:

$$d_a = \begin{pmatrix} x_a \\ y_a \\ z_a \end{pmatrix} = \begin{pmatrix} a_1 x \\ a_1 a_2 y \\ z \end{pmatrix}$$

(7)
Anisotropic
orientation
vector

With normalization follows:

$$d_{normalized} = \frac{1}{|d_a|} d_a = \frac{1}{\sqrt{(a_1 x)^2 + (a_1 a_2 y)^2 + z^2}} \begin{pmatrix} a_1 x \\ a_1 a_2 y \\ z \end{pmatrix}$$

(8)
Normalized
anisotropic
orientation
vector

Before normalization, **Anisotropy 1** controls the first two coordinates, while **Anisotropy 2** only affects the second coordinate and none of them changes the third. After normalization, the anisotropy parameters both have impact on all three coordinates, where the influence on the object direction differs. Whereas high values for **Anisotropy 1** lead to objects parallel to the XY-plane, high values for **Anisotropy 2** result in objects oriented in Y-direction. Objects oriented in Z-direction are obtained by low values for **Anisotropy 1**, and low values for **Anisotropy 2** result in objects parallel to the XZ-plane.

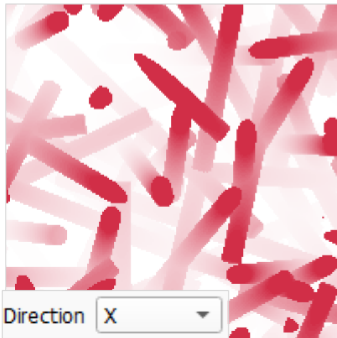
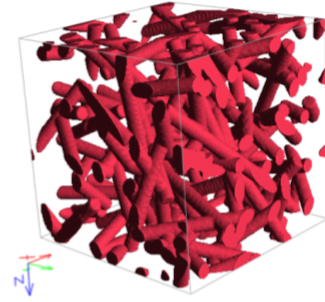
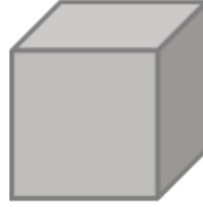
In the following, five main cases for the anisotropy parameters are described:

1. **Anisotropy 1 = Anisotropy 2 = 1 (Isotropic material)**

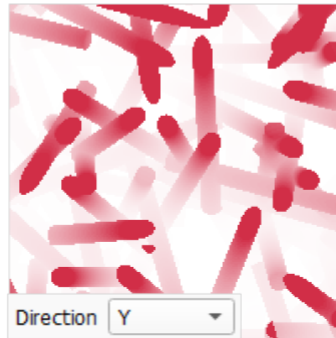
The object orientation is isotropic. All directions have the same probability, as the direction obtained from the random algorithm is not changed:

$$d_a = \begin{pmatrix} a_1 x \\ a_1 a_2 y \\ z \end{pmatrix} = \begin{pmatrix} 1 \cdot x \\ 1 \cdot 1 \cdot y \\ z \end{pmatrix} = \begin{pmatrix} x \\ y \\ z \end{pmatrix} = d$$

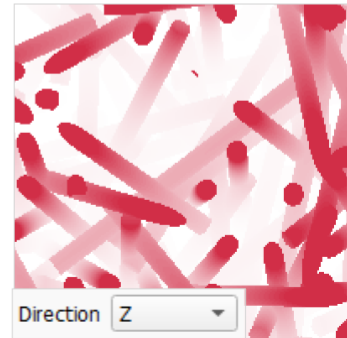
Anisotropy 1	1
Anisotropy 2	1



Direction



Direction



Direction

2. Anisotropy 1 < 1 and Anisotropy 2 = 1

Values smaller than 1 for **Anisotropy 1** lead to orientations in Z-direction, so that the objects are parallel to the YZ-plane and the XZ-plane when viewed from the X- or Y-direction. The smaller the value of **Anisotropy 1**, the more anisotropic the objects have.

For example, with the values 0.01 for **Anisotropy 1** and 1 for **Anisotropy 2** it follows:

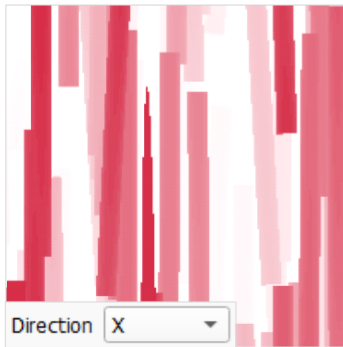
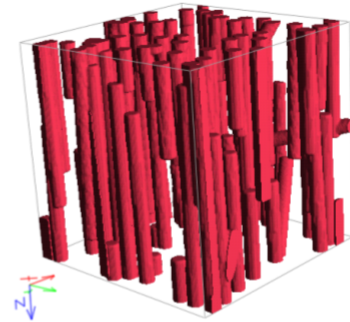
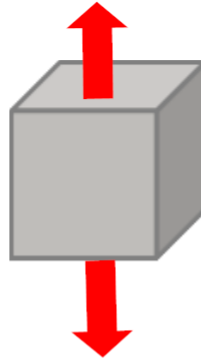
$$d_a = \begin{pmatrix} a_1 x \\ a_1 a_2 y \\ z \end{pmatrix} = \begin{pmatrix} 0.01 \cdot x \\ 0.01 \cdot y \\ z \end{pmatrix}$$

Thus, after normalization the direction vectors of the objects approximate the unit vector:

$$d_{normalized} = \frac{1}{\sqrt{0.0001 \cdot x^2 + 0.0001 \cdot y^2 + z^2}} \begin{pmatrix} 0.01 \cdot x \\ 0.01 \cdot y \\ z \end{pmatrix} \cong \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix}$$

That results in objects oriented in Z-direction.

Anisotropy 1
 Anisotropy 2



3. Anisotropy 1 > 1 and Anisotropy 2 = 1

The objects are isotropic in the XY-plane (Z-slice). The higher the value of **Anisotropy 1**, the stronger is the anisotropy.

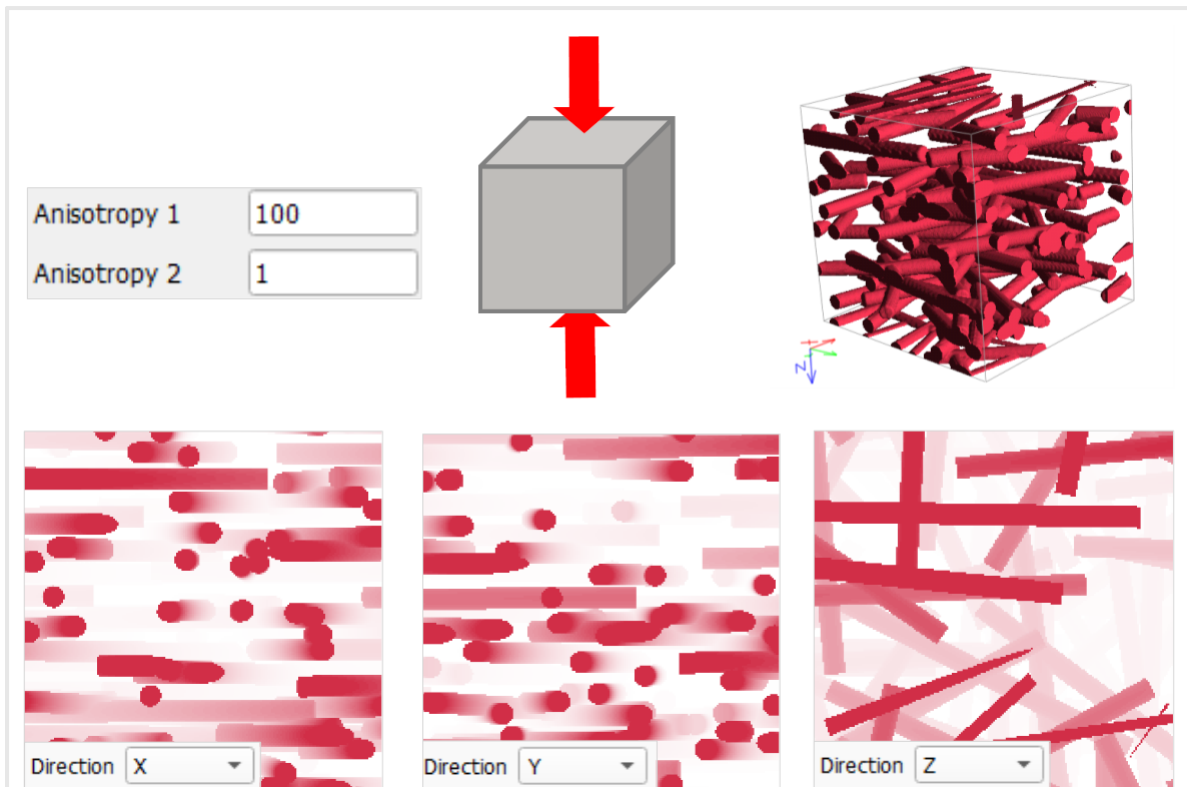
For example, with the values 100 for **Anisotropy 1** and 1 for **Anisotropy 2** it follows:

$$d_a = \begin{pmatrix} a_1 x \\ a_1 a_2 y \\ z \end{pmatrix} = \begin{pmatrix} 100 \cdot x \\ 100 \cdot y \\ z \end{pmatrix}$$

Thus, after normalization the direction vectors of the objects approximate the vector:

$$d_{normalized} = \frac{1}{\sqrt{10000 \cdot x^2 + 10000 \cdot y^2 + z^2}} \begin{pmatrix} 100 \cdot x \\ 100 \cdot y \\ z \end{pmatrix} \cong \begin{pmatrix} x \\ y \\ 0 \end{pmatrix}$$

That results in objects oriented in the XY-plane.



4. Anisotropy 1 = 1 and Anisotropy 2 < 1

Small values for **Anisotropy 2** lead to objects oriented parallel to the XZ-plane. Observe that the objects are isotropic in the XZ-plane (Y-slice).

For example, with the values 1 for **Anisotropy 1** and 0.01 for **Anisotropy 2** it follows:

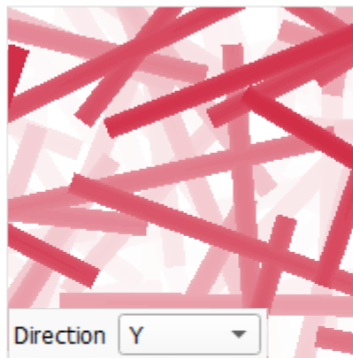
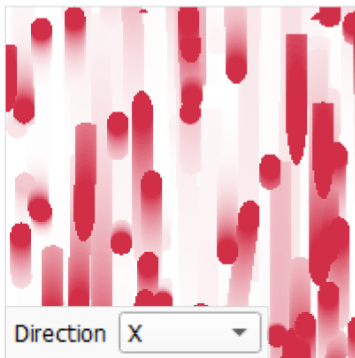
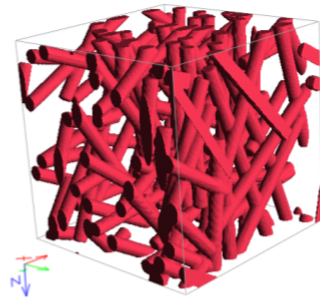
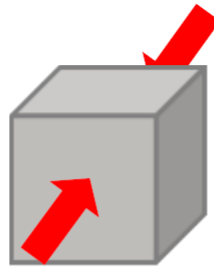
$$d_a = \begin{pmatrix} a_1 x \\ a_1 a_2 y \\ z \end{pmatrix} = \begin{pmatrix} x \\ 0.01 \cdot y \\ z \end{pmatrix}$$

Thus, after normalization the direction vectors of the objects approximate the vector:

$$d_{normalized} = \frac{1}{\sqrt{x^2 + 0.0001 \cdot y^2 + z^2}} \begin{pmatrix} x \\ 0.01 \cdot y \\ z \end{pmatrix} \cong \begin{pmatrix} x \\ 0 \\ z \end{pmatrix}$$

That results in objects oriented in the XZ-plane.

Anisotropy 1	1
Anisotropy 2	0.01



5. Anisotropy 1 = 1 and Anisotropy 2 > 1

The higher the values for **Anisotropy 2**, the more the objects tend to be oriented along the Y-axis. Observe that the objects cut the XZ-plane (Y-slice), while they run parallel to the YZ-plane and the XY-plane when viewing them from the X- or the Z-direction.

For example, with the values 1 for **Anisotropy 1** and 100 for **Anisotropy 2**, it follows:

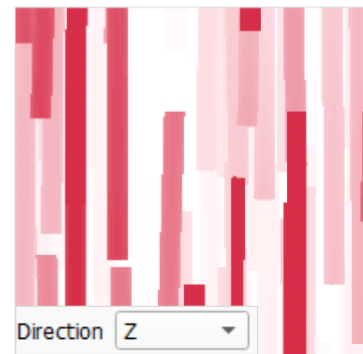
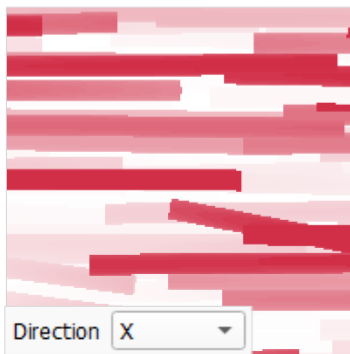
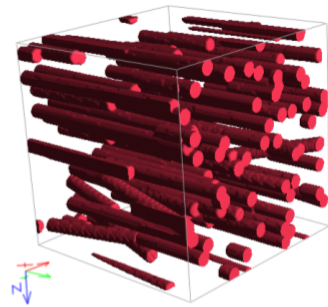
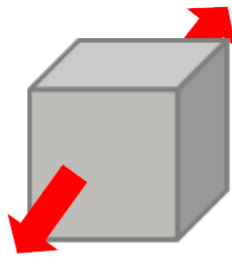
$$d_a = \begin{pmatrix} a_1 x \\ a_1 a_2 y \\ z \end{pmatrix} = \begin{pmatrix} x \\ 100 \cdot y \\ z \end{pmatrix}$$

Thus, after normalization the direction vectors of the objects approximate the unit vector:

$$d_{normalized} = \frac{1}{\sqrt{x^2 + 10000 \cdot y^2 + z^2}} \begin{pmatrix} x \\ 100 \cdot y \\ z \end{pmatrix} \cong \begin{pmatrix} 0 \\ 1 \\ 0 \end{pmatrix}$$

That results in objects oriented in Y-direction.

Anisotropy 1	1
Anisotropy 2	100

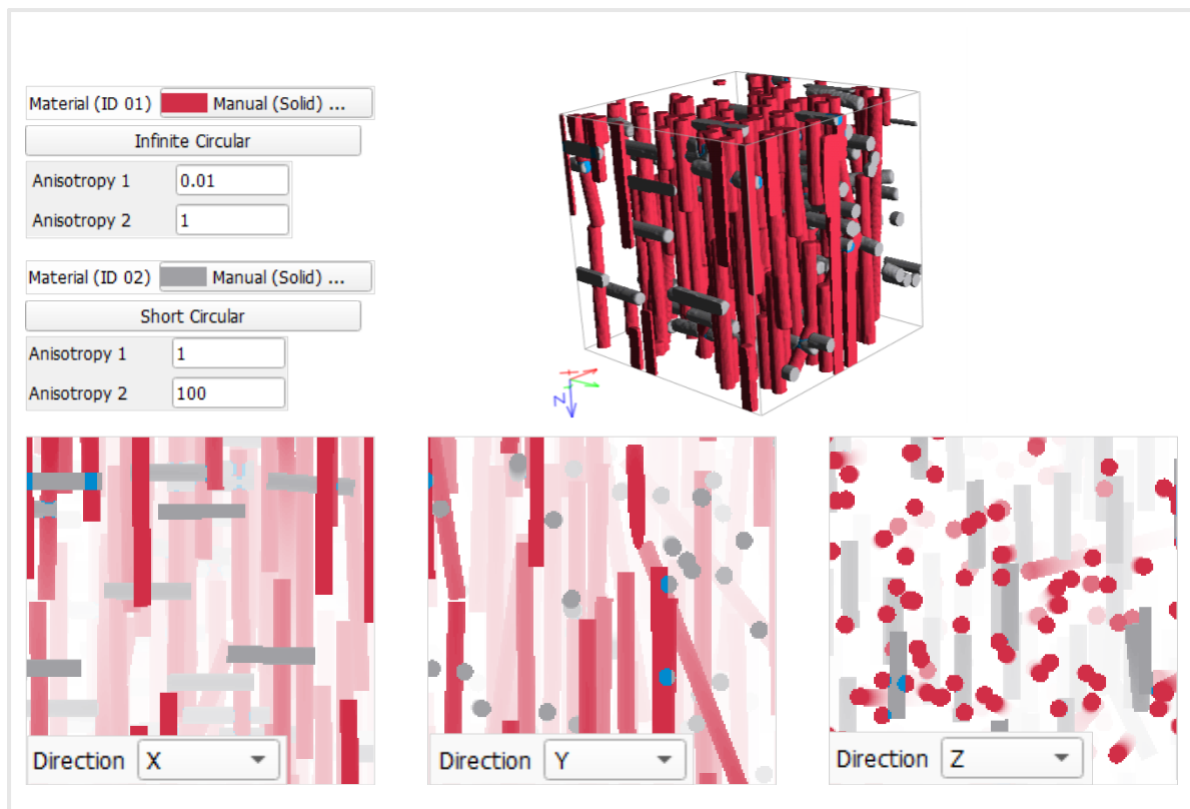


Different anisotropy values for different object types

As mentioned before, the orientation can be separately set for each object type so that differently oriented objects may coexist within the same structure. In the following structure, observe that **Anisotropy 1** and **Anisotropy 2** are set to 0.01 and 1 for the short circular (red) fibers. The short circular (gray) fibers have **Anisotropy 1** and **Anisotropy 2** of 1 and 100, respectively.

The red fibers tend to be oriented along the Z-axis, and the fibers run parallel when viewed from the X- or Y-direction.

The gray fibers tend to be oriented in the Y-axis and cut the XZ-plane, while they run parallel to the YZ-plane and the XY-plane, as observed from the X- or the Z-direction.

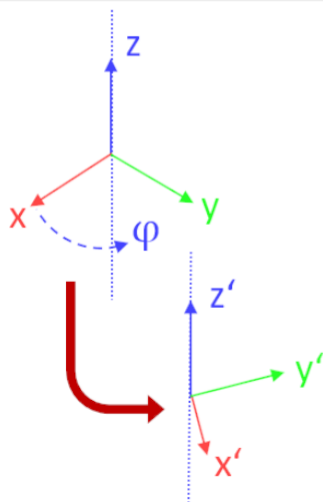


✓ Euler Angles

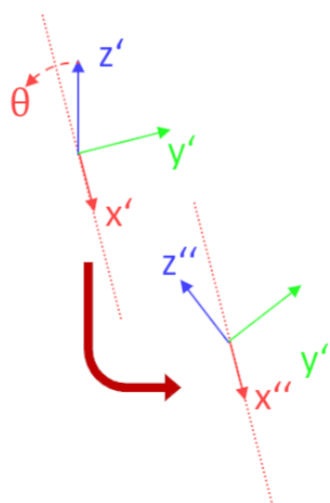
The [Euler rotation angles](#) are applied to the objects during the generation after applying the anisotropy parameters following the order **Phi** → **Theta** → **Psi**.

Euler Angles	Phi / (°)	90
	Theta / (°)	30
	Psi / (°)	30

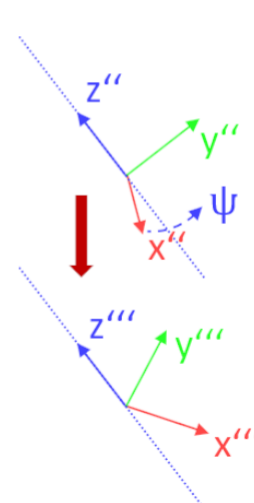
Z-axis fixed
Phi applies rotation around existing Z-axis



new X-axis fixed
Theta applies rotation around new X-axis



new Z-axis fixed
Psi applies rotation around new Z-axis



✓ Orientation Tensor

Alternatively, when selecting **Orientation Tensor** from the **Direction Mode** pull-down menu, the values for the orientation tensor for the anisotropic objects can be entered.

The **Orientation Tensor** provides an equivalent alternative to the combination of the **Anisotropy Parameters** and the **Euler Angles**.

☒ Anisotropic Direction

Direction Mode: Orientation Tensor

Anisotropy 1: 1

Anisotropy 2: 1

Phi / (°): 90.0000

Euler Angles: Theta / (°): 180.0000

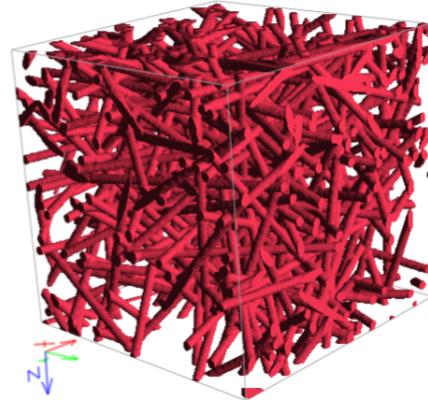
Psi / (°): 0.0000

0.3333 0.0000 0.0000

Orientation Tensor: - 0.3333 0.0000

- - 0.3334

Normalize + Calculate Anisotropy Parameters



Clicking the **Normalize + Calculate Anisotropy Parameters** button enters the adjusted values in the orientation tensor and the **Anisotropy 1** and **Anisotropy 2** boxes.

In detail, let

$$\mathbf{d}_k = \begin{pmatrix} x_k \\ y_k \\ z_k \end{pmatrix}$$

be the unit vector describing the direction of the k-th object and **n** the number of objects. Then the orientation tensor **T** is the sum over the dyadic products of the **d_k** from all **n** objects, divided by **n**:

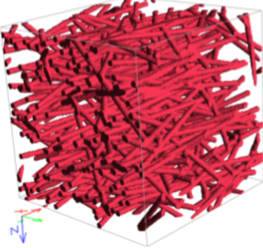
$$\mathbf{T} = \frac{1}{n} \left(\sum_{k=1}^n \mathbf{d}_k \mathbf{d}_k^T \right) = \frac{1}{n} \sum_{k=1}^n \begin{pmatrix} x_k x_k & x_k y_k & x_k z_k \\ y_k x_k & y_k y_k & y_k z_k \\ z_k x_k & z_k y_k & z_k z_k \end{pmatrix} = \begin{pmatrix} t_{11} & t_{12} & t_{13} \\ t_{21} & t_{22} & t_{23} \\ t_{31} & t_{32} & t_{33} \end{pmatrix} \quad (9) \text{ Orientation Tensor}$$

The diagonal elements define the orientation strength for the corresponding directions and sum up to 1. Thus, if for example **t₁₁=1** (and **t₂₂=t₃₃=0**), all objects are oriented in the X-direction. For **t₁₁=0** all objects are oriented normally to the X-direction and same values for all diagonal elements (**t₁₁=t₂₂=t₃₃=1/3**) result in a uniform distribution for the object orientation.

Observe the effect of changing the default values of the isotropic **Orientation Tensor** to obtain anisotropic structures oriented in the X-, Y-, or Z-direction.

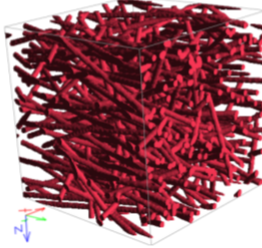
X-direction

0.7	0.0000	0.0000
-	0.15	0
-	-	0.15



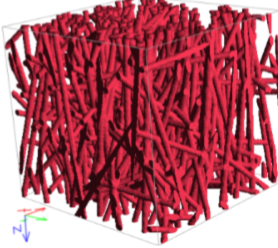
Y-direction

0.15	0.0000	0.0000
-	0.7	0
-	-	0.15



Z-direction

0.15	0.0000	0.0000
-	0.15	0
-	-	0.7



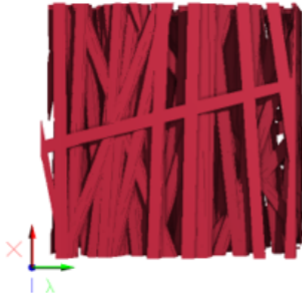
The extra-diagonal values define the statistical variation of the orientations given by the diagonal values. For example, if t_{11} has a high value near 1, and t_{12} has a relatively high value near 0.1, less fibers are oriented straight in X-direction than it is the case for a lower value for t_{12} .

Realized direction tensor:

0.8932	0.0130	-0.0001
-	0.1066	-0.0003
-	-	0.0002

Target direction tensor:

0.8995	0.0000	0.0000
-	0.1000	0.0000
-	-	0.0005

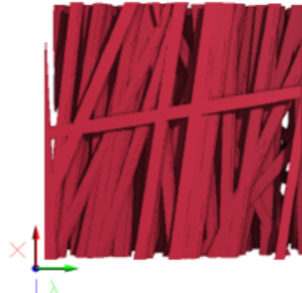


Realized direction tensor:

0.9006	0.1080	0.0003
-	0.0992	-0.0007
-	-	0.0002

Target direction tensor:

0.8995	0.1000	0.0000
-	0.1000	0.0000
-	-	0.0005



Clicking the **Normalize + Calculate Anisotropy Parameters** button, the **Orientation Tensor** is normalized, and the **Anisotropy values** and the **Euler Angles** are calculated and entered in the boxes above.

Anisotropic Orientation

To control not only the object direction, but also the position of the cross-section with respect to the XY-plane, check **Anisotropic Orientation** and select either [Anisotropy Parameter](#)^[56] or [Orientation Tensor](#)^[63] from the **Orientation Mode** pull-down menu. Since all other parameters are the same as for the [Anisotropic Direction](#)^[56], here only the **Profile Angle** is described.

☒ Anisotropic Orientation

Orientation Mode: Anisotropy Parameter

Anisotropy 1: 1

Anisotropy 2: 1

Euler Angles: Phi / (°): 0, Theta / (°): 0, Psi / (°): 0

Orientation Tensor: 0.3333, 0.0000, 0.0000, 0.0, 0.3333, 0.0000, 0.0, 0.0, 0.3334

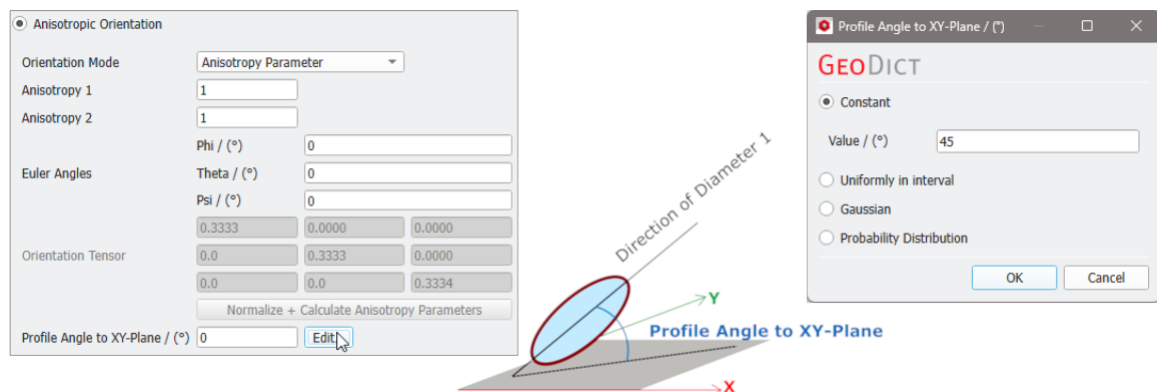
Normalize + Calculate Anisotropy Parameters

Profile Angle to XY-Plane / (°): 0 Edit...

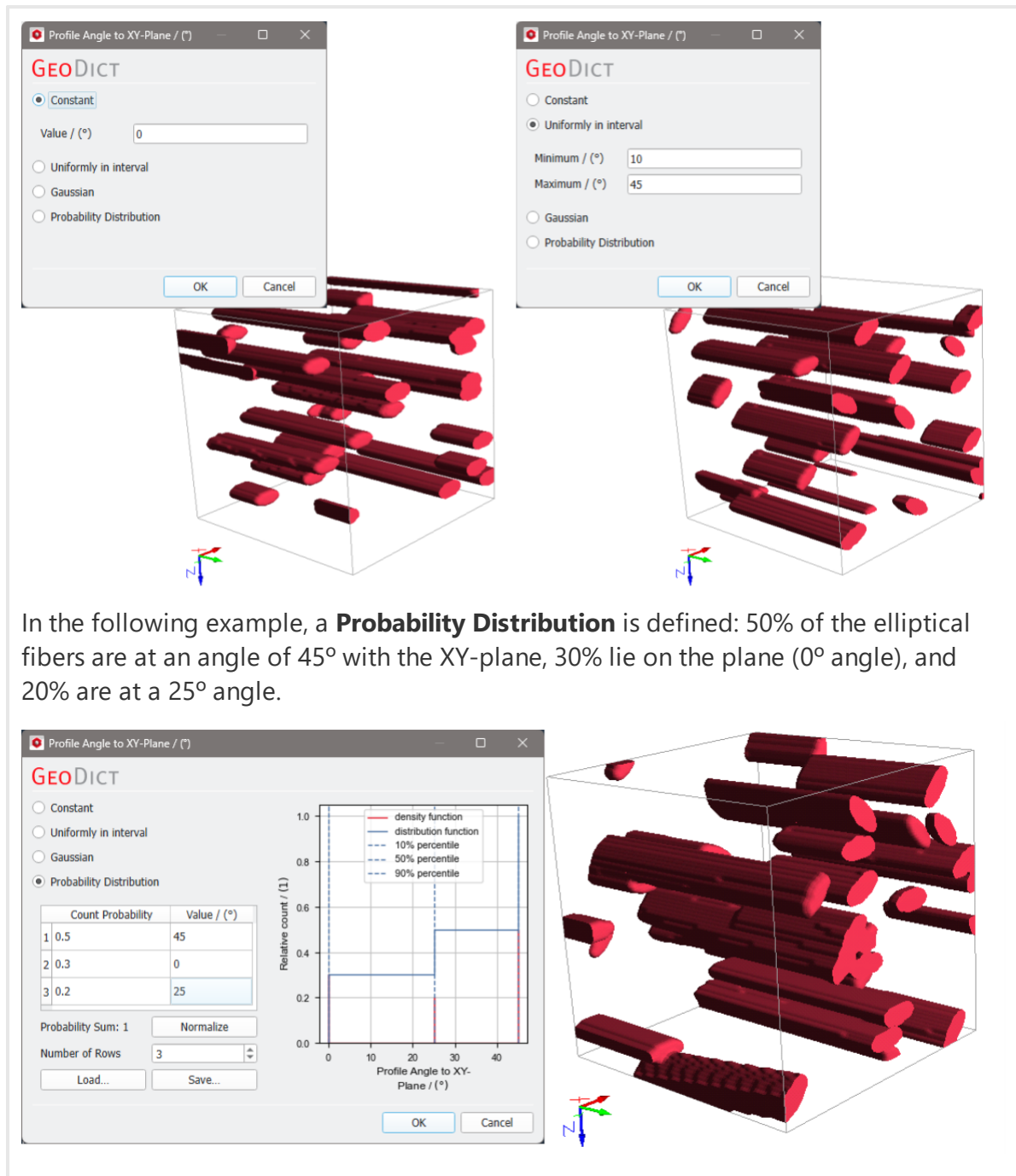
✓ Profile Angle to XY-Plane

The angle between the object cross section axis and XY-plane can be entered in the **Profile Angle to XY-Plane** dialog.

The object **Profile Angle to XY-Plane**, can be set to be a **Constant** value, or to follow a distribution (**Uniformly in interval**, **Gaussian**, or **Probability Distribution**).



Observe the effect of varying the **Profile Angle To XY-Plane** in a structure made of **Short Elliptical** fibers strongly oriented in the Y-axis (Anisotropy 1 = 1, Anisotropy 2 = 1000). Other parameters are unchanged.



In the following example, a **Probability Distribution** is defined: 50% of the elliptical fibers are at an angle of 45° with the XY-plane, 30% lie on the plane (0° angle), and 20% are at a 25° angle.

Given Directions

By checking **Given Directions**, a distribution gradient can be entered for different direction vectors for the objects in the generated structure.

☒ Given Directions

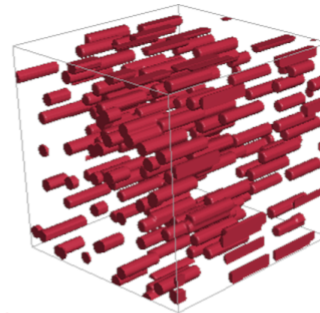
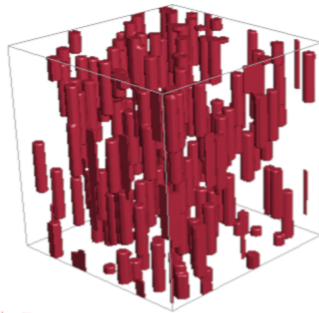
Count Probability	X-Dir.	Y-Dir.	Z-Dir.
1 1	0	0	1

Probability Sum: Normalize

Number of Rows

✓ Table: Count Probability and Number of Rows

In the left column the **Count Probability** can be entered. A value of 1 means all objects will have the given direction on the right. For example, a **Count Probability** of 1 for the direction vector 0, 0, 1 means that all objects follow the Z-direction, and 1, 0, 0 means that all objects follow the X-direction.



☒ Given Directions

Count Probability	X-Dir.	Y-Dir.	Z-Dir.
1 1	0	0	1

Probability Sum: Normalize

Number of Rows

☒ Given Directions

Count Probability	X-Dir.	Y-Dir.	Z-Dir.
1 1	1	0	0

Probability Sum: 1 Normalize

Number of Rows

If more rows are given via **Number of Rows**, every given direction will be applied to the generated objects with the corresponding count probability. In the following example observe how 80% of the short circular fibers are oriented in X-direction while the other 20% are oriented along the Z-axis.

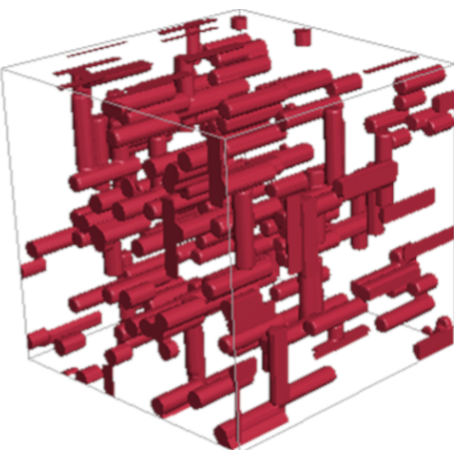
☒ Given Directions

	Count	Probability	X-Dir.	Y-Dir.	Z-Dir.
1	0.2	0	0	1	
2	0.8	1	0	0	

Probability Sum: 1

Number of Rows: 2

Load... Normalize Save...





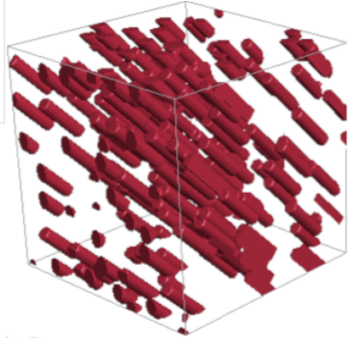
Every direction in the 3-dimensional space is possible, as seen in these examples:

	Count	Probability	X-Dir.	Y-Dir.	Z-Dir.
1	1	1	0	1	

Direction-tensor object type 1:

Realized direction tensor:

0.5000	0.0000	0.5000
-	0.0000	0.0000
-	-	0.5000



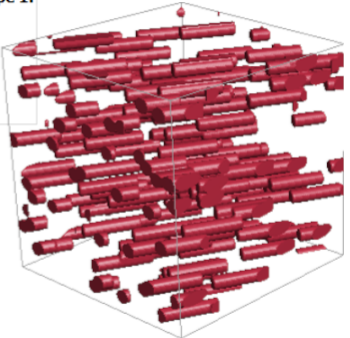


	Count	Probability	X-Dir.	Y-Dir.	Z-Dir.
1	1	1	0.5	0	

Direction-tensor object type 1:

Realized direction tensor:

0.8000	0.4000	0.0000
-	0.2000	0.0000
-	-	0.0000





✓ Normalize, Save and Load

Clicking the **Normalize** button ensures the **Count Probability** values sum up to one.

	Count	Probability	X-Dir.	Y-Dir.	Z-Dir.
1	0.2	1	0	1	
2	5	1	0.5	0	
3	4	0	1	1	

Probability Sum: 9.2

Normalize

	Count	Probability	X-Dir.	Y-Dir.	Z-Dir.
1	0.0217391304	1	0	1	
2	0.543478261	1	0.5	0	
3	0.434782609	0	1	1	

Probability Sum: 1

Normalize

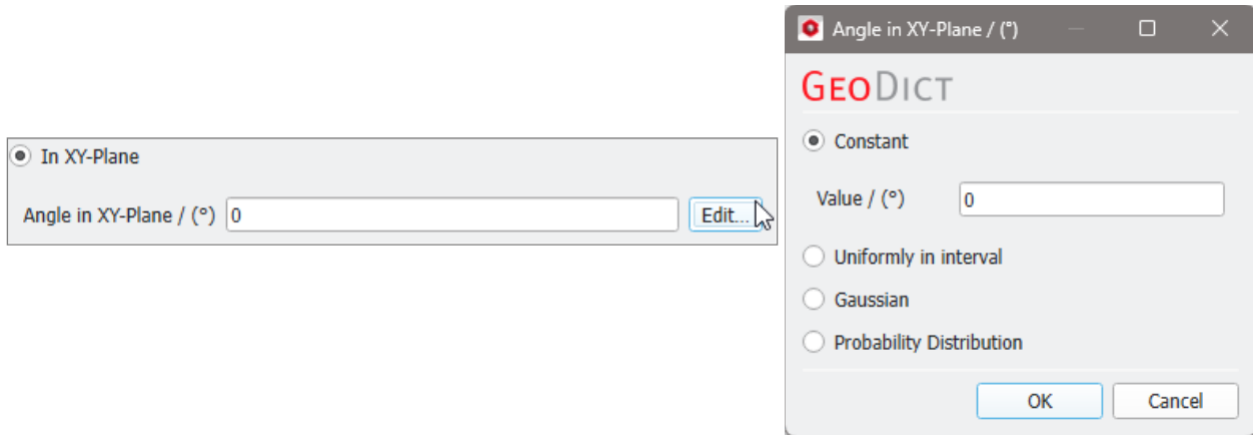
The **Given Directions** distribution settings can be saved as text file and loaded by clicking **Save** and **Load**, respectively.

Load...

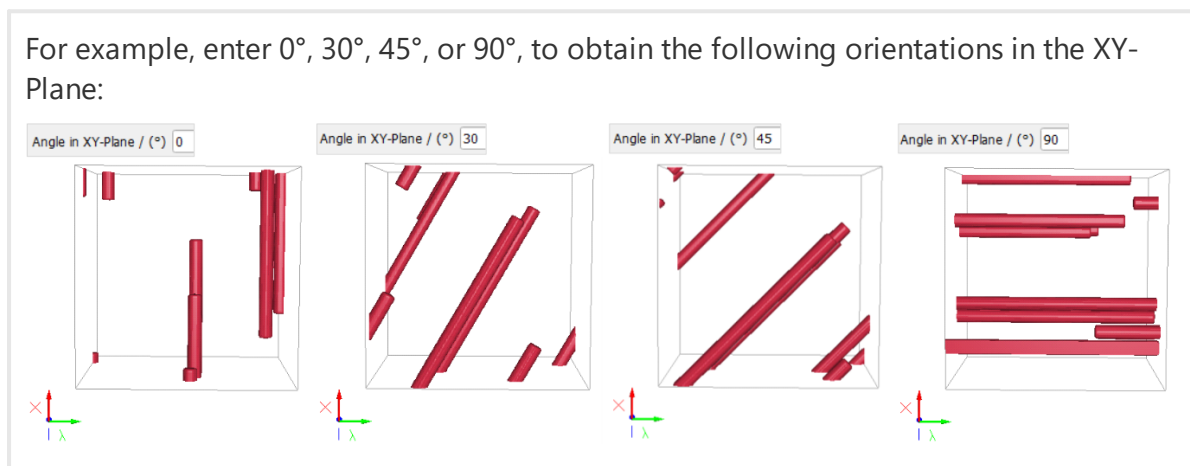
Save...

In XY-Plane

By checking **In XY-Plane**, the angle of the objects main axis in the XY-Plane can be set. The objects lie in the XY-Plane and their main axis orientation in relation to the X-direction is controlled by the entered value. The **Angle in XY-Plane** can be set to be a **Constant** value, or to follow a distribution (**Uniformly in interval**, **Gaussian**, or **Probability Distribution**).



✓ Example



Angle Around Direction

If **Angle Around Direction** is checked, define the **Main Direction Vector** of the objects generated in the structure. The orientation of the objects can vary if an **Angle Around Direction** is given.

The **Angle Around Direction** defines the maximum angle the object orientation varies from the **Main Direction**. The **Angle Around Direction** can be set to be a **Constant** value, or to follow a distribution (**Uniformly in interval**, **Gaussian**, or **Probability Distribution**).

☒ Angle Around Direction

Main Direction Vector

Angle Around Direction / (°) [Edit...](#)

Angle Around Direction / (°)

GEODICT

☒ Constant

Value / (°)

☐ Uniformly in interval

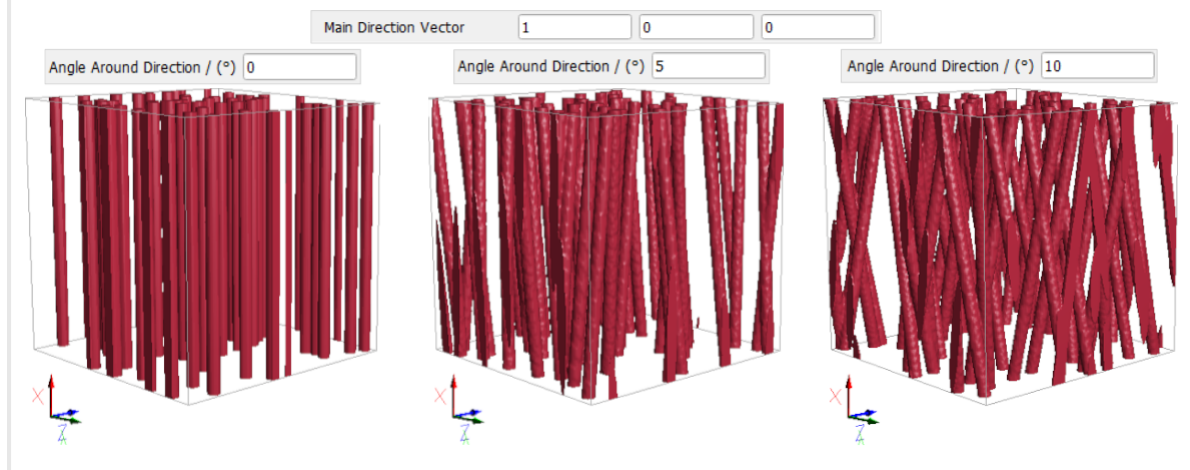
☐ Gaussian

☐ Probability Distribution

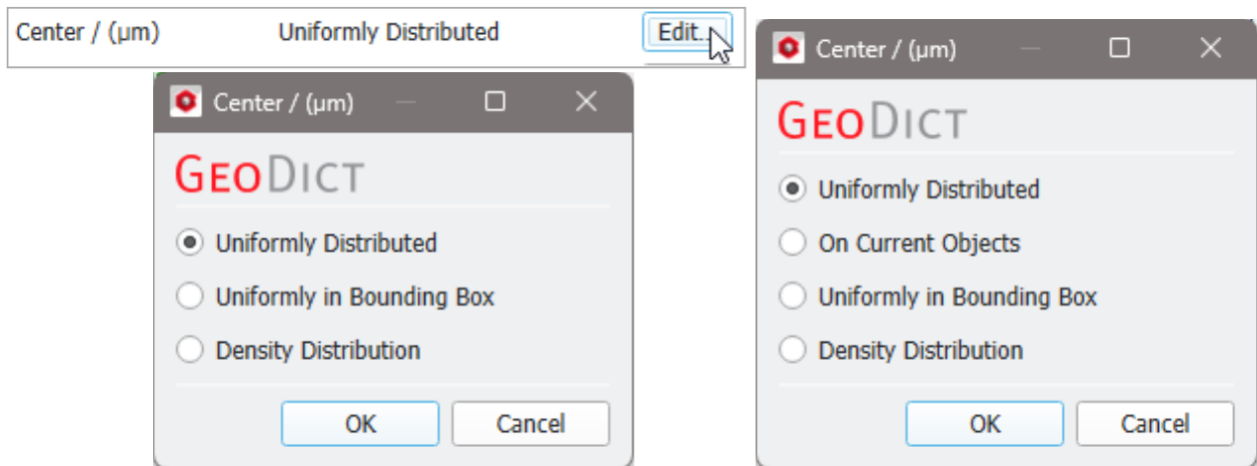
[OK](#) [Cancel](#)

✓ Example

Observe how the orientation varies in the following example with angles around direction of 0°, 5°, and 10° together with a **Main Direction Vector** of (1, 0, 0).

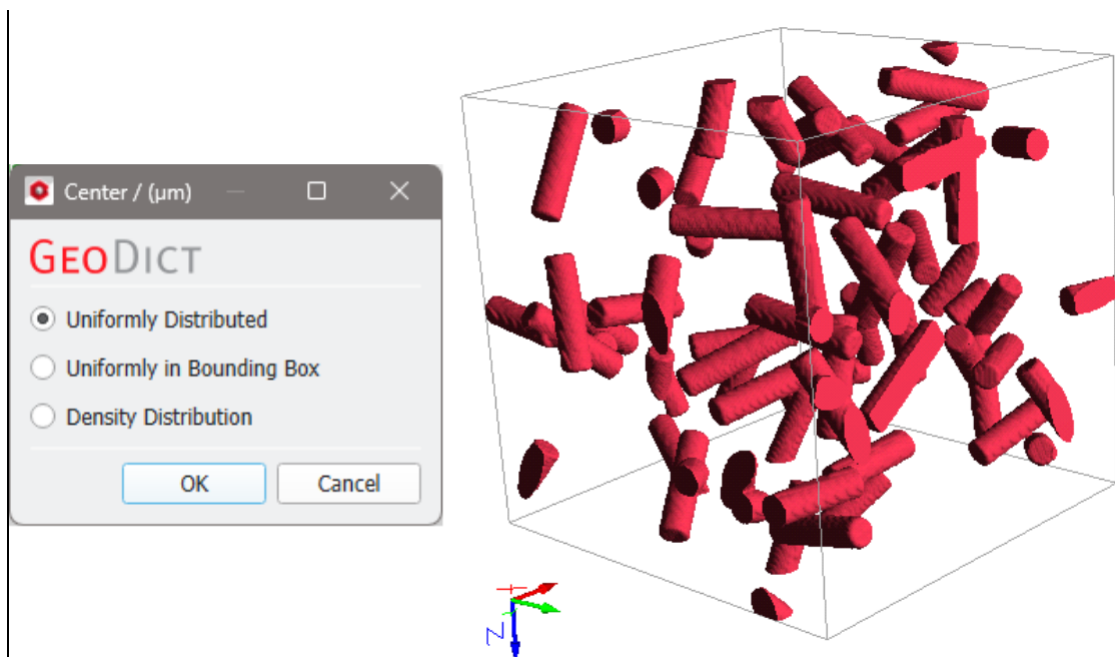


Define how the object's centers should be distributed throughout the domain. The **Center**, for short and curved fibers (not for infinite), can be set to distribute **Uniformly, On Current Objects** (when [Create in Current Domain](#)⁹ is checked under **Create Options**), **Uniformly in Bounding Box**, or to follow a **Density Distribution**. The position of short and curved fibers in a generated structure can be controlled by adjusting the position of their **Center** through the **Edit...** button. In the image below the Center dialog is shown for [Create in Current Domain](#)⁹ unchecked (left) and checked (right).



✓ Uniformly Distributed

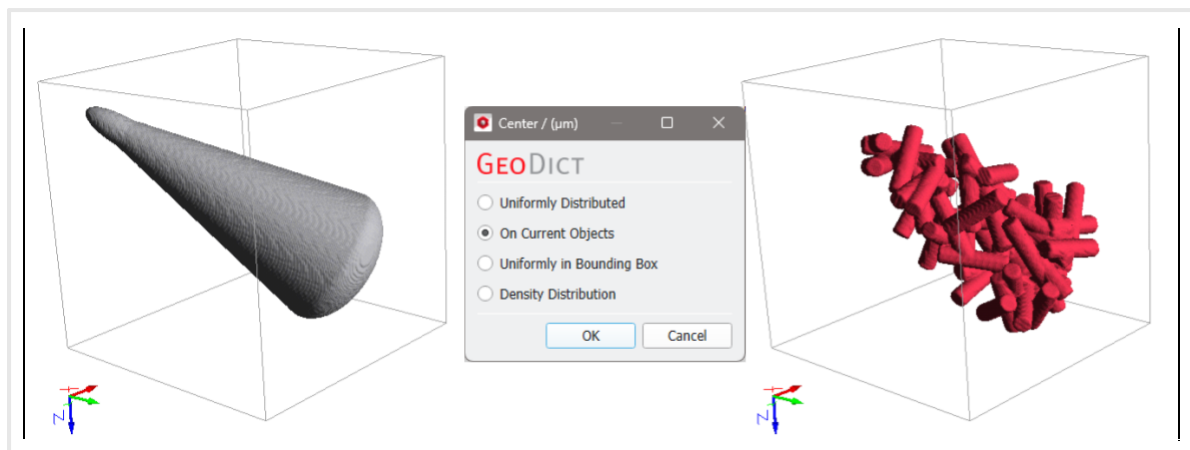
When **Uniformly Distributed** is selected, the random fiber center values are uniformly distributed across the whole structure. The uniform distribution of the centers is clearly observed when the fibers in the structure are fairly short circular fibers.



✓ On Current Objects

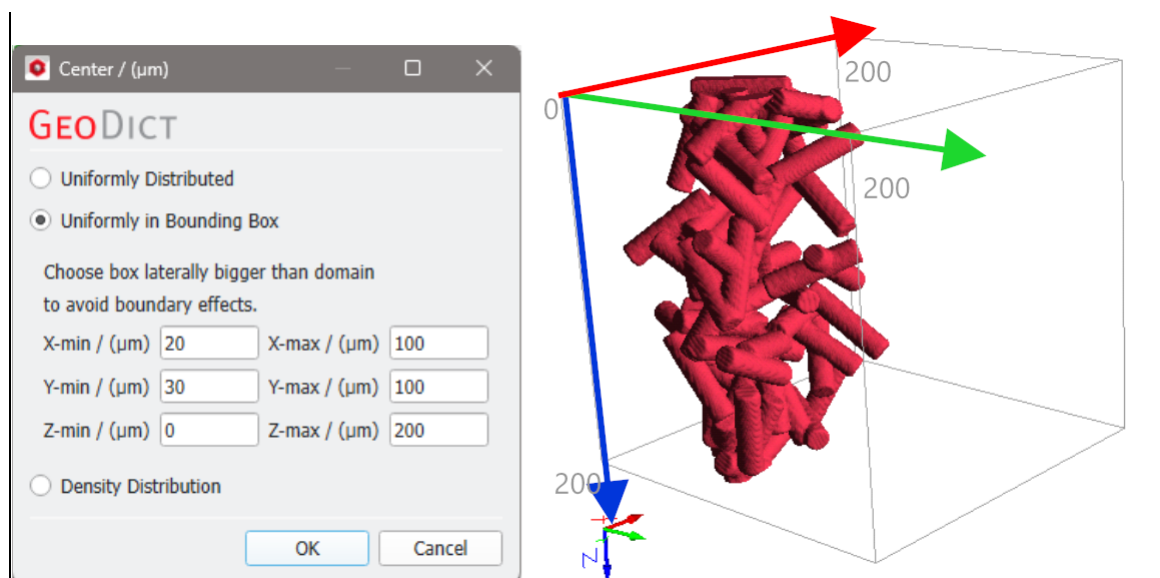
The option to position the centers **On Current Objects** appears in the **Center** dialog only when **Create in Current Domain** is checked under the [Create Options](#) tab.

Observe the placement of short circular fibers' centers on the loaded cone structure (generated with GadGeo), when **On Current Objects** is chosen in the **Center** dialog.



✓ Uniformly in Bounding Box

With **Uniformly in Bounding Box** checked, the values entered for **X-min**, **X-max**, **Y-min**, **Y-max**, **Z-min**, and **Z-max** limit the distribution of the center's positions to certain areas.



These values define an area in which the fiber centers are placed. For a 200 x 200 x 200 μm structure, the values in the dialog limit an area in which the fibers' centers lay between 20 μm and 100 μm in the X-direction, 30 μm and 100 μm in the Y-direction, and between the origin (0 μm) and the end of the domain in the Z-direction.

✓ Density Distribution

The **Density Distribution** table describes the [probability](#) of a random center taking certain position values in Z-direction.



Note! The center density distribution should be defined with monotonously increasing Z-values. If Z is non-monotonic or monotonously decreasing, the

values are ordered as needed after closing the dialog.

	Relative Position in Z-Direction	Density			Relative Position in Z-Direction	Density
1	0	0		1	0	0
2	0.5	2		2	0.2	0
3	0.2	0	→	3	0.5	2
4	1	10		4	1	10
Number of Rows				Number of Rows		
4				4		

When checking **Use Relative Position** in the density distribution table, the left column values from 0 to 1 correspond to locations in the structure. In the Z-direction, the value 0 is at the origin and the value 1 is at end of the domain.

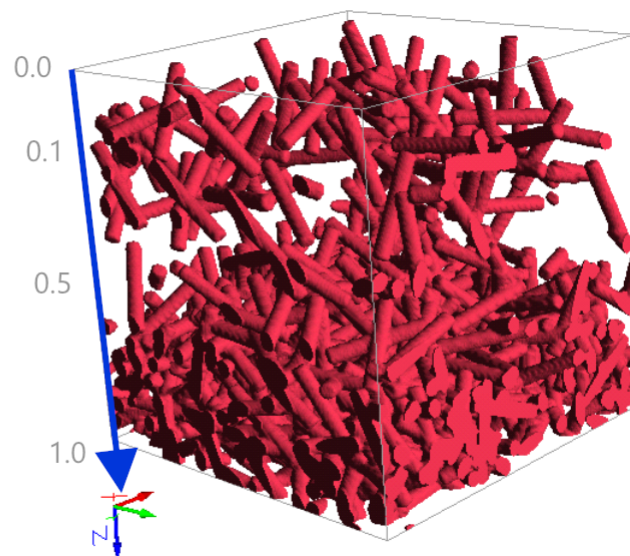
The right column assigns relative density values at these locations. The value **10** means that there are five times more fiber centers at $Z = 1$ than at $Z = 0.1$, with a density value of **2**. The fiber density increases and decreases linearly between the given locations in the Z-direction.

☒ Density Distribution

☒ Use Relative Position

	Relative Position in Z-Direction	Density
1	0.1	2
2	0.5	0
3	1	10

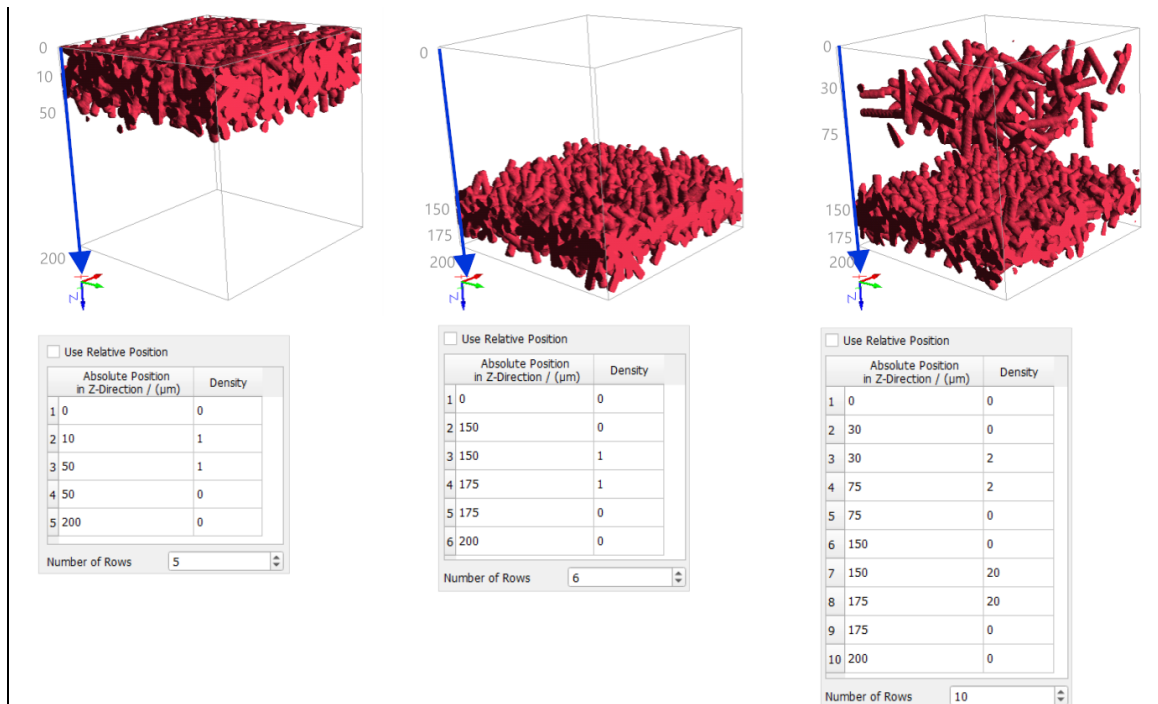
Number of Rows 3



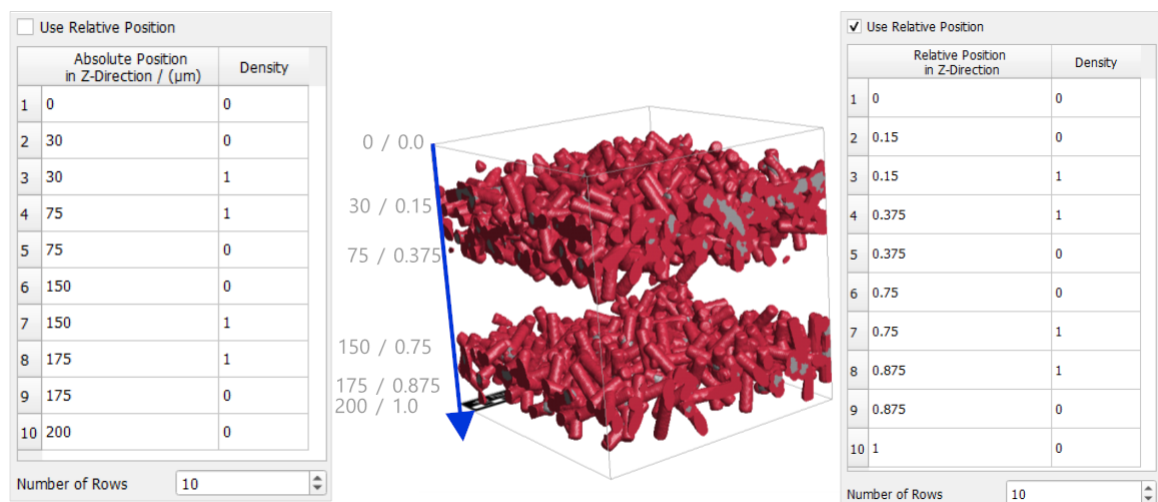
With **Use Relative Position** unchecked, the left column values of the density distribution table correspond to absolute locations in the structure. The position values are coordinates to be entered in the given unit. Thus, to define the positions consider [origin](#)¹³ and [periodicity](#)¹⁴. If **Origin Z** is set to 0, the value 0 lays in the origin. If **Origin Z** is set to 50, position 0 lays 50 μm outside of the domain or, if **Periodic Z** is checked additionally, 50 μm before the domain's end in Z-direction.

The right column assigns density values at these locations, where 0 means that fiber centers are absent at that location, and values larger than 0 means that fiber centers are present at the location.

In a structure of size $200 \times 200 \times 200 \mu\text{m}^3$ and origin set to (0,0,0), observe how, with the values in these tables, fibers are absent or appear at the given locations. The fiber density increases and decreases linearly between the given locations in the Z-direction. Therefore, in the following example, the positions where a sharp transition is desired are given twice: once with positive density and once with density of 0.

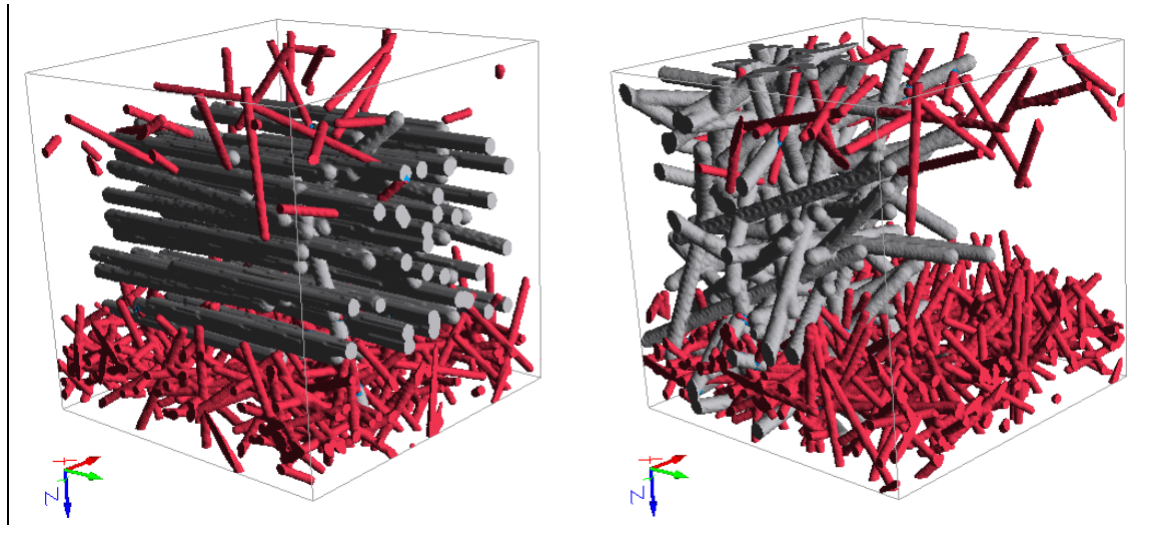


The same structures can be obtained when using or not using relative positions, as seen in the following example. Both structures are based on the same random seed.



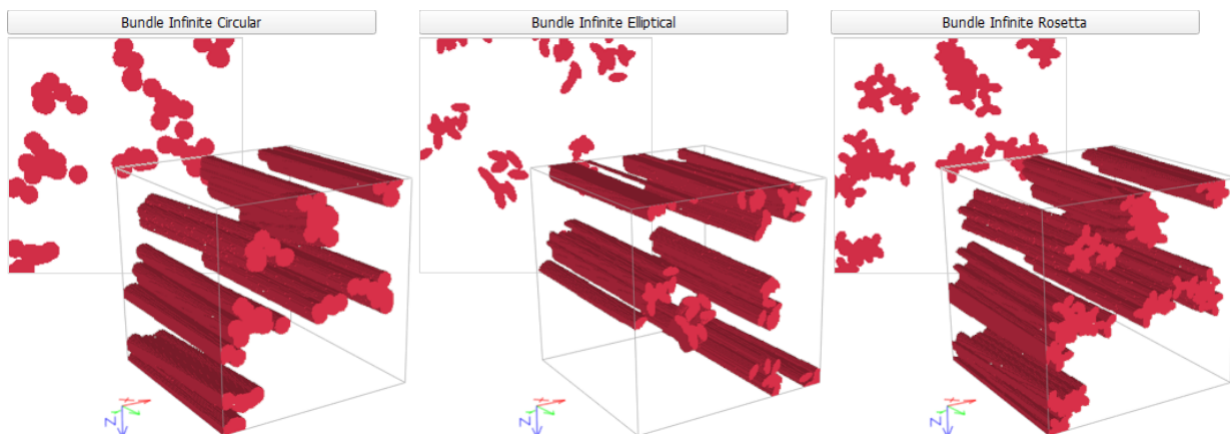
As before with orientation, the distribution of centers can be separately set for each fiber type so that differently distributed fiber types may coexist within the same

structure. In the following structures, observe that the gray short circular fibers are distributed **Uniformly in Box**, whereas the red short circular fibers follow a **Density Distribution**.

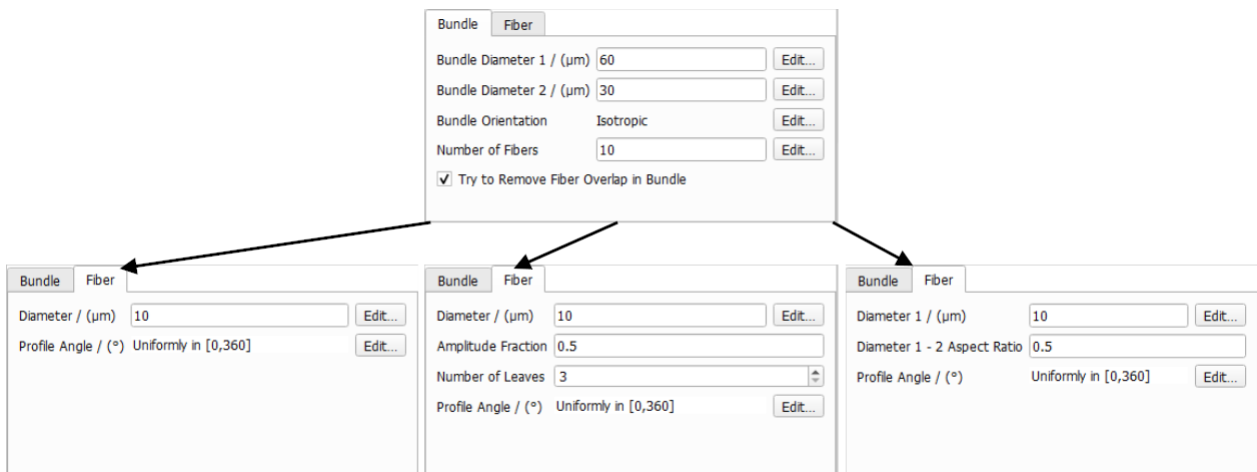


Bundle Tab

Circular, elliptical, or rosetta cross-sectioned fibers can be generated as bundles, meaning fibers are clumped together forming bundles.



The compaction of the bundles is given by the [bundle diameters](#)^[77], the bundle [profile angle](#)^[80] (in the **Fiber** tab) and the [number of fibers](#)^[78] in it. Fibers in the bundle are defined by their specific parameters, explained [here](#)^[48].



For short bundles, additionally, the parameter [Center](#)^[71] is available under the **Bundle** tab and the parameter [Length](#)^[51] under the **Fiber** tab.

Bundle		Fiber	
Bundle Diameter 1 / (μm)	60	Edit...	
Bundle Diameter 2 / (μm)	30	Edit...	
Bundle Orientation	Isotropic	Edit...	
Number of Fibers	10	Edit...	
Center / (μm)	Uniformly Distributed	Edit...	
☒ Try to Remove Fiber Overlap in Bundle			

✓ Bundle Diameter

The bundle cross section can be defined in an ellipsoidal shape given by **Diameter 1** and **Diameter 2**. The diameters can be set to a **Constant** value or follow a [distribution](#)^[101] (**Uniformly in interval**, **Gaussian**, **Probability Distribution**, or **Log-Normal**).

Bundle Diameter 1 / (μm)	60	Edit...
Bundle Diameter 2 / (μm)	30	Edit...

Bundle Diameter 1 / (μm)

Constant

Value / (μm)

60

Uniformly in interval

Gaussian

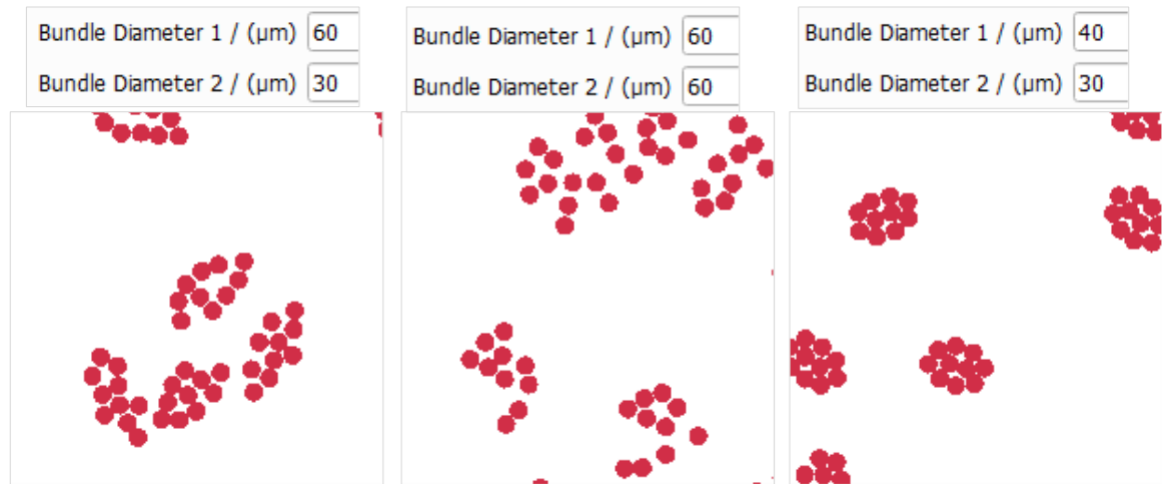
Probability Distribution

Log-Normal

OK

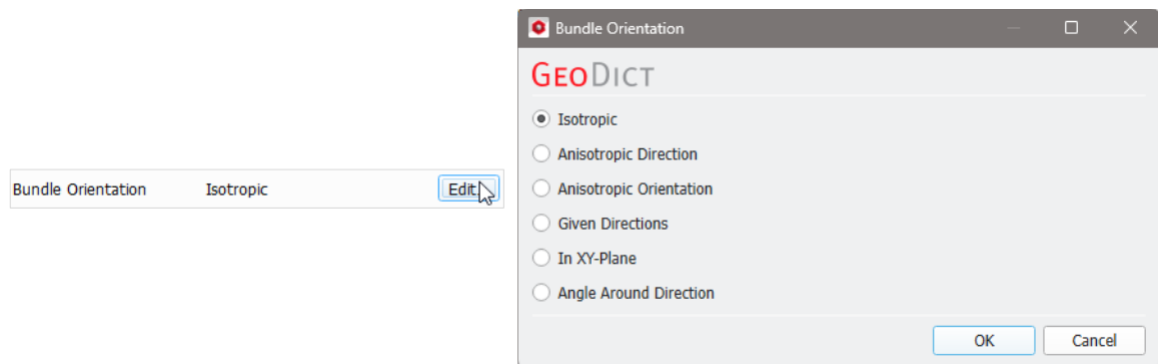
Cancel

In the example observe how the fibers are distributed in the varying bundle cross-section sizes.

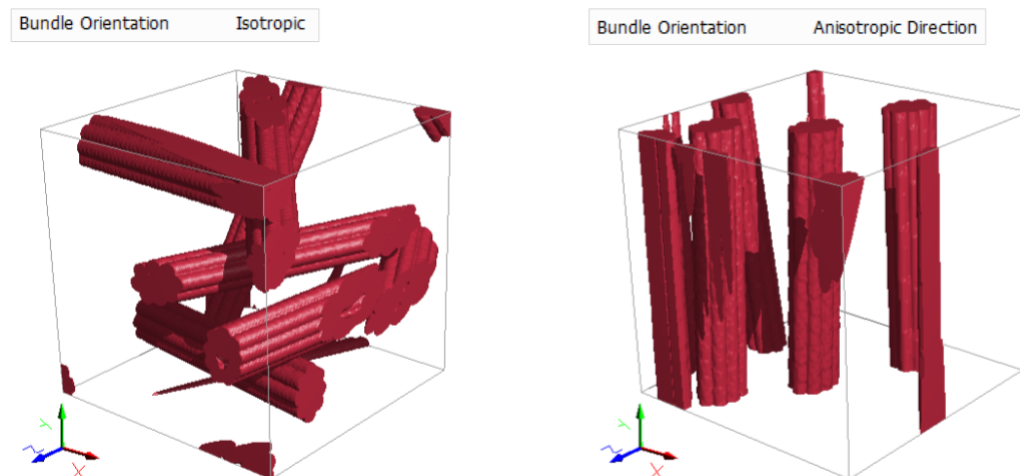


✓ Bundle Orientation

The bundle can follow the different orientations explained [here](#) ⁵⁵.

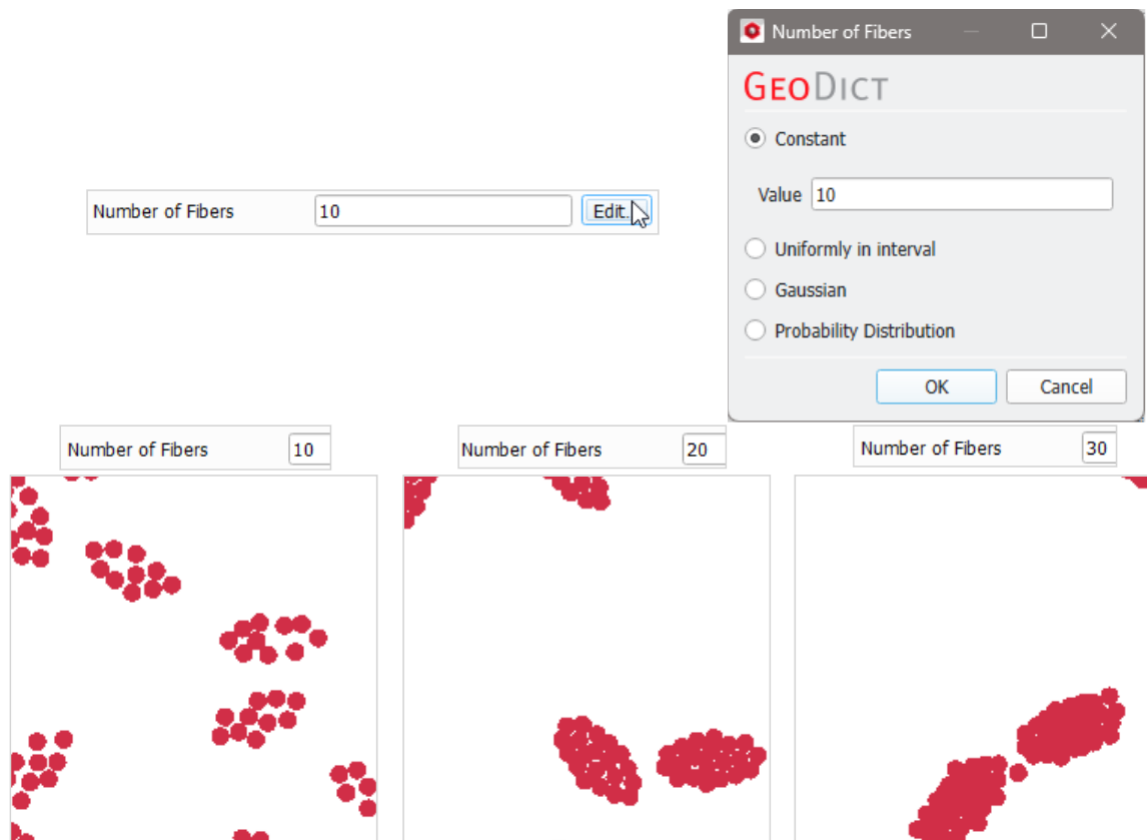


Observe the fiber orientation in the following example:



✓ Number of Fibers

Define the **Number of Fibers** within a single bundle. The number can be set to a **Constant** value or follow a [distribution](#)¹⁰¹.



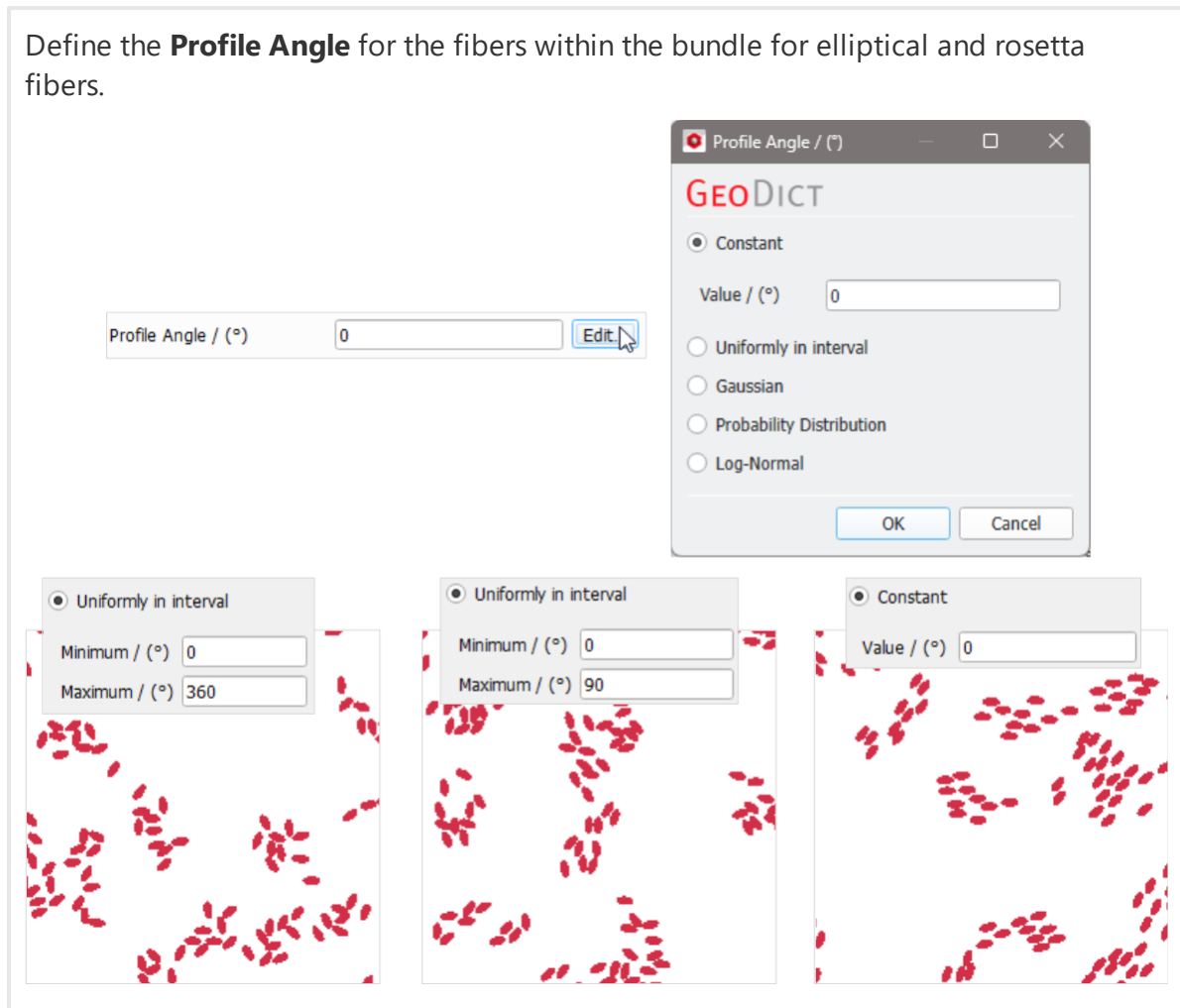
✓ Try to Remove Fiber Overlap in Bundle

Checking **Try to Remove Fiber Overlap in Bundle** removes the overlap as good as possible within the bundle boundaries given by **Diameter 1** and **2** but increases the runtime of the fiber generation.



✓ Profile Angle

Define the **Profile Angle** for the fibers within the bundle for elliptical and rosetta fibers.



Curl Tab

If the fibers added to the structure are **curved fibers**, a **Curl** tab appears in the right panel. Curved fibers can bend in up to four modes, selectable in the **Curl Mode** pull-down menu: **Spiral**, **Sine**, **Random**, and **Curvature**. The curl parameters are different for these modes. The default mode is **Random**.

Fiber	Curl
Curl Mode	Sine
Sine Length 1 / (μm)	100
Sine Length 2 / (μm)	200
Sine Amplitude 1 / (μm)	10
Sine Amplitude 2 / (μm)	10

Fiber	Curl
Curl Mode	Random
Segment Length / (μm)	30
☐ Isotropic	X-Direction Y-Direction Z-Direction
Local Straightness [0:1]	0 0 0
Global Straightness [0:1]	0 0 0
Randomness	0.1 0.1 0.01
☒ Bend Fibers Back to Media-Layer	

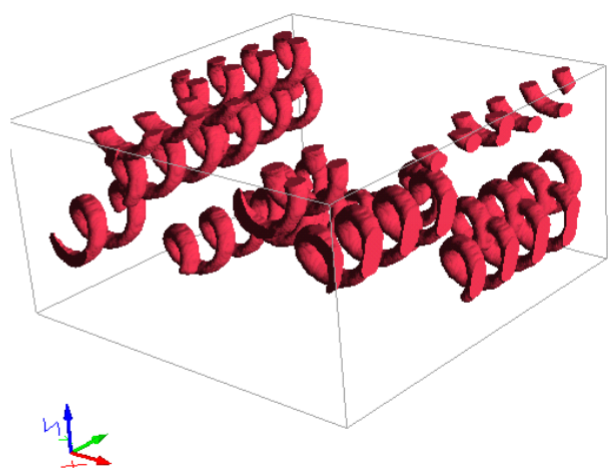
Fiber	Curl
Curl Mode	Curvature
Curvature Radius / (μm)	100
Winding / ($1/\mu\text{m}$)	Gaussian
Correlation Length / (μm)	100
Epsilon / (μm)	0.1
Randomness	0.1 0.1 0.01
☒ Bend Fibers Back to Media-Layer	

Spiral

Spiral curved fibers form a three-dimensional curve that winds around an axis. The spirals are defined by the **Spiral Diameter** and the **Spiral Shift**. The spiral shift is the distance between the same relative positions in two consecutive loops of the spiral. The segment lengths for spiral fibers are optimized to obtain smoothly curved fibers for the chosen parameters.

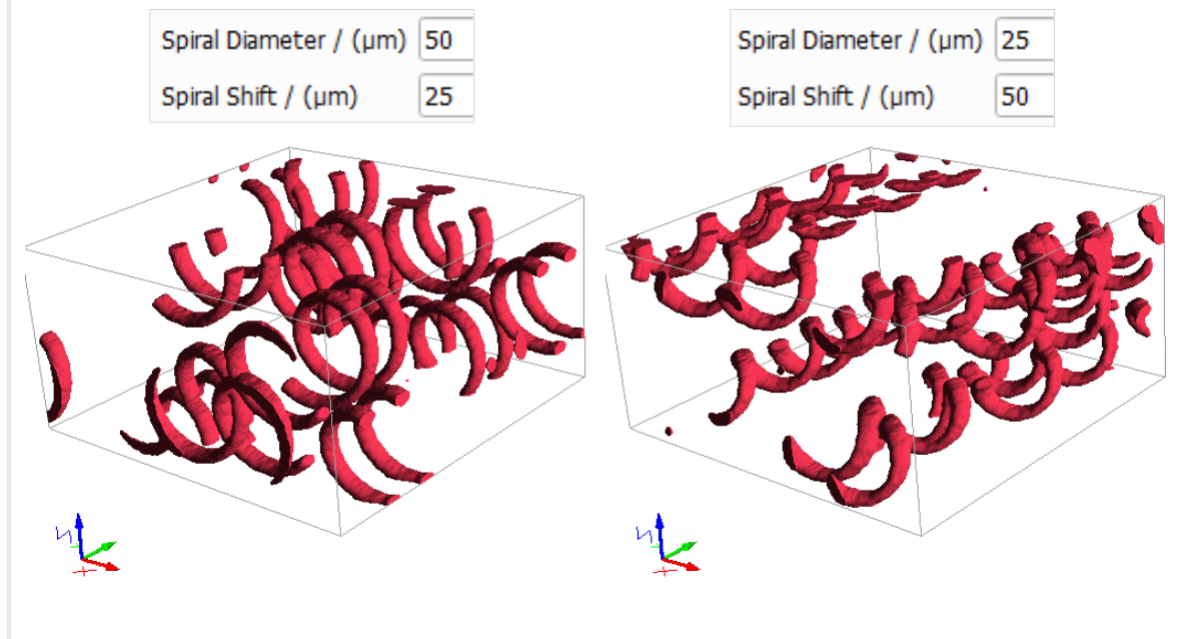
The two parameters can be set to have a **Constant** value, or to follow a diameter [distribution](#)^[101] (**Uniformly in interval, Gaussian, Probability Distribution or Log-Normal**).

Fiber	Curl
Curl Mode	Spiral
Spiral Diameter / (μm)	25
Spiral Shift / (μm)	25



✓ Example

Observe the effect that changing these two parameters has on the form of the generated spiral curved fibers.



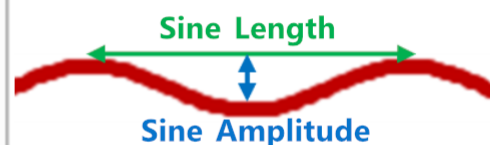
Sine

Sine (sinusoidal) curved fibers follow a sinusoid curve defined by the equation

$$y = \sin(x)$$

(10) Sine
Fibers

Fiber		Curl	
Curl Mode		Sine	
Sine Length 1 / (μm)	100	Edit...	
Sine Length 2 / (μm)	200	Edit...	
Sine Amplitude 1 / (μm)	10	Edit...	
Sine Amplitude 2 / (μm)	10	Edit...	



For sine curved fibers, the parameters **Sine Length 1**, **Sine Length 2**, **Sine Amplitude 1**, and **Sine Amplitude 2** are determined by the fiber orientation.

The segment lengths for sine fibers are optimized to obtain smoothly curved fibers for the chosen parameters.

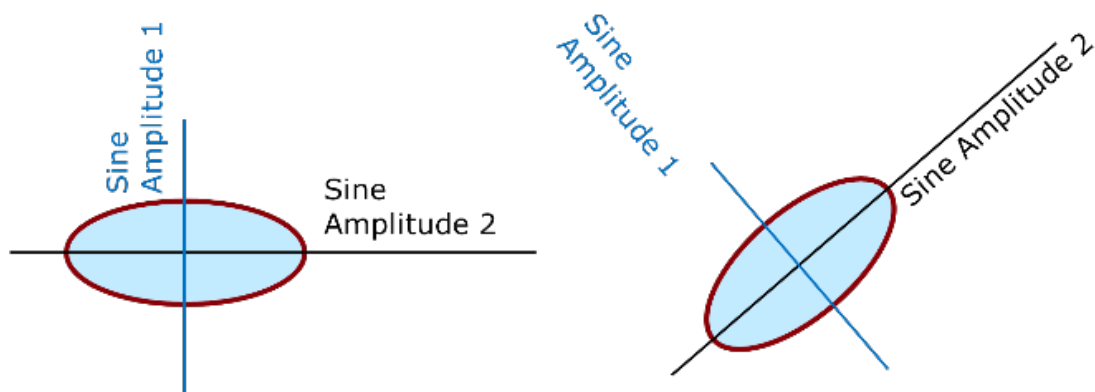
✓ Sine Length

The **Sine Length** controls the length of one periodic sine section. A sine curvature can only be applied if the amplitude is set to positive values. Then, the fibers oscillate in direction of the main axis.

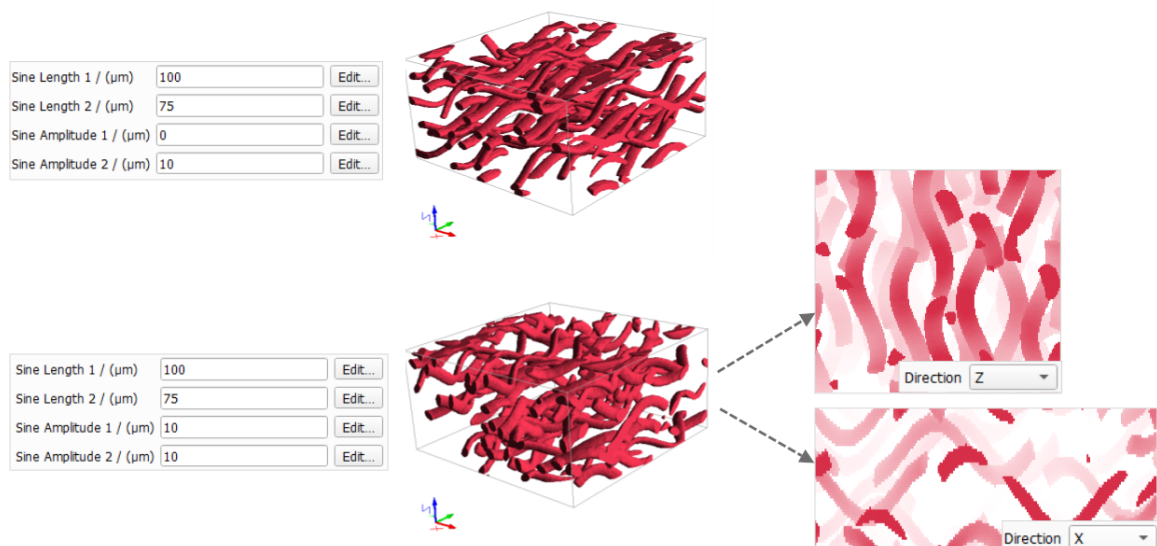
The sine length can be set to have a **Constant** value, or to follow a diameter [distribution](#)^[101] (**Uniformly in interval**, **Gaussian**, or **Probability Distribution**).

✓ Sine Amplitude

Sine Amplitude 1 and **Sine Amplitude 2** describe the oscillation amplitude in the direction of the main axis. This is shown below for an elliptical fiber.



Sine fibers have only one sinusoidal component when the **Sine Amplitude 1** (or **Sine Amplitude 2**) is 0, while the other sine amplitude is set to a positive value. Sine fibers with a combination of components are obtained when both sine amplitudes are set to positive values. For example, with the following values:



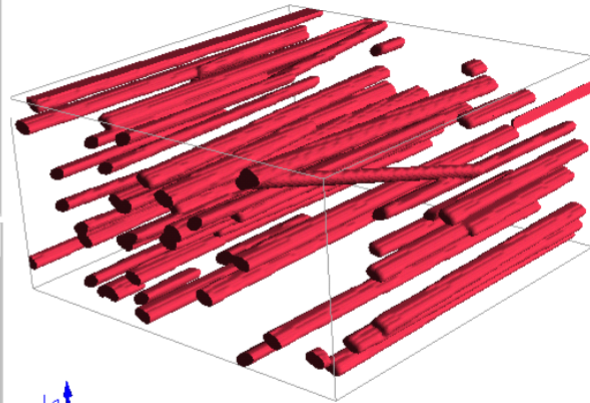
The sine amplitude can be set to have a **Constant** value, or to follow a diameter [distribution](#)^[101] (**Uniformly in interval**, **Gaussian**, or **Probability Distribution**).

✓ Combination with Torsion

Initially, keep the default values of **Sine Length 1** and **Sine Length 2**, whereas the **Sine Amplitude 1** and **Sine Amplitude 2** are set to 0, as is the **Torsion Start Angle**. These parameters produce straight fibers.

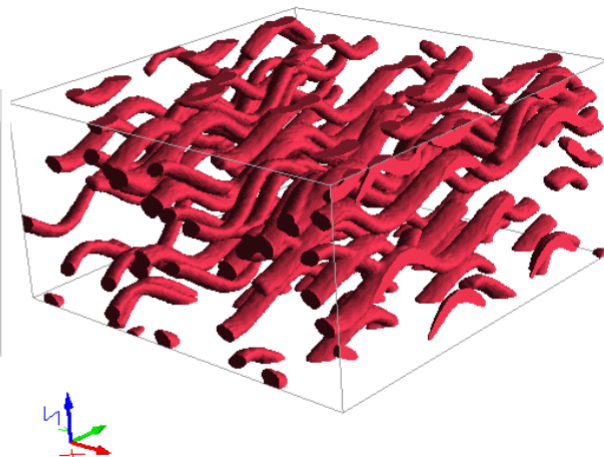
Fiber	Curl	Torsion
Torsion Start Angle / (°) 0 Edit...		
Max Torsion Change / (°) 0		

Fiber	Curl	Torsion
Curl Mode Sine		
Sine Length 1 / (μm)	100	Edit...
Sine Length 2 / (μm)	200	Edit...
Sine Amplitude 1 / (μm)	0	Edit...
Sine Amplitude 2 / (μm)	0	Edit...

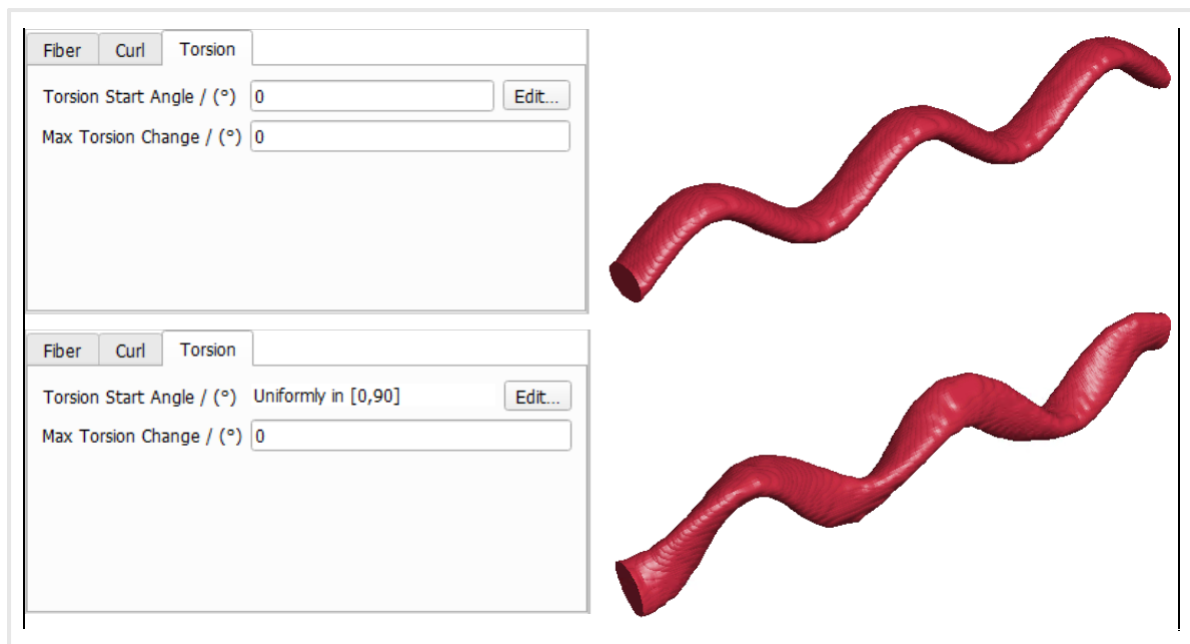


When the same fibers are created with a smaller **Sine Length 2** (75 μm) and a **Sine Amplitude 2** of 10 μm, the sine fibers appear curved.

Fiber	Curl	Torsion
Curl Mode Sine		
Sine Length 1 / (μm)	100	Edit...
Sine Length 2 / (μm)	75	Edit...
Sine Amplitude 1 / (μm)	0	Edit...
Sine Amplitude 2 / (μm)	10	Edit...



When these same curved sine fibers are created with a **Torsion Start Angle** that follows a uniform distribution in the interval 0 to 90°, the sine fibers appear curved and twisted.



Random

Curved **Random** fibers consist of straight fiber segments of a given **Segment Length**. Its value determines the length of the linear parts that build the fiber. This way small values lead to well resolved fibers with smooth curving. A large segment length leads to fibers with long straight segments.

Fiber	Curl	Torsion
Curl Mode Random		
Segment Length / (μm) 30		
☐ Isotropic	X-Direction	Y-Direction
Local Straightness [0:1]	0	0
Global Straightness [0:1]	0	0
Randomness	0.1	0.01
☒ Bend Fibers Back to Media-Layer		

✓ Algorithm

The first segment is placed in space according to the **Center** and **Orientation** values defined under the **Fiber** tab. The curved fiber follows a **main fiber direction** given by the [fiber orientation](#)⁵⁵. The first segment is the middle segment. The other segments are attached to both ends according to the Straightness and Randomness parameters.

The checking or un-checking of **Isotropic** controls the direction in which the parameters **Local Straightness**, **Global Straightness**, and **Randomness** are applied to the new segment. These parameter values (between 0 and 1) define the direction of

each newly attached segment and determine how strongly a fiber may change direction from one segment to the next.

Randomness corresponds to the standard deviation σ of the Gaussian distribution $G_\sigma(0)$ with mean value 0. The direction of the new segment d_{n+1} is determined by the following rule:

$$d_{n+1} = \beta d + (1 - \beta)d_n + (1 - \alpha)(d_n - d_{n-1}) + G_\sigma(0) \quad (11) \text{ Random Curved Fibers}$$

where

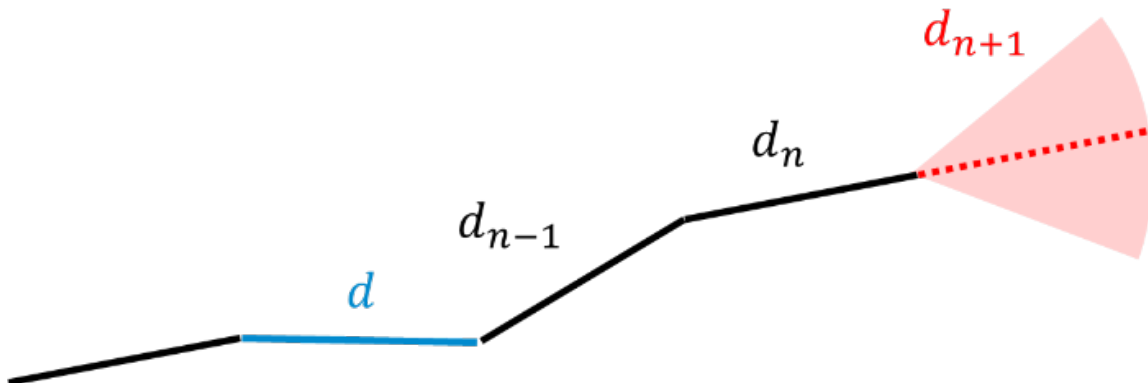
- d : main direction of the fiber (orientation applied on first segment),
- d_n : direction of the current segment,
- d_{n-1} : direction of the last segment,
- α : Local Straightness,
- β : Global Straightness.

For the shape of the fiber, there are four main cases considering the parameters for local and global straightness (α and β). The impact of these parameters on each new segment is explained below.

The blue segment is the center segment which is the first segment placed according to the parameters for orientation (d) and center defined in the Fiber tab. The red dotted line would be the new segment for $G_\sigma(0) = 0$, as the Randomness value $G_\sigma(0)$ controls the width of the red area.

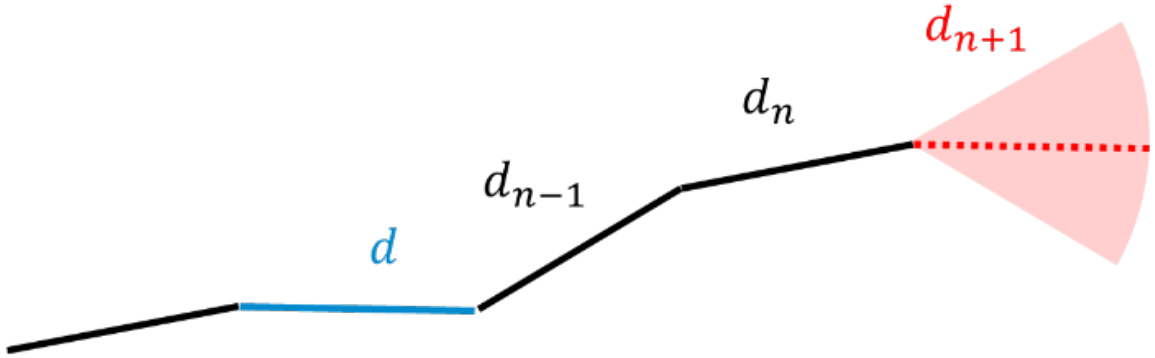
1. The previous direction is kept, i.e., the fiber tends to be locally straight.

$$\alpha = 1, \beta = 0 \Rightarrow d_{n+1} = d_n + G_\sigma(0) \quad (12)$$



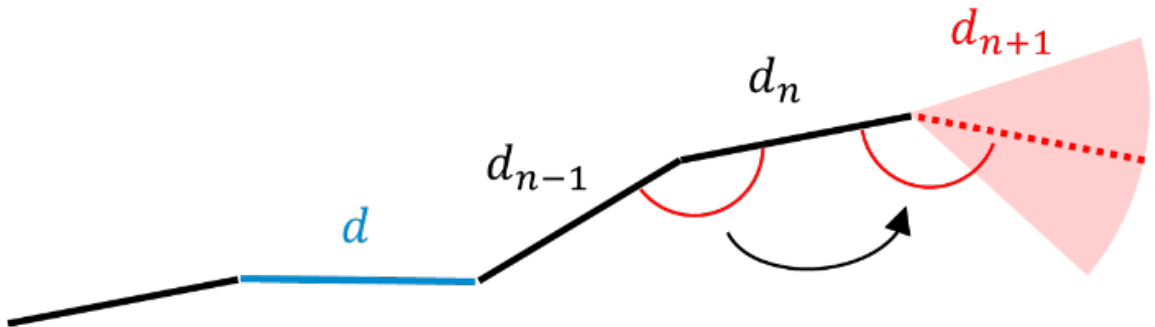
2. The main fiber direction is kept, i.e., the fiber tends to be globally straight.

$$\alpha = 1, \beta = 1 \Rightarrow d_{n+1} = d + G_{\sigma}(0) \quad (13)$$



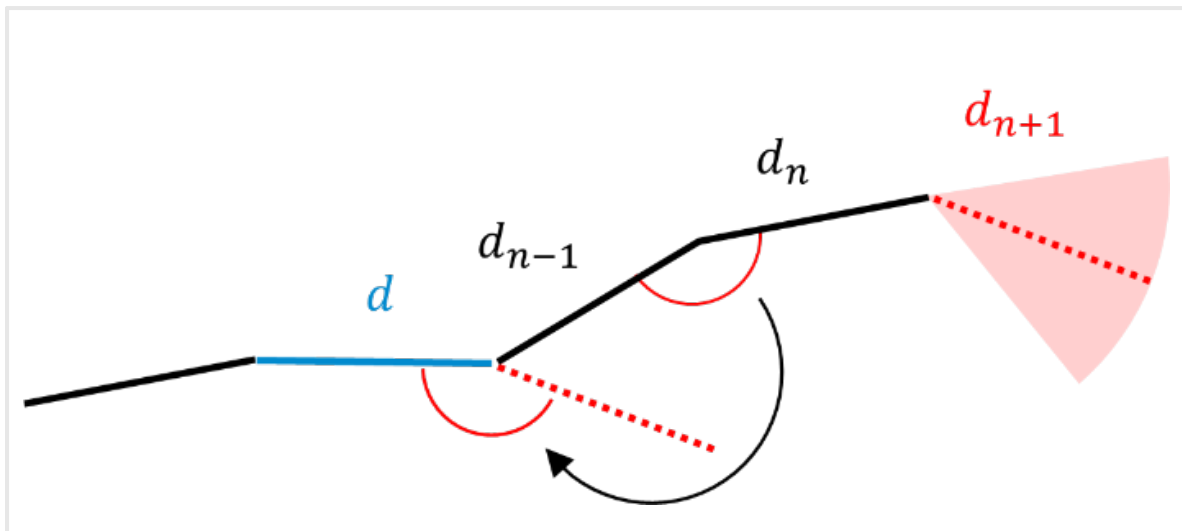
3. The previous curvature is kept.

$$\alpha = 0, \beta = 0 \Rightarrow (d_{n+1} - d_n) = (d_n - d_{n-1}) + G_{\sigma}(0) \quad (14)$$



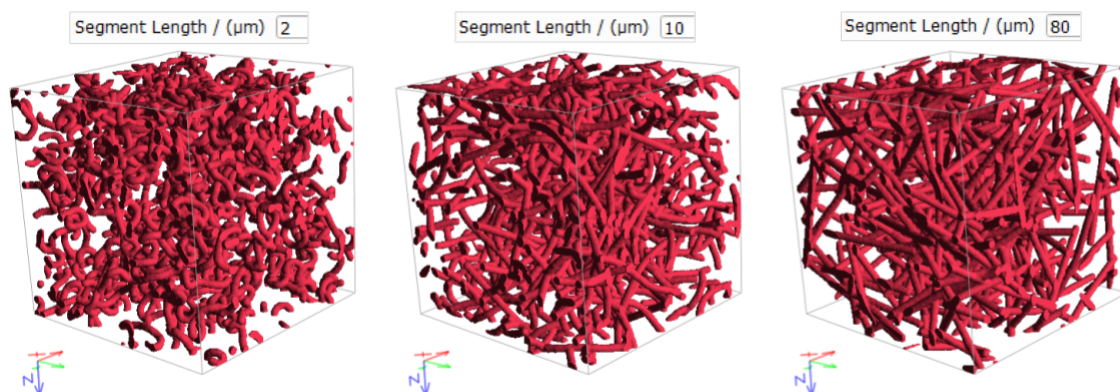
4. The angle between the current and the last segment, defined by the previous curvature, is considered for the attachment of the new segment. This angle is applied between the direction of the new segment and the main direction, i.e., the fiber always bends with respect to the main direction. Thus, it tends to be globally straight, while the local curvature is taken into account.

$$\alpha = 0, \beta = 1 \Rightarrow (d_{n+1} - d) = (d_n - d_{n-1}) + G_{\sigma}(0) \quad (15)$$



✓ Segment Length

In the following examples, all parameters are left unchanged while curved circular fibers with a length of 100 μm are given varying **Segment Length**, as indicated.

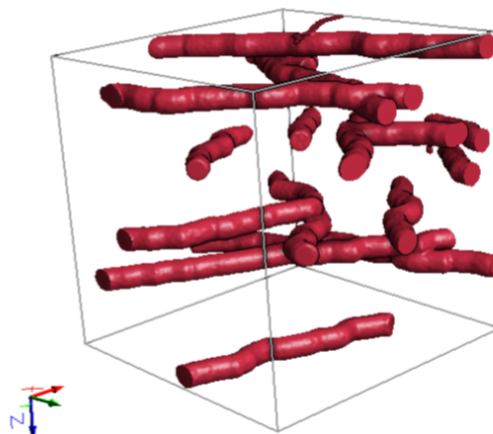


✓ Isotropic or Anisotropic

The **Curl Parameters** are not **Isotropic** by default. The parameters for each direction (X, Y, and Z) are entered separately. Alternatively, isotropic curl parameters can be defined by checking **Isotropic**. Then, all directions are treated with the same parameter values.

Here, the same curl parameter values are entered for the X- and Y-directions, whereas no deformation is allowed in Z-direction, where **Local Straightness** and **Global Straightness** have been set to 1 and **Randomness** to 0.

Fiber	Curl	Torsion
Curl Mode Random		
Segment Length / (μm) 5		
☐ Isotropic	X-Direction	Y-Direction Z-Direction
Local Straightness [0:1]	0.8	0.8 1
Global Straightness [0:1]	0.6	0.6 1
Randomness	0.3	0.3 0
☒ Bend Fibers Back to Media-Layer		

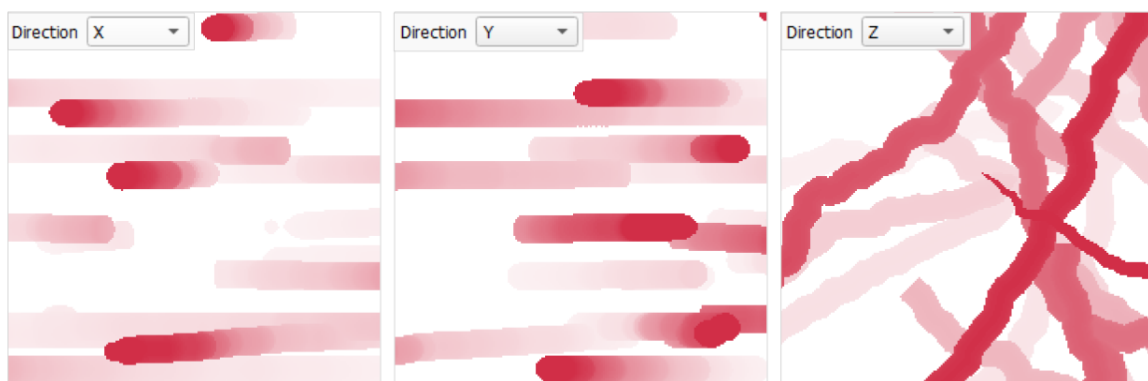


In this example, observe how the deformation of curved circular fibers occurs only in the XY-plane of an anisotropic-oriented structure (**Anisotropy 1** =100 and **Anisotropy 2** =1) when entering the anisotropic curl parameters shown above.

With values of Anisotropy 1 and Anisotropy 2 being 100 and 1, the generated fibers are oriented perpendicular to the Z-axis.

Views from the X- and the Y-direction show that there is no deformation of fibers in Z-direction. This is a consequence of setting the **Randomness** in Z-direction to zero.

The view from the Z-direction shows that the fibers are curved in the X and Y directions.

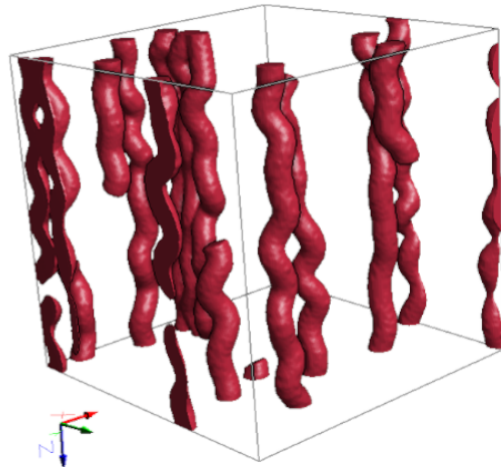


✓ Local and Global Straightness

The **Straightness** values can be set between 0 and 1. The higher the value for **Global Straightness**, the more the fiber tends towards the main direction.

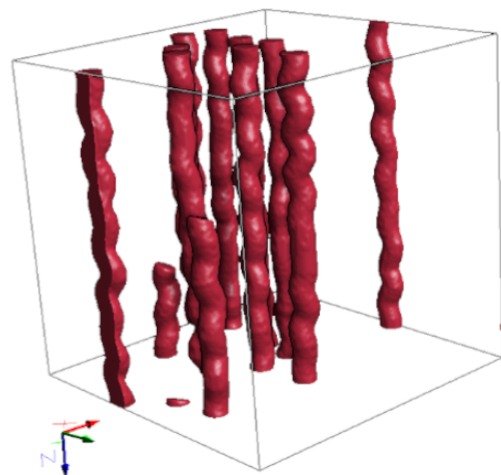
With a non-zero **Global Straightness** value, the fibers tend to return to the initial prescribed **Orientation**.

Fiber	Curl	Torsion
Curl Mode	Random	
Segment Length / (μm)	5	
☒ Isotropic	All-Directions	
Local Straightness [0:1]	0	
Global Straightness [0:1]	0.5	
Randomness	0.1	
☒ Bend Fibers Back to Media-Layer		



With a **Global Straightness** value of 1, the fibers globally keep the **Orientation**, while a **Local Straightness** of 0 leads to fibers locally keeping curvature.

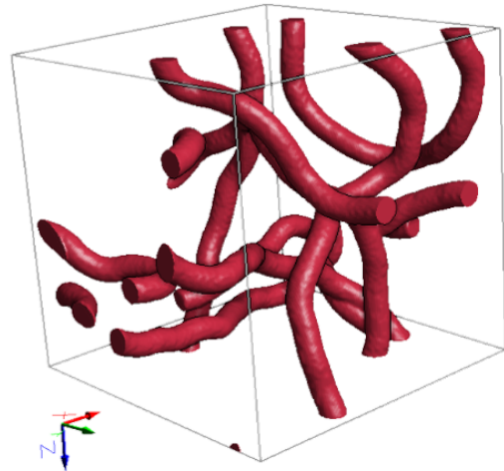
Fiber	Curl	Torsion
Curl Mode	Random	
Segment Length / (μm)	5	
☒ Isotropic	All-Directions	
Local Straightness [0:1]	0	
Global Straightness [0:1]	1	
Randomness	0.1	
☒ Bend Fibers Back to Media-Layer		



The higher the value for **Local Straightness** the smoother the curves, as the local directions tend to be kept. If the **Global Straightness** value is 0, the fibers are not restrained to stay in the predefined Orientation.

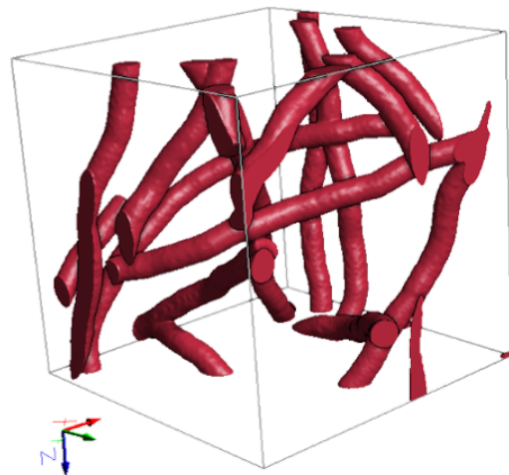
A non-zero value of **Local Straightness** results in a reduction of the fibers' curvature (compared to the structure with Local Straightness of 0 above).

Fiber	Curl	Torsion
Curl Mode	Random	
Segment Length / (μm)	5	
☒ Isotropic	All-Directions	
Local Straightness [0:1]	0.5	
Global Straightness [0:1]	0	
Randomness	0.1	
☒ Bend Fibers Back to Media-Layer		



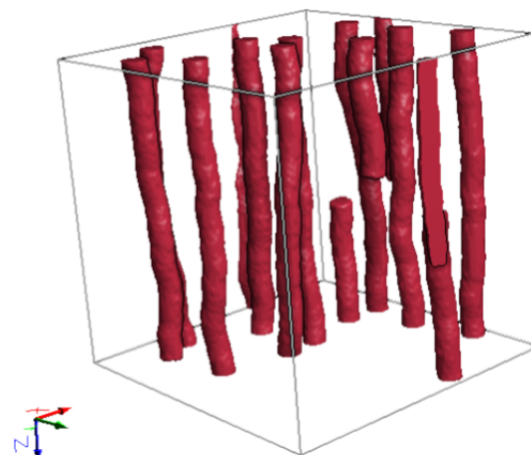
A **Local Straightness** value of 1 leads to low curvature and straighter fibers.

Fiber	Curl	Torsion
Curl Mode	Random	
Segment Length / (μm)	5	
☒ Isotropic	All-Directions	
Local Straightness [0:1]	1	
Global Straightness [0:1]	0	
Randomness	0.1	
☒ Bend Fibers Back to Media-Layer		



A higher **Global Straightness** value, with a **Local Straightness** value of 1, results in almost straight fibers keeping the main direction.

Fiber	Curl	Torsion
Curl Mode	Random	
Segment Length / (μm)	5	
☒ Isotropic	All-Directions	
Local Straightness [0:1]	1	
Global Straightness [0:1]	0.5	
Randomness	0.1	
☒ Bend Fibers Back to Media-Layer		

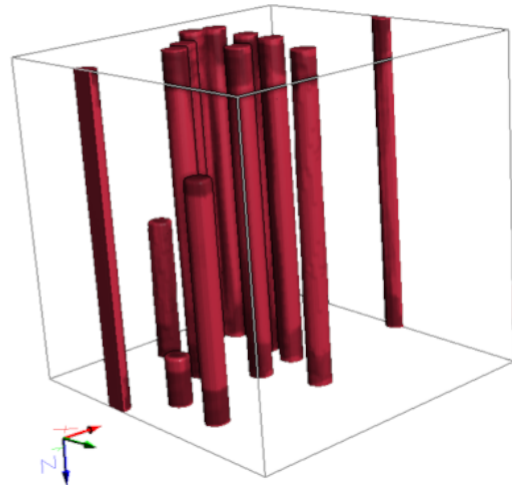


✓ Randomness

Observe the effect of varying **Local Straightness**, **Global Straightness**, and **Randomness** on a structure made of highly anisotropic (oriented in the Z-axis, **Anisotropy 1** = 0.001, **Anisotropy 2** = 1) curved circular fibers. All other parameters remain unchanged.

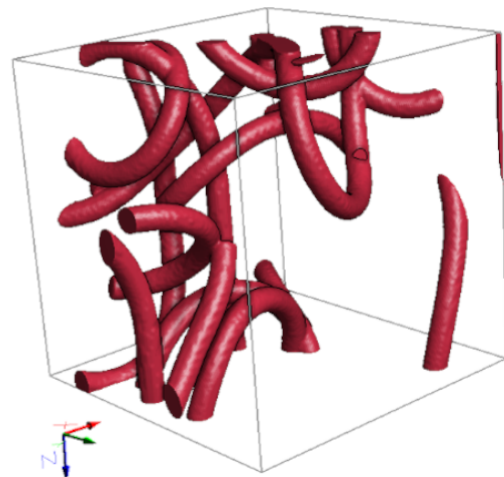
With **Randomness** set to zero, all segments have the same direction, resulting in straight fibers.

Fiber	Curl	Torsion
Curl Mode	Random	
Segment Length / (μm)	5	
☒ Isotropic	All-Directions	
Local Straightness [0:1]	0	
Global Straightness [0:1]	0	
Randomness	0	
☒ Bend Fibers Back to Media-Layer		

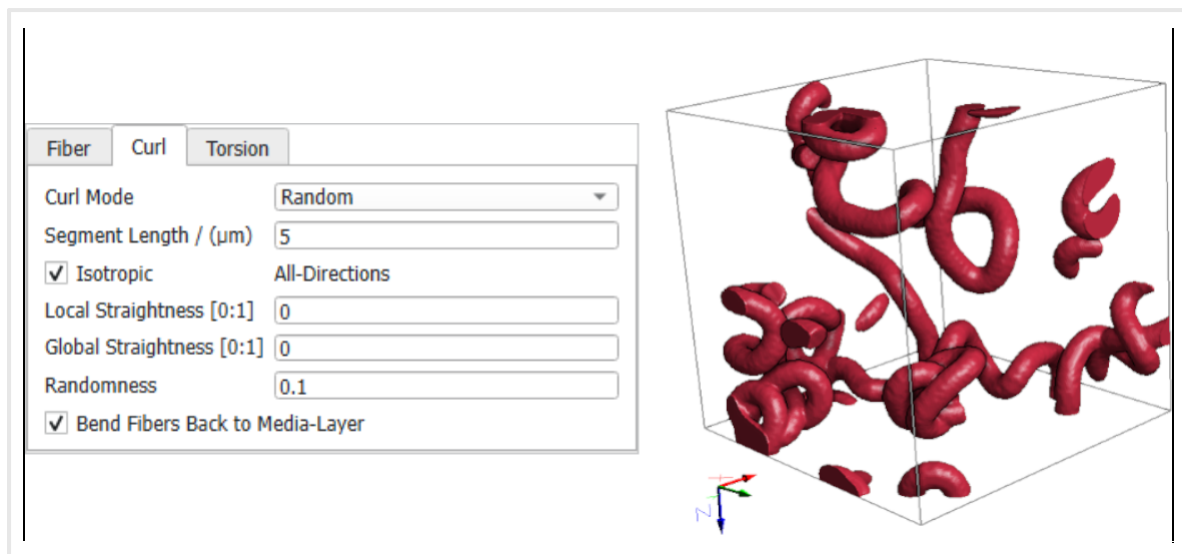


With a slightly higher **Randomness** value (0.01), curvature is introduced. With **Global Straightness** and **Local Straightness** set to 0, the predefined orientation is only applied to the initial segment and the curvature differs not much between adjacent segments, leading to spiral-like curves.

Fiber	Curl	Torsion
Curl Mode	Random	
Segment Length / (μm)	5	
☒ Isotropic	All-Directions	
Local Straightness [0:1]	0	
Global Straightness [0:1]	0	
Randomness	0.01	
☒ Bend Fibers Back to Media-Layer		



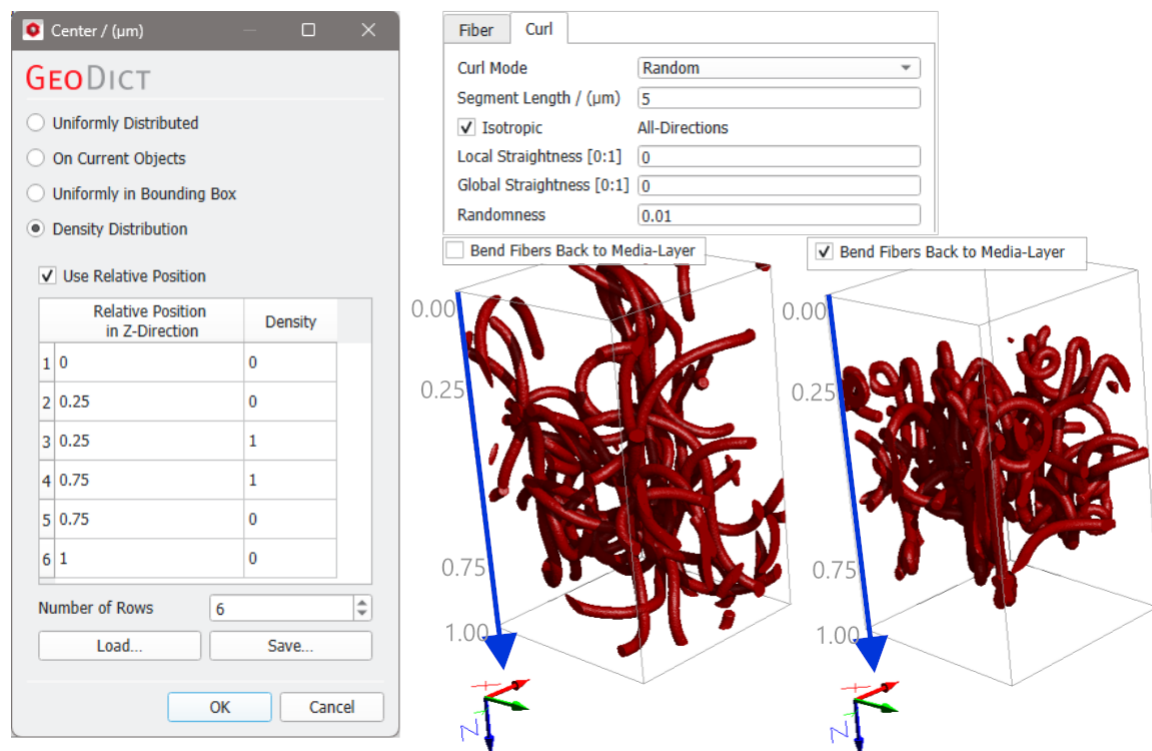
The fiber curvature increases with the **Randomness** value.



✓ Bend Fibers Back to Media-Layer

Since GeoDict 2026 fibers can be bent back to a defined media-layer if the structure is created with inlet and outlet. Define inlet and outlet by setting a [density distribution](#) ⁹³ for the fiber centers.

In the example below a density distribution is defined. The fiber centers are only located between 0.25 and 0.75 relative position. While in the left fiber structure the density is higher in the center, still fiber parts are found in the inlet and outlet regions. When checking **Bend Fibers Back to Media-Layer** all fiber parts which left the region between 0.25 and 0.75 before are bent back, so that no fibers can be found outside of the defined media-layer.



Curvature

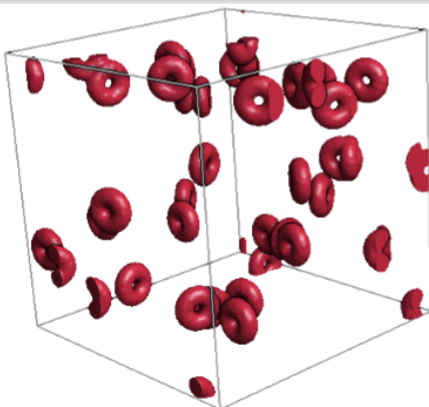
The **Curvature** is only selectable for curved circular, curved hollow, curved rosetta, and curved angular fibers.

Fiber	Curl
Curl Mode Curvature	
Curvature Radius / (μm)	100 Edit...
Winding / ($1/\mu\text{m}$)	Gaussian Edit...
Correlation Length / (μm)	100
Epsilon / (μm)	0.1
Randomness	0.1 0.1 0.01
☒ Bend Fibers Back to Media-Layer	

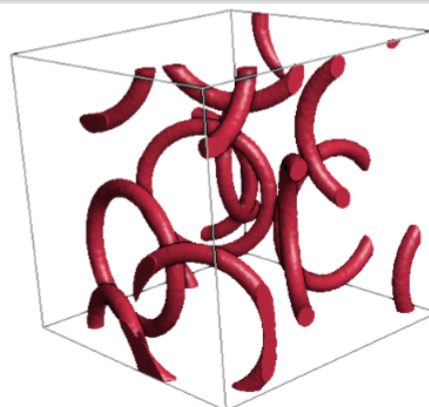
✓ Curvature Radius

The **Curvature Radius** controls the radius of the spiral followed by the fiber. Choosing the values of **Randomness** and **Winding** to be 0 leads to loops with the radius defined by **Curvature Radius**.

Fiber	Curl
Curl Mode Curvature	
Curvature Radius / (μm)	10 Edit...
Winding / ($1/\mu\text{m}$)	0 Edit...
Correlation Length / (μm)	100
Epsilon / (μm)	0.1
Randomness	0 0 0
☒ Bend Fibers Back to Media-Layer	



Fiber	Curl
Curl Mode Curvature	
Curvature Radius / (μm)	50 Edit...
Winding / ($1/\mu\text{m}$)	0 Edit...
Correlation Length / (μm)	100
Epsilon / (μm)	0.1
Randomness	0 0 0
☒ Bend Fibers Back to Media-Layer	

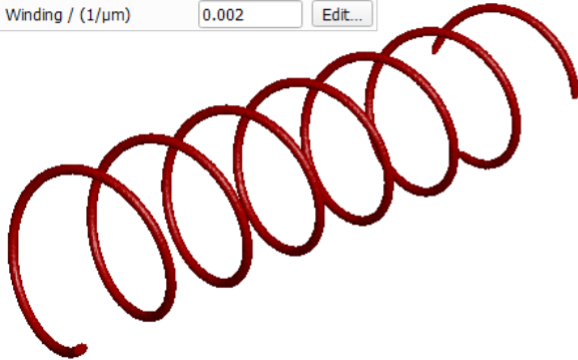


The curvature radius can be set to have a **Constant** value, or to follow a diameter [distribution](#)^[101] (**Uniformly in interval**, **Gaussian**, **Probability Distribution**, or **Log-Normal**).

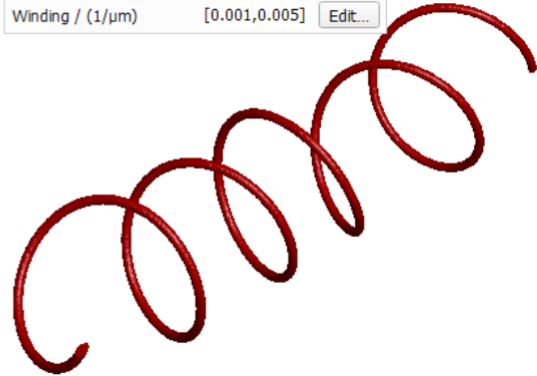
✓ Winding

Winding controls the distance between each spiral loop. Lower winding values lead to shorter distances between the loops.

Curvature Radius / (μm)	100	Edit...
Winding / ($1/\mu\text{m}$)	0.002	Edit...



Curvature Radius / (μm)	100	Edit...
Winding / ($1/\mu\text{m}$)	[0.001,0.005]	Edit...

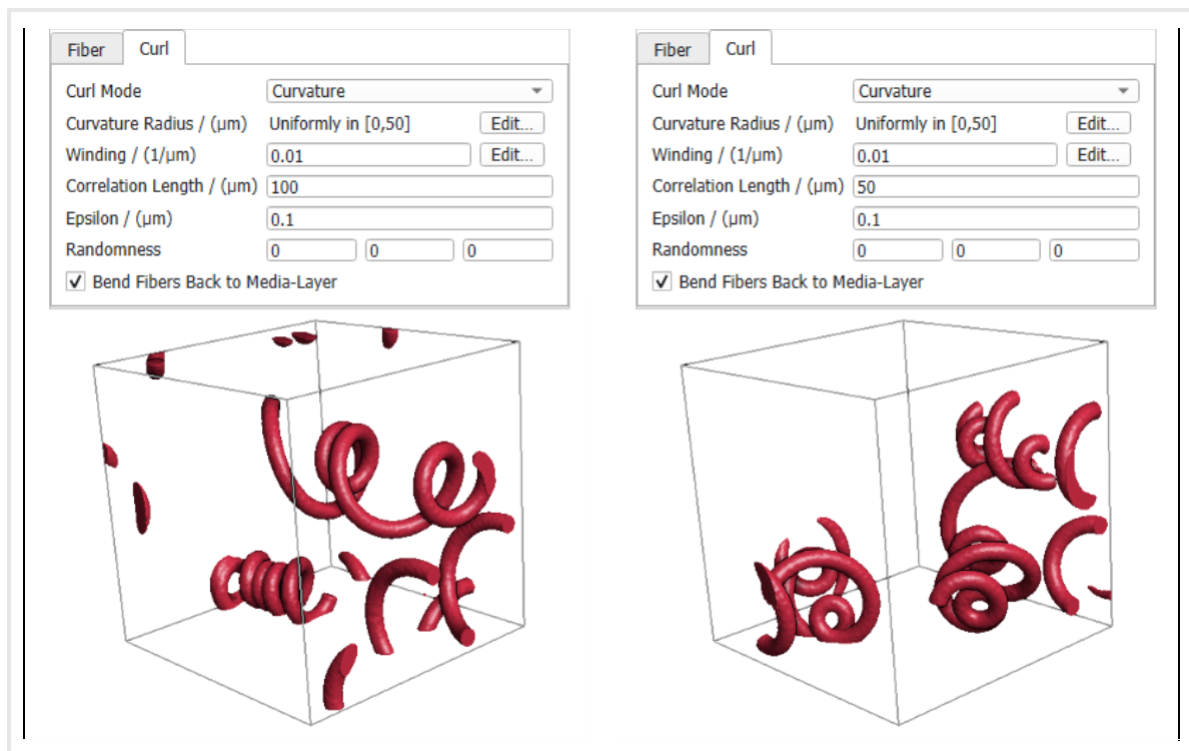


The curvature radius can be set to have a **Constant** value, or to follow a diameter [distribution](#) (Uniformly in interval, Gaussian, Probability Distribution, or Log-Normal).

✓ Correlation Length

The **Correlation Length** defines the length of the fiber section for which **Curvature Radius** and **Winding** are applied. For each of those sections, these parameters are applied anew. If none of the two parameters is set to a random distribution, the Correlation Length has no impact.

In the example below, the **Curvature Radius** is deviated uniformly between 0 and 50. The winding is set to the constant value 0.01. With a **Correlation Length** of 50 each spiral is different but with a **Correlation Length** of 100 the spirals with small radius are repeated. As the Winding is kept constant, the Correlation Length is only applied to the Curvature Radius.



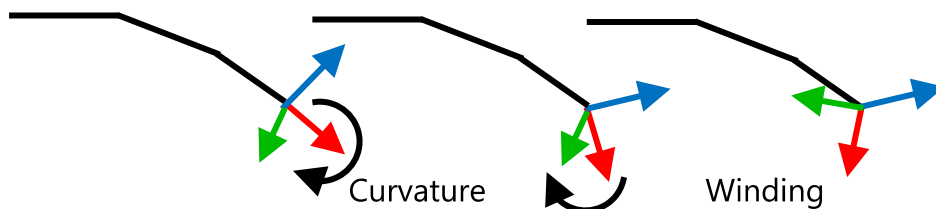
✓ Epsilon

For curvature the **Epsilon** determines the maximal difference of the discretized fiber from an analytical circle with the curvature of the fiber in the segment defined by the other parameters.

For each new segment a curvature is drawn corresponding to the curvature radius.

The correlation length determines when a new curvature is drawn. Within this correlation length the curvatures (and the winding) are interpolated to gain a smooth transition.

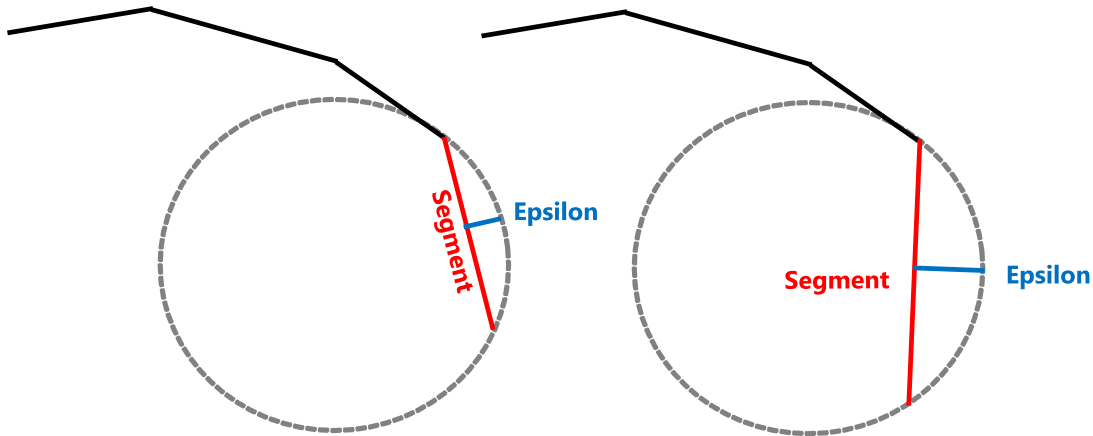
The curvature radius determines the direction of the new segment within the local 2D plane. The winding is the deviation from this plane for each segment. In the figure below, the three colored arrows are the local coordinate system for the current fiber segment. From the left image to the center image, the curvature rotates the local coordinate system around the green Y-axis. From the center image to the right image the winding is applied, rotating the local coordinate system around the blue Z-axis.



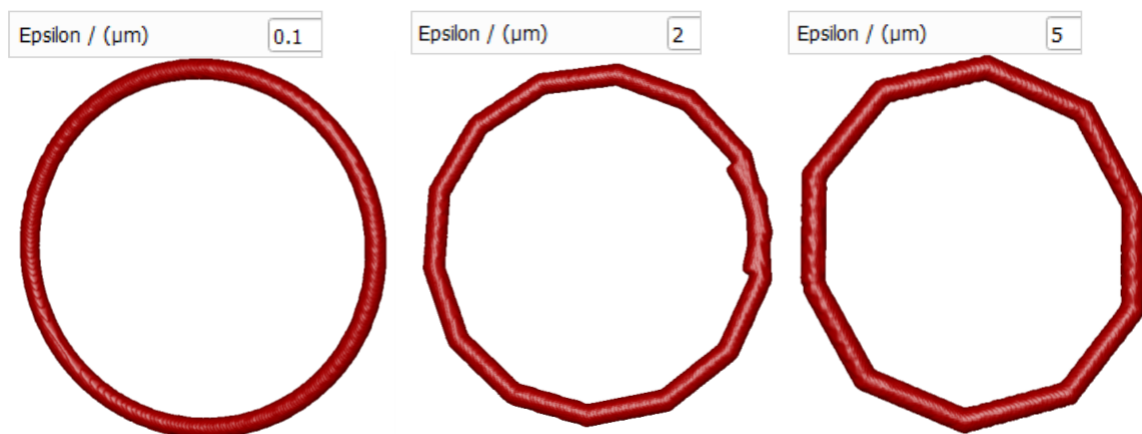
If winding and curvature differ due to parameter distributions or randomness, the segment length is also not constant. It varies corresponding to the parameters applied to it.

The curvature radius drawn for the new segment defines an analytical circle. The value entered for epsilon then is the distance between the circle boundary and the new segment.

In the figure below, a new segment is applied (red) for two different epsilon values.

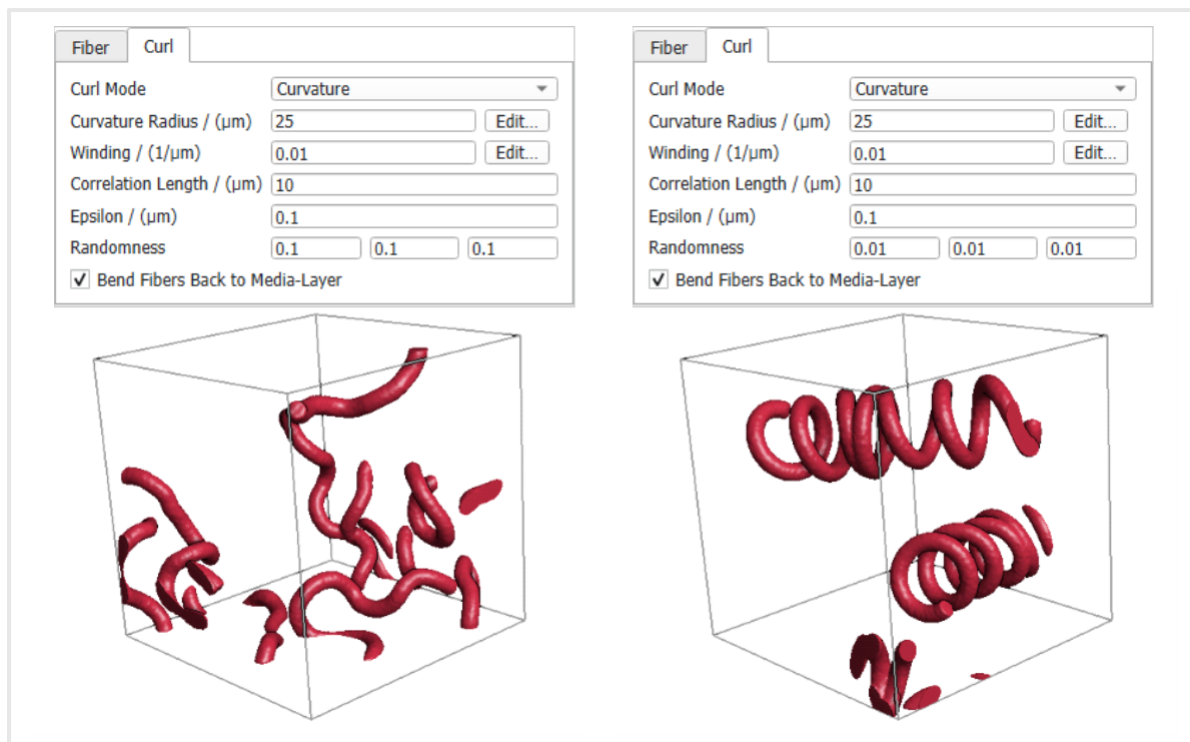


For constant parameters, 0 winding and 0 randomness all segments would lay within the same circle leading to an analytical circle.



✓ Randomness

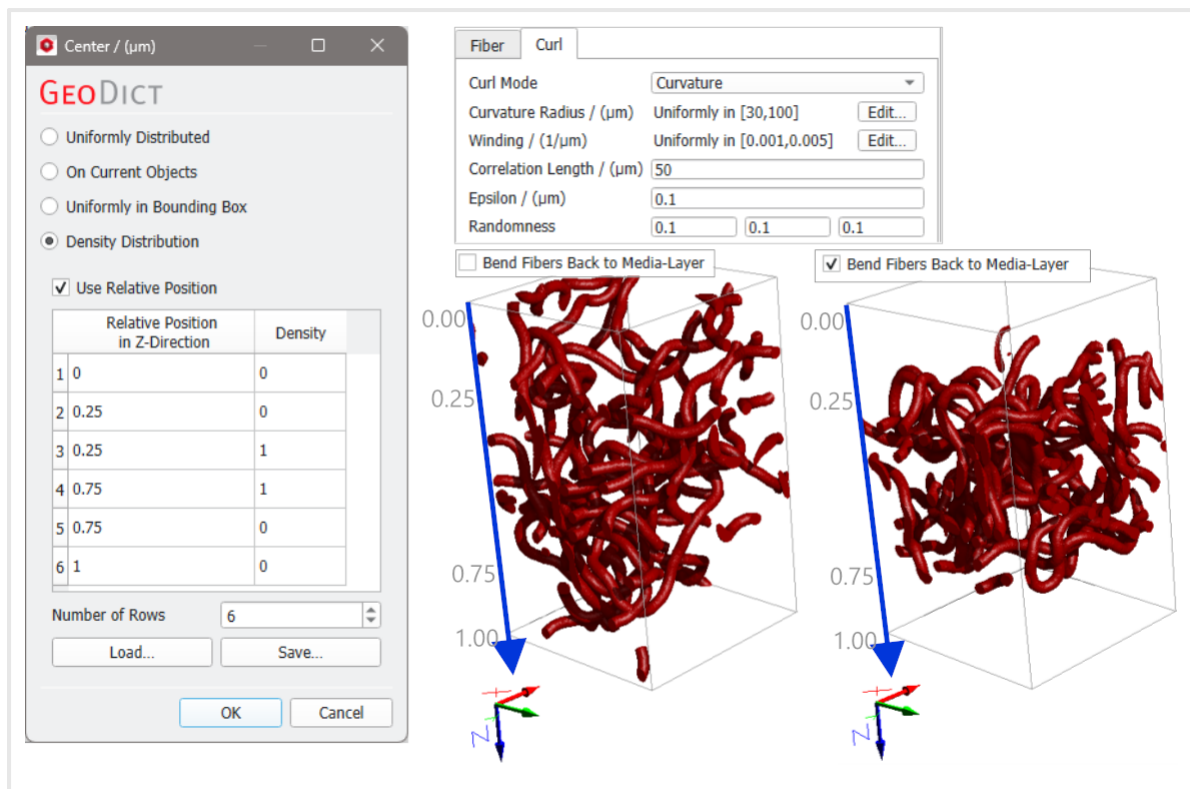
The higher the **Randomness** value, the stronger are the changes of curvature radius and winding in each section. Setting Randomness close to 0 creates loops and spirals.



✓ Bend Fibers Back to Media-Layer

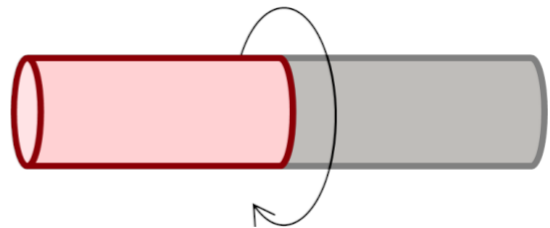
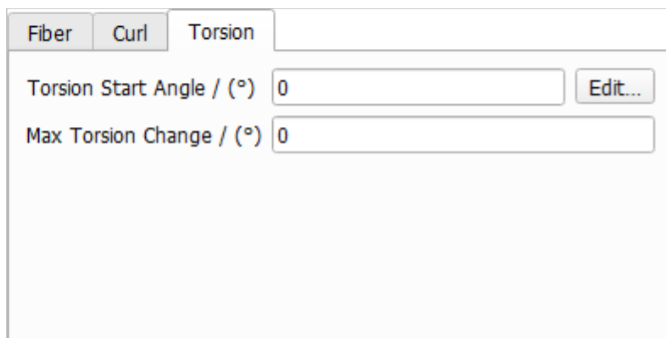
Since GeoDict 2026 fibers can be bent back to a defined media-layer if the structure is created with inlet and outlet. Define inlet and outlet by setting a [density distribution](#)⁹³ for the fiber centers.

In the example below a density distribution is defined. The fiber centers are only located between 0.25 and 0.75 relative position. While in the left fiber structure the density is higher in the center, still fiber parts are found in the inlet and outlet regions. When checking **Bend Fibers Back to Media-Layer** all fiber parts which left the region between 0.25 and 0.75 before are bent back, so that no fibers can be found outside of the defined media-layer.

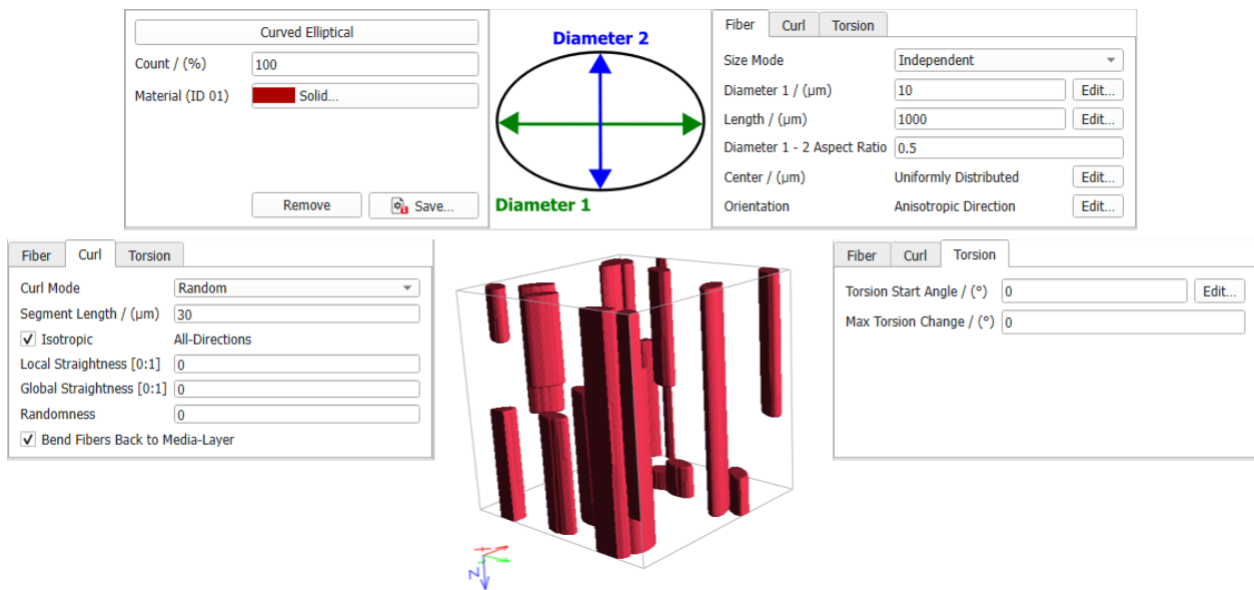


Torsion Tab

Curved Rectangular, Elliptical, and Cellulose fibers can be twisted to achieve torsion, when entering adequate values for **Torsion Start Angle** and **Max Torsion Change**.



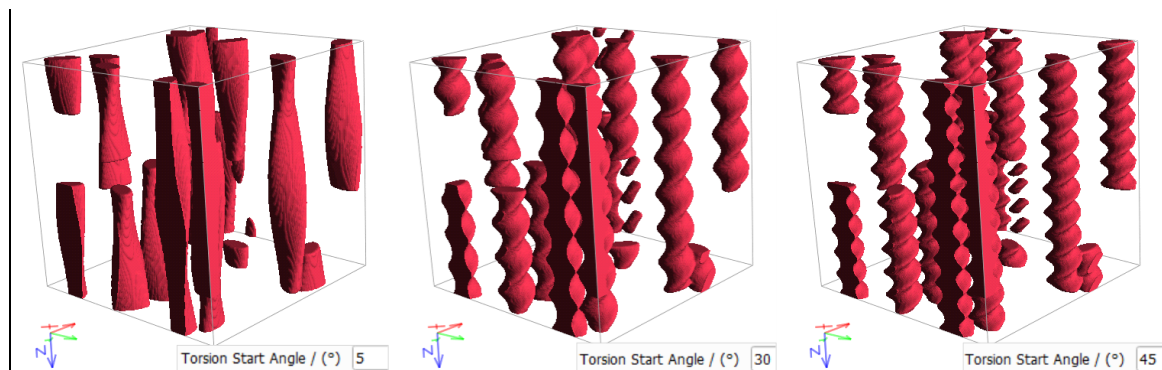
In the examples below, observe the effect of varying the torsion parameters on a highly anisotropic structure (**Anisotropy 1** = 0.001, **Anisotropy 2** = 1) made of curved ellipsoidal fibers. The curl parameters are **Isotropic**, and **Randomness** is 0, producing straight fibers parallel to the Z-axis. Both **Torsion Start Angle** and **Max Torsion Change** values are initially set to 0 in the **Torsion** panel to generate fibers without torsion.



✓ Torsion Start Angle

The **Torsion Start Angle** defines how strongly the fibers are twisted within one segment length.

With **Torsion Start Angle** values of 5, 30, and 45, and a **Max Torsion Change** value of 0, fibers with a constant spin of 5°, 30°, and 45° within each segment are generated.



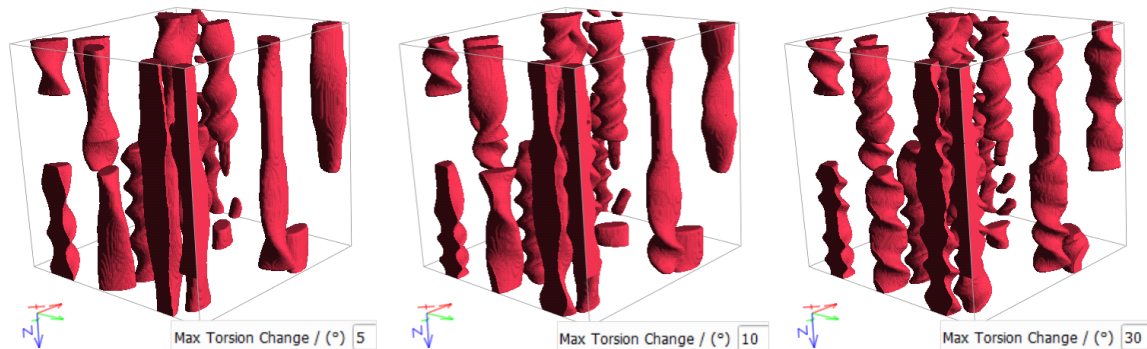
The torsion start angle can be set to have a **Constant** value, or to follow a [diameter distribution](#)₁₀₁ (**Uniformly in interval**, or **Probability Distribution**).

✓ Max Torsion Change

The **Max Torsion Change** determines the maximum allowed degree of change of the **Torsion Angle** from one segment to the next. The torsion change between different segments is uniformly distributed.

The use of **Max Torsion Change** adds a random component the torsion angle. The torsion change angle is drawn from a uniform distribution with the limits **[-Max Torsion Change, Max Torsion Change]** and is added to the current torsion angle.

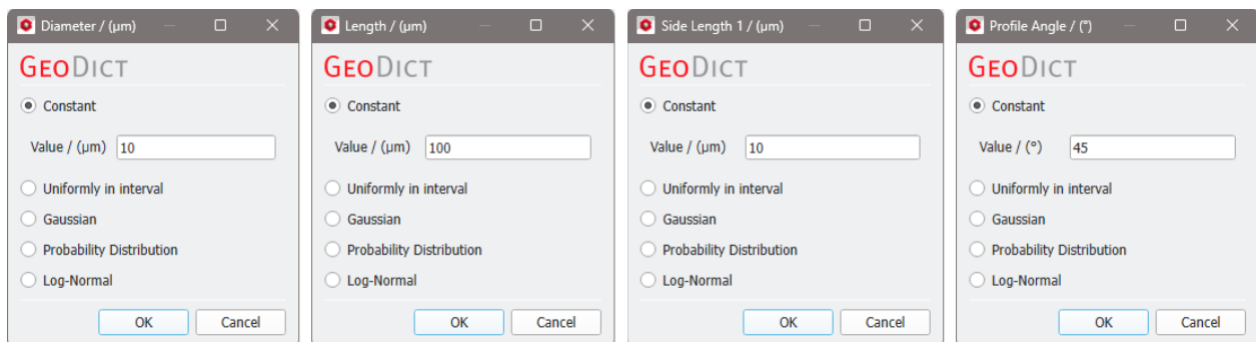
Observe the effect of keeping a **Torsion Start Angle** of 0 and entering increasing values of **Maximal Torsion Change** (5, 10, and 30) on a highly anisotropic structure made of curved cellulose fibers.



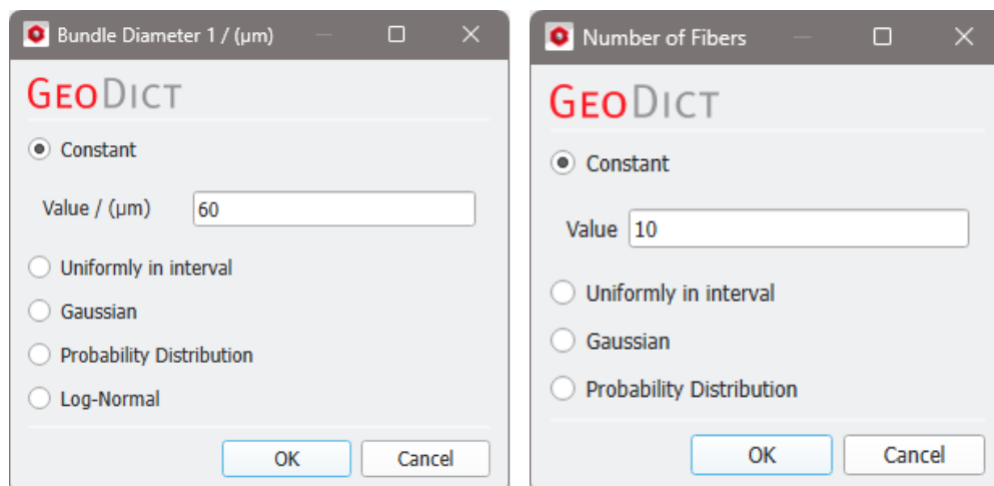
Distribution

Define the parameter's distribution in the dialogs which open when clicking the corresponding **Edit...** buttons.

Under the **Fiber** tab, the fiber **Diameter**, the **Length**, the **Side Length**, and the **Profile Angle** can be set to a **Constant** value, or to follow a **Uniformly in interval** distribution, a **Gaussian** distribution, a user-defined **Probability Distribution**, or a **Log-Normal** distribution.

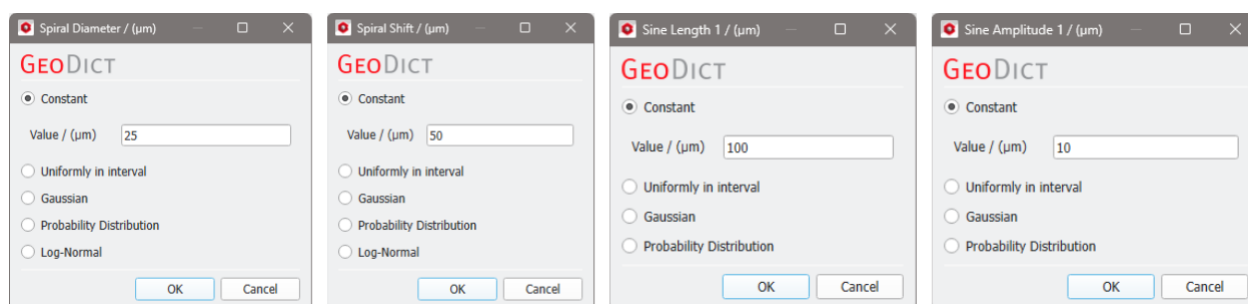


Under the **Bundle** tab the same is true for the **Bundle Diameter**. The **Number of Fibers** can be set to a **Constant** value or to follow a **Uniformly in interval** distribution, a **Gaussian** distribution, or a user-defined **Probability Distribution**.

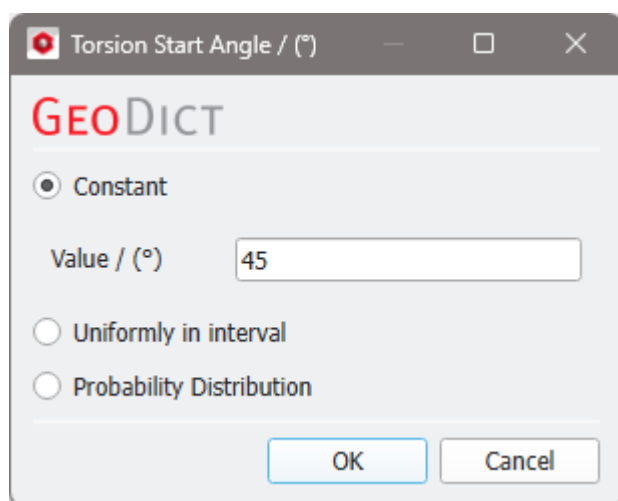


Under the **Curl** tab, **Spiral Diameter**, **Spiral Shift**, **Curvature Radius**, and **Winding** can be set to a **Constant** value, or to follow a **Uniformly in interval** distribution, a **Gaussian** distribution, a user-defined **Probability Distribution**, or a **Log-Normal** distribution.

Sine Length and **Sine Amplitude** can be set to a **Constant** value, or to follow a **Uniformly in interval** distribution, a **Gaussian** distribution, or a user-defined **Probability Distribution**.

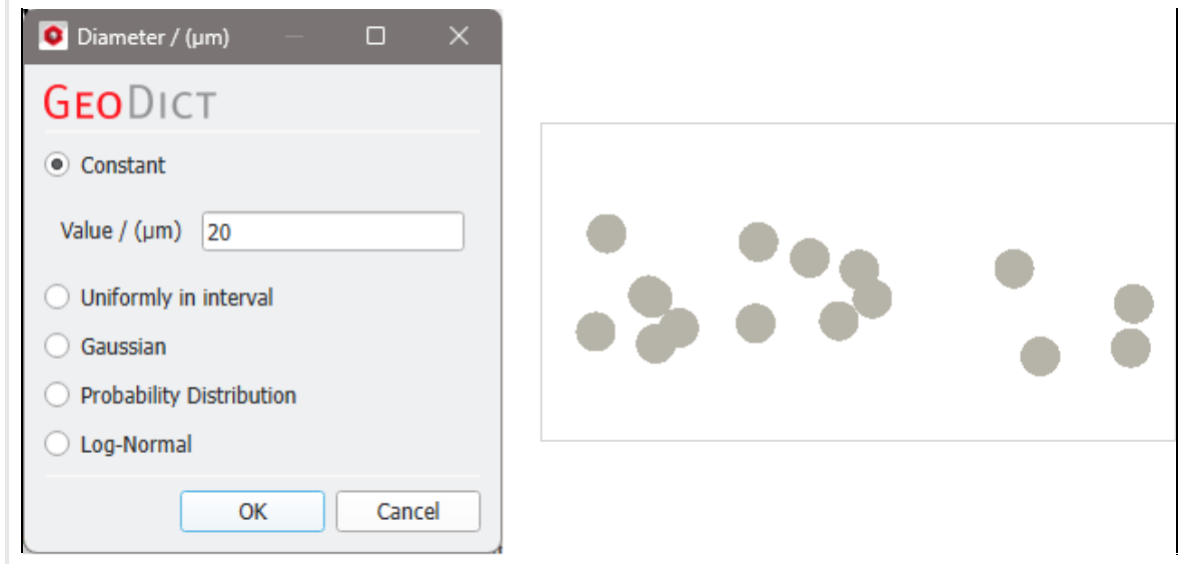


Under the **Torsion** tab the **Torsion Start Angle** value (for Curved Elliptical, Curved Cellulose, and Curved Rectangular cross-sections) can be set to be **Constant**, to distribute **Uniformly in interval**, or to follow a **Probability Distribution**.



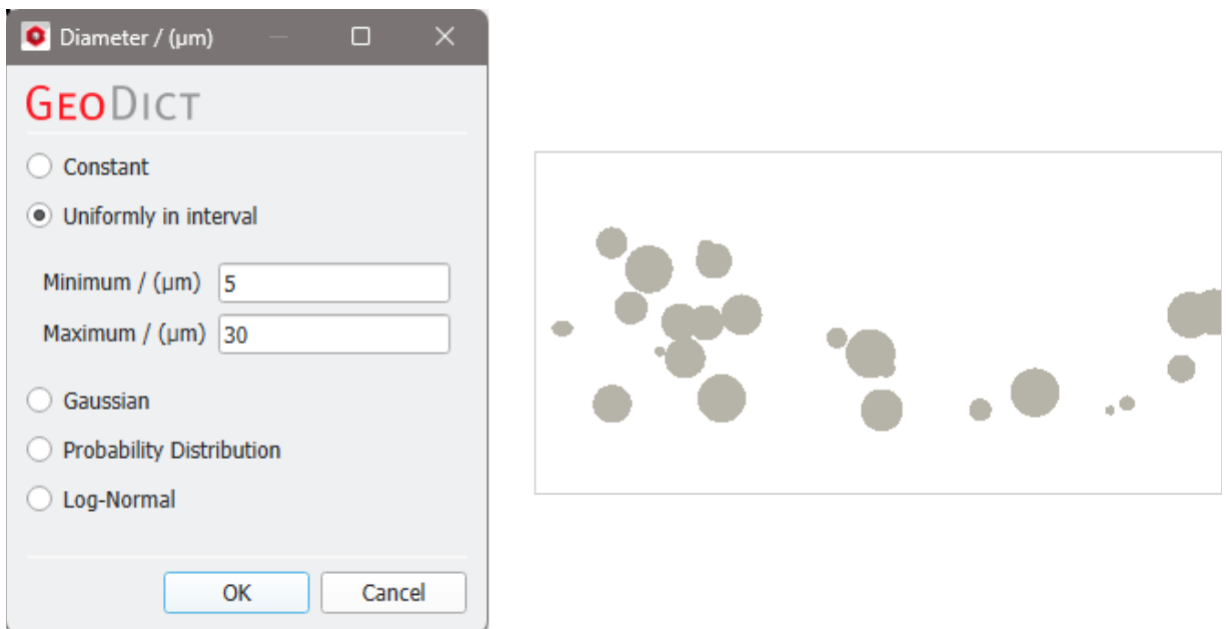
✓ Constant

Observe the effect of choosing the diameter to be **Constant** in the following example with only circular cross-section fibers. The generated structures are shown as 2D cross-section. To better observe the circular cross-section in 2D view, the fibers are all oriented perpendicular to the view direction.



✓ Uniformly in interval

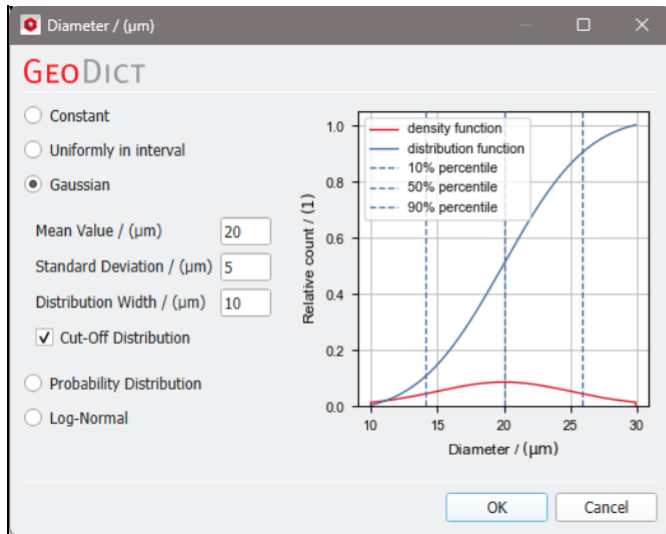
When selecting **Uniformly in interval**, and entering a **Minimum** value and a **Maximum** value, the random diameters are distributed within the given interval and every feasible diameter has the same probability.



✓ Gaussian

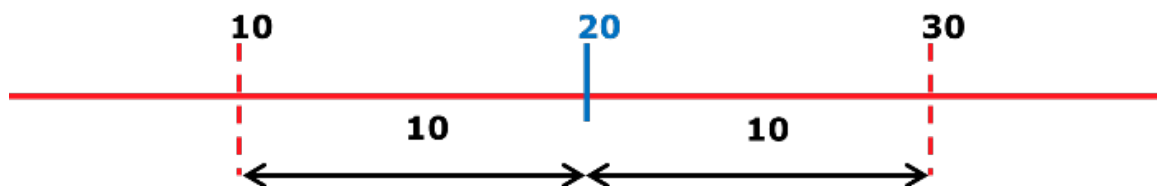
Taking the **Gaussian** distribution, the random diameter, length, or side length values

follow a bell-shaped distribution. The values cluster around the entered **Mean Value** but may vary according to the entered **Standard Deviation**.



The value in **Distribution Width** corresponds to the interval on both sides of the mean value limiting the random diameter or angle values that are accepted.

As an example, a **Distribution Width** value of 10 means that the values may vary only -10 to +10 from the given **Mean Value**.



You can set the parameters so that negative values would be possible. Then, the negative values are ignored and only the range of possible values is generated. For example, a mean value of 20 and a distribution width of 25 would lead to values between 1 and 45.

For all distribution options (Gaussian, Probability Distribution and Log-Normal) on the right of the dialog the distribution is visualized in a 2D plot.

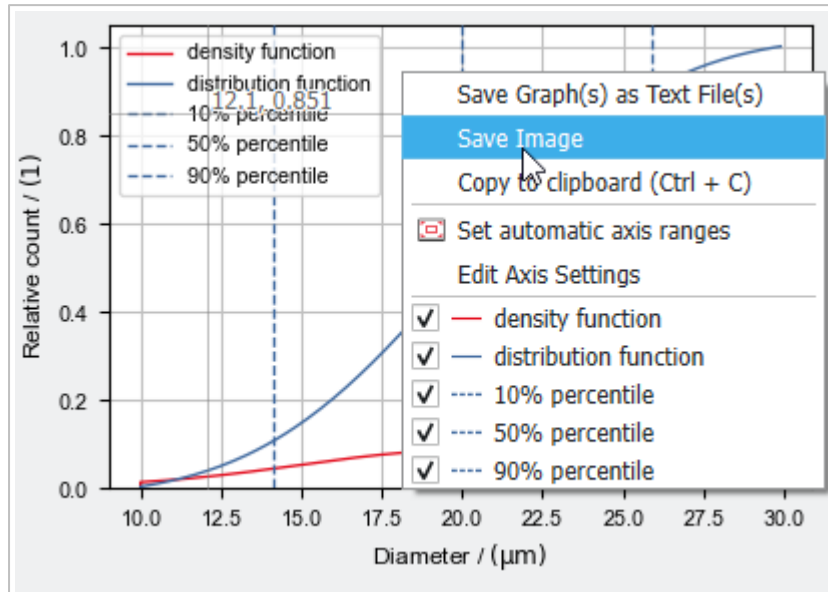
The **red** line shows the density distribution defined by Mean Value, Standard Deviation and Distribution Width. It displays how many objects of which diameter will be generated in percent. The **blue** curve shows the cumulative distribution.

The three **dashed blue** lines show the diameter values for 10% percentile, 50% percentile and 90% percentile of the distribution. For example, if the distribution is given for diameters as shown in the screenshot above, on average, 10% of the objects have a diameter smaller than 14μm (10% percentile), and 90% of the generated objects have a diameter smaller than 26μm (90% percentile). For further explanations, see the [Wikipedia](#) article.

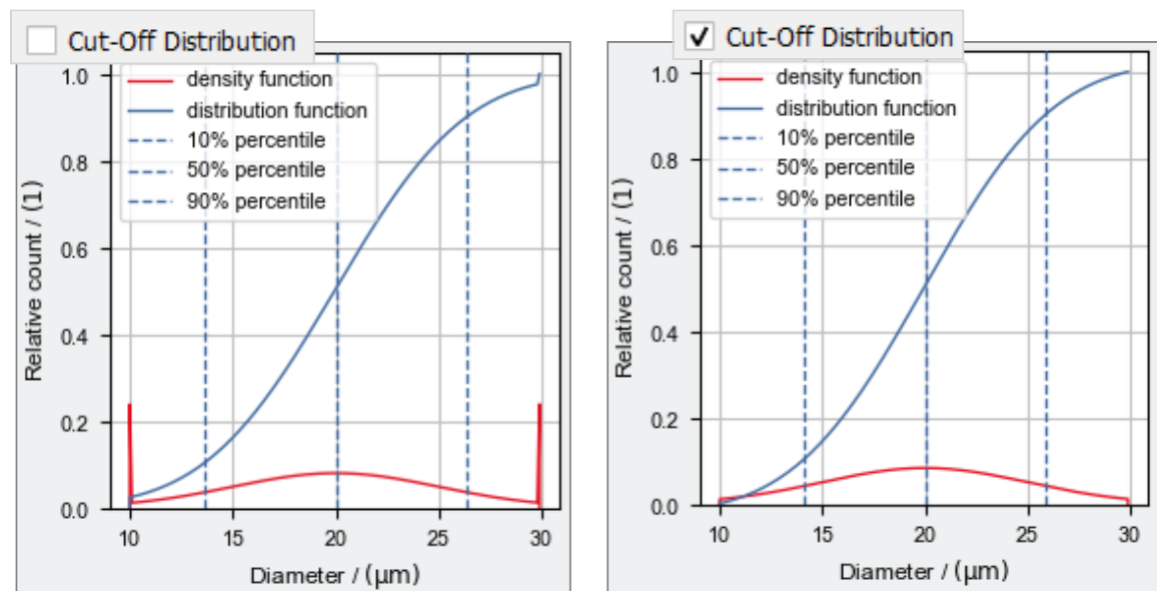
Right-clicking into the plot opens a dialog to **save** the plot or to **Edit** the **Axis**

Settings. Checking or unchecking the checkboxes next to the graph names decides which curves should be displayed.

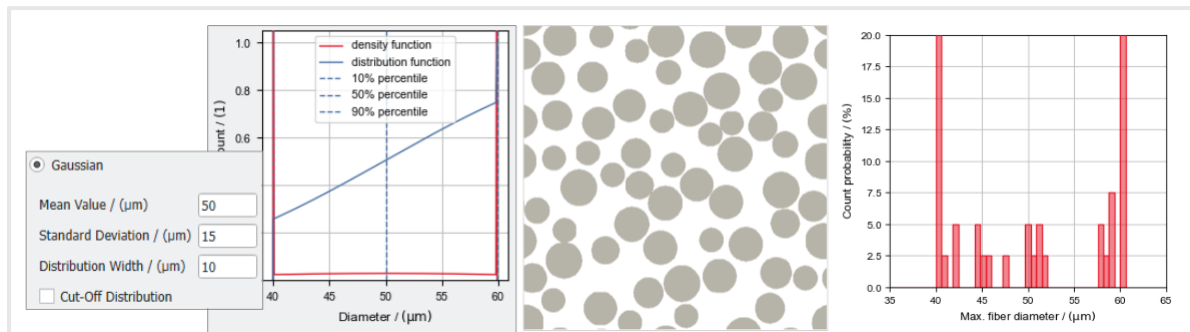
More information about these options can be found in the [Result Viewer User Guide](#).



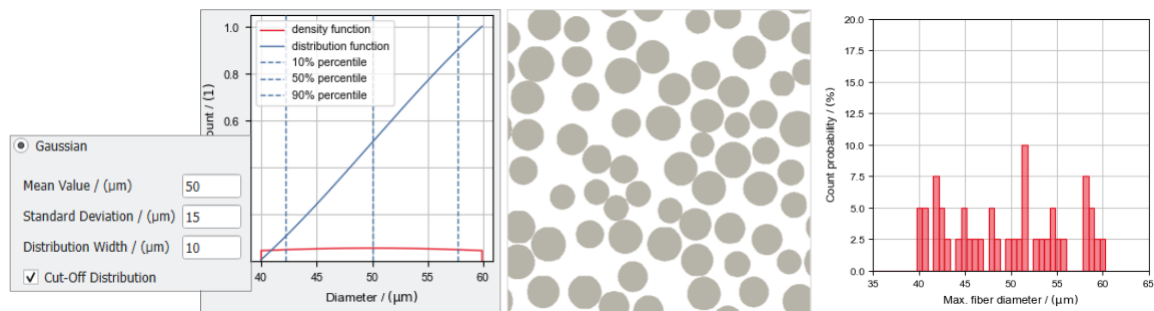
If **Cut-Off Distribution** is checked, the distribution is truncated at the bounds. This means, that all values outside the bounds are dropped and not considered for generation. If this option is not checked, then all values that are outside of the bounds are set to be on the distribution bound. Not checking this option leads to an accumulation of values on the bounds.



In the following example, leaving **Cut-Off Distribution** unchecked leads to many objects with diameters of 40 or 60 μm.



In contrast, checking **Cut-Off Distribution** leads to more grains with diameter of 50 μm .



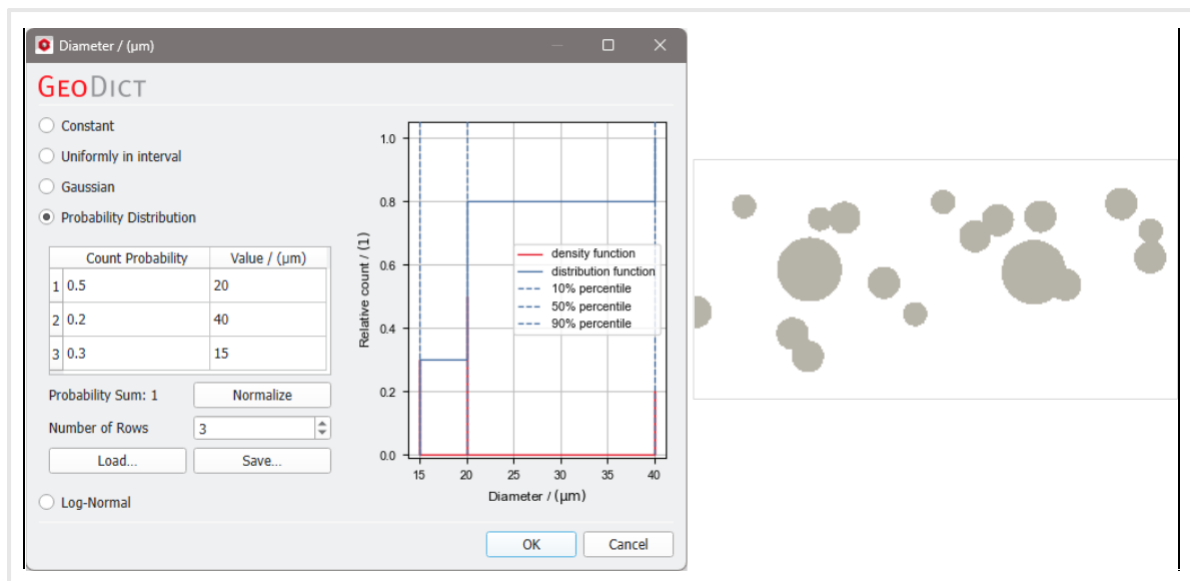
Further details on Gaussian distributions can be found, e.g., on [Wikipedia](https://en.wikipedia.org/wiki/Normal_distribution) on Normal (or Gaussian) distributions.

✓ Probability Distribution

The **Probability Distribution** table allows to enter user-defined probability distributions. The **Number of Rows** can be increased or decreased to enter as many value pairs as desired. The **Value** corresponds to the chosen property, e.g., diameter, length, or angle. The **Count Probability** of the values must lay between 0 and 1 and their sum must be equal to 1.

Especially for large tables, it is useful to observe the value of **Probability Sum**, i.e., the sum of the count probabilities. When the **Probability Sum** is not equal to 1, click the **Normalize** button to automatically round the **Count Probability** values.

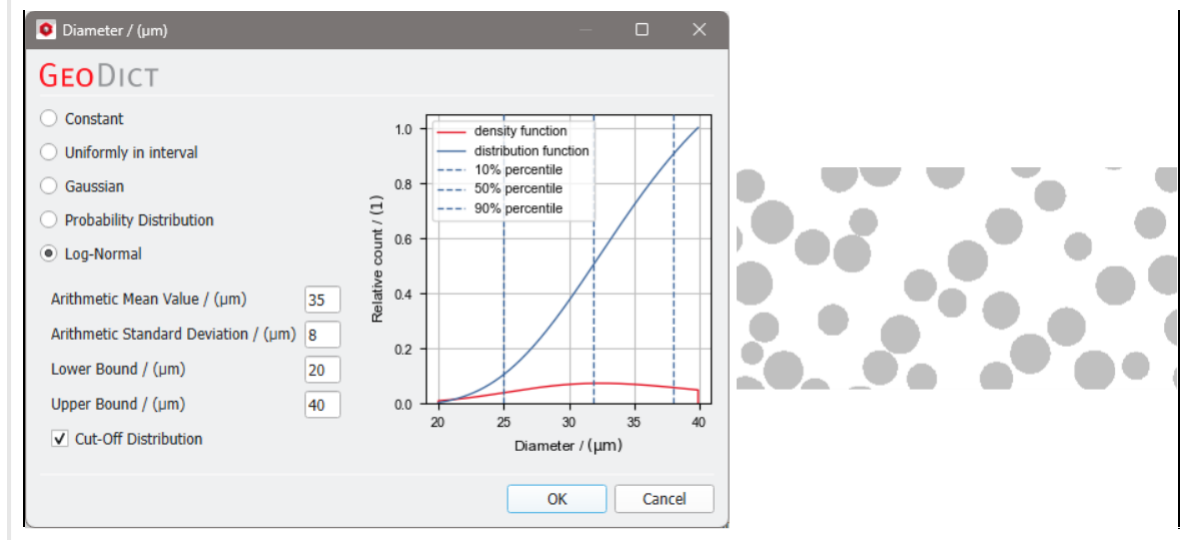
The buttons **Load** and **Save** allow loading a previous probability distribution and saving the current one for later use.



✓ Log-Normal

The **Log-Normal** distribution describes the situation in which the logarithm of the diameter values follows a normal distribution.

The diameter values group around the entered **Arithmetic Mean Value** and scatter according to the entered **Arithmetic Standard Deviation**. The values in **Lower Bound** and **Upper Bound** restrict the possible values that the random diameters can take to the given interval.



Fiber Overlap

The **Fiber Overlap** tab contains options dealing with how to define the Material ID in locations where materials in the structure overlap. The overlap locations may exhibit other properties than those of the original materials.

Material ID Mode: Material ID per Object-Type

☐ Resolve Overlap

☒ Mark Contact Voxels

Default Overlap Material (ID 02): Overlap (Solid)...

Number of Overlap Rules: 1

	Material ID 1	Material ID 2	Overlap Material ID
1	01 Solid	01 Solid	01 Solid

✓ Material ID Mode

Through the **Material ID Mode**, select between applying the Material ID based on the materials or the types of objects present in the structure.

Material ID Mode: Material ID per Object-Type

✓ Resolve Overlap

If **Resolve Overlap** is checked, the overlap of objects is not assigned to a new Material ID. Instead, the water-shed algorithm is used to decide which of the overlap voxels belongs to which object in a post-processing step. Thus, each overlap voxel is assigned to one specific object. This option needs more memory and a longer run-time.

In detail, the **Resolve Overlap** algorithm starts with computing a distance map for the overlap voxels, i.e., it computes the distance to the next object for each overlap voxel. On this distance map the watershed algorithm is run using all voxels belonging to an object as seeds. There, all voxels contained in the same object have the same Material ID. Thus, the overlap area is filled with the object IDs according to the distance map.

To mark the contact voxels between the objects with a separate Material ID, select **Mark Contact Voxels** and choose a **Contact Material** from the **Material Database**.

The voxels, where two or more objects IDs meet, are marked as contact voxels, by reassigning them with a new Material ID. Thus, the layer of contact voxels always has a thickness of two voxels.

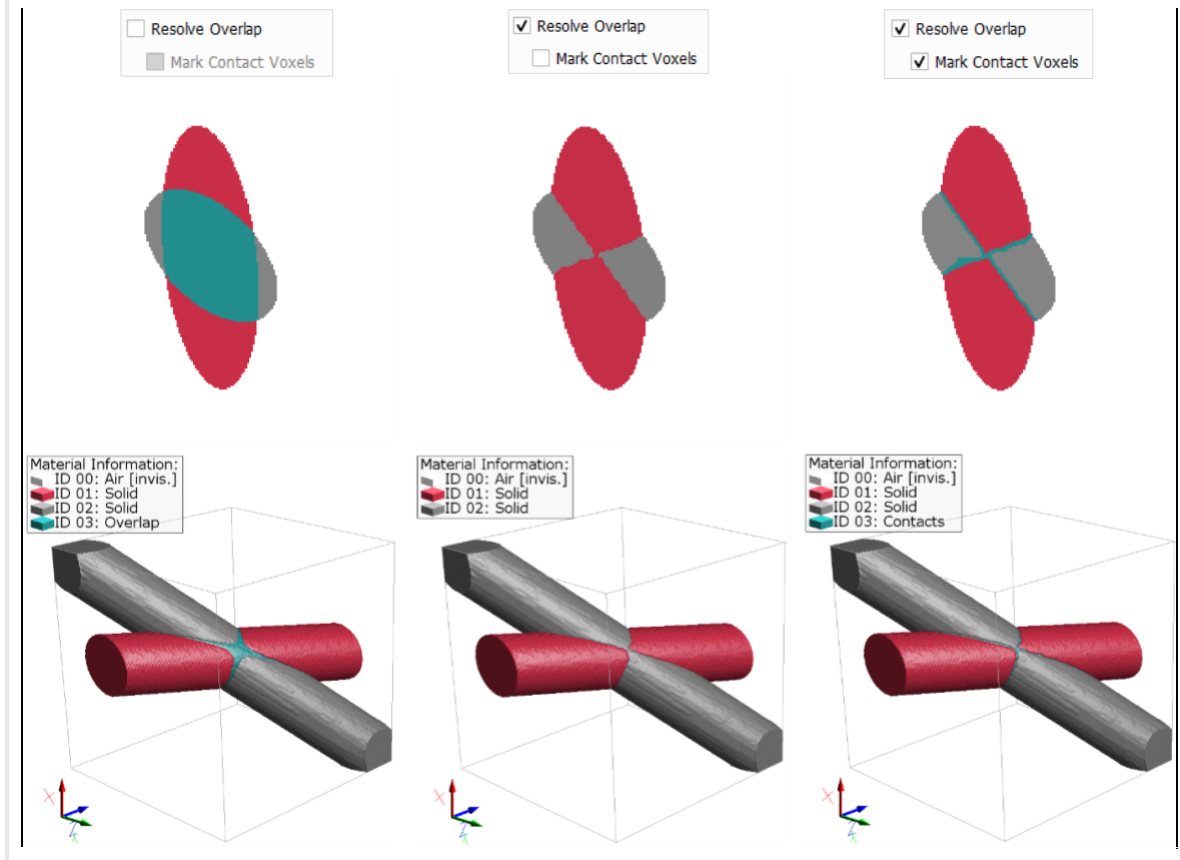
☒ Resolve Overlap

☒ Mark Contact Voxels

Contact Material (ID 03): Contact (Solid)...

In the following observe the resulting Material IDs for the overlap for not resolved, resolved and resolved overlap with marked contact voxels, while all other settings are

kept the same.



✓Overlap Rules and Default Overlap Material

Default Overlap Material controls the material assigned to the regions where objects of the generated structure overlap and is only available if [Resolve Overlap](#)^[108] is disabled. The Material ID of these regions is chosen by default as the next available Material ID. The material can be changed by clicking on the button.

Overlap rules can be set to control how the overlap between Material IDs should be handled in the structure. You can set up to 100 rules by selecting a number in the box for **Number of Overlap Rules**, and then define these rules in the panel below.

The materials shown in the panel (as buttons or pull-down menu) correspond to the materials selected under the **Fiber Options** tab.

For example, you simulate a structure made of plastic fibers that melt together using a negative [isolation distance](#)^[21] as a **Generation and Overlap Mode** under the **Create Options** tab. Then, you can set up a rule that defines what happens with the Material ID at the melting location.

In the example shown below, three rules have been defined: The overlap of objects with Material ID 1 (dark red) will be assigned to ID 3 (turquoise). The overlap of objects with Material ID 2 (gray) will be assigned to ID 4 (blue) and the overlap of ID 1 and ID 2 will be assigned to ID 5 (purple). For all other possible overlap cases, the **Default**

Overlap Material ID is applied.

Number of Overlap Rules

	Material ID 1	Material ID 2	Overlap Material ID
1	01 Glass (Solid) ▾	01 Glass (Solid) ▾	03 Glass (Solid) ▾
2	02 Glass (Solid) ▾	02 Glass (Solid) ▾	04 Solid ▾
3	01 Glass (Solid) ▾	02 Glass (Solid) ▾	05 Solid ▾

✓Overlap Results

Note, that the results for volume in the resulting report do not change for different overlap rules, as the values are computed before the post-processing is applied.

In the three examples given for **Resolve Overlap**, the **Absolute object distribution** is shown below.

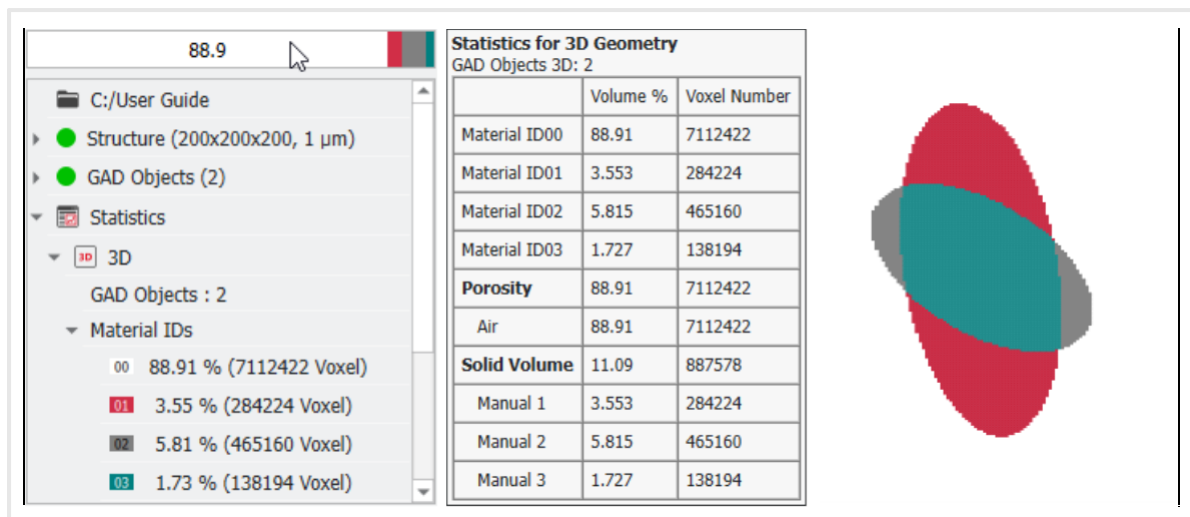
Absolute object distribution:

	Count	Volume / (%)	Grammage / (g/m ²)	Density / (g/cm ³)	Weight / (%)
Total	realized: 2 target: 2 error: 0.00	realized: 11.09 target: --- error: ---	realized: --- target: --- error: ---	realized: --- target: --- error: ---	realized: --- target: --- error: ---
Object type 1	realized: 1 target: 1 error: 0.00	realized: 4.42 target: --- error: ---	realized: --- target: --- error: ---	realized: --- target: --- error: ---	realized: --- target: --- error: ---
Object type 2	realized: 1 target: 1 error: 0.00	realized: 6.68 target: --- error: ---	realized: --- target: --- error: ---	realized: --- target: --- error: ---	realized: --- target: --- error: ---

For the volume percentages of the final structure, refer to the **Statistics** in the left of the GeoDict main window. Either just hover over the statistics bar or unfold the Statistics section in the project status panel below.

Here, the volume statistics are shown for the example with default overlap rules. The red fiber has 3.55% of the volume, the gray fiber has 5.81% and the overlap 1.73%.

In the result file the overlap volume is proportionally added to the volume of the overlapping fibers. Here, the red fiber obtains $3.55\% + (1.73/2)\% = 4.415\%$. Rounded, this results in the 4.42% shown in the report.



Result Options

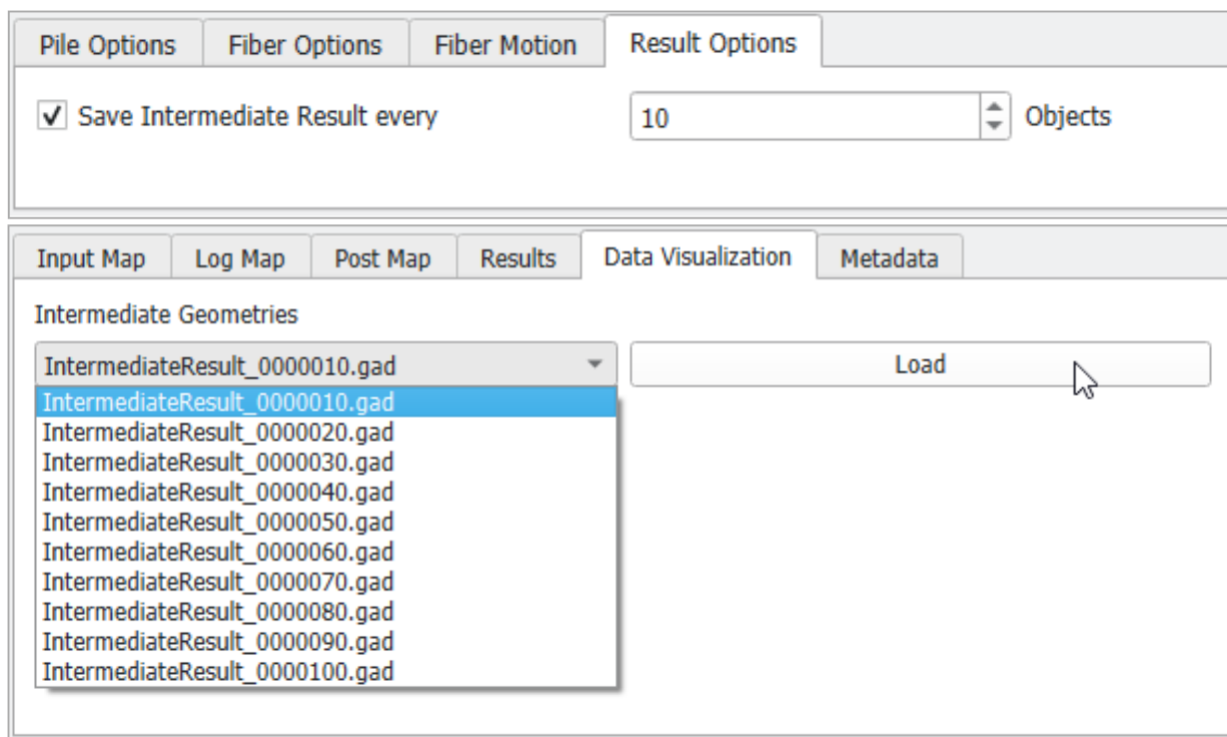
The generated structure is always saved as a **GeoDict structure file (*.gdt)** (GeoDict binary data). The file is placed in an automatically created result folder inside the chosen project folder (**File** → **Choose Project Folder...** in the menu bar).

The result file as well as the result folder take the name entered as **Result File Name (*.gdr)** at the top of the dialog.

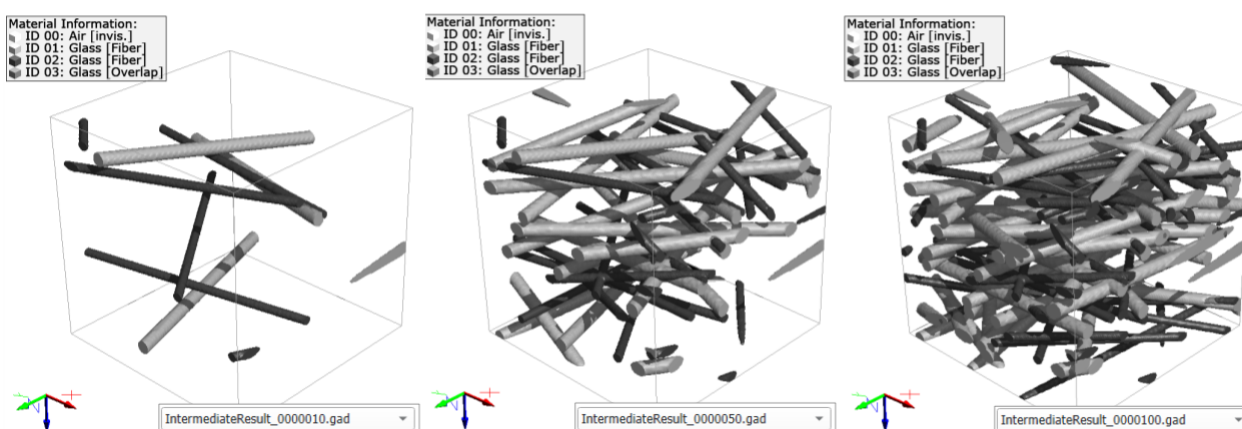
An additional option to save the generated structure data is to check **Save Intermediate Result every** and enter a number of **Objects** in the box. As objects are added to the structure during the generation, an intermediate result file is saved each time the number of placed objects reaches a multiple of the entered value.

This option may be interesting when studying the properties of a series of structures with increasing density.

After running the generation, the intermediate geometries can be found as ***.gad** analytic files in the result folder and can be loaded directly from the **Result Viewer** of the *.gdr result file.



Below find an example for the creating 100 fibers. Observe how more and more fibers are added.



1.1.2 Results

The generated structure is shown in the visualization area. Learn more about visualization in GeoDict in the **Visualization** chapter.

The result file is automatically opened in the Result Viewer and shows structure statistics in the **Results-Report** and **Results-Plot** tabs. Additionally, it offers 3D **Data Visualization** options depending on the generation settings. Find more information on GeoDict result files in the **Result Viewer** chapter.

Results

✓ Report

The first two tables show the **Absolute** and **Relative object distribution** for all object types.

Input Map

Log Map

Post Map

Results

Data Visualization

Metadata

Report

Plots

Map

Absolute object distribution:

	Count	Volume / (%)	Grammage / (g/m ²)	Density / (g/cm ³)	Weight / (%)
Total	realized: 1794 target: --- error: ---	realized: 34.99 target: 35.00 error: -0.01	realized: --- target: --- error: ---	realized: --- target: --- error: ---	realized: --- target: --- error: ---
Object type 1	realized: 992 target: --- error: ---	realized: 17.47 target: 17.50 error: -0.03	realized: --- target: --- error: ---	realized: --- target: --- error: ---	realized: --- target: --- error: ---
Object type 2	realized: 801 target: --- error: ---	realized: 17.52 target: 17.50 error: 0.02	realized: --- target: --- error: ---	realized: --- target: --- error: ---	realized: --- target: --- error: ---

Stopping criterion error: -0.016 %

Relative object distribution:

	Count / (%)	Volume / (%)	Weight / (%)
Object type 1	realized: 55.35 target: --- error: ---	realized: 49.93 target: 50.00 error: -0.14%	realized: --- target: --- error: ---
Object type 2	realized: 44.65 target: --- error: ---	realized: 50.07 target: 50.00 error: 0.14%	realized: --- target: --- error: ---

Maximal probability error: 0.14%

Afterwards follows a section regarding the overlap between different object types.

Overlap Information:

Overlap of objects of different type: 3.94526 %

(This overlap may be handled in the geometry post-processing, by the specified overlap rules or by resolve overlap. Both options may change the object type volume fractions.)

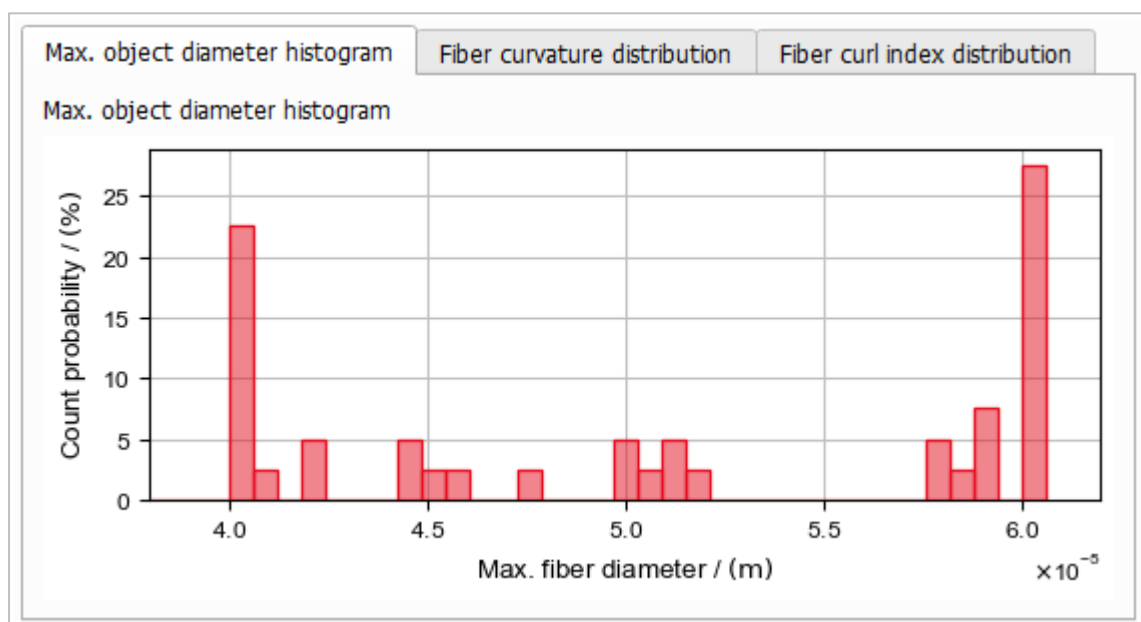
Then, the realized, the target, and the error direction tensors for all object types are given. Find below different examples of the direction tensors with isotropic orientation, anisotropy parameters, or orientation tensors.

Direction-tensor object type 1:	Direction-tensor object type 1:	Direction-tensor object type 1:																																																																																	
Anisotropy 1: Target 1.000 Anisotropy 2: Target 1.000 Realized direction tensor: <table border="1"> <tr><td>0.3320</td><td>0.0036</td><td>0.0084</td></tr> <tr><td>-</td><td>0.3338</td><td>-0.0036</td></tr> <tr><td>-</td><td>-</td><td>0.3342</td></tr> </table> Target direction tensor: <table border="1"> <tr><td>0.3333</td><td>0.0000</td><td>0.0000</td></tr> <tr><td>-</td><td>0.3333</td><td>0.0000</td></tr> <tr><td>-</td><td>-</td><td>0.3333</td></tr> </table> Error tensor: <table border="1"> <tr><td>-0.14%</td><td>0.36%</td><td>0.84%</td></tr> <tr><td>-</td><td>0.05%</td><td>-0.36%</td></tr> <tr><td>-</td><td>-</td><td>0.09%</td></tr> </table>	0.3320	0.0036	0.0084	-	0.3338	-0.0036	-	-	0.3342	0.3333	0.0000	0.0000	-	0.3333	0.0000	-	-	0.3333	-0.14%	0.36%	0.84%	-	0.05%	-0.36%	-	-	0.09%	Anisotropy 1: Target 100.000 Anisotropy 2: Target 1.000 Realized direction tensor: <table border="1"> <tr><td>0.5026</td><td>-0.0276</td><td>-0.0003</td></tr> <tr><td>-</td><td>0.4970</td><td>0.0000</td></tr> <tr><td>-</td><td>-</td><td>0.0004</td></tr> </table> Target direction tensor: <table border="1"> <tr><td>0.4998</td><td>0.0000</td><td>0.0000</td></tr> <tr><td>-</td><td>0.4998</td><td>0.0000</td></tr> <tr><td>-</td><td>-</td><td>0.0004</td></tr> </table> Error tensor: <table border="1"> <tr><td>0.28%</td><td>-2.76%</td><td>-0.03%</td></tr> <tr><td>-</td><td>-0.28%</td><td>0.00%</td></tr> <tr><td>-</td><td>-</td><td>0.00%</td></tr> </table>	0.5026	-0.0276	-0.0003	-	0.4970	0.0000	-	-	0.0004	0.4998	0.0000	0.0000	-	0.4998	0.0000	-	-	0.0004	0.28%	-2.76%	-0.03%	-	-0.28%	0.00%	-	-	0.00%	Realized direction tensor: <table border="1"> <tr><td>0.8080</td><td>0.0029</td><td>-0.0074</td></tr> <tr><td>-</td><td>0.0934</td><td>0.0000</td></tr> <tr><td>-</td><td>-</td><td>0.0986</td></tr> </table> Target direction tensor: <table border="1"> <tr><td>0.8000</td><td>0.0000</td><td>0.0000</td></tr> <tr><td>-</td><td>0.1000</td><td>0.0000</td></tr> <tr><td>-</td><td>-</td><td>0.1000</td></tr> </table> Error tensor: <table border="1"> <tr><td>0.80%</td><td>0.29%</td><td>-0.74%</td></tr> <tr><td>-</td><td>-0.66%</td><td>0.00%</td></tr> <tr><td>-</td><td>-</td><td>-0.14%</td></tr> </table>	0.8080	0.0029	-0.0074	-	0.0934	0.0000	-	-	0.0986	0.8000	0.0000	0.0000	-	0.1000	0.0000	-	-	0.1000	0.80%	0.29%	-0.74%	-	-0.66%	0.00%	-	-	-0.14%
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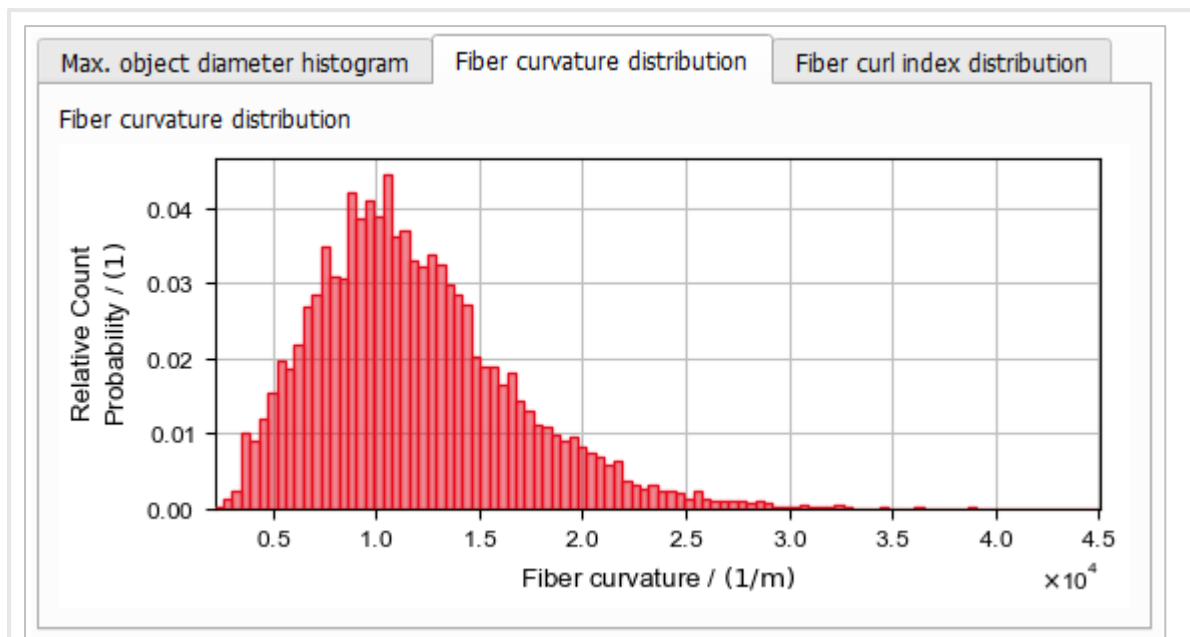
✓ Plots

For FiberGeo results three different plots are available.

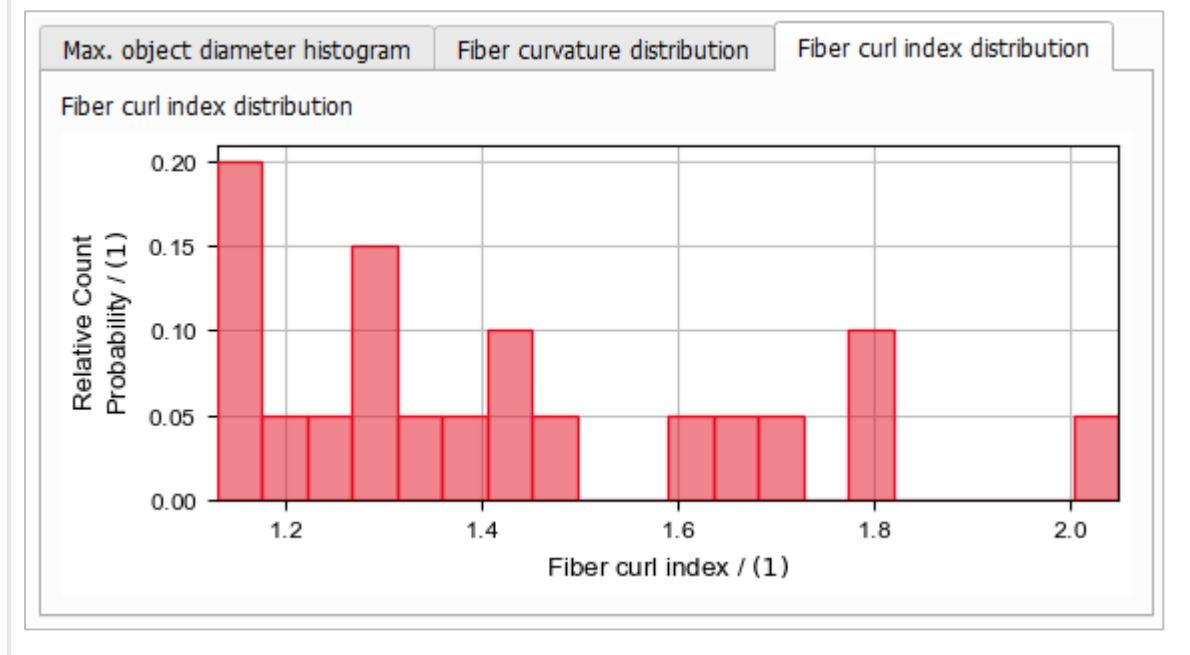
The plot **Max. object diameter histogram** shows the object's diameter distribution.



To observe the **Fiber curvature distribution** have a look at the second plot.



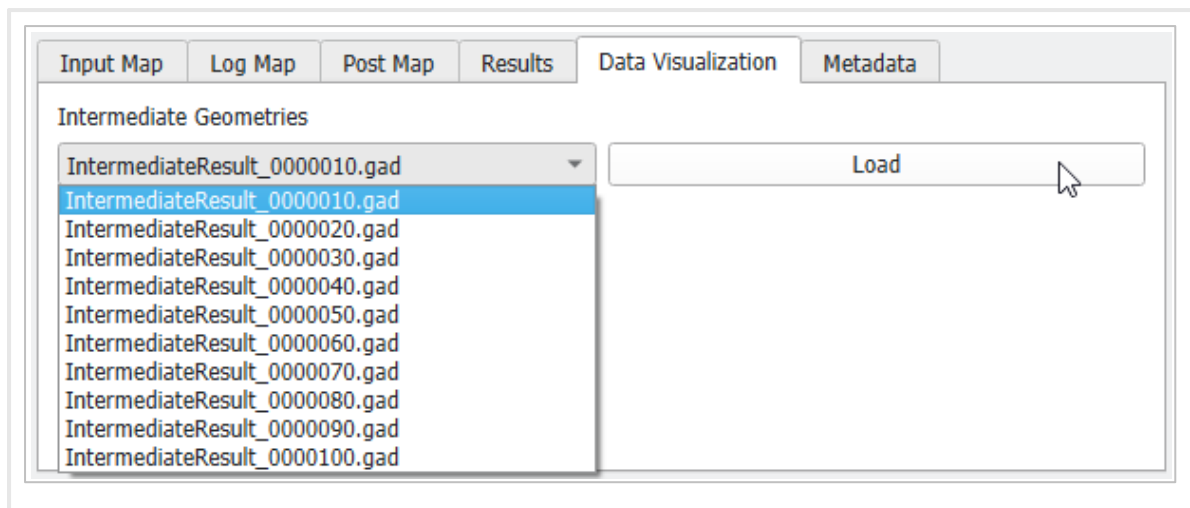
The last plot shows the **Fiber curl index distribution**.



Data Visualization

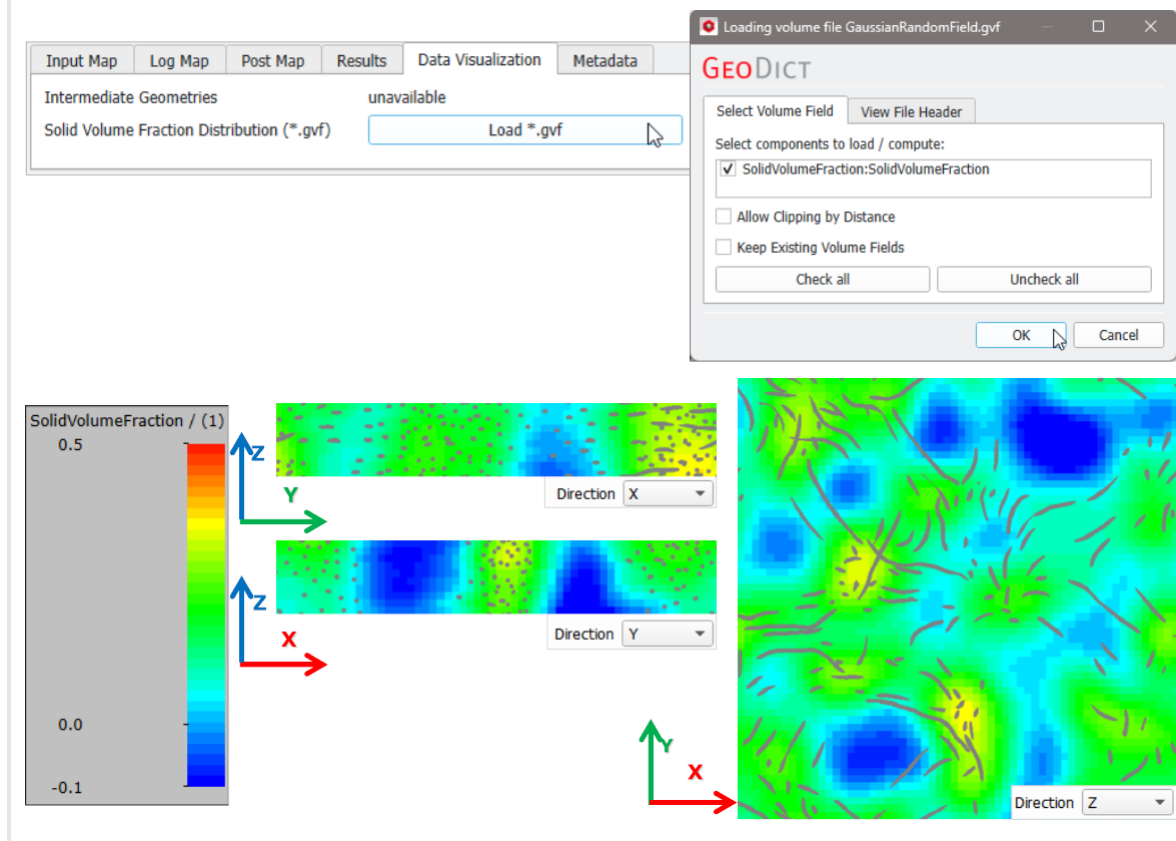
✓ Intermediate Geometries

When selecting **Save Intermediate Results every # Objects** under the **Result Options** tab, you can open the intermediate geometry files (*.gad) after selecting them in the pull-down menu.



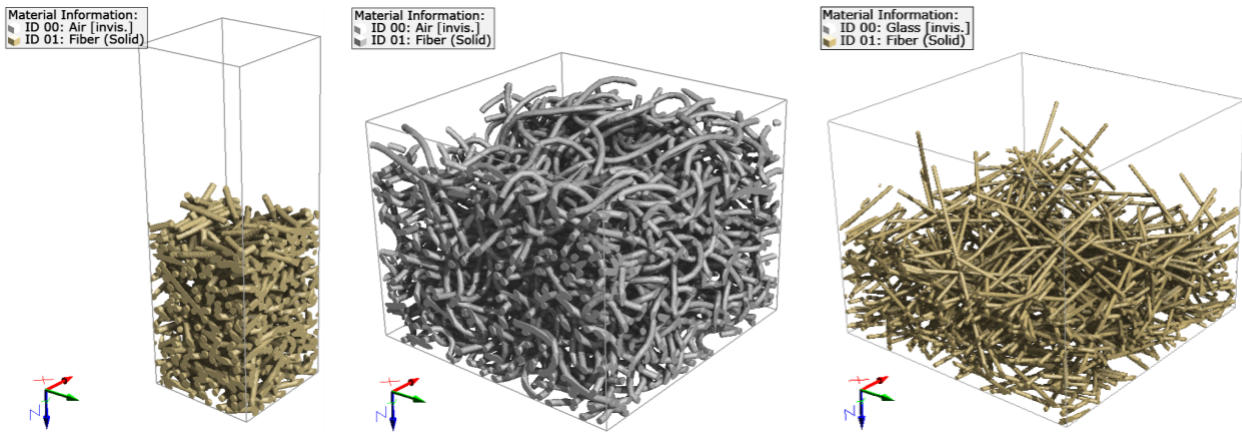
✓ Solid Volume Fraction Distribution

If **Match Solid Volume Fraction Distribution** is checked in the **Generation and Overlap Mode**^[21] panel under the **Create Options** tab, the volume distribution field (*.gvf) file is saved. Click **Load *.gvf** to load the volume field to the visualization area. Learn more about volume field visualization in the **Visualization** User Guide.



1.2 Pile Fibers

Simulate fibers falling, rotating, and finally settling to create a piled fibrous structure. The fibers either fall from the top or from their initial position in an existing structure. The fibers can be from various shapes and sizes.



The Pile Fibers command:

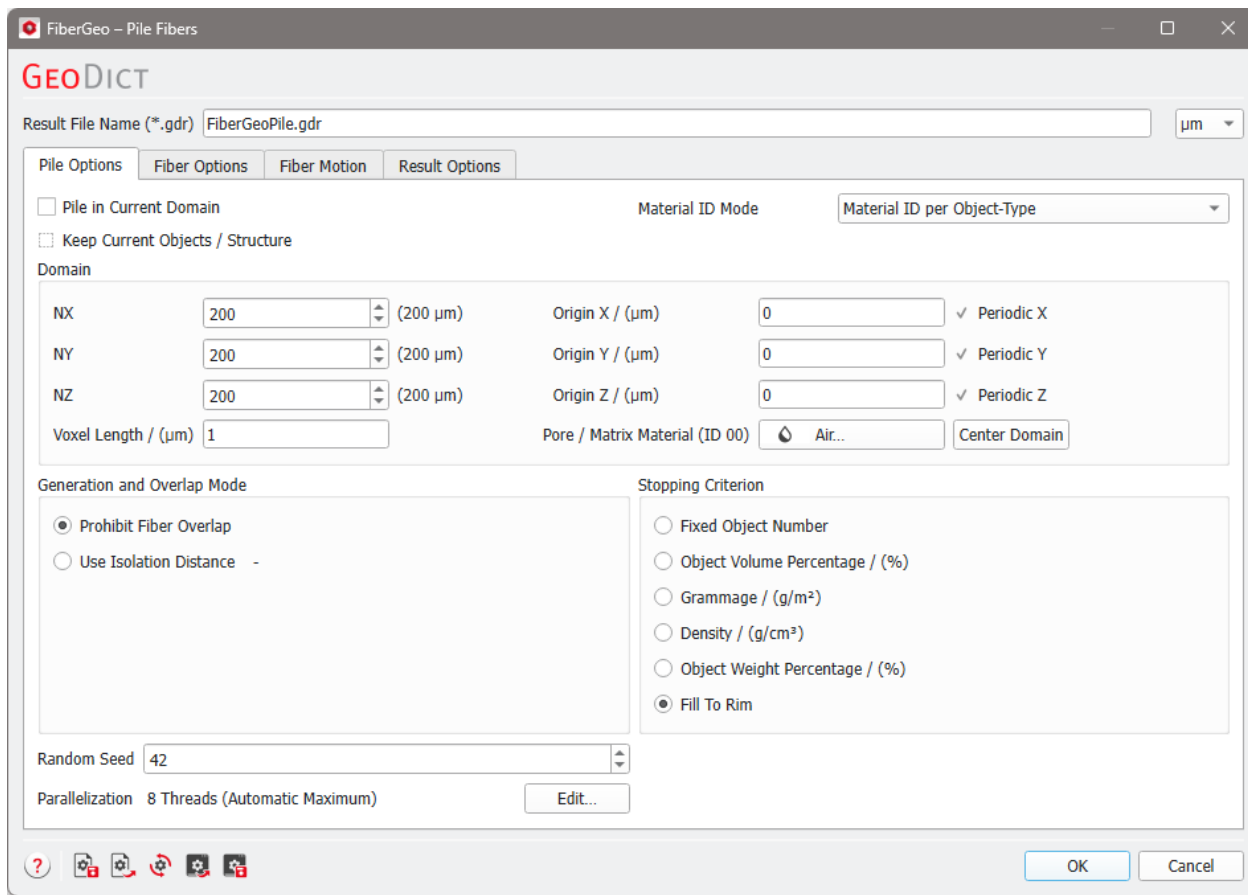
- [Options](#)¹¹⁷
Define the fiber piling parameters.
- [Results](#)¹³⁹
Inspect the result file in the Result Viewer.

1.2.1 Options

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

The result files are saved in the chosen project folder (**File** → **Choose Project Folder**, in the **Menu bar**). If a GeoDict result file (*.gdr) with the given name already exists in the project folder, a warning message is shown at the start of the creation process. You can either decide to rename the chosen file name to a new one, to cancel the generation process, to overwrite or to back up the old file. When nothing is selected, GeoDict uses the **Back-Up** option after a waiting time.

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



The options are organized into tabs:

- [Pile Options](#)¹¹⁹
Determine general properties of the resulting structure model such as size, resolution, and solid volume fraction.
- [Fiber Options](#)¹²⁹
Define the geometrical properties of individual fiber types such as cross-section, length, and orientation. Up to 254 different object types can be used in one structure.
- [Fiber Motion](#)¹³⁰
Control the way the fibers are piled. This is done by defining, e.g., different step parameters and the initial object positions.
- [Result Options](#)¹³⁸
Determine if intermediate geometries are saved.



- Opens the corresponding User Guide section.
- Saves the settings to a GeoDict settings file (*.gps).
- Loads the settings from a GeoDict settings file (*.gps) or a GeoDict result file (*.gdr).

-  Resets all parameter settings to the built-in default settings.
-  Resets all parameter settings to the saved start-up settings.
-  Saves the current parameter settings as start-up settings.

Each option is explained by a tooltip which appears when resting the mouse over the icon.

Pile Options

Determine physical properties of the resulting structure model such as size, resolution, overlapping mode, and object volume percentage.

The parameters defining the general properties of the piled structure are entered under the **Pile Options** tab. They are grouped into **Domain**, **Generation and Overlap Mode**, and **Stopping Criterion** panels. Additionally, five or six single options, depending on the chosen Stopping Criterion, are available in two groups: the **Structure Options** at the top and the **General Options** at the bottom of the dialog.

The parameters are organized in the following groups:

- [Structure Options](#)¹²⁰
Pile in the current domain with or without keeping the current structure and define the Material ID Mode.
- [Domain](#)¹²²
Define the domain parameters, such as resolution and matrix material.

The parameters are organized in the following groups:

- [Generation and Overlap Mode](#)¹²⁴
Decide about prohibiting overlap or defining an isolation distance.
- [Stopping Criterion](#)¹²⁵
Define according to which criteria the piling of fibers should be stopped.
- [General Options](#)¹²⁶
Define parallelization, temperature, and random seed for the piling process.

Structure Options

The following **Structure Options** are available:

- piling in the current domain without keeping the current objects / structure,
- piling in the current domain keeping the current objects / structure, and
- defining how the Material IDs should be set.

☐ Pile in Current Domain	Material ID Mode	Material ID per Object-Type ▼
☐ Keep Current Objects / Structure		

Pile in Current Domain and Keep Current Objects / Structure

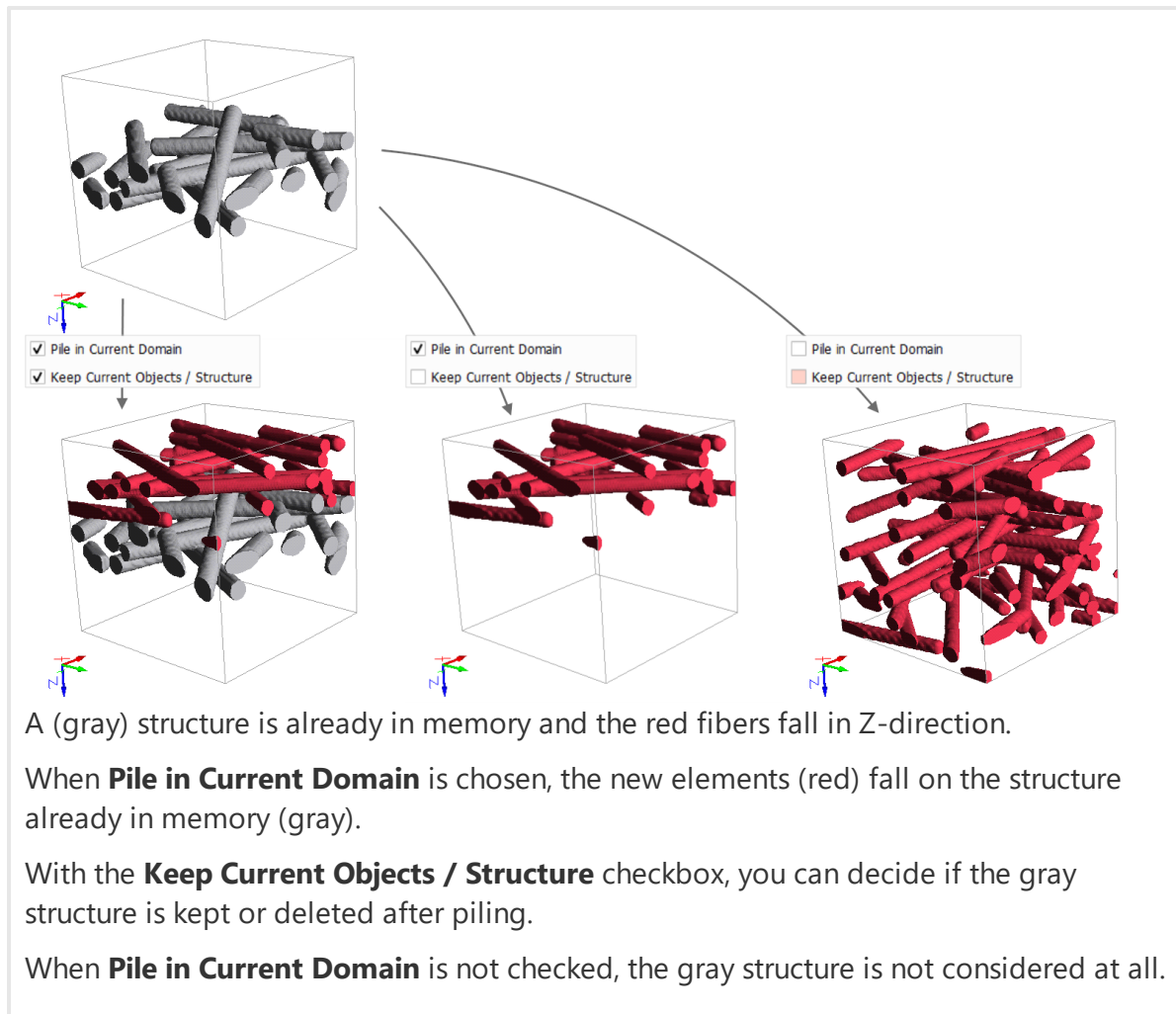
When checking **Pile in Current Domain**, the structure currently in memory is used in combination with the newly piled structure.

Note that the domain parameters, grouped under the **Domain** panel, cannot be modified when the **Pile in Current Domain** box is checked, because they are taken from the structure already in memory.

☒ Pile in Current Domain	Material ID Mode	Material ID per Object-Type ▼
☐ Keep Current Objects / Structure		
Domain		
NX	500 (500 μm)	Origin X / (μm) 0 ✓ Periodic X
NY	500 (500 μm)	Origin Y / (μm) 0 ✓ Periodic Y
NZ	400 (400 μm)	Origin Z / (μm) 0 ✓ Periodic Z
Voxel Length / (μm) 1	Pore / Matrix Material (ID 00) Air	

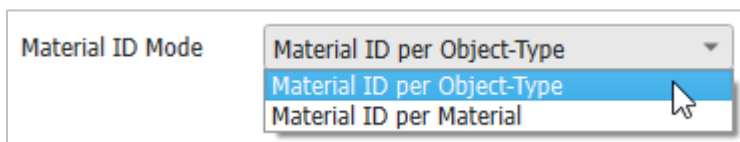
✓ Example

Observe the effect that checking, or leaving un-checked, the **Pile in Current Domain** and the **Keep Current Objects / Structure** boxes have on the generation of a fibrous structure.



Material ID Mode

The **Material ID Mode** pull-down menu allows selecting between applying the Material ID based on the materials or the types of objects present in the generated structure.



Assigning a **Material ID** is part of the GeoDict Material Database concept, in which objects in the structure are ascribed to an individual material (e.g., glass, cellulose, PET) with specific physical properties.

If selecting **Material ID per Object-Type**, every object type selected under the **Fiber Options** tab is assigned to a different Material ID. Otherwise, the chosen material defines the Material ID. Consider for example four object types are chosen, where two of them should be of material cellulose and two should be manual. Then, with **Material ID per Material** selected, the resulting structure consists of only two solid Material IDs.

Domain

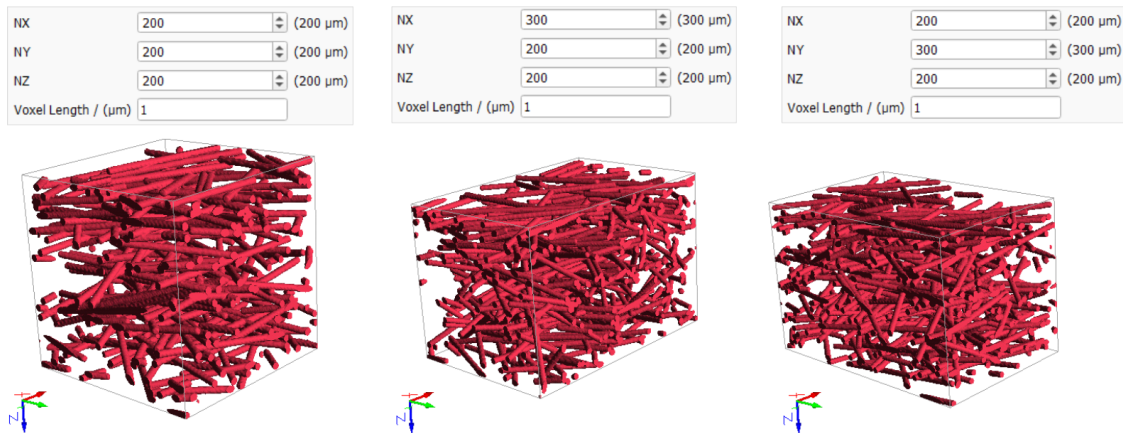
The **Domain** panel contains the parameters defining the structure size (**NX**, **NY**, and **NZ**) in combination with the resolution (**Voxel Length**), as well as the **Origin** parameters, the **Periodicity** checkboxes, the **Center Domain** button, and the **Pore / Matrix Material** pull-down menu. The periodicity boxes are always checked for **Pile**, because the objects must be piled periodically.

Domain					
NX	200	(200 μm)	Origin X / (μm)	0	☒ Periodic X
NY	200	(200 μm)	Origin Y / (μm)	0	☒ Periodic Y
NZ	200	(200 μm)	Origin Z / (μm)	0	☒ Periodic Z
Voxel Length / (μm) 1			Pore / Matrix Material (ID 00) 🔹 Air [Fiber]... Center Domain		

✓ NX, NY, NZ, and Voxel Length

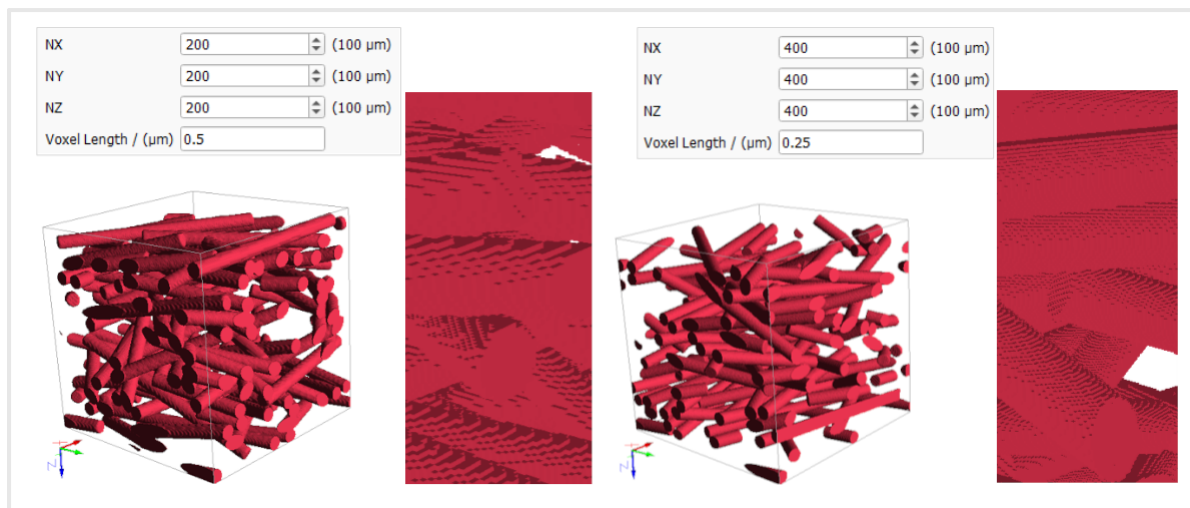
The internal representation of a structure in GeoDict consists of rectangular 3D arrays of equally sized boxes, hereafter called volume elements or **voxels**. **NX**, **NY**, and **NZ** are the number (N) of voxels in X, Y, and Z directions.

The **Voxel Length** is the size of one voxel in the chosen units. Varying the values for **NX**, **NY**, and **NZ** changes the size of the piled structure in the given direction.



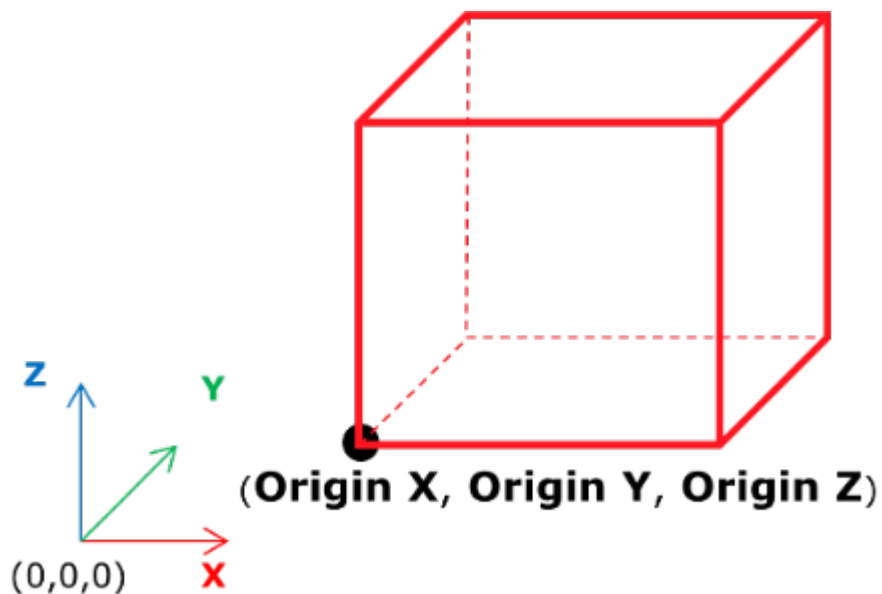
Low values for voxel length result in higher resolution, but also in higher computational time. After setting the values of **NX**, **NY**, **NZ**, and **Voxel Length**, the physical structure size is automatically displayed in the chosen units.

Observe how keeping the structure size at a constant $100 \times 100 \times 100 \mu\text{m}^3$ while decreasing the Voxel Length from $0.5 \mu\text{m}$ to $0.25 \mu\text{m}$ has the effect of refining the fibers in the pile by increasing the resolution. Since the voxel length has decreased to half, the size of the structure is kept by doubling the **NX**, **NY**, and **NZ** values from 200 to 400.

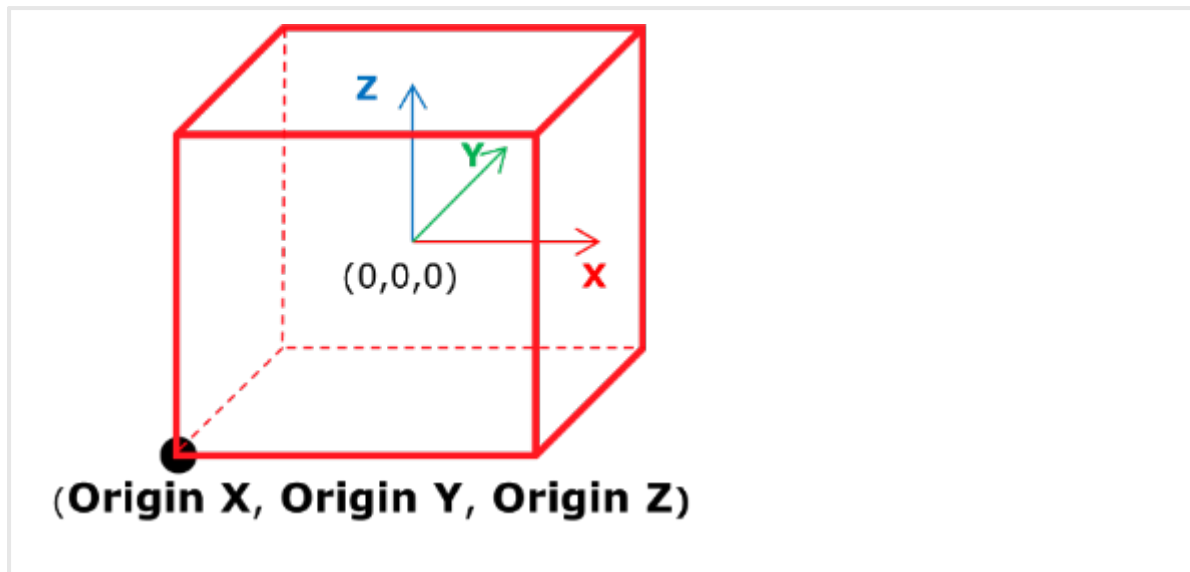


✓ Origin X, Origin Y, Origin Z, and Center Domain

The **Origin X**, **Origin Y**, and **Origin Z** parameters, together with the **Center Domain** button, determine the placement of the structure in the physical space. Zero values for Origin X, Origin Y, and Origin Z mean that the point with (0, 0, 0) coordinates is located at the lower left corner of the structure.



When clicking the **Center Domain** button, the (0, 0, 0)-point is set to the center of the structure as shown below.



✓ Periodic X, Periodic Y, and Periodic Z

For **FiberGeo Pile** periodicity is always applied in all three directions. To learn more about periodicity refer to the [Domain](#)^[14] chapter of the **Create** parameters.

✓ Pore / Matrix Material

Choose the material of the pore space or the matrix around the fibers from the pull-down menu.

When the material is chosen to be **Pore**, the fibers are embedded in empty pore space. Otherwise, the material filling the space around the fibers can be chosen to be a **Solid**, **Porous** medium, or **Fluid** in which the fibers are embedded.

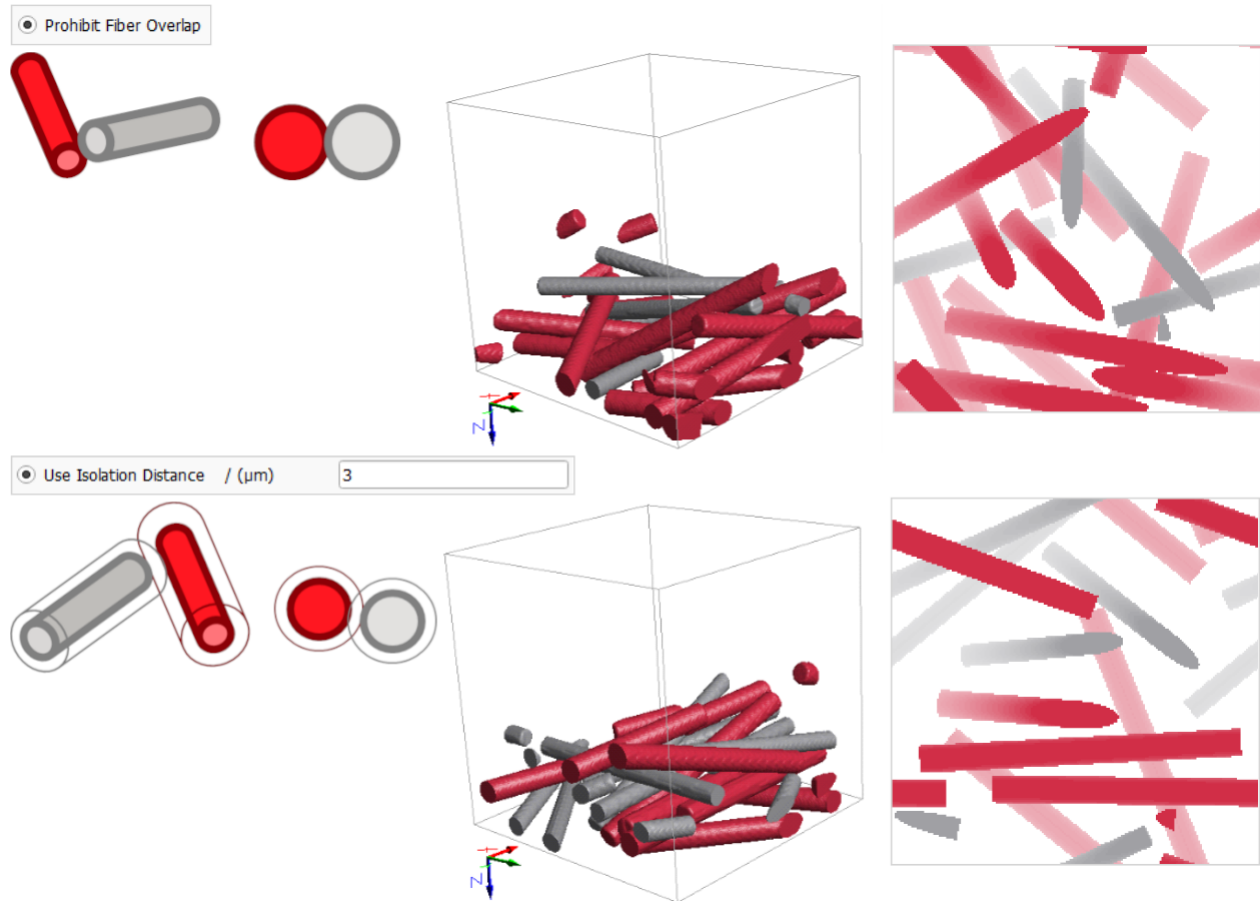
Generation and Overlap Mode

The options in the **Generation and Overlap Mode** panel control the relative position among the fibers in the pile (or with the objects of the structure currently in memory).

Generation and Overlap Mode

☒ Prohibit Fiber Overlap
☐ Use Isolation Distance -

Fibers may touch (but not overlap) when **Prohibit Fiber Overlap** is selected. Fibers may not touch when **Use Isolation Distance** is selected, and a positive value is entered. Then, the gaps between fibers have at least this preset voxel distance. The choice of **Use Isolation Distance** may lead to long computation times when using a high resolution in big structures.



Stopping Criterion

The parameters in the **Stopping Criterion** panel control whether the pile process should be continued, or the material is finished. The analysis of the [results file](#)^[139] (GDT file) shows any disparity between achieved result values and desired ones.

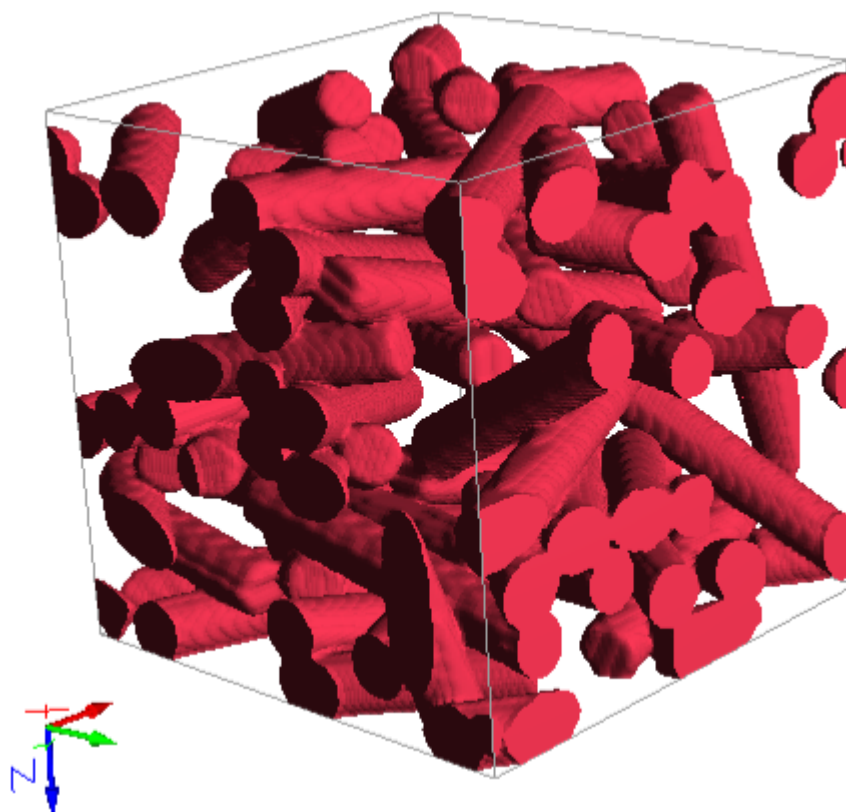
Besides the same options available for [FiberGeo – Create](#)^[29], it is also possible to choose **Fill To Rim**.

Stopping Criterion

- ☐ Fixed Object Number
- ☐ Object Volume Percentage / (%)
- ☐ Grammage / (g/m²)
- ☐ Density / (g/cm³)
- ☐ Object Weight Percentage / (%)
- ☒ Fill To Rim

Fill To Rim

Fill To Rim forces the fibers to keep piling until they reach the top of the bounding box in the Z-direction.



General Options

Define the general parameters temperature, random seed and parallelization.

Random Seed	42	Temperature	20	°C
Parallelization	8 Threads (Automatic Maximum) Edit...			

Temperature

When **Grammage** (or **Density** or **Object Weight Percentage**) is chosen as **Stopping Criterion**, a temperature can be entered. The temperature is considered for materials with temperature dependent density.

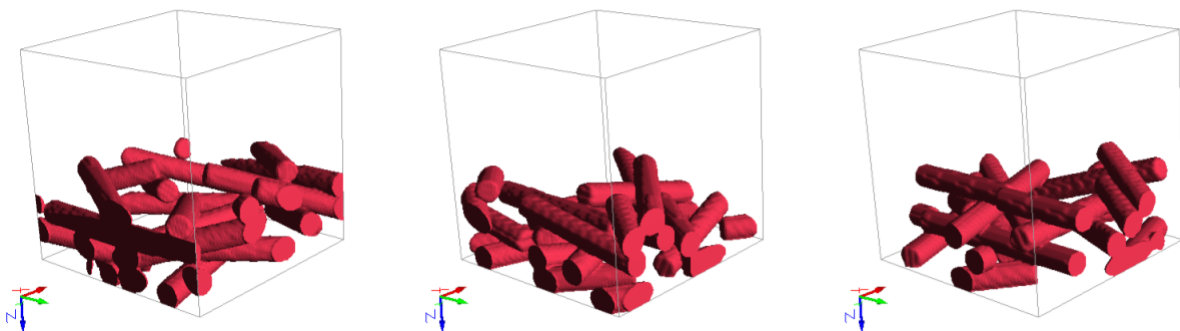
Choose the temperature in Kelvin, Celsius, or Fahrenheit.

Temperature	20	°C
		K
		°C
		°F

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, as shown by the **Structure ID** number in the Status section. The **Random Seed** is a non-negative integer number, it increases automatically with every generation run.

Varying the **Random Seed** allows generating different samples of the same structure for a series of experiments. In the following examples, all parameters are unchanged while the random seed is modified with every generation run.



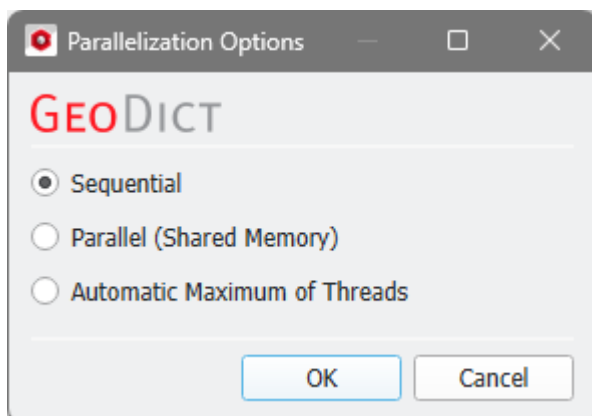
Parallelization

Control how many threads are used for the computation. Parallelization is possible if your license and hardware allow it.

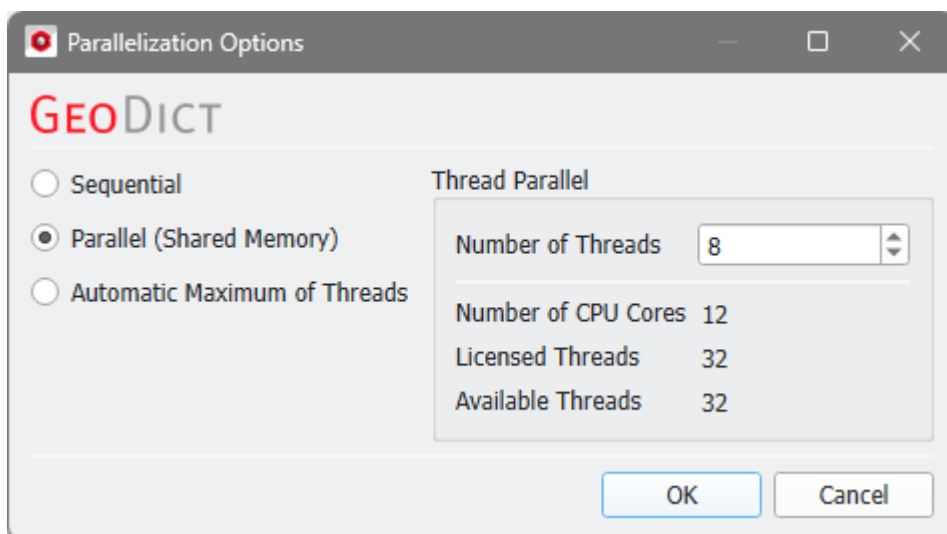
The **Parallelization Options** dialog opens when clicking the **Edit** button and you can choose between **Sequential**, **Parallel (Shared Memory)**, or **Automatic Maximum of Threads**.

Parallelization 12 Threads (Automatic Maximum)	Edit...
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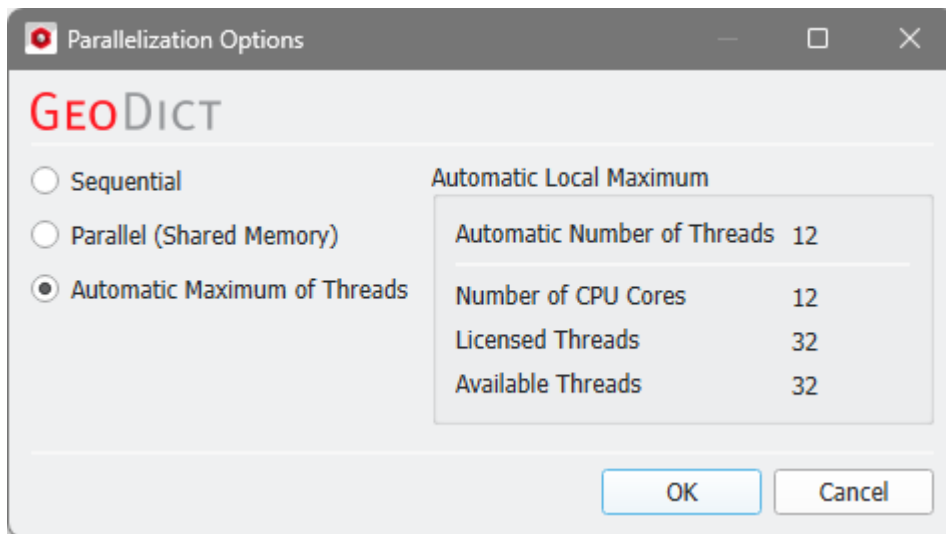
Selecting **Sequential** will not apply parallelization and only one thread is used for the computation.



When **Parallel (Shared Memory)** is selected, the **Number of Threads** can be entered. Below, the **Number of CPU Cores** that the current machine has, the maximum number of **Licensed Threads** and the number of those licensed threads that are available (**Available Threads**) are shown in the dialog. Of course, the maximal number of parallel processes you can use, is the smallest of those three numbers.



If **Automatic Maximum of Threads** is selected, the number of parallel processes is automatically selected for optimal speed, based on the CPU cores and licensed parallel processes.

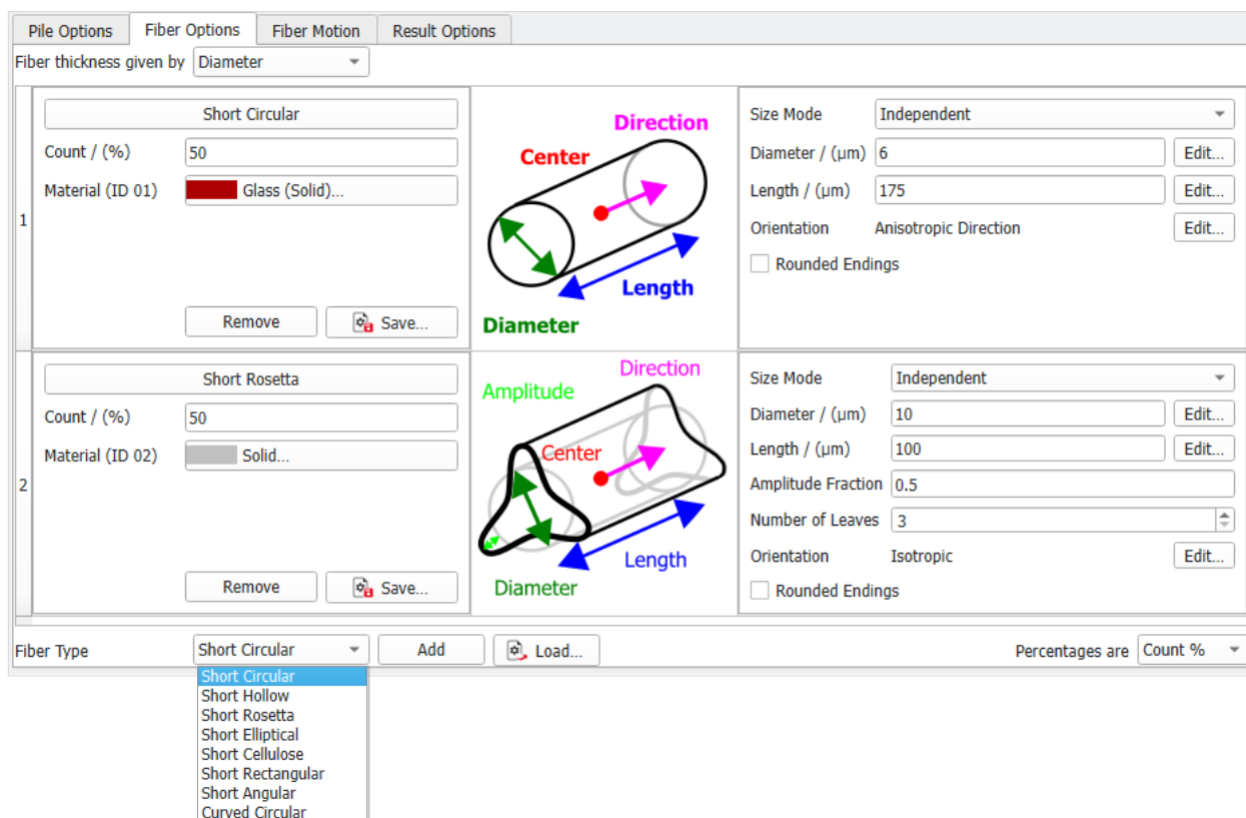


The **Automatic Local Maximum** of processes is automatically selected, which is the minimum of **Number of CPU Cores**, **Licensed Threads**, and **Available Threads**.

Fiber Options

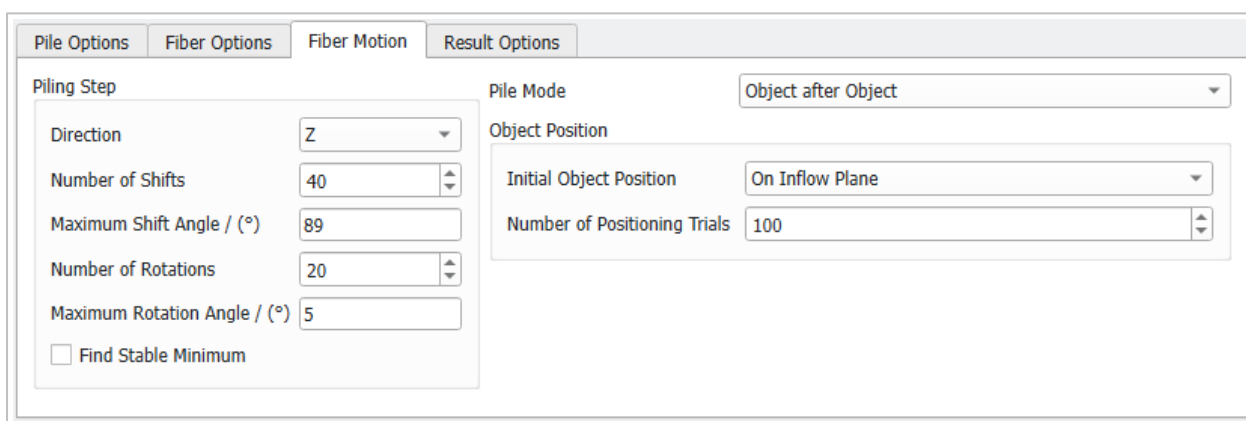
Define the geometrical properties of individual fiber types. All fiber options listed here can be separately set for each fiber type. Up to 254 different object types may be added to the same structure. The fiber types and their parameters are very similar to those defined for [Create](#)^[36]. However, the object list is limited to **Short** fibers (**Circular**, **Hollow**, **Rosetta**, **Elliptical**, **Cellulose**, **Rectangular**, and **Angular**) and **Curved Circular** fibers. The center position of the objects is a result of the piling process and cannot be specified.

The fibers for the piling of fibers are organized and listed in three columns. In the left one define the [Fiber Type](#)^[37] together with its percentage and material. The center one shows a [cross-section](#)^[43] of the chosen fiber type and in the right one you can edit the [fiber parameters](#)^[47]. In the bottom, find the options to choose additional fiber types and how the fiber percentage should be given.



Fiber Motion

The **Fiber Motion** parameters control the object's movement and initial position during the piling process, and are grouped into the **Piling Step**, and the **Object Position** panels. The **Pile Mode** can be selected from the pull-down menu.



The parameters are organized in two panels:

- [Piling Step](#)¹³¹
Define the parameters for the piling algorithm.
- [Pile Mode](#)¹³³
Define the pile mode and initial object positions.

Piling Step

The object movements during the piling steps are mainly defined by the falling **Direction** and by the automatic finding of the stable minimum (**Find Stable Minimum**).

When the result is unsatisfactory, additional parameters can be used to refine it (**Number of Shifts**, **Maximum Shift Angle**, **Number of Rotations** per shift, and **Maximum Rotation Angle**).

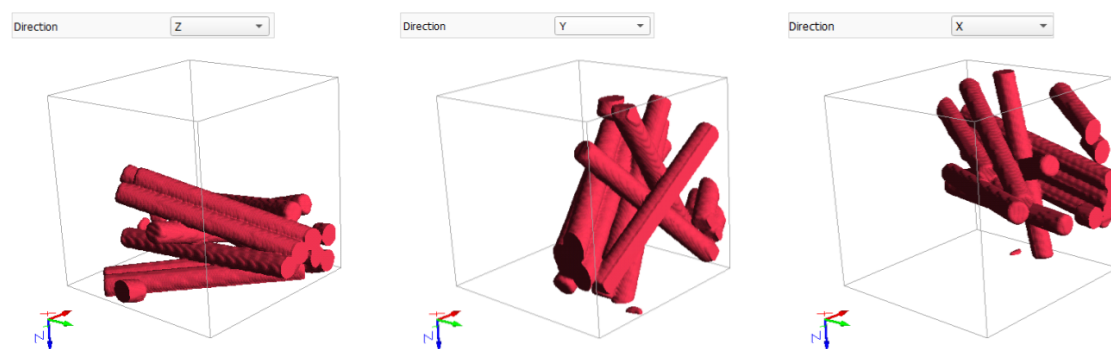
Piling Step

Direction	Z
Number of Shifts	40
Maximum Shift Angle / (°)	89
Number of Rotations	20
Maximum Rotation Angle / (°)	5
☐ Find Stable Minimum	

The option to find the stable minimum is not available when all objects fall at the same time ([Pile Mode → All Objects at Once](#)¹³³).

✓ Direction

The **Direction** in which the piling process happens can be chosen from the pull-down menu. For all three axes, the objects fall towards the positive direction (X+, Y+, or Z+). Observe the piling of objects with **On Inflow Plane Center** as initial object position, falling from all three directions.



✓ Number of Shifts, Maximum Shift Angle, Number of Rotations, Maximum Rotation Angle

Throughout the piling process, the objects fall and roll to their final location in the structure. After the fall, i.e., after hitting an obstacle as the bottom domain boundary or another object, the objects shift and rotate as many times as defined by the values for **Number of Shifts** and **Number of Rotations** before they come to rest at the bottom

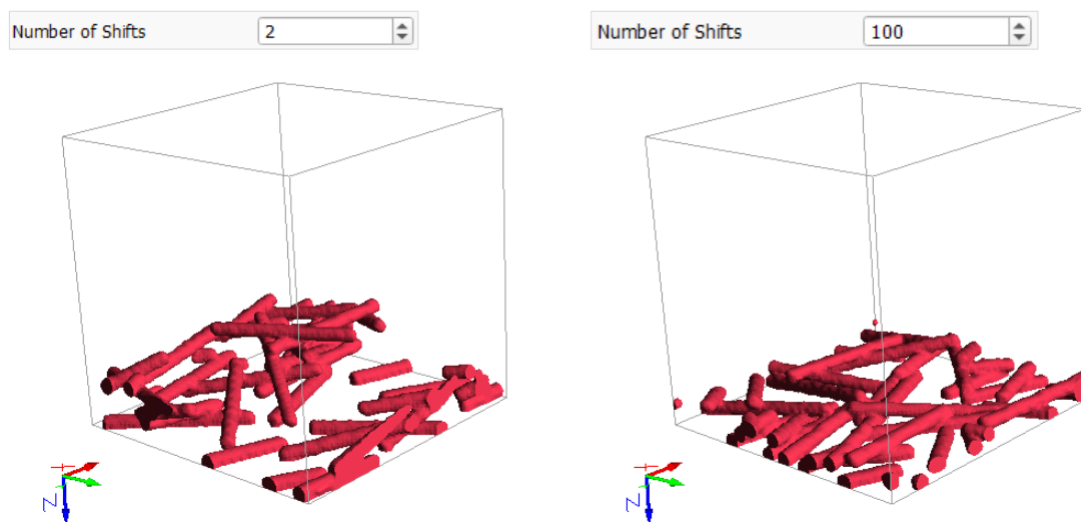
of the structure. Low values for shifts and rotations produce structures with objects that settle earlier compared to larger values of these parameters, resulting in a lower packing density.

In detail, the algorithm for each shift tries the given number of rotations. If a better position is found for the object, lower in the specified direction and without overlapping with other objects, it is used as a new point for the object. Then, the numbers of shift and rotation are reset. The algorithm terminates if no new position is found for the given number of shifts and rotations.

The **Maximum Shift Angle** restricts the angle that the objects can shift with respect to the piling direction. The maximum shift angle must be smaller than 90° .

The **Maximum Rotation Angle** describes the maximum angle the objects can rotate from step to step. The object is rotated around the center defined for the object, which in most cases is the center of mass.

Observe the effect of setting a low or a high **Number of Shifts** value on the final position of objects in the otherwise same structure.

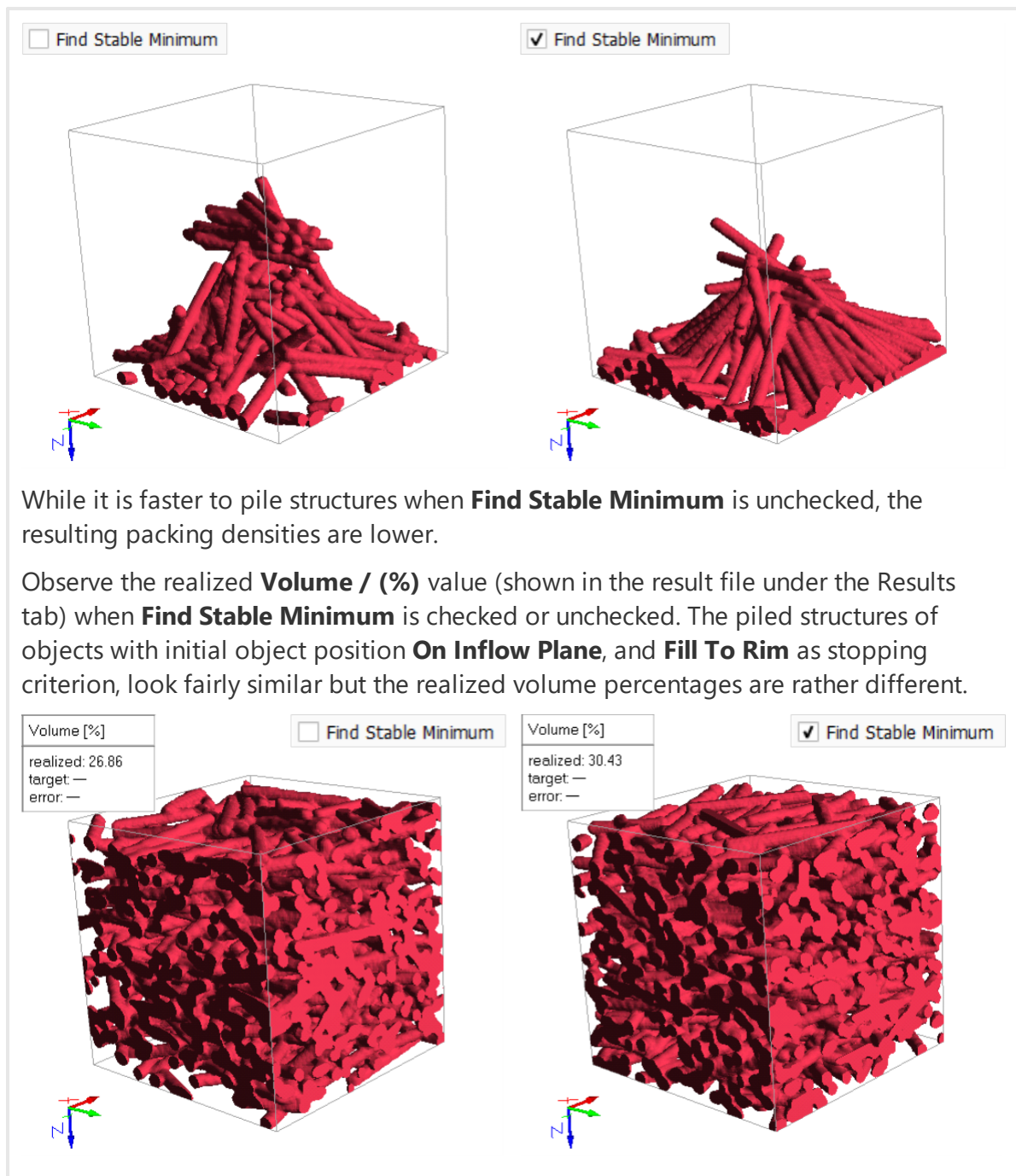


✓ Find Stable Minimum

When checking **Find Stable Minimum**, each object is checked to have a stable state with respect to gravity at the end of the piling process.

When an object cannot be moved further downwards, it is checked if it is possible to move it in the plane perpendicular to the specified direction without obtaining overlap with other objects to find a new position where the potential energy can be further reduced. If not, it has the lowest position possible and is considered as stable.

Observe the effect of checking or unchecking **Find Stable Minimum** in the piling 100 objects with initial object position **On Inflow Plane Center**.



While it is faster to pile structures when **Find Stable Minimum** is unchecked, the resulting packing densities are lower.

Observe the realized **Volume / (%)** value (shown in the result file under the Results tab) when **Find Stable Minimum** is checked or unchecked. The piled structures of objects with initial object position **On Inflow Plane**, and **Fill To Rim** as stopping criterion, look fairly similar but the realized volume percentages are rather different.

✓ Maximum Check Length

The **Maximum Check Length** is a further refinement when finding the stable minimum. For every object, the algorithm checks for an even more stable position around the already reached minimum with a radius defined by the voxel value entered in the field. A higher value increases the stability of the pile.

Pile Mode

Define the pile mode and the initial object position.

Pile Mode

Select from the pull-down menu whether the objects should fall one after another (**Object after Object**) or all should fall at once (**All Objects at Once**).

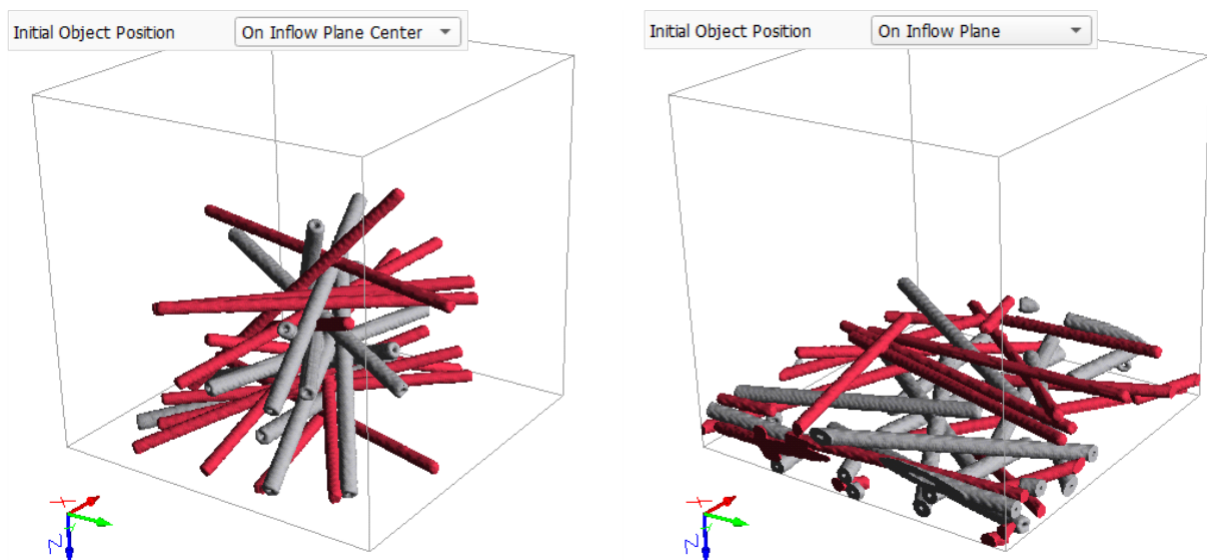
Pile Mode Object after Object	Pile Mode All Objects at Once
Object Position Initial Object Position On Inflow Plane	Object Position Initial Object Position Objects from gad-File
Number of Positioning Trials 100	Start File (*.gad) [] Browse...
	Loosen Objects 0
	Lift Objects / (μm) 0

Object Position

When choosing **Object after Object**, the pull-down menu for **Initial Object Position** allows setting the initial position from which the piling objects are set to fall: the whole initial position plane (**On Inflow Plane**), from its center (**On Inflow Plane Center**), or to originate from an existing structure (**Objects from gad-File**). When **All Objects at Once** is selected, the objects must be loaded from a *.gad file.

On Inflow Plane or On Inflow Plane Center

When piling objects **On Inflow Plane** or **On Inflow Plane Center**, the **Number of Positioning Trials** can be adjusted at the cost of additional runtime to increase the quality of the piled structure.



Objects from gad-File

When piling from an existing *.gad file, the objects are taken from that file. Thus, no objects (and their geometry parameters) need to be selected through the **Fiber Options** tab. Clicking **Browse**, a structure saved in GAD format can be selected as the origin of the objects.



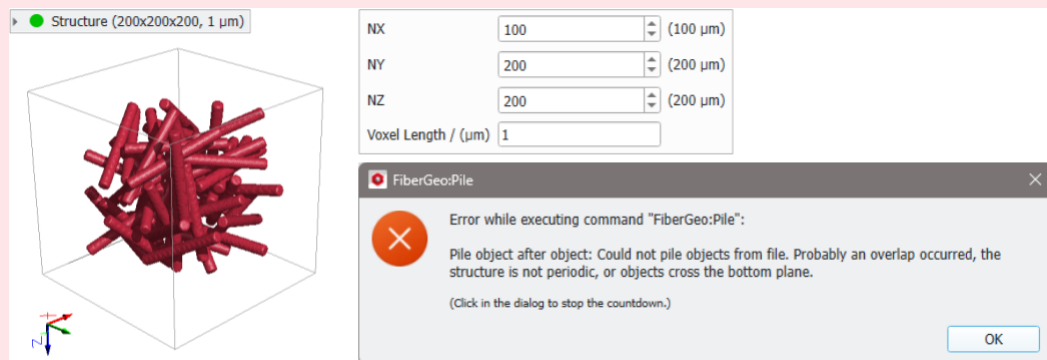
Important! Structures in GAD format to be used for piling must conform to certain requirements (no overlapping, periodicity, no objects crossing bottom plate) and should be generated for later piling with these requirements in mind. Overlap can be removed after generation using **GadGeo** → **Remove Object Overlap**, as explained in the GadGeo chapter.

✓ Requirements for objects from gad-file

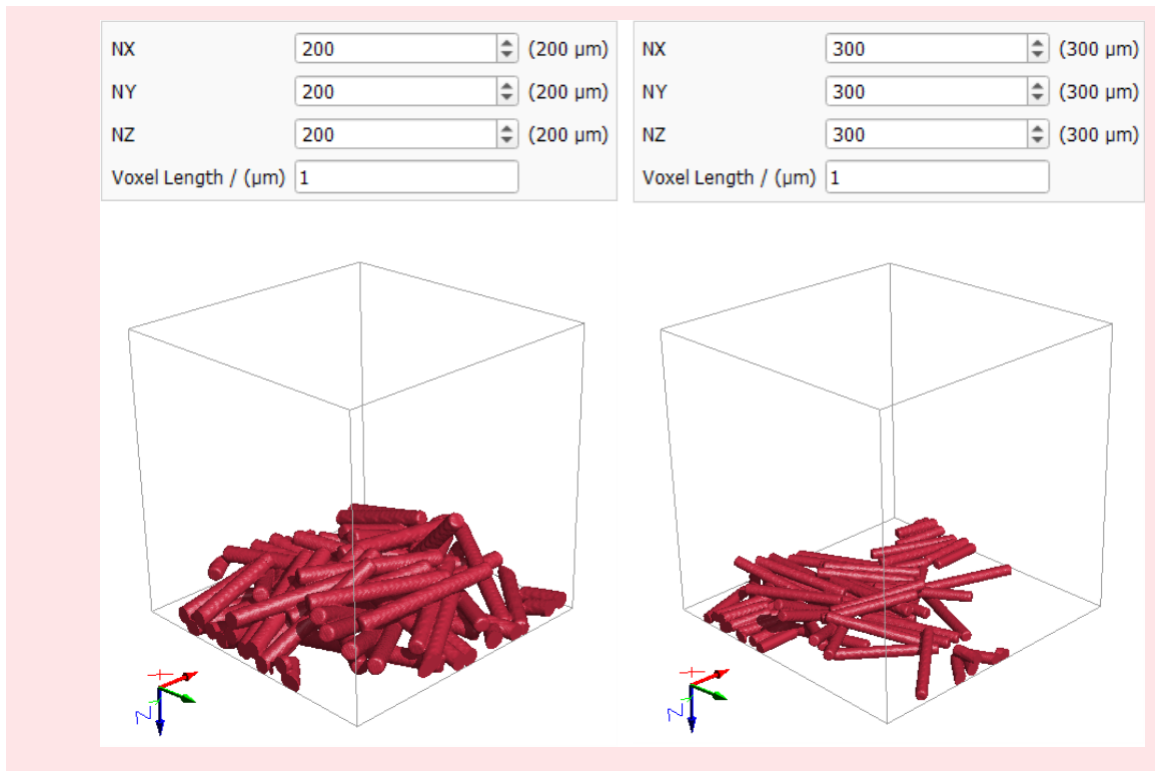


Important! Before piling, the domain size in all three directions under the **Pile Options** tab must be set to at least the size of the gad file.

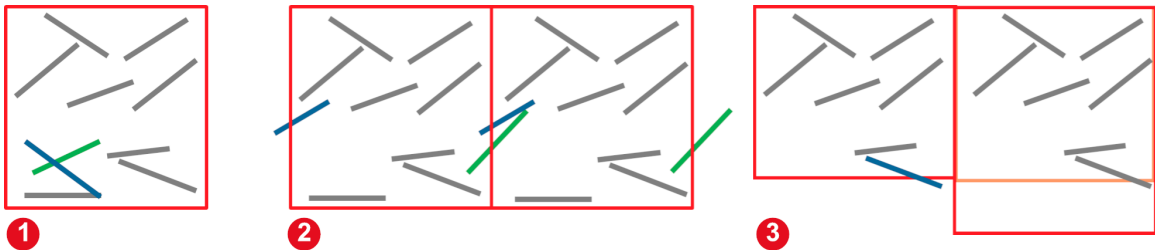
Consider the example gad file in the image below. It has a domain size of 200x200x200 voxel. Thus, entering less voxels in one direction leads to an error message:



But the following domain size settings are valid:



Assuming the Z-direction to be the piling direction, and downwards to be the positive direction (Z+), the following situations have to be considered:

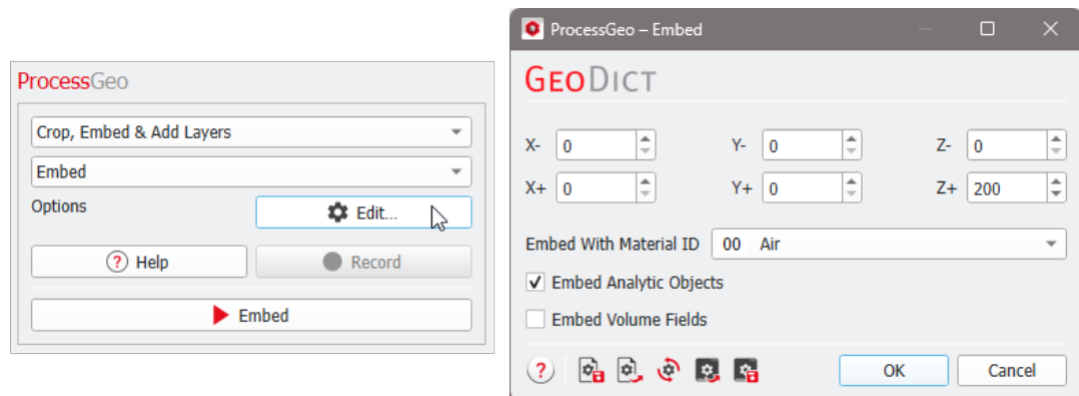


1. Touching, but not overlapping, is allowed for piling. The initial structure must be generated without overlapping. For example, by selecting Remove Overlap when generating with Create (or other GeoDict structure generators).
2. Periodicity is needed in the X and Y directions for piling, to avoid undesired intersections at the edge of the structure. The initial GAD file must be generated to be periodic (in all directions).
3. No objects are allowed to drop off the bottom of the structure. When this happens, the dimensions of the initial *.gad file must be processed to include the extruding object.

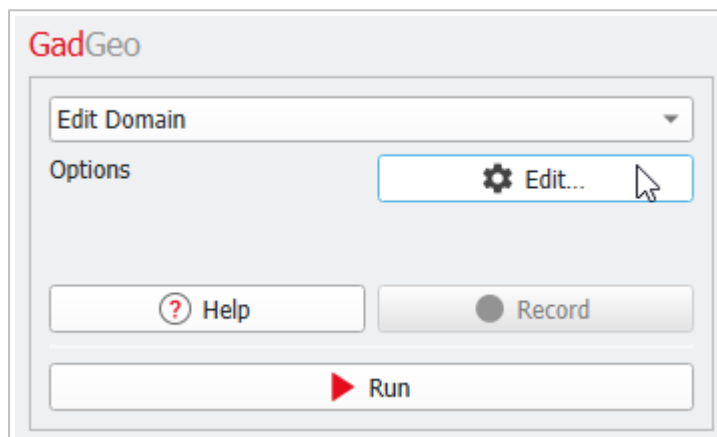
The dimensions of the initial *.gad file can be changed by adding enough empty voxels in Z+ direction. The number of voxels to be added depends on how far objects overlap the original domain in Z-direction. Two different possibilities are available for this task:

1. **Model** → **ProcessGeo** → **Embed** and check **Embed Analytic Objects**. This explicitly

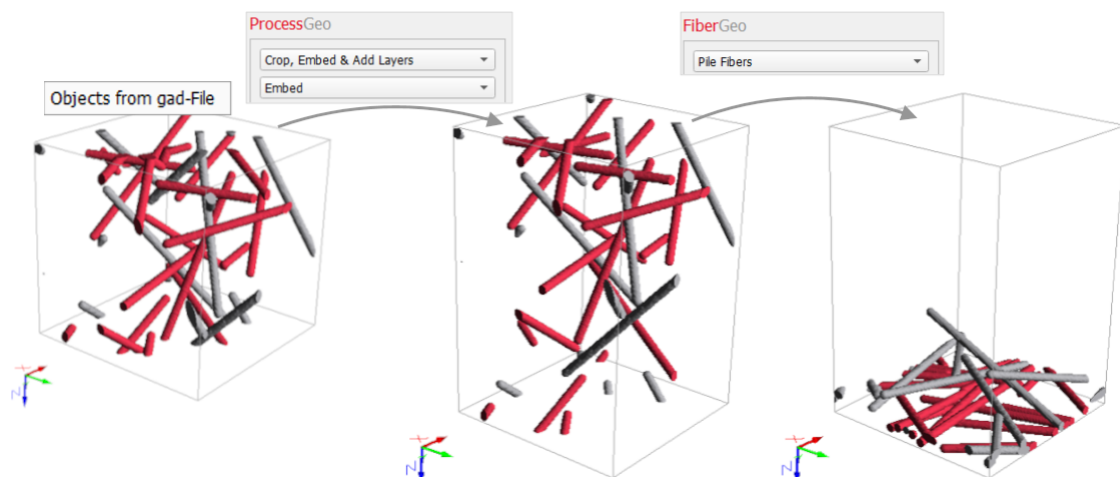
adds voxels in the specified direction. For more information refer to the ProcessGeo chapter.



2. **Model** → **GadGeo** → **Edit Domain**. This changes the domain size as defined. For more information refer to the GadGeo chapter.



Example:



✓ Parameters for objects from gad file

Before the piling process starts from a structure in GAD-format, the initial position of

the contained objects can be slightly changed by two parameters.

Loosen Objects	0
Lift Objects / (μm)	0

The distance between the objects in the piling direction can be enlarged by the factor entered in **Loosen Objects**.

Additionally, all objects can be lifted by the distance entered in **Lift Objects**. For example, these parameters can be used to generate structures similar to those from sieving processes combined with additional shaking.

Result Options

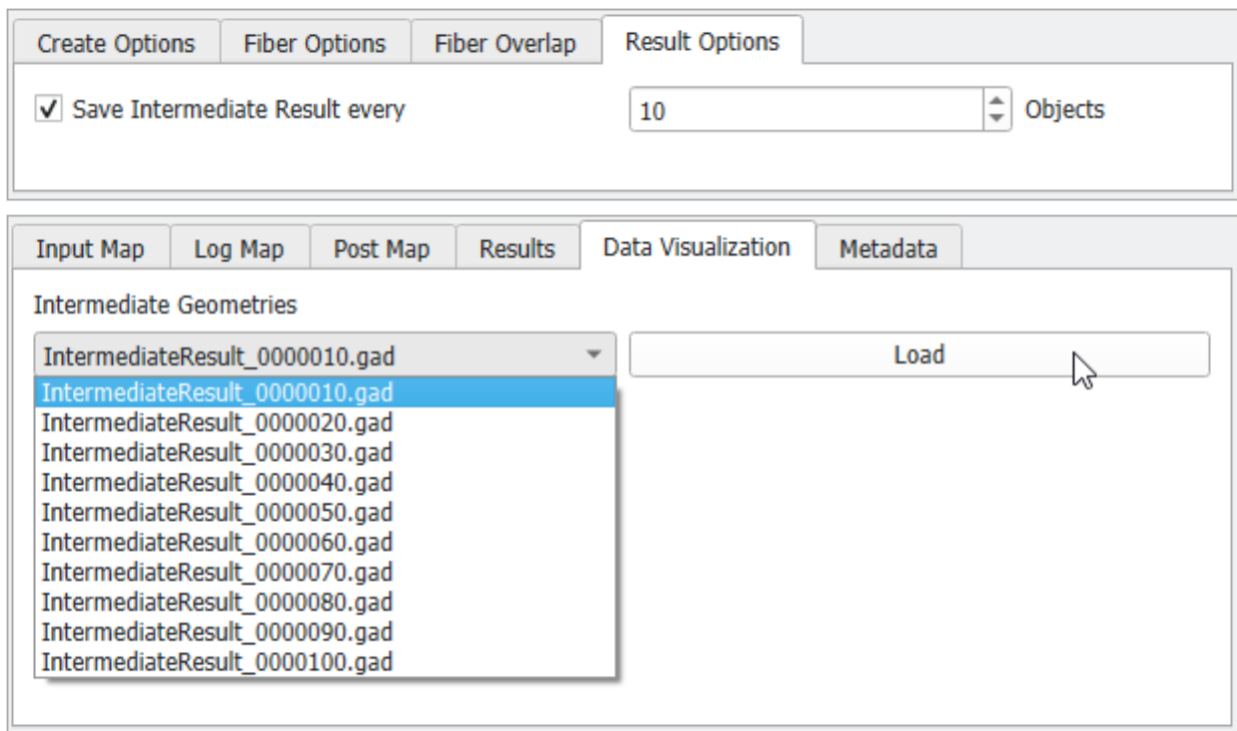
The generated structure is always saved as a **GeoDict structure file (*.gdt)** (GeoDict binary data). The file is placed in an automatically created result folder inside the chosen project folder (**File** → **Choose Project Folder...** in the menu bar).

The result file as well as the result folder take the name entered as **Result File Name (*.gdr)** at the top of the dialog.

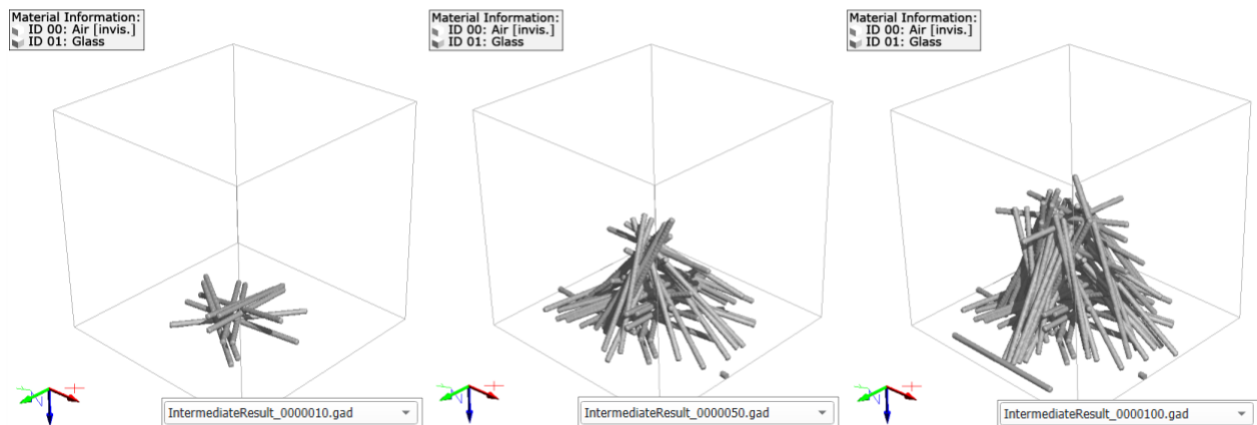
An additional option to save the generated structure data is to check **Save Intermediate Result every** and enter a number of **Objects** in the box. As objects are added to the structure during the generation, an intermediate result file is saved each time the number of placed objects reaches a multiple of the entered value.

This option may be interesting when studying the properties of a series of structures with increasing density.

After running the generation, the intermediate geometries can be found as ***.gad** analytic files in the result folder and can be loaded directly from the **Result Viewer** of the *.gdr result file.



Below find an example for the piling of 100 fibers. Observe how more and more fibers are added.



1.2.2 Results

The generated structure is shown in the visualization area. Learn more about visualization in GeoDict in the **Visualization** chapter.

The result file is automatically opened in the Result Viewer and shows structure statistics in the **Results-Report** and **Results-Plot** tabs. Additionally, it offers 3D **Data Visualization** options depending on the generation settings. Find more information on GeoDict result files in the **Result Viewer** chapter.

Results - Report

The first two tables show the **Absolute** and **Relative object distribution** for all object types.

Input Map

Log Map

Post Map

Results

Data Visualization

Metadata

Report

Plots

Map

Absolute object distribution:

	Count	Volume / (%)	Grammage / (g/m ²)	Density / (g/cm ³)	Weight / (%)
Total	realized: 1794 target: --- error: ---	realized: 34.99 target: 35.00 error: -0.01	realized: --- target: --- error: ---	realized: --- target: --- error: ---	realized: --- target: --- error: ---
Object type 1	realized: 992 target: --- error: ---	realized: 17.47 target: 17.50 error: -0.03	realized: --- target: --- error: ---	realized: --- target: --- error: ---	realized: --- target: --- error: ---
Object type 2	realized: 801 target: --- error: ---	realized: 17.52 target: 17.50 error: 0.02	realized: --- target: --- error: ---	realized: --- target: --- error: ---	realized: --- target: --- error: ---

Stopping criterion error: -0.016 %

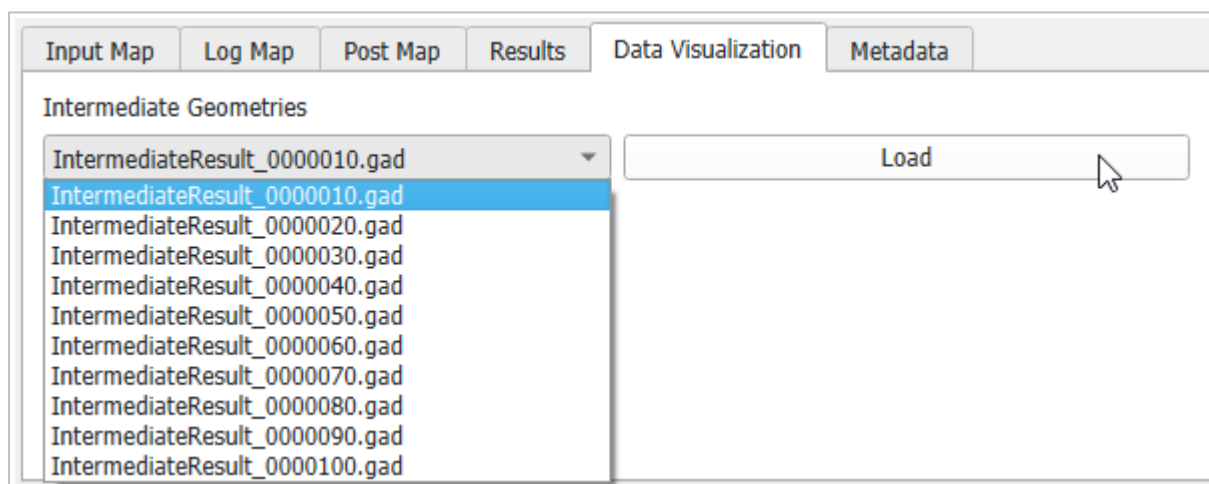
Relative object distribution:

	Count / (%)	Volume / (%)	Weight / (%)
Object type 1	realized: 55.35 target: --- error: ---	realized: 49.93 target: 50.00 error: -0.14%	realized: --- target: --- error: ---
Object type 2	realized: 44.65 target: --- error: ---	realized: 50.07 target: 50.00 error: 0.14%	realized: --- target: --- error: ---

Maximal probability error: 0.14%

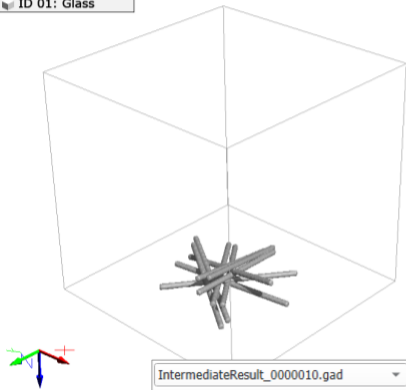
Data Visualization

When selecting **Save Intermediate Results every # Objects** under the **Result Options** tab, you can open the intermediate geometry files (*.gad) after selecting them in the pull-down menu.

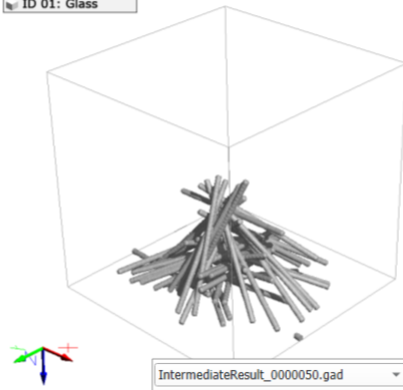


Below find an example for the piling of 100 fibers. Observe how more and more fibers are added.

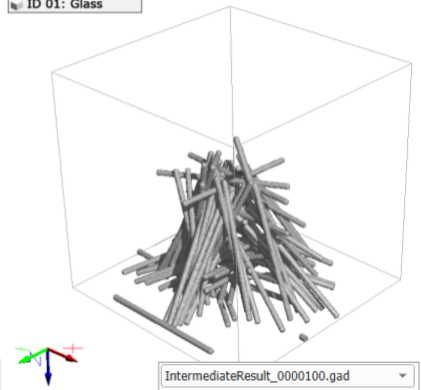
Material Information:
ID 00: Air [invis.]
ID 01: Glass



Material Information:
ID 00: Air [invis.]
ID 01: Glass



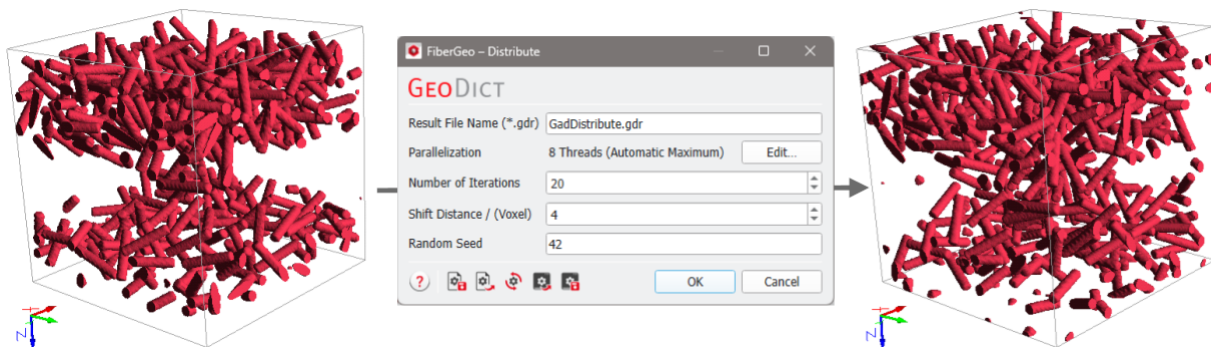
Material Information:
ID 00: Air [invis.]
ID 01: Glass



1.3 Distribute

When **Distribute** is selected from the pull-down menu in the **FiberGeo** section, the fibers are uniformly spread throughout the structure. Only structures that contain analytic information (GAD objects) can be used for the distribution of objects. For example, such information is available after creating a structure with FiberGeo.

Observe the process of distributing the short circular fibers in a 200 x 200 x 200 structure, periodic in all directions, generated with **FiberGeo Create** with a Voxel Length of 1 μm . The fiber centers follow a density distribution, which results in a layered structure.



Clicking the **Options' Edit...** button opens the **Distribute Options** dialog.

When the desired parameters have been entered in the **Distribute** options dialog, clicking **OK** closes the dialog and returns to the **FiberGeo** section.

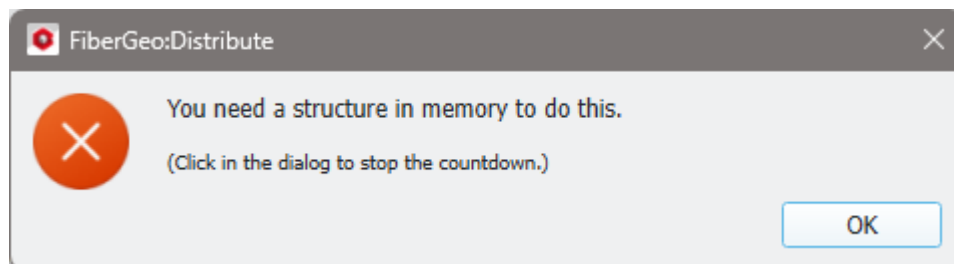
Clicking **Generate** starts the distribution process.

✓ Preparations and Requirements

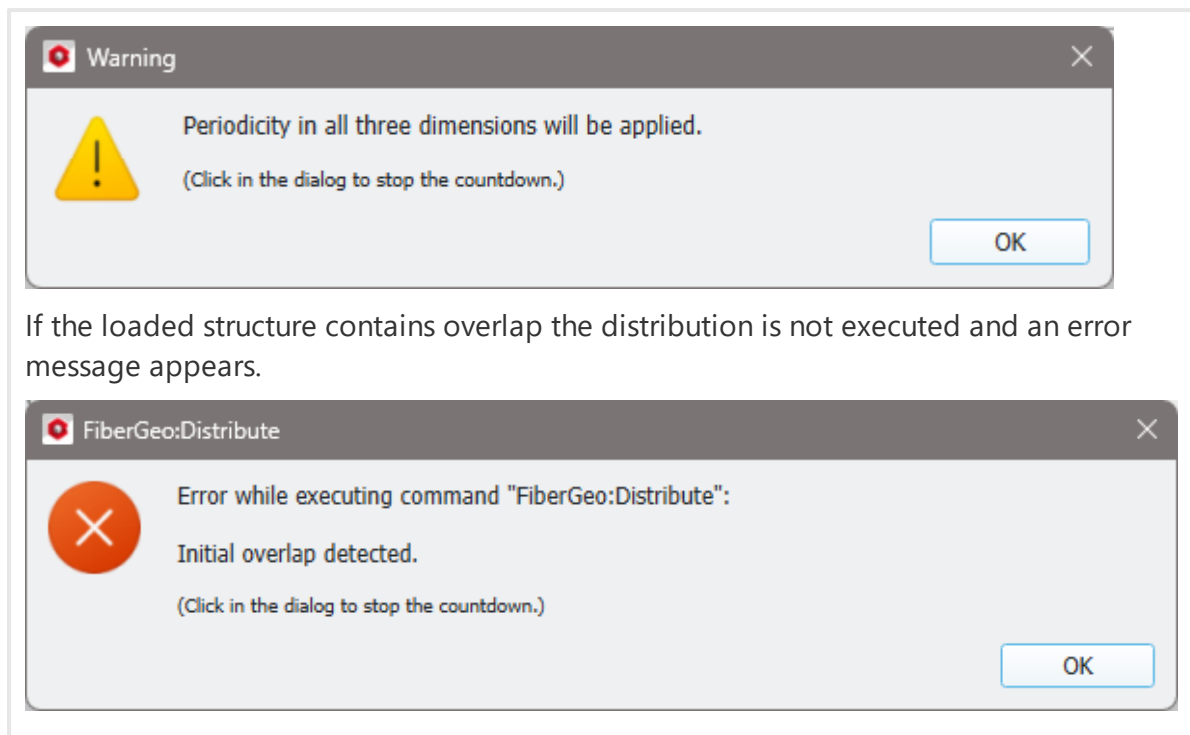
A fibrous structure containing GAD information has to be in memory.

To use this feature, the domain must be periodic, and the objects are not allowed to overlap. **Distribute** allows to create a homogeneous structure even for structures created with **Pile** where boundary effects occur in the lay-down direction.

Without a structure in memory, clicking **Generate** results in an error message.



When the structure in the selected file is not periodic, an information message appears indicating that periodicity will be applied in all three directions and the loaded structure will be treated as periodic. The GAD objects are still distributed.



If the loaded structure contains overlap the distribution is not executed and an error message appears.

Distribute Parameters

In the **Distribute Options** dialog, **Number of Iterations**, **Shift Distance**, and **Random Seed** specify the distribution process.

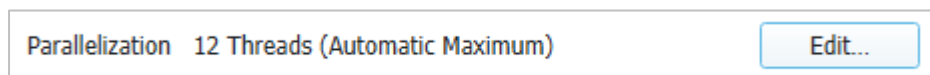
✓ Result File Name

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

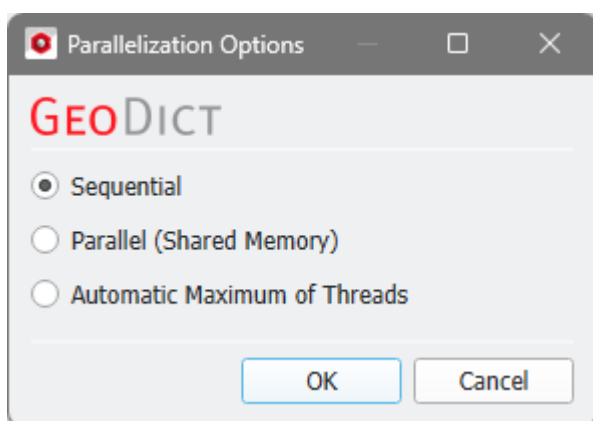
✓ Parallelization

Control how many threads are used for the computation. Parallelization is possible if your license and hardware allow it.

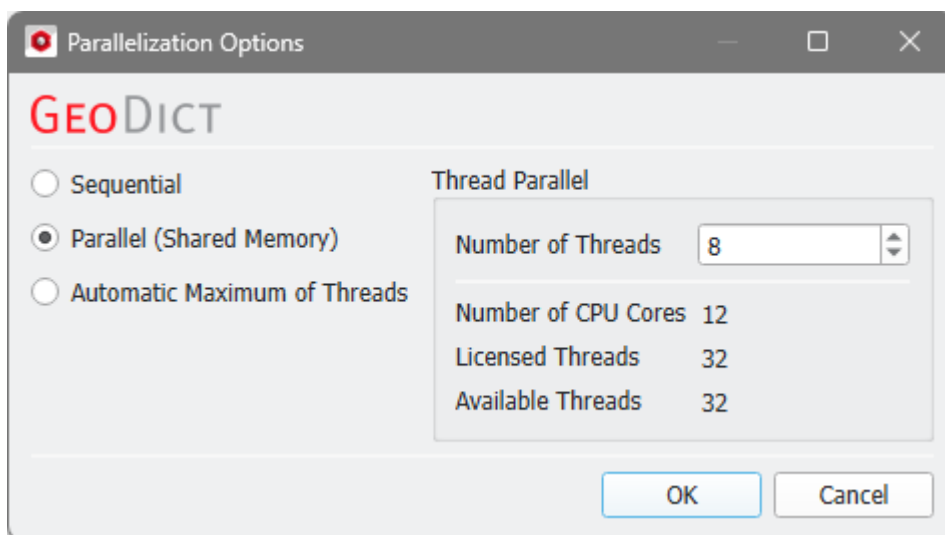
The **Parallelization Options** dialog opens when clicking the **Edit** button and you can choose between **Sequential**, **Parallel (Shared Memory)**, or **Automatic Maximum of Threads**.



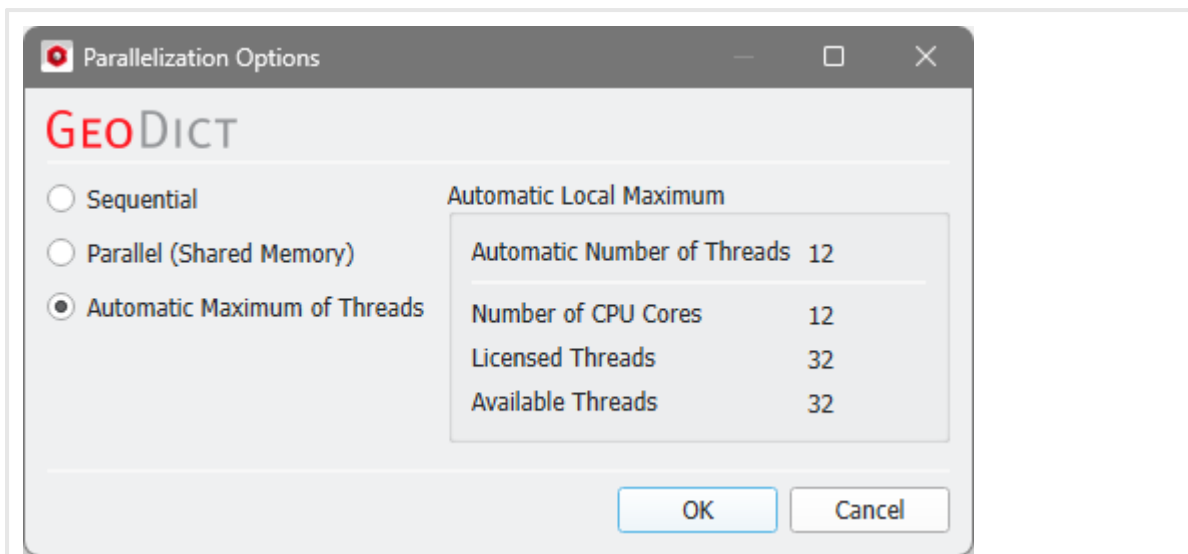
Selecting **Sequential** will not apply parallelization and only one thread is used for the computation.



When **Parallel (Shared Memory)** is selected, the **Number of Threads** can be entered. Below, the **Number of CPU Cores** that the current machine has, the maximum number of **Licensed Threads** and the number of those licensed threads that are available (**Available Threads**) are shown in the dialog. Of course, the maximal number of parallel processes you can use, is the smallest of those three numbers.



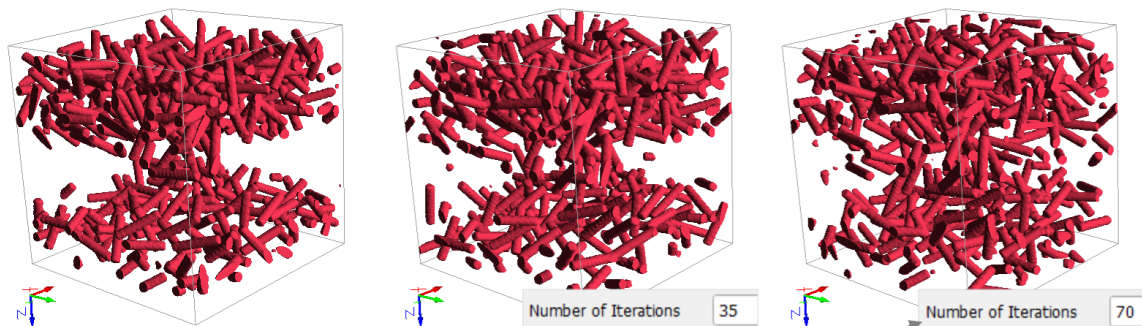
If **Automatic Maximum of Threads** is selected, the number of parallel processes is automatically selected for optimal speed, based on the CPU cores and licensed parallel processes.



The **Automatic Local Maximum** of processes is automatically selected, which is the minimum of **Number of CPU Cores**, **Licensed Threads**, and **Available Threads**.

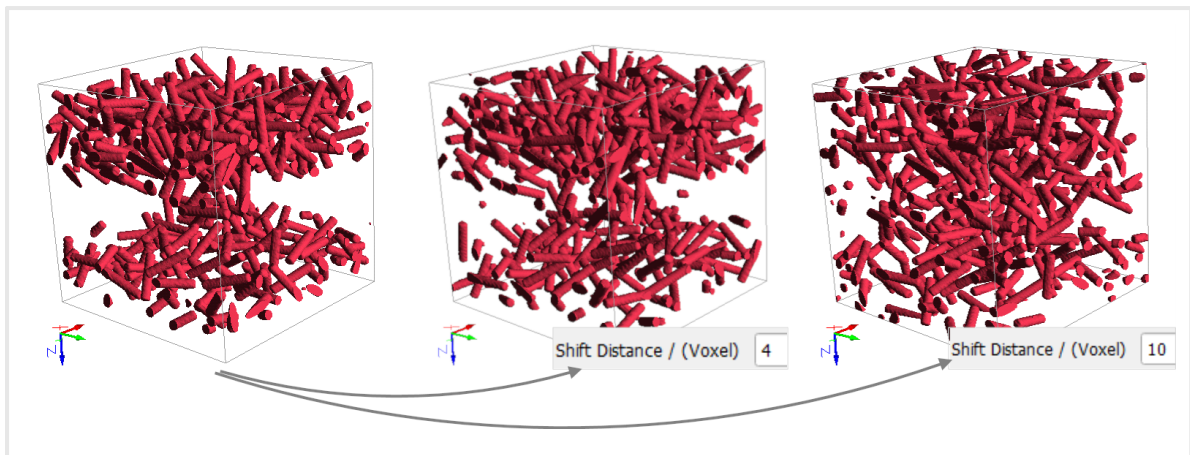
✓ Number of Iterations

The **Number of Iterations** determines how many distribution steps are done. More distribution steps lead to a wider distribution of the objects, which is getting closer to a uniform distribution.



✓ Shift Distance

The **Shift Distance** determines the maximal object movement during a single iteration. Large shift distances lead to more computational time per iteration. Observe the effect of increasing the shift distance from 1 to 4 and then to 10, while the number of iterations is kept at 35.

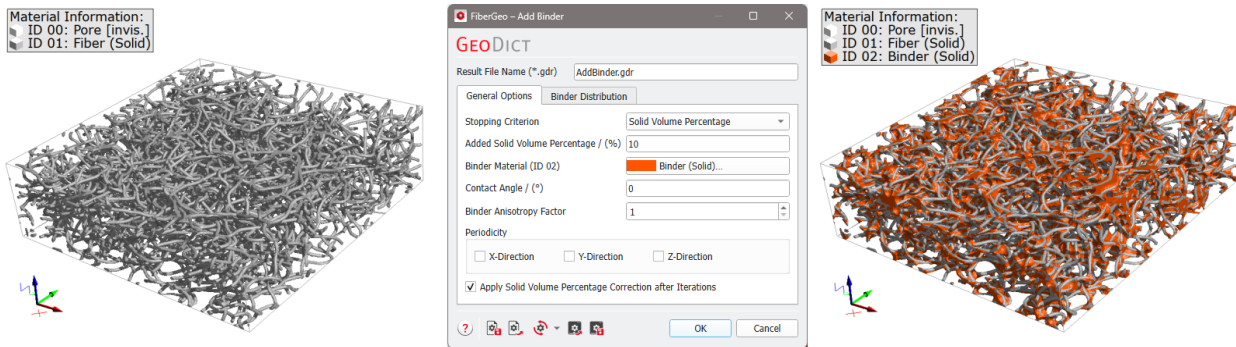


✓ Random Seed

Random Seed initializes the random number generator behind the object distribution. Changing its value produces different sequences of random numbers and hence, different realizations of the distribution. If all settings are equal, distributing the same initial structure with the same **Random Seed** value produces exactly the same structure. The **Random Seed** is a non-negative integer number, it increases automatically with every generation run.

1.4 Add Binder

To generate realistic models of nonwoven fibrous structures (for example for the technical textile industry), the correct addition of binder is essential. It is used to provide structural integrity by bonding the fibers.



Adding binder to a structure means adding material in the shape of a concave meniscus in the pore space where surfaces in that structure's material get close together. If there is no pore material in the structure, a warning is given.

For hollow objects, such as cellulose fibers, curved cellulose fibers, hollow fibers, curved hollow fibers, and hollow spheres, the algorithm under **Add Binder** needs analytic data (**GAD objects**) to discern that the empty voxels inside the fibers are not part of the pore space. Without analytic data, i.e., when using voxelized models, binder is also added inside the hollow fibers, which is physically inaccurate.

The Add Binder command:

- [Options](#)¹⁴⁷
Define the Add Binder parameters.
- [Results](#)¹⁶⁰
View the Add Binder results.

1.4.1 Options

Clicking the **Options' Edit...** button opens the **Add Binder** dialog.

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

Clicking **OK** in it closes the dialog and returns to the module section. Clicking **Generate** starts the process.

The options are organized into tabs:

- [General Options](#)¹⁴⁸
Define shape and material of the binder.
- [Binder Distribution](#)¹⁵⁷
Define how the binder should be distributed throughout the domain.

General Options

Define the general options, as the amount of binder to be added, the material and stopping criteria.

General Options

Binder Distribution

Stopping Criterion

Solid Volume Percentage

Added Solid Volume Percentage / (%)

10

Binder Material (ID 02)

Binder (Solid)...

Contact Angle / (°)

0

Binder Anisotropy Factor

1

Periodicity

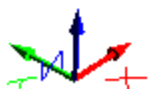
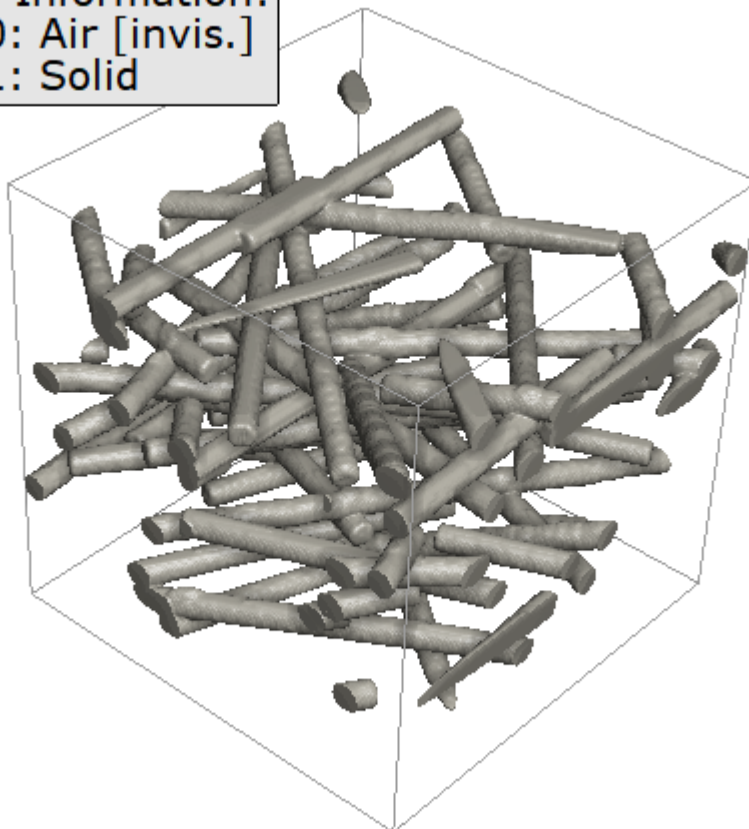
☐ X-Direction
☐ Y-Direction
☐ Z-Direction

☒ Apply Solid Volume Percentage Correction after Iterations

Stopping Criterion

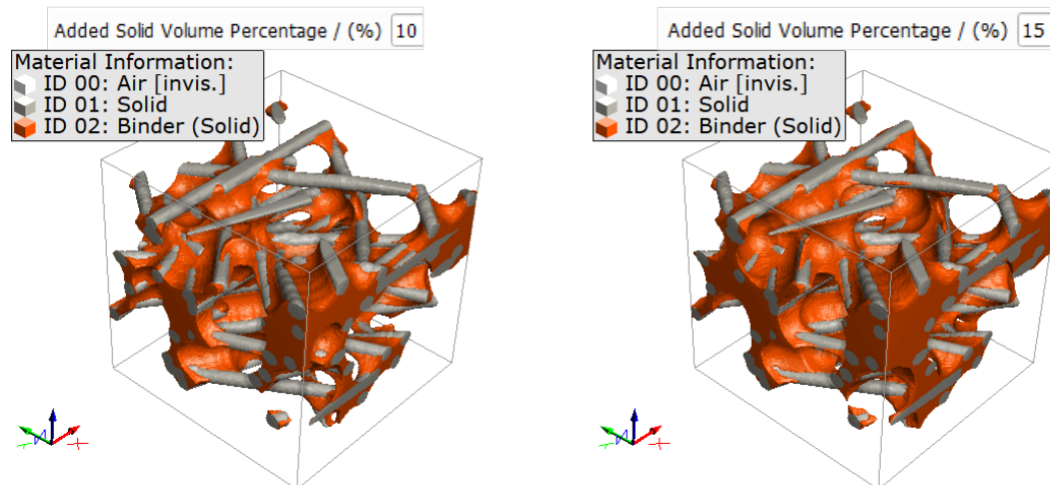
You may choose the most practical stopping criterion when adding binder. The chosen **Stopping Criterion** interrupts the addition of binder when it is reached. The possible stopping criteria are **Solid Volume Percentage**, **Weight Percentage**, and **Grammage**.

Material Information:
 ID 00: Air [invis.]
 ID 01: Solid



✓ Solid Volume Percentage

The process is stopped if the binder volume reaches the desired **Added Solid Volume Percentage**.



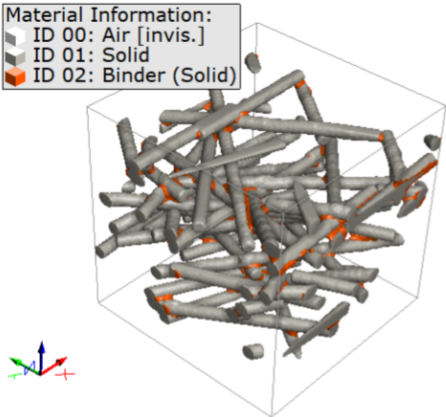
✓ Weight Percentage

The process is stopped if the weight of binder reaches a certain percentage of the weight of material. See [below](#) ¹⁵¹ how to select a material for the binder.

It is necessary to set the density for the structure's material (**Material Density**) and for the binder material (**Binder Density**) both in g/cm^3 , as well as the desired (weight) percentage of binder material to structure material (**Binder Weight Percentage**, in %). That is, a binder weight percentage of 20 means that there are 20 g of binder added per 100 g of objects in the structure.

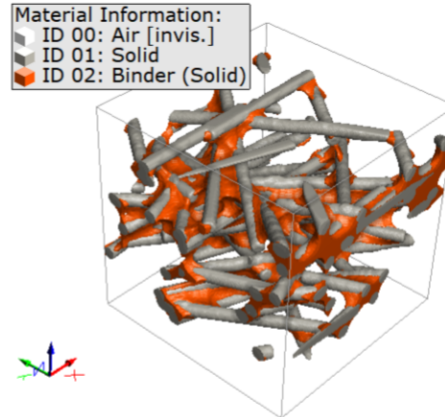
Stopping Criterion	Weight Percentage
Binder Weight Percentage / (%)	20
Material Density / (g/cm^3)	1
Binder Material (ID 02)	 Binder (Solid)...
Binder Density / (g/cm^3)	2.70009

In the following example, two types of binder (high density: 5 g/cm^3 and low density: 0.5 g/cm^3) are added to a structure material with a density of 1.1399 g/cm^3 . Setting a binder weight percentage of 20% (20 g binder/100 g objects), the amount of binder material deposited is much larger when the binder is less dense.



Material Information:
 ID 00: Air [invis.]
 ID 01: Solid
 ID 02: Binder (Solid)

Stopping Criterion	Weight Percentage
Binder Weight Percentage / (%)	20
Material Density / (g/cm³)	1.1399
Binder Material (ID 02)	Binder (Solid)...
Binder Density / (g/cm³)	5



Material Information:
 ID 00: Air [invis.]
 ID 01: Solid
 ID 02: Binder (Solid)

Stopping Criterion	Weight Percentage
Binder Weight Percentage / (%)	20
Material Density / (g/cm³)	1.1399
Binder Material (ID 02)	Binder (Solid)...
Binder Density / (g/cm³)	0.5

For **Weight Percentage**, when **Manual** or **Undefined** are selected, you must enter the density of the binder (**Binder Density (g/cm³)**). If a material is selected from the database, the **Binder Density** of the binder material is automatically entered. If a manual material is used frequently, it is useful to save it to the material database.

✓ Grammage

The addition of binder stops when the **Added Grammage** (material and binder, g/m²) is reached.

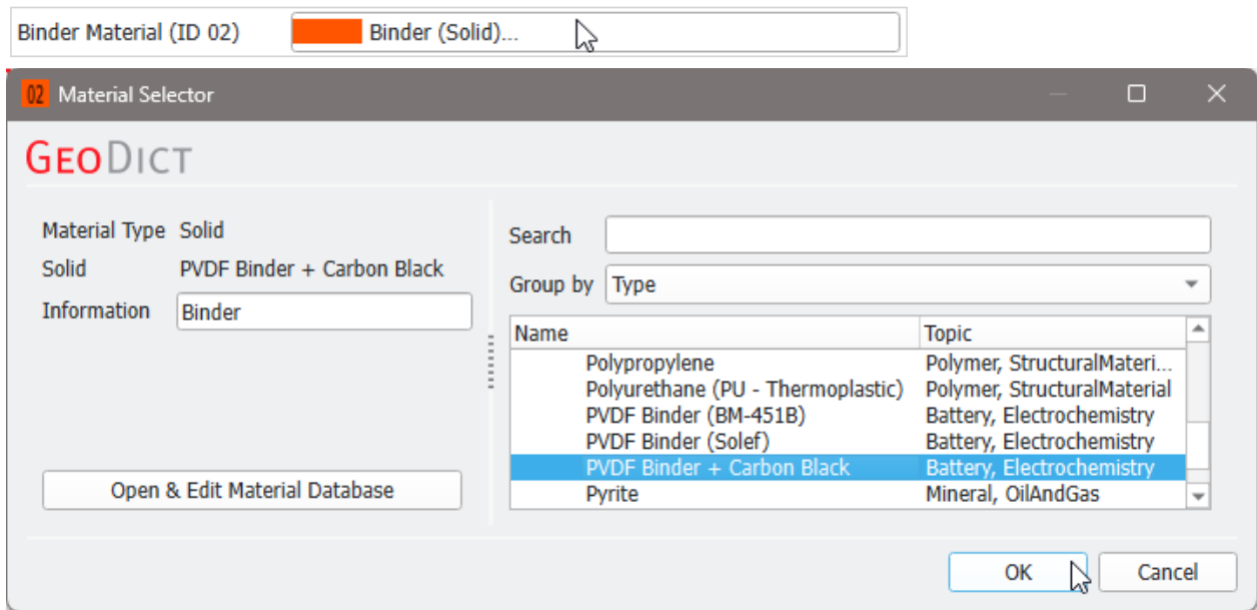
See [below](#) , how to select a material for the binder.

Stopping Criterion	Grammage
Added Grammage / (g/m²)	10
Binder Material (ID 02)	Binder (Solid)...
Binder Density / (g/cm³)	2.7

For grammage, when manual or undefined are selected, the density of the binder is not automatically taken from the database and you must enter it manually (**Binder Density (g/cm³)**). If a manual material is used frequently, it is useful to save it to the material database.

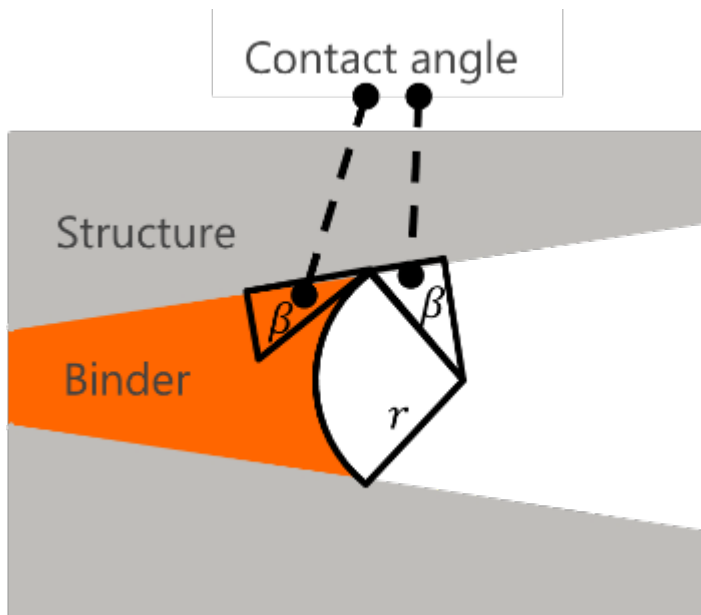
Binder Material

The **Binder Material** is assigned to the next available Material ID, and the appropriate material to be used as binder should be selected from the material database by clicking the button.



Contact Angle

The **Contact Angle** defines the angle in which the binder is deposited in relation to the materials in the structure. Values between 0° and 60° are accepted. When entering values larger than 60° , the value will be changed to 60° automatically. The contact angle helps to optimize and realistically model the addition of binder.



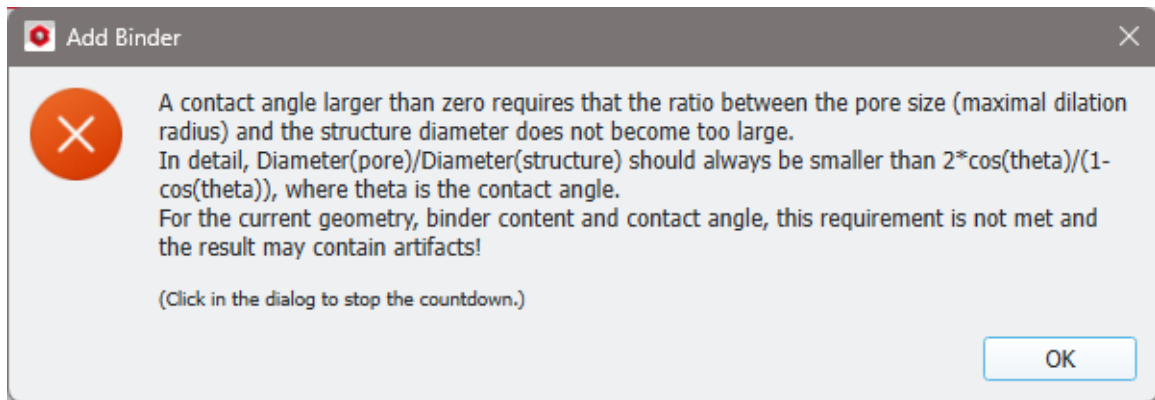
✓ Requirements for large contact angles

The contact angle must fulfill the following requirement:

$$\frac{\text{Diameter(Pore)}}{\text{Diameter(Structure)}} < \frac{2 \cos(\theta)}{1 - \cos(\theta)}$$

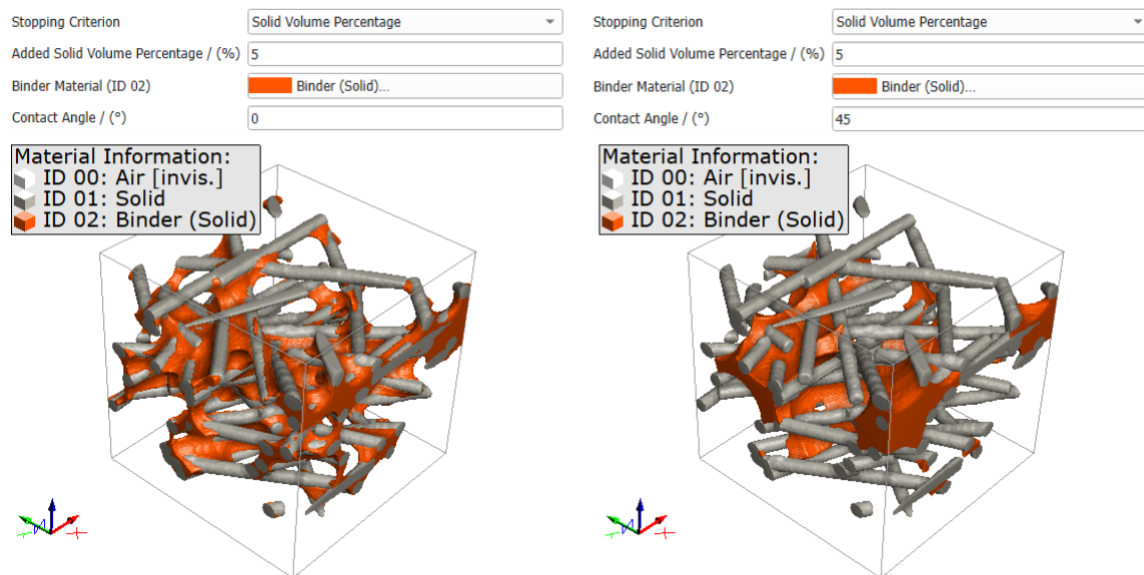
(16) Contact Angle Requirement

where θ is the contact angle and Diameter(Pore) means the maximal dilation radius. If this requirement is not met, a warning message appears. It is recommended to inspect the resulting structure to detect artifacts.



✓ Contact Angle Example

Observe the effect of adding binder with a **Contact Angle** of 0° or 45°.



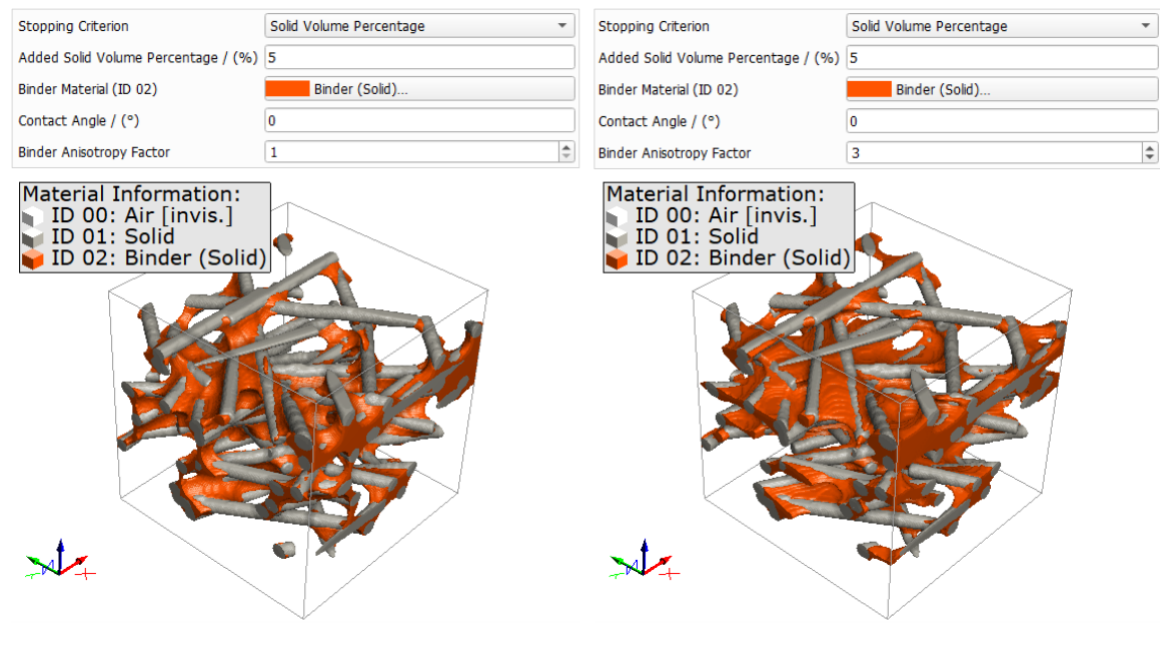
Binder Anisotropy Factor

The **Binder Anisotropy Factor** allows to control the grade of binder anisotropy in the X-Y-plane. If the factor is the default value of 1, the binder is distributed isotropically. By choosing larger values, the binder is distributed in the XY-plane but then, the contact angle value is not

accurate anymore.

✓ Binder Anisotropy Factor Example

Observe the effect of changing the **Binder Anisotropy Factor** from (the default) 1 to 3 when adding binder. With a binder anisotropy factor of 3, the binder is added in the direction of the XY-plane.



Periodicity

When the 3D-structure model is periodic in one or more directions, the binder can be added periodically: in all directions, only in the selected direction (**Periodic X**, **Periodic Y** and/or **Periodic Z**), or non-periodically. Adding binder periodically in certain direction(s) only makes sense if the 3D-structure model is periodic in that/those direction(s).

Periodicity

☐ X-Direction
☐ Y-Direction
☐ Z-Direction

Apply Solid Volume Percentage / Weight Percentage / Grammage Correction after Iterations

The algorithm adds binder until the iteration stops according to the given stopping criterion. Thus, the given value for **Solid Volume Percentage** / **Weight Percentage** / **Grammage** is usually not reached precisely and there are few cases, where the algorithm even does not converge.

If the amount of binder should be reached perfectly, it can be corrected by checking **Apply**

Solid Volume Percentage Correction after Iterations, Apply Weight Percentage Correction after Iterations or **Apply Grammage Correction after Iterations** depending on the chosen stopping criterion.

Selecting this option adds or removes binder surface voxels after the iterations are stopped until the given binder value is reached precisely.



Important! Using the correction feature reduces the **Contact Angle** precision.

General Options Binder Distribution

Stopping Criterion: Solid Volume Percentage

Added Solid Volume Percentage / (%): 5

Binder Material (ID 02): Binder (Solid)...

Contact Angle / (°): 0

Binder Anisotropy Factor: 1

Periodicity

☐ X-Direction ☐ Y-Direction ☐ Z-Direction

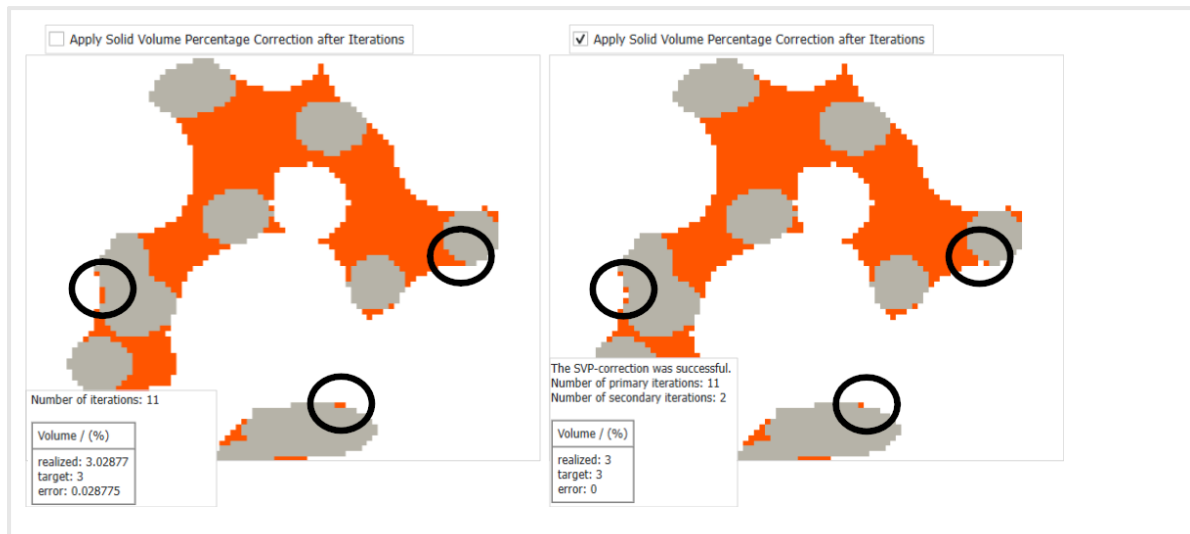
☒ Apply Solid Volume Percentage Correction after Iterations

☒ Apply Weight Percentage Correction after Iterations

☒ Apply Grammage Correction after Iterations

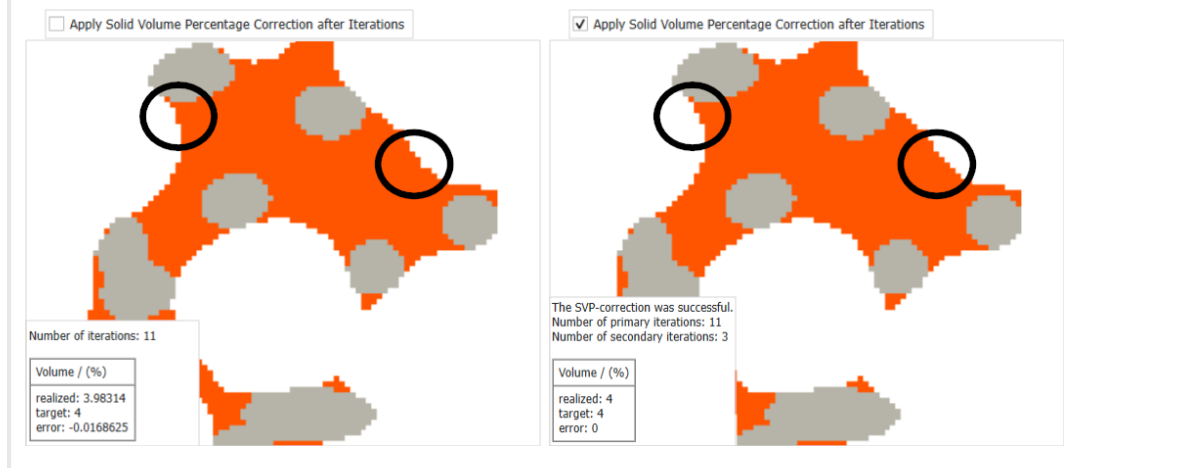
✓ **Binder amount larger than target**

If the realized amount of binder after the iterations is larger than the target value, voxels are removed from exposed positions, i.e., voxels with only one contact to another binder voxel.



✓ Binder amount smaller than target

In the other case, if the amount of binder is smaller than the target value, the algorithm adds voxels on positions with the most binder voxel neighbors.



✓ Algorithm

In detail, the algorithm applies small dilations and erosions to keep a smooth surface. In detail four steps are performed:

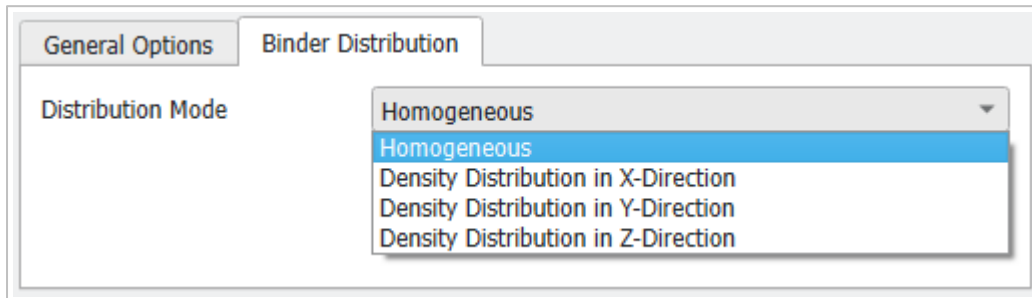
1. First, a voxel-zone at the surface is defined by the smallest possible dilation / erosion.
2. Within this voxel zone the algorithm again applies dilations / erosions. This reduces the voxel zone further.
3. Afterwards only a small surface layer remains that is maximal one voxel thick.
4. These remaining voxels are randomly reassigned.

The random reassignment is done to prevent biased change of the curvature.

Binder Distribution

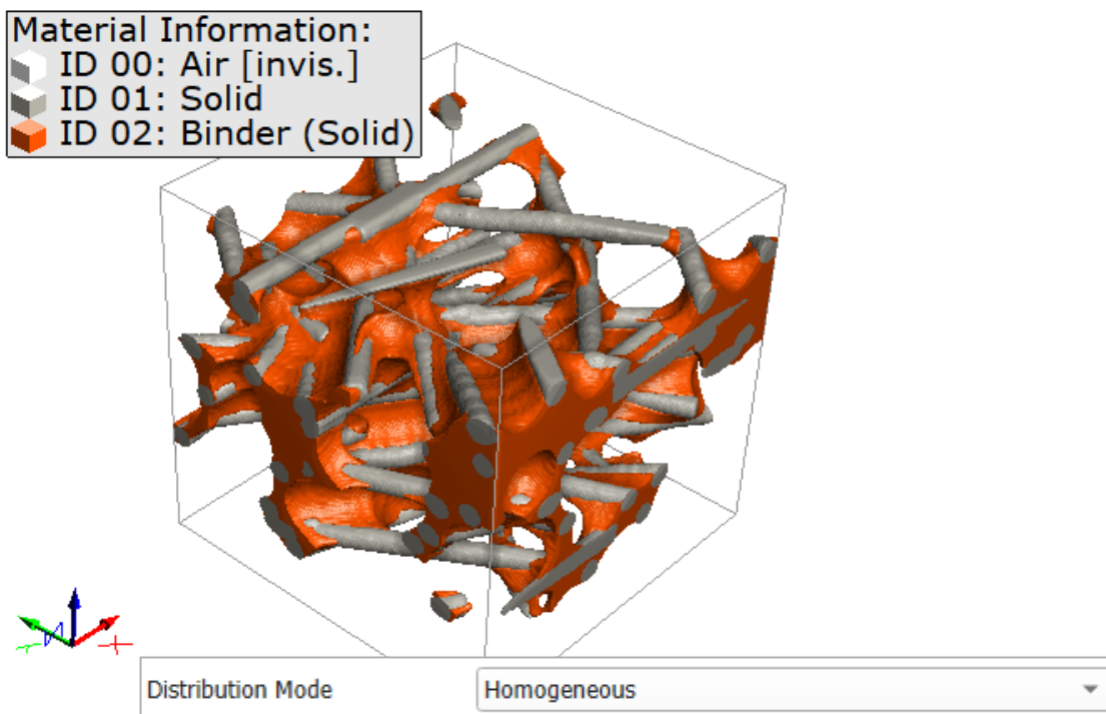
In real life, the process of adding binder to the material is affected by gravity and the viscosity of the binder, leading to inhomogeneous distributions. This effect can be modeled by defining a distribution of the binder under the **Binder Distribution** tab.

The binder either can be distributed homogeneously throughout the domain or follow a distribution in X-, Y- or Z- direction.



Homogeneous

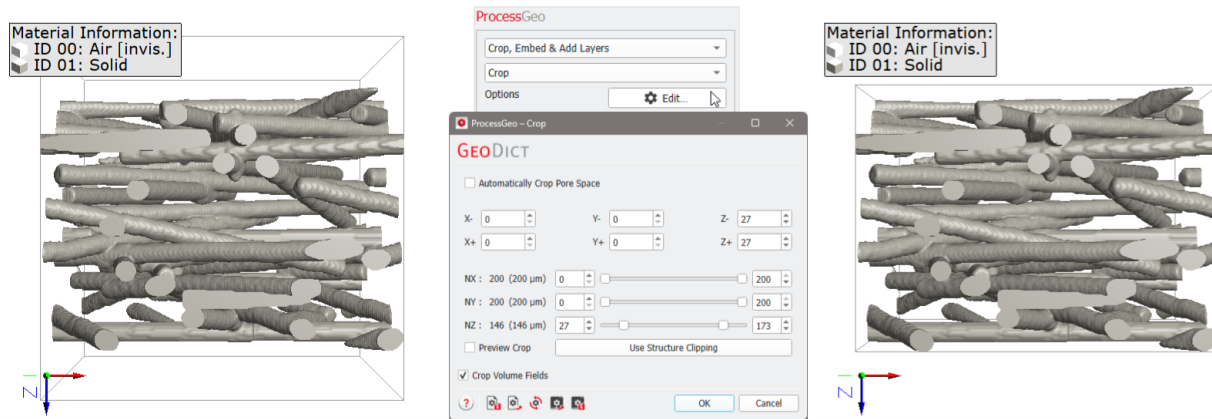
The default distribution is **Homogeneous**, but it can be changed to a **Density Distribution** to allow the modeling of inhomogeneity. For the default case, the binder is distributed homogeneously throughout the domain.



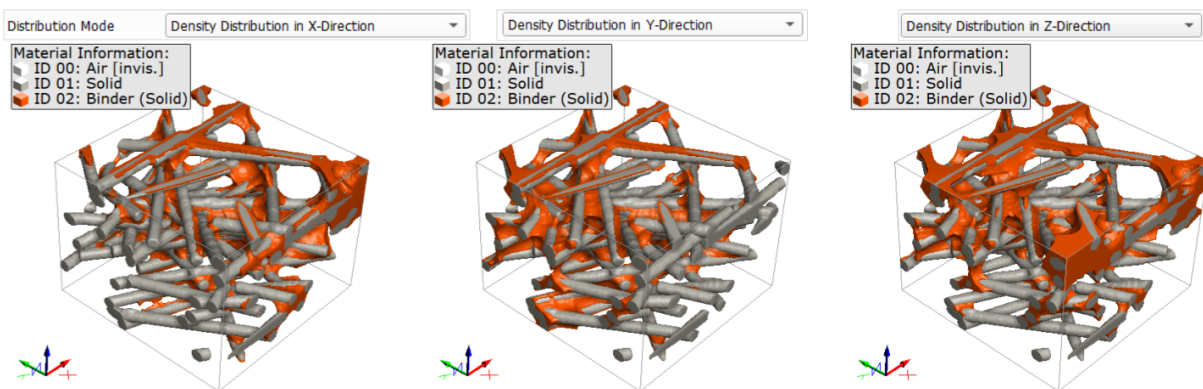
Density Distribution

To model a **Density Distribution**, no inlet or outlet should be left in the structure. If the

structure has an inlet or outlet in the chosen direction, remove it by cropping with **Model - ProcessGeo - Crop, Embed & Add Layers - Crop**. This is necessary because the algorithm strives to reach the desired binder amount for each sub-segment and will try to add binder in the empty domain. Alternatively, the amount of binder might be set to zero for these segments.



Select the direction for the desired density distribution.



In the examples we consider a density distribution in Z-direction. Then, the **Number of Rows** defines the number of Z-segments. To change the number of segments, change the **Number of Rows** to the number of segments desired.

Distribution Mode: Density Distribution in Z-Direction

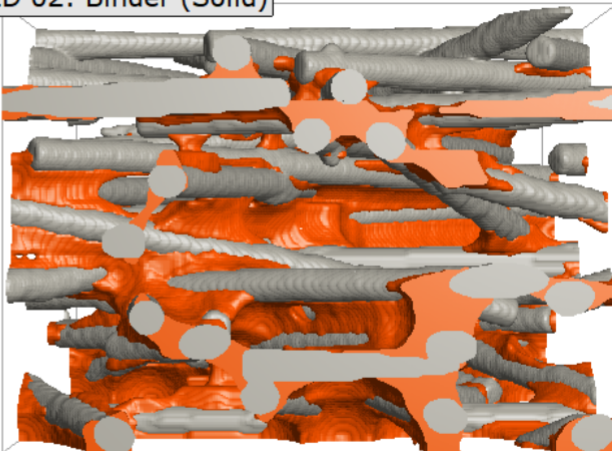
Relative Density	
Z-layer 1 (0 , 16)	0
Z-layer 2 (16 , 32)	0.25
Z-layer 3 (32 , 48)	0.5
Z-layer 4 (48 , 64)	0.75
Z-layer 5 (64 , 81)	1
Z-layer 6 (81 , 97)	1.25
Z-layer 7 (97 , 113)	1.5
Z-layer 8 (113 , 129)	1.75
Z-layer 9 (129 , 146)	2

Probability Sum:

Number of Rows:

Material Information:

- ID 00: Air [invis.]
- ID 01: Solid
- ID 02: Binder (Solid)

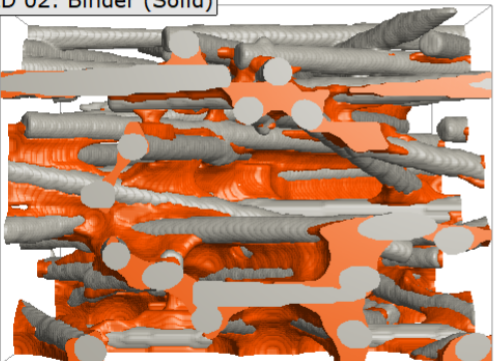


In each section the binder is generated separately according to the rules defined in the **General Options** tab. The **Added Solid Volume Percentage / (%)** is scaled with the normalized **Relative Density** given in the table of **Binder Distribution**.

Added Solid Volume Percentage / (%)

Material Information:

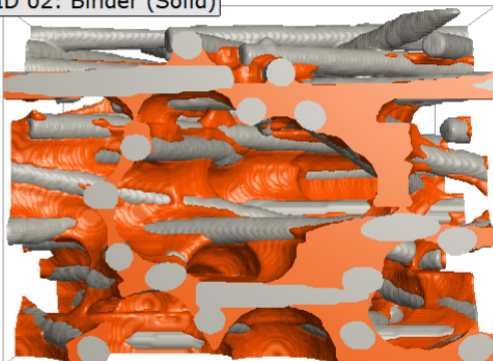
- ID 00: Air [invis.]
- ID 01: Solid
- ID 02: Binder (Solid)



Added Solid Volume Percentage / (%)

Material Information:

- ID 00: Air [invis.]
- ID 01: Solid
- ID 02: Binder (Solid)



The **Binder Distribution** can be entered in form of a ratio in the **Relative Density** table.

In the images below, three different segments are clearly discernible with a binder distribution according to the relative values given in the table.

Distribution Mode: Density Distribution in Z-Direction

Relative Density	
Z-layer 1 (0 , 48)	0.9
Z-layer 2 (48 , 97)	0
Z-layer 3 (97 , 146)	0.1

Probability Sum: 1

Number of Rows: 3

Normalize

Material Information:

- ID 00: Air [invis.]
- ID 01: Solid
- ID 02: Binder (Solid)

90% of the binder is distributed in the Z-layers 0-48.

0% of the binder is distributed in the Z-

10 % of the binder is distributed in the Z-

Distribution Mode: Density Distribution in Z-Direction

Relative Density	
Z-layer 1 (0 , 48)	1
Z-layer 2 (48 , 97)	5
Z-layer 3 (97 , 146)	10

Probability Sum: 16

Number of Rows: 3

Normalize

Material Information:

- ID 00: Air [invis.]
- ID 01: Solid
- ID 02: Binder (Solid)

6% of the binder is distributed in the Z-layers 0-48.

31% of the binder is distributed in the Z-

63% of the binder is distributed in the Z-

Clicking the **Normalize** button ensures the Relative Density values sum up to one.

Distribution Mode: Density Distribution in Z-Direction

Relative Density	
Z-layer 1 (0 , 48)	1
Z-layer 2 (48 , 97)	5
Z-layer 3 (97 , 146)	10

Probability Sum: 16

Number of Rows: 3

Normalize

→

Distribution Mode: Density Distribution in Z-Direction

Relative Density	
Z-layer 1 (0 , 48)	0.0625
Z-layer 2 (48 , 97)	0.3125
Z-layer 3 (97 , 146)	0.625

Probability Sum: 1

Number of Rows: 3

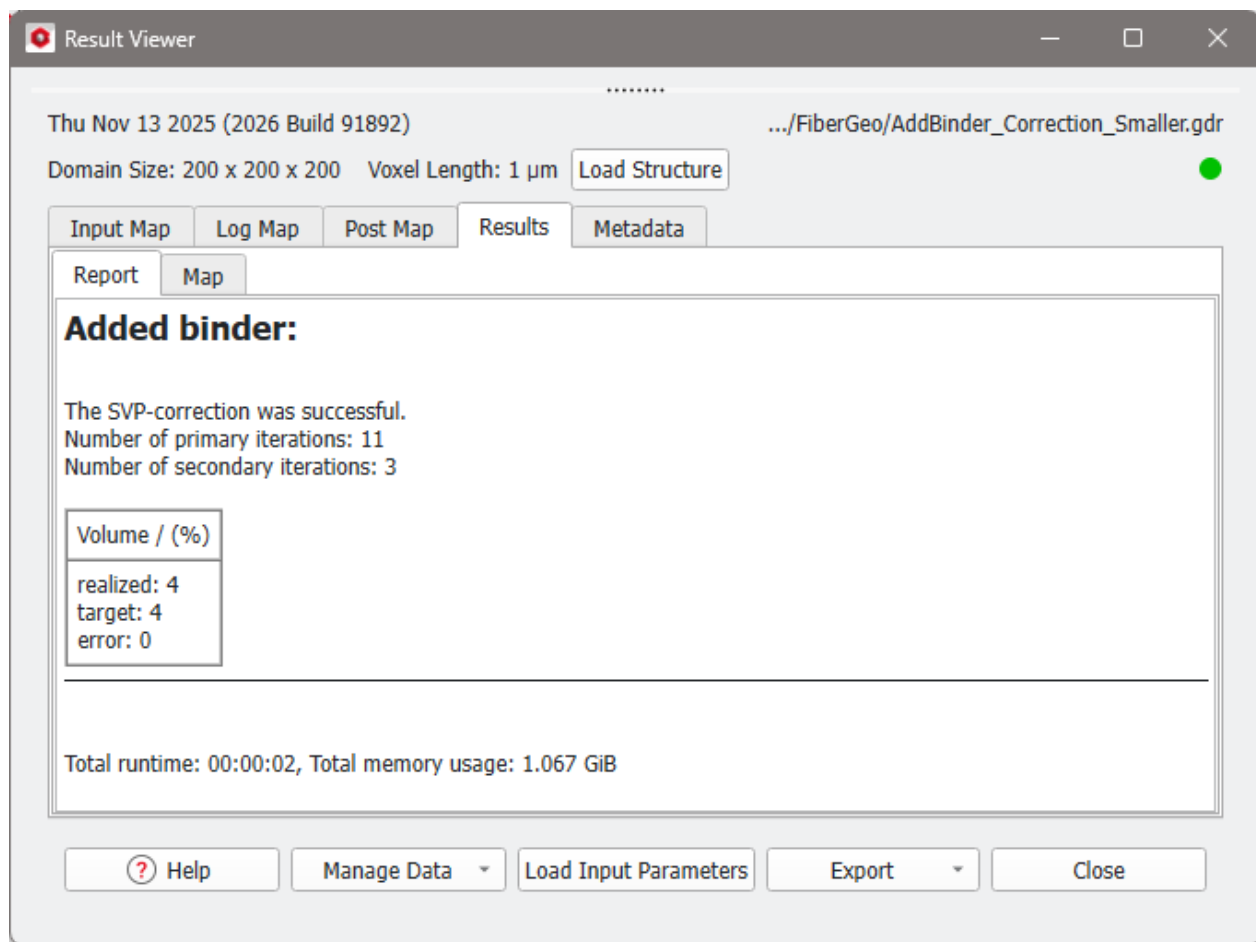
Normalize

With the buttons **Load...** and **Save...** the distribution can be loaded/saved as text file which can be opened with other software as, e.g., Microsoft Excel.

1.4.2 Results

After the binder generation, the new structure with added binder is shown in the visualization area and the result file (*.gdr) is opened in the Result Viewer.

The **Results - Report** tab shows information about the binder generation, as number of iterations, target binder volume and realized binder volume.



If **Weight Percentage** or **Grammage** were selected as **Stopping Criterion**, additionally the realized and target binder weight percentage and grammage are given.

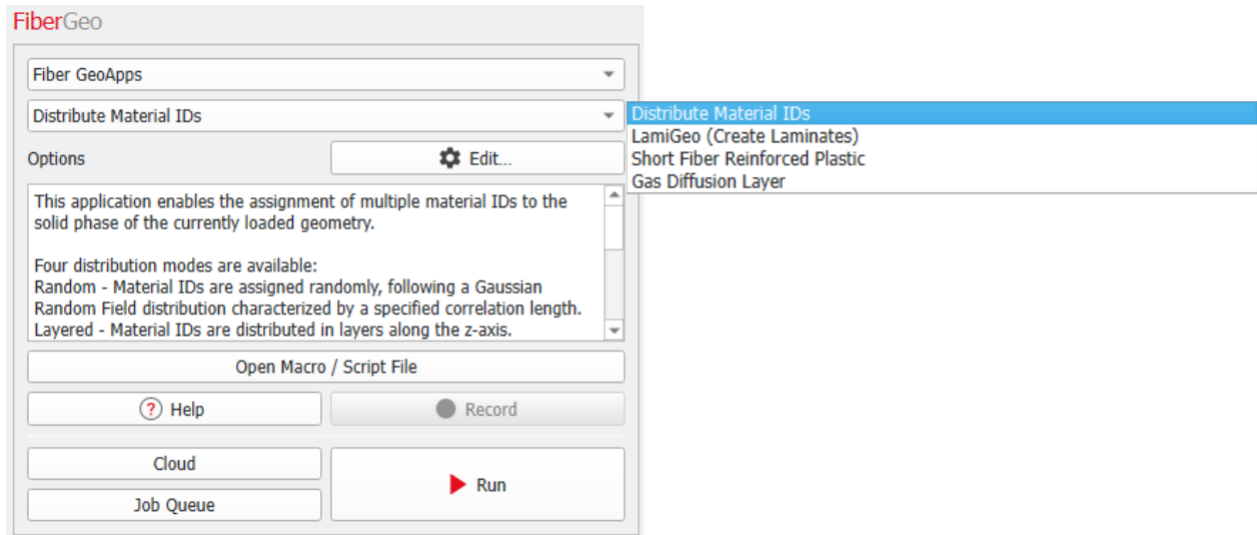
Volume / (%)	Grammage / (g/m ²)	Weight / (%)
realized: 3.46524 target: --- error: ---	realized: 20 target: --- error: ---	realized: 20 target: 20 error: 2.59463e-05

If a non-homogeneous binder distribution was defined, the binder volumes additionally are given for each defined layer.

Input Map	Log Map	Post Map	Results	Metadata						
Report Map										
Added binder: <table border="1"> <thead> <tr> <th>Volume / (%)</th> <th>Grammage / (g/m²)</th> <th>Weight / (%)</th> </tr> </thead> <tbody> <tr> <td>realized: 1.27263 target: --- error: ---</td> <td>realized: 19.9999 target: --- error: ---</td> <td>realized: 19.9999 target: 20 error: -5.52607e-05</td> </tr> </tbody> </table>					Volume / (%)	Grammage / (g/m ²)	Weight / (%)	realized: 1.27263 target: --- error: ---	realized: 19.9999 target: --- error: ---	realized: 19.9999 target: 20 error: -5.52607e-05
Volume / (%)	Grammage / (g/m ²)	Weight / (%)								
realized: 1.27263 target: --- error: ---	realized: 19.9999 target: --- error: ---	realized: 19.9999 target: 20 error: -5.52607e-05								
Layer 1 The SVP-correction was successful. <table border="1"> <thead> <tr> <th>Volume / (%)</th> <th>Grammage / (g/m²)</th> <th>Weight / (%)</th> </tr> </thead> <tbody> <tr> <td>realized: 3.62099 target: --- error: ---</td> <td>realized: 53.9998 target: --- error: ---</td> <td>realized: 53.9998 target: 54 error: -0.00017705</td> </tr> </tbody> </table>					Volume / (%)	Grammage / (g/m ²)	Weight / (%)	realized: 3.62099 target: --- error: ---	realized: 53.9998 target: --- error: ---	realized: 53.9998 target: 54 error: -0.00017705
Volume / (%)	Grammage / (g/m ²)	Weight / (%)								
realized: 3.62099 target: --- error: ---	realized: 53.9998 target: --- error: ---	realized: 53.9998 target: 54 error: -0.00017705								
Layer 2 No binder to add. The SVP-correction was skipped. <table border="1"> <thead> <tr> <th>Volume / (%)</th> <th>Grammage / (g/m²)</th> <th>Weight / (%)</th> </tr> </thead> <tbody> <tr> <td>realized: 0 target: --- error: ---</td> <td>realized: 0 target: --- error: ---</td> <td>realized: 0 target: 0 error: 0</td> </tr> </tbody> </table>					Volume / (%)	Grammage / (g/m ²)	Weight / (%)	realized: 0 target: --- error: ---	realized: 0 target: --- error: ---	realized: 0 target: 0 error: 0
Volume / (%)	Grammage / (g/m ²)	Weight / (%)								
realized: 0 target: --- error: ---	realized: 0 target: --- error: ---	realized: 0 target: 0 error: 0								
Layer 3 The SVP-correction was successful. <table border="1"> <thead> <tr> <th>Volume / (%)</th> <th>Grammage / (g/m²)</th> <th>Weight / (%)</th> </tr> </thead> <tbody> <tr> <td>realized: 0.196888 target: --- error: ---</td> <td>realized: 6.00001 target: --- error: ---</td> <td>realized: 6.00001 target: 6 error: 1.12676e-05</td> </tr> </tbody> </table>					Volume / (%)	Grammage / (g/m ²)	Weight / (%)	realized: 0.196888 target: --- error: ---	realized: 6.00001 target: --- error: ---	realized: 6.00001 target: 6 error: 1.12676e-05
Volume / (%)	Grammage / (g/m ²)	Weight / (%)								
realized: 0.196888 target: --- error: ---	realized: 6.00001 target: --- error: ---	realized: 6.00001 target: 6 error: 1.12676e-05								

1.5 Fiber GeoApps

When **Fiber GeoApps** is selected in the FiberGeo section, several GeoApps can be chosen from the pull-down menu in the Fiber GeoApps panel. To learn how to add your own custom GeoApps, refer to the GeoApp User Guide.



GeoApps available in FiberGeo are:

- [Distribute Material IDs](#)¹⁶³
Assign multiple Material IDs to the solid phase of the currently loaded geometry.
- [LamiGeo \(Create Laminates\)](#)¹⁶⁶
Generates a model of a multi-layer laminate composite.
- [Short Fiber Reinforced Plastic](#)¹⁶⁸
Create a predefined fiber structure.
- [Gas Diffusion Layer](#)¹⁷⁰
Create a gas diffusion layer of a PEM fuel cell.

1.5.1 Distribute Material IDs

The **Distribute Material IDs** GeoApp enables the assignment of multiple material IDs to the solid phase of the currently loaded geometry.

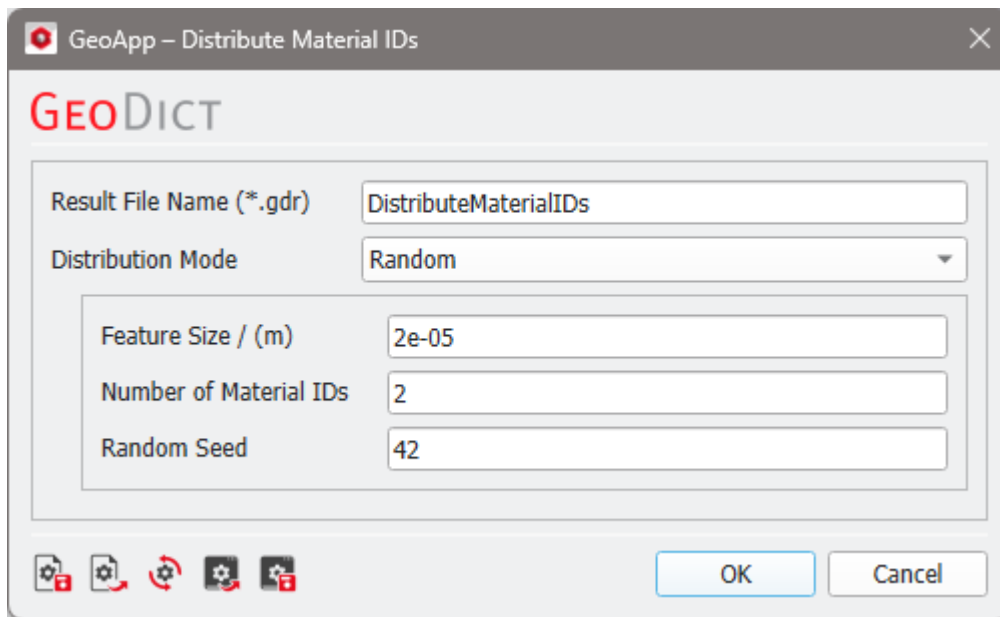
A common use of this tool is simulating electrospun fibers, where different surface charges are assigned to material IDs to model heterogeneous electrostatic behavior. When electrostatic effects are enabled, the Material Charge can be set as **Individual per material type**, which requires a heterogeneous material distribution.



Modules needed to run this GeoApp:

FiberGeo or GrainGeo

Select a **Result File Name** fitting to the current project.



Depending on the selected **Distribution Mode**, the GeoApp assigns material ID numbers to the 3D structure. It does not assign materials to those numbers. For example, if you select 20 as the **Number of Material IDs** in the app, you may have to assign a material and all the corresponding parameters to each of the 20 IDs.



Important! Be aware that the app changes the material IDs of all solid materials.

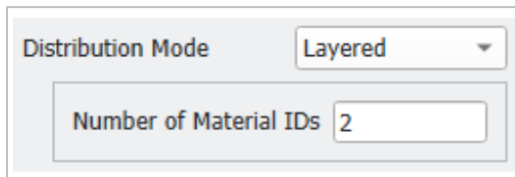
✓ Random

Material IDs are randomly assigned according to a Gaussian Random Field distribution. First, define the **Feature Size**, which is the correlation length that characterizes the Gaussian random field. Next, define the **Number of Material IDs** that will be present after the distribution is complete. Finally, define the **Random Seed** for the generator of the Gaussian random field.

✓ Layered

Material IDs are distributed in layers along the Z-axis. Specify the **Number of Material**

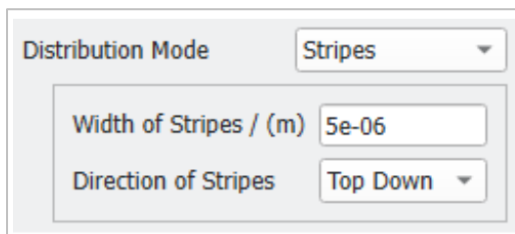
IDs that will be present once the distribution is complete.



A screenshot of a software interface for the 'Layered' distribution mode. It features a 'Distribution Mode' dropdown menu set to 'Layered' and a 'Number of Material IDs' input field containing the value '2'.

✓ Stripes

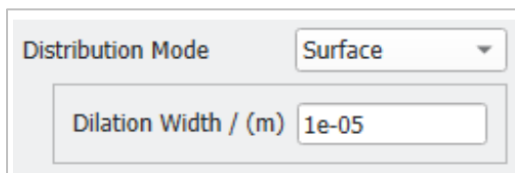
Material IDs are assigned in stripe patterns across the geometry. This mode requires GAD objects. Define the **Width of Stripes** that the GAD objects are split into. Then, define the **Direction of Stripes**.



A screenshot of a software interface for the 'Stripes' distribution mode. It includes a 'Distribution Mode' dropdown set to 'Stripes', a 'Width of Stripes / (m)' input field with '5e-06', and a 'Direction of Stripes' dropdown set to 'Top Down'.

✓ Surface

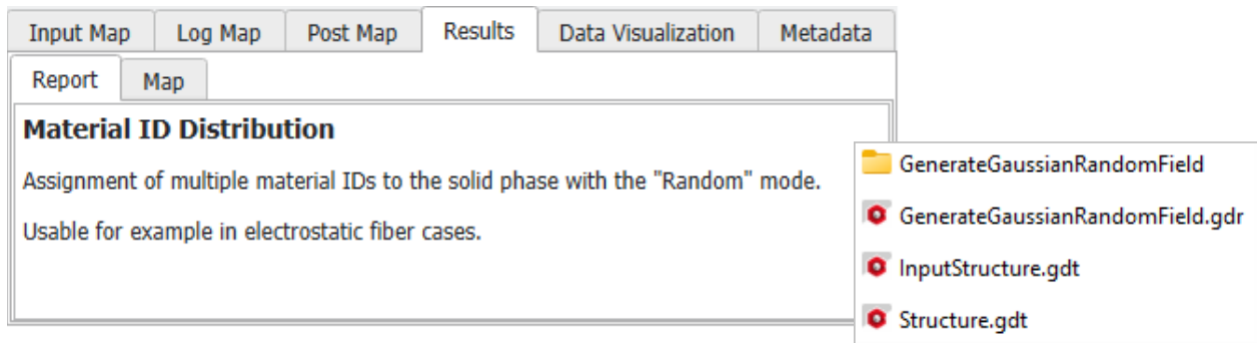
Material IDs are assigned to the uppermost and lowermost voxels in the Z-direction, which can be followed by dilation. Specify the dilation of these uppermost and lowermost materials or "capped materials" via the **Dilation Width**.



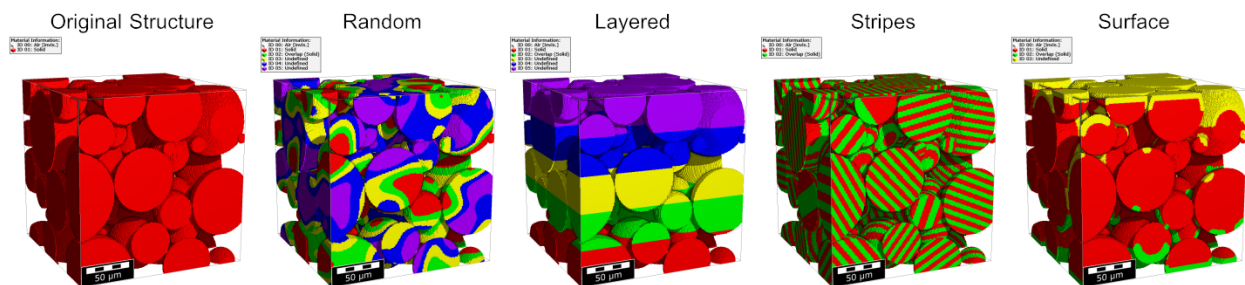
A screenshot of a software interface for the 'Surface' distribution mode. It shows a 'Distribution Mode' dropdown set to 'Surface' and a 'Dilation Width / (m)' input field with '1e-05'.

Results

Once the computation is finished, a result file will be generated stating that the material IDs were assigned using the selected **Distribution Mode**. The generated structure is automatically loaded into GeoDict. You can load the **Input Structure** from the result viewer via the **Data Visualization** tab. The corresponding result folder contains the generated and input structures, as well as the Gaussian random field when using the **Random** distribution mode.



View results for the different distribution modes in the example below:



1.5.2 LamiGeo (Create Laminates)

The **LamiGeo** app generates a laminate structure.



Modules needed to run this GeoApp:

FiberGeo

Parameters

Clicking **Edit** opens the **LamiGeo Parameters** dialog.

GeoApp - LamiGeo (Create Laminates)

GeODICT

Result File Name (*.gdr)

Voxel Length / (μm)

Domain Width / Length / (μm)

Materials

Matrix Material

Fiber Material

Fibers

Diameter / (μm)

Solid Volume Percentage / (%)

Waviness / (Deg)

☒ No Fiber Overlap

Isolation Distance / (μm)

Layers

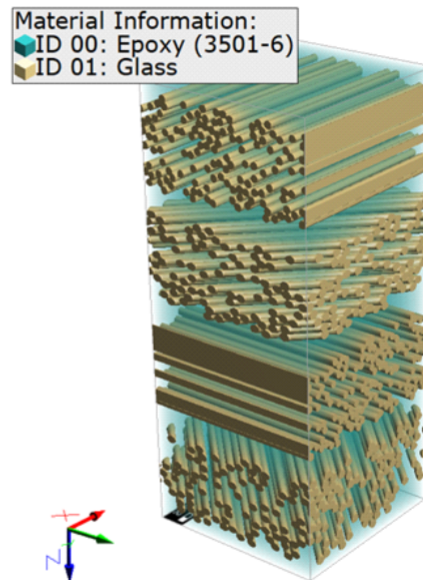
Layer Height / (μm)

Layer Coating / (μm)

Number of Layers with Fiber Angle in Layer

	Fiber Angle in Layer / (Deg)
1	0
2	45
3	90
4	135
5	

OK Cancel



Enter a **Result File Name** for the generated result file (*.gdr) and the corresponding result folder.

Define **Voxel Length** and the **Domain Width / Length** in X- and Y-direction.

In the **Materials** panel select the **Matrix Material** and the **Fiber Material** from the GeoDict material database.

Below, in the **Fibers** panel, define the parameters for the generated [circular fibers](#)⁴³:

- Define **Diameter** of the fibers in μm.
- Select a **Solid Volume Percentage** to define the fibers volume percentage for each layer.
- Enter the fiber **Waviness** as angle around the fiber orientation direction, where positive values lead to slightly curved fibers.
- Choose, if the [overlap](#)¹⁷ should be removed (**No Fiber Overlap**) or not.
- Set an **Isolation Distance**, in case the overlap is removed.

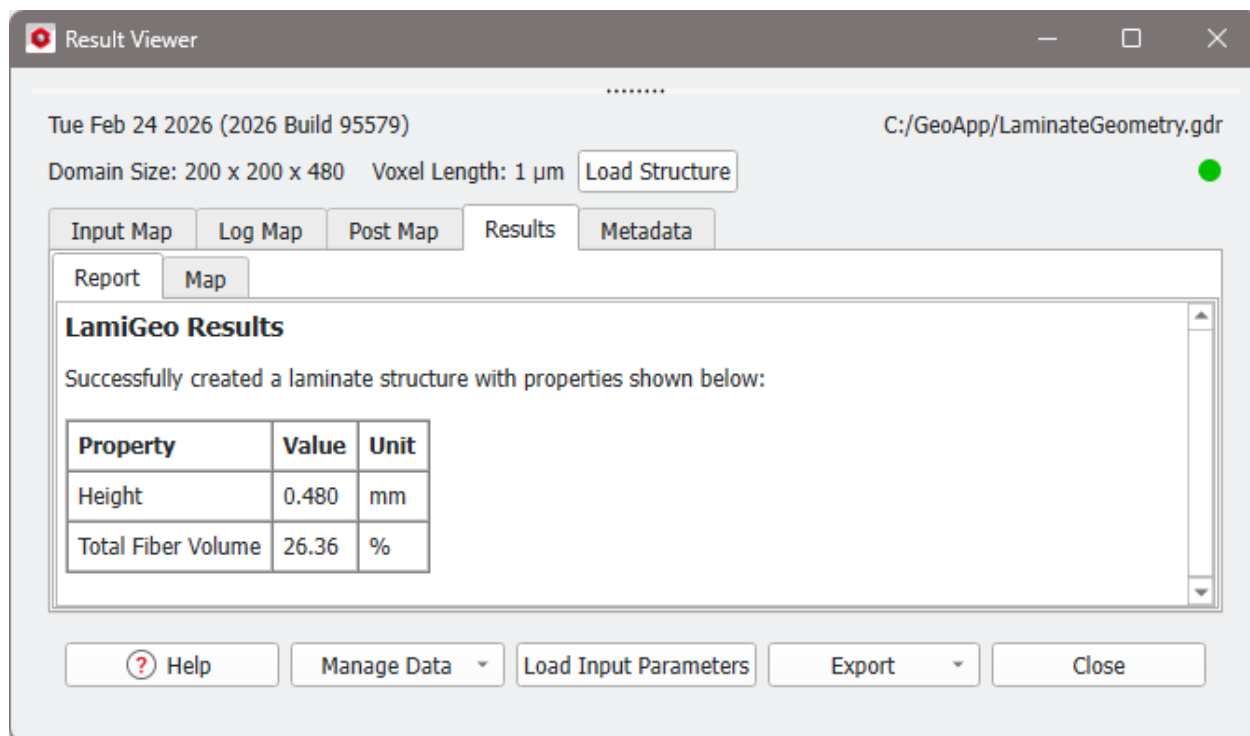
In the **Layers** panel enter the desired **Layer Height** for each layer and how much **Layer Coating** should be generated around the fibers in Z-direction. In the table, enter the **Fiber Angle in Layer**. Entering a value in the last row adds another row below, while deleting an entry, deletes the row. The generated structure will have as many layers as values are entered in this table.

Clicking on **OK** closes the dialog and clicking on **Run** creates the plastic structure.

When the structure generation is finished, the **Result Viewer** of the result file (*.gdr) opens automatically.

Results

The **Results - Report** tab displays a short report about the resulting structure. Note, that the total fiber volume is lower than the given Solid Volume Percentage because of the added layers of coating material.



1.5.3 Short Fiber Reinforced Plastic

The **Short Fiber Reinforced Plastic** app generates a predefined fibrous structure.

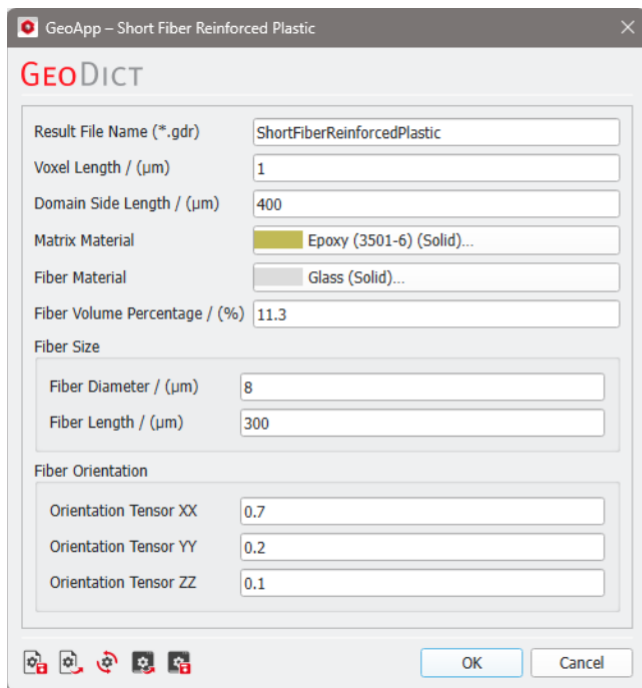


Modules needed to run this GeoApp:

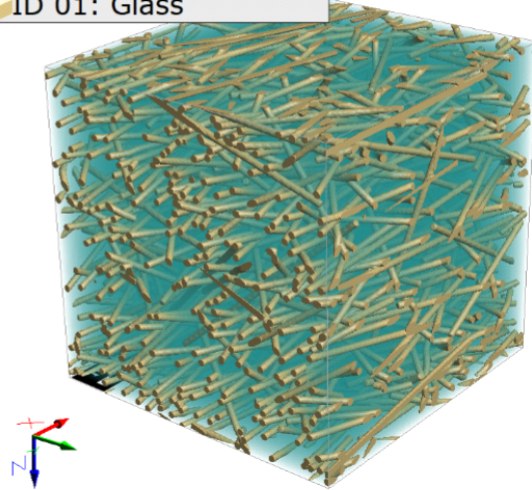
FiberGeo

Parameters

Clicking **Edit** opens the **Short Fiber Reinforced Plastic** parameters dialog.



Material Information:
 ID 00: Epoxy (3501-6)
 ID 01: Glass



Enter a **Result File Name** for the generated result file (*.gdr) and the corresponding result folder.

Define **Voxel Length** and the **Domain Side Length** in X- and Y-direction.

Select the **Matrix Material** and the **Fiber Material** from the GeoDict material database.

Set the **Fiber Volume Percentage** to define how many fibers should be generated.

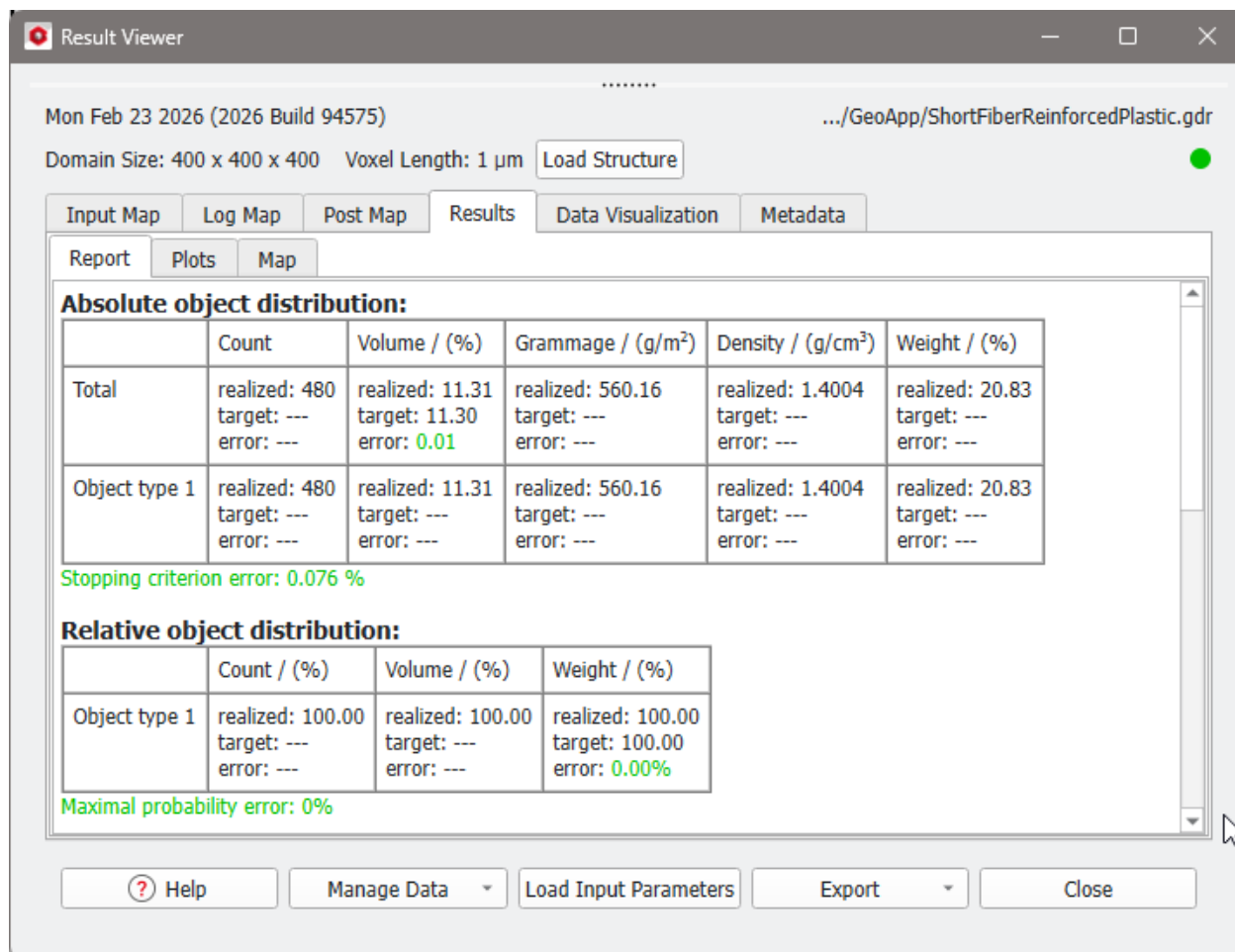
In the **Fiber Size** panel, enter the **Fiber Diameter** and the **Fiber Length** of the generated [curved circular fibers](#)^[43].

Below, in the **Fiber Orientation** panel, define the entries on the diagonal of the [Orientation Tensor](#)^[63]. Please note that the sum of the three orientation values **XX**, **YY**, and **ZZ** has to be 1.

Clicking on **OK** closes the dialog and clicking on **Run** creates the plastic structure.

Results

When the structure generation finishes, the **Result Viewer** of the result file (*.gdr) opens automatically. The resulting structure has no overlap. For more information on this result file refer to the [FiberGeo](#)^[112] User Guide.



1.5.4 Gas Diffusion Layer

The **Gas Diffusion Layer** app creates a gas diffusion layer of a PEM fuel cell.



Modules needed to run this GeoApp:

FiberGeo

Parameters

Clicking **Edit** opens the **Gas Diffusion Layer** parameters dialog.

GeoApp – Gas Diffusion Layer

GEODict

Result File Name (*.gdr)

Voxel Length / (μm)

Width (X-Direction) / (μm)

Width (Y-Direction) / (μm)

Height (Z-Direction) / (μm)

Materials

Fiber Material

Binder Material

Create Fibers

Fiber Volume Percentage / (%)

Fiber Size

Fiber Diameter / (μm)

Fiber Length / (μm)

Fiber Orientation

Orientation Tensor XX

Orientation Tensor YY

Orientation Tensor ZZ

Add Binder

Binder Volume Percentage / (%)

OK Cancel

Enter a **Result File Name** for the generated result file (*.gdr) and the corresponding result folder.

Set the domain parameters in μm using the parameters **Voxel Length**, **Width (X-Direction)**, **Length (Y-Direction)**, and **Height (Z-Direction)**.

Select **Materials** for the fibers and the binder from the GeoDict material database.

The gas diffusion layer consists of [short circular fibers](#)⁴³. In the **Create Fibers** panel define the

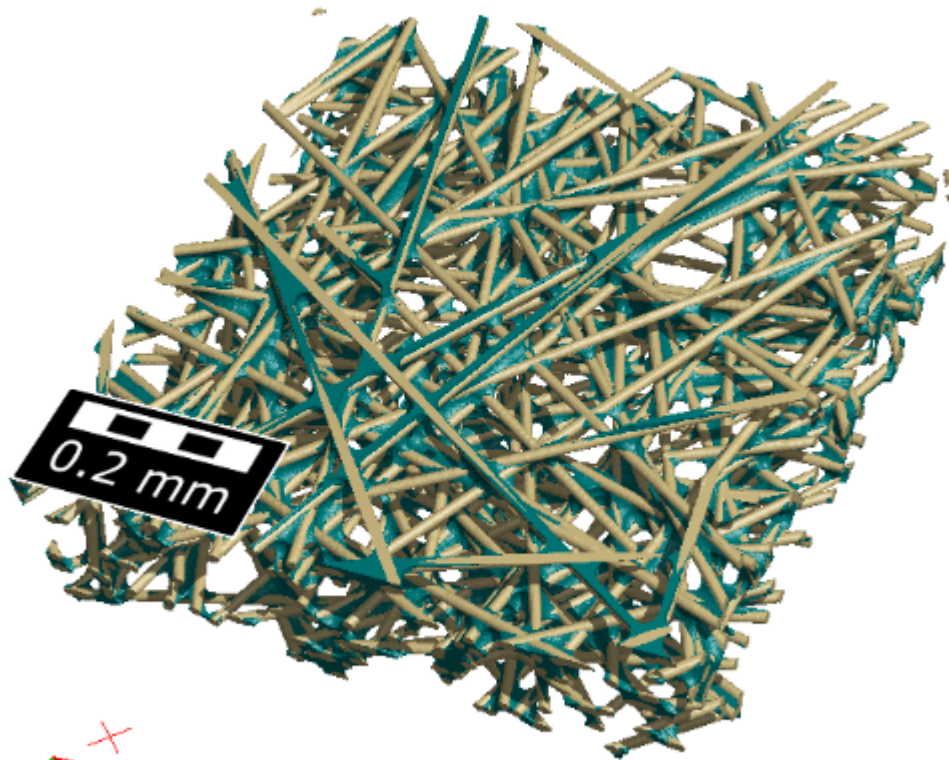
Fiber Volume Percentage and set the **Fiber Diameter** and **Fiber Length** of the generated fibers. Define the **Fiber Orientation** by giving the diagonal of the [orientation tensor](#)⁶³. The three entries are normalized by the GeoApp.

Finally, define the **Binder Volume Percentage**.

Results

Clicking **Run** creates the diffusion layer and saves the structure file in the result folder.

Material Information:	
	ID 00: Pore [invis.]
	ID 01: Carbon Fiber
	ID 02: Binder (Solid)



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



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