Fraunhofer ITWM

FiberMath Structure Generator

User Guide

Overview

FiberMath is a GeoApp within GeoDict that generates synthetic fiber structures (e.g. short-fiber composites). The GUI consists of three sequential dialogs:

1. **General Input** – Domain size, output options, and algorithm settings.
2. **Fiber Parameterization** – Properties of each fiber type.
3. **Layer Parameterization** – Layer-wise composition of the structure.

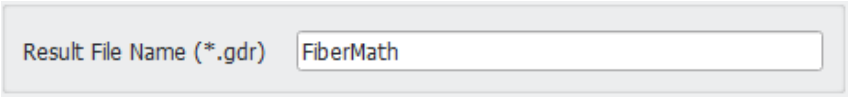
After completing all inputs, the generator produces a voxelized fiber geometry that is automatically loaded into the GeoDict workspace.

More information on FiberMath can be found here:

`https://www.itwm.fraunhofer.de/fibermath-en`

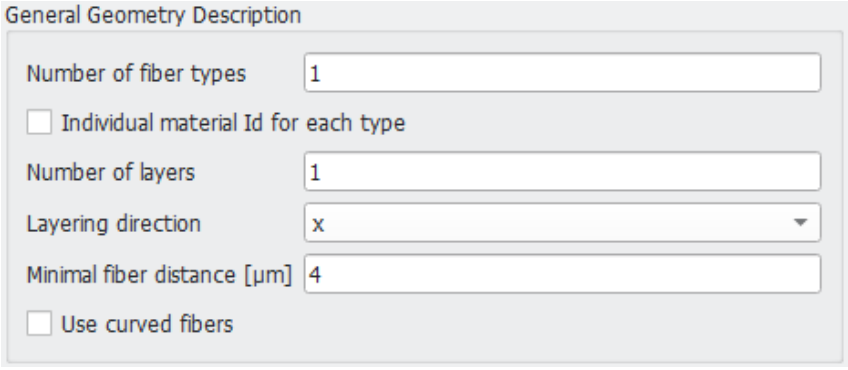
Dialog 1: General Input

Result File Name



- **Result File Name (`*.gdr`):** Base name for all output files. Default: `FiberMath`.

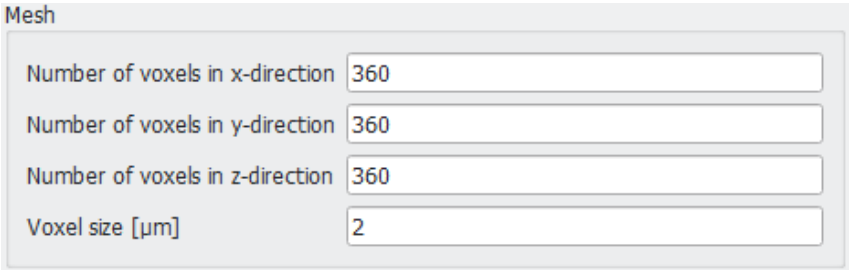
General Geometry Description



- **Number of fiber types:** Number of distinct fiber types in the geometry (≥ 1). Each type is parameterized separately in Dialog 2.

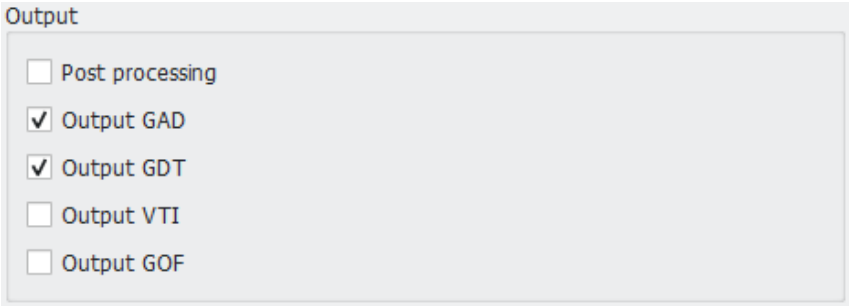
- **Individual material Id for each type:** If unchecked, all fibers share material Id 1. If checked, each fiber type receives its own material Id matching its type number.
- **Number of layers:** Number of layers in the geometry (≥ 1). Each layer is parameterized separately in Dialog 3.
- **Layering direction:** Normal direction of the layer surfaces. Options: `x`, `y`, or `z`.
- **Minimal fiber distance [μm]:** Minimum allowed distance between individual fibers (≥ 0). Default: 4 μm.
- **Use curved fibers:** If unchecked, all fibers are straight. If checked, fibers will have curvature (additional parameters appear in Dialog 2).

Mesh



- **Number of voxels in x-direction:** Voxel count along the x-axis (≥ 1). Default: 360.
- **Number of voxels in y-direction:** Voxel count along the y-axis (≥ 1). Default: 360.
- **Number of voxels in z-direction:** Voxel count along the z-axis (≥ 1). Default: 360.
- **Voxel size [μm]:** Edge length of a single cubic voxel (> 0). Default: 2 μm. The physical domain size equals number of voxels $\times$ voxel size in each direction.

Output

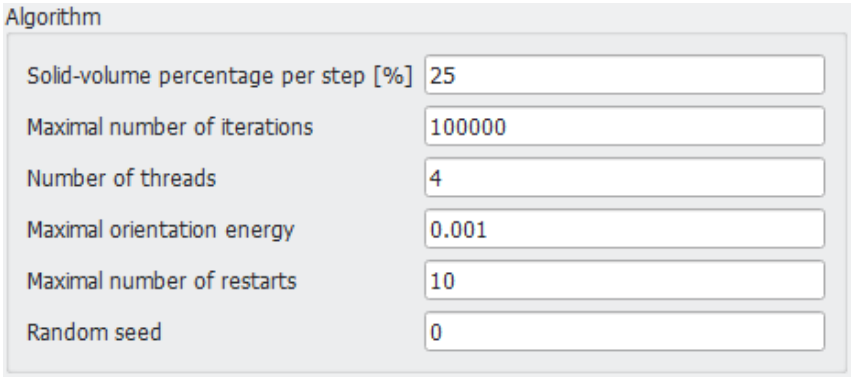


- **Post processing:** If checked, the fiber length distribution of the generated structure is compared to provided measurement data. **Requirements:** Only one fiber type, one layer, and "Output GAD" must be checked.
- **Output GAD:** Write a `.gad` (GeoDict Analytic Description) file. Default: checked.
- **Output GDT:** Write a `.gdt` (GeoDict voxel data) file. Default: checked.
- **Output VTI:** Write a `.vti` (VTK ImageData) file. Default: unchecked.

- **Output GOF:** Write a `.gof` (GeoDict Object File) file. Default: unchecked.

Note: At least one output format must be selected.

Algorithm

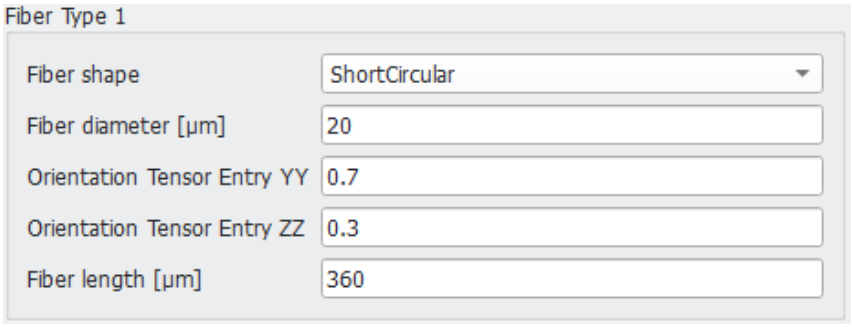


- **Solid-volume percentage per step [%]:** Fraction of the total fiber volume added per iteration step (0–100). Default: 25. For high solid-volume fractions, use a smaller value.
- **Maximal number of iterations:** Upper limit on algorithm iterations (≥ 1). Default: 100 000.
- **Number of threads:** Number of OpenMP threads for parallel execution (≥ 1). Default: 4.
- **Maximal orientation energy:** Convergence criterion for orientation matching (≥ 0). Default: 0.001.
- **Maximal number of restarts:** How many times the algorithm may restart if convergence fails (≥ 1). Default: 10.
- **Random seed:** Seed for the random number generator (≥ 0). Use the same seed to reproduce identical results. Default: 0.

Dialog 2: Fiber Parameterization

One parameter group is displayed per fiber type defined in Dialog 1.

Per Fiber Type

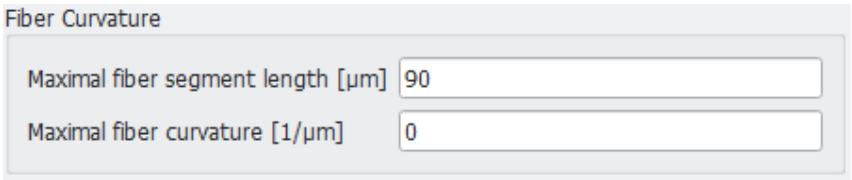


- **Fiber shape:** Geometric shape of the fiber cross-section. Currently available: `ShortCircular` (cylindrical short fiber).
- **Fiber diameter [μm]:** Diameter of the fiber (> 0). Default: 20 μm.
- **Orientation Tensor Entry XX/YY/ZZ:** Two diagonal entries of the second-order fiber orientation tensor (values between 0 and 1). The third diagonal entry is computed automatically as $1 - (\text{entry}_1 + \text{entry}_2)$. The sum of the two provided entries must not exceed 1. Default: 0.7 / 0.3.
- **Fiber length [μm]:** Constant length of all fibers of this type (> 0). Default: 360 μm.

Note: Which two orientation tensor entries are shown depends on the layering direction:
- Layering in **z** $\rightarrow$ entries **XX** and **YY** are shown (ZZ is computed).
- Layering in **x** $\rightarrow$ entries **YY** and **ZZ** are shown (XX is computed).
- Layering in **y** $\rightarrow$ entries **XX** and **ZZ** are shown (YY is computed).

Fiber Curvature

This section is only visible if “Use curved fibers” is checked in Dialog 1.

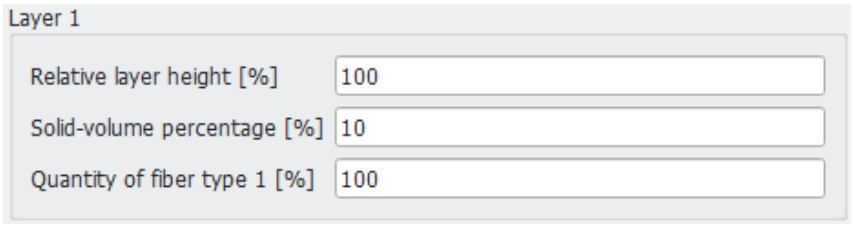


- **Maximal fiber segment length [μm]:** Maximum length of straight segments used to approximate the curved fiber. Must be $\leq$ half of the shortest RVE edge length. Default: 90 μm.
- **Maximal fiber curvature [1/μm]:** Maximum allowed curvature, which limits the angle between two adjacent segments (≥ 0). Default: 0.0.

Dialog 3: Layer Parameterization

One parameter group is displayed per layer defined in Dialog 1.

Per Layer



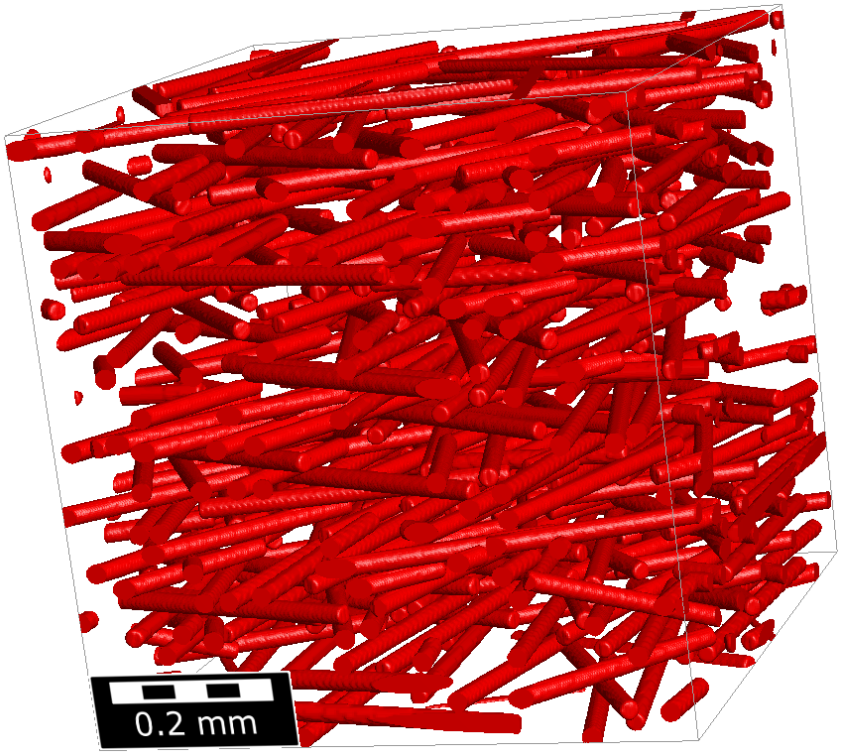
- **Relative layer height [%]:** Height of this layer relative to the total domain height in the layering direction (0–100). Default: $100/$number of layers. All layers must sum to $\leq 100\%$. If the sum is less than 100%, the remainder is added to the last layer.
- **Solid-volume percentage [%]:** Volume fraction of fibers within this layer (0–100). Default: 10%.
- **Quantity of fiber type n [%]:** Relative share of each fiber type within the layer's solid volume (0–100). Default: $100/$number of fiber types. All fiber type quantities within a layer must sum to $\leq 100\%$. If the sum is less than 100%, the remainder is added to the last type.

Generated Output

After all dialogs are completed and the generator finishes successfully, the following files are produced in the current working directory:

- `fiberGeneratorInput_<basename>.xml`: XML configuration file consumed by the Fiber Generator executable.
- `<basename>.gad`: GeoDict Analytic Description file (if “Output GAD” is checked).
- `<basename>.gdt`: GeoDict voxel data file (if “Output GDT” is checked).
- `<basename>.vti`: VTK ImageData file (if “Output VTI” is checked).
- `<basename>.gof`: GeoDict Object File (if “Output GOF” is checked).
- `<basename>.gdr`: GeoDict result report containing voxel dimensions and a reference to the generated structure.
- `comparison_generator_countWeighted.png`: Post-processing comparison plot – count-weighted (only if post-processing is enabled).
- `comparison_generator_lengthWeighted.png`: Post-processing comparison plot – length-weighted (only if post-processing is enabled).

After successful generation, the structure is automatically loaded into the GeoDict workspace (preferring `.gad` if available, otherwise `.gdt`).



Typical Workflow

1. **Dialog 1** – Define domain size (voxels + voxel size), number of fiber types and layers, layering direction, minimal fiber distance, output formats, and algorithm settings. Click *OK*.
2. **Dialog 2** – For each fiber type, specify diameter, length, cross-section shape, orientation tensor entries, and (optionally) curvature parameters. Click *OK*.
3. **Dialog 3** – For each layer, define relative height, solid-volume fraction, and fiber type distribution. Click *OK*.
4. The Fiber Generator runs automatically; a progress bar is displayed within GeoDict.
5. The resulting structure is loaded into the GeoDict workspace for visualization and further simulation.

Validation Rules & Constraints

- **Orientation tensor:** The sum of the two provided diagonal entries must not exceed 1.
- **Output format:** At least one output format (GAD, GDT, VTI, or GOF) must be selected.
- **Post-processing:** Requires exactly one fiber type, one layer, and “Output GAD” enabled.
- **Curved fibers:** Maximal fiber segment length must be $\leq$ half of the shortest RVE edge length.
- **Layer heights:** The sum of all relative layer heights must be $\leq 100\%$.
- **Fiber type quantities:** The sum of fiber type quantities per layer must be $\leq 100\%$.
- **Load structure:** Requires “Output GAD” or “Output GDT” to be enabled.