FiberScanner3D *Application Note*

Full-Component 3D Fiber Mapping for High-Fidelity Digital Twins

X-ray Aided Engineering (XAE):

XAE represents a paradigm shift in fiber-reinforced composite manufacturing where high-fidelity digital twins are directly informed by structural information of manufactured components. Traditionally, characterizing composites is notoriously difficult with the standard X-ray approach due to several critical limitations:

Geometric & Resolution Constraints: Capturing micron-scale fiber details typically requires placing the sample very close to the X-ray source, which effectively limits high-resolution scans to very small objects.

Destructive Sampling Requirements: To overcome geometric limits and achieve the resolution needed for identifying fibers, large composite parts often must be cut into small coupons. This process prevents the analysis of "as-manufactured" full-scale components.

Demanding Processing: Conventional absorption data requires exhaustive fine-tuning of scan parameters and complex segmentation to capture individual fibers and bundles, often leading to uncertainties in the final performance predictions.

2 mm
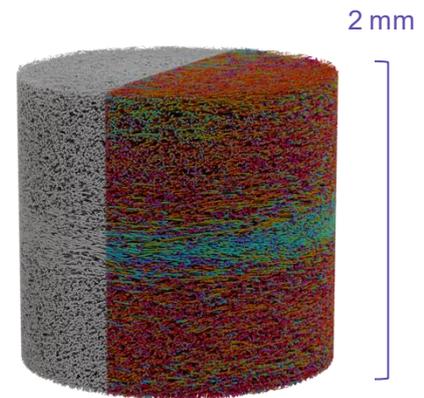
Absorption + Fiber Orientation

Full-component 3D Mapping with FiberScanner3D

The **FiberScanner3D** overcomes traditional contrast and scale challenges by employing multimodal analysis. By analyzing changes in the X-ray scattering signal alongside conventional absorption data, the technology enables three-dimensional characterization of the full-component volume:

- **Direct Orientation Mapping**: 3D fiber orientation within every voxel.

- **Fiber Volume Fraction**: Local concentration of the filler material.

- **Directional Anisotropy**: Degree of fiber alignment (random to aligned)

- **Porosity & Inclusion Analysis**: Quantification of voids and defects

- **Nominal (CAD) vs. Actual Comparison**: Design deviation analysis

- **Mesh Generation**: High-fidelity FE meshes for geometric accuracy

Component dimensions: 150 x 100 x 80 mm³

Component provided by Lasse Staal@3DPMolds (former Addifab | Nexa3D)

150 mm

Case Study: Digital Twin of Injection-Molded Component

This case study demonstrates the creation of a high-fidelity Digital Twin by utilizing a full-component analysis. The resulting model non-destructively captures the true "as-manufactured" state of the part, accounting for process-induced variations in fiber orientation and geometry:

- Microstructural Fiber Length Analysis using a Region-of-Interest CT Scan

- Full-Component Fiber Orientation & Geometry using **FiberScanner3D** Scan

Component Description:

Material: PPA with 30% Carbon Fiber filler
Fiber length: 160 µm
Dimensions: 25 x 12 x 12 mm^3

FiberScanner3D Scan Details:

Scan resolution: 100 µm (Fiber) / 10 µm (Shape)
Total scan time: 1 hour
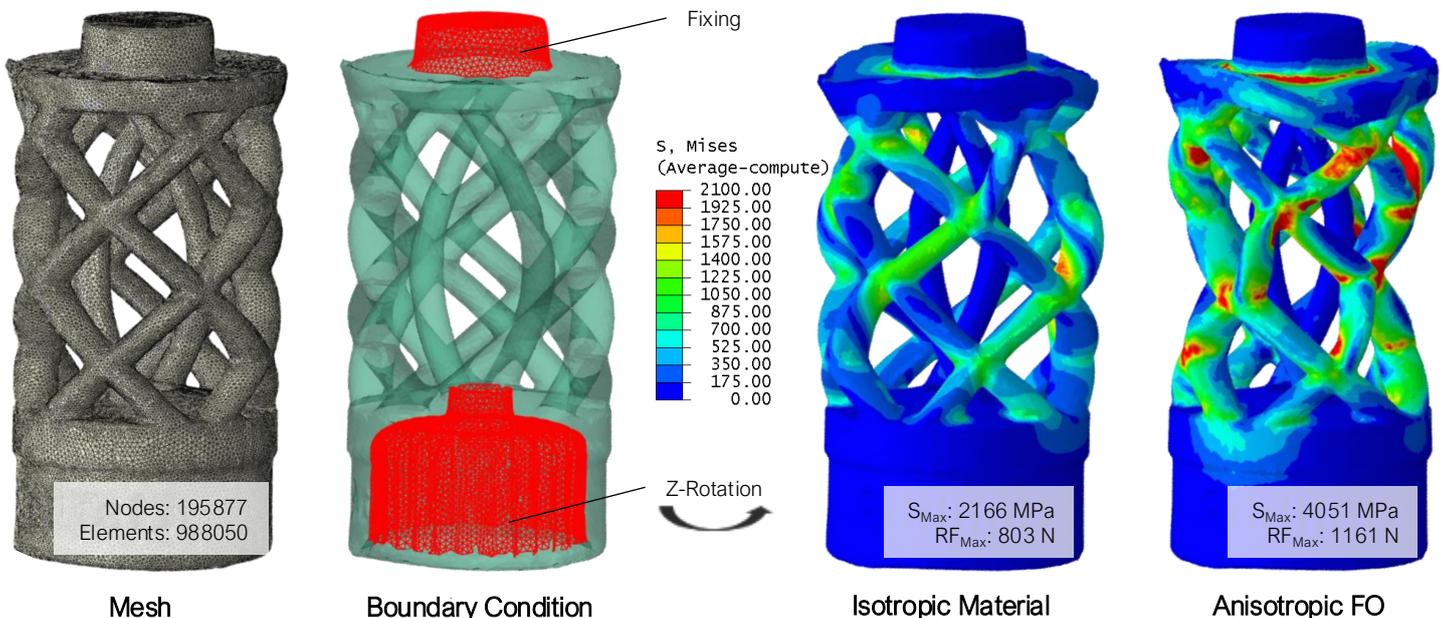Field-of-view: 25 x 25 x 25 mm^3

200 µm

25 mm
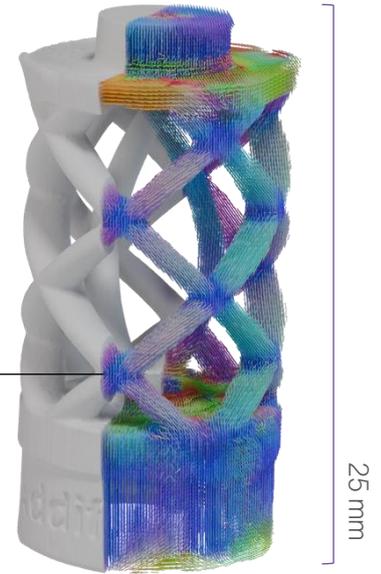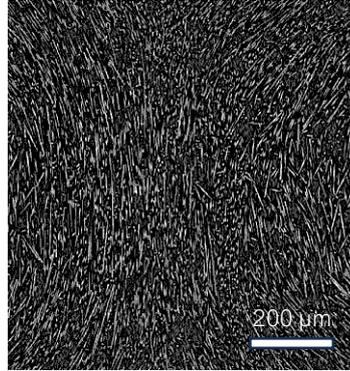
FiberScanner3D

Finite Element Analysis

The integration of **FiberScanner3D** data into finite element models allows for highly realistic predictions by using the as-manufactured fiber architecture as input parameters. A torsion simulation is performed on the reconstructed 3D mesh with a linear elastic material law.

Boundary Condition: One side of the part is designated as Fixed Support (the displacement in all directions is zero)

Loading Scenario: The opposite end is rotated in the negative direction of the Z-axis (37°)

Simulation Result: Without taking the underlying fiber orientation (FO) distribution into account, both stresses (S) and reaction forces (RF) are significantly underestimated in simulation. Utilizing the advanced knowledge about local fiber orientations from **FiberScanner3D**, a more accurate representation of the material behavior can be achieved, leading to improved predictions of mechanical performance.

Fixing

Z-Rotation

S, Mises
(Average-compute)

2100.00
1925.00
1750.00
1575.00
1400.00
1225.00
1050.00
875.00
700.00
525.00
350.00
175.00
0.00

Nodes: 195877
Elements: 988050

S_{Max}: 2166 MPa
RF_{Max}: 803 N

S_{Max}: 4051 MPa
RF_{Max}: 1161 N

Mesh **Boundary Condition** **Isotropic Material** **Anisotropic FO**

Simulations are performed by Fraunhofer ITWM

Component provided by Lasse Staal@3DPMolds (former Addifab | Nexa3D)

Fraunhofer ITWM

xnovotech
— a **RAITH** company —