GeoDict

MATH
2 MARKET

Case Study
Material-CAE for Composites

Our Mission

The composite industry faces challenging questions.

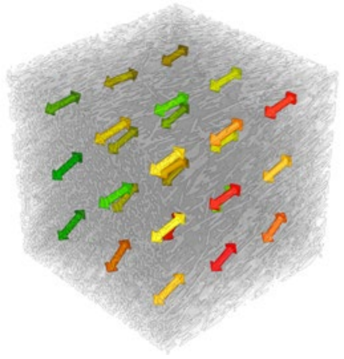
- Does the new composite material improve my component?
- Does it combine sufficient stiffness with low weight?
- Do I understand the microscopic behavior of the composite for my component simulation?

GeoDict, the digital material laboratory, provides answers to such questions. It helps to avoid trial-and-error and to prototype only the most promising composites.

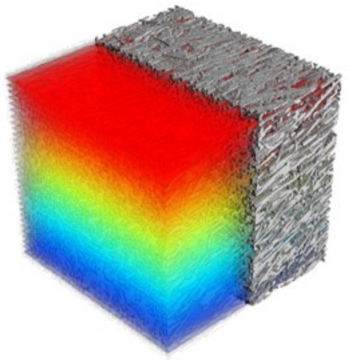
GeoDict's material-CAE bridges the gap between process-CAE and structure-CAE. Compute composite material properties, e.g. for component simulations, on detailed 3D material models or µCT scans.GeoDict's accurate and quick computations run on standard hardware.

Here, we analyze the material properties of an engine bearer. The component's composite is PA 66 GF50 (polyamide, 50% glass-fibers).

[1]



[2]



[3]

[1]: PA66 - GF50
[2]: Fiber orientation
[3]: Thermal conductivity

Workflow

Scanning of small pieces of the engine bearer to resolve features of the fibers by µCT. In the resulting grayscale image, the brightness correlates to the constituent materials within the object.

Segmenting, which refers to the identification and labeling of fibers and matrix within the µCT scan, as a foundation for later simulations.

Geometric analysis on the segmented µCT scan, to obtain fiber weight percentage, fiber diameters, and local fiber orientation.

Simulating important material properties on the segmented µCT scan, like thermal conductivity, mechanical behavior, and material failure.

Modelling of the micro structure with given statistics e.g. for fiber diameter distribution and fiber orientation distribution. If these are known from process-CAE, the workflow does not require a µCT scan.

Optimization by changing the statistical parameters or the constituent materials of the model.

For this case, segmentation of the µCT scan into glass fibers and polyamide matrix is done with image processing module ImportGeo to get 30% solid volume percentage for the fibers (weight percentage 50%).

Composite properties analyzed with GeoDict

Fiber structure

is analyzed with FiberGuess, Fig. [2], [6]:
Fiber diameter: 8.56 $^{+}/_{-}$ 1.9 µm

Fiber orientation tensor		
0.597	-0.050	0.145
-	0.143	0.003
-	-	0.260

Thermal conductivity

is simulated with ConductoDict assuming conductivities 0.76 W/(mK) for glass and 0.33 W/(mK) for polyamide.

Thermal conductivity	(W/mK)
GeoDict	0.43
Product Datasheet	0.37

Effective linear elastic properties

are simulated with ElastoDict, assuming Young’s modulus E = 86.9 GPa and Poisson ratio ν = 0.2 for the fibers (S2-Glass), and E = 3 GPa and ν = 0.15 for the polyamide matrix (Fig. [4]). The Young’s modulus of the composite parallel and perpendicular to the fibers is shown in Fig. [5].

Thermal expansion tensor

is computed with ElastoDict, assuming 5e-06 1/K as linear thermal expansion coefficient of glass and 8e-05 1/K for polyamide.

Thermal expansion tensor (1/K)		
16.060	2.603	-10.140
2.603	38.970	-6.010
-10.140	-6.010	34.930

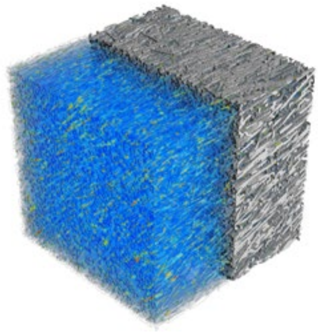
Cyclic tensile experiment

with 6% strain in z-direction. Consider matrix damage, modeled by an Abaqus UMAT in ElastoDict, Ref. [1],[2]. Fiber breakage is not considered. The resulting strain-stress curve is shown in Fig. [7].

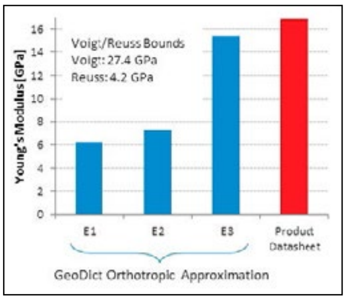
Composite design

Fiber SVP (%)	25	30	35
Young’s Modulus [GPa]	11.9	13.7	16.2

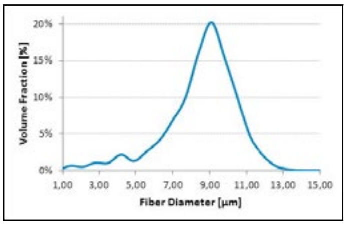
is done with the module FiberGeo, where input parameters are fiber weight percentage, fiber diameter distribution, and fiber orientation. Models with different solid volume percentages are created and the influence of density variations on the elastic properties studied.



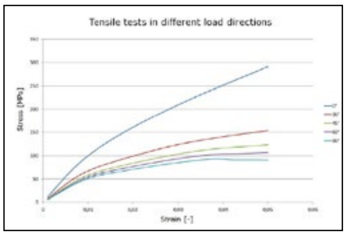
[4]



[5]



[6]



[7]

References

[1] J. Spahn, H. Andrä, M. Kabel, R. Müller, A multiscale approach for modeling progressive damage of composite materials using fast Fourier transforms, Computer Methods in Applied Mechanics and Engineering, Volume 268, Pages 871-883, ISSN 0045-7825, 2014.

[2] J. Sliseris, H. Andrä, M. Kabel, B. Dix, B. Plinke, O. Wirjadi, G. Frolovs, Numerical prediction of the stiffness and strength of medium density fiberboards, Mechanics of Materials. 01/2014

[4]: Von Mises Strain
[5]: Elastic Properties
[6]: Fiber Diameter Distribution
[7]: Cyclic tensile experiment with matrix damage

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