MATH
2 MARKET

Simulation of a Multifunctional Hybrid Composite with Continuous Steel and Carbon Fiber Reinforcement on the micro-level

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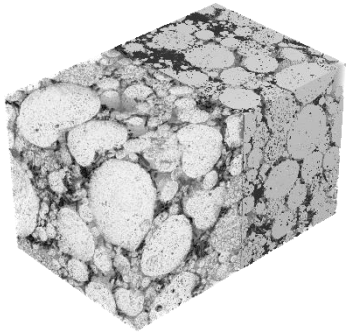
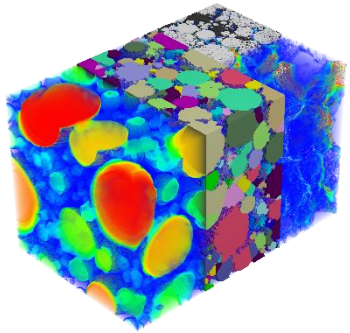
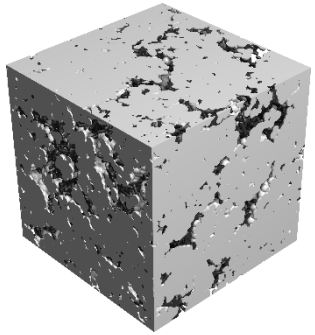
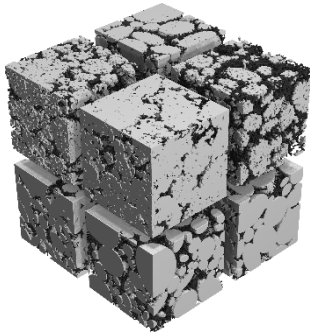
Outline

The Workflow for Digital Material Design with GeoDict®

GeoDict

Import	Analyze	Model	Design	Next Generation Material
				
The idea is the beginning. Design a material from scratch or import images from an existing material to create a digital model.	Discover the geometric properties and compute the physical properties of the material. This is the start of creating a Digital Twin.	A Digital Twin is the statistical representation of the material in the digital world. Here begins the design process.	Digital prototypes are easily and rapidly created. Simulate and evaluate in a loop to find the material with the desired properties.	The materials of the future are within reach and we help you find them faster.
Digital Material	Statistical Model	Digital Twin	Digital Prototypes	This is innovation through simulation.

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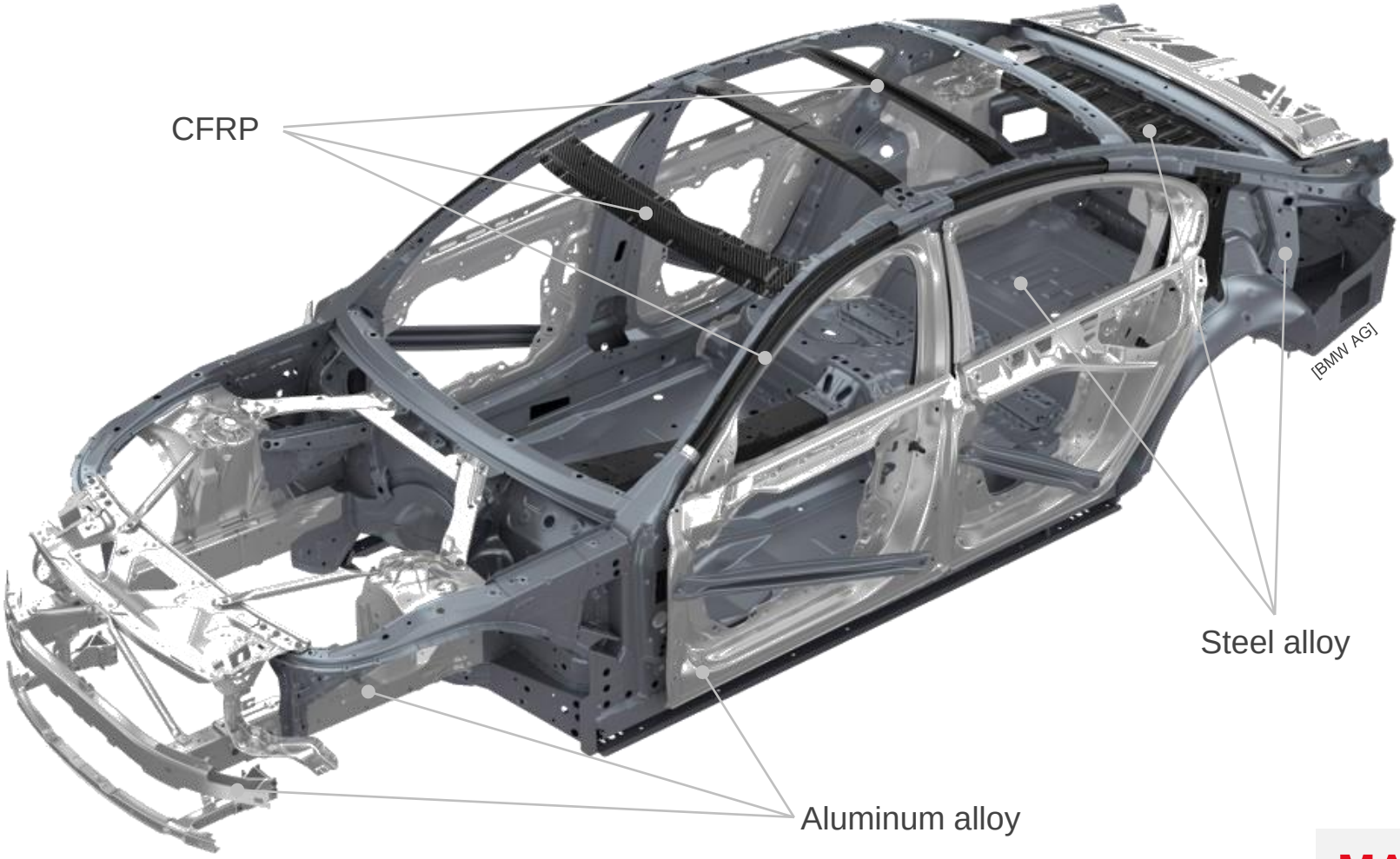
Outline

Motivation

new BMW 7 car body

GeoDict



MATH 2 MARKET

Motivation

Material Properties

GeoDict

	CFRP		New hybrid mat		Metal
+	High stiffr	+	High stiffr	+	High stiffness
+	High strer	+	High strer	+	Good strength
+	Very low de	+	Acceptable	-	High density
-	Brittle fai	+	Optimized f	+	Ductile failure
-	Poor energy ab in tensi	o	Good energy ab in tensi	+	High energy absorption in tension
+	High energy ab in compres	+	Good energy ab in compre	+	Good energy absorption in compression
-	Limited stru integrity in	+	Good struc integrity in	+	Superior structure integrity in crash
-	Poor elect conducti	+	Sufficient ele conducti	+	High electrical conductivity
-	High co	o	Acceptable	+	Low cost

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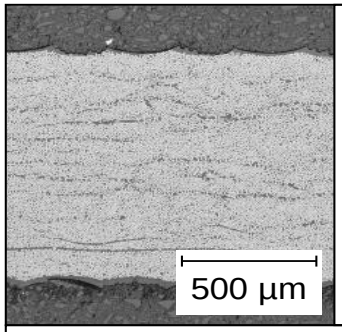
Outline

CHARACTERIZATION OF THE HYBRID COMPOSITES

GEODICT

MATERIAL ANALYSIS

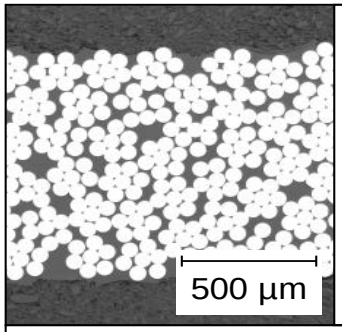
CFRP UD



φ_C: 64.1 vol.%
φ_S: 0.0 vol.%
φ_R: 35.9 vol.%
ρ: 1.60 g/cm³
t: 0.95 mm

(0_8^C)

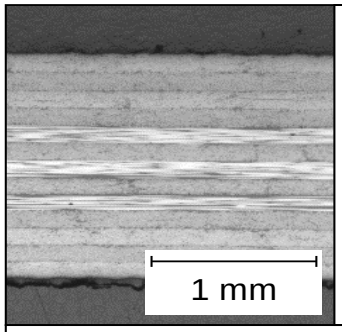
SFRP UD



φ_C: 0.0 vol.%
φ_S: 61.7 vol.%
φ_R: 38.3 vol.%
ρ: 5.40 g/cm³
t: 1.01 mm

(0_6^S)

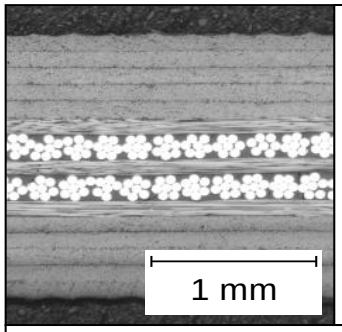
CFRP MD



φ_C: 61.6 vol.%
φ_S: 0.0 vol.%
φ_R: 38.4 vol.%
ρ: 1.59 g/cm³
t: 1.60 mm

$(45^C/-45^C/45^C/-45^C/90^C/0^C/\overline{90}^C)_s$

SCFRP 10i 0° MD



φ_C: 52.7 vol.%
φ_S: 11.2 vol.%
φ_R: 36.2 vol.%
ρ: 2.29 g/cm³
t: 1.87 mm

$(0^C/45^C/-45^C/45^C/-45^C/90^C/0^S/\overline{90}^C)_s$

C: Carbon, S: Steel, R: Resin, φ: Volume share, ρ: Density, t: Laminate thickness

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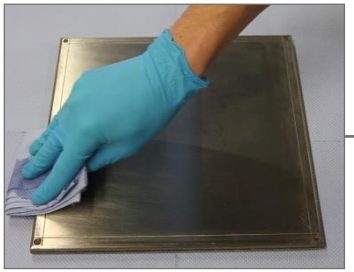
Characterization of the hybrid composites

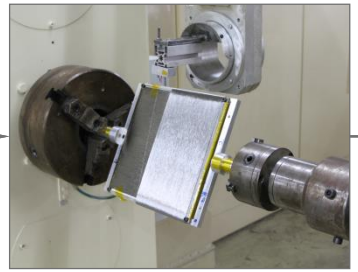
GeoDict

Manufacturing process

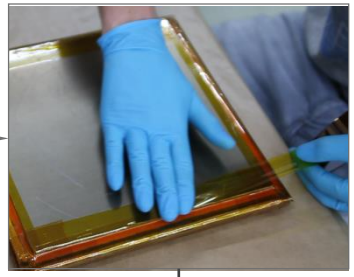
Tool preparation



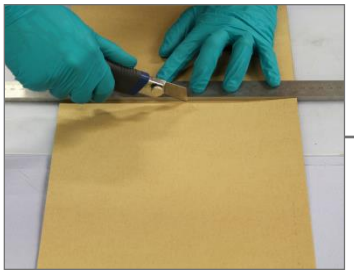
Winding + tape placement



Packing

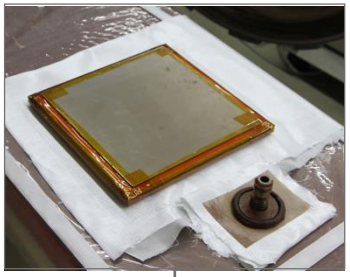


Tape pre-cut



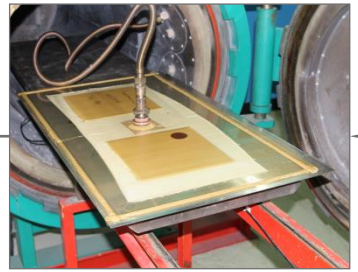
time & cost consuming process

Vacuum bagging



Waterjet Cutting

Debagging



Autoclave curing

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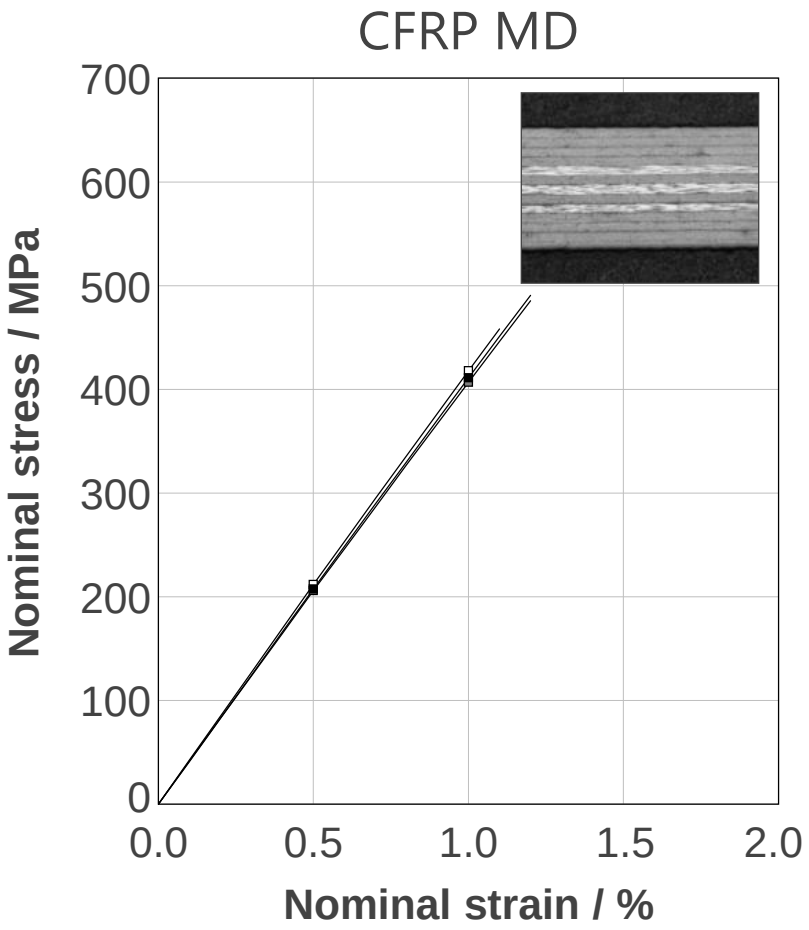
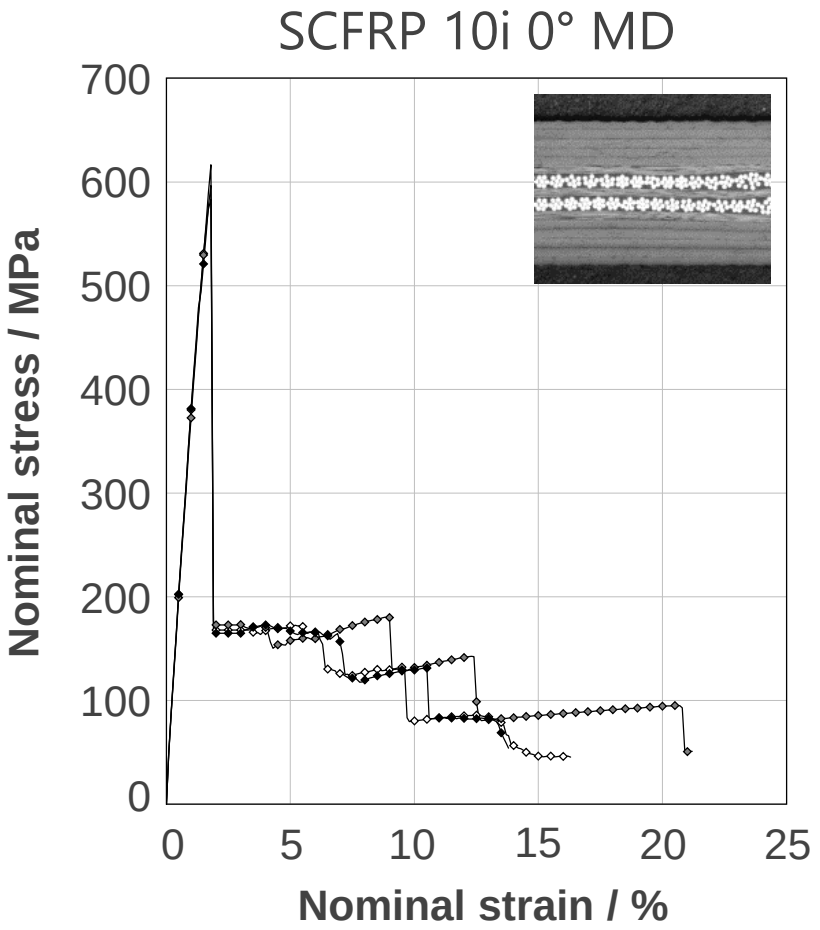
Characterization of the hybrid composites

GeoDict

Experimental results





Steel fibers can increase fail safe behavior significantly!

MATH 2 MARKET

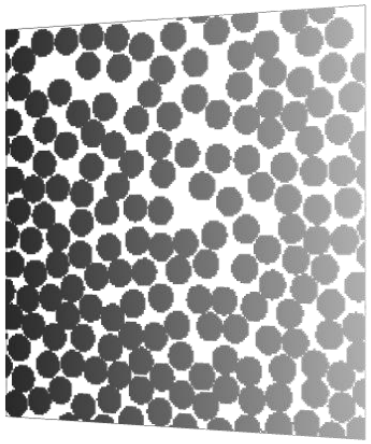
Outline

MICROSTRUCTURAL SIMULATION

MODEL DESIGN

GEODICT

- models of the different laminates with 0.7 µm resolution

CFRP UD	SFRP UD	CFRP MD	SCFRP 10i 0° MD
			
(0_8^C)	$(0_8^R/0_8^S/0_8^R)$	$(45^C/-45^C/45^C/-45^C/90^C/0^C/\overline{90}^C)_s$	$(0^C/45^C/-45^C/45^C/-45^C/90^C/0^S/0^R/\overline{90}^C)_s$
1x200x200 (40,000 voxel)	1x200x200 (40,000 voxel)	100x250x1141 (28,525,000 voxel)	100x250x1320 (33,000,000 voxel)

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Microstructural simulation

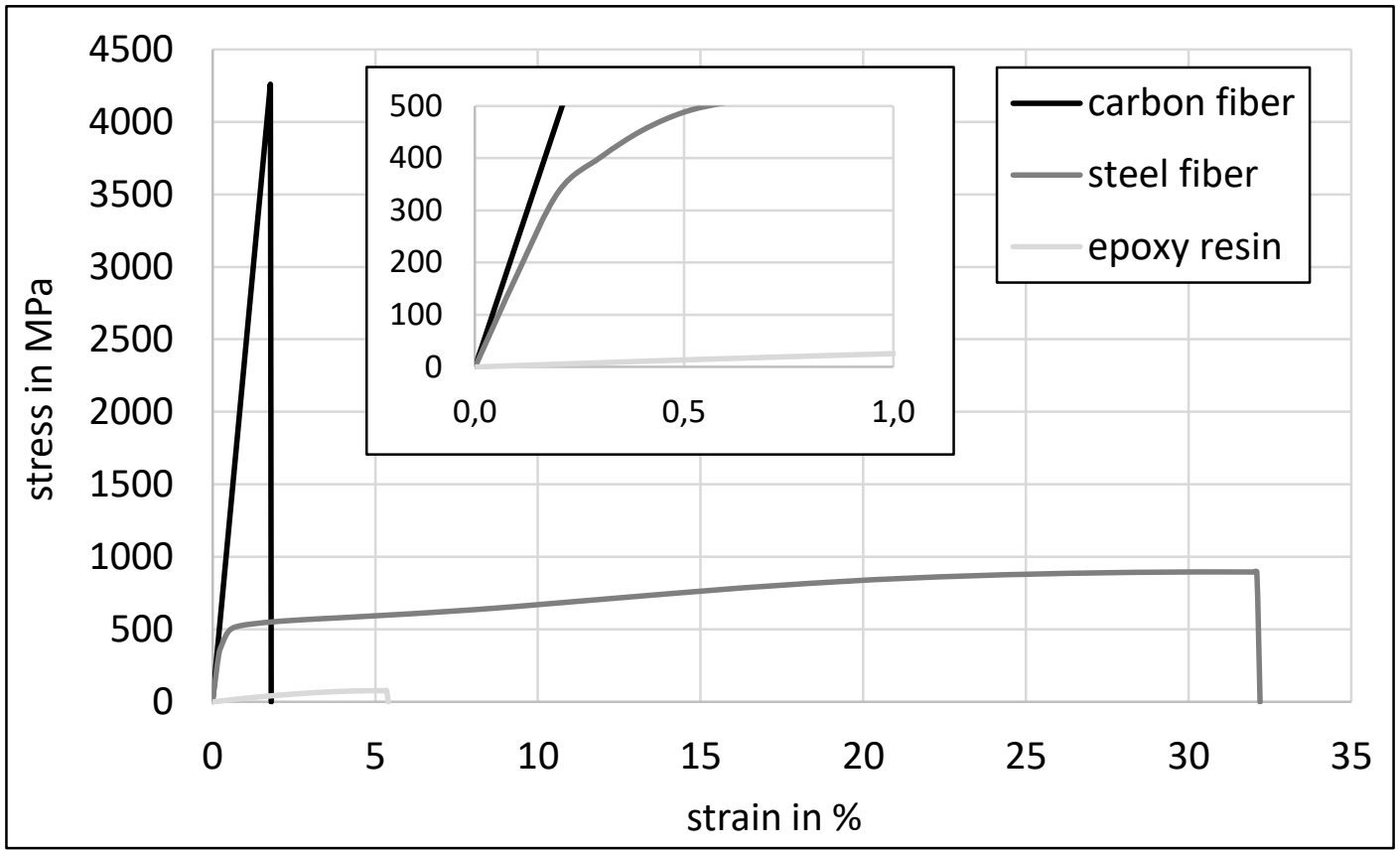
material models

- epoxy matrix
  - linear isotropic UMAT
  - damage function: $\Delta C = (T_1 \cdot \log(-T_2 \cdot \log(D)) + T_3) \cdot T_4$
  - failure criterion: maximum strain
- carbon fiber
  - linear elastic UMAT
  - failure criterion: maximum stress
- steel fiber
  - linear elastic
  - with general von-Mises yield criterion

Microstructural simulation

Material models

- different material behaviors

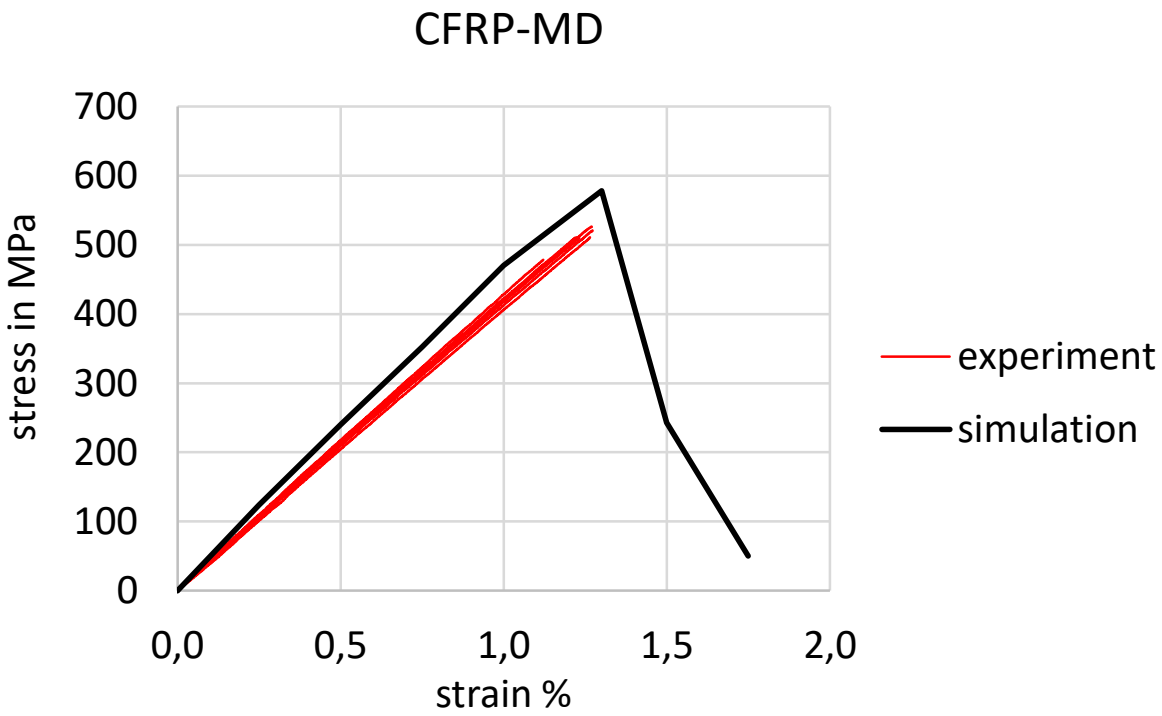


MICROSTRUCTURAL SIMULATION

SIMULATION RESULTS

GEODICT

- multidirectional CFRP



MATH 2 MARKET

Microstructural simulation

Simulation results

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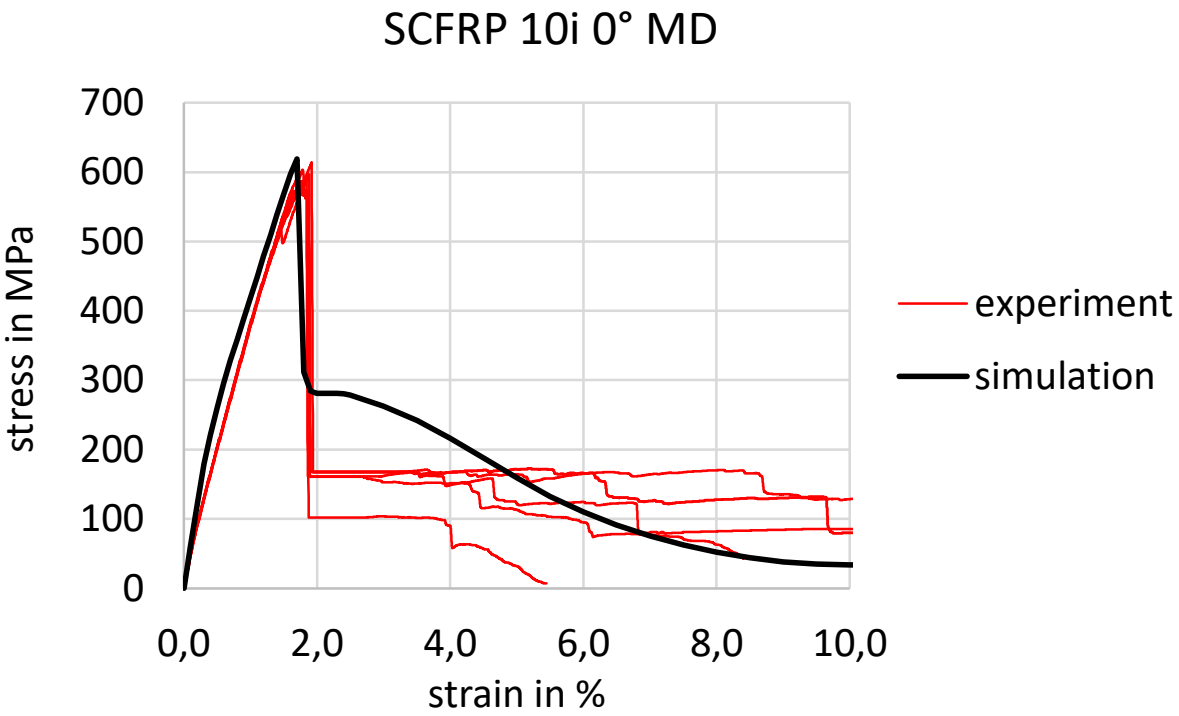


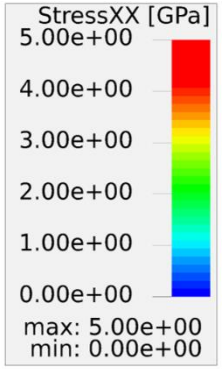
MICROSTRUCTURAL SIMULATION

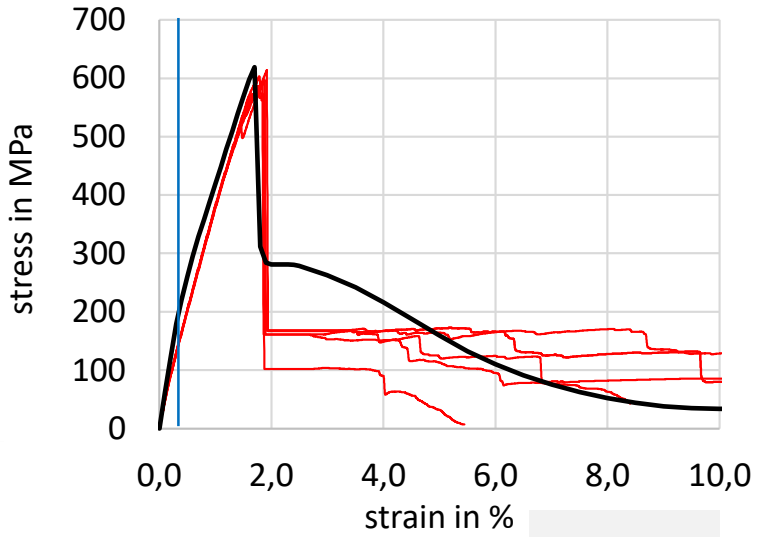
VISUALIZATION OF SIMULATION RESULTS

GEODICT

- stress in loading direction (XX)

0.3 %





macroscopic strain

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VISUALIZATION OF SIMULATION RESULTS

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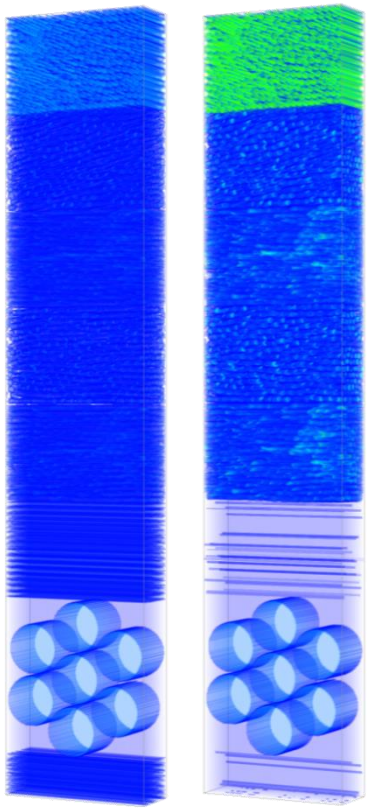
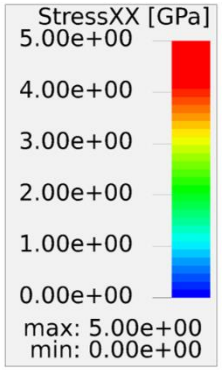
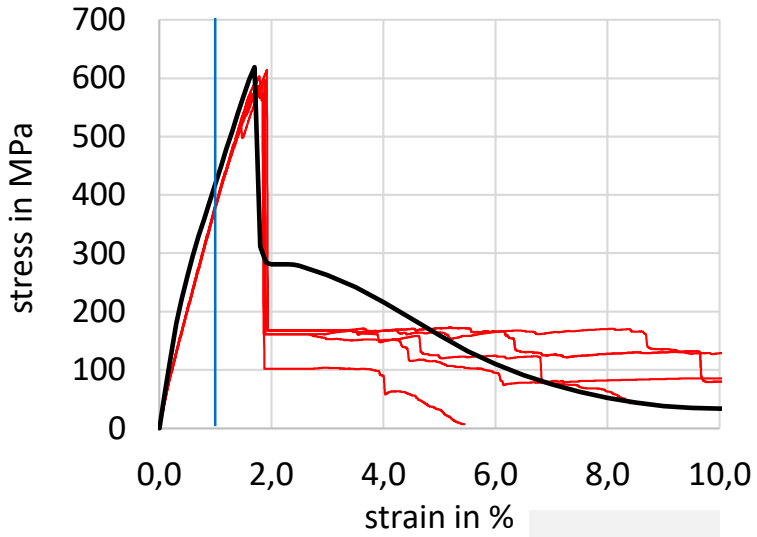


0.3 % 1.0 %

macroscopic strain





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VISUALIZATION OF SIMULATION RESULTS

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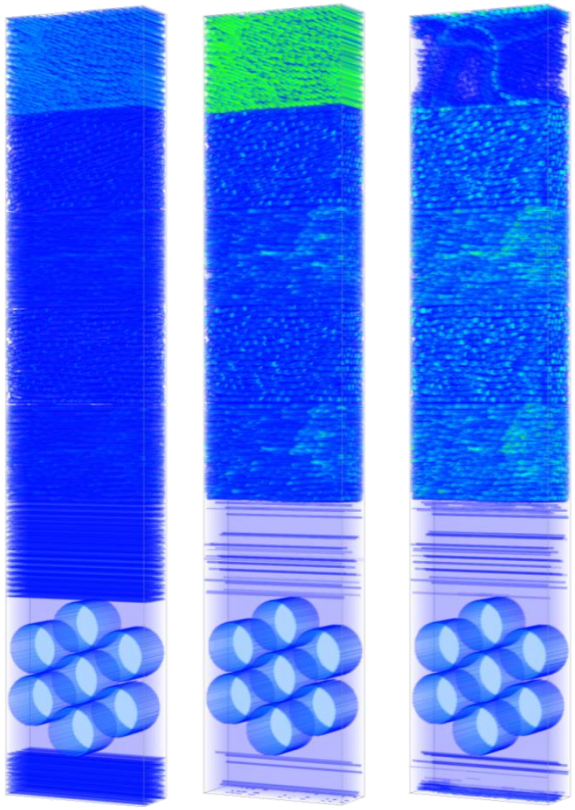

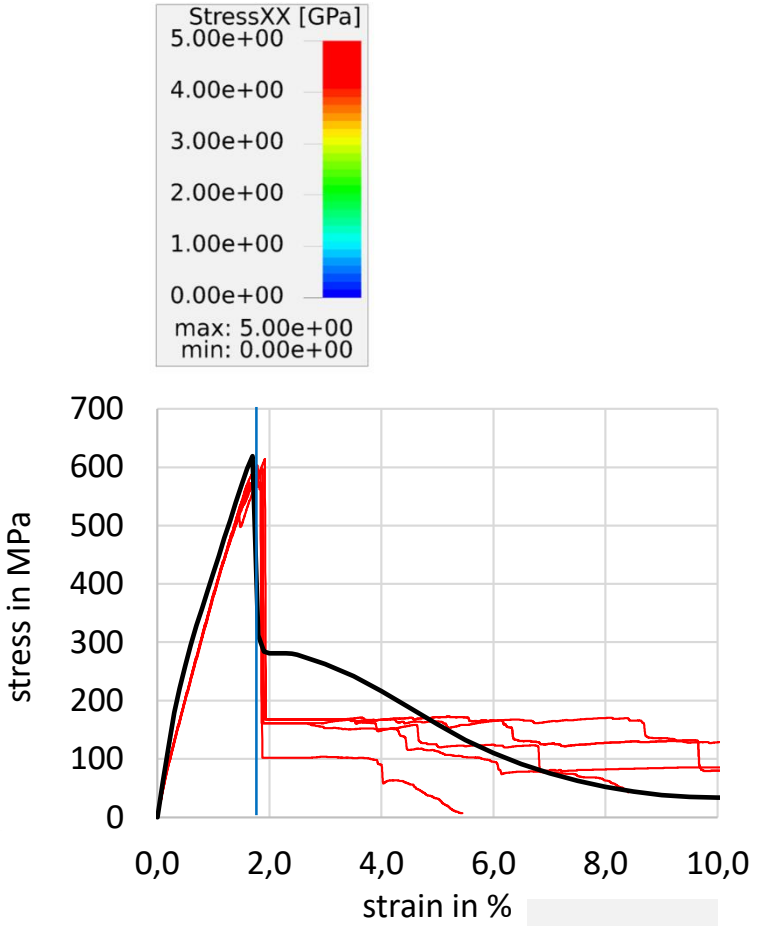

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VISUALIZATION OF SIMULATION RESULTS

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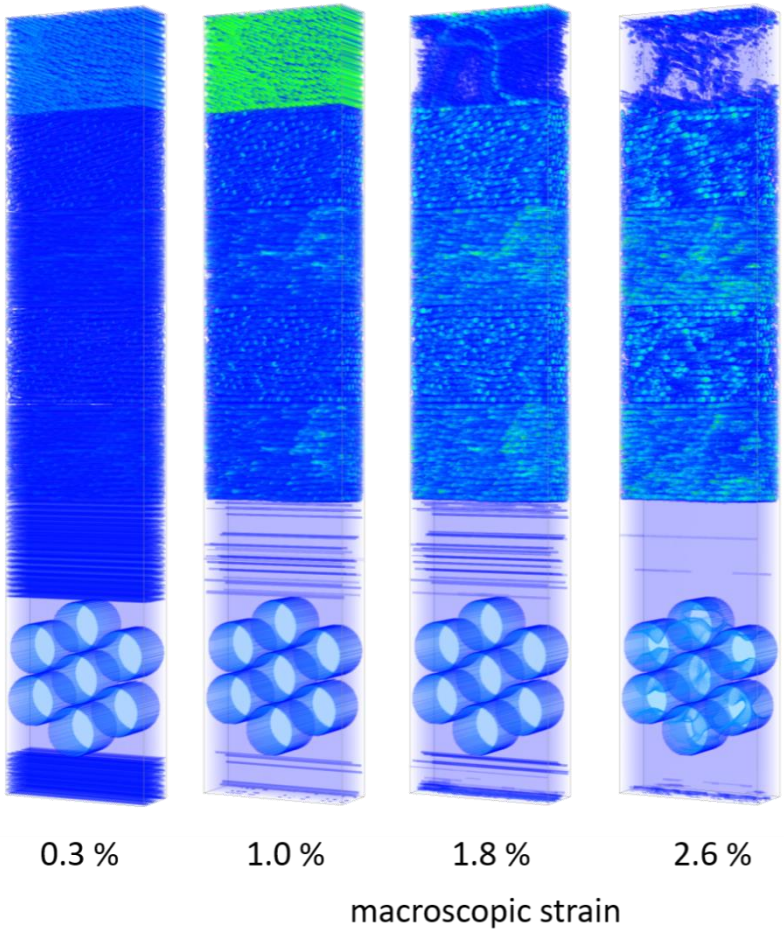

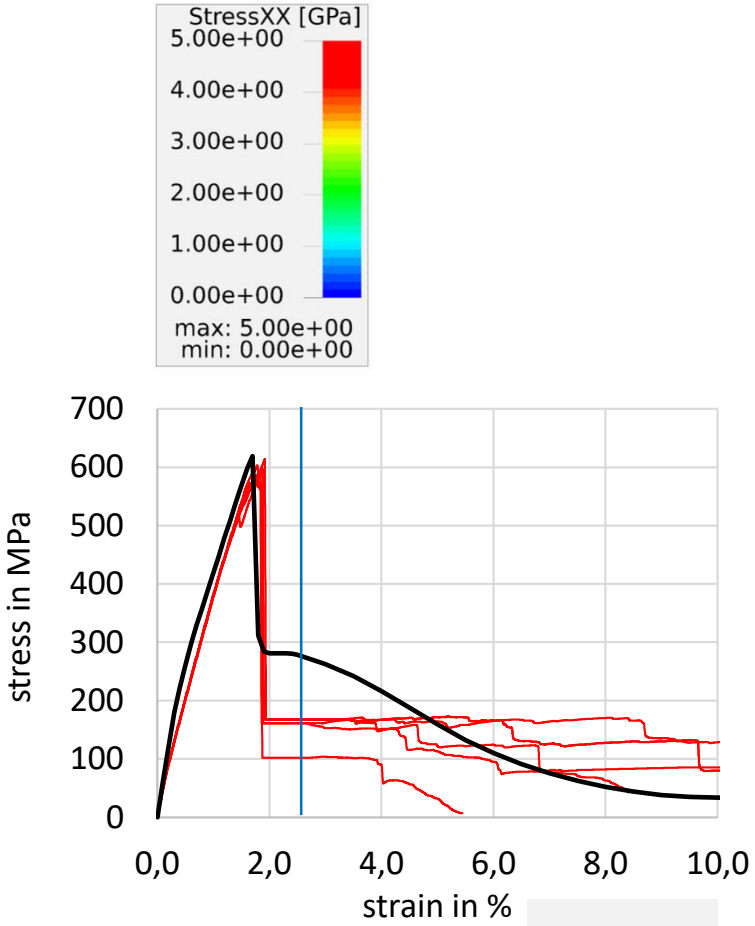

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MICROSTRUCTURAL SIMULATION

VISUALIZATION OF SIMULATION RESULTS

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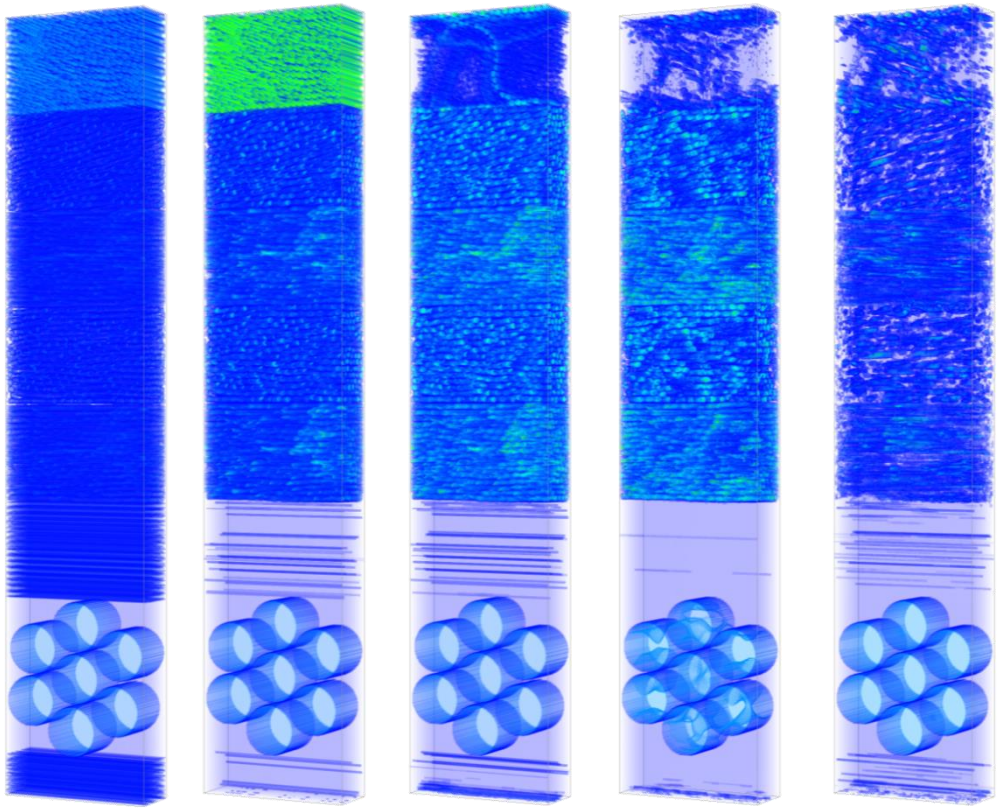
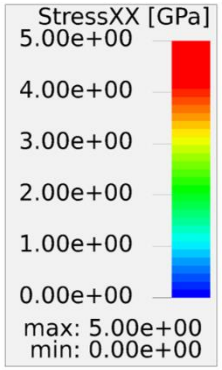
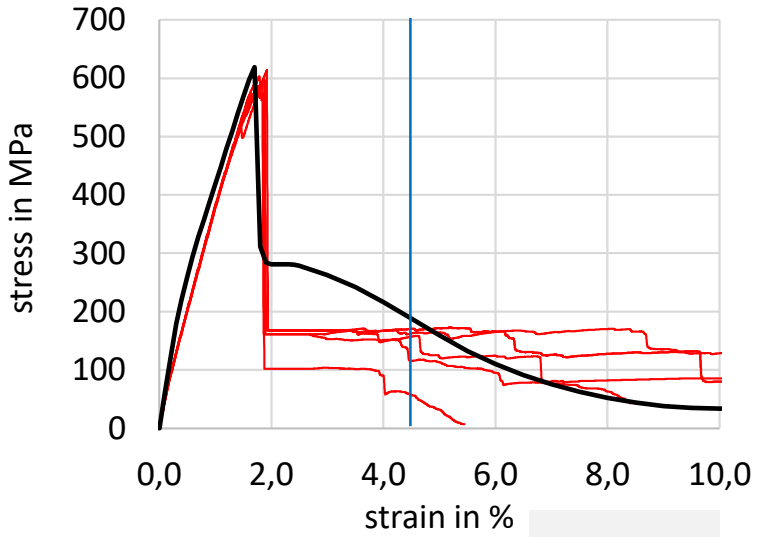






MATH 2 MARKET

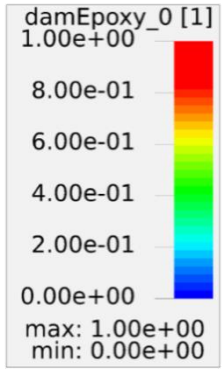
Microstructural simulation

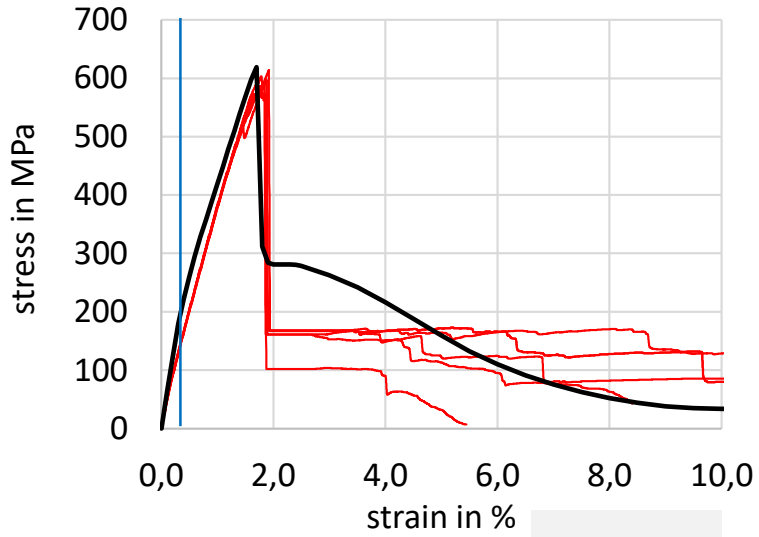
Visualization of simulation results

- damage in epoxy resin

0.3 %

macroscopic strain



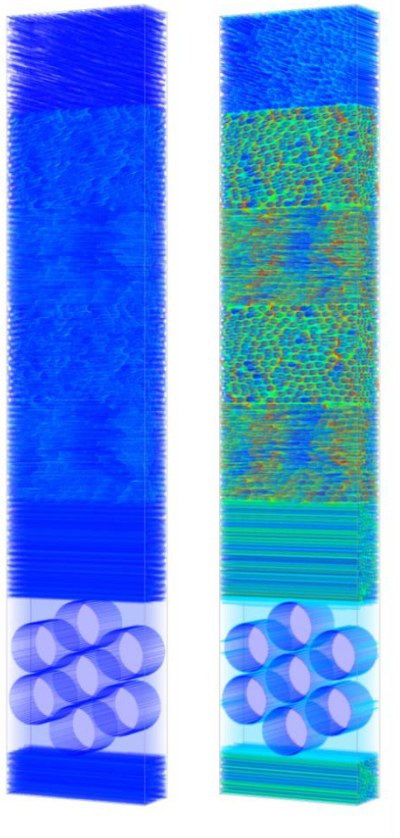


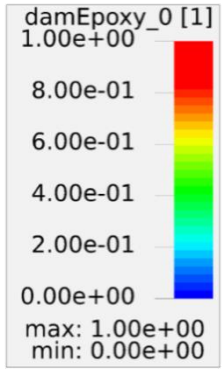
MICROSTRUCTURAL SIMULATION

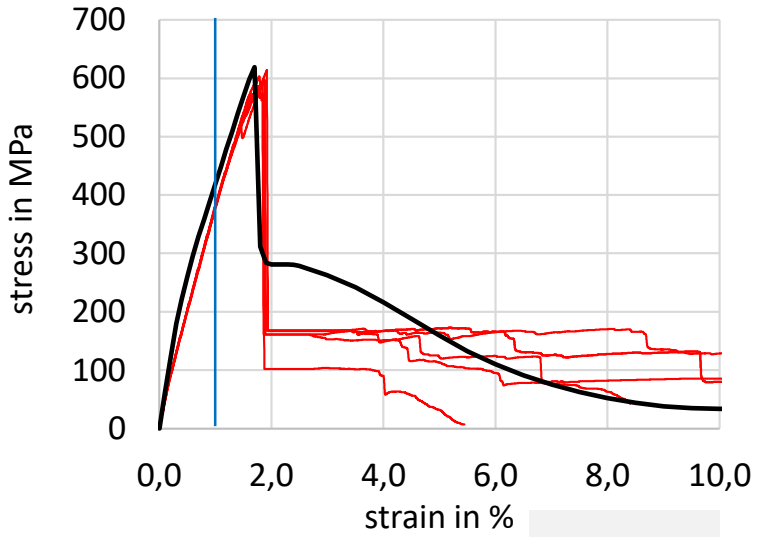
VISUALIZATION OF SIMULATION RESULTS

GEODICT

- damage in epoxy resin







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VISUALIZATION OF SIMULATION RESULTS

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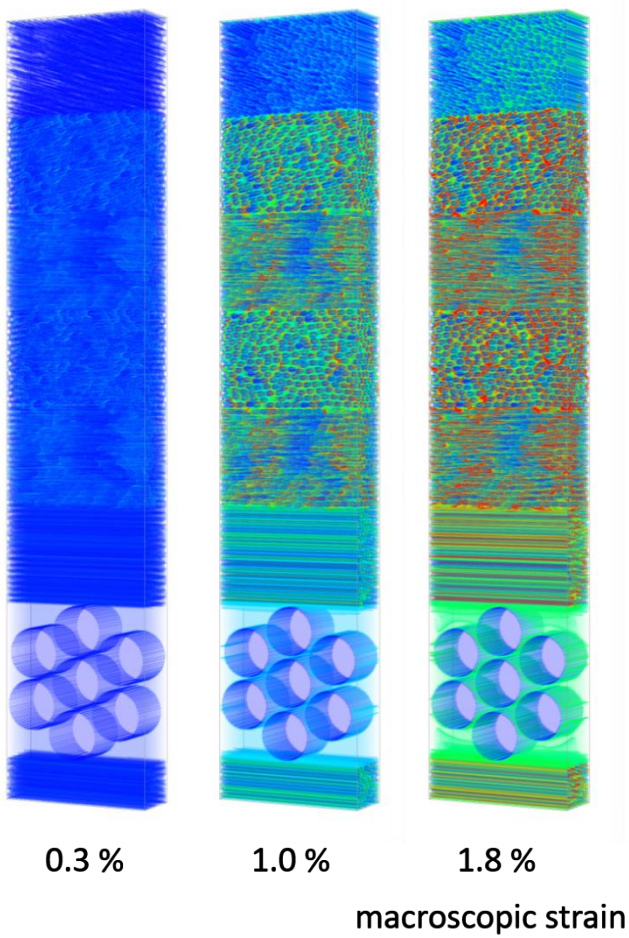

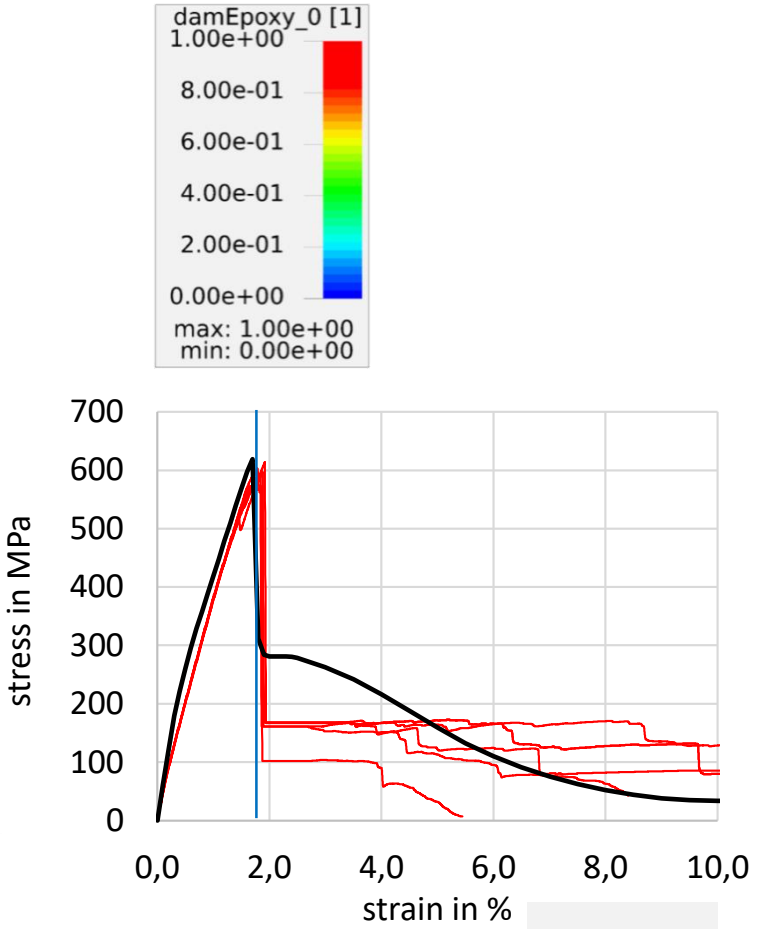

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MICROSTRUCTURAL SIMULATION

VISUALIZATION OF SIMULATION RESULTS

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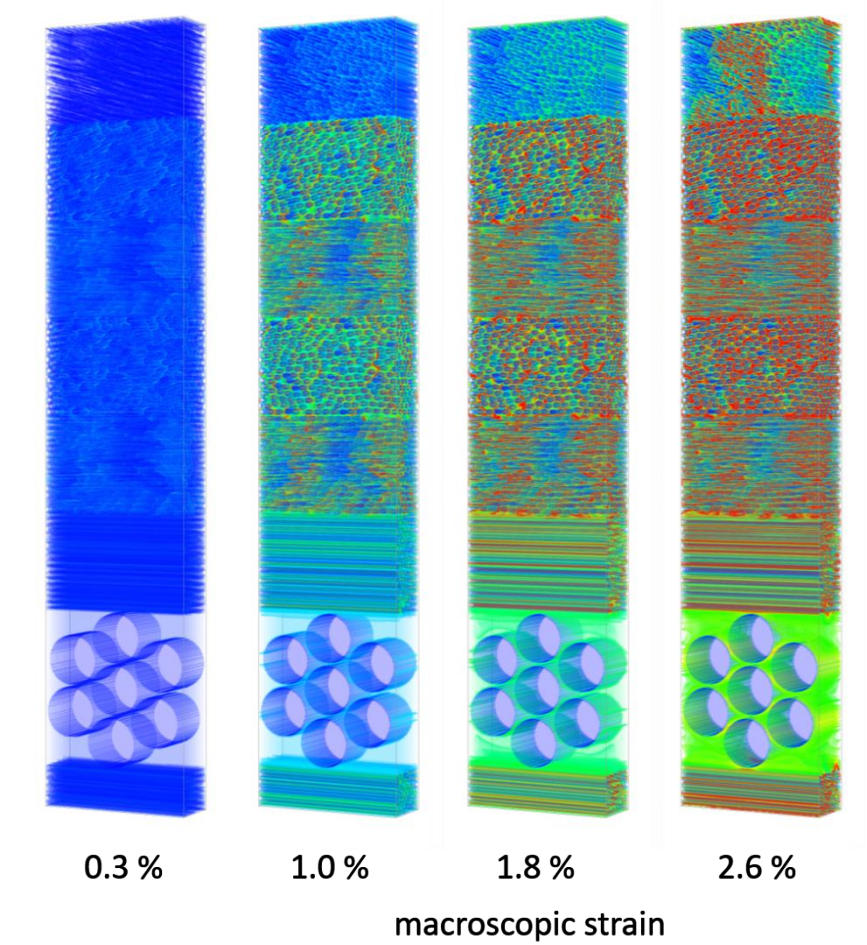

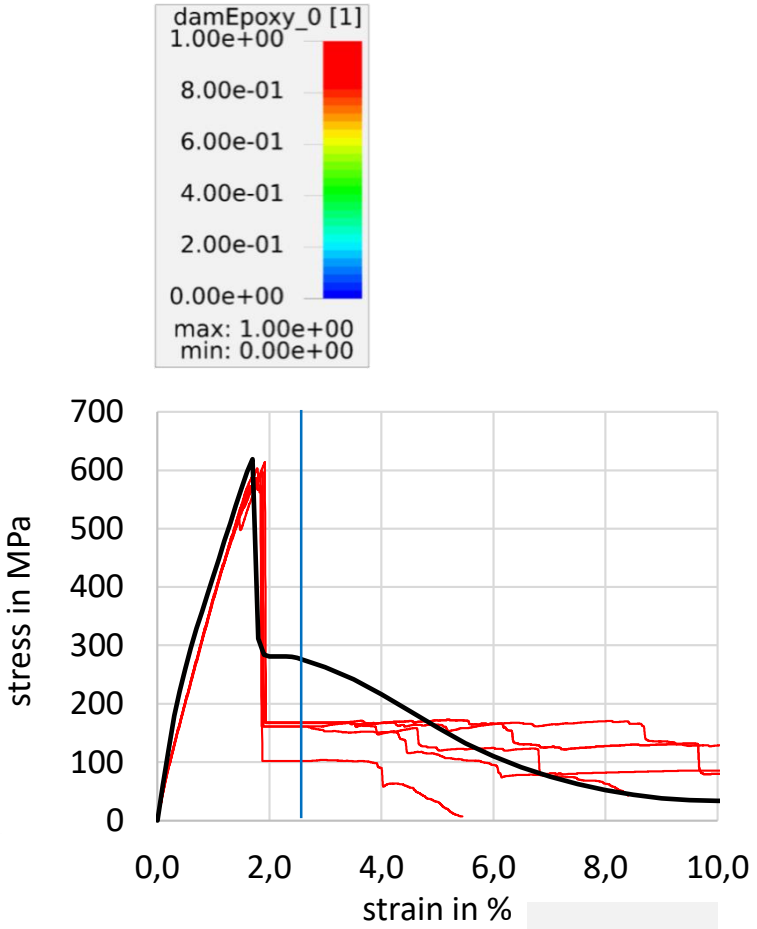

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VISUALIZATION OF SIMULATION RESULTS

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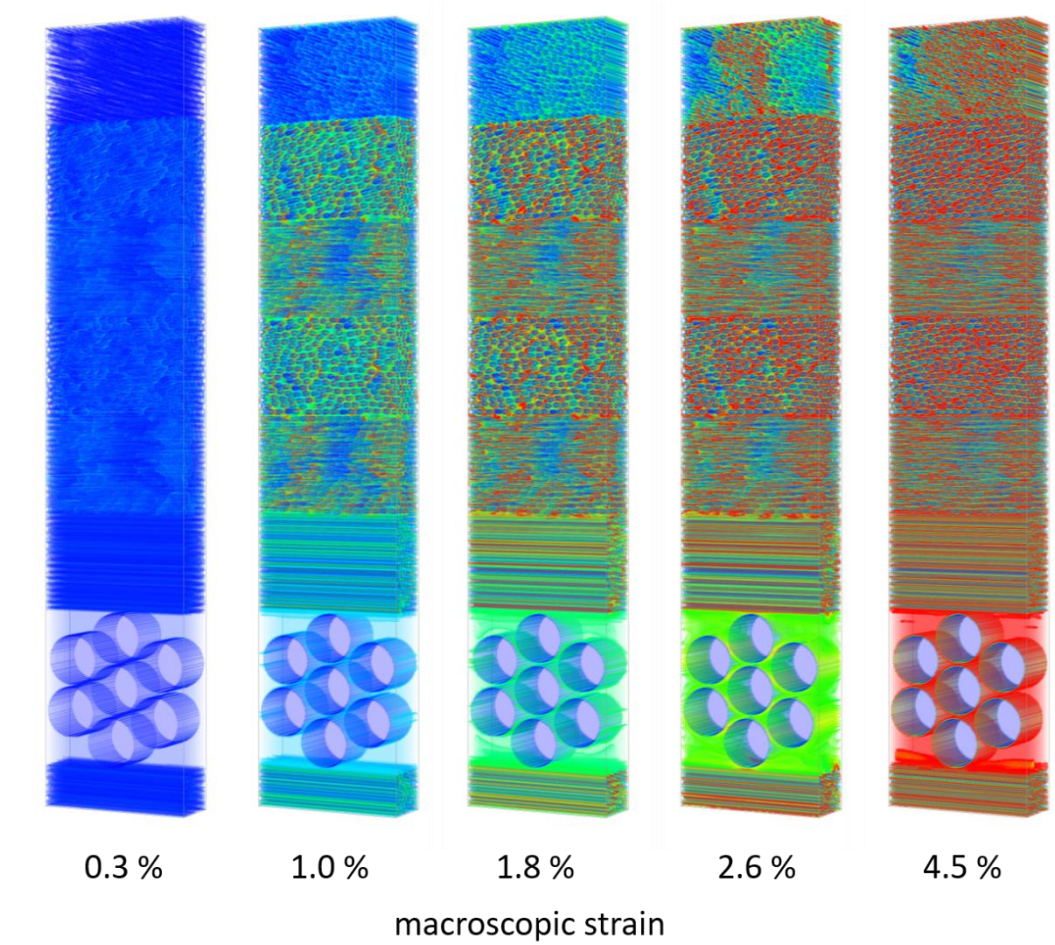

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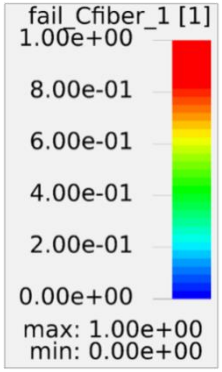
Microstructural simulation

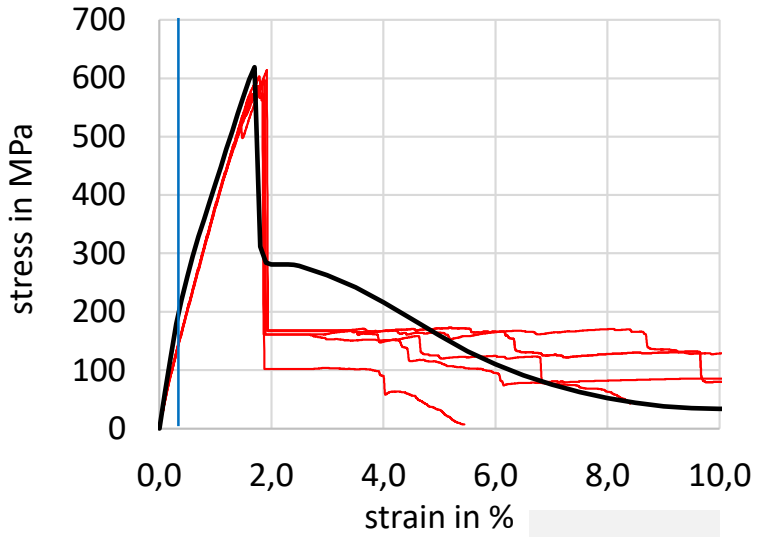
Visualization of simulation results

- failure in carbon fiber

0.3 %

macroscopic strain





MICROSTRUCTURAL SIMULATION

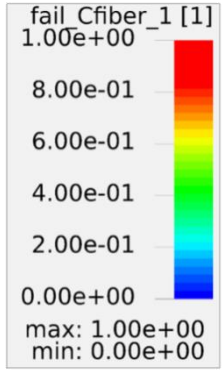
VISUALIZATION OF SIMULATION RESULTS

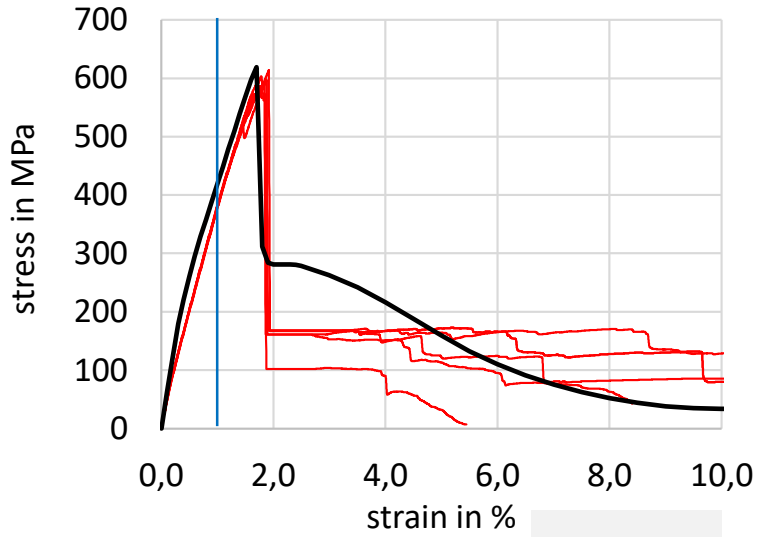
GEODICT

- failure in carbon fiber

0.3 % 1.0 %

macroscopic strain





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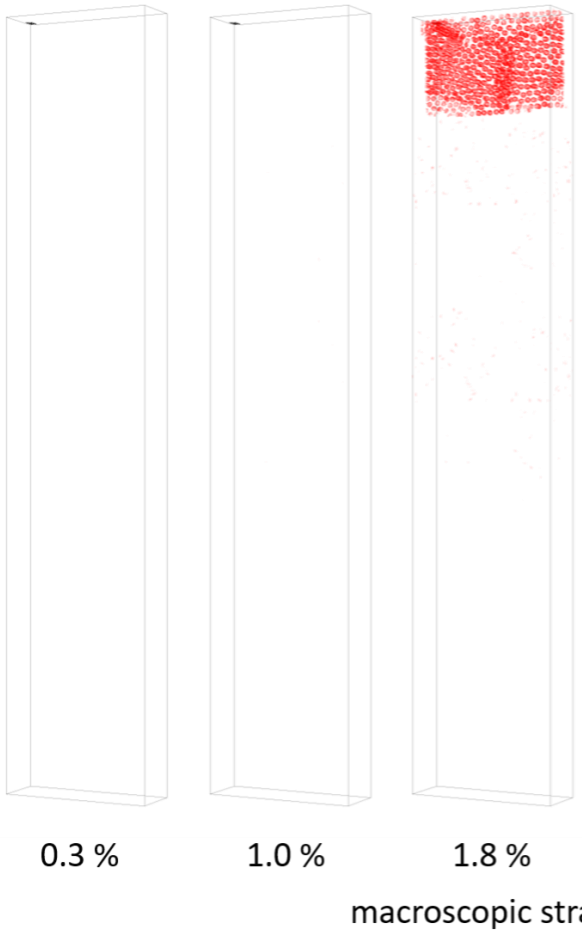
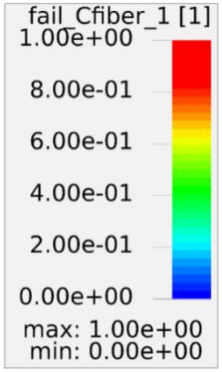
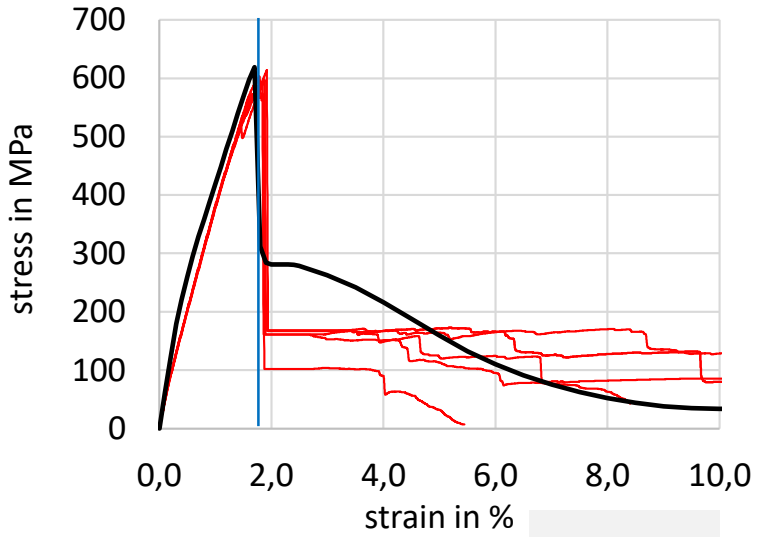
VISUALIZATION OF SIMULATION RESULTS

GEODICT

- failure in carbon fiber





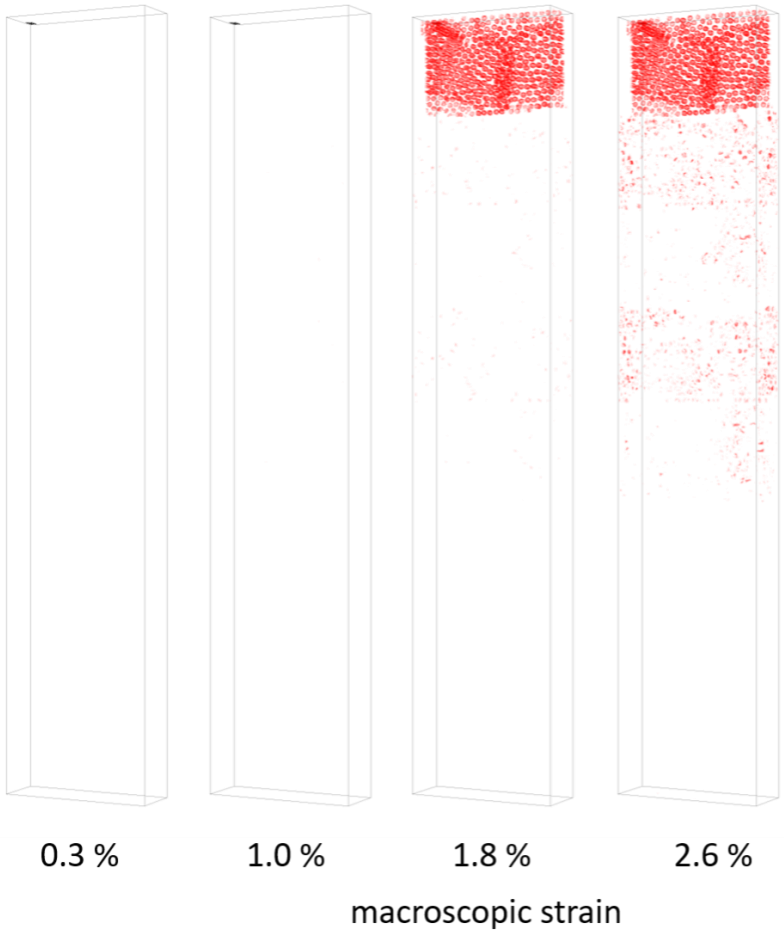


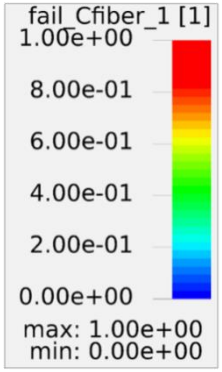
MATH 2 MARKET

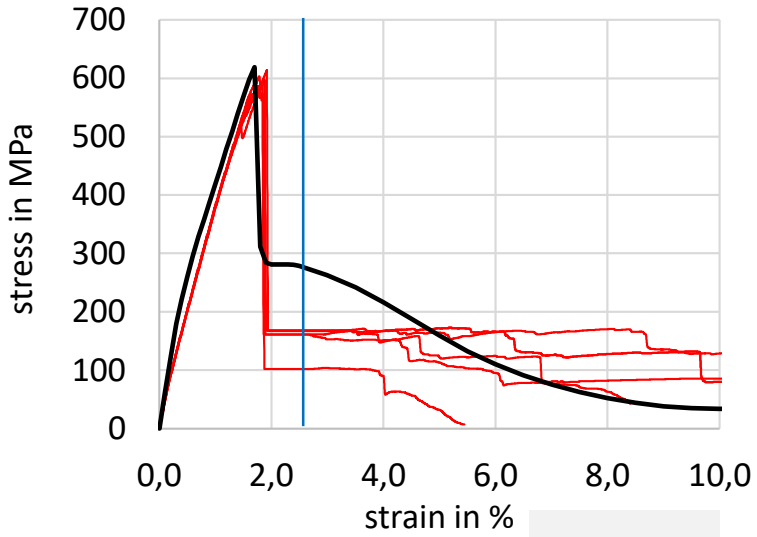
Microstructural simulation

Visualization of simulation results

- failure in carbon fiber





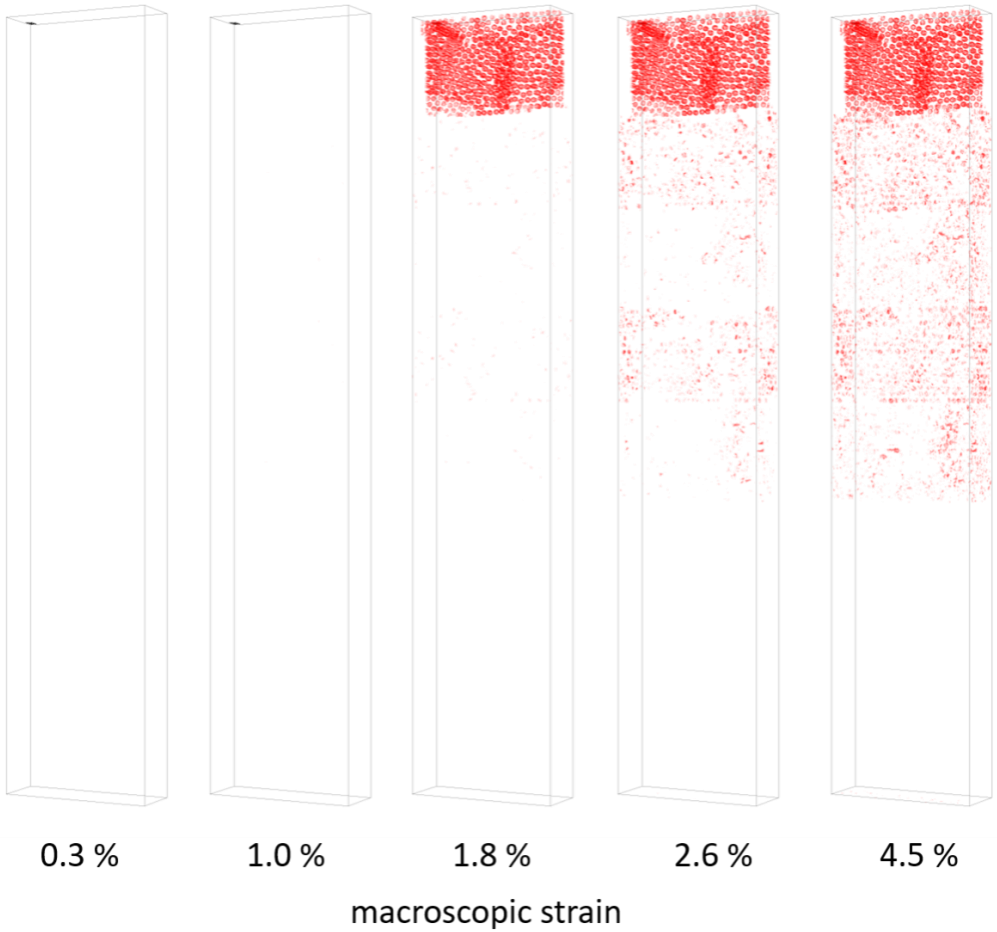


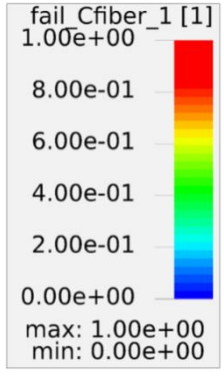
MICROSTRUCTURAL SIMULATION

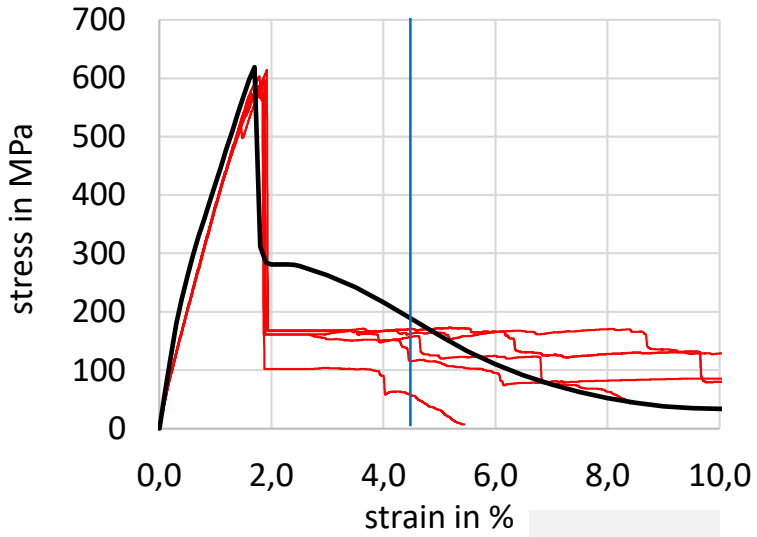
VISUALIZATION OF SIMULATION RESULTS

GEODICT

- failure in carbon fiber







MATH 2 MARKET

Outline

Conclusions

- Steel fibers increase the structural integrity of carbon fiber reinforced polymers significantly
- Microstructural simulation of such complex materials is possible and can be used to
  - reduce prototyping and testing effort
  - give insights into the micromechanical behavior of the materials
  - accelerates the material development process

Thank you for your Attention!

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come to our next Talk about “Digital Twin Modeling”

17:15, S1/01-A4

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