TECHNOLOGIETAG LEICHTBAU REGIONAL

2021 NOVEMBER 25TH

DESIGN OPTIMIZATION ENABLED BY ADVANCED SIMULATION METHODS

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ROBERT BOSCH GMBH, RENNINGEN

BOSCH

Design Optimization Enabled by Advanced Simulation Methods

Agenda

- Bosch and Bosch Research
- Motivation and Goal
- Virtual testing concept
- Validation example
- Conclusion and Outlook

Bosch Research Campus, Renningen

Design Optimization Enabled by Advanced Simulation Methods

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Bosch Research Campus, Renningen

Design Optimization Enabled by Advanced Simulation Methods

Bosch

Business Sectors in 2020

Mobility Solutions

42.1

billion euros
sales revenue

Industrial Technology

5.1

billion euros
sales revenue

Energy and Building Technology

5.5

billion euros
sales revenue

Consumer Goods

18.8

billion euros
sales revenue

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Bosch Research

In 2020

1,740

highly specialized employees

90%

of associates are scientists

152

PhD students

+11

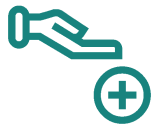
top research facilities around the globe

1,855

invention reports

74%

resulted in patents



328

mio. € invested in Bosch Research & Center for Artificial Intelligence

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Design Optimization Enabled by Advanced Simulation Methods

Bosch Research

Fields of Innovations

Artificial intelligence research

Chemical energy conversion

Electrified mobility and systems

Healthcare solutions

Sustainability for resource and energy efficiency

Production systems

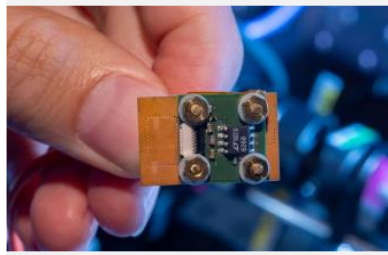
Information and communication technologies

IoT @ life

AI-enabled fully autonomous systems

Modeling, simulation, optimization & new materials

New business



Smart sensor & hardware systems

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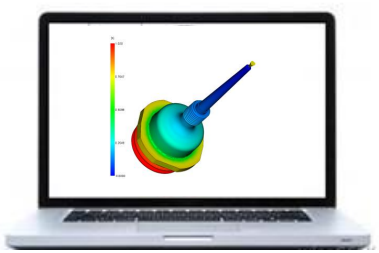
Our Research Group

Increase pace in product development by virtual engineering of polymer components



Process settings

Rheological properties

Geometrical models

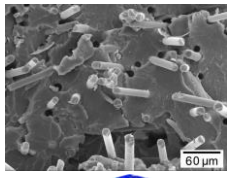
Thermal properties

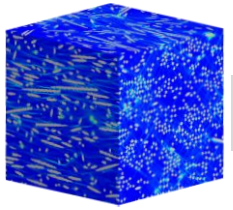
Fiber orientation

Fiber content

Fiber length

Crystalline content

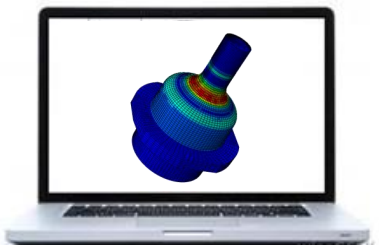




Deformation

Damage

Failure



Warpage

Quasi-static deformation

Creep

Fatigue

Relaxation

Process Simulation
Virtual Process

Microstructural Characteristics
Virtual Material and Testing

Structural Simulation
Virtual Component

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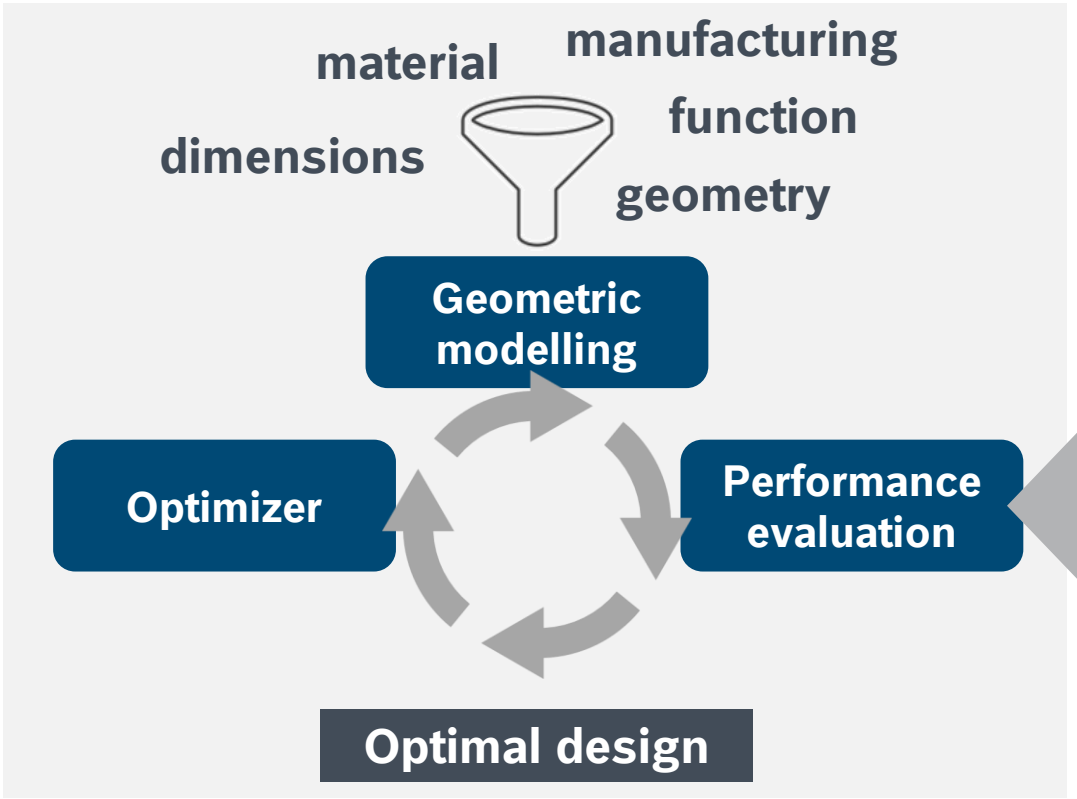
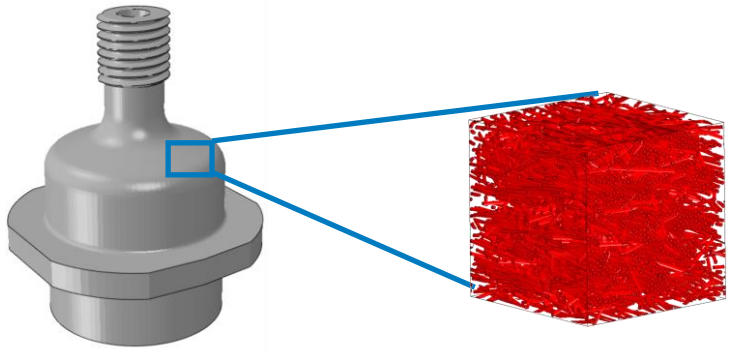
Motivation and Goal





CR demonstrator

microstructure model (PBT-GF30)

Considered load cases:

- Creep
- Quasi-static deformation
- Relaxation
- Fatigue

Optimal design enable by an efficient simulation-based performance evaluation

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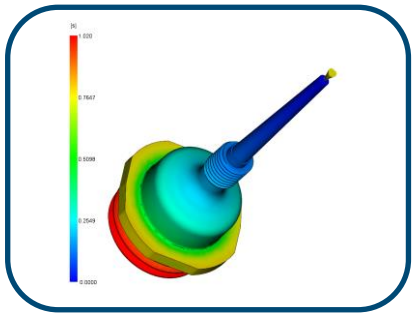
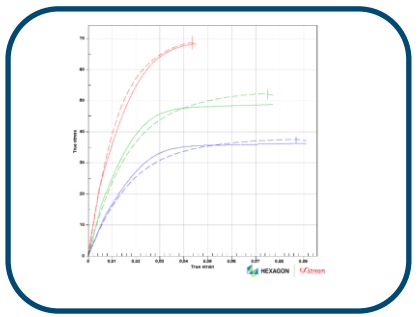
Quasi-static Deformation

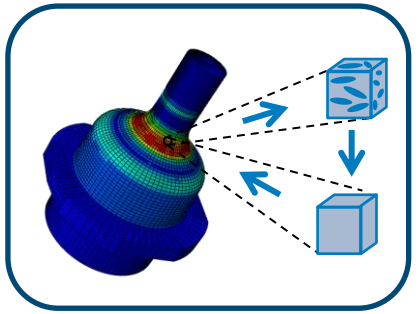
Processing



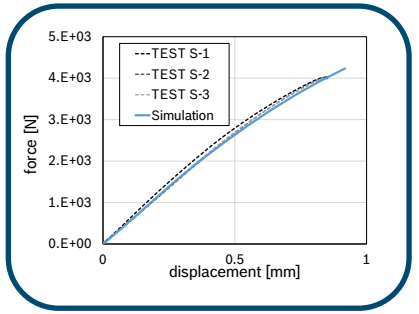
Model Parameter Identification | QS



Structure Simulation

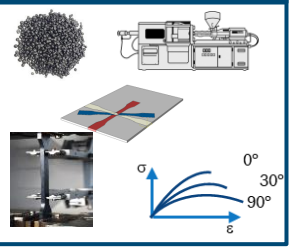


Reliability Assessment



Standard Today

Experimental Testing



Effort:
~1 month per material ⚠

Standard Today

Integrative Simulation Chain

Virtual component testing method established

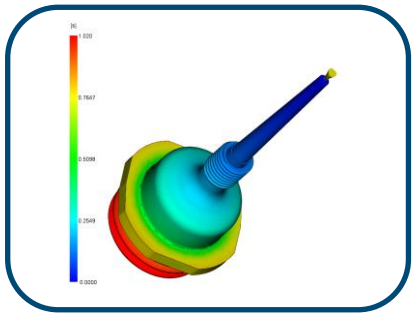
Goal: replace experimental quasi-static testing

QS: Quasi-static

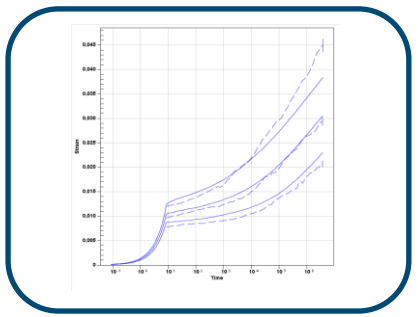
Design Optimization Enabled by Advanced Simulation Methods

Long-Term Creep / Relaxation

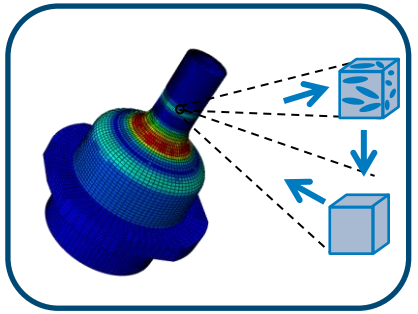
Processing



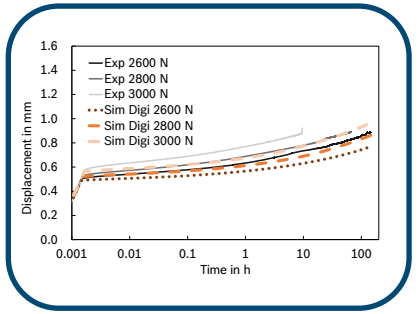
Model Parameter Identification | Creep



Structure Simulation

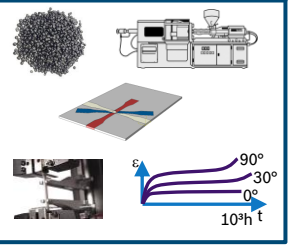


Reliability Assessment



Standard Today

Experimental Testing



Standard Today

Integrative Simulation Chain

eXstream ENGINEERING
MSC Software Company

Virtual component testing method established

Effort:
>3 months per material ⚠

Goal: replace experimental creep testing

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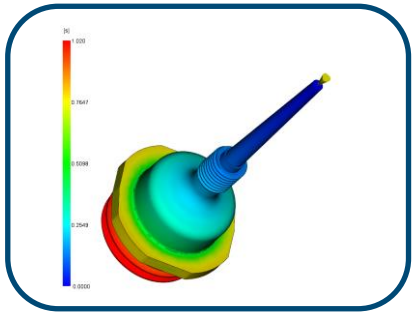
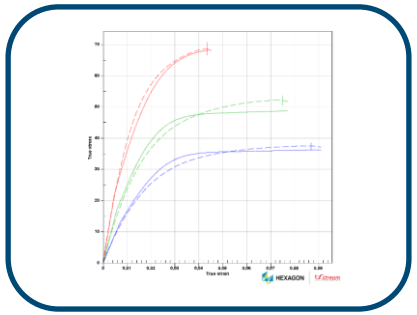
Fatigue Lifetime Assessment

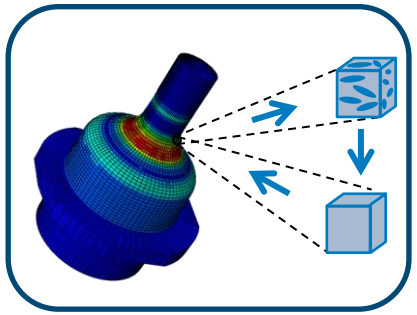
Processing



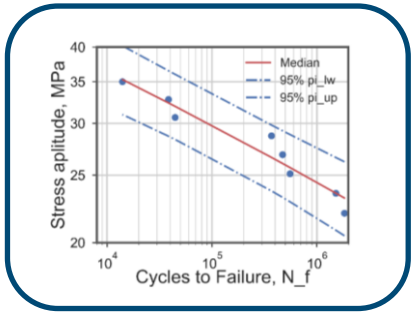
Model Parameter Identification | QS



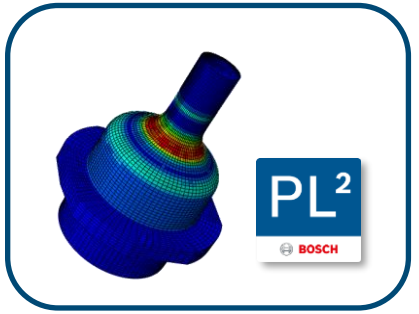
Structure Simulation



Model Parameter Identification | Fatigue

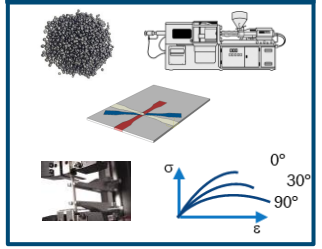


Reliability Assessment



Standard Today

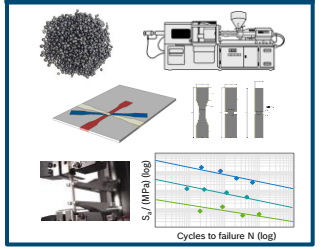
Experimental Testing



Effort:
~1 month per material ⚠

Standard Today

Experimental Testing



Effort:
~4-6 months per material ⚠

Standard Today

Integrative Simulation Chain

PL² BOSCH

Virtual component testing method established

Goal: replace experimental quasi-static and fatigue testing

QS: Quasi-static
CT: Computed

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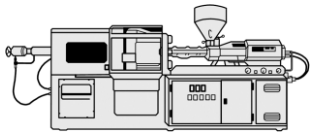
Design Optimization Enabled by Advanced Simulation Methods

Simulation Concept

Data for Material Card – State of the Art | QS, Anisotropic

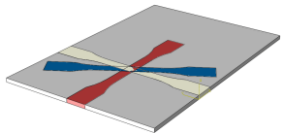
Material delivery

+



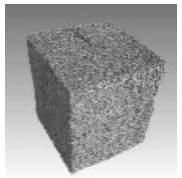
Injection molding of plates

+



Milling of samples

+

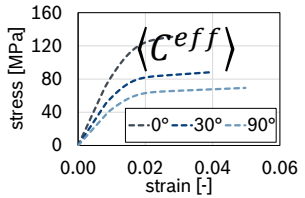


CT scan (Microstructure)

+

Tensile testing

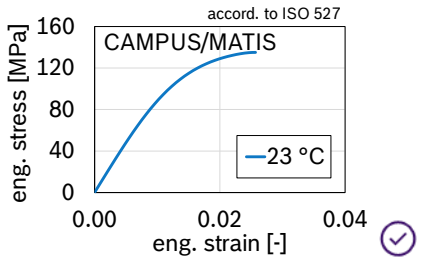
=



Data for parameter identification

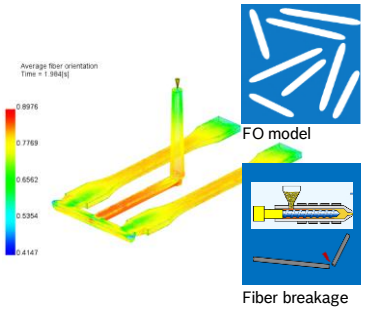
Testing time: min. 1 month

Data for Material Card – Our Method | QS, Anisotropic



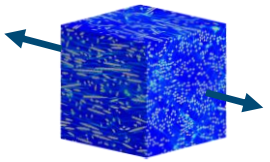
Database composite data (only 0°)

+



Microstructure via simulation

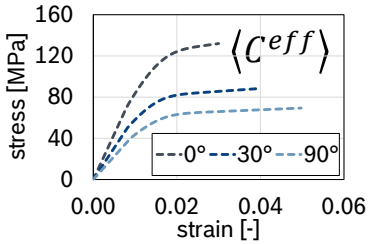
***Representative** virtual material microstructure*



***Efficient** problem solving*

Tensile testing via simulation

=



Data for parameter identification

Engineering time: few days

Representative microstructure + efficient problem solving → Time effort reduction from months to days

QS: Quasi-static
CT: Computed Tomography
FO: Fiber Orientation

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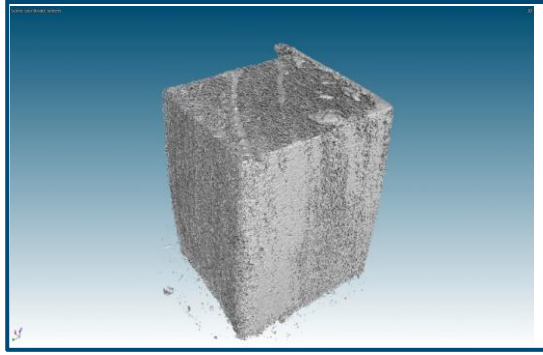
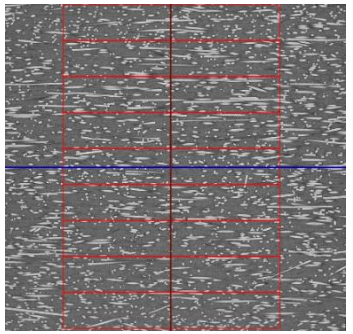
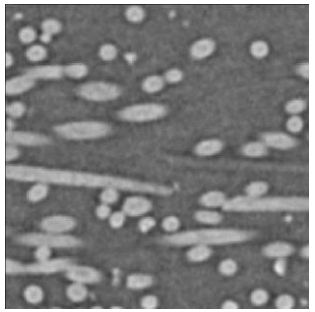
Representative Material Microstructure Descriptors

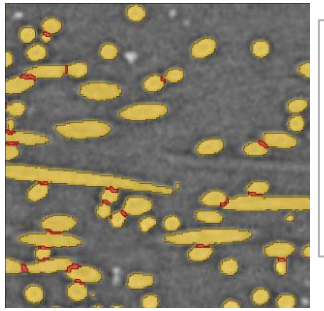
Measurement of Fiber Orientation

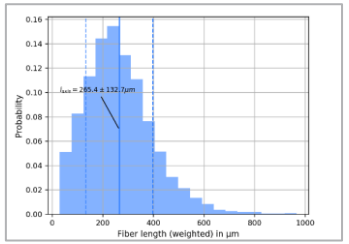




Measurement of Fiber Length

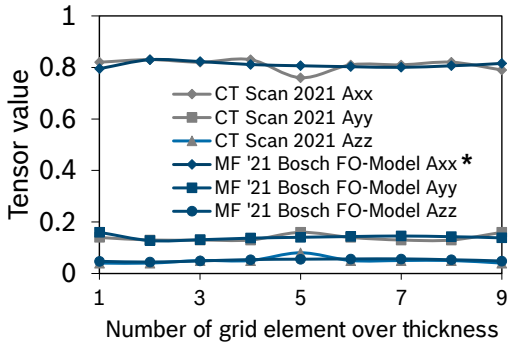




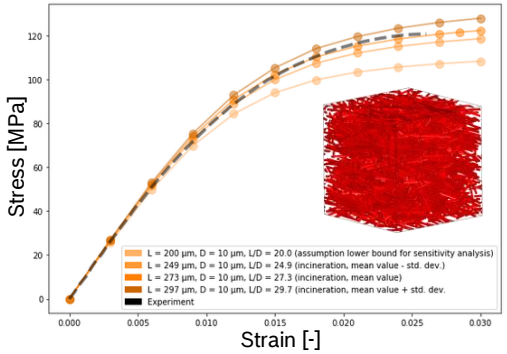


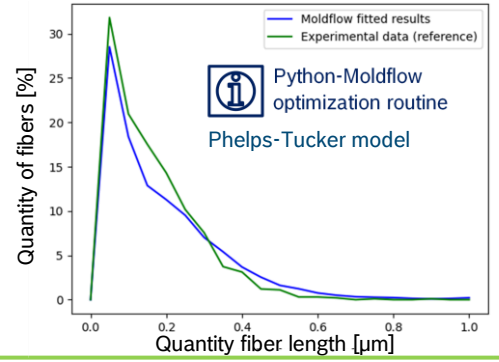
Fiber Orientation via Simulation

Fiber orientation via process simulation



Fiber Length Approximation & Simulation





Representative microstructure descriptors generation

* *S. K. Kugler et al.: A Flow-Dependent Fiber Orientation Model, J. Compos. Sci. 2020, 4(3), 96*

CT: Computed Tomography
MF: Moldflow, FO: Fiber Orientation

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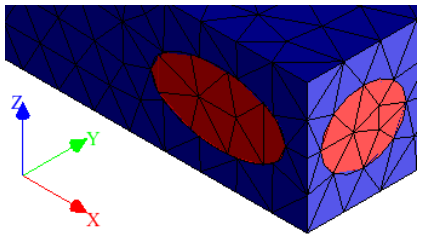
Design Optimization Enabled by Advanced Simulation Methods
Efficient Problem Solving

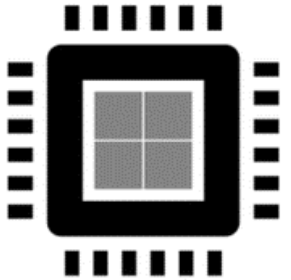
Conforming FE Mesh

- Fiber geometry and periodicity requirements due to periodic boundary conditions lead to
  - complex meshing procedures
  - and low element quality



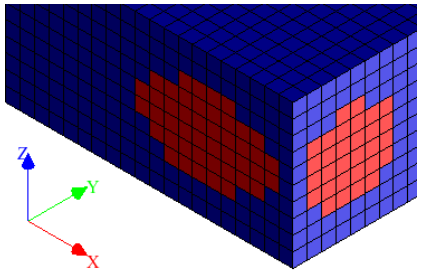
CPU Computation

- Central processing unit (CPU)
  - 4 cores (or more)
  - good for serial processing
  - example: 256³ voxel with 4 CPUs[1)]
    - total time: **580 s**



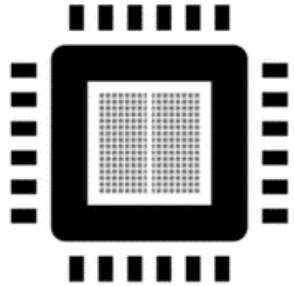
Pixel Based Voxel Mesh

- Fiber geometry simplified by non-conforming voxel mesh
- Periodicity inherent in method



GPU Computation

- Graphics processing unit
  - 640 cores (or even more)
  - good for parallel processing
  - example: 256³ voxel with 640 GPUs[2)]
    - total time: **100 s**



Efficient problem solving within minutes

Workstation with:
[1)] Intel Xeon E5-1620 and
[2)] Nvidia quadro K2200

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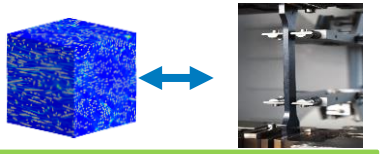
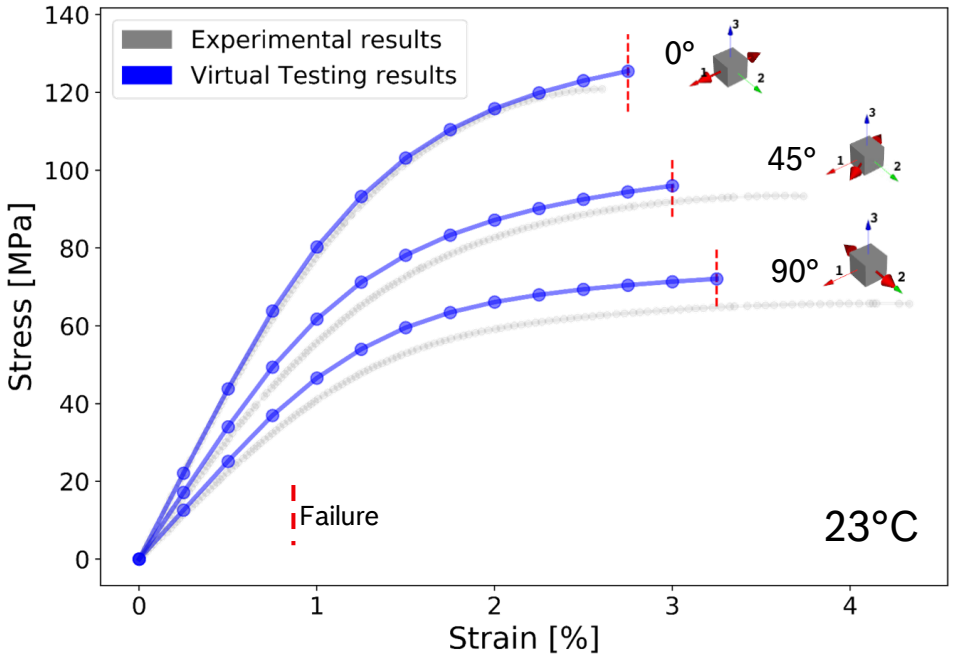
Bosch Research Campus, Renningen

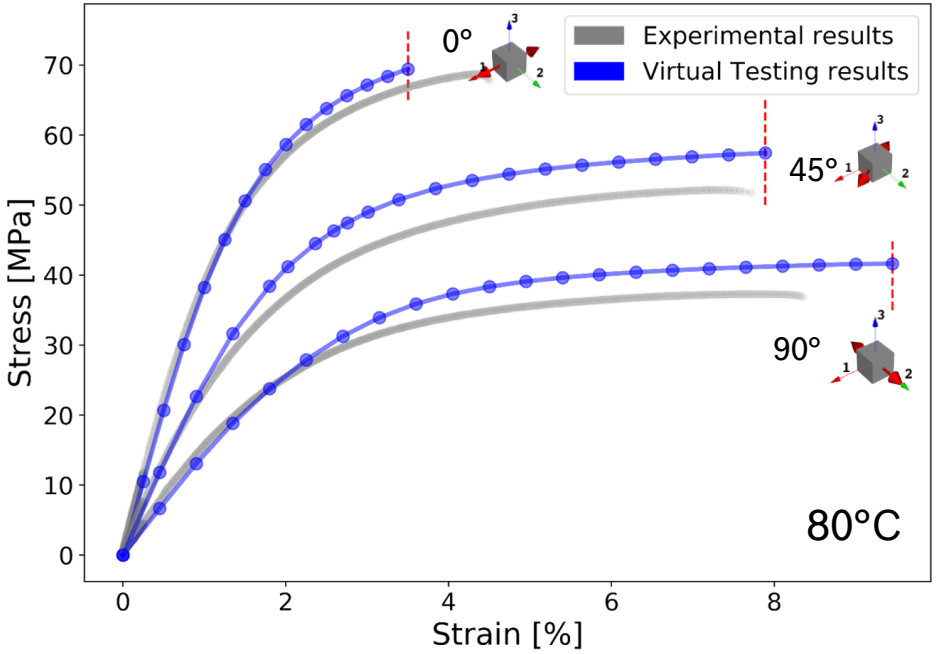
Design Optimization Enabled by Advanced Simulation Methods

Validation Example



PBT-GF30 - Validation on Specimen with Different Fiber Orientation





Good prediction of stress – strain behavior and of failure

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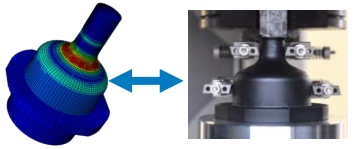
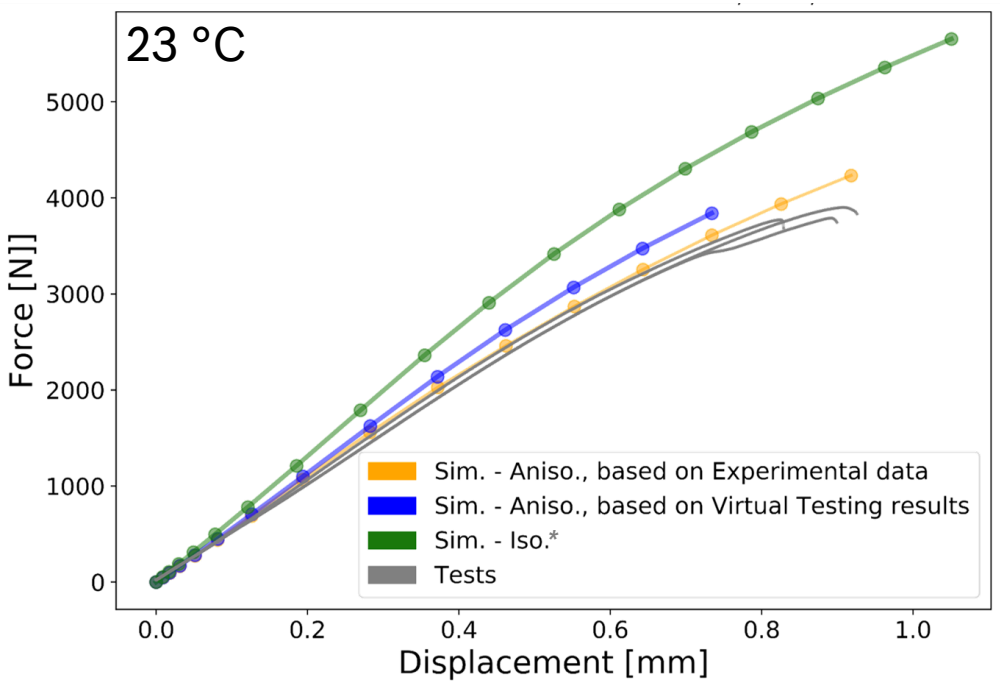
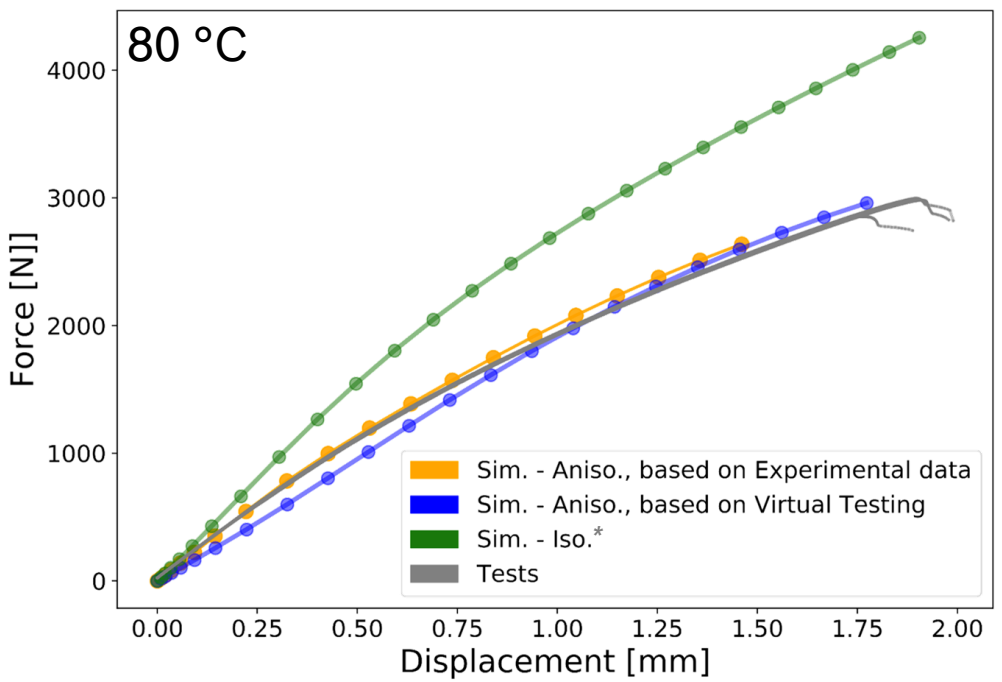
Validation Example



PBT-GF30 - Validation on Component





Very good prediction quality with anisotropic approach | Similar results based on virtual testing and exp. data

** based on CAMPUS data and reduction concept*

BOSCH

Design Optimization Enabled by Advanced Simulation Methods

Agenda

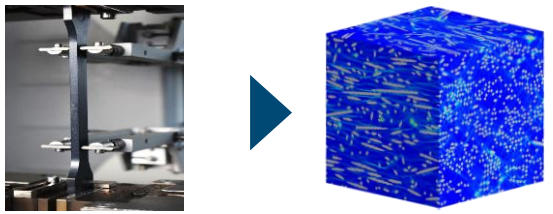
- Bosch and Bosch Research
- Motivation and Goal
- Simulation Concepts
- Validation example
- **Conclusion and Outlook**

Bosch Research Campus, Renningen

Design Optimization Enabled by Advanced Simulation Methods
Conclusion and Outlook

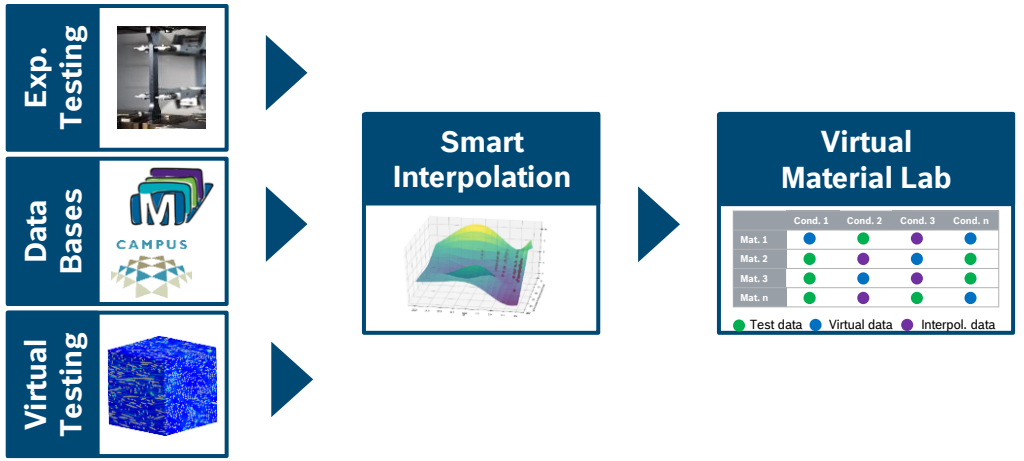
Conclusion

- Today's engineering simulation tasks highly relay on cost and time intensive experimental material data for model parameter identification
- Presented approach enables efficient generation of material data
- Synthetic generation of material data empowers Bosch's plastic simulation experts



What's next?

- Extension of concept for
  - long term loading: creep/relaxation and fatigue
  - Investigate application of AI/ML based methods for intelligent interpolation
  - Combine synthetic & experimental material data, as well as AI/ML methods within virtual material lab
- Enable metamodeling of simulation chain for efficient application in optimization cycle



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