Moldflow Summit 2017

Using Moldflow and ULTRASIM® for Superior Mechanical Simulations – Recent Developments

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Sr. CAE Engineer, BASF Performance Materials

AUTODESK.

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  - Who Cares About Fiber Orientation?
- ULTRASIM – What Is It?
- Optimization of Fiber Orientation Parameters
- Recent Development – Thermal Model
- Future Endeavors/Other Areas

Acknowledgment
Thanks to Dr. Andreas Wonisch

AUTODESK.

Motivation:
Who Cares about Fiber Orientation?

Who Cares about Fiber Orientation?

Motivation:
Who Cares about Fiber Orientation?

- BASF supplies fiber reinforced materials to our customers

	Automotive Engineering	Electrical/ Electronics	Communi-cation, Consumer Electronics and Computer	Appliances	Consumer Products	Industrial Applications	Building and Construction	Packaging and Food Services	Medical
Ultradur® (PBT)	●	●		●	●	●	●		
Ultraform® (POM)	●	●	●	●	●	●	●		
Ultramid® (PA)	●	●		●	●	●	●	●	
Ultrason® (PESU, PSU, PPSU)	●	●		●	●	●	●		●
Petra® (PET)	●	●		●	●	●			●

Motivation:
Who Cares about Fiber Orientation?

We provide customer support to help our customers achieve success in designing and manufacturing with our materials.

- Structural Analysis
  - ABAQUS
  - LS-Dyna
- Mold Filling Analysis
  - Moldflow
  - Moldex3D
- Optimization
  - Genesis
  - Optistruct
  - LS Opt

Motivation:
Who Cares about Fiber Orientation?

- In the molding simulation arena warpage prediction is now our customer's primary request.
  - Other Moldflow results are a "given".
- For fiber reinforced materials, fiber orientation is a dominant factor in warpage.

Motivation:
Who Cares about Fiber Orientation?

- Seeking better, more accurate structural analysis is an ongoing quest
  - Fiber orientation has an enormous impact on the local structural properties of the material.
  - Injection molded fiber reinforced materials are not isotropic.
  - Data-sheet values do not work well for many analyses.

Motivation:
Who Cares about Fiber Orientation?

- We are not alone in our quest for better structural analysis based on fiber orientation information:
  - Digimat
  - Helius

ULTRASIM – What Is It?

ULTRASIM - Integrative Analysis

Integrating Manufacturing Knowledge with Part Performance Analysis

ULTRASIM

- System of Applied Material Modeling
- An Interface between Mold Filling Analysis

  - and -

- Other software which can use accurate, non-isotropic material properties:
  - ABAQUS
  - LS-Dyna

ULTRASIM - Integrative Simulation for Fiber Reinforced Materials

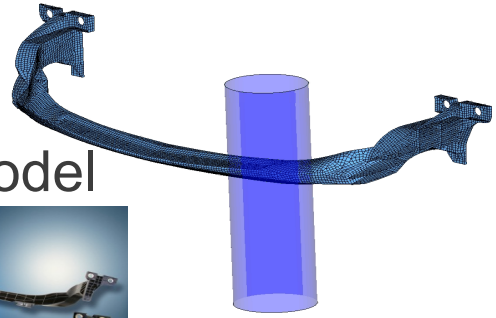
Process

Measurement

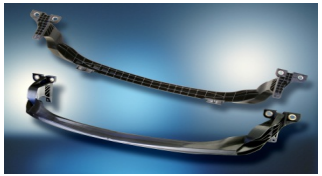
BASF Material Model

- Anisotropic
- Nonlinear
- Strain-rate sensitive
- Tensile-compression asymmetric
- Failure model included

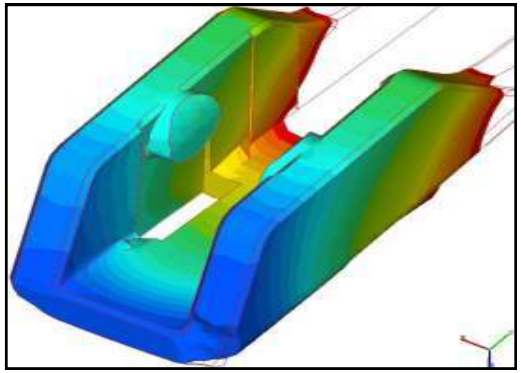
Material



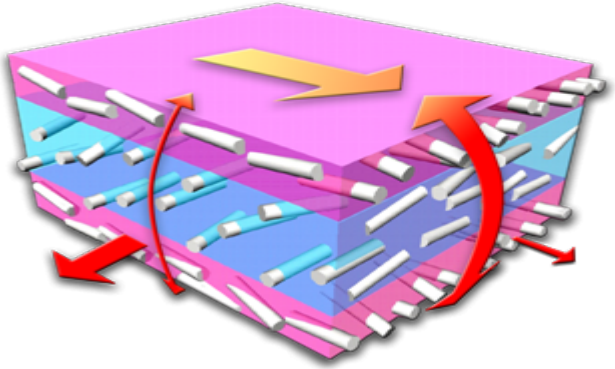
Part Model



ULTRASIM
Fiber Orientation

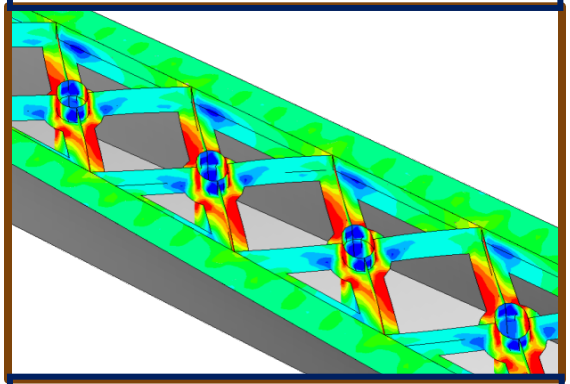


PROCESS



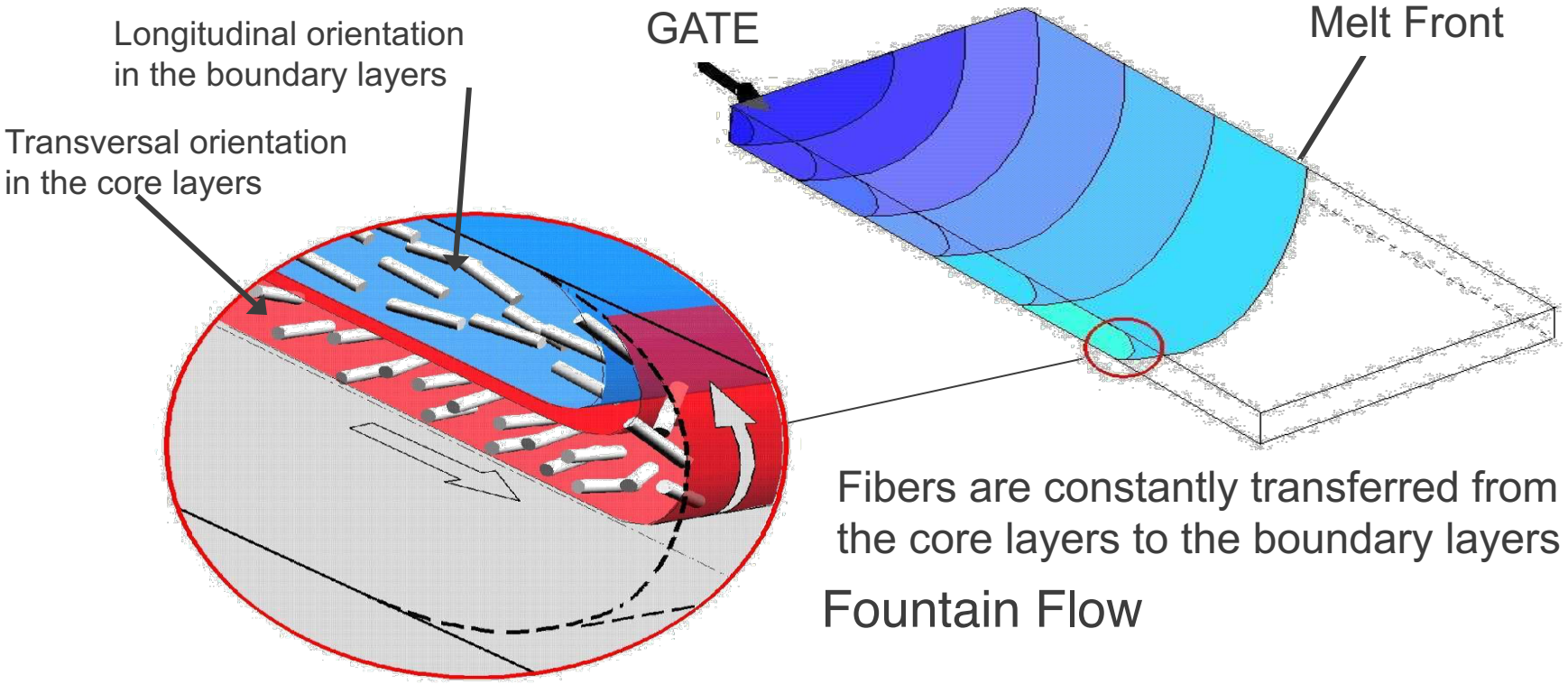
MATERIAL MODEL

DETAILED STRUCTURAL



MODEL

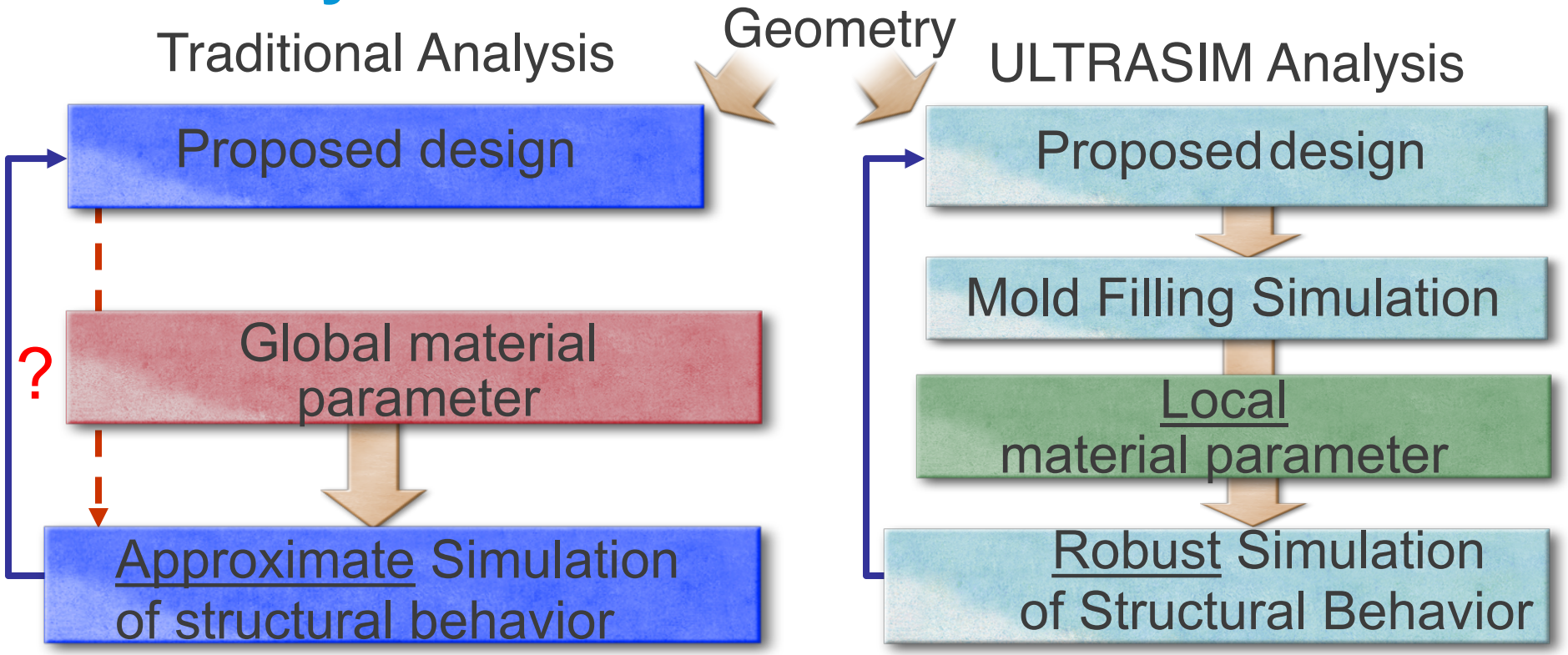
ULTRASIM
Fiber Orientation in the Mold Filling Process



Fibers are constantly transferred from the core layers to the boundary layers

Fountain Flow

ULTRASIM
CAE Analysis

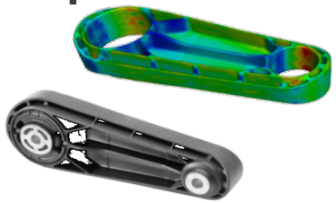


ULTRASIM
Serial Production Parts

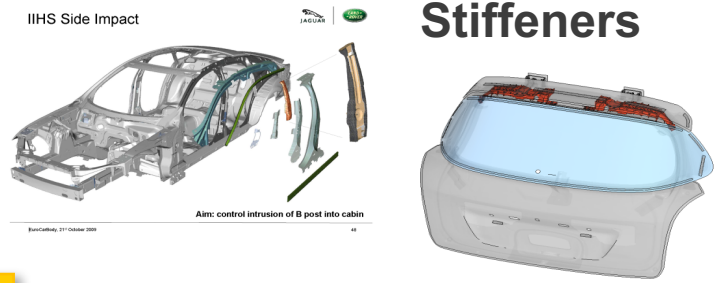
Designer Lamp

Engine Mounts

Torque Stabilizer



Structural Stiffeners

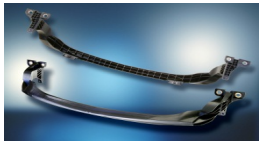


ULTRASIM®

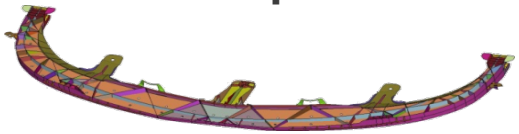
Transmission Cross Beam

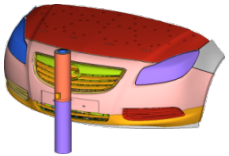
Solar Roof Mount

Oil Pans

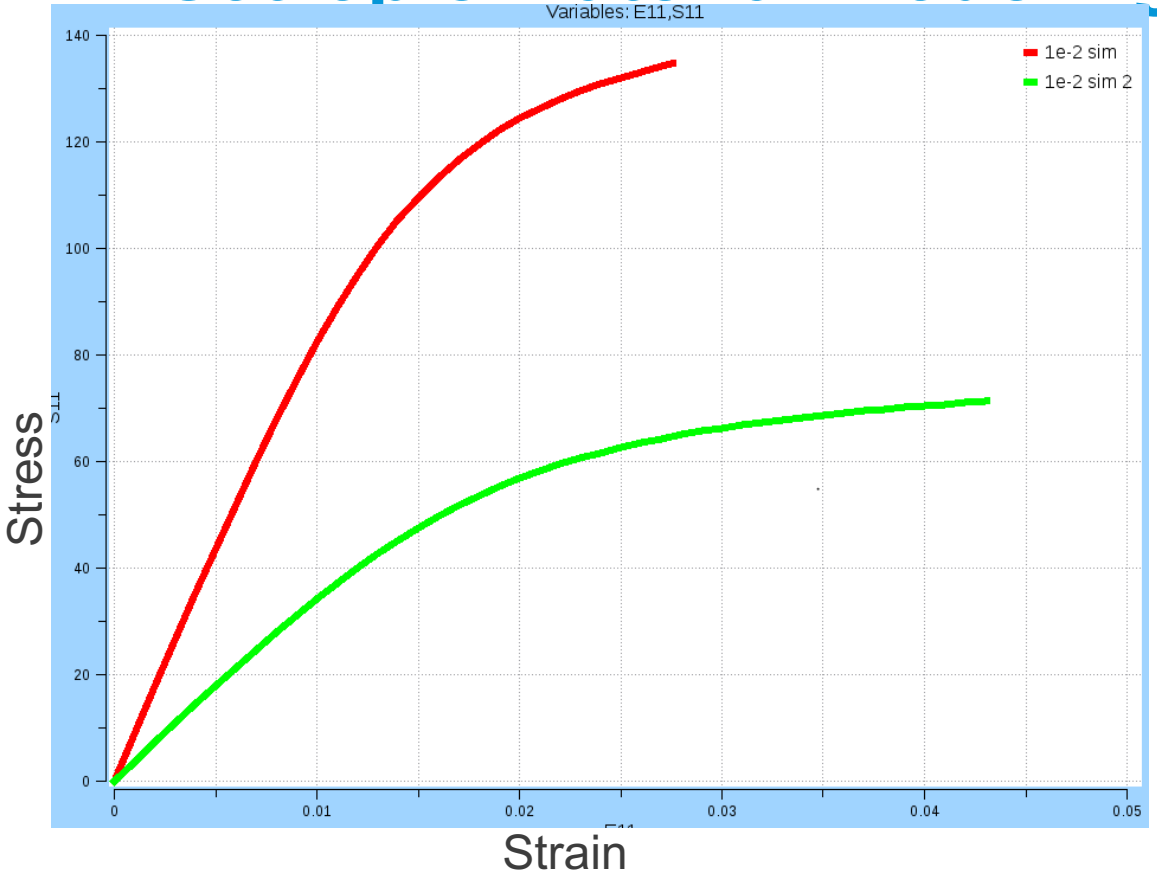


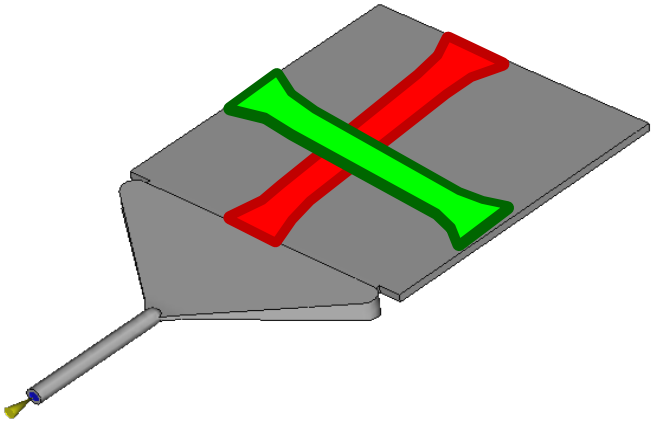
Lower Bumper Stiffeners

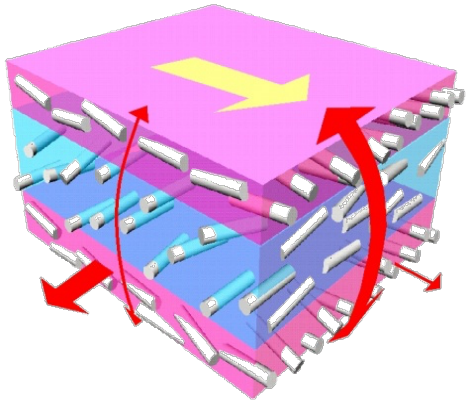




ULTRASIM
Anisotropic Material Modeling





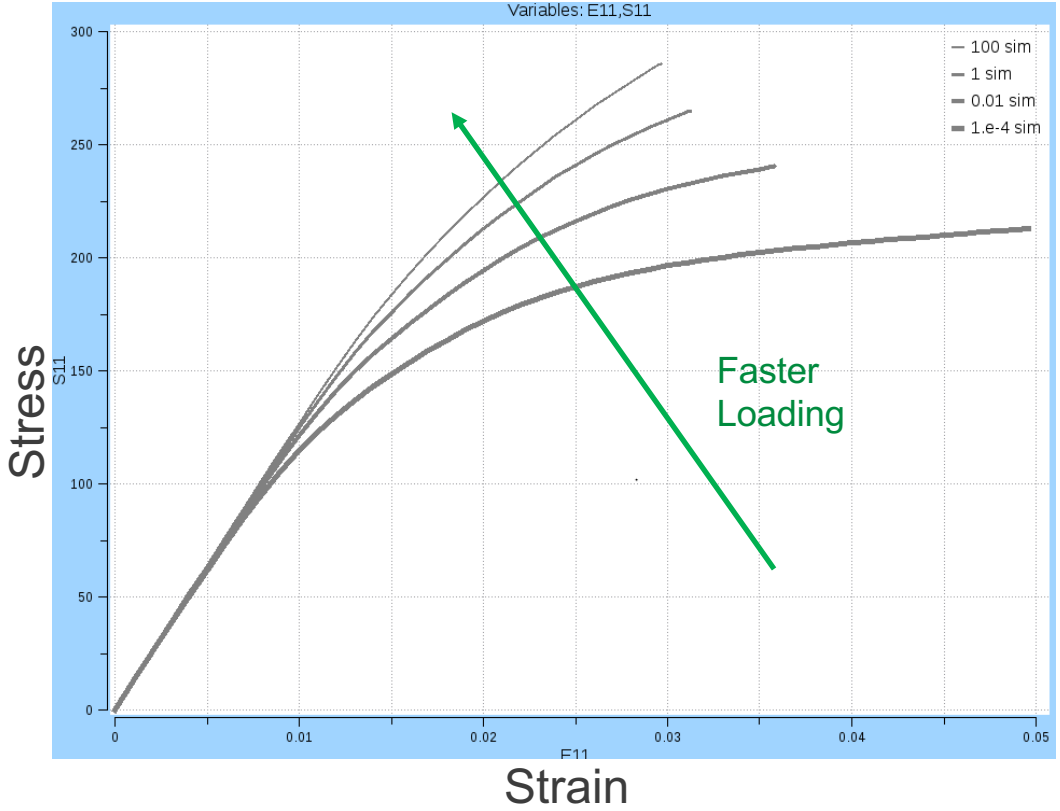


ULTRASIM
Other Factors

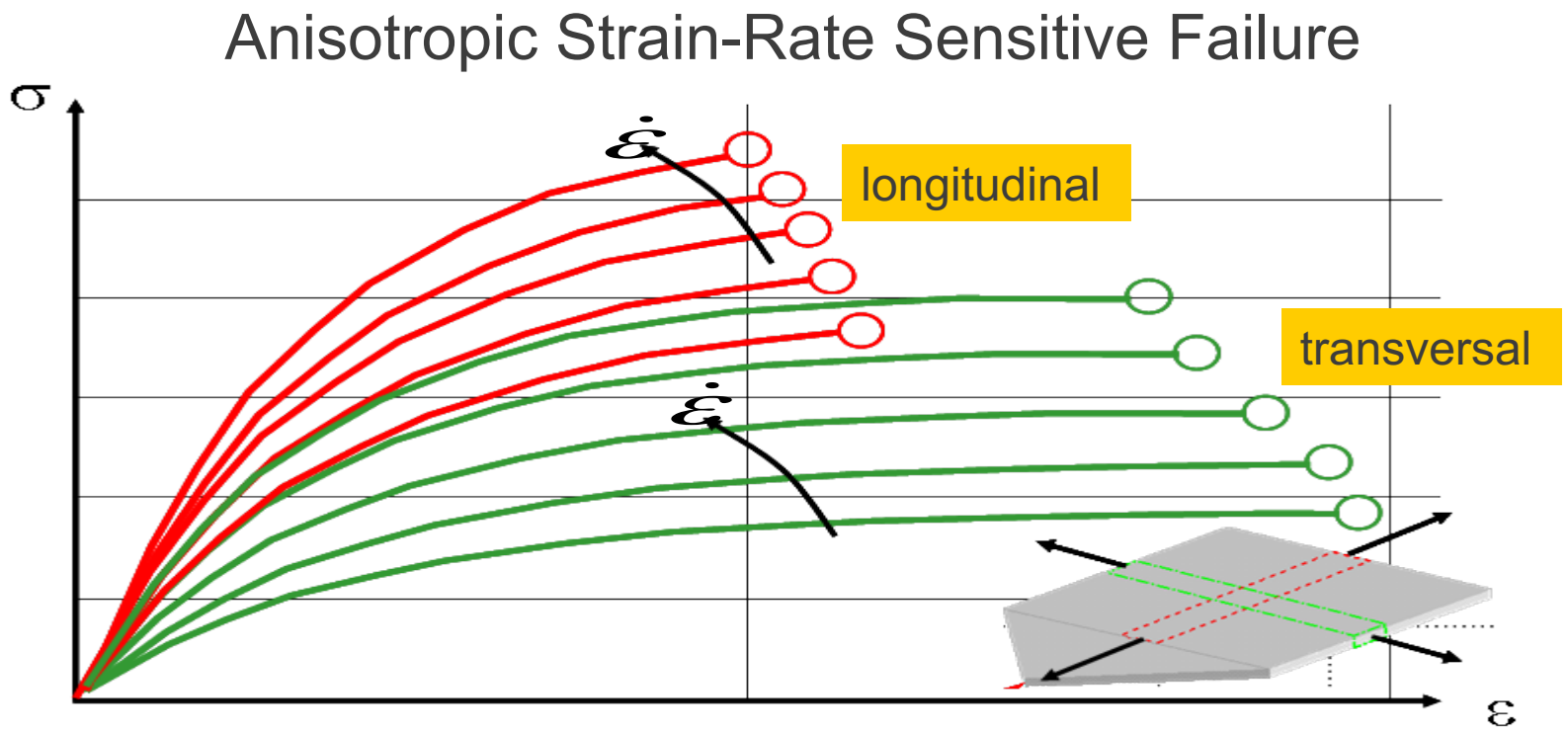
- Besides fiber orientation from Moldflow, other factors:
  - Strain Rate
  - Moisture Content
  - Temperature

will significantly influence the physical properties of the material.

ULTRASIM
Strain Rate - Crash Loading

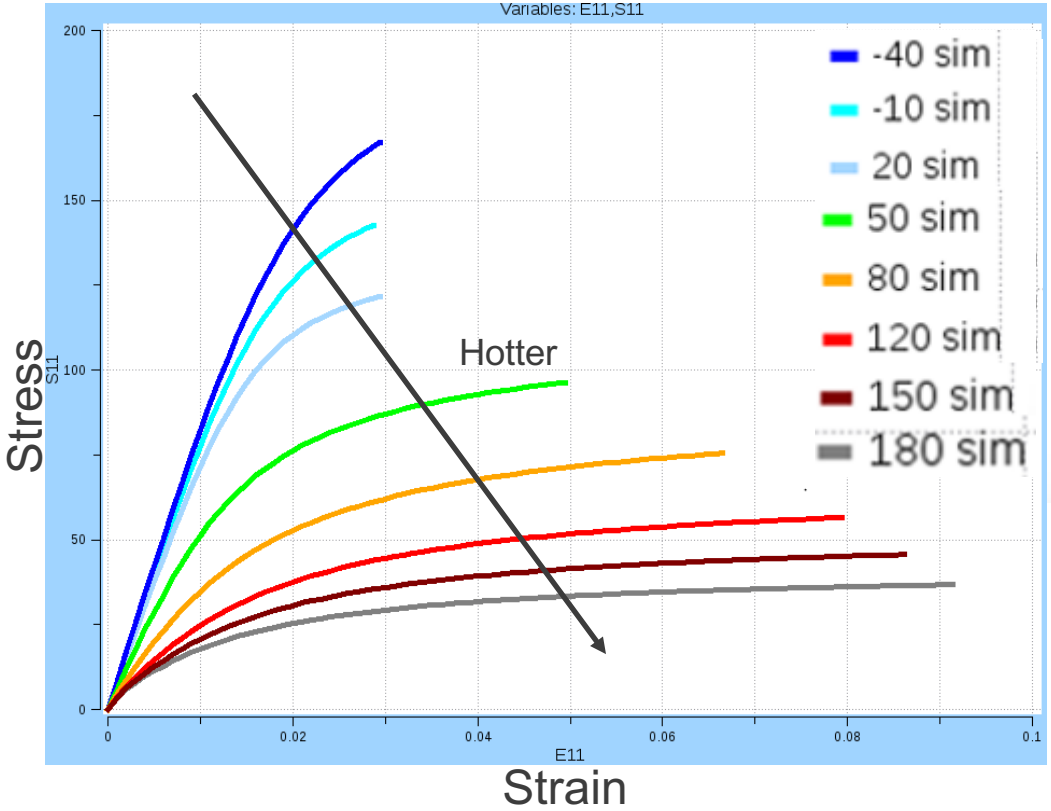


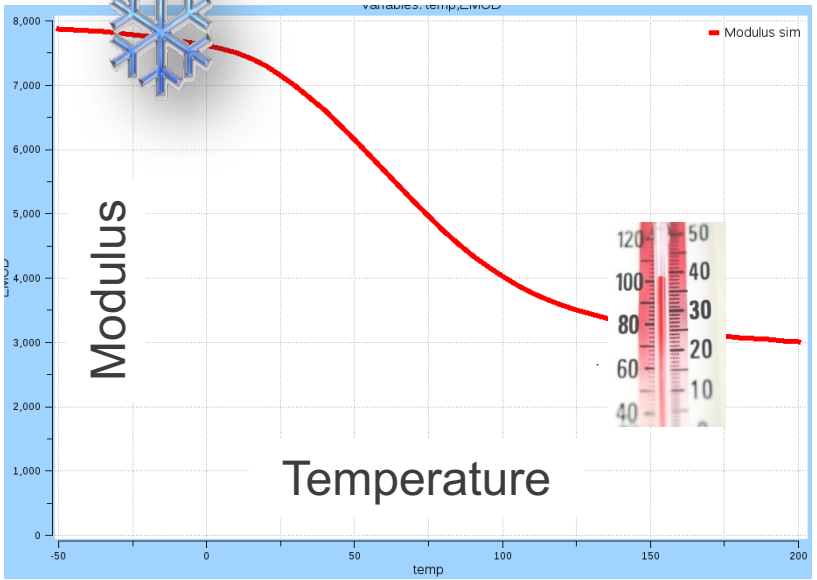
ULTRASIM
Anisotropy



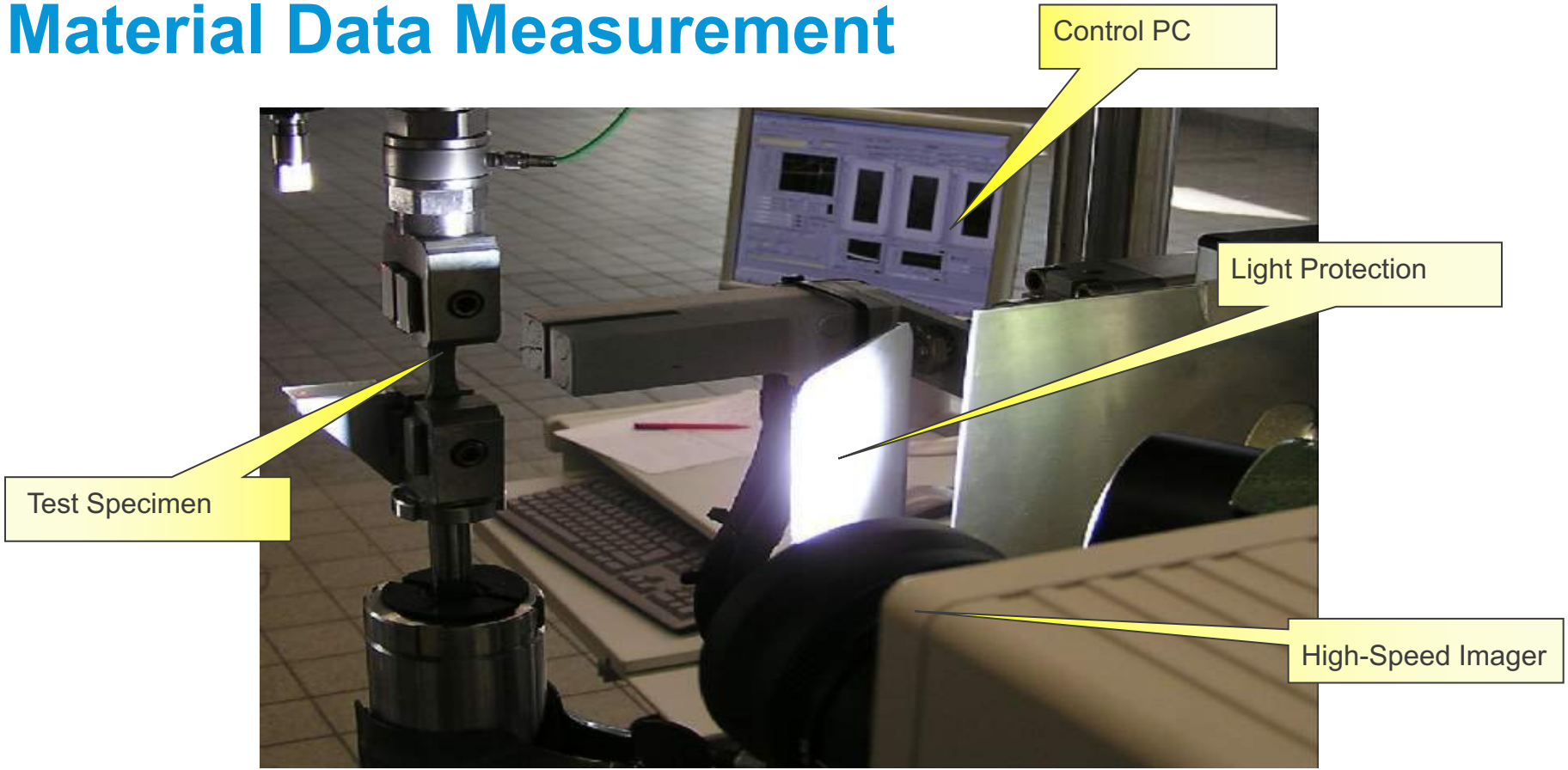
ULTRASIM Temperature

Moisture has a similar effect

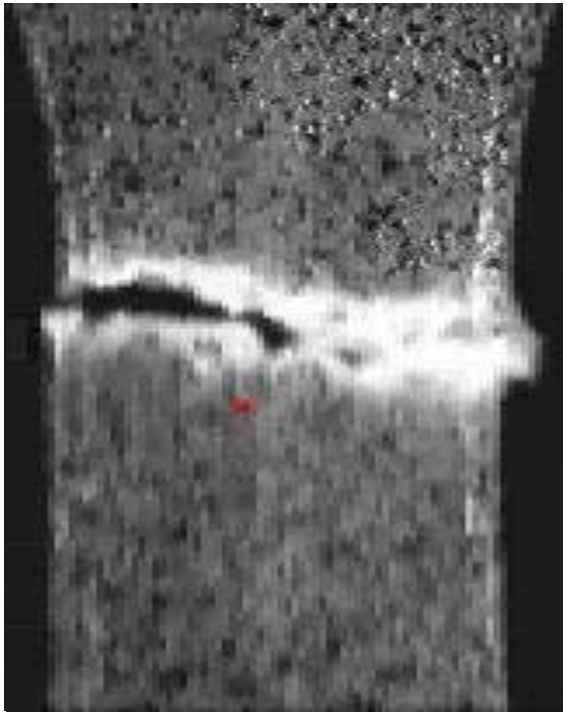




ULTRASIM
Material Data Measurement



ULTRASIM
Optical Strain Measurement

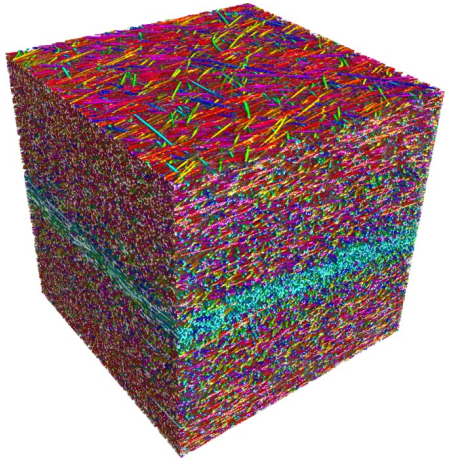


What is ULTRASIM?
Fiber Orientation

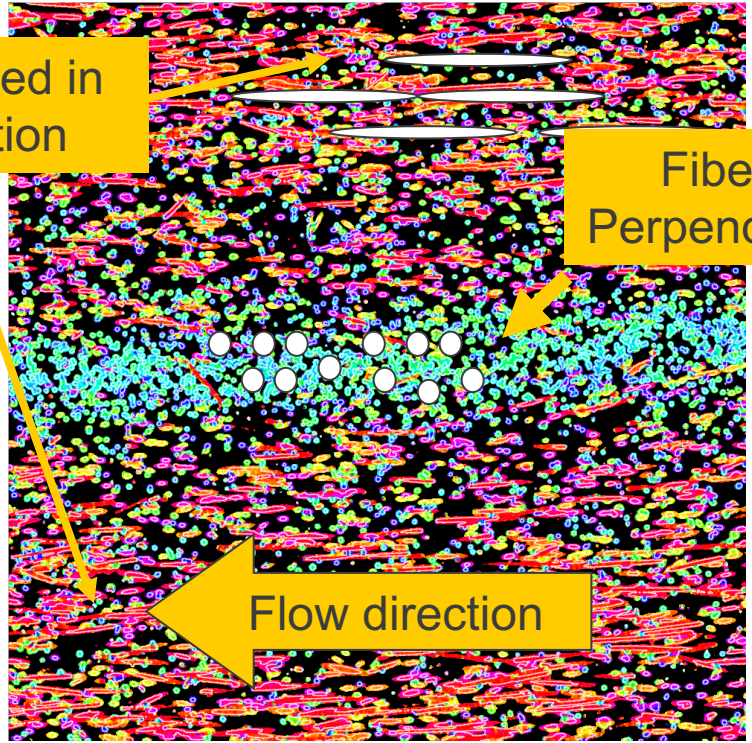
- Assumption:
  - Fiber Orientation Data from Moldflow are good…
  - Significant Effort to Confirm this

Fiber Orientation Measurements

- Layering also seen in CT measurement of real parts



short glass fiber

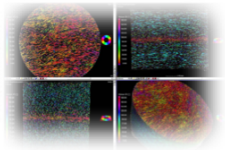


ULTRASIM
Fiber Orientation Key Points

- Correct fiber orientation information from Moldflow is crucial
  - Even if you are “just” predicting warped shapes of your parts.
  - Structural performance depends on fiber orientation.

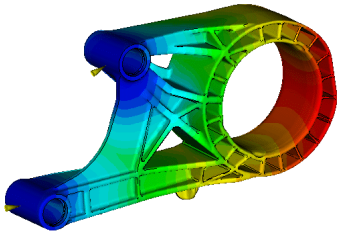
ULTRASIM
The Workflow

rheological measurements



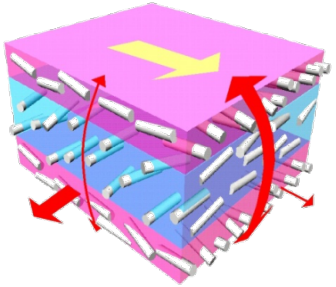
viscosity, thermal properties, fiber orientation characteristics etc.

process simulation



fiber orientation distribution tensor

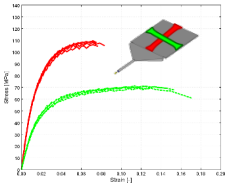
ULTRASIM® mechanical model



- Anisotropic
- Non-linear
- Temperature dependent
- Strain-rate sensitive
- Tensile-compression asymmetric
- Failure modelling

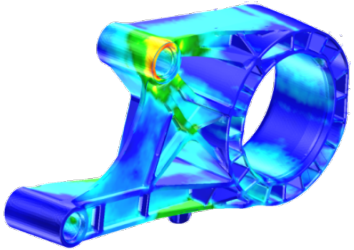
stress-strain curves

mechanical measurements



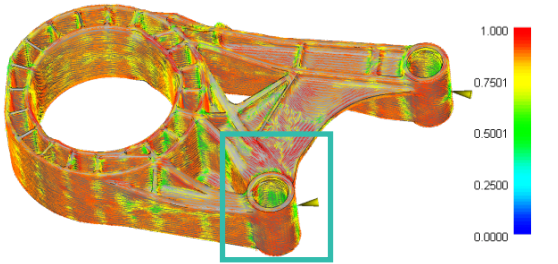
homogenized anisotropic mechanical properties

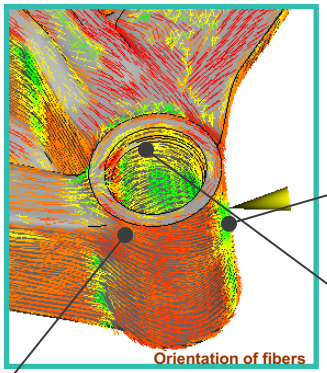
structural simulation

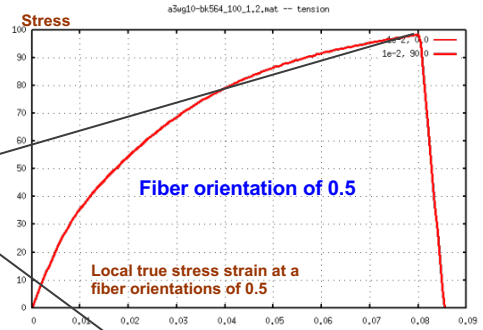


ULTRASIM
Engine Mount

Calculated glass fiber orientation based on optimum processing conditions

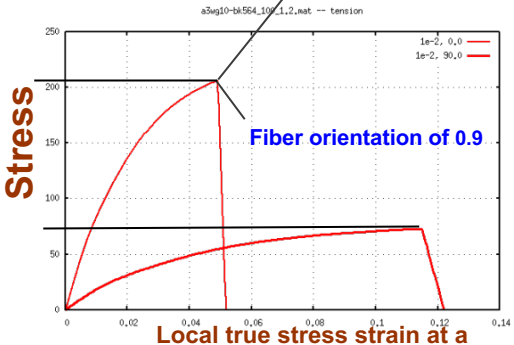




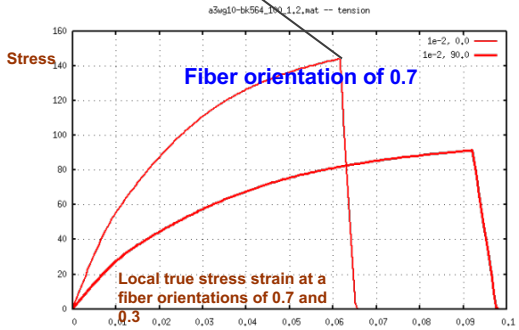


205 MPa

70 MPa



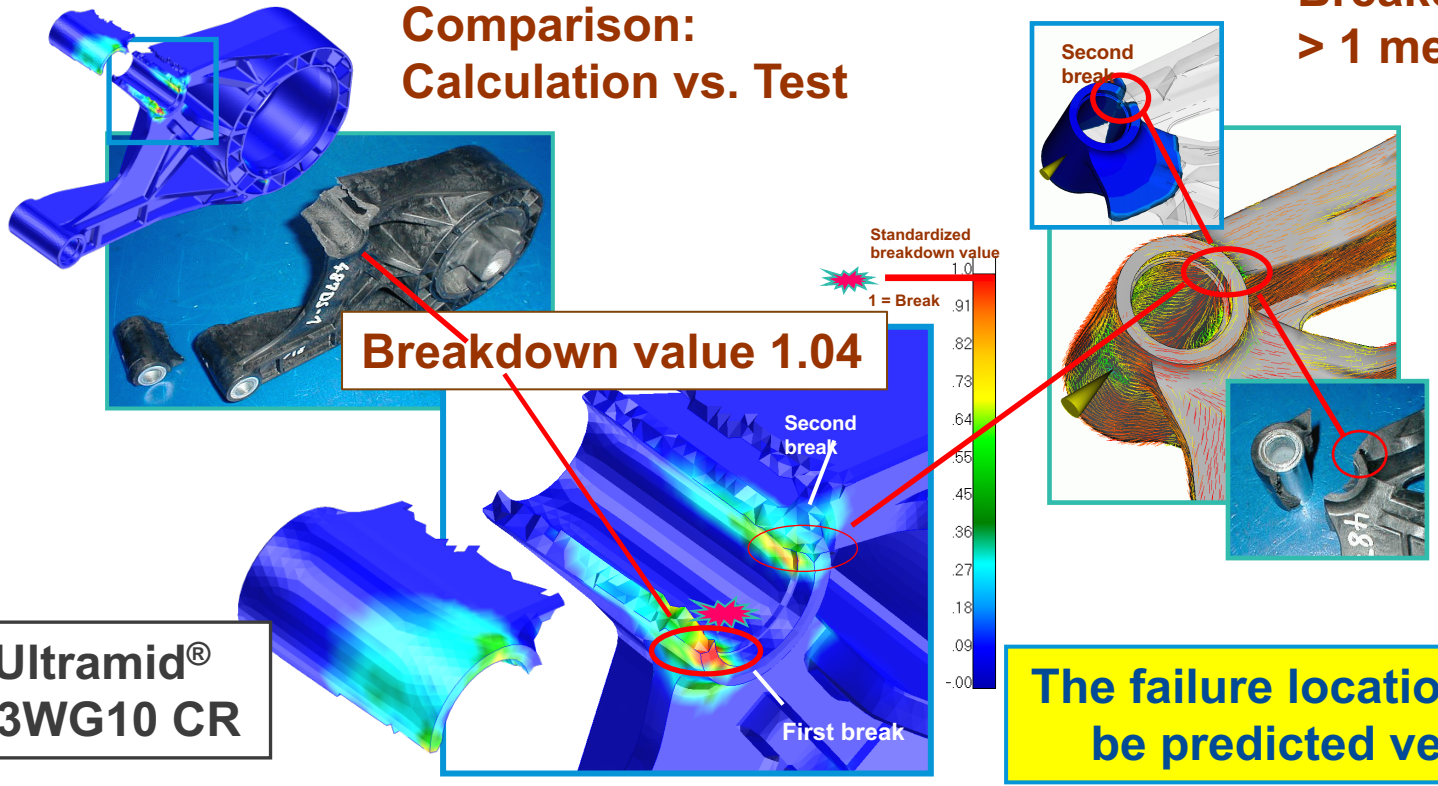
Local true stress strain at a fiber orientations of 0.9 and 0.1



ULTRASIM
Engine Mount – Testing at 125 °C

Comparison:
Calculation vs. Test

Breakdown value
> 1 means a break



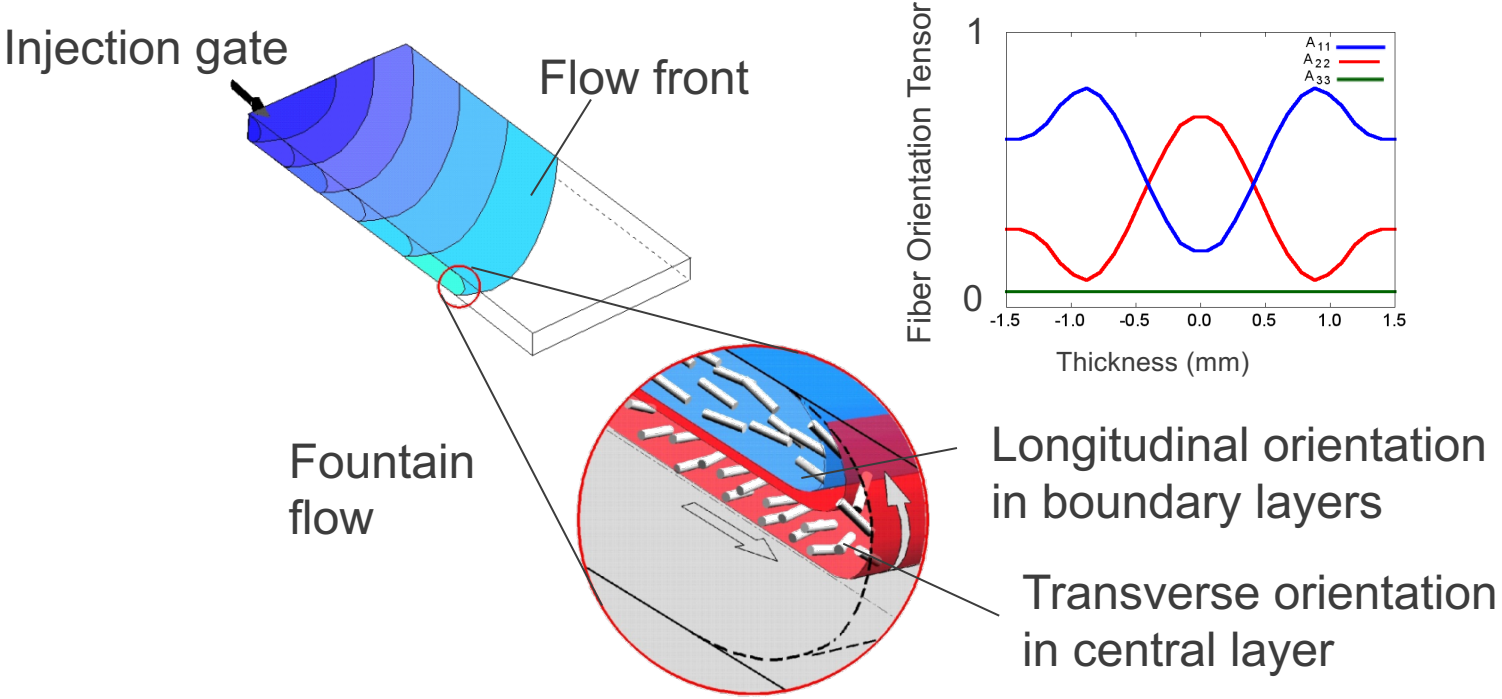
Ultramid®
A3WG10 CR

The failure location & loading can be predicted very accurately

Fiber Orientation Optimization

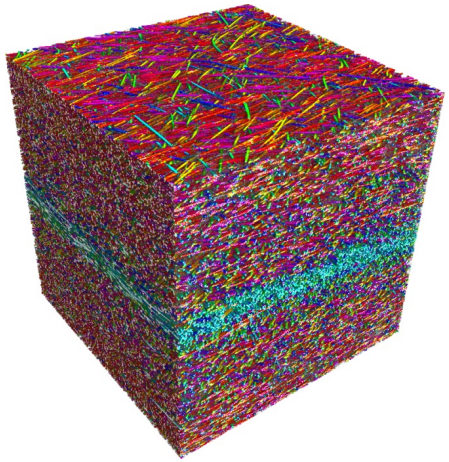
Fiber Orientation Development

- Combination of stretch and shear flow leads to layering:

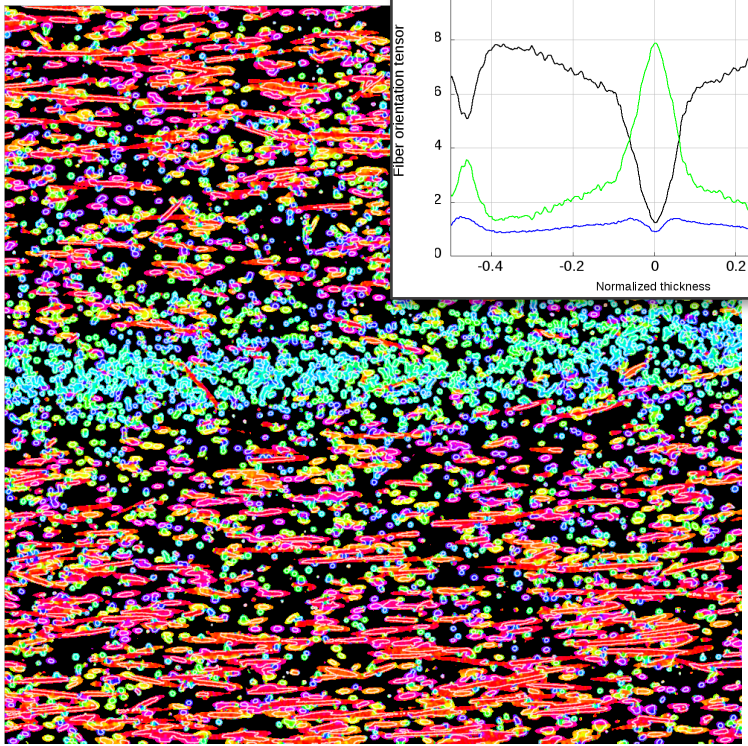


Fiber Orientation Measurement

- Layering also seen in CT measurement of real parts

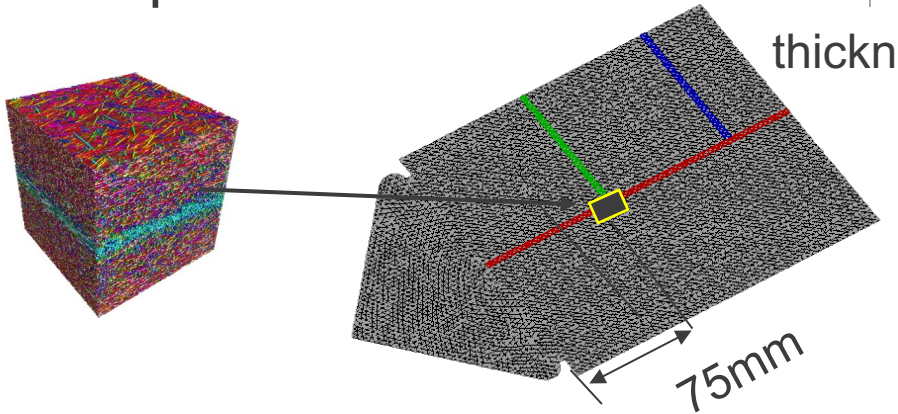


short glass fiber

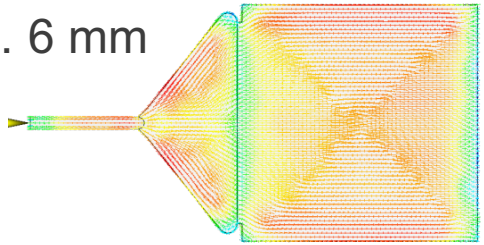


Model Parameter Optimization

- Fiber orientation CT measurements
- p11 test plate for fiber orientation measurements



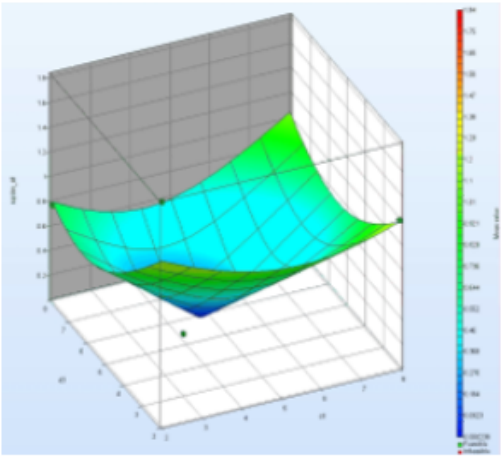
thickness = 1 … 6 mm



- Measured by micro computer tomography (µCT, resolution < 3 µm)
- Determination of fiber orientation tensor over wall thickness

Model Parameter Optimization
Integrative Optimization

- Integrative optimization



Mathematical optimizer

Vector of design variables $\begin{pmatrix} x_1 \\ x_2 \\ x_3 \end{pmatrix}$

Fiber orientation model parameters (c_i, RSC factor, …)

Modification file

Vector of responses $\begin{pmatrix} r_1 \\ r_2 \\ r_3 \end{pmatrix}$

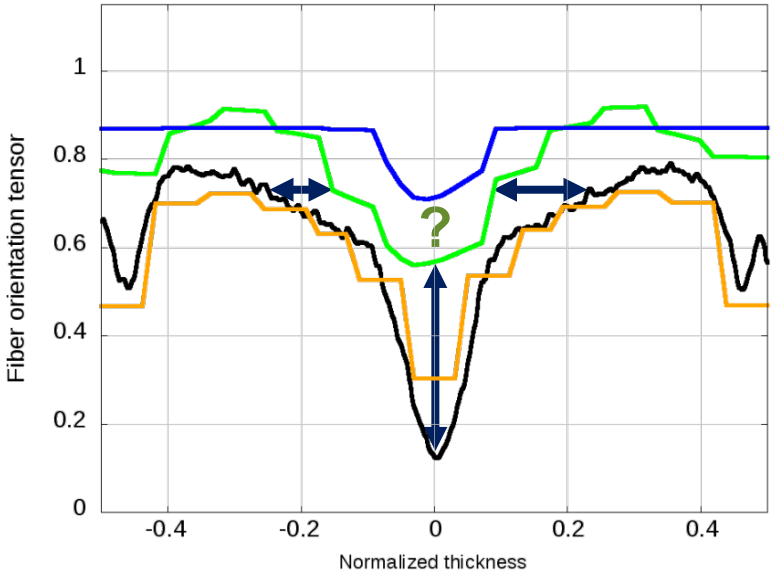
Process simulation of test plate *MOLDFLOW (Moldex, …)*

BASF ULTRASIM® Determination of fiber orientation

Calculation of deviation: Simulation / Experiment

Model Parameter Optimization
Comparing Simulation with Experiment

- Determining model parameters by comparing simulation with experiments

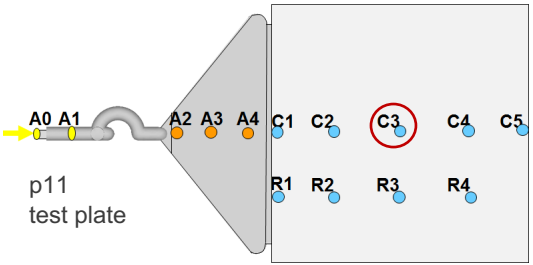


3-D simulation, Folgar-Tucker model (standard parameters)

3-D simulation, RSC model (standard parameters)

3-D simulation, Moldex3D (standard parameters)

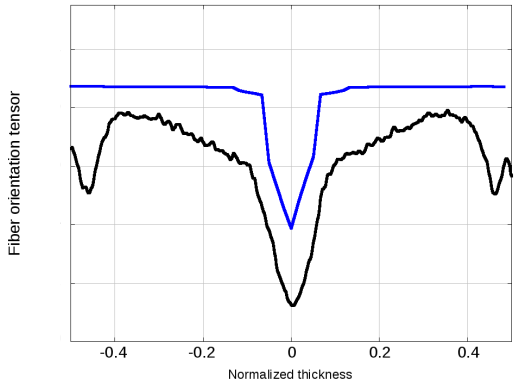
CT measurement



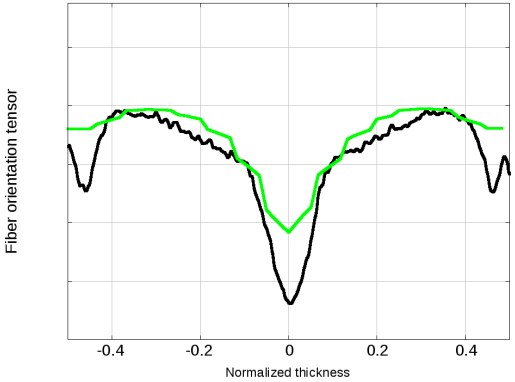
Model Parameter Optimization
Optimization Results

- Perform numerical optimization to find best model parameters that fit results from selected positions
- Result of numerical optimization (C3):

Folgar-Tucker



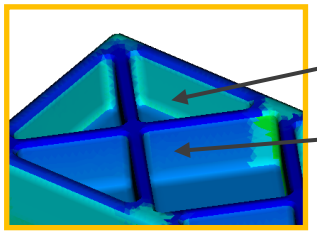
RSC Model



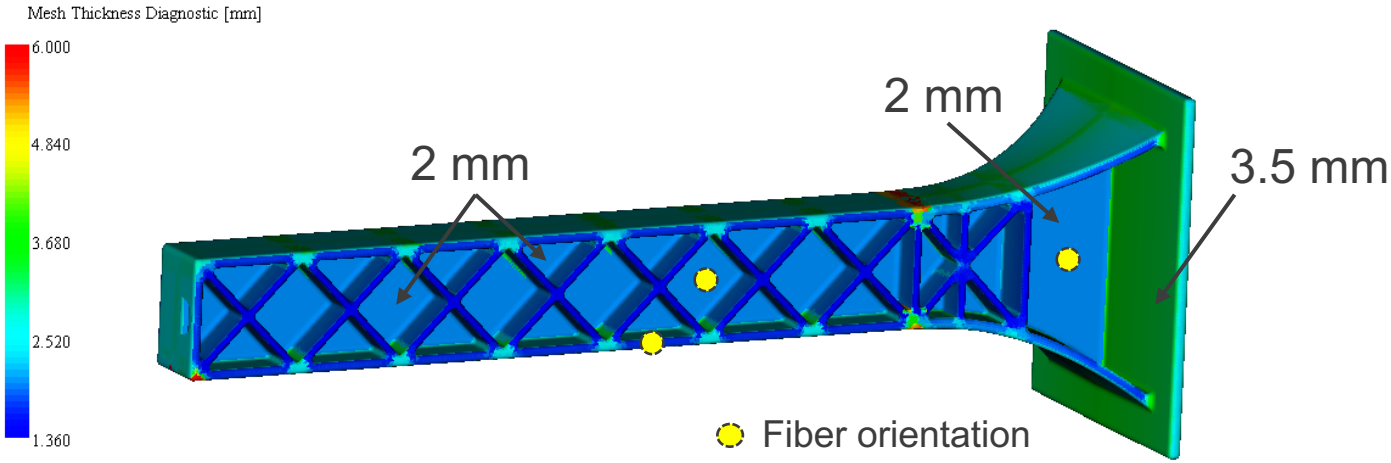
New MRD model looks promising…

- Great improvement in the fit.

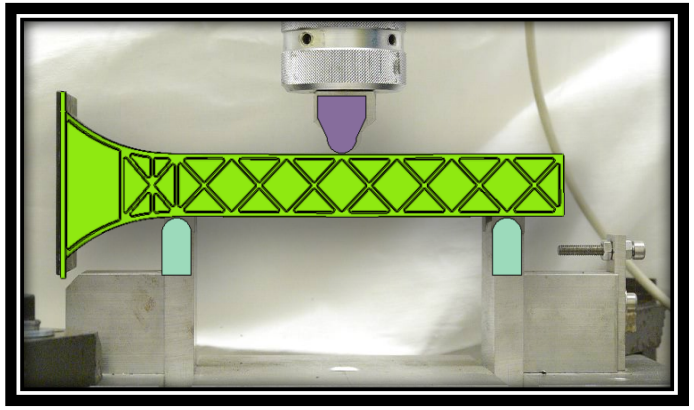
Model Parameter Optimization
Transfer to Complex Geometry



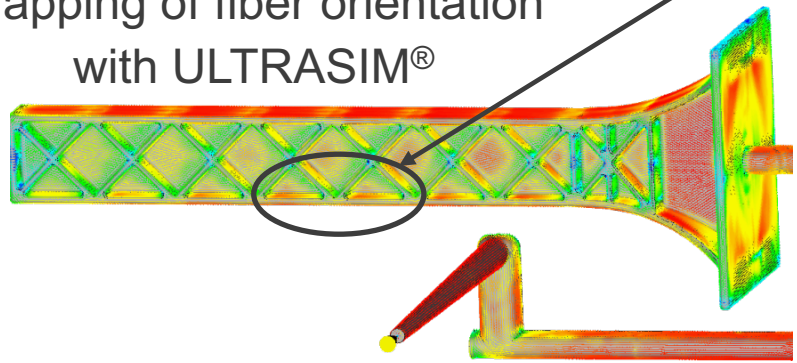
main wall thickness = 2.0 .. 3.5 mm



Simulations with Optimized Parameters
Three Point Bending

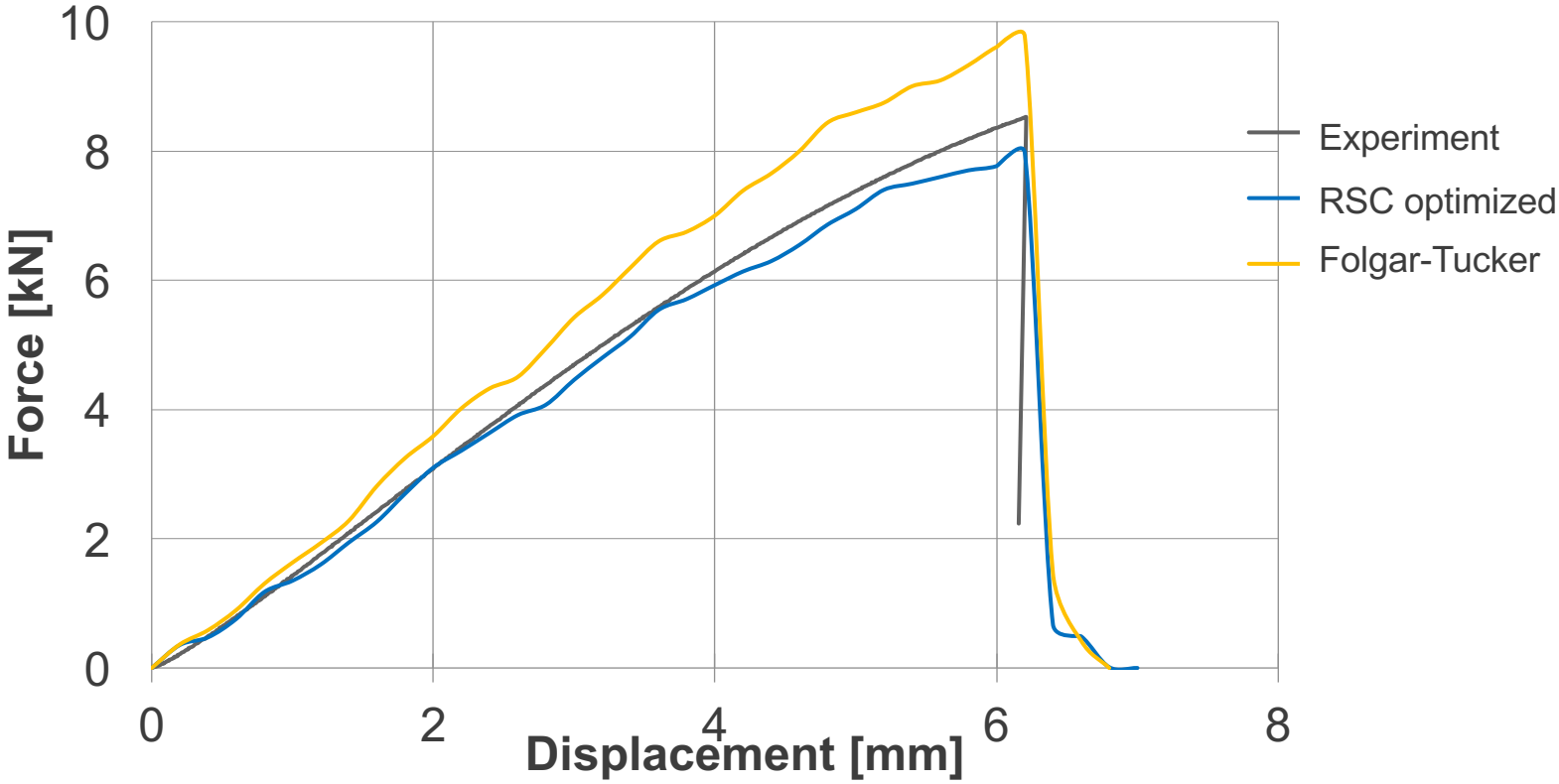


Mapping of fiber orientation
with ULTRASIM®



Different degree of fiber orientation before and after the ribs

Simulations with Optimized Parameters
Three Point Bending

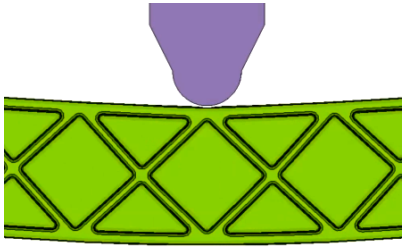


Simulations with Optimized Parameters
Three Point Bending

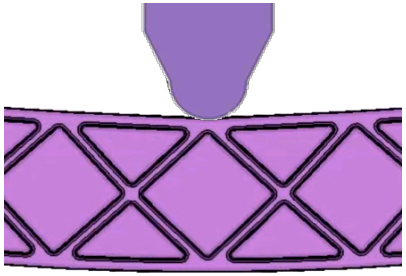
Simulation

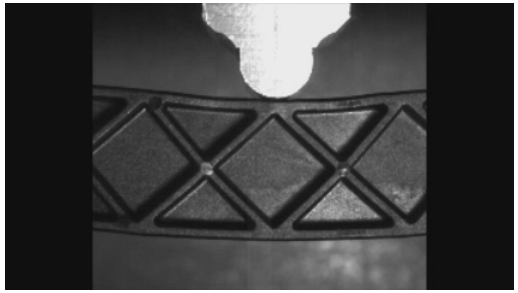
Experiment

Folgar-Tucker
(Standard)



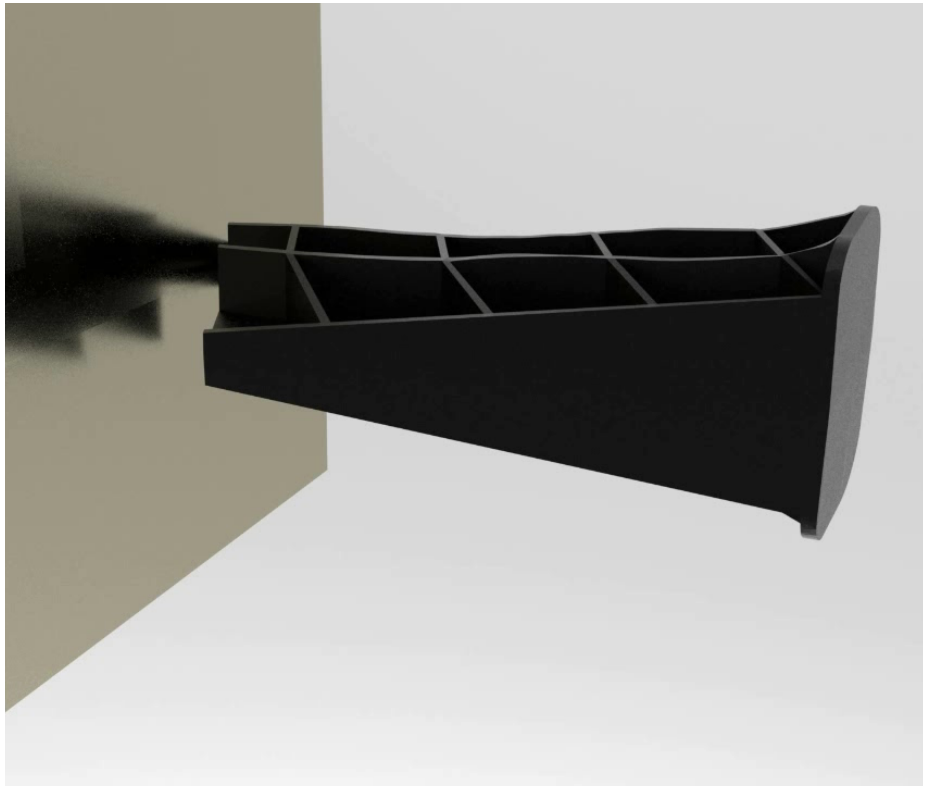
RSC
(optimized)





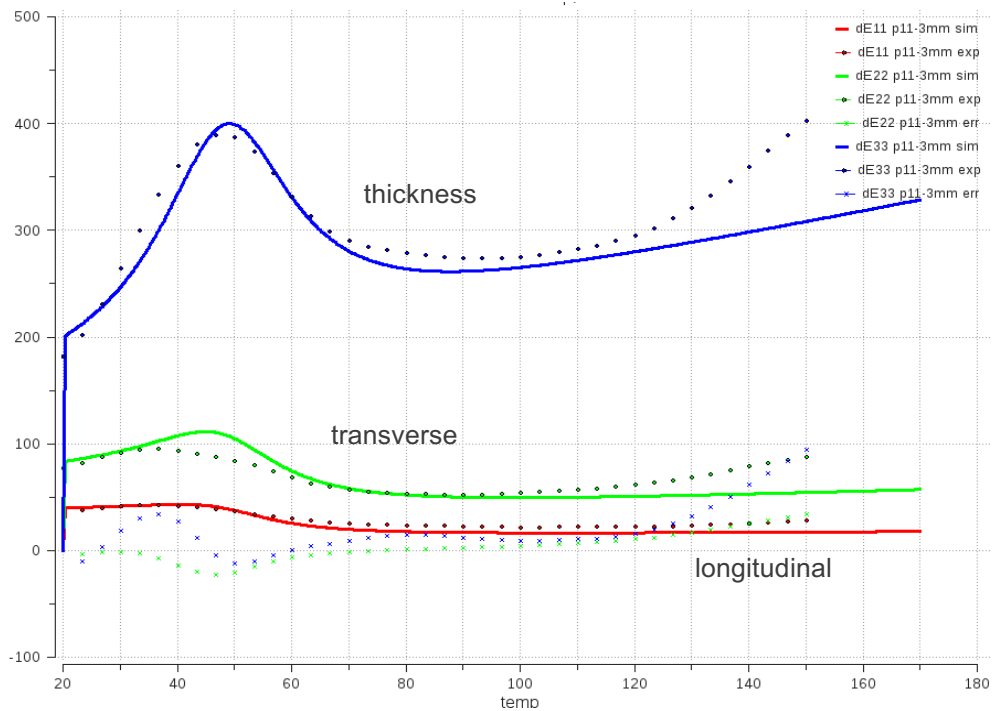
Simulations with Optimized Parameters

Realistic Simulation



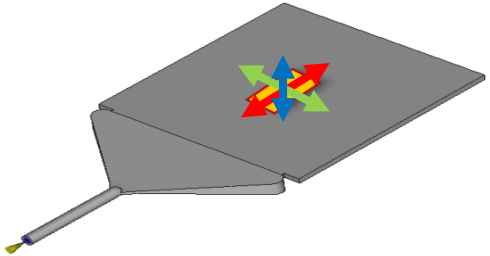
- BASF's proprietary simulation framework combining material know-how with design and processing expertise
- Select the optimal material
- Identify suitable applications for lightweight plastics
- **Advantages**
  - Less prototyping needed
  - Lower development cost
  - Shorter development time

Simulations with Optimized Parameters
New Developments



New thermomechanical material law

- Takes fiber orientation anisotropy into account
- Strain-rate dependent
- Failure modelling
- Compressions-tension asymmetry
- New: Full temperature-dependent modelling
- New: Considers thermal expansion



Simulations with Optimized Parameters
PU Foams

- Filling behavior
- Weldlines, air traps
- Process optimization

Conclusions & Outlook

- Much work has been performed to determine optimal fiber orientation parameters for a wide range of materials by comparing CT measurement from test geometries with Moldflow (and other) simulations
- Simulations with optimized parameters show higher accuracy:
  - Better results for mechanical verification tests
  - Better fracture behavior in ULTRASIM®
  - Warpage results improve qualitatively
- Integrative optimization approach allows quick determination of optimal parameters, especially useful after (numerical) changes to models
- Optimized parameters provided to selected BASF customers under NDA

Using Moldflow and ULTRASIM for Superior Mechanical Simulations – Recent Developments

Thank you for your attention!

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