# A Simple Method for an Appropriate Simulation of Short-Fiber-Reinforced Injection Molded Plastics

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# CAE Services & Software

## Technical Simulation

**Contract Simulation Services in FEA**

## CAE Staffing

**Resident Engineers at customers‘ sites**

## CAE Software

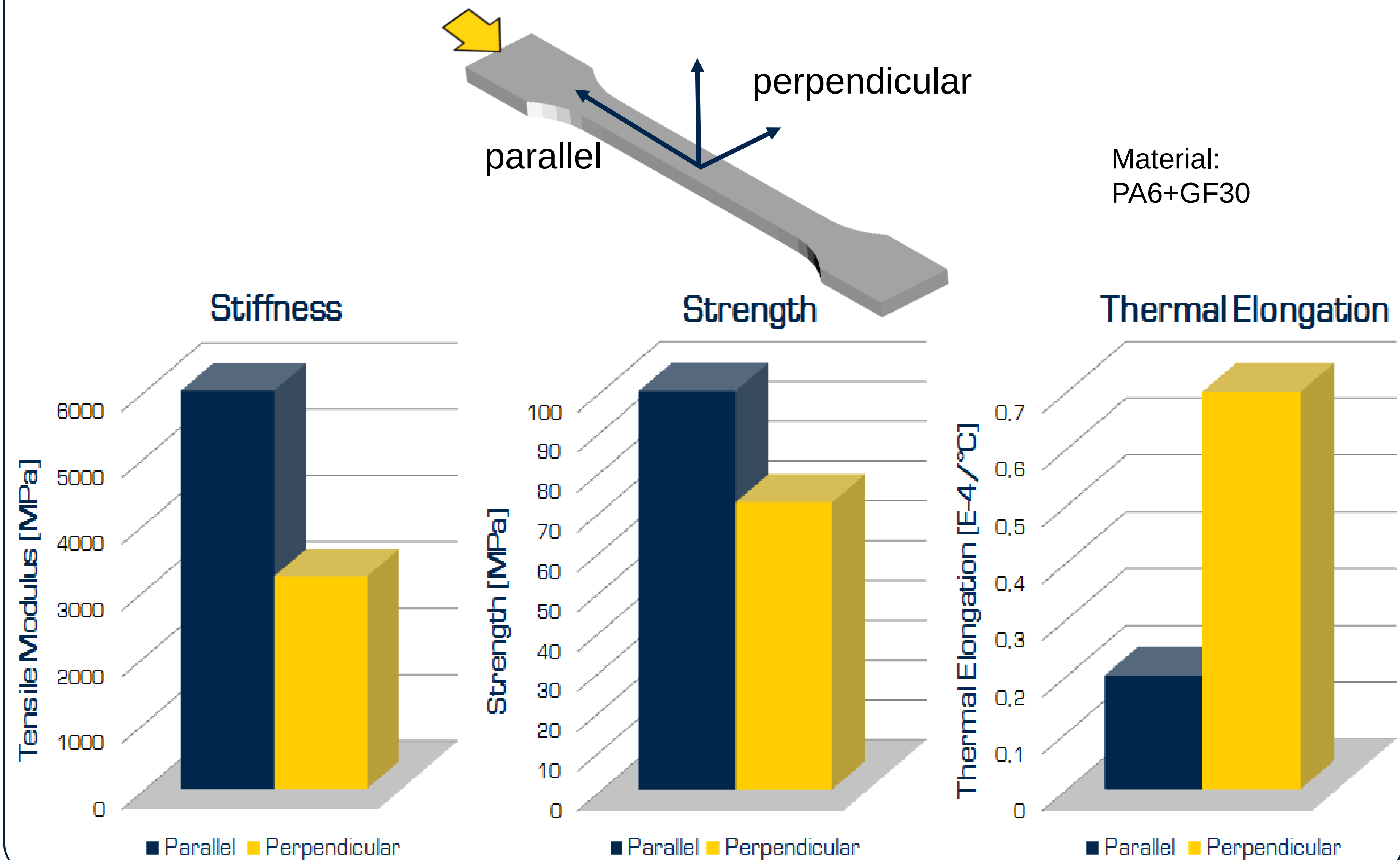
- **Process-Structure-Interaction**
- **Strength & Fatigue Assessment**

Elastomers

Converse

Plastics

Metals




Influence of Fiber Orientation onto Material Properties

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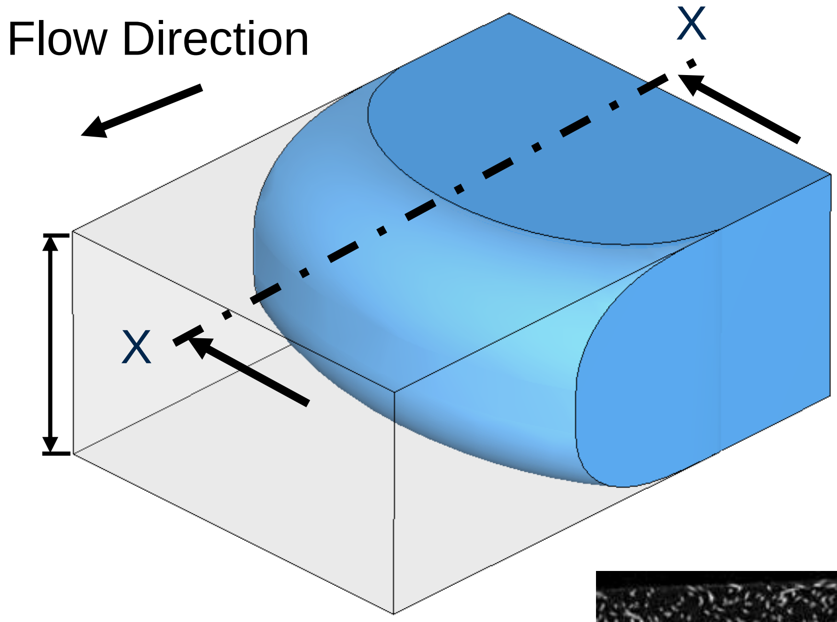
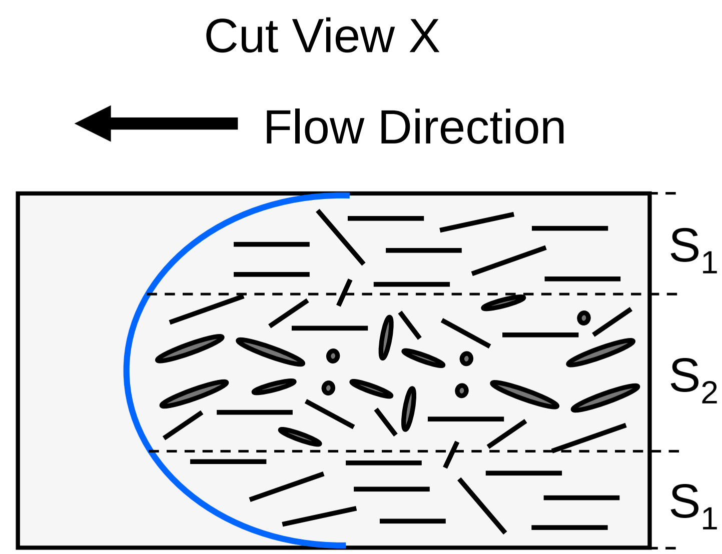
Fig. 2

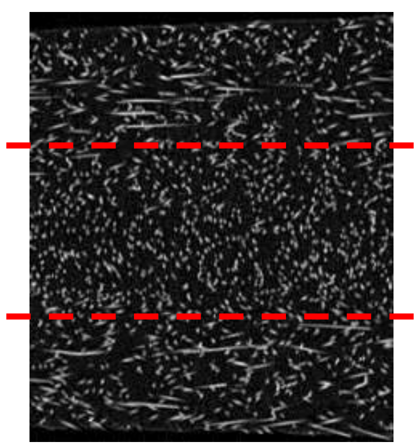
$S_1$ Shear layer: Fibers oriented parallel to flow direction
$S_2$ Mid layer: Fibers oriented perpendicular to flow direction



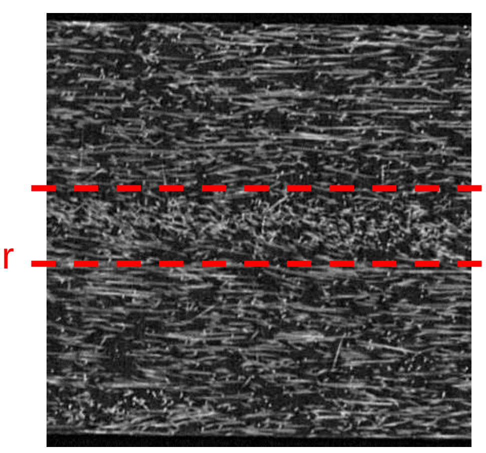




Example Micrograph Pictures:

Thick Mid Layer



Thin Mid Layer



## Fiber Orientations in Short-Fiber-Reinforced Plastics

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Fig. 3

*MAT_108

The yield function is defined as

$$f = \bar{f}(\boldsymbol{\sigma}) - \left[\sigma_0 + R\left(\varepsilon^p\right)\right]$$

where the equivalent stress $\sigma_{eq}$ is defined as an anisotropic yield criterion

$$\sigma_{eq} = \sqrt{F(\sigma_{22}-\sigma_{33})^2 + G(\sigma_{33}-\sigma_{11})^2 + H(\sigma_{11}-\sigma_{22})^2 + 2L\sigma_{23}^2 + 2M\sigma_{31}^2 + 2N\sigma_{12}^2}$$

Where F, G, H, L, M and N are constants obtained by test of the material in different orientations. They are defined as

$$F = \frac{1}{2}\left(\frac{1}{R_{22}^2} + \frac{1}{R_{33}^2} - \frac{1}{R_{11}^2}\right)$$

$$G = \frac{1}{2}\left(\frac{1}{R_{33}^2} + \frac{1}{R_{11}^2} - \frac{1}{R_{22}^2}\right)$$

$$H = \frac{1}{2}\left(\frac{1}{R_{11}^2} + \frac{1}{R_{22}^2} - \frac{1}{R_{33}^2}\right)$$

$$L = \frac{3}{2R_{23}^2}$$

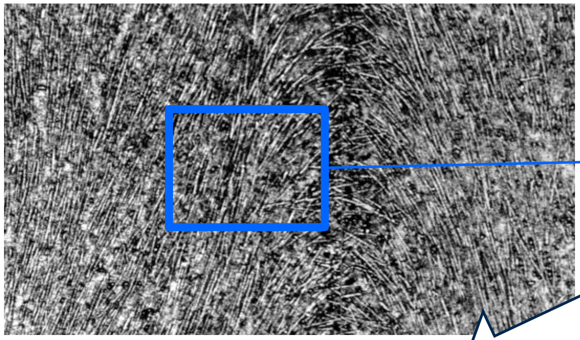
$$M = \frac{3}{2R_{13}^2}$$

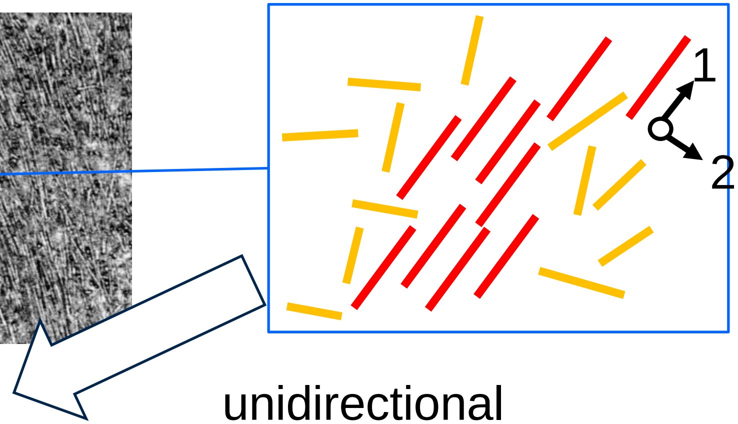
$$N = \frac{3}{2R_{31}^2}$$

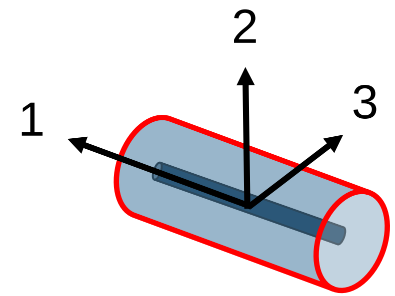
[Source: ls-dyna-971-manual-k]

## Orthotropic Elastic Plastic Material Model

Fig. 4

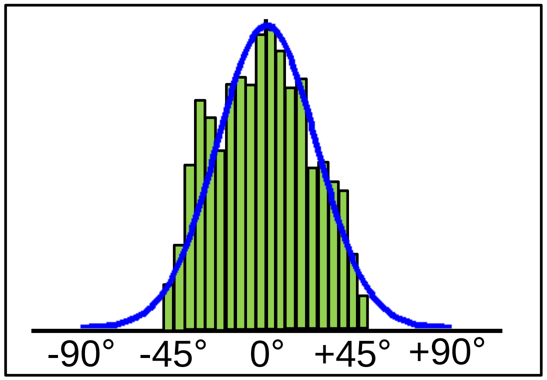




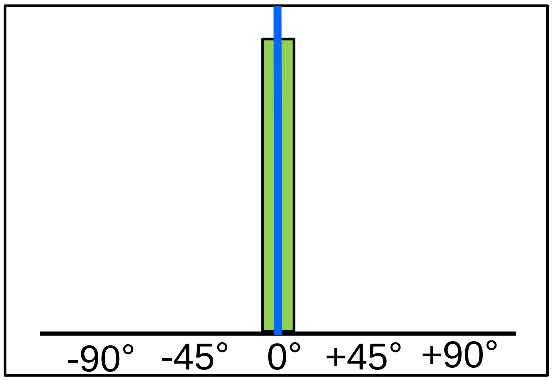

general case

$$\begin{pmatrix} a_{11} & a_{12} & a_{13} \\ . & a_{22} & a_{23} \\ . & . & a_{33} \end{pmatrix}$$



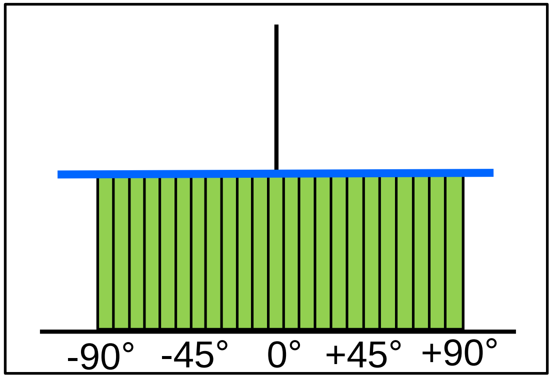

unidirectional

$$\begin{pmatrix} 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}$$




quasi-isotropic

$$\begin{pmatrix} 0.33 & 0 & 0 \\ 0 & 0.33 & 0 \\ 0 & 0 & 0.33 \end{pmatrix}$$




Degree of Orientation

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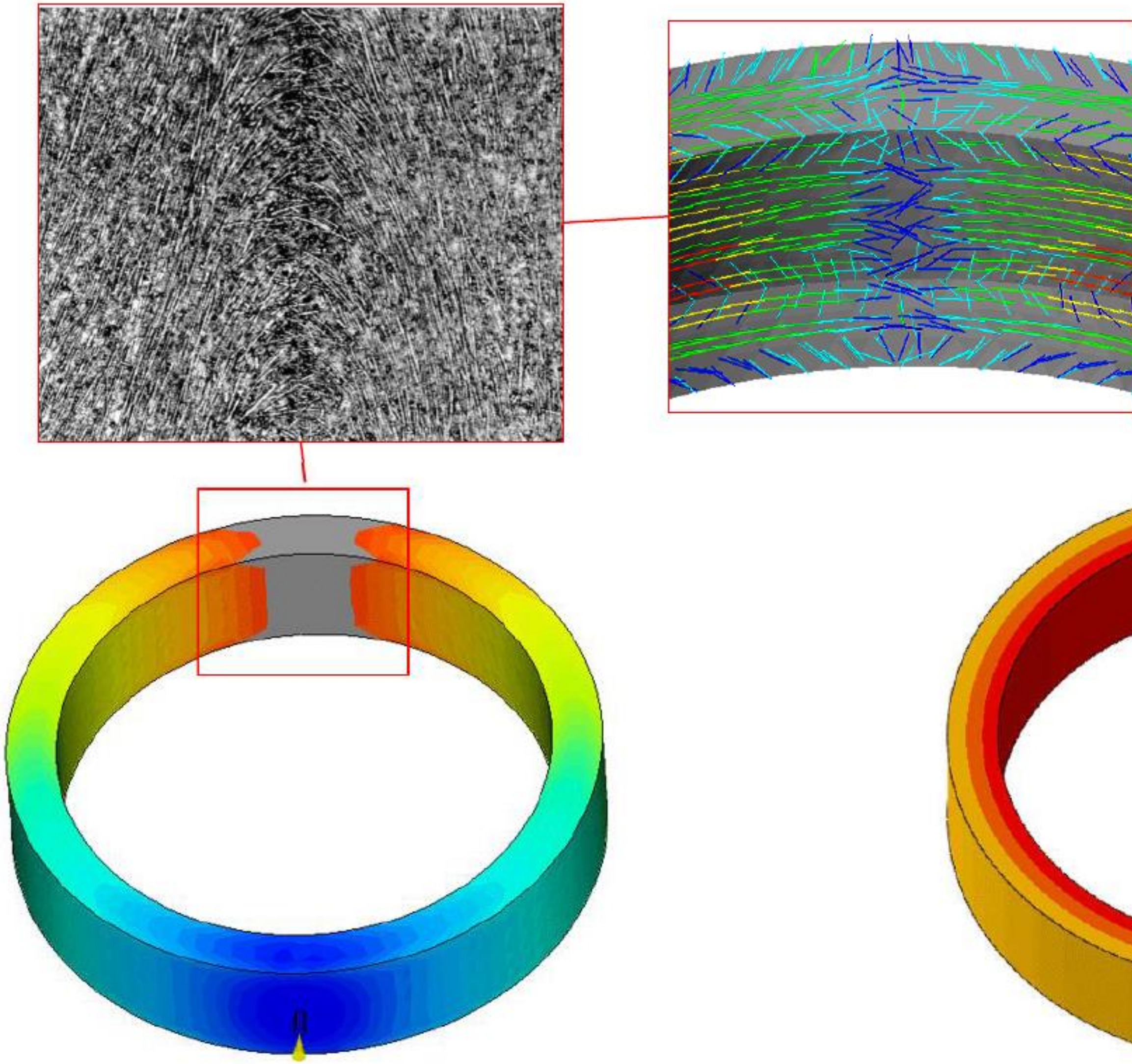
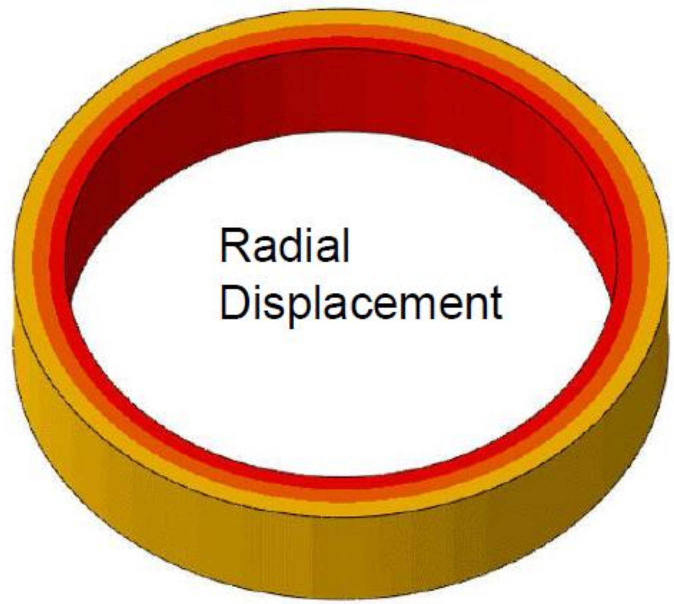
Fig. 5



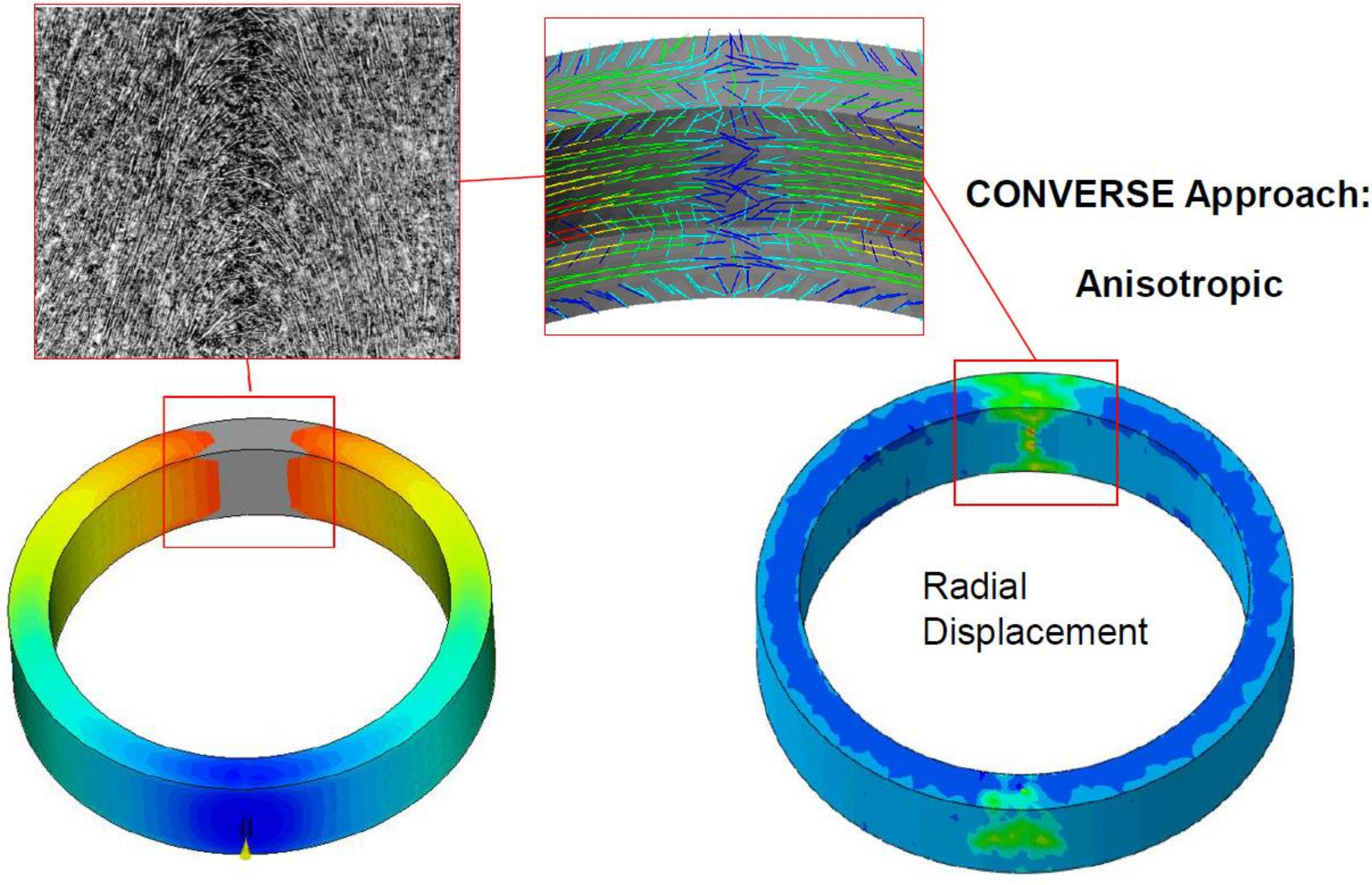
**Common Approach:**

**Isotropic**




Example: Weld Lines
Isotropic Approach

Fig. 6




Example: Weld Lines
Anisotropic Approach

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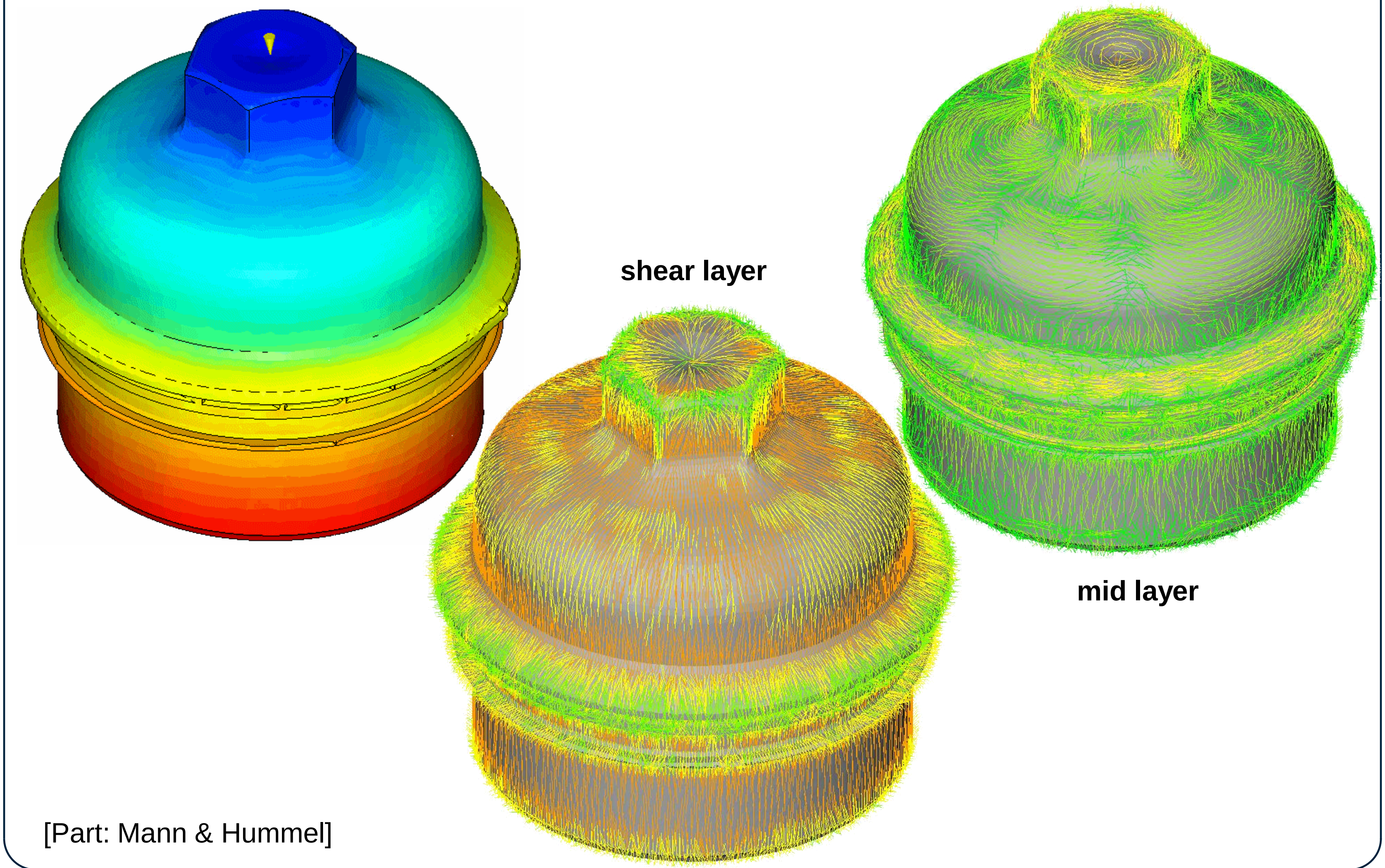
Fig. 7




[Part: Mann & Hummel]

# Orientation and Degree of Orientation from Injection Molding Simulation

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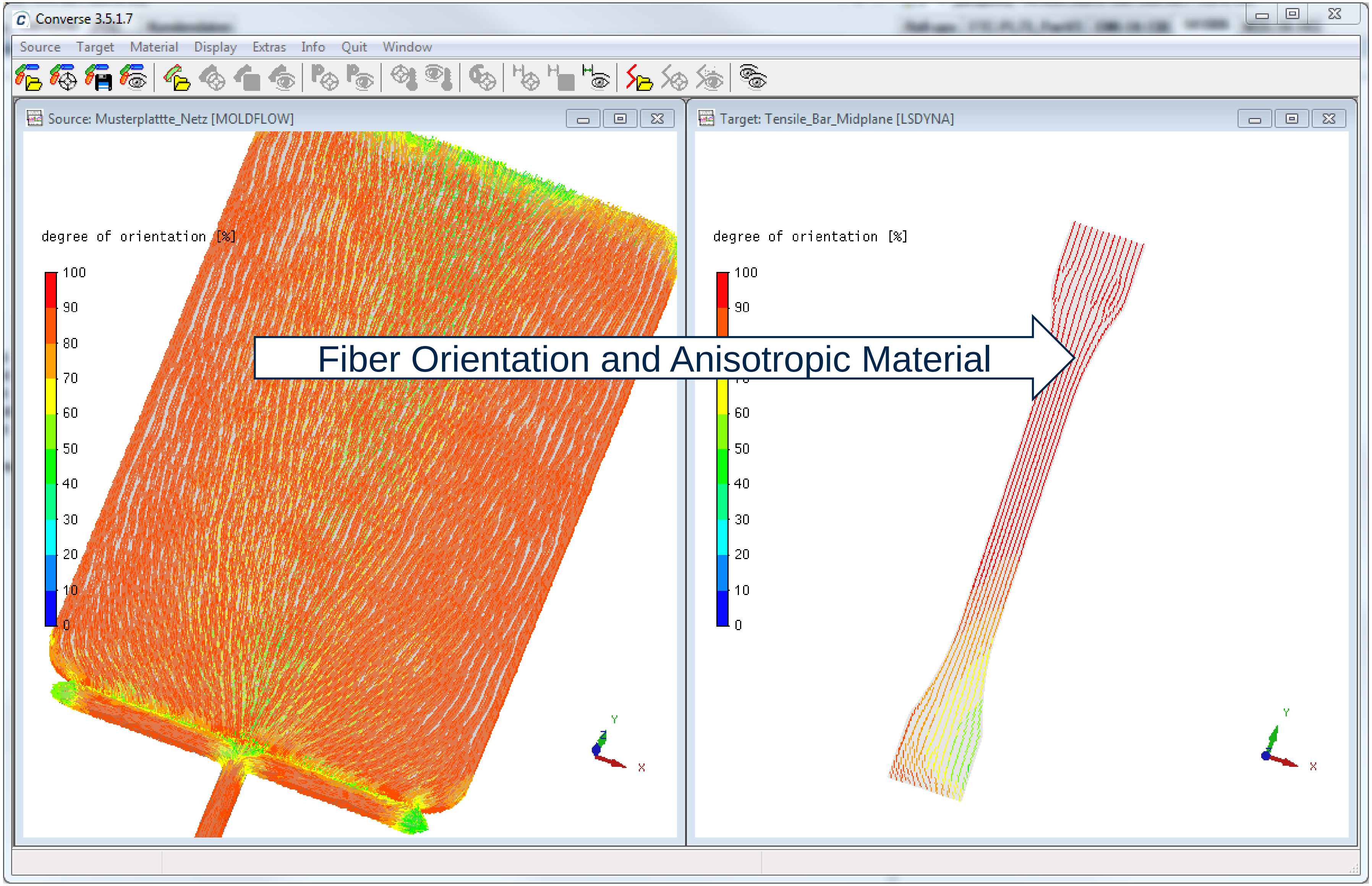
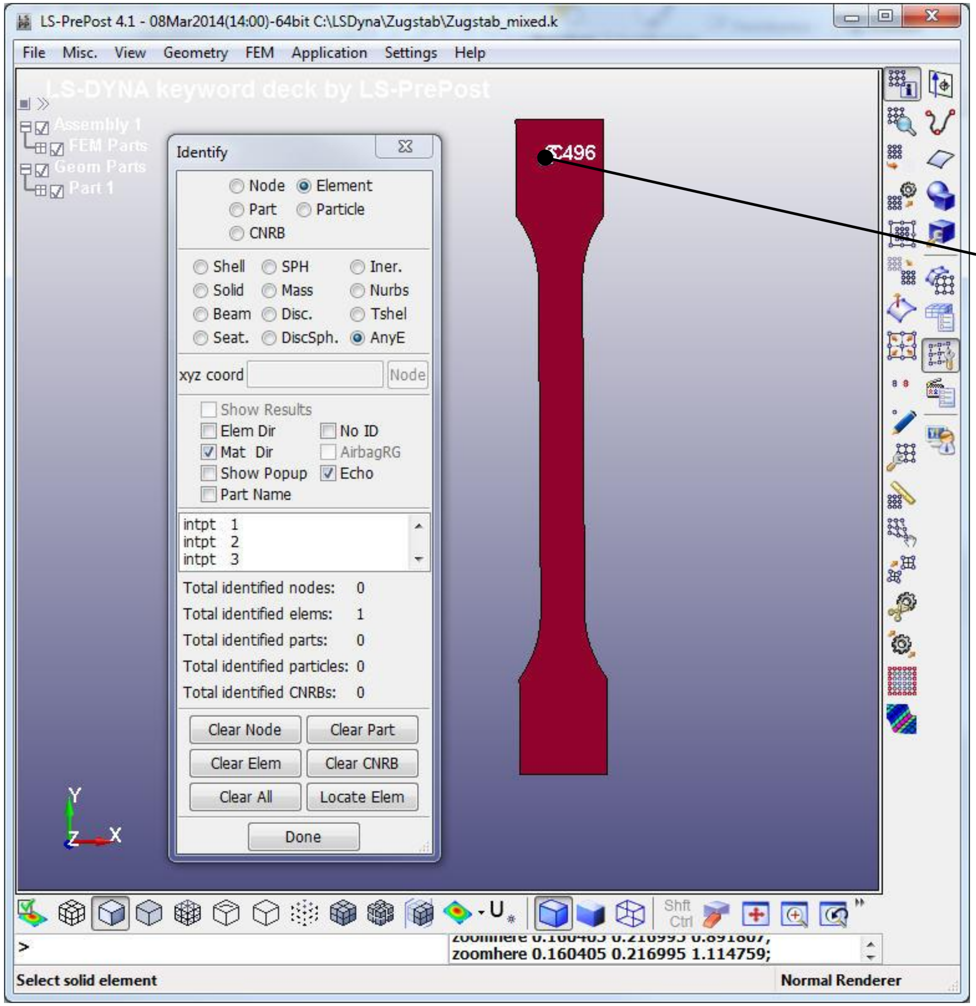
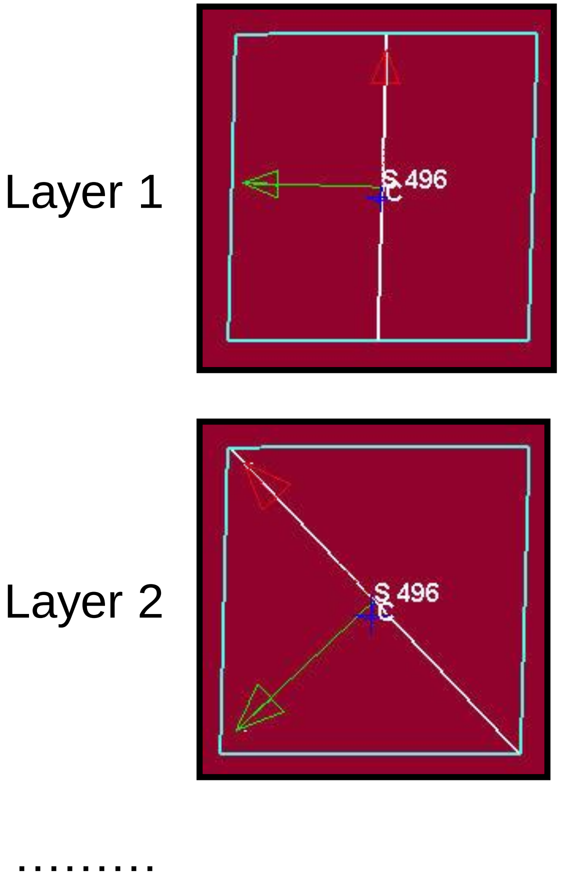
Fig. 8




Converse Graphical User Interface

Fig. 9




material type 108

*MAT_ORTHO_ELASTIC_PLASTIC

## Example: Tensile Bar Specimen

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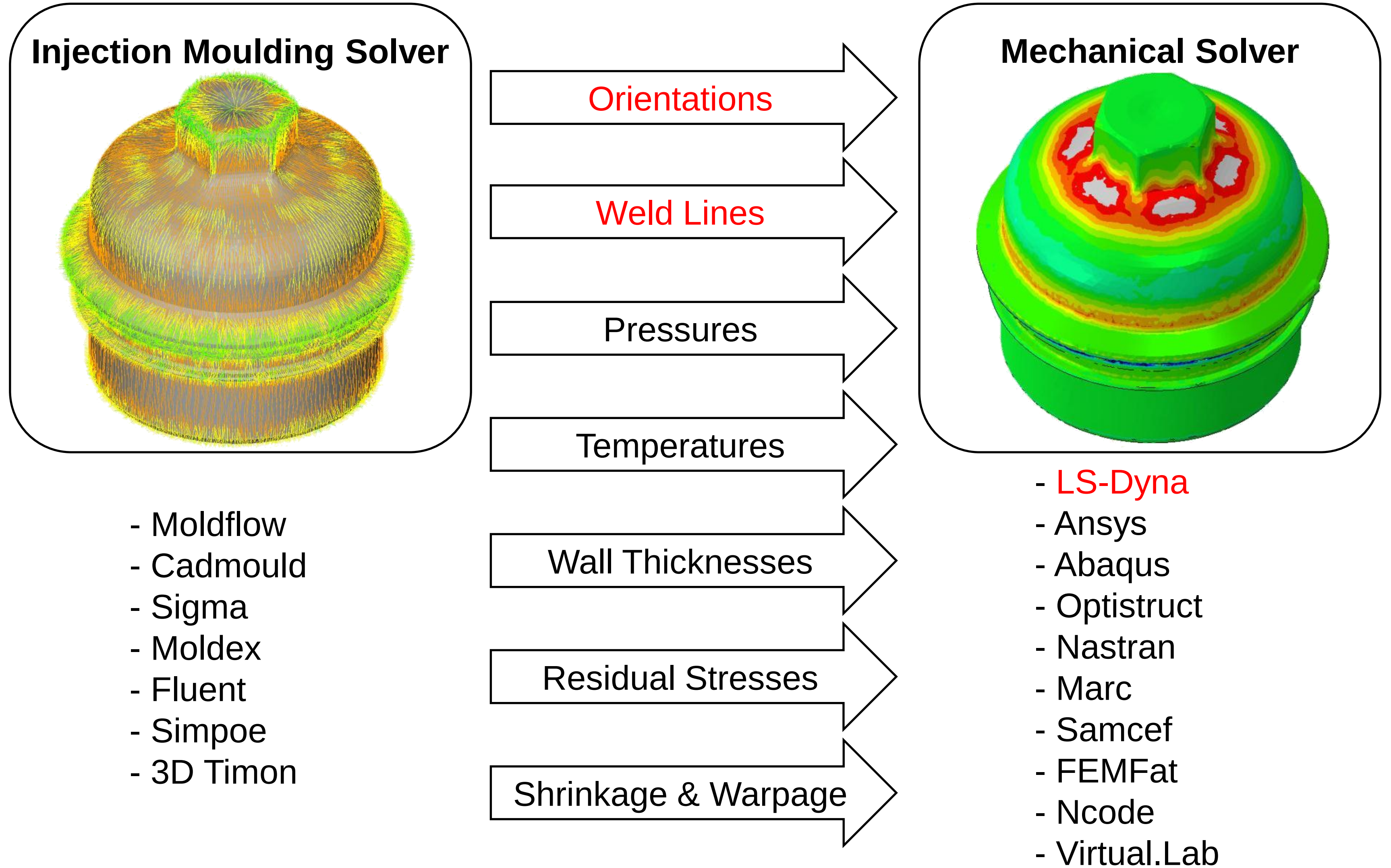
Fig. 10




Converse Features and Interfaces

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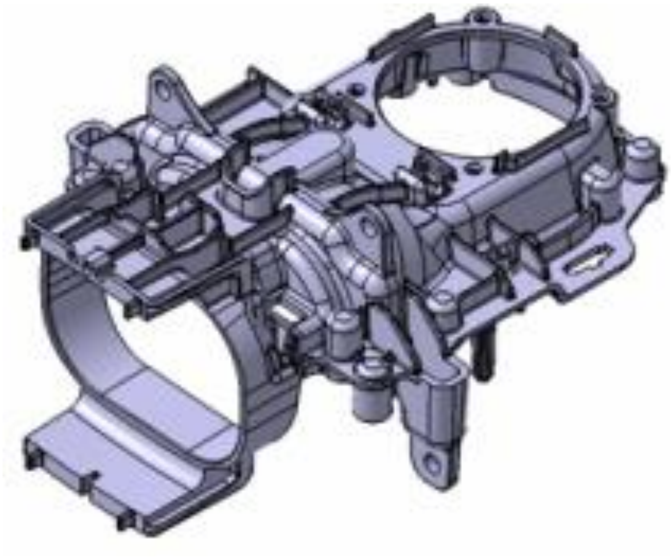
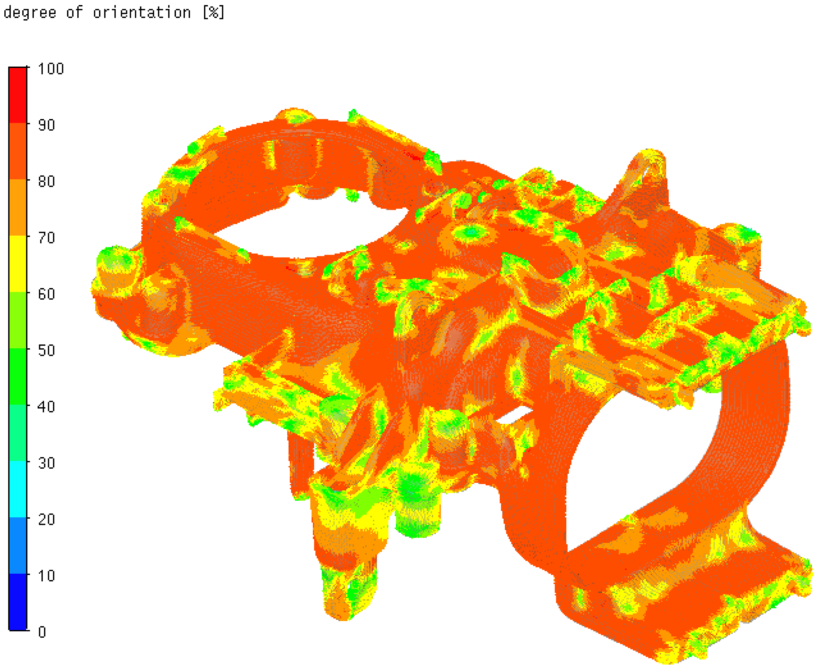
Fig. 11

Part Geometry

Fiber Orientation in Converse






[Valeo Lighting Systems]

Lens Bracket Example

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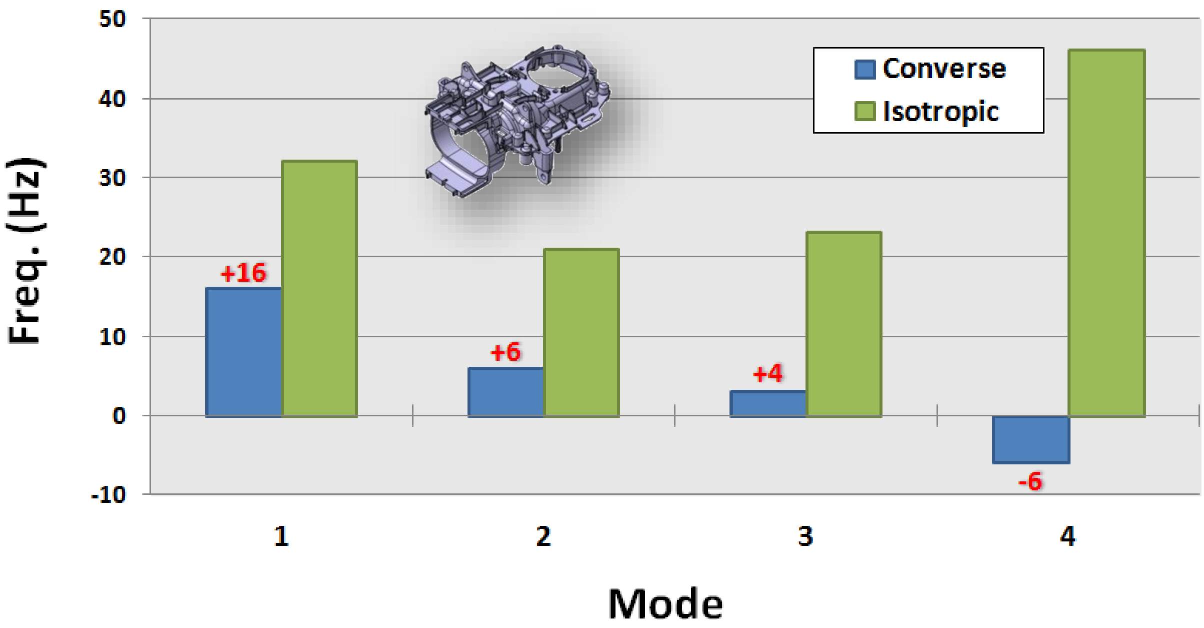
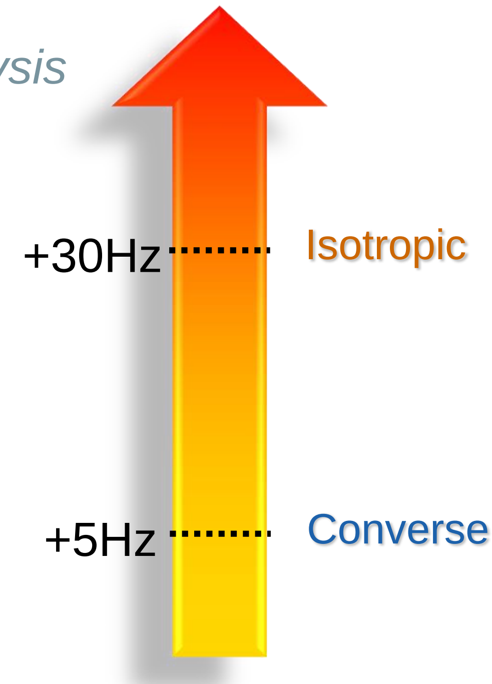
Fig. 12

## *Frequency correlation – simulation to Xp. modal analysis*



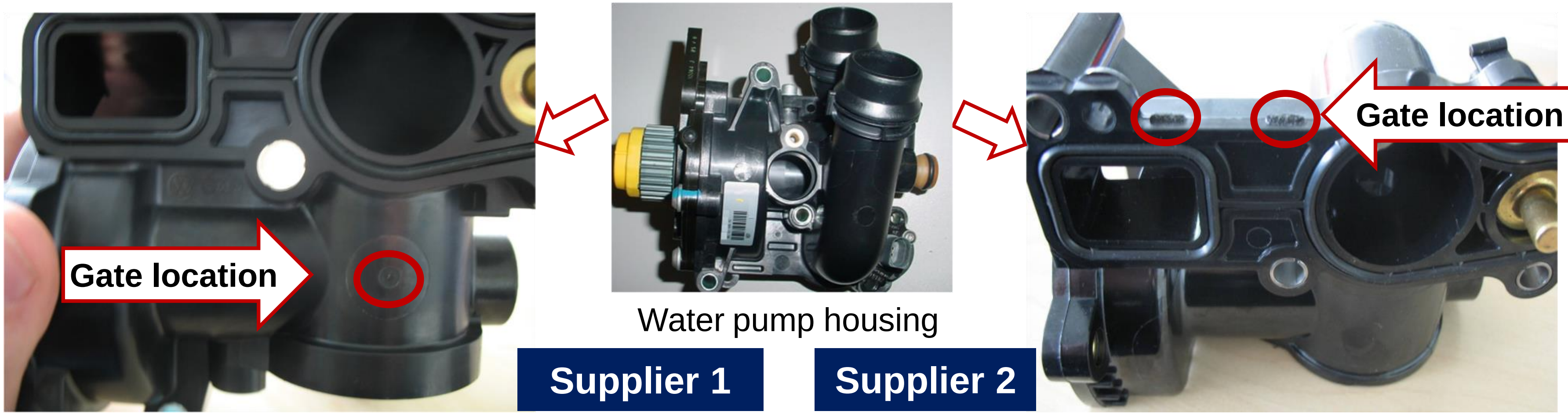

*Average error – 4 Modes*

| Mode | Experimental (Hz) | Isotropic (Hz) | Converse (Hz) |
|---|---|---|---|
| **1** | 44 | 76 | 60 |
| **2** | 56 | 77 | 62 |
| **3** | 91 | 114 | 94 |
| **4** | 224 | 270 | 218 |

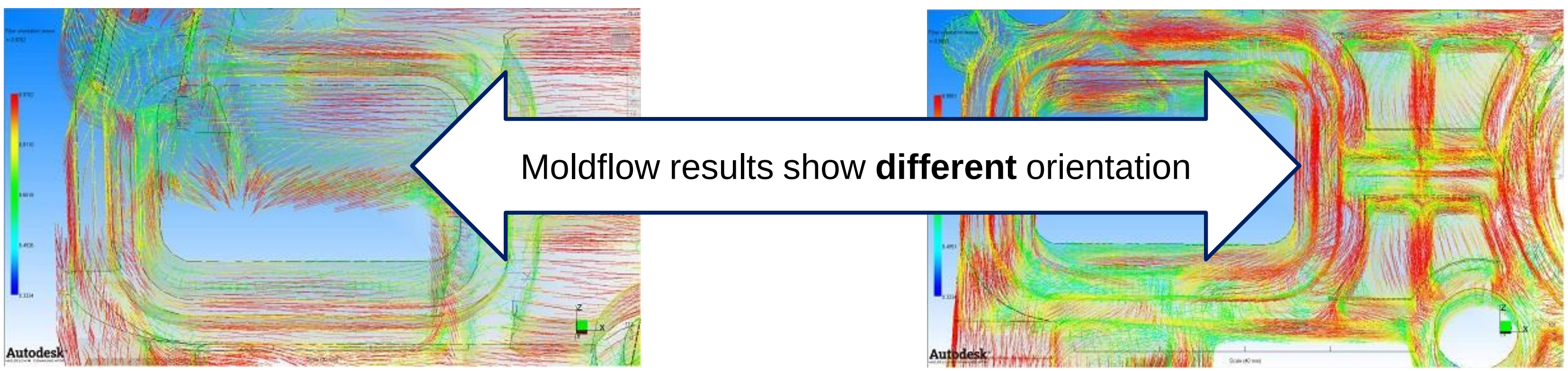
[Valeo Lighting Systems]

Lens Bracket Example

Fig. 13




- **Two suppliers** but parts are geometrically up to 95% **equal**.
- Same material supplier, same mashine settings, etc.
- Different gating location means two **completly different** engine components!

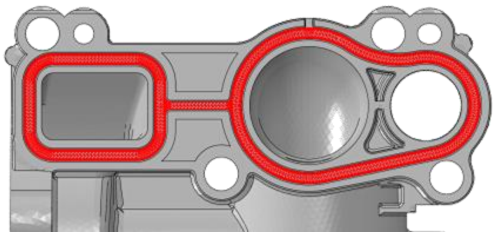



# Influence Of Production on Fiber Orientation

Fig. 14

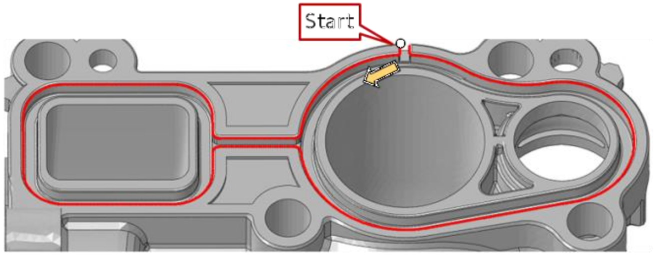
Audi Hungaria

1. distributed pressure on sealing contact surface



Untolerable **error** if **homogeneous isotropic** material is used!

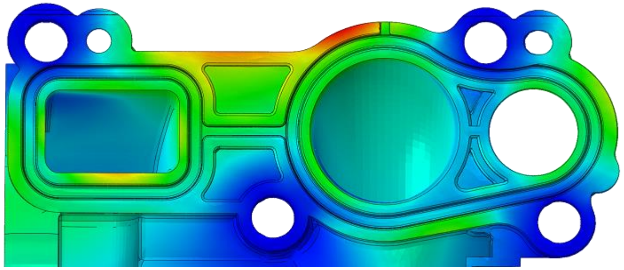
2. results evaluated on a path

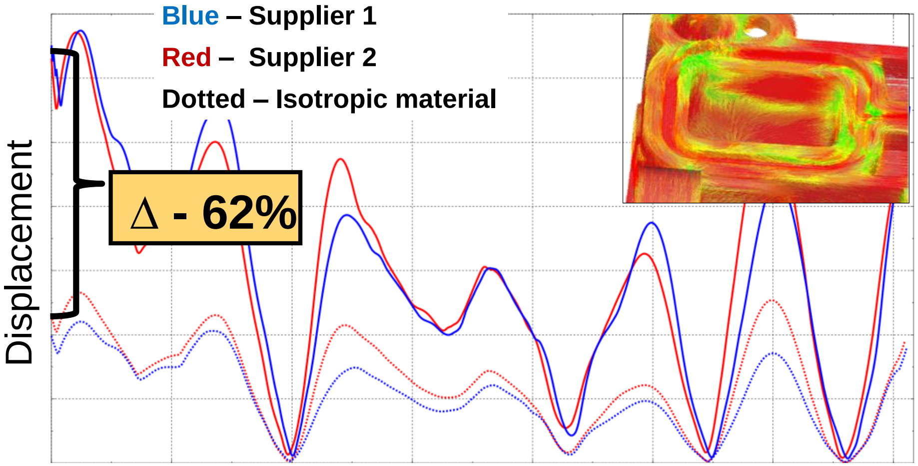



4. isotropic vs. anisotropic results

fiber orientation and material model by Converse

3. displacements






# Influence Of Production on Anisotropic Part Stiffness

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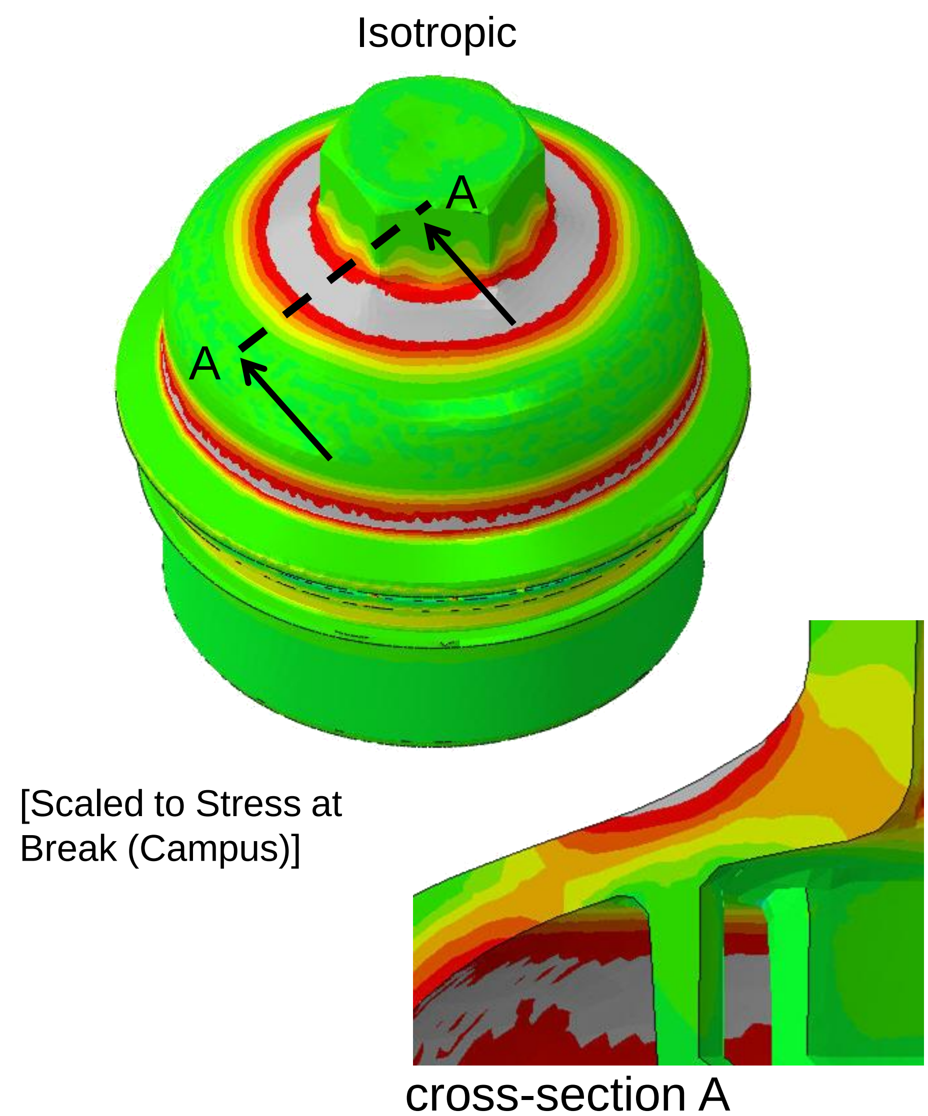
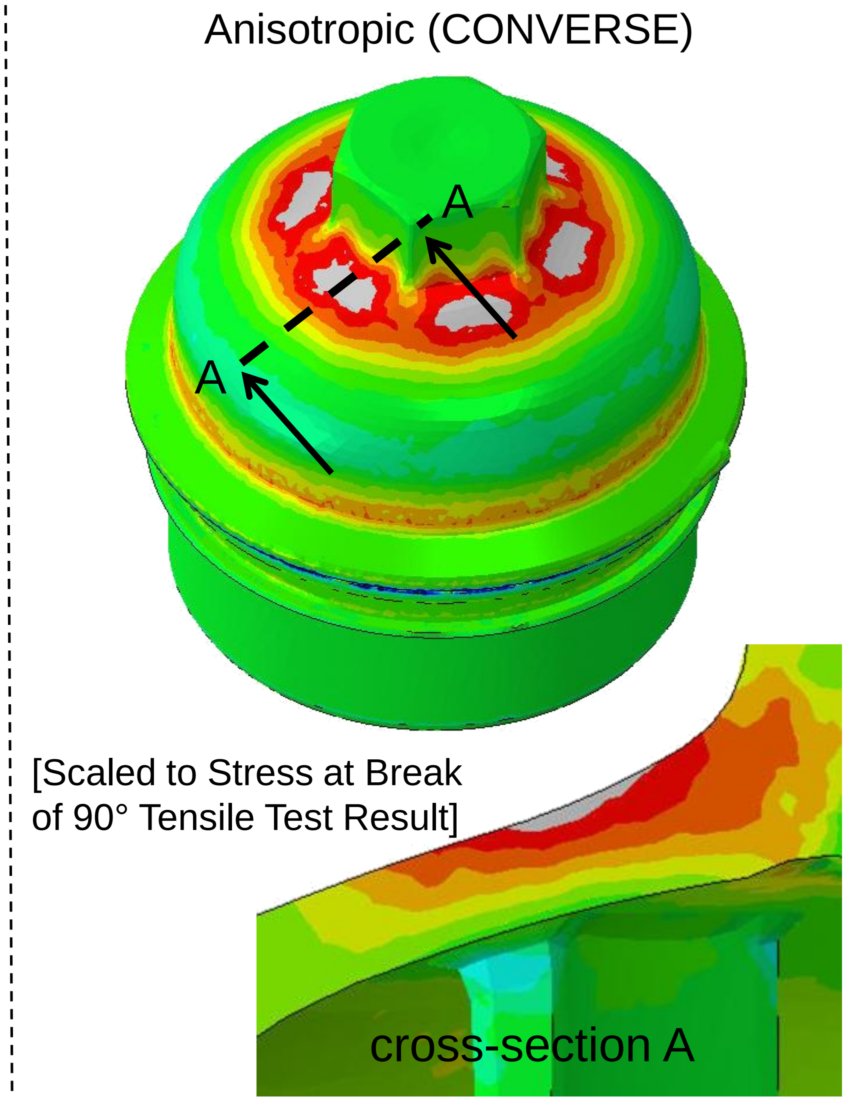
Fig. 15




Oil Filter Cover at Burst Pressure 87,5 bar (Test Result)

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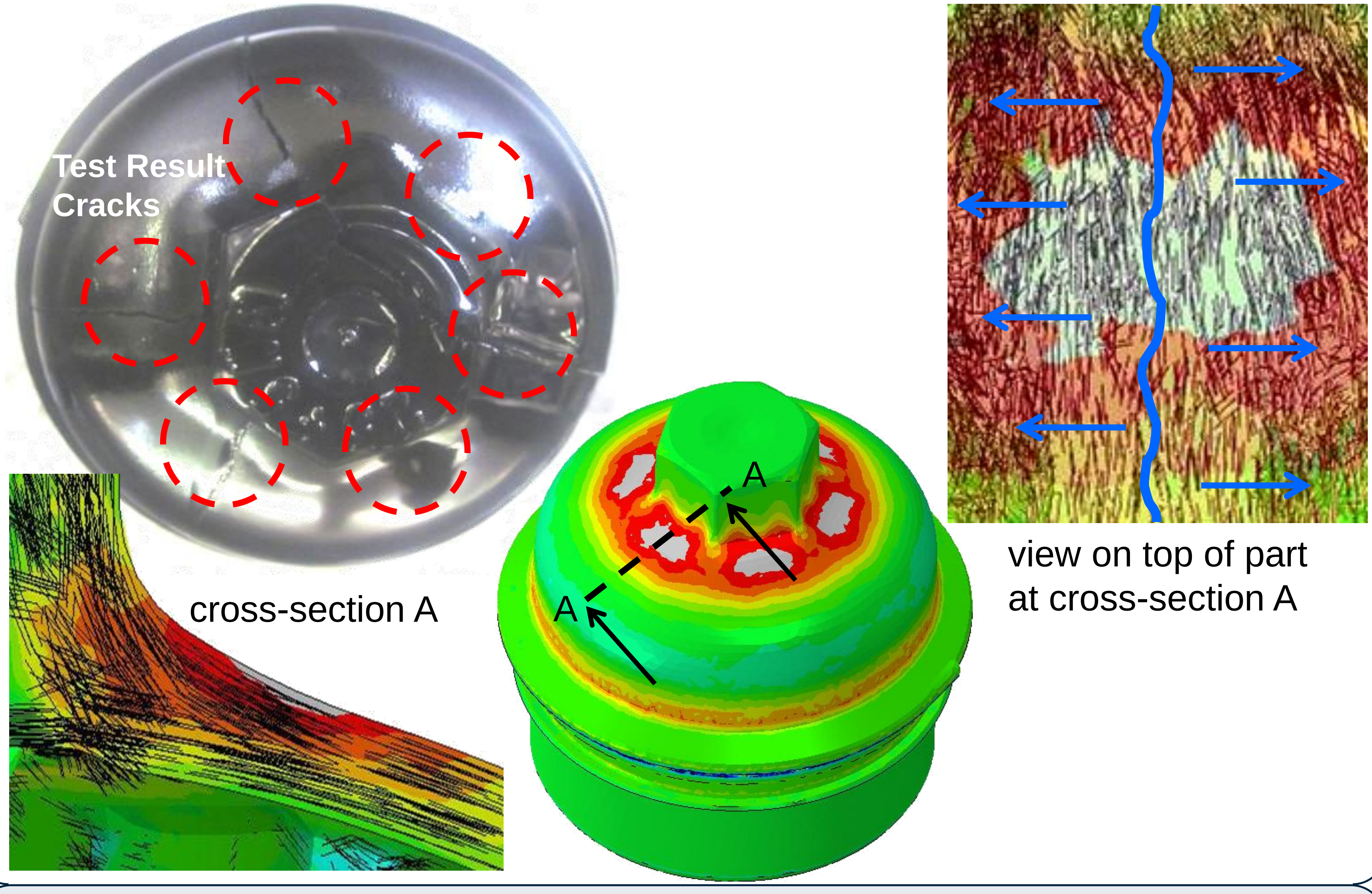
Fig. 16




Oil Filter Cover at Burst Pressure 87,5 bar (Test Result)

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Fig. 17

**FE-Molding Simulation**

- orientation tensor
- FE-mesh of part

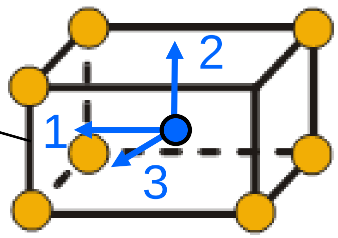
**CONVERSE**

- orientation mapping
- orientation averaging
- micromechan. model

**FE-Mechanical Simulation**

- props. of fiber & matrix
- FE-mesh of structure

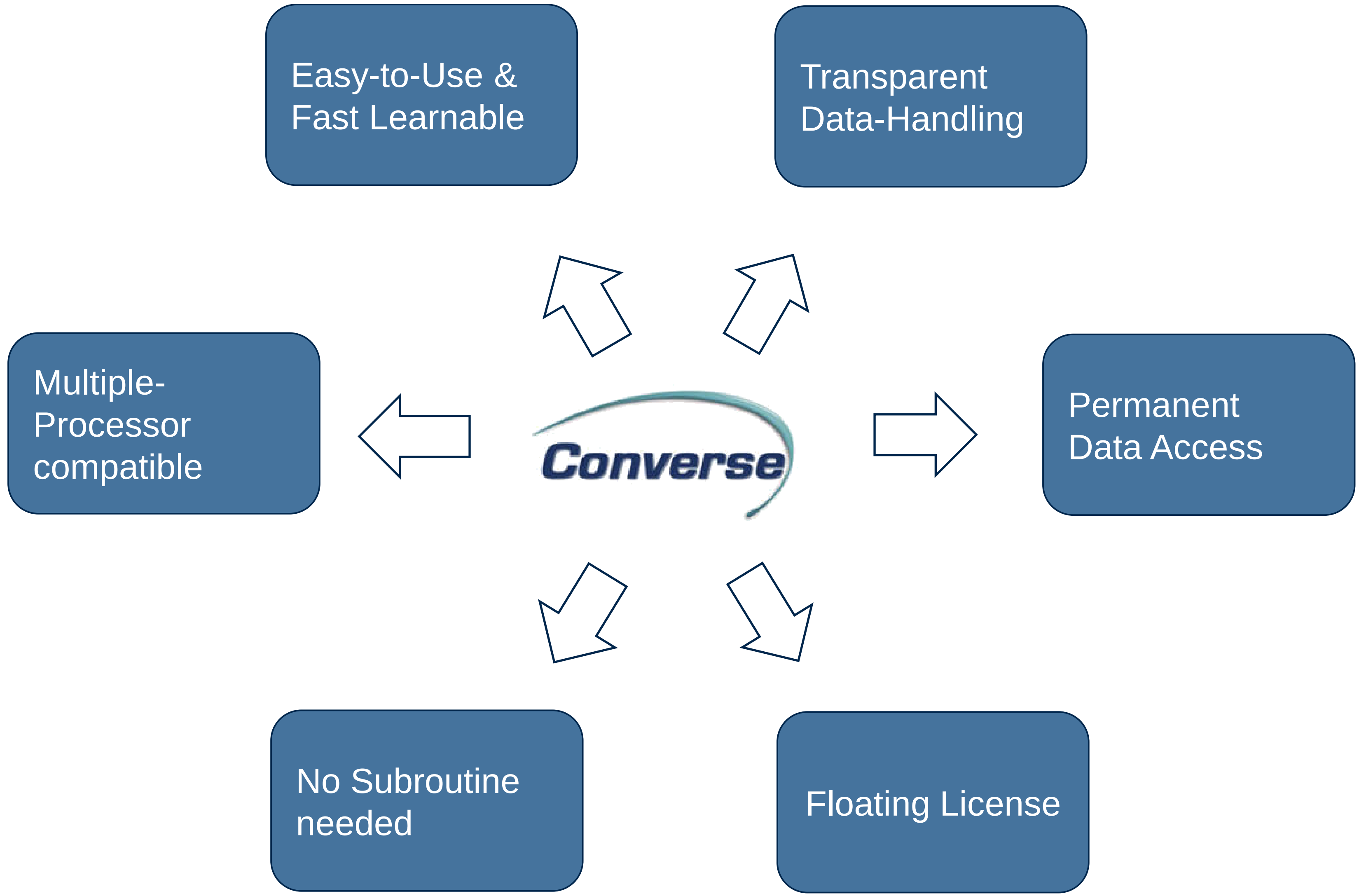
Properties of anisotropic homogenious composite




**Implicit or Explicit Simulation**

Summary of the Procedure for Application in FEA

Fig.18




Benefits

Fig.19