Potential of MAT157 for Short-Fiber-Reinforced Injection Molded Plastic Components

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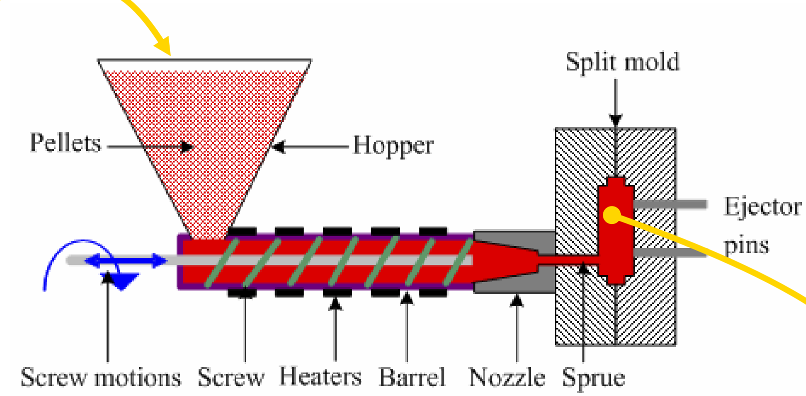
Overview

- Introduction
- Material Models for SFR Plastics
- MAT_157 for SFR Plastics
- Conclusion

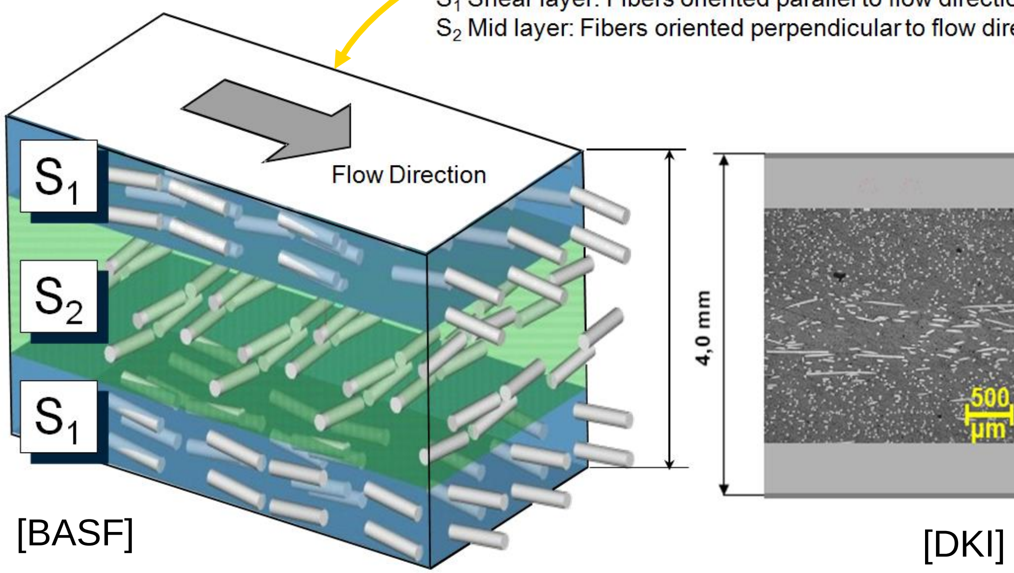
Material is Generated During Processing

Short-Fiber-Reinforced Plastic Resin
(fiber length: ~ 0,1 - 0,5 mm)



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

Molded Component



[BASF]

[DKI]

Fig. 2

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Influence of Fiber Orientation on Mechanical Properties

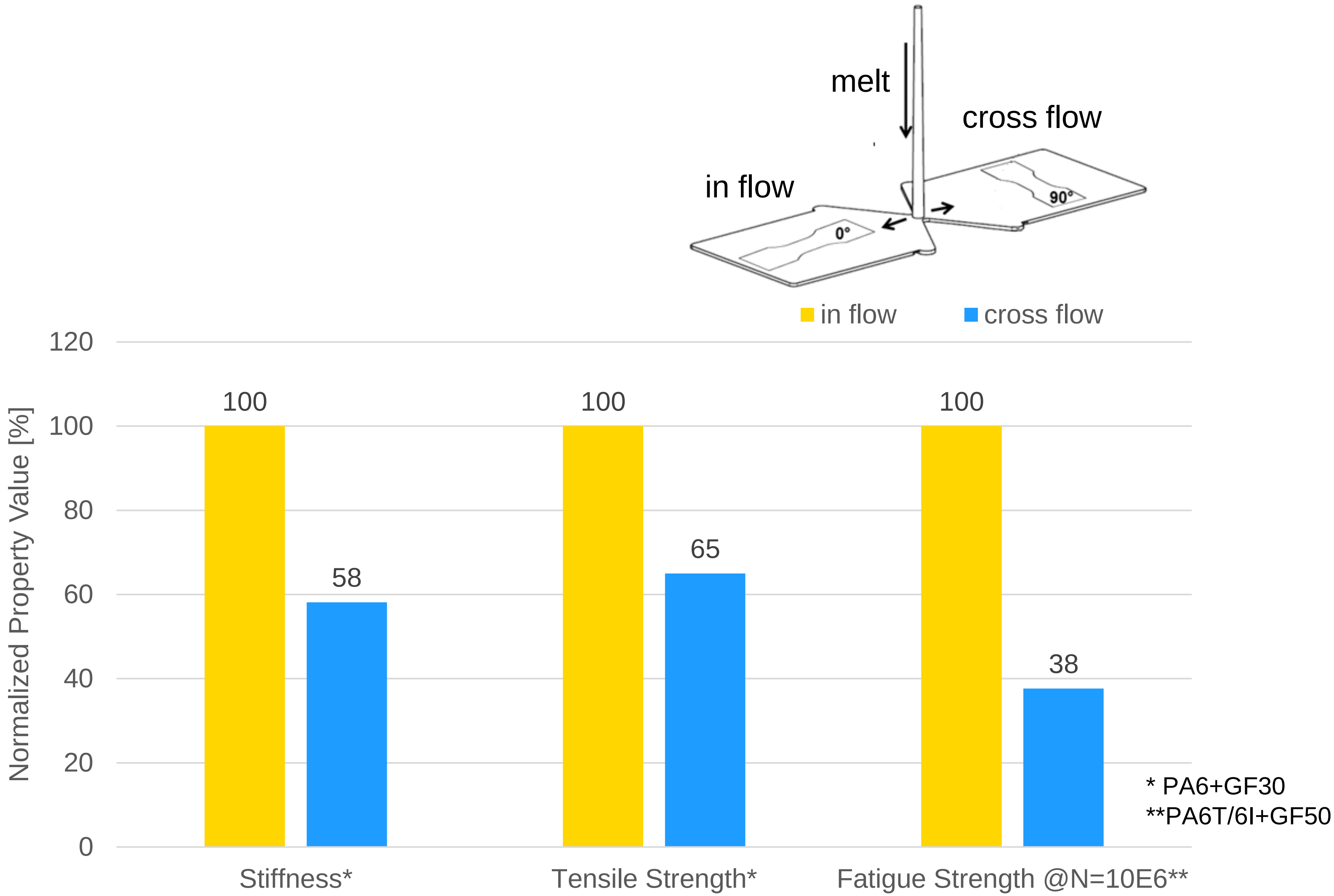

Fig. 3

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Needed Process Steps for FEM of SFR Plastics

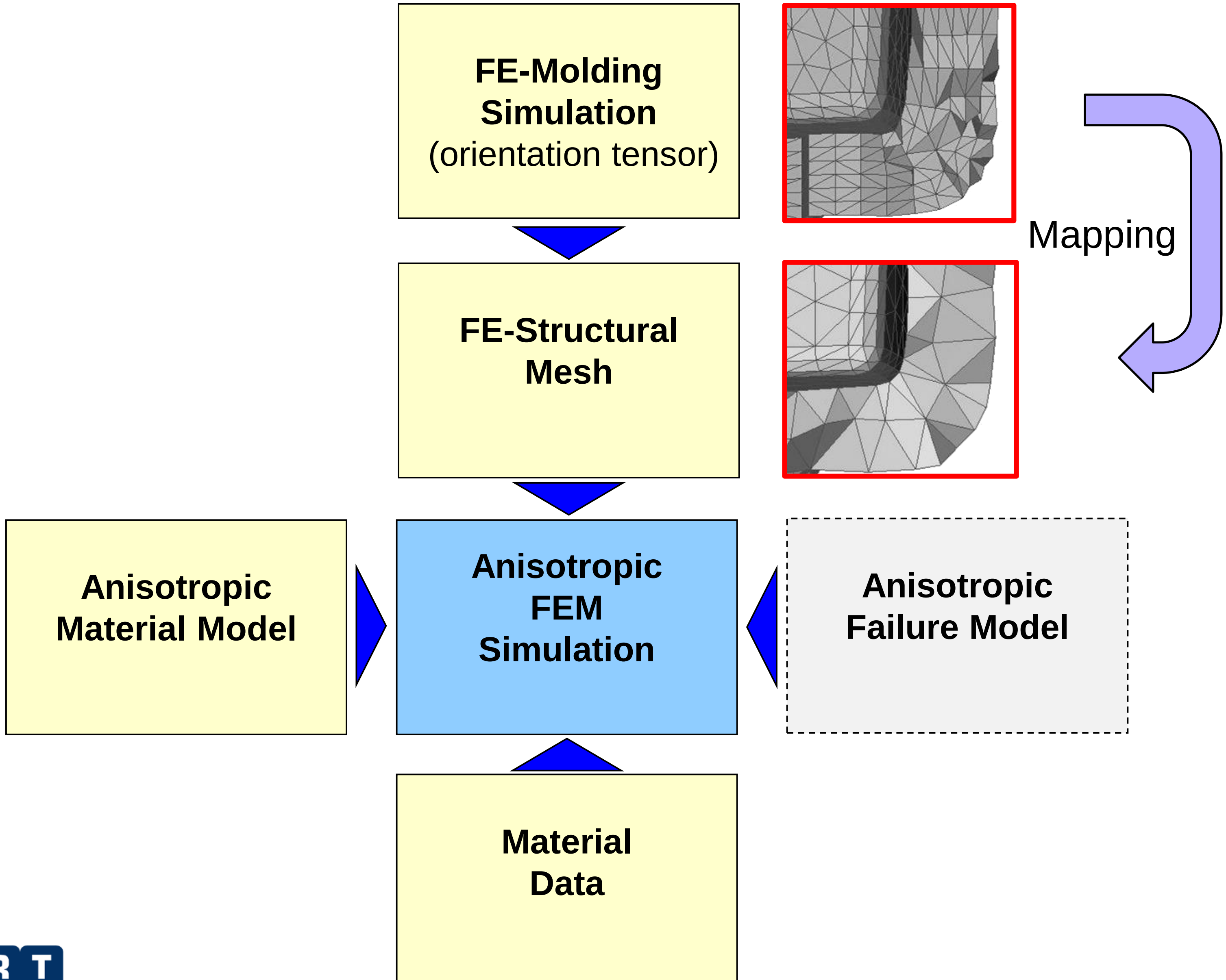
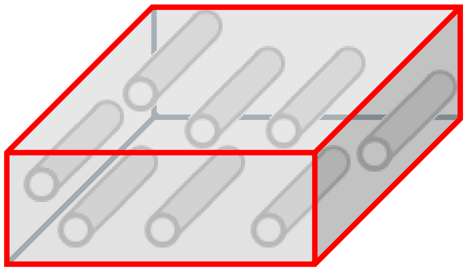
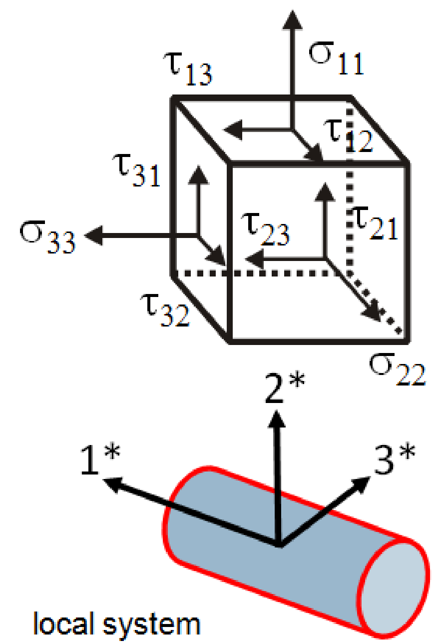


Fig.4

Approaches for Anisotropic Material Models



Macro-Approach
(works on the composite)



local system
(orthotropic system)

Orthotropic Material Model (linear elastic)

$$\begin{Bmatrix} \varepsilon_{11} \\ \varepsilon_{22} \\ \varepsilon_{33} \\ \gamma_{12} \\ \gamma_{13} \\ \gamma_{23} \end{Bmatrix} = \begin{bmatrix} 1/E_1 & -\nu_{21}/E_2 & -\nu_{31}/E_3 & 0 & 0 & 0 \\ -\nu_{12}/E_1 & 1/E_2 & -\nu_{32}/E_3 & 0 & 0 & 0 \\ -\nu_{13}/E_1 & -\nu_{23}/E_2 & 1/E_3 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1/G_{12} & 0 & 0 \\ 0 & 0 & 0 & 0 & 1/G_{13} & 0 \\ 0 & 0 & 0 & 0 & 0 & 1/G_{23} \end{bmatrix} \begin{Bmatrix} \sigma_{11} \\ \sigma_{22} \\ \sigma_{33} \\ \sigma_{12} \\ \sigma_{13} \\ \sigma_{23} \end{Bmatrix}.$$

needs **9** material properties:

- tensile modulii the 3 orthotropic axes E_1, E_2, E_3
- shear modulii the 3 orthotropic planes G_{12}, G_{13}, G_{23}
- Poisson ratios ν_{12}, ν_{13}, ν_{23}
- local fiber (element) coordinate system

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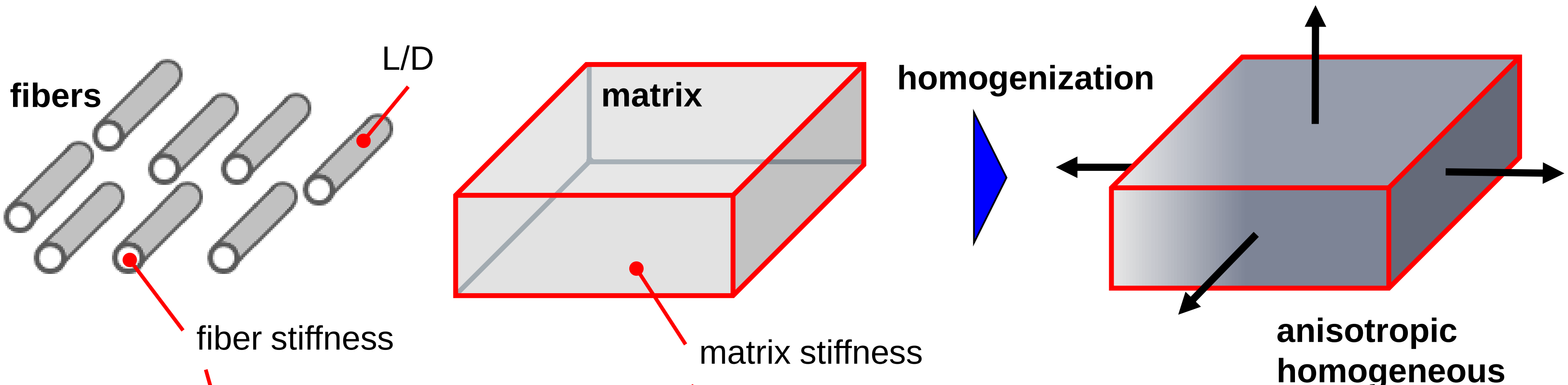
Approaches for Anisotropic Material Models

Micro Mechanics-Approach

(works on the constituents of the composite)



Mori-Tanaka (Eshelby) Model

$$\overline{\boldsymbol{c}}_{n+\alpha} = [v_1 \hat{\boldsymbol{c}}_{1_{(n+\alpha)}} : \boldsymbol{B}^{\epsilon} + (1-v_1)\hat{\boldsymbol{c}}_{0_{(n+\alpha)}}] : [v_1 \boldsymbol{B}^{\epsilon} + (1-v_1)\boldsymbol{I}]^{-1}$$

$$\mathbf{B}^{\epsilon} = \mathbf{H}^{\epsilon}(\mathrm{I}, \mathbf{c}_0, \mathbf{c}_1)$$

$$\mathbf{H}^{\epsilon}(\mathrm{I}, \mathbf{c}_0, \mathbf{c}_1) = \{\mathbf{I} + \mathfrak{E}(\mathrm{I}, \mathbf{c}_0) : [(\mathbf{c}_0)^{-1} : \mathbf{c}_1 - \mathbf{I}]\}^{-1}$$

needs material properties of the constituents of the composite:

- tensile modulii of fiber and matrix
- aspect ration L/D
- local fiber (element) coordinate system

Fig. 6

Approaches for Anisotropic Material Models

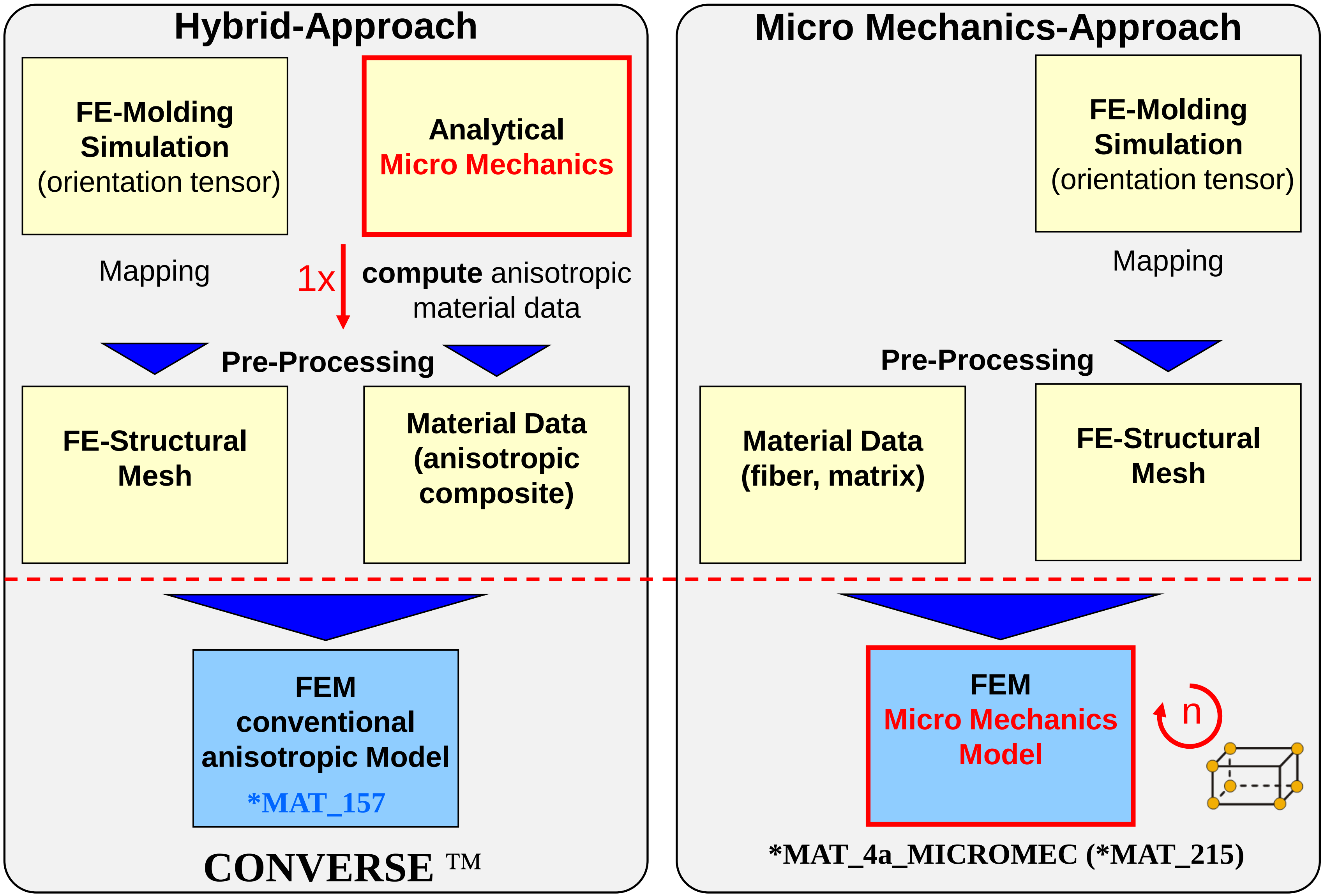


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Fig.7

Anisotropic Elastic Plastic Material Model in Dyna *MAT_157

Hill 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

syntax template:

*ELEMENT_SOLID_ORTHO
local coord. systems (element-wise)

*MAT_ANISOTROPIC_ELASTIC_PLASTIC (*MAT_157)
anisotropic stiffnesses (entry of elastic stiffness tensor)
anisotropic constants (Hill coefficients F, G, H, L, M, N)
id of reference stress-strain curve (plastic yield curve)

*DEFINE_CURVE
reference stress-strain curve (plastic yield curve)

*INITIAL_STRESS_SOLID
element-wise overwriting of material parameters accord. to local orientation tensor

*MAT_ADD_EROSION

Anisotropic Elastic Plastic Material Model in Dyna *MAT_157

Hill 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

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

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

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

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

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

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

yield ratios:

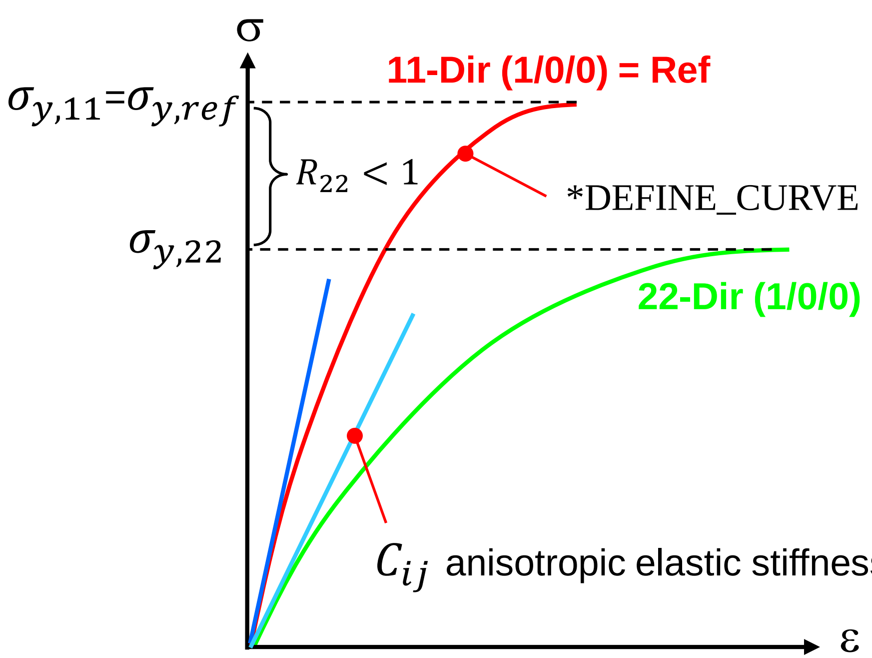
$$R_{11} = \frac{\sigma_{y,11}}{\sigma_{y,ref}}$$

$$R_{22} = \frac{\sigma_{y,22}}{\sigma_{y,ref}}$$

$$R_{33} = \frac{\sigma_{y,33}}{\sigma_{y,ref}}$$

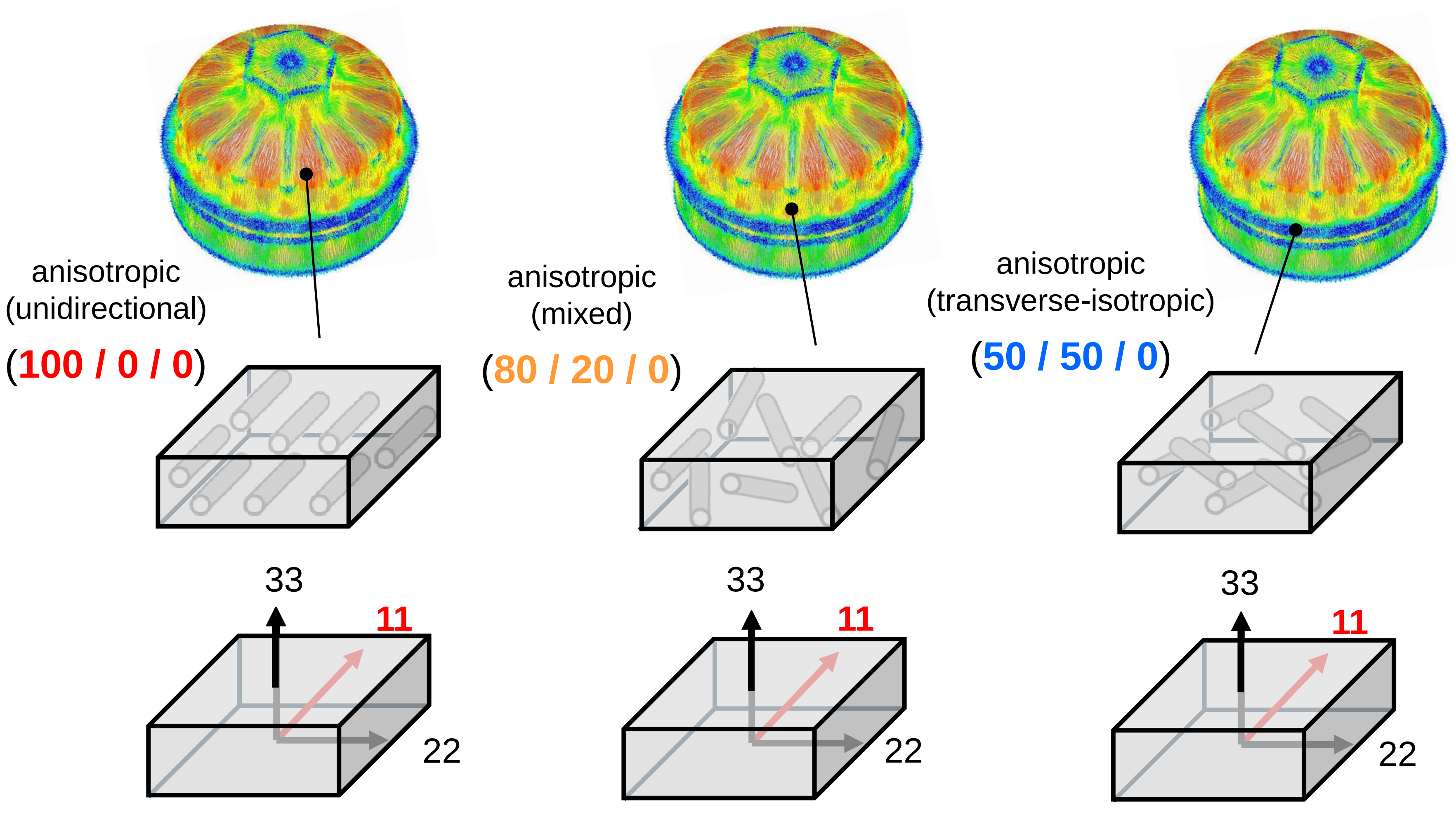
etc. ….

Example:



11-Dir: fiber axis direction

Orientation Distribution Function in SFR components



Example: Different orientation distribution, but same principal fiber direction.

Dependency of Material Properties on the Orientation Distribution

anisotropic
(unidirectional)

(100 / 0 / 0)

anisotropic
(mixed)

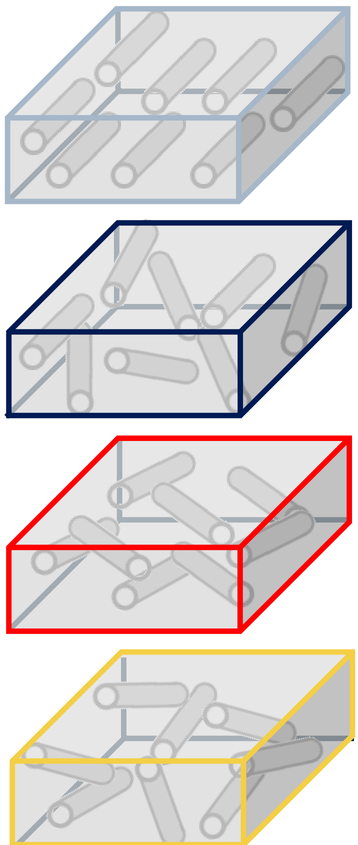
(80 / 20 / 0)

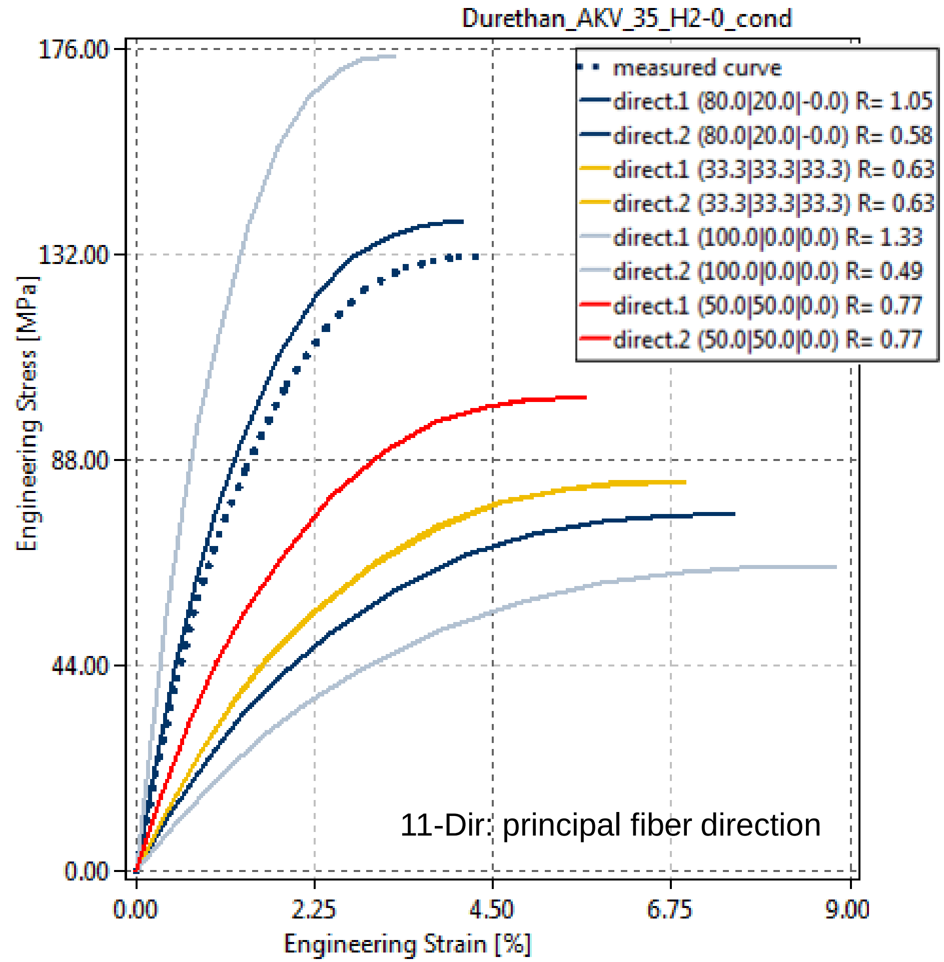
anisotropic
(transverse-isotropic)

(50 / 50 / 0)

anisotropic
(quasi-isotropic)

(33 / 33 / 33)





Required: ODF dependent material properties

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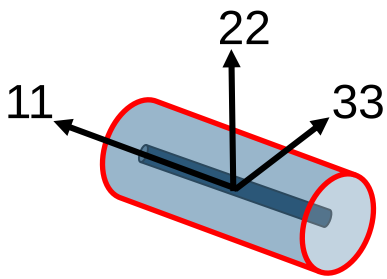
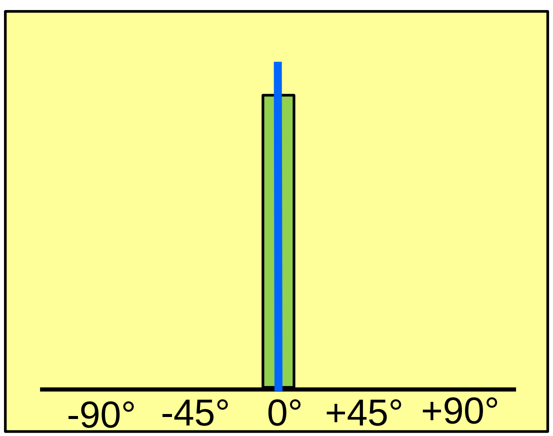
Consideration of ODF by Orientation Averaging

Micro-Mechanical Model (Mori-Tanaka)

ideal behavior in the micro-mechanical model of a **unidirectional** representative volume element





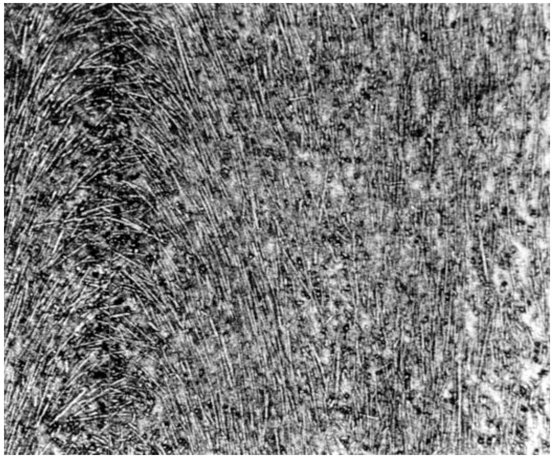
orientation tensor
general case

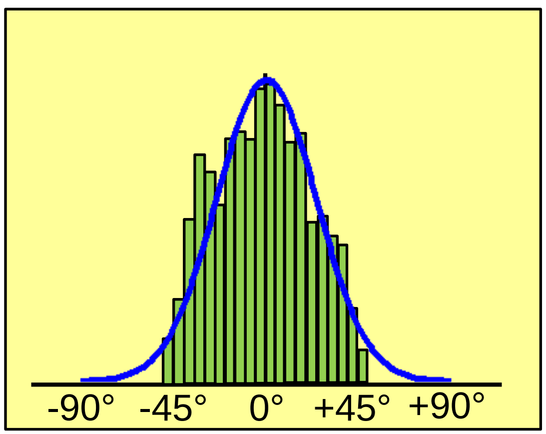
$$\begin{pmatrix} a_{11} & a_{12} & a_{13} \\ . & a_{22} & a_{23} \\ . & . & a_{33} \end{pmatrix}$$

weighted averaging of mechanical properties

Fiber Orientation Distribution

real behavior in injection molded part





ODF-Dependent Hill Yield Criterion

Hill Yield Criterion:

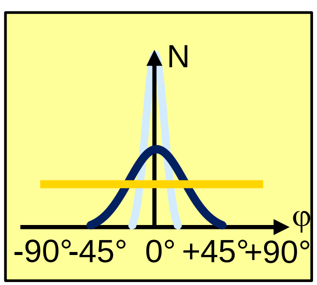
$$\sigma_{eq} = \sqrt{F(\sigma_{22}-\sigma_{33})^2 + G(\sigma_{33}-\sigma_{11})^2 + H(\sigma_{11}-\sigma_{22})^2 + 2L\sigma_{23}^2 + 2M\sigma_{31}^2 + 2N\sigma_{12}^2}$$

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

Hill coefficients F, G, H, L, M, N = f(ODF)

as well as elastic stiffnesses $C_{i,j}$ = f(ODF)

ODF



elasto-plastic stress-strain curves are **computed**

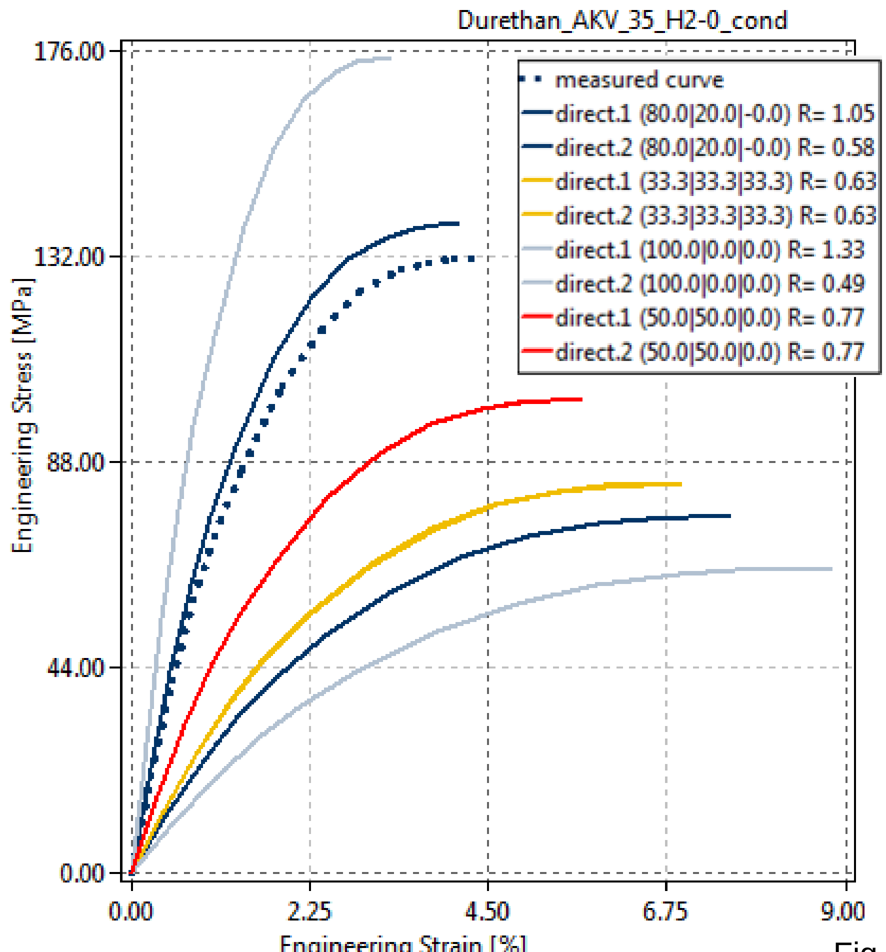
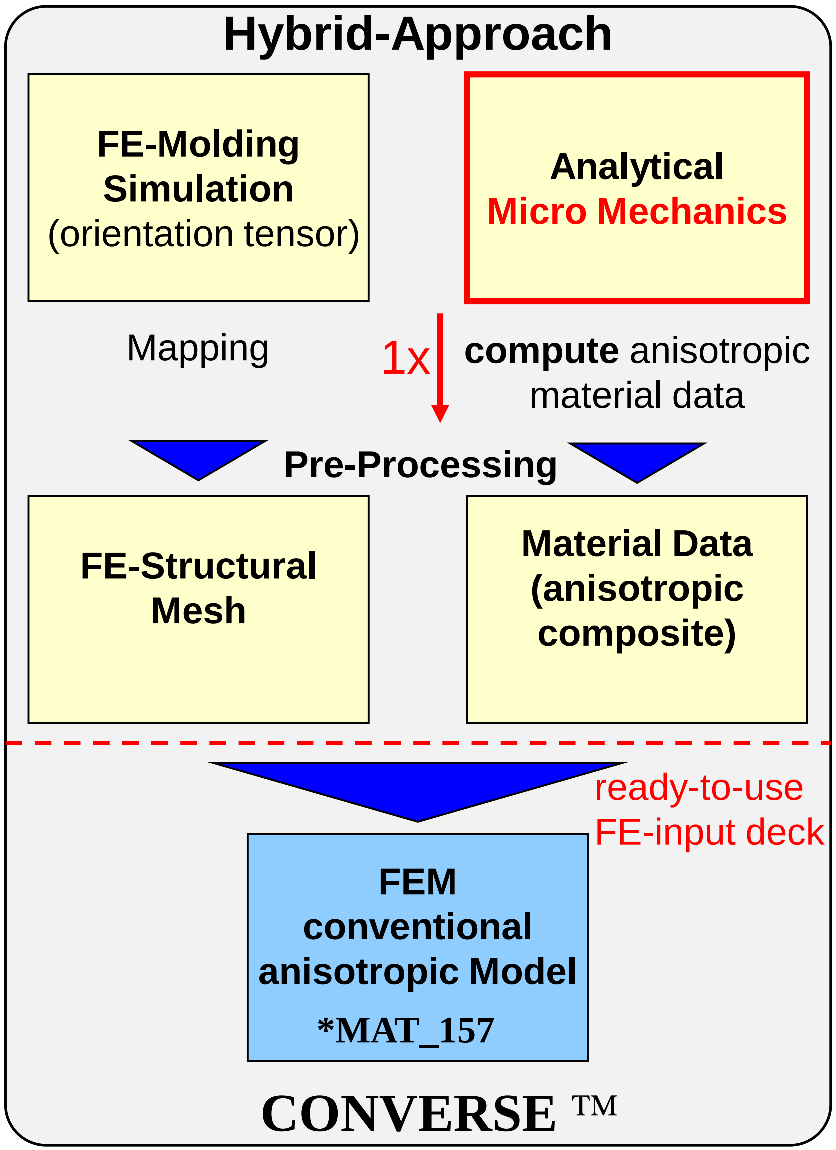


Fig. 13

Implementation of Approach in LS-Dyna



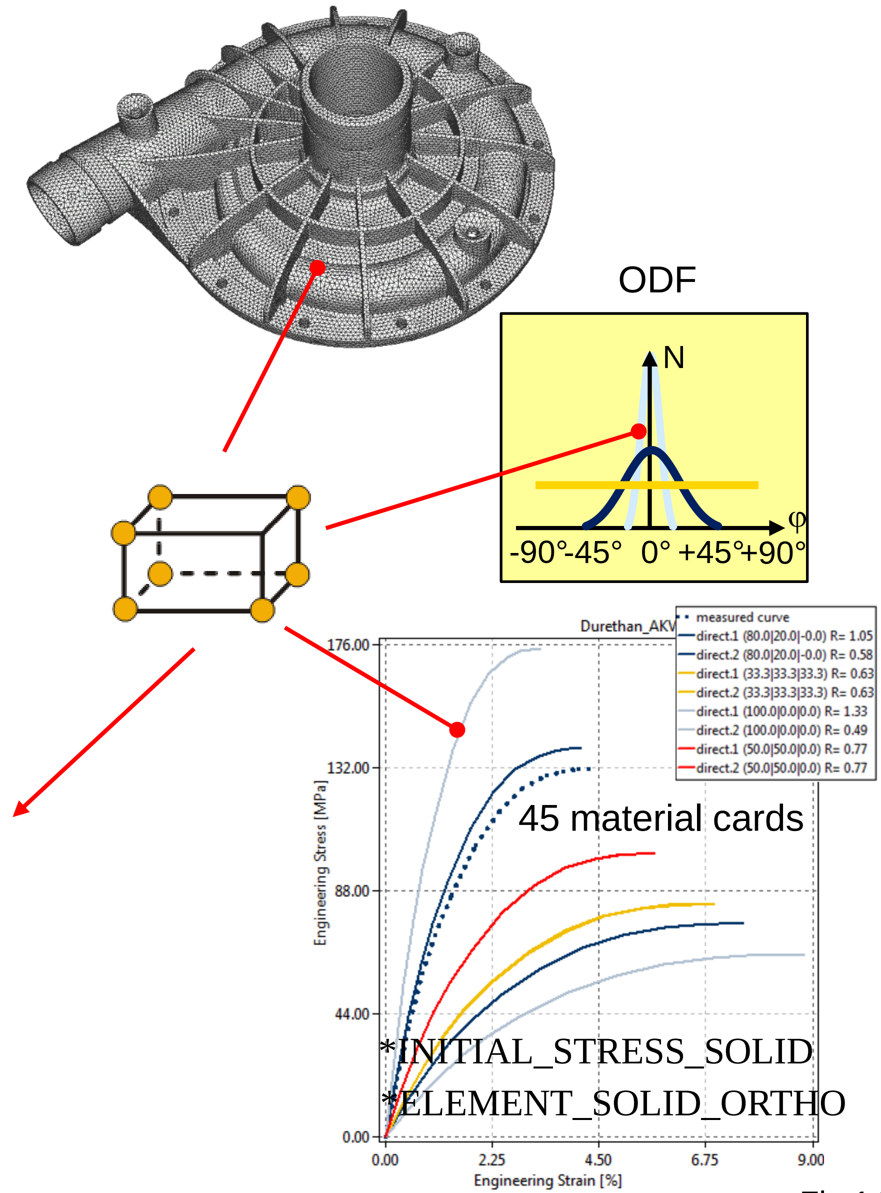


Fig.14

Validation of Approach with Numerical RVE (Unidirectional)

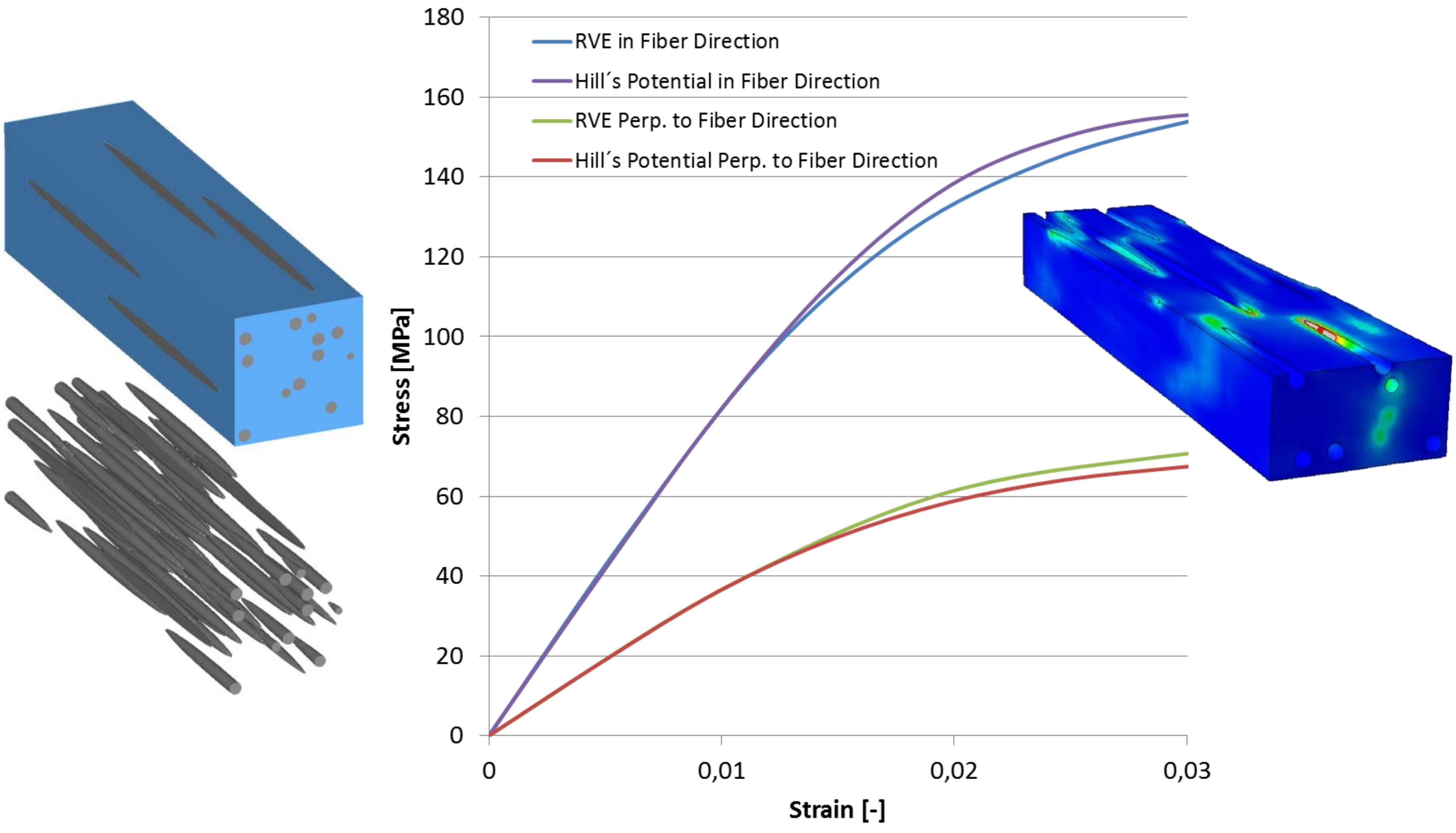


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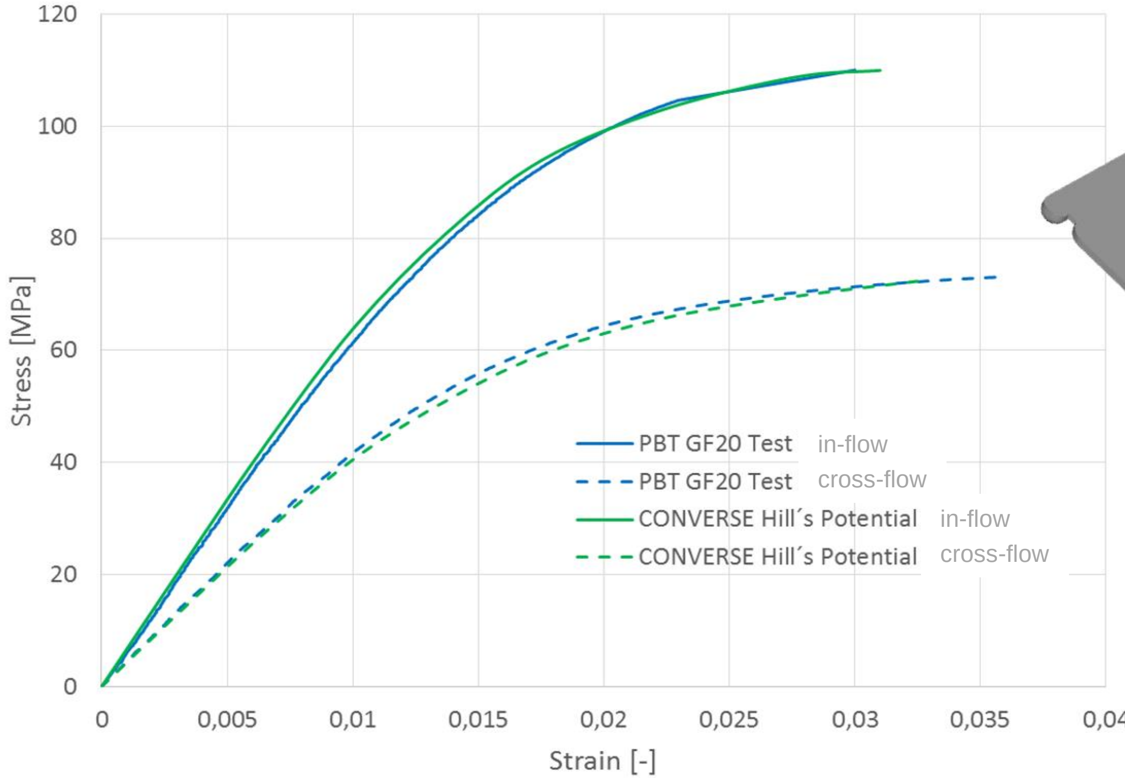
Fig. 15

Validation of Approach with Tests



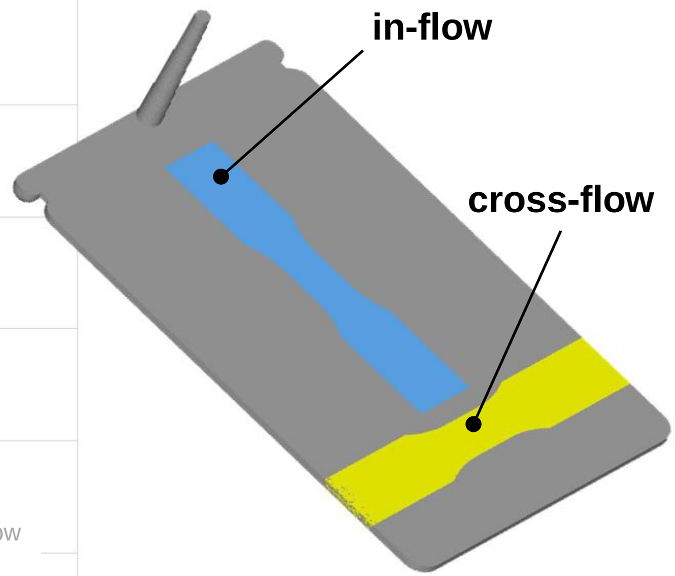


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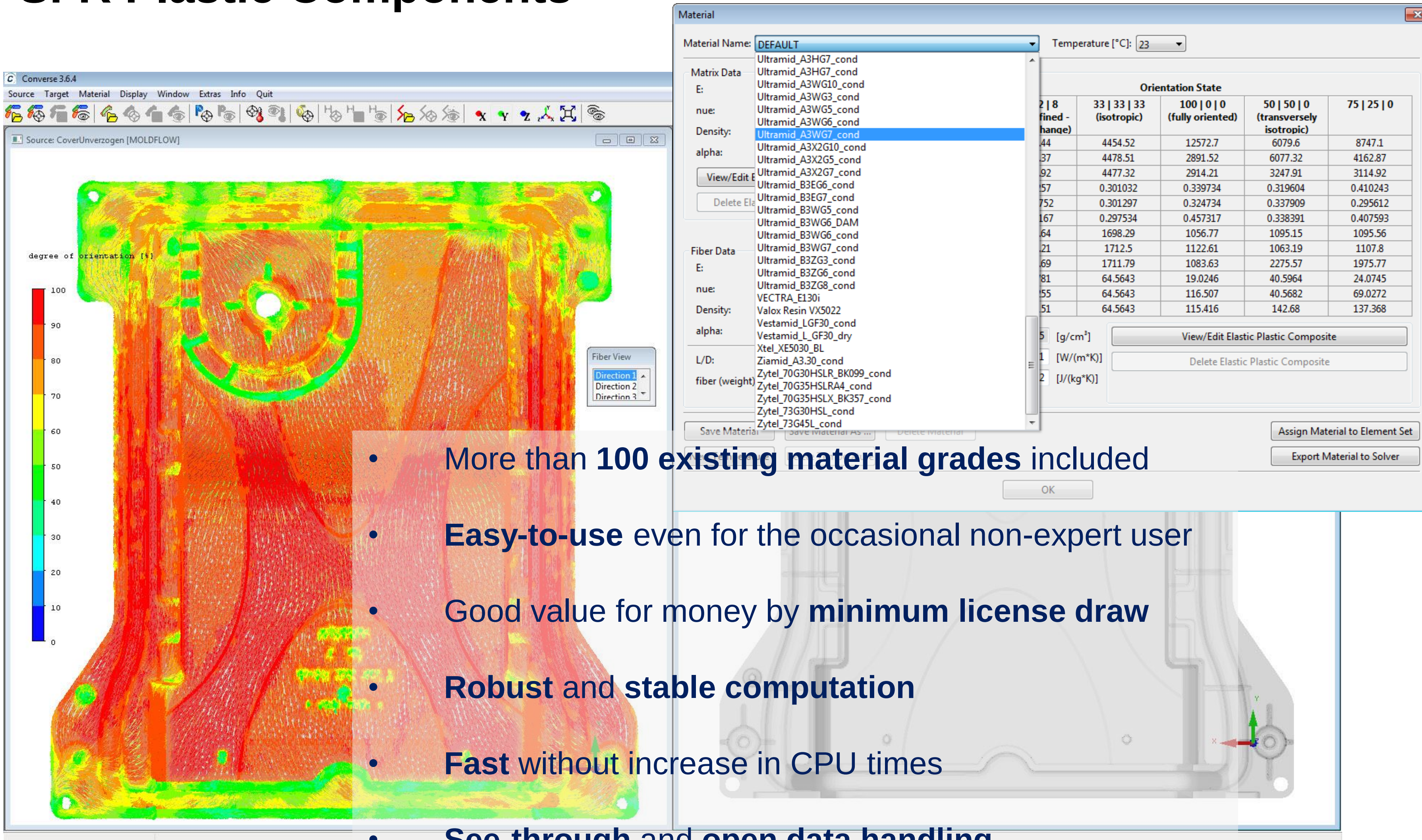
Fig. 16

Converse – Easy-to-use Software for FEM-Simulation of SFR Plastic Components



- More than **100 existing material grades** included
- **Easy-to-use** even for the occasional non-expert user
- Good value for money by **minimum license draw**
- **Robust** and **stable computation**
- **Fast** without increase in CPU times
- **See-through** and **open data handling**
- **Seamless integration** into CAE process chain

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Fig. 17

Converse - Integrated Software Solution for FEM-Simulation of SFR Plastic Components

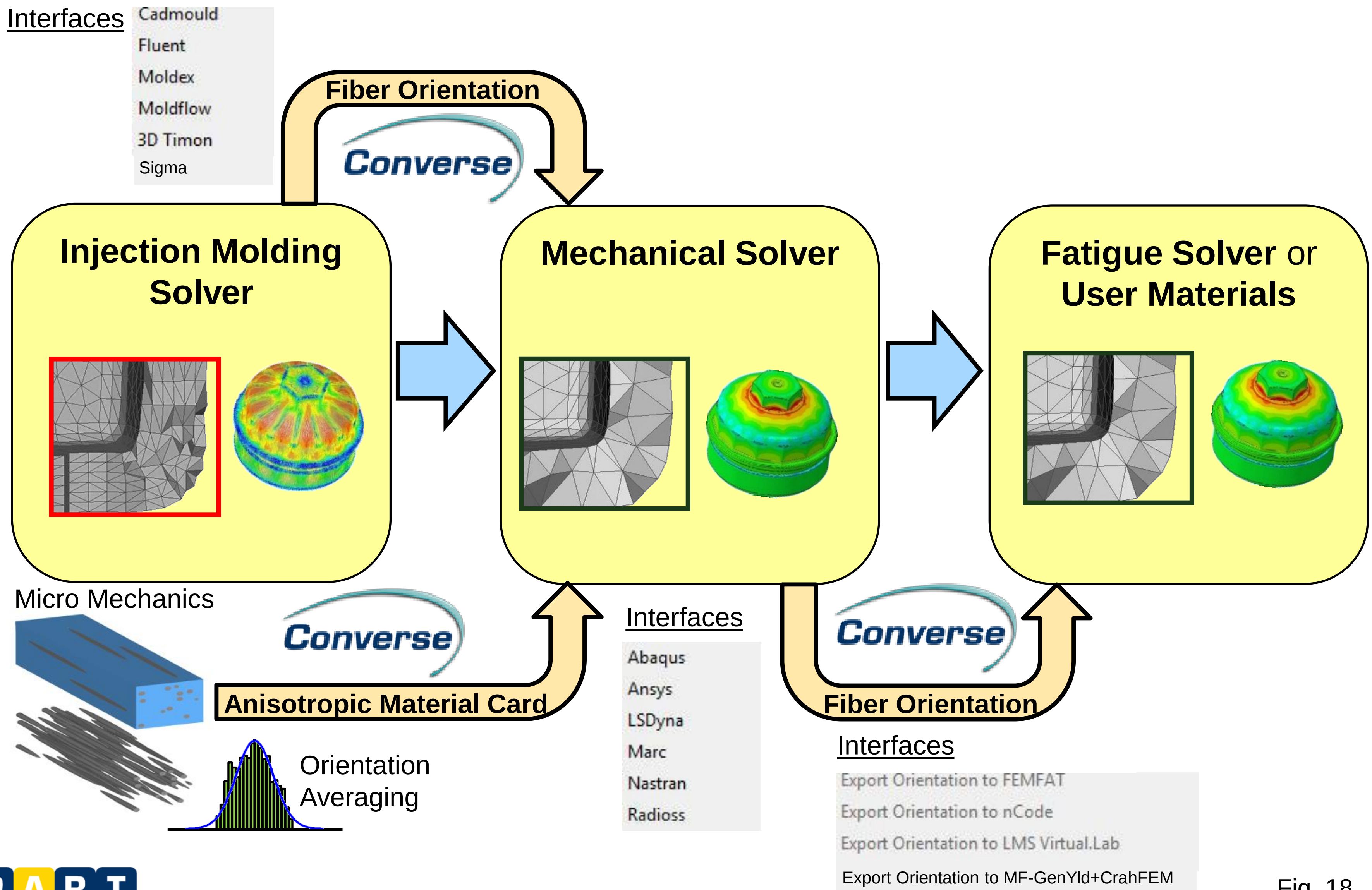

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Fig. 18

Danksagung

Teile der in dieser Präsentation dargestellten Untersuchungen und Softwareprodukte wurden mit Mitteln des Bundesministeriums für Wirtschaft und Technologie gefördert.

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