4a Summer School
Material card generation: Fiber reinforced plastics and their modelling approach: an extensive guide

P. Reithofer, H. Pothukuchi
Traboch, 16.07.2020

4a Summer School

2^{nd} week - Advanced topics

14. July - Evaluating and checking test data
interpretation of typical results

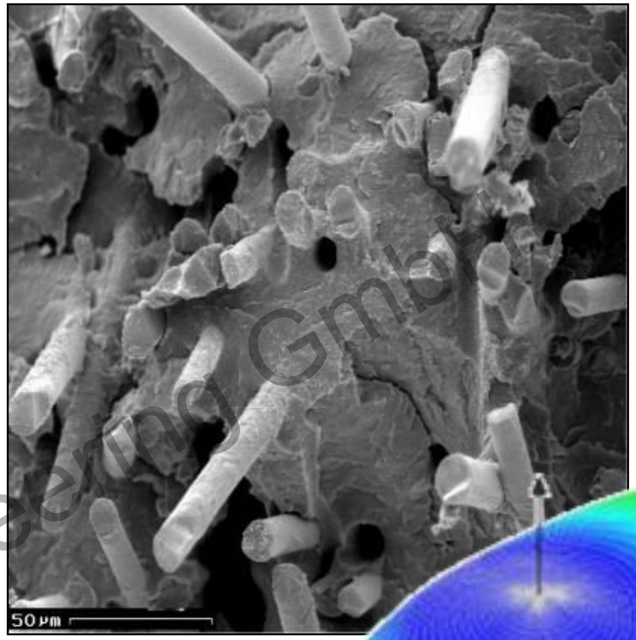
15. July - general yield surface (*MAT_187) and other material models,
failure approaches and comprehensive Autofit setup

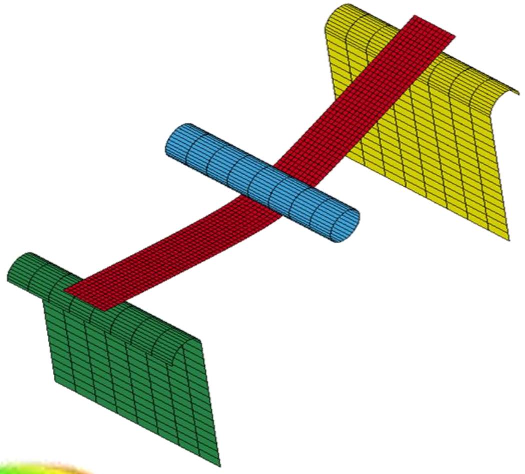
16. July - Fiber reinforced plastics and their modelling approach
an extensive guide

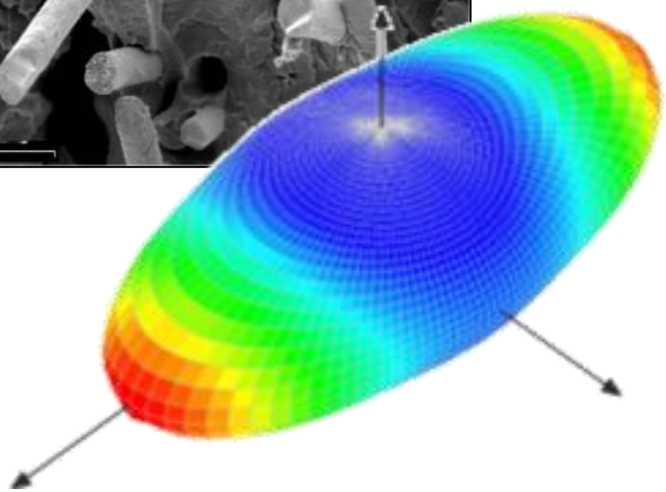
17. July - Python: a powerful tool with VALIMAT®,
user defined material cards/specimen

Content

- Recap DAY 6
- Introduction MICROMEC®
- Material model in LS DYNA
- Motivation
- Material model approaches
- Manufacturing influence
- Material characterization
- Casestudy - sleeve



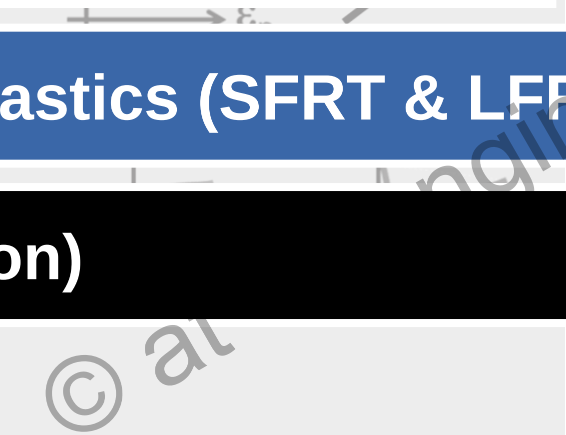




intelligent reliable solutions for plastics, composites, metals, foams, ...

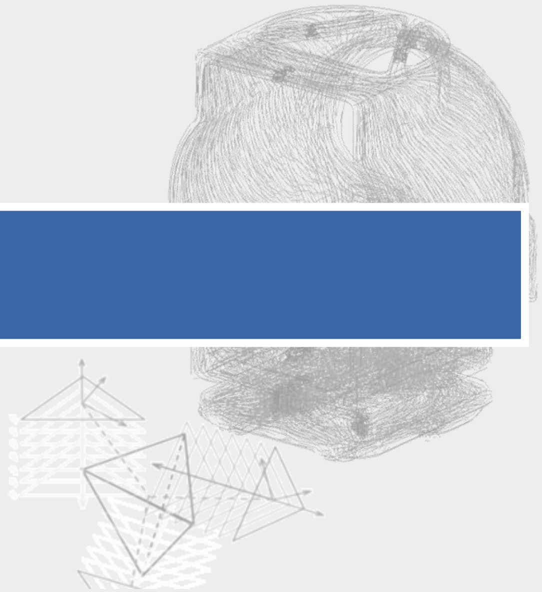
IMPETUS

VALIMAT



MICROMEC

FIBERMAP



Thermoplastics

Fiber reinforced Plastics (SFRT & LFRT)

Composites (Carbon)

efficient
dynamic testing

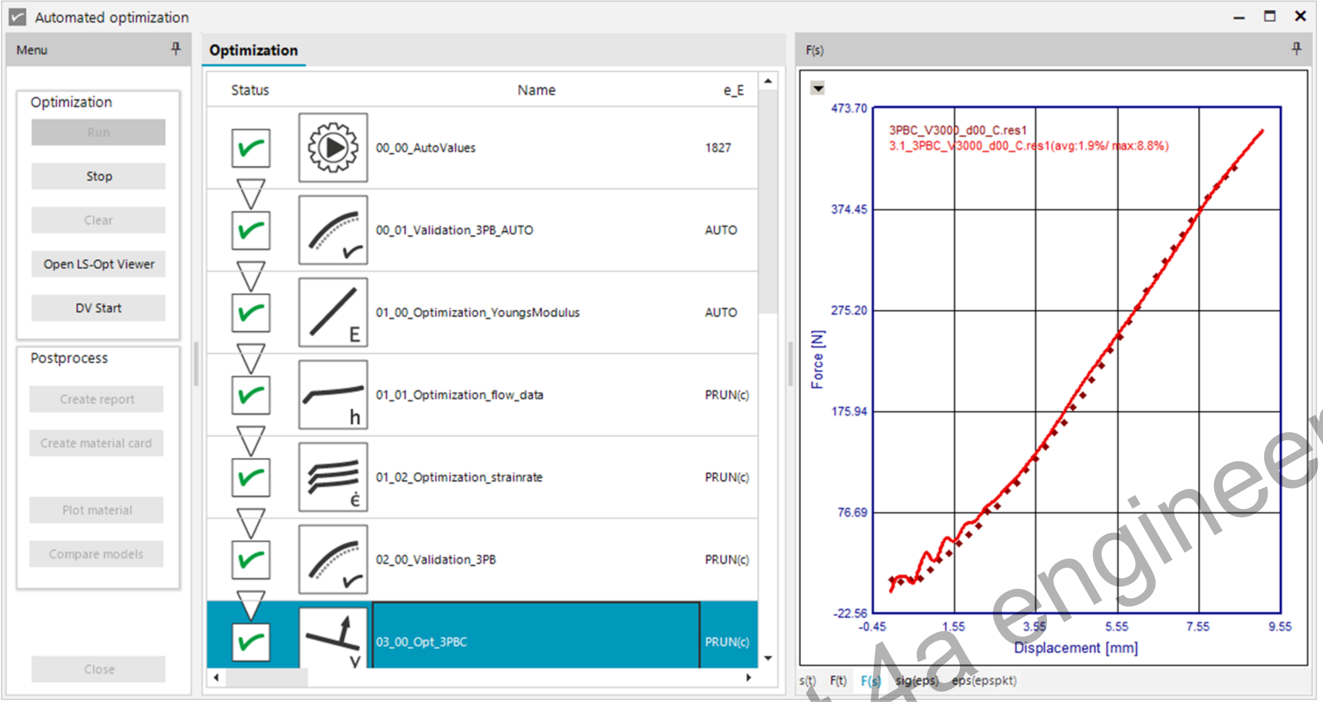
from test to validated
material cards

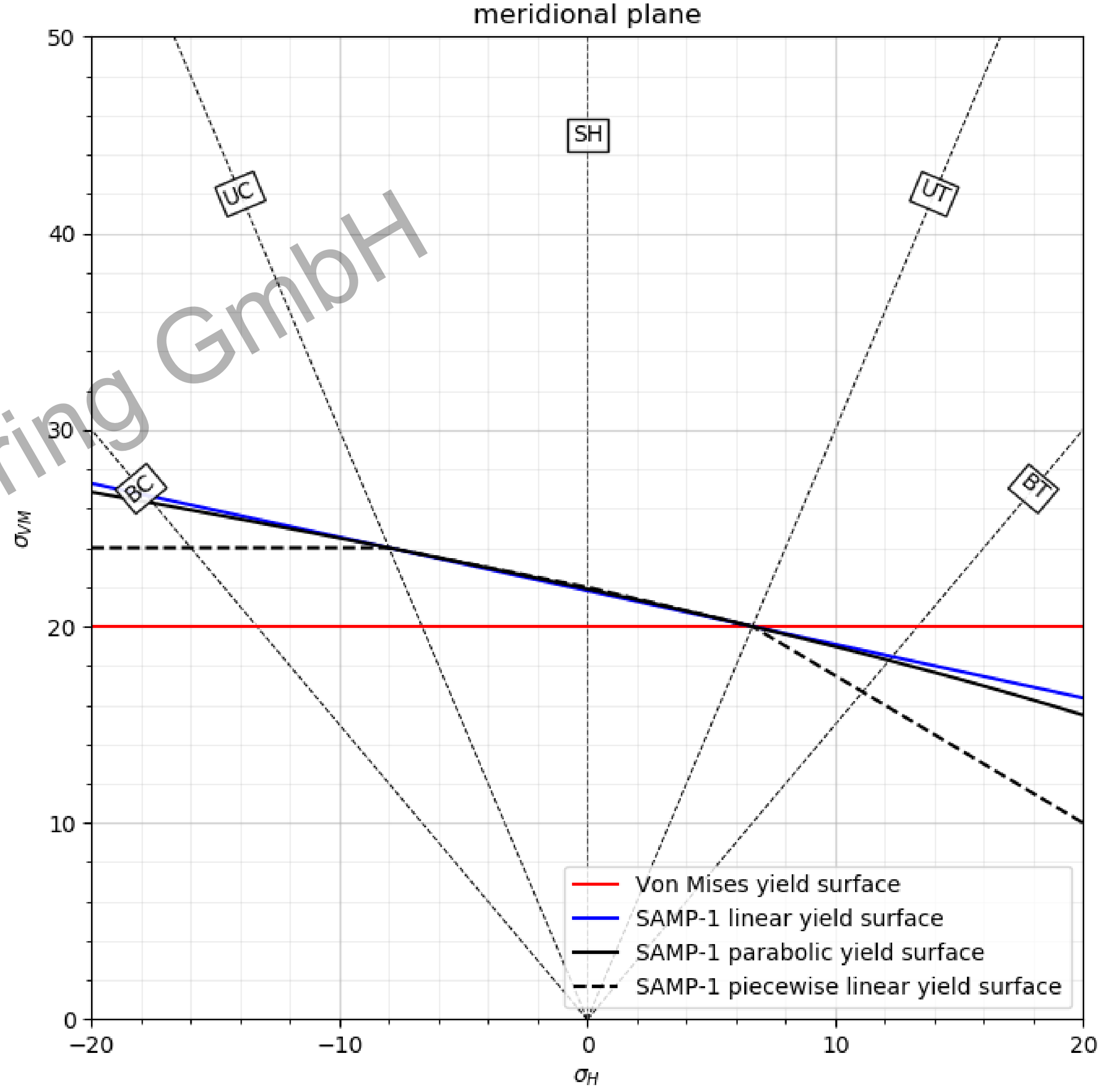
3D anisotropic
material cards

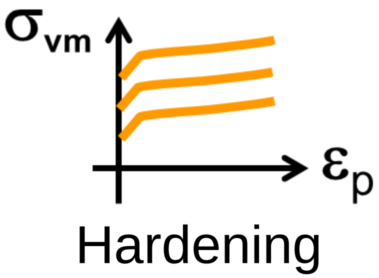
individual mapping
process information

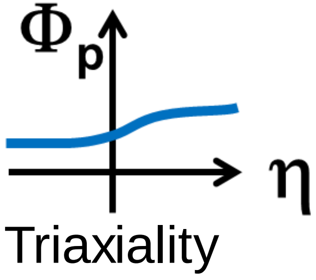
Workflow for Material Card Generation - AUTOFIT

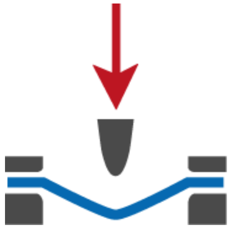
VALIMAT





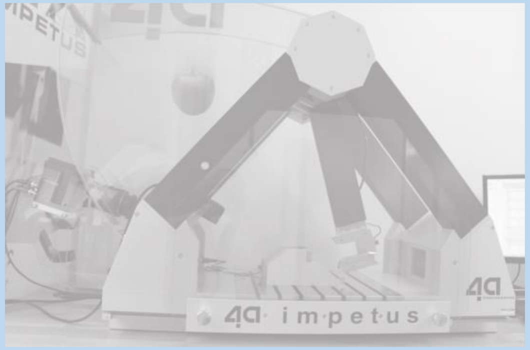






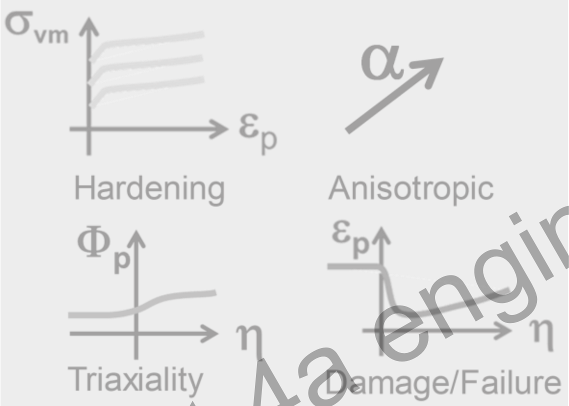
intelligent reliable solutions for plastics, composites, metals, foams, ...

IMPETUS



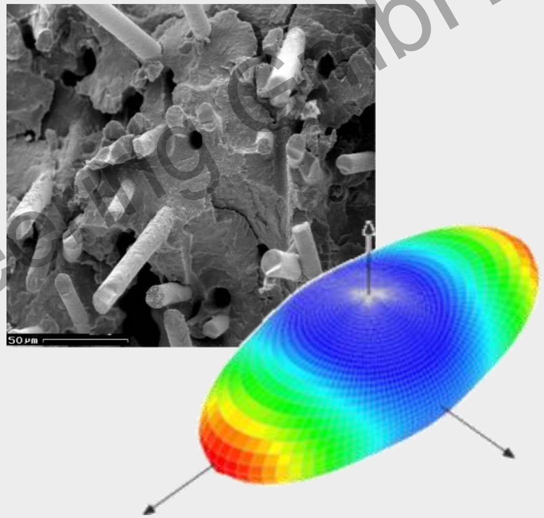
efficient
dynamic testing

VALIMAT



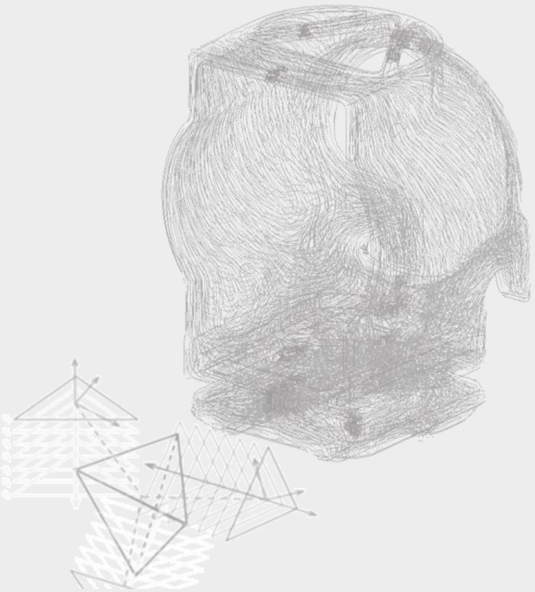
from test to validated
material cards

MICROMEC



3D anisotropic
material cards

FIBERMAP

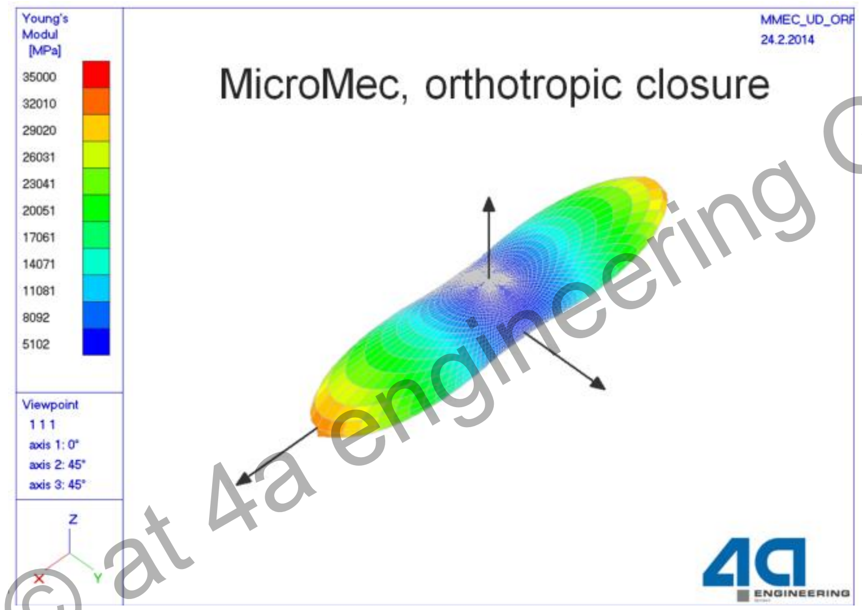


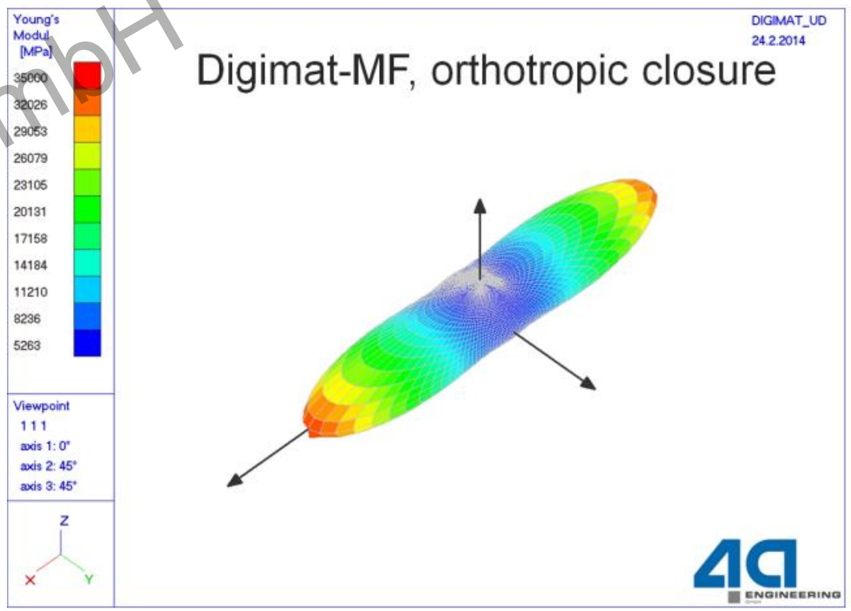
individual mapping
process information

Material models – micro mechanical motivated

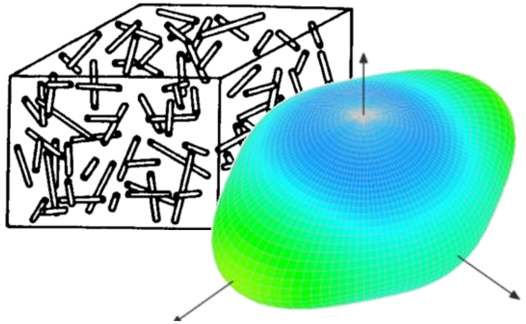
MICROMEC

Standalone product





Comparison by University of Leoben [Bodor2014]



$$\overline{\sigma}^{C} = \varphi \overline{\sigma}^{F} + (1-\varphi)\overline{\sigma}^{M}$$

C...composite, F...fiber, M...matrix

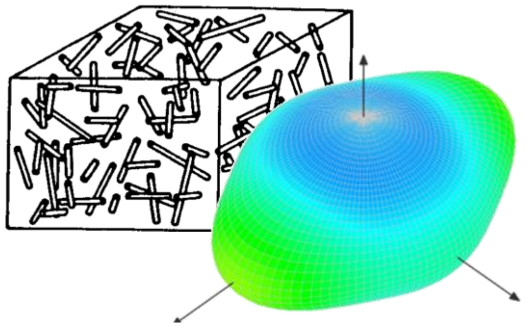
Material models – micro mechanical motivated

MICROMEC

Standalone product

Library → VALIMAT®

calculate parameter for constitutive law → ***MAT_157**



$$\overline{\sigma}^{C} = \varphi\overline{\sigma}^{F} + (1-\varphi)\overline{\sigma}^{M}$$

C...composite, F...fiber, M...matrix

160223_006 | Material | Designvariablen | Layers

VALIMAT

Strain rate dependency	Table
Strain rate dependency	Johnson Cook
Micromec	User defined
Matrix	
Density of the matrix	900
E-Modulus	1500
Poisson's ratio	0.3
Yield strength	15
Strength at Break	17
Failure strain	0.05
Fiber	
Fillerlength	1000
Fillerdiameter	20
Phi or Psi	φ
Phi	12.9
Psi	30.1
Fillermaterial	E-Glas
Orientation	
Fillerorientationtype	CA lin. OF
Fillerorientationvalue 1	0.6
Fillerorientationvalue 2	0.33

Composite Density	1126	[g/dm³]
c_C11	6172	[MPa]
c_C12	1808	[MPa]
c_C13	1231	[MPa]
c_C14	0	[MPa]
c_C15	0	[MPa]
c_C16	0	[MPa]
c_C22	4135	[MPa]
c_C23	1181	[MPa]
c_C24	0	[MPa]
c_C25	0	[MPa]
c_C26	0	[MPa]
c_C33	2616	[MPa]
c_C34	0	[MPa]
c_C35	0	[MPa]
c_C36	0	[MPa]
c_C44	1554	[MPa]
c_C45	0	[MPa]
c_C46	0	[MPa]
c_C55	888.6	[MPa]
c_C56	0	[MPa]
c_C66	957.5	[MPa]
y_r00	1	[1]
y_r45	0.5105	[1]
y_r90	0.2665	[1]
y_scalematrix0	3.076	[1]

Material models – micro mechanical motivated

MICROMEC

- Standalone product
- Library → VALIMAT®
- usermaterial

$$\Delta\varepsilon^C \Rightarrow \Delta\varepsilon^M, \left(\Delta\varepsilon^F\right)$$

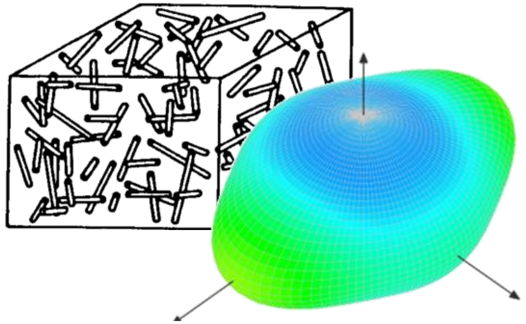
$$\Delta\varepsilon^M = \frac{1}{\varphi\overline{B}_i + (1-\varphi)I}\Delta\varepsilon^C$$

$$\Delta\varepsilon^M \Rightarrow E_M^T, \Delta\varepsilon^M{}_{pl}, \Delta\sigma^M$$

$$\overline{B}_{i+1} = f\left(fo^{(4)}, E_M^T, {}^{l}\!/\!_{d}\right)$$

$$\overline{A} = S^F\,\overline{B}_{i+1} C^M$$

$$\Delta\sigma^C = \left[\varphi\overline{A} + (1-\varphi)I\right]\Delta\sigma^M$$



$$\overline{\sigma}^C = \varphi\overline{\sigma}^F + (1-\varphi)\overline{\sigma}^M$$

C...composite, F...fiber, M...matrix

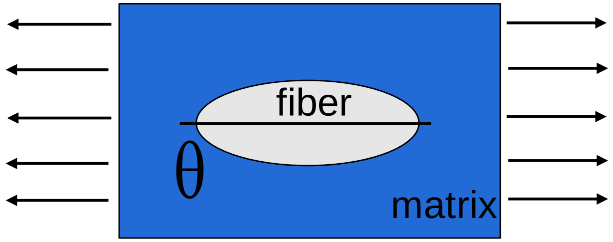
Main Framework
Mori Tanaka Mean Field Theory

Composite stresses, strains (i)
↓
Matrix stresses, strains → Yield condition
↓
Fiber stresses, strains
↓
Failure, Damage Criteria
↓
Composite stresses, strains (i+1)

plug able
possible extensions
other plasticity formulations, ...

→ J2 Plasticity
Isotropic Harding

Table Lookup or Parameter Setup



assumption elliptical inclusion (Eshelby Tensor)

Material models – micro mechanical motivated

MICROMEC

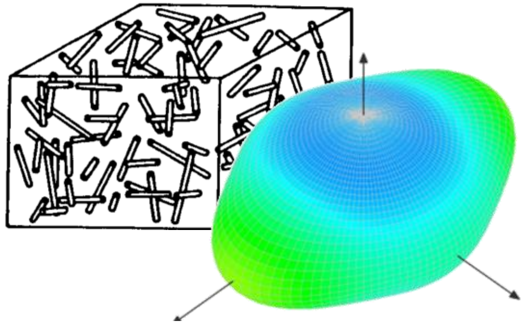
Standalone product

Library → VALIMAT®

usermaterial

*MAT_4A_MICROMEC

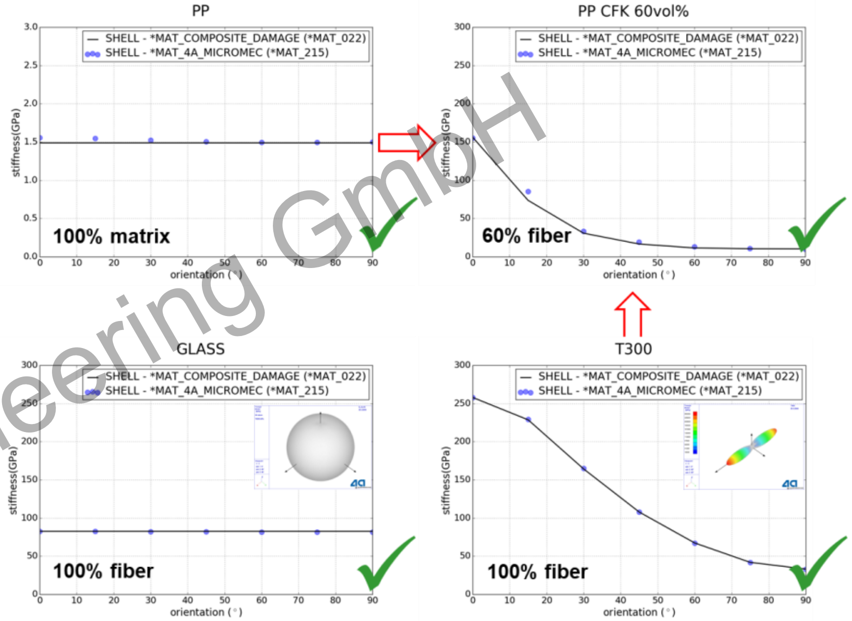
→ LS-DYNA R10

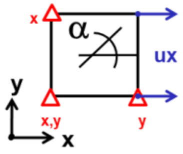


$$\overline{\sigma}^{C} = \varphi\overline{\sigma}^{F} + (1-\varphi)\overline{\sigma}^{M}$$

C...composite, F...fiber, M...matrix

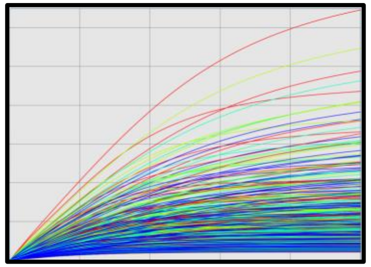
Verifications





Robustness

DOE - RUNS
without an error



material models in LS DYNA – overview composites

No.	Elastic	Plastic	Damage	Strain rate	Failure	
2	**Ortho / Anisotropic**	**None**	**None**	**None**	***MAT_ADD_EROSION**	**SFRT / LFRT**
24	Isotropic	Mises	None	Plasticity	*MAT_ADD_EROSION	
103	Isotropic	Hill	None	Plasticity	*MAT_ADD_EROSION	
108	Orthotropic	Hill	None	None	*MAT_ADD_EROSION	
157	**Anisotropic**	**Hill**	**None**	**Plasticity**	***MAT_ADD_EROSION**	
215	***MAT_4a_micromec in development: Model based on MORI TANAKA MEANFIELD**					
22	Orthotropic	None	None	None	Orientation dependent	**Carbon, Glass, Kevlar endless & fabric**
54/55	Orthotropic	None	Elastic Orthotropic	Strength	Chang-Chang/ Tsai-Wu Orientation dependent	
58	Orthotropic	None	Elastic Orthotropic	Strength, Stiffness	mod. Hashin Orientation dependent	
158	Orthotropic	None	Elastic Orthotropic	Visco-elasticity	Orientation dependent	
261	Orthotropic	None	Elastic Orthotropic	None	failure Pinho (Puck) Orientation dependent	
262	Orthotropic	None	Elastic Orthotropic	None	failure Camanho (Puck) Orientation dependent	

Intelligent reliable solutions for plastics, composites, metals, foams, ...

Fiber reinforced Plastics (SFRT & LFRT)

IMPETUS

efficient
dynamic testing

VALIMAT

from test to validated
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3D anisotropic
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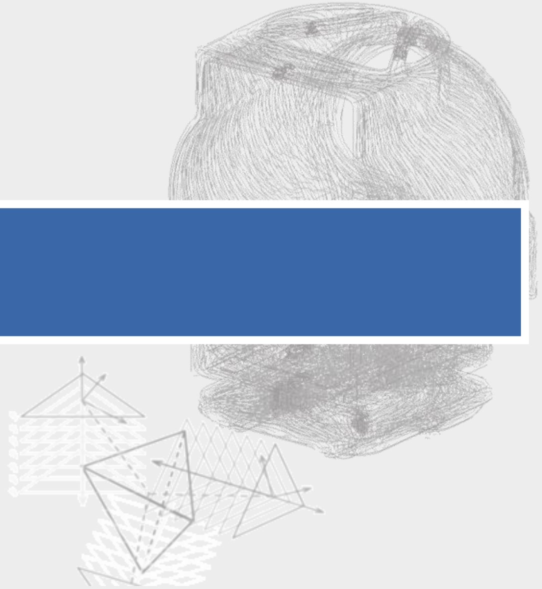
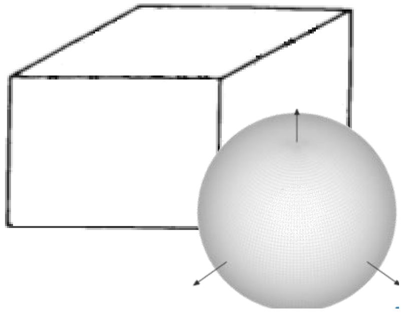
FIBERMAP



individual mapping
process information

Motivation – current simulation standard

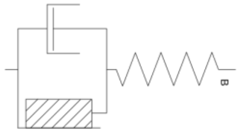
*MAT_024



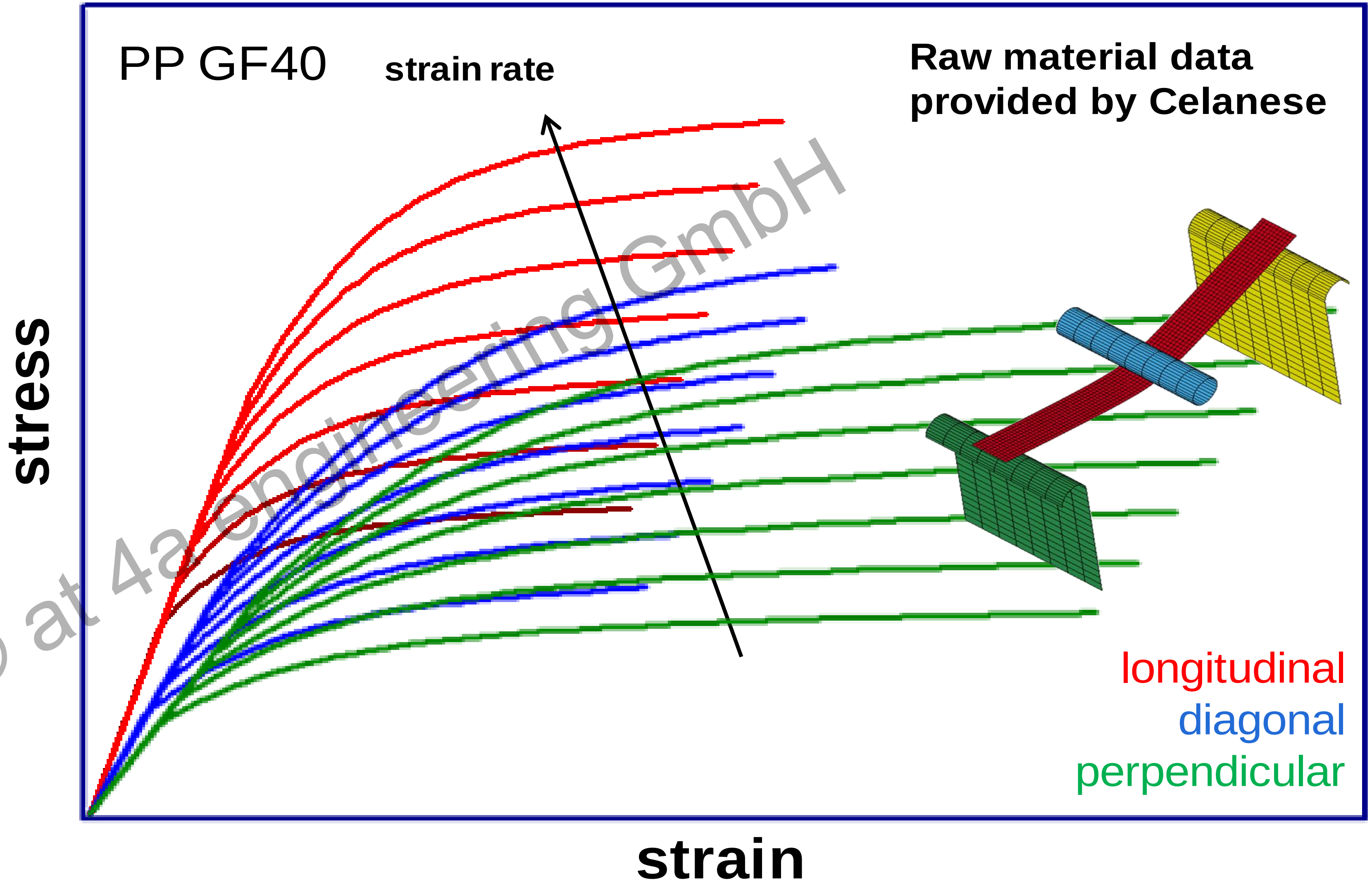
macro scale constitutive law

Mises plasticity

- quick & dirty

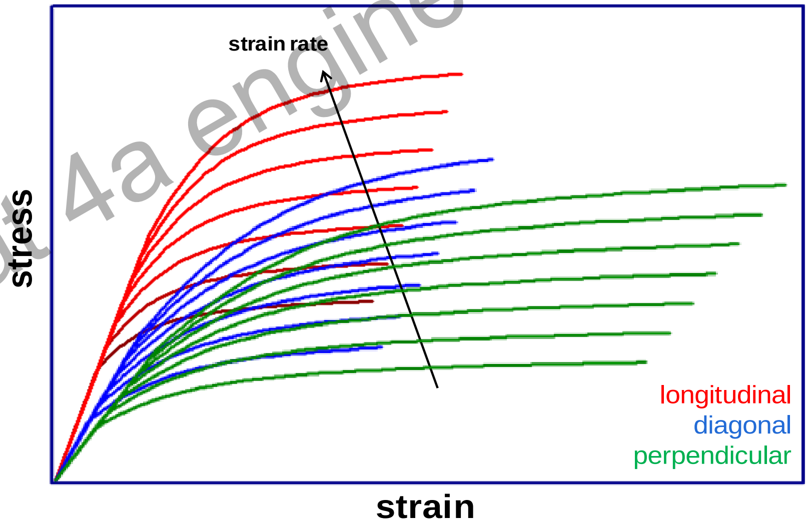


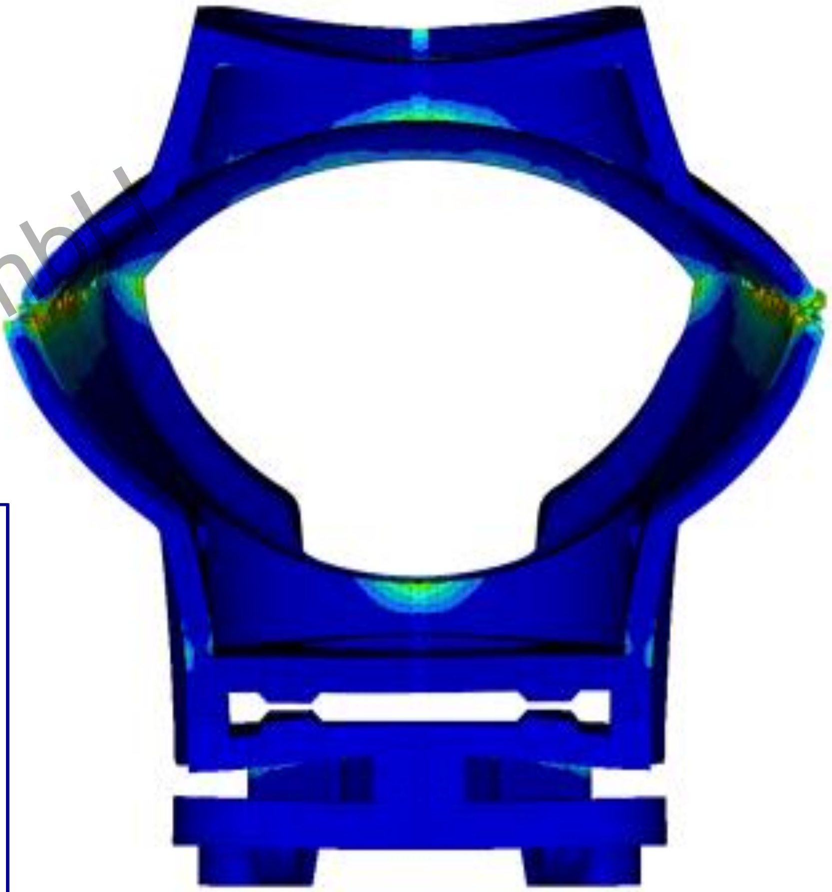
- critical loading transversal to fiber orientation



Motivation – current simulation standard

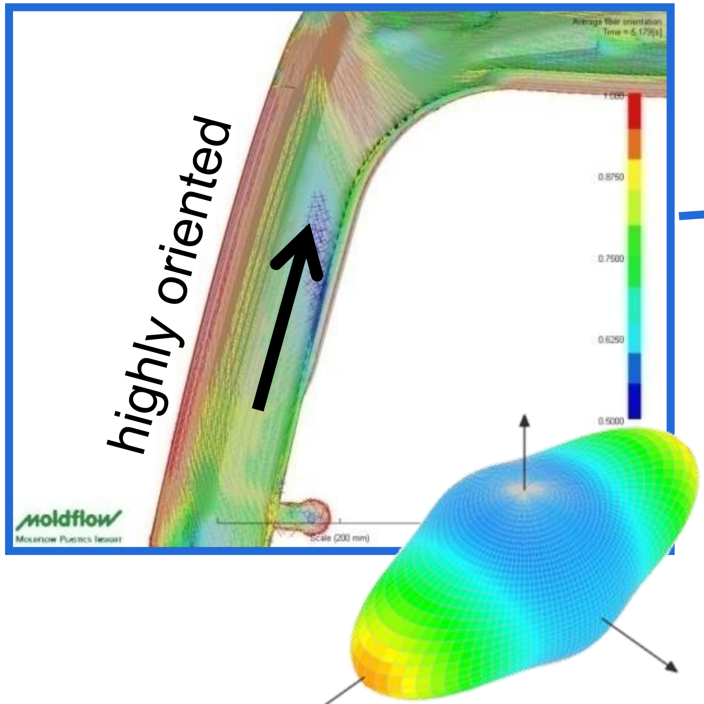
isotropic



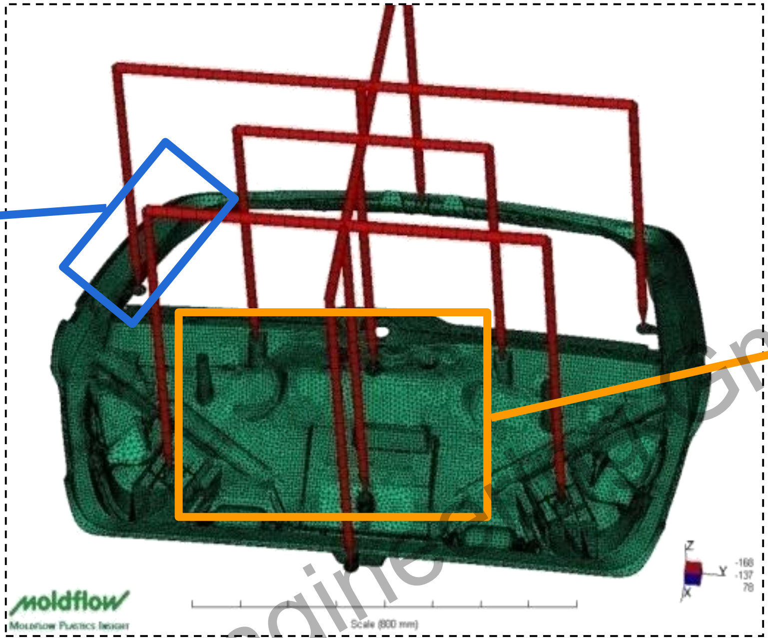


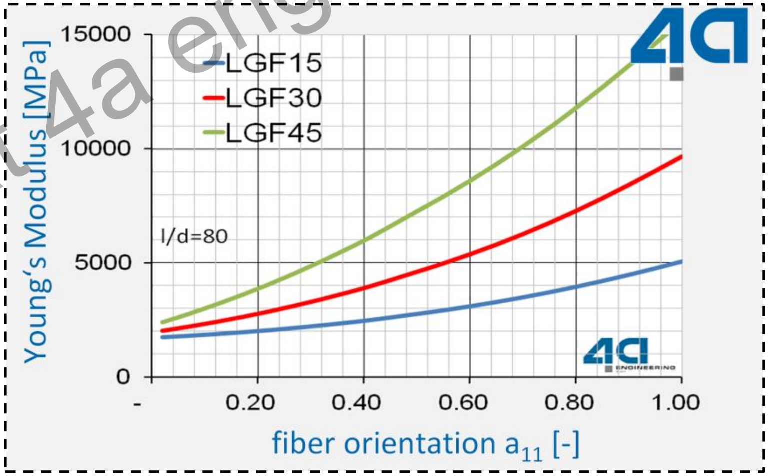
See more: R. Steinberger, et.al. Hirtenberger Automotive Group – *Considering the Local Anisotropy of Short Fiber Reinforced Plastics, European Dynaforum 2017*

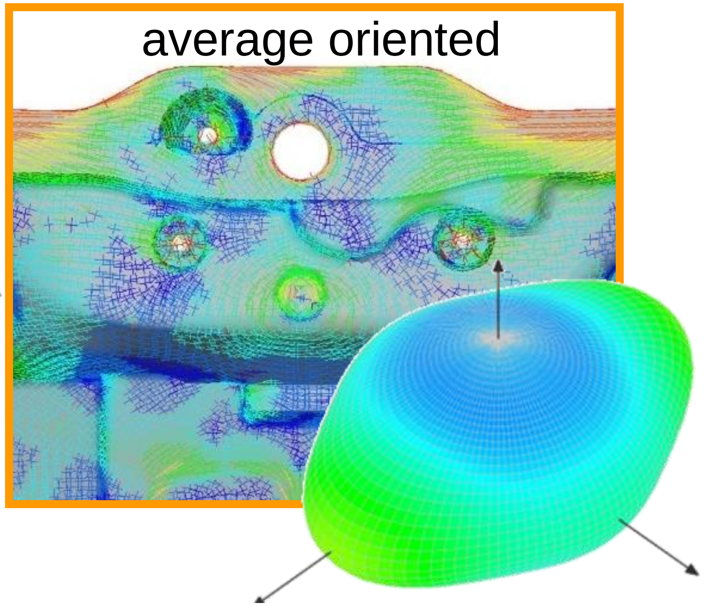
Fiber orientation – development in typical part



$$a_{ij} = \begin{bmatrix} 0,87 & 0 & 0 \\ 0 & 0,11 & 0 \\ 0 & 0 & 0,02 \end{bmatrix}$$





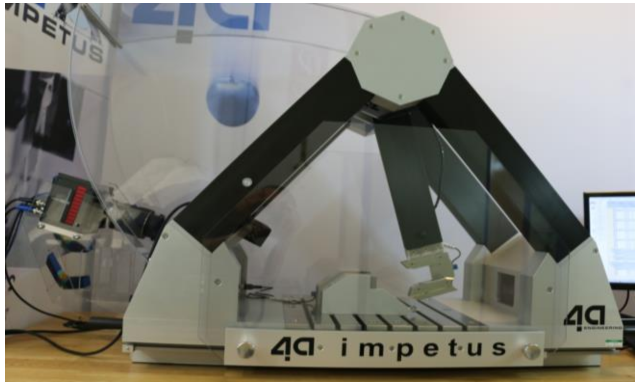


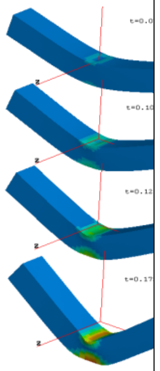
$$a_{ij} = \begin{bmatrix} 0,66 & 0 & 0 \\ 0 & 0,32 & 0 \\ 0 & 0 & 0,02 \end{bmatrix}$$

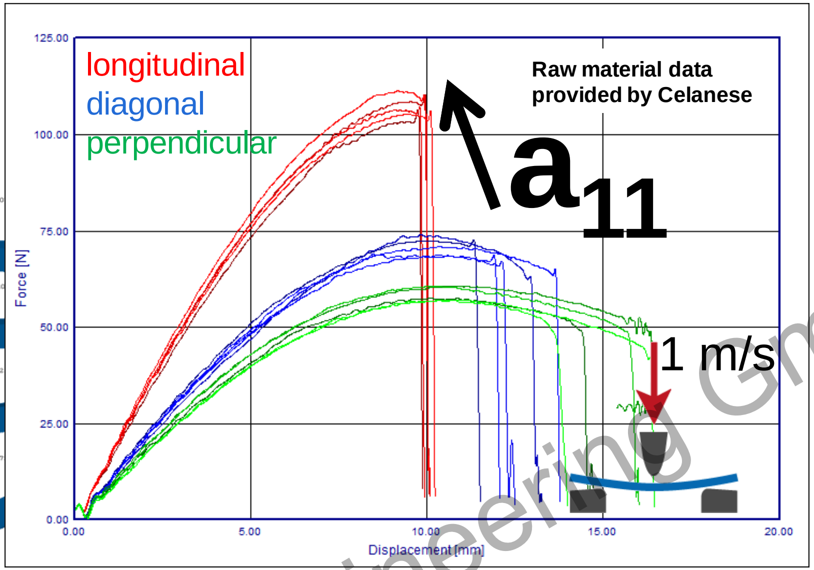
Source: P. Reithofer - *Integrative Simulation – Berücksichtigung der prozessbedingten Anisotropie,* 4a Technologietag 2011

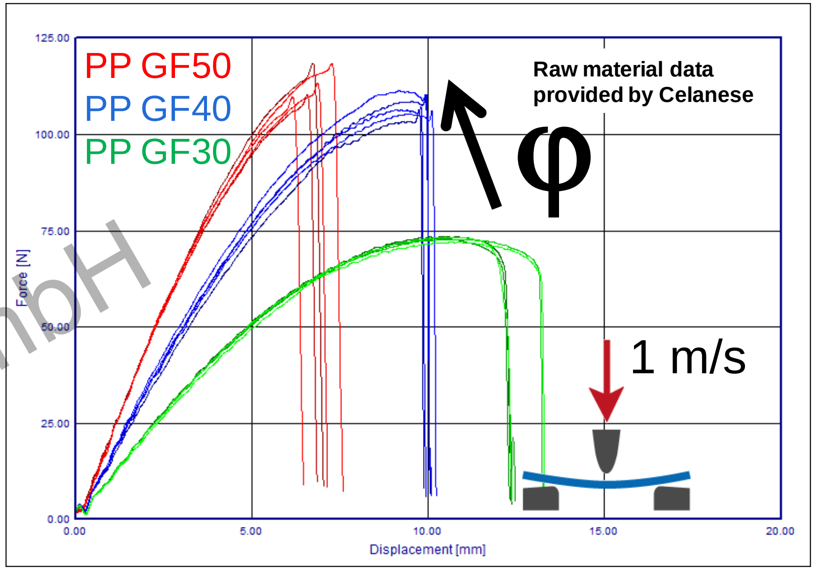
Typical material behavior – SFRT / LFRT

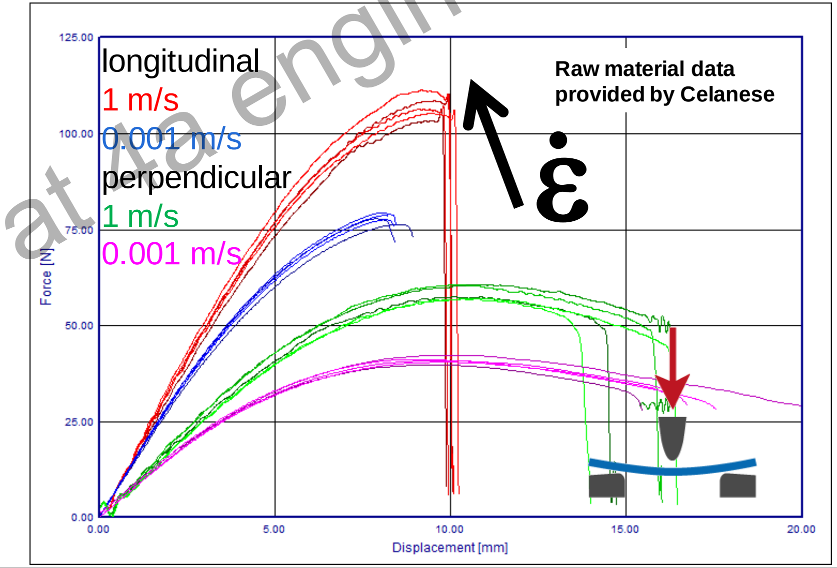
IMPETUS

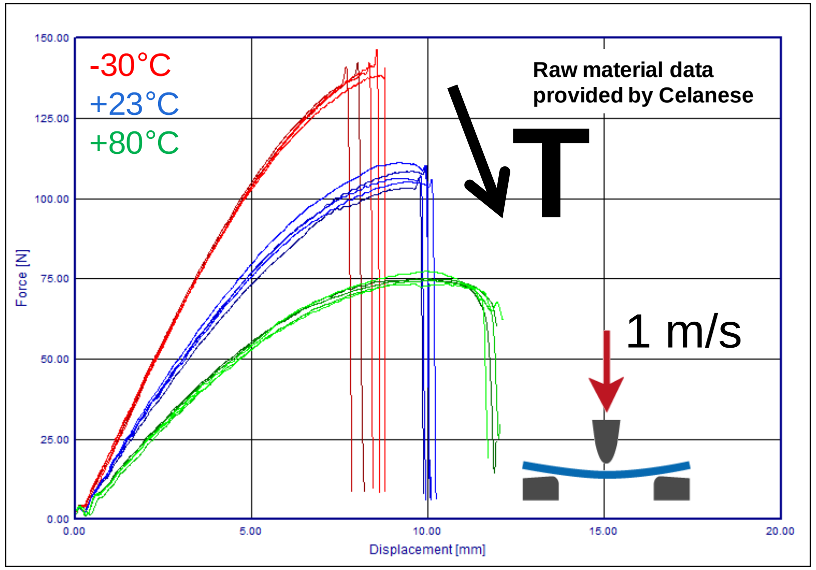




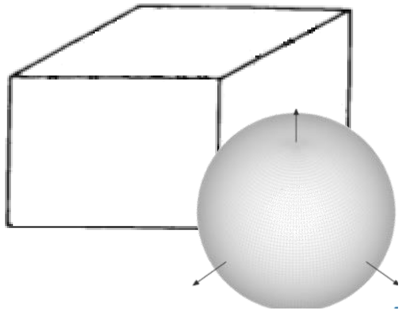


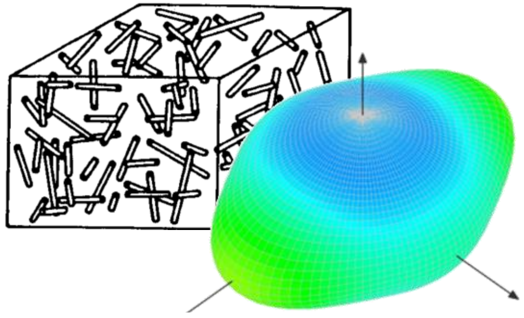






Typical material models in LS-DYNA





Hill plasticity → „extended" von Mises

$$\sigma_{eq} = \sqrt{F(\sigma_{22}-\sigma_{33})^2 + G(\sigma_{33}-\sigma_{11})^2 + H(\sigma_{11}-\sigma_{22})^2 + \cdots}$$

macro scale

constitutive law → composi

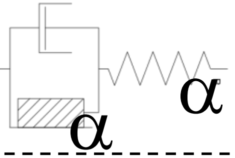
*MAT_024

Mises plasticity
- quick & d
- criti g t l orientation

*MAT_157

elastic
- orthotro
- aniso

elastic stic
- city

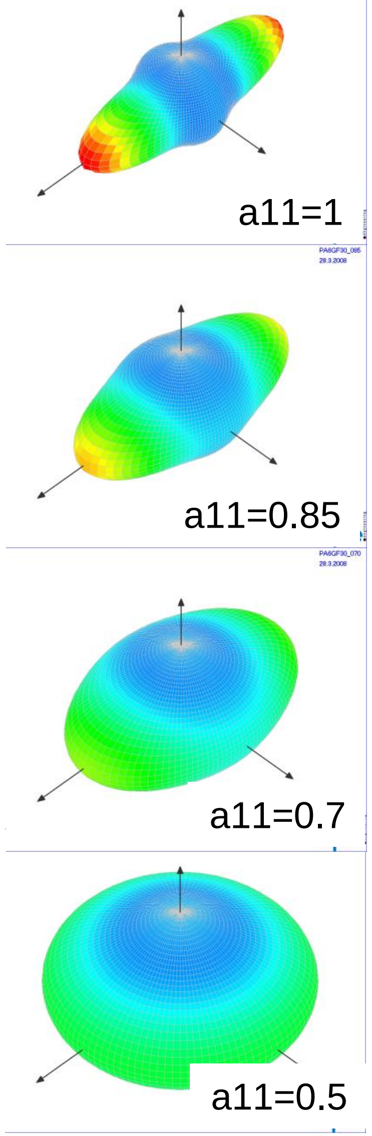


α – orientation dependent

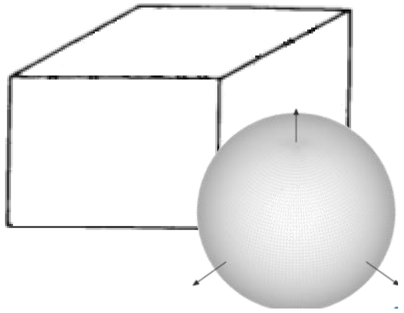
description	variables	Number of variables	dependencies
anisotropic stiffness	Cij	21	$C_{ij}\left(a_{ij},\varphi,C^{M},C^{F}\right)$
Hill plasticity	3D: F, G, H, L, M, N 2D: r00, r45, r90	6	$f\left(a_{ij},\varphi,\sigma^{M},\sigma^{F}\right)$
stress-strain curve	Loadcurve	3	$f\left(a_{ij},\varphi\right)$
failure	Loadcurve	6	$f\left(a_{ij},\varphi\right)$

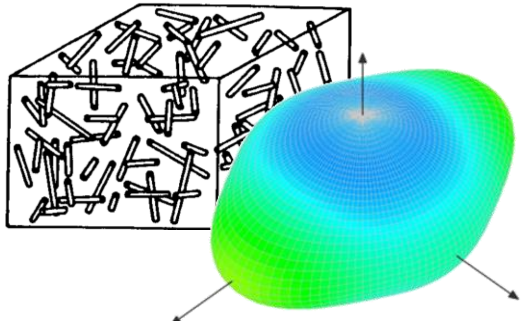
- Not possible to generate samples with **explicit defined and varying a_{ij}**
- **Hard to characterize, too many possibilities in a_{ij}**

→ Micro mechanical model is needed

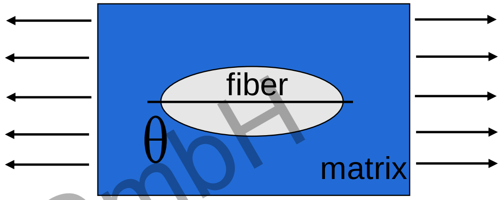


Typical material models in LS-DYNA





$$\overline{\sigma}^{C} = \varphi \overline{\sigma}^{F} + (1-\varphi)\overline{\sigma}^{M}$$



Eshelby Tensor

macro scale

constitutive law → composi…

micro scale

homogenizat…

*MAT_024

Mises plasticity
- quick & d…
- criti… …g … orientation

*MAT_157

elastic
- orthotro…
- aniso…

elastic… …stic
- … …city

α — orientation dependent

*MAT_215

M… matrix
- isotropic elas… viscoplasti…

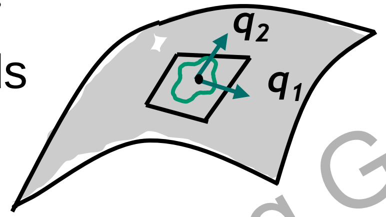
F… fiber
- iso… …stic

Material models – *MAT_215 KEYWORD

CARD 1: General Options / Parameter

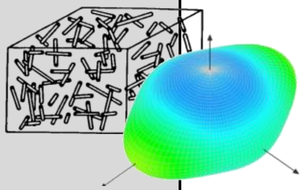
CARD 2-3: Element orientation*

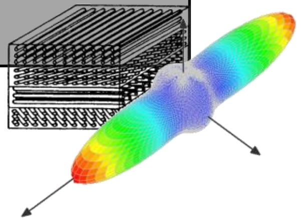
analog to LSDYNA standard anisotropic material cards



CARD 4: Composite Buildup*

Card 4	1	2	3	4	5	6	7	8
	FVF		FL	FD		A11	A22	
PP GF30	**-0.3**		**200.0**	**10.0**		**0.7**	**0.25**	
PP LGF50	**-0.5**		**1000.0**	**20.0**		**0.65**	**0.30**	
PA6 GF45	**-0.45**		**250.0**	**10.0**		**0.8**	**0.15**	
Carbon UD	**0.6**		**10000.0**	**10.0**		**1.0**	**0.0**	





FVF > 0: fiber volume fraction → Composite
FVF < 0: fiber mass fraction → SFRT/LFRT

exemplary values without any warranty

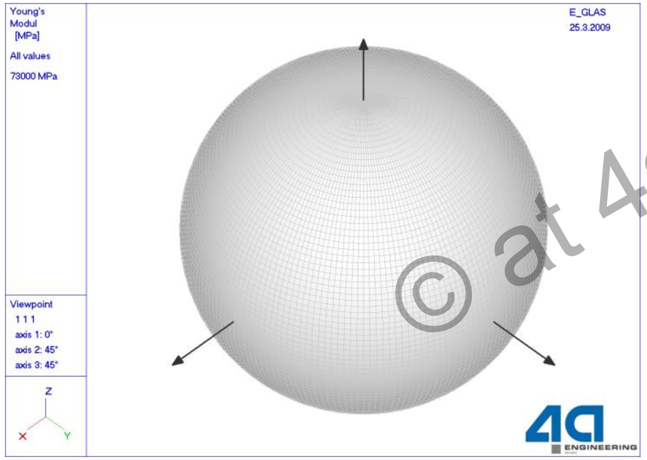
*may be overwritten by
`*INITIAL_STRESS_SHELL/SOLID`

Material models – *MAT_215 KEYWORD

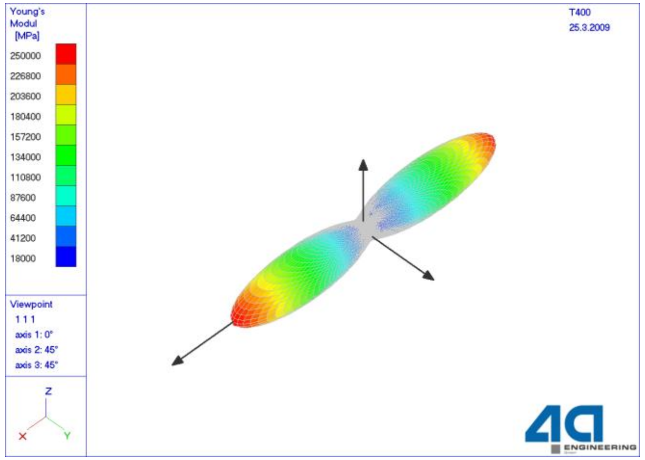
CARD 5: fiber material

Card 5	1	2	3	4	5	6	7	8
FIBER	ROF	EL	ET	GLT	PRTL	PRTT		
UNITS	kg/mm³	GPa	GPa	GPa	-	-		
glass	**2.59E-6**	**70.0**	**70.0**	**28.8**	**0.217**	**0.217**		
T400	**1.76E-6**	**218.8**	**28.0**	**50.0**	**0.02943**	**0.390**		

glass fiber (isotropic)



T400 (transversal isotropic)



exemplary values without any warranty

Material models – *MAT_215 KEYWORD

CARD 7-8: matrix material

from material characterization (e.g. VALIMAT® Workflow)

Card 7	1	2	3	4	5	6	7	8
Matrix	ROM	E	PR					
Units	kg/mm³	GPa	-					
PP	**0.9E-6**	**1.5**	**0.4**					
PA6 dry	**1.2E-6**	**3.2**	**0.35**					
PA6 cond.	**1.2E-6**	**2.0**	**0.35**					

elasticity

Card 7	1	2	3	4	5	6	7	8
Matrix	SIGYT	ETAN			EPS0	C		
Units	GPa	GPa	-		1/ms	-		
PP	**0.015**	**0.5**			**1.E-6**	**10**		
PA6 dry	**0.06**	**1.0**			**1.E-6**	**15**		
PA6 cond.	**0.04**	**0.8**			**1.E-6**	**10**		

visco plasticity

Bilinear + Johnson Cook

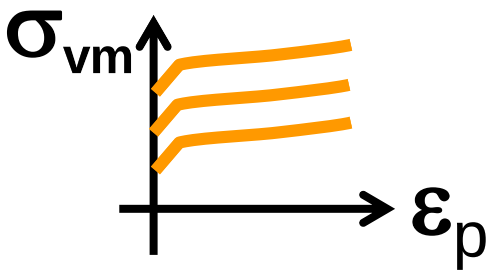
exemplary values without any warranty

Material models – *MAT_215 KEYWORD

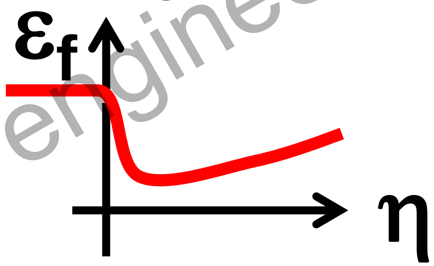
CARD 9: matrix material tables

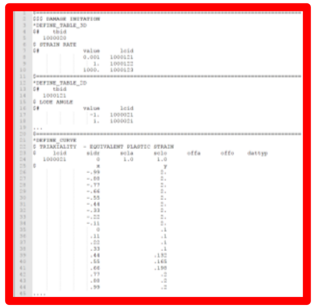
Card 9	1	2	3	4	5	6	7	8
Variable	LCIDT				LCDI	UPF		
Type	F				F	F		
Default	0				0	0.0		

Hardening

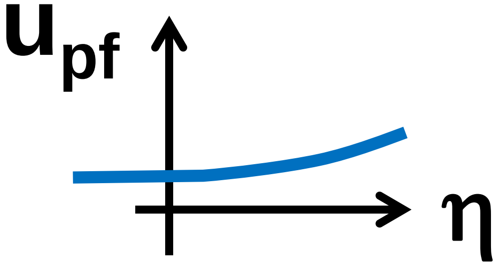


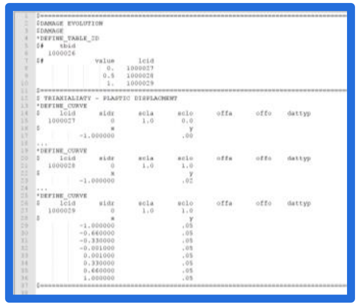
Damage Initiation





Damage Evolution



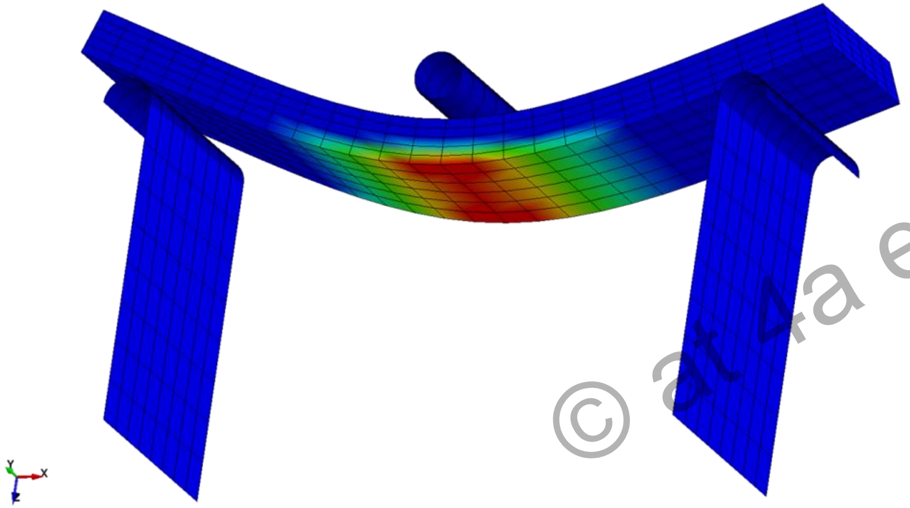


LCIDT	Effective stress (Table)
LCDI	Damage initiation (Table)
UPF	Damage evolution parameter

Material models – *MAT_215 KEYWORD

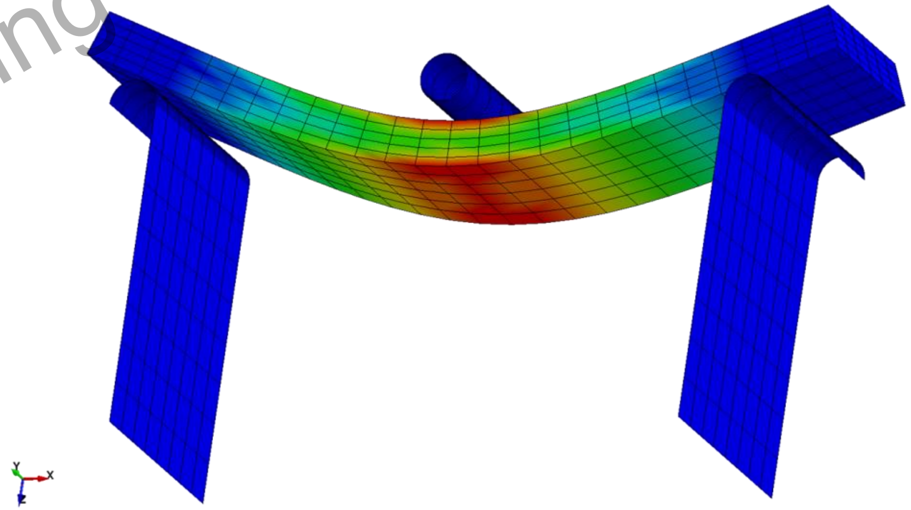
CARD 1: General Options / Parameter

Card 1	1	2	3	4	5	6	7	8
Variable	MID	MMOPT	BUPD			FAILM	FAILF	NUMINT
Type	A8	F	F			F	F	F
Default	**none**	**0.0**	**0.01**			**0.0**	**0.0**	**1.0**



History#4 (step8: 0-0.81):

dm - matrix damage init.



History#6 (step8: 0-0.13):

Fiber damage init.

Micro mechanical motivated failure

failure criteria

Stress based	Strain based

equivalent | principal | cipal | damage

MEAN FIELD APPROACH

$$\bar{\sigma}^{C} = \varphi \bar{\sigma}^{F} + (1-\varphi)\bar{\sigma}^{M}$$

C...composite, F...fiber, M...matrix

assumption elliptical inclusion
(Eshelby Tensor)

*MAT_215

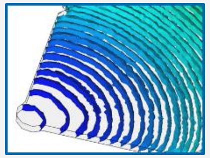
FAILF: Fiber failure

FAILM: Matrix failure – ductile DIEM-Model

Damage Initiation **Damage Evolution**

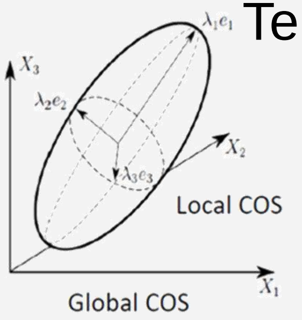
Material models – present approaches

Process simulation



$$a_{ij} = \begin{bmatrix} a_{xx} & a_{xy} & a_{xz} \\ & a_{yy} & a_{yz} \\ & & a_{zz} \end{bmatrix}$$

Tensor 2nd order



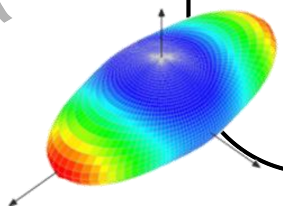
CADMOULD 3D-F SIMULATION

Moldex3D MOLDING INNOVATION

MOLDFLOW

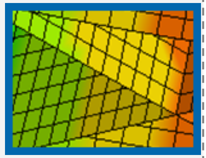
FIBERMAP

$$C^{-1} = \begin{bmatrix} \frac{1}{E_1} & -\frac{\nu_{21}}{E_2} & -\frac{\nu_{31}}{E_3} & 0 & 0 & 0 \\ -\frac{\nu_{12}}{E_1} & \frac{1}{E_2} & -\frac{\nu_{32}}{E_3} & 0 & 0 & 0 \\ -\frac{\nu_{13}}{E_1} & -\frac{\nu_{23}}{E_2} & \frac{1}{E_3} & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{1}{G_{23}} & 0 & 0 \\ 0 & 0 & 0 & 0 & \frac{1}{G_{31}} & 0 \\ 0 & 0 & 0 & 0 & 0 & \frac{1}{G_{21}} \end{bmatrix}$$



MICROMEC

Structural simulation

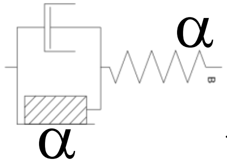


Homogenization (Micro Scale)
Mean Field Theory

$$\bar{\sigma}^{C} = \varphi \bar{\sigma}^{F} + (1-\varphi)\bar{\sigma}^{M}$$

*MAT_215

Composite (Macro Scale)
Hill Plasticity



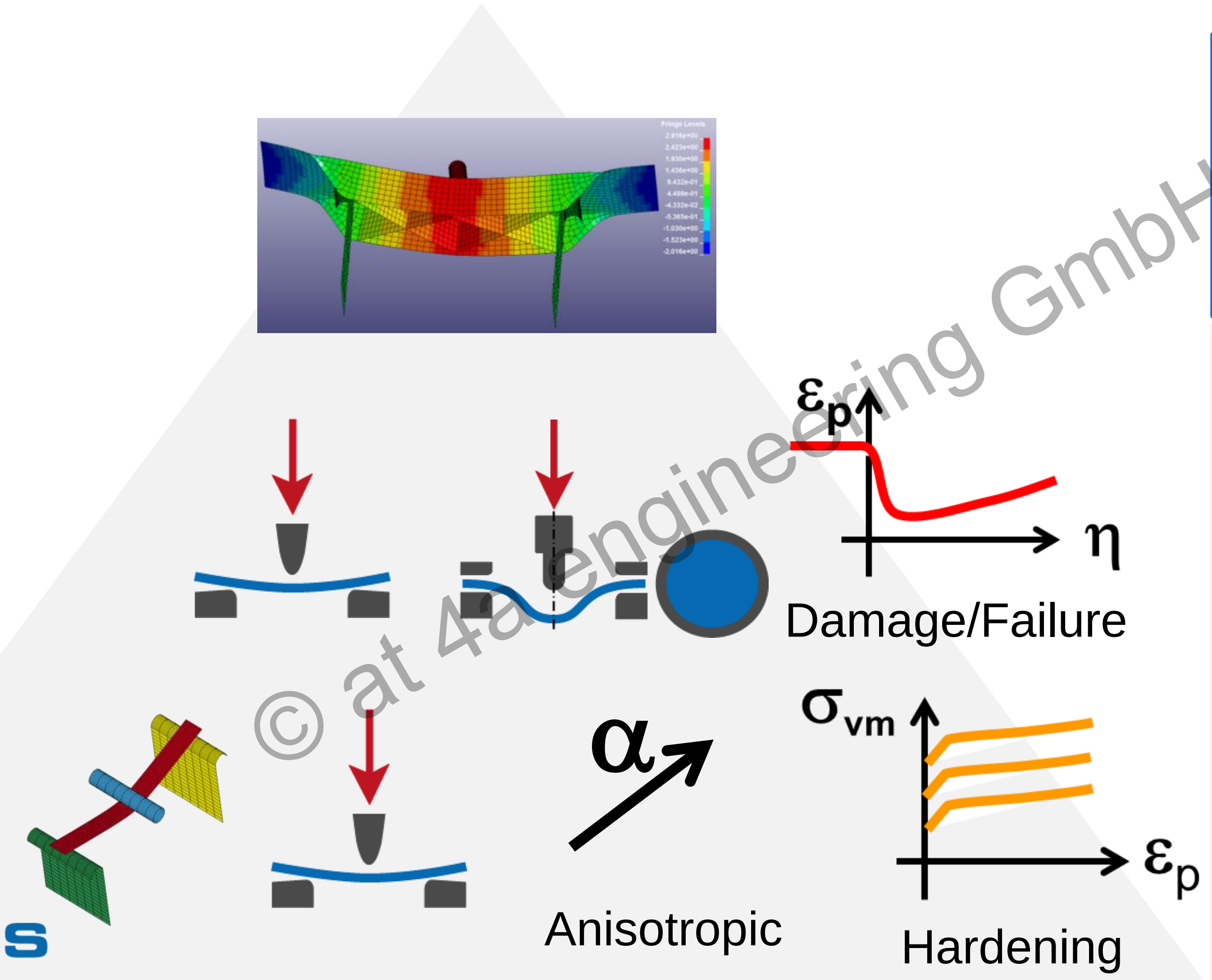
*MAT_157

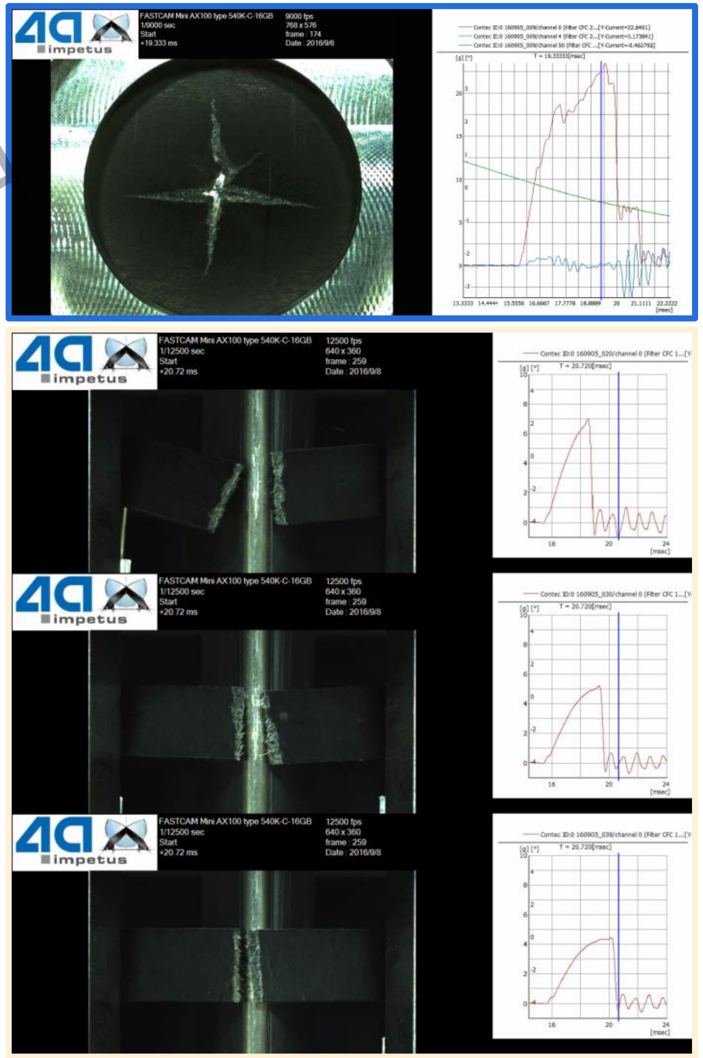
LSTC Livermore Software Technology Corp.
LS-DYNA®

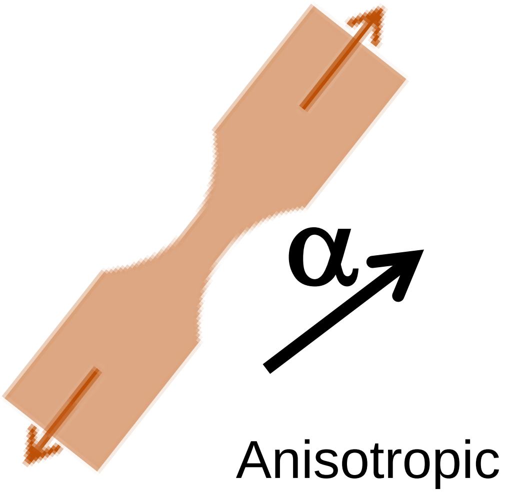
VALIMAT

From test to material card

from test to material card



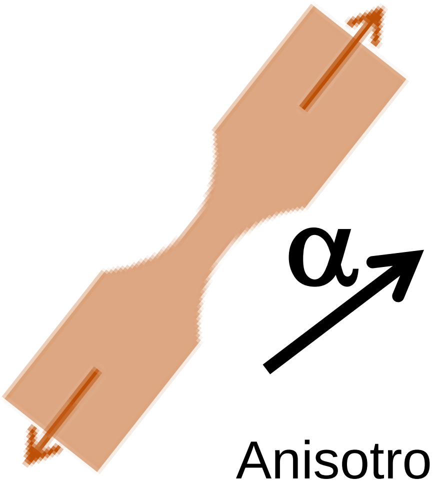




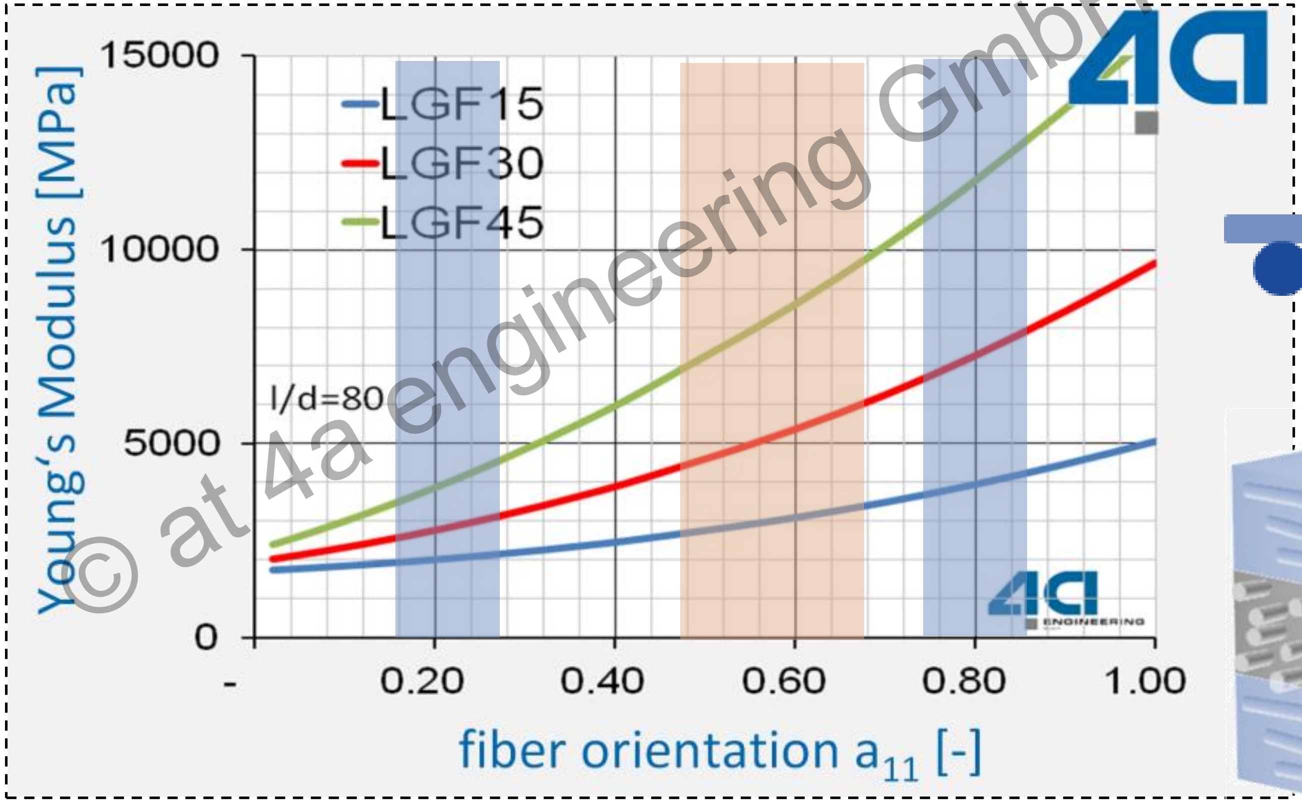
Why not tension (only)?

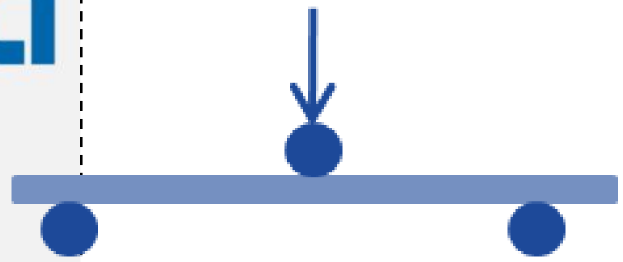
From test to material card

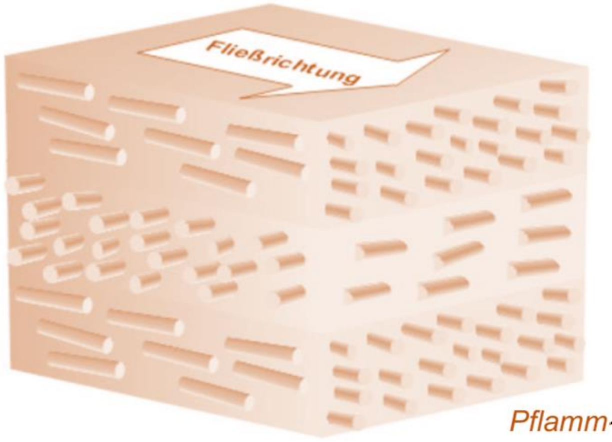
Why not tension (only)?

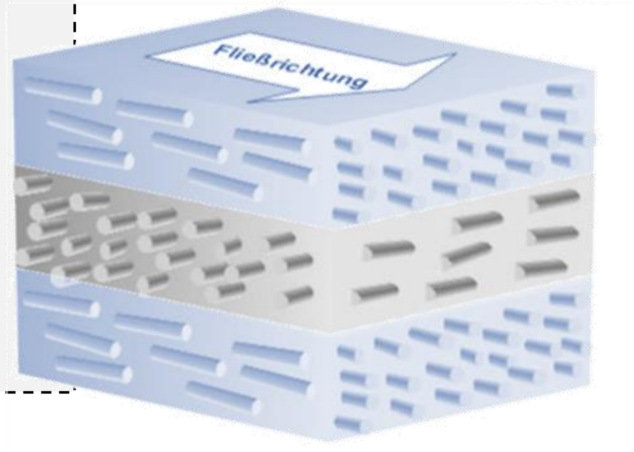


Anisotropic



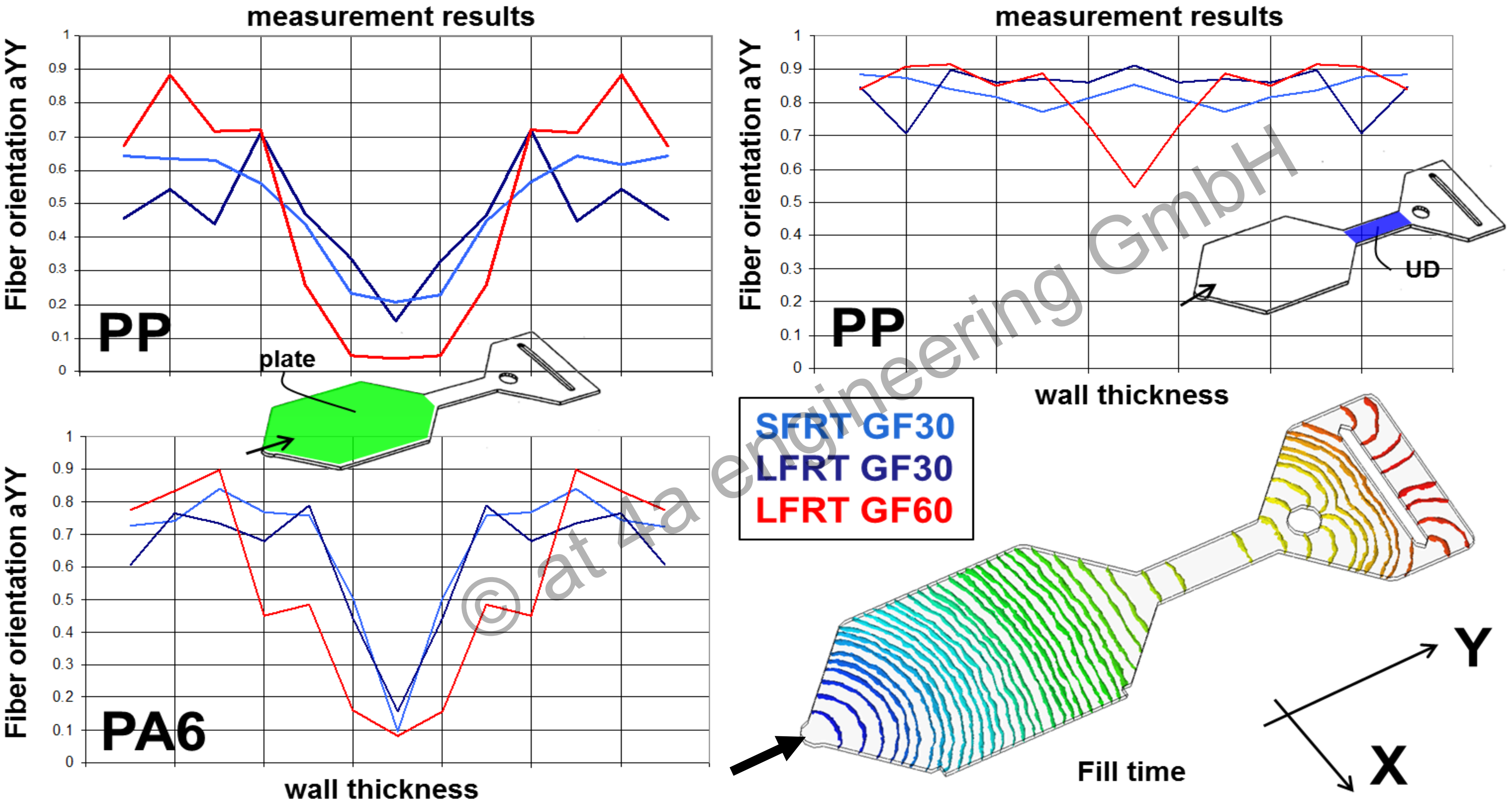






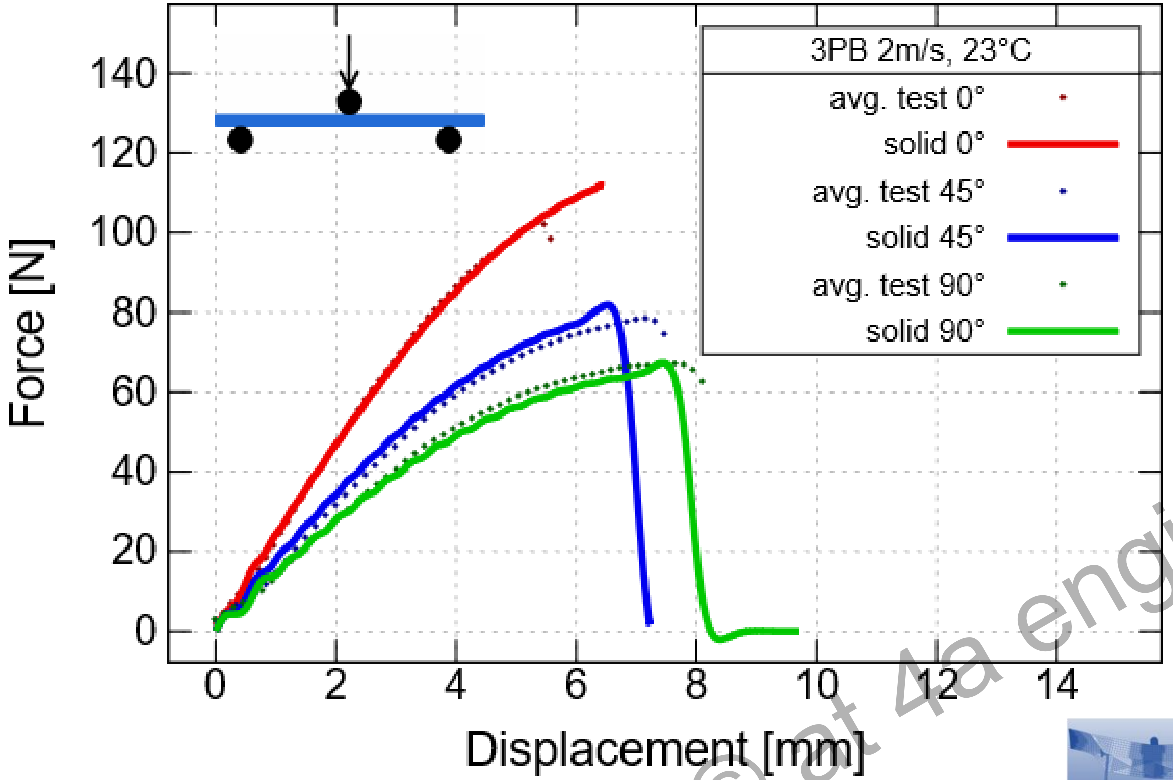
Pflamm-Jonas 2001

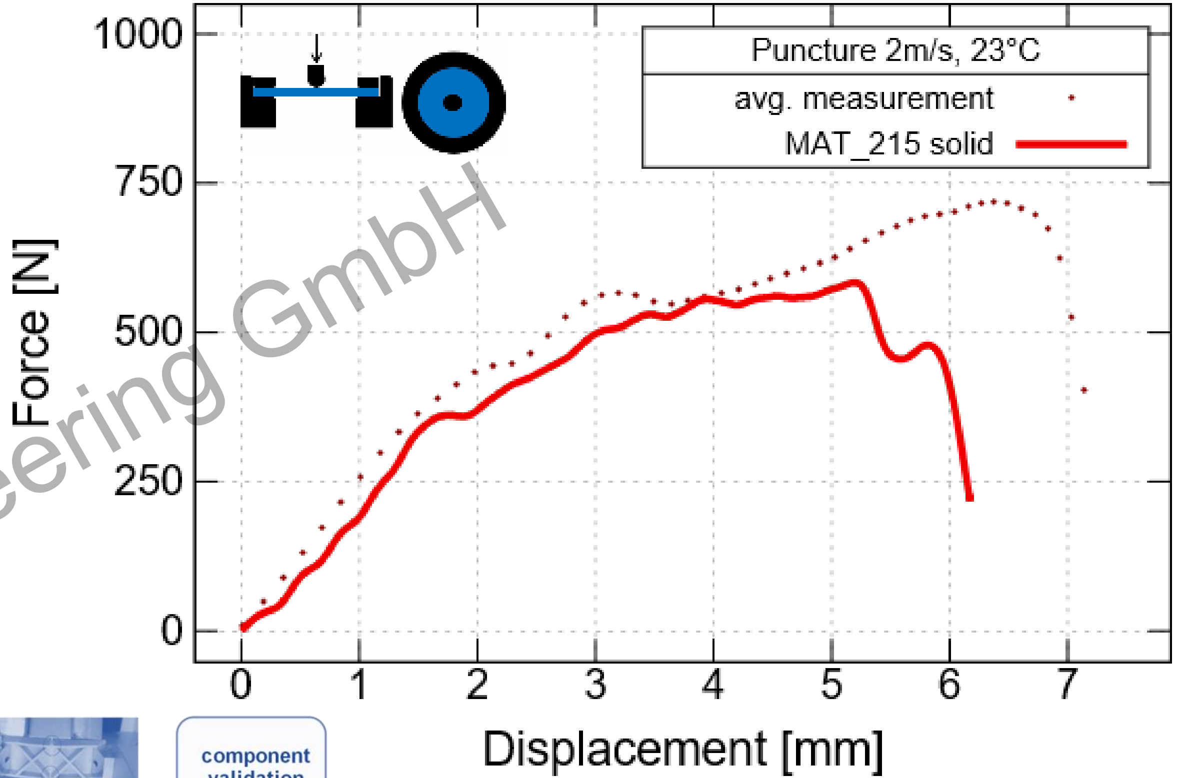
Fiber orientation – development based on flow / viscosity

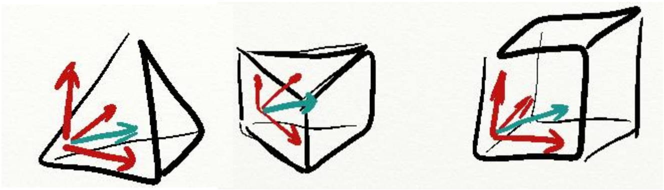


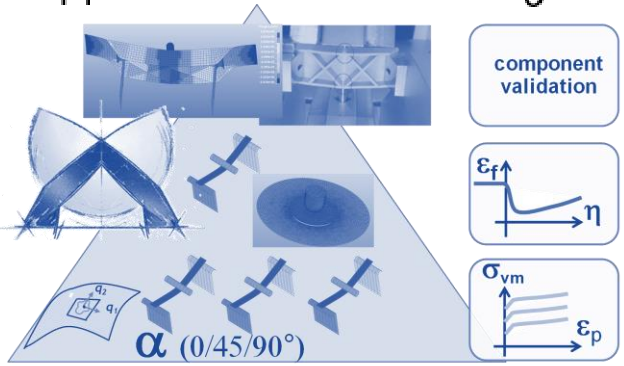
Source: 4a – EU Nelofite project , 2005

From test to material card – PP LGF30 *MAT_215





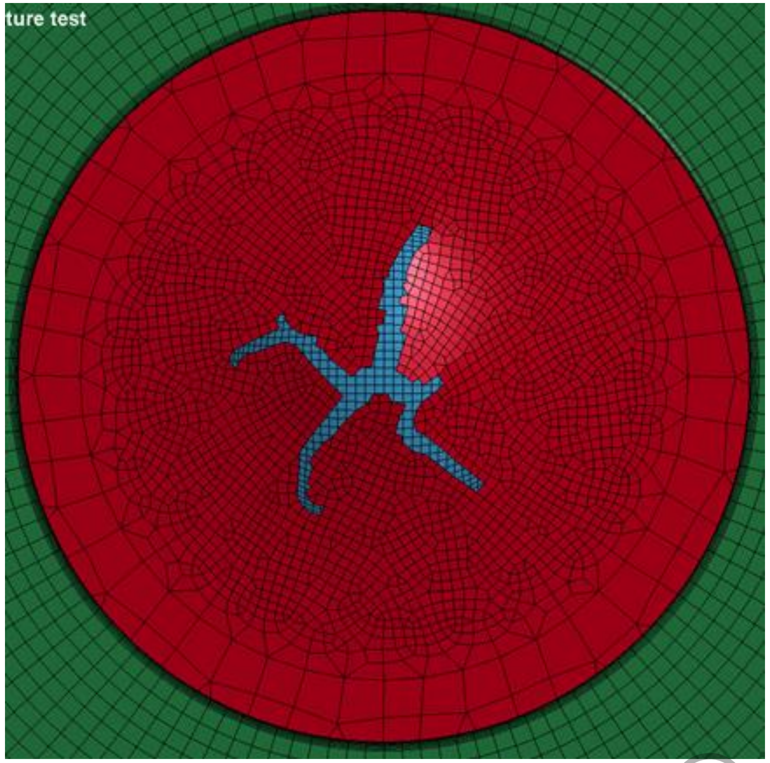


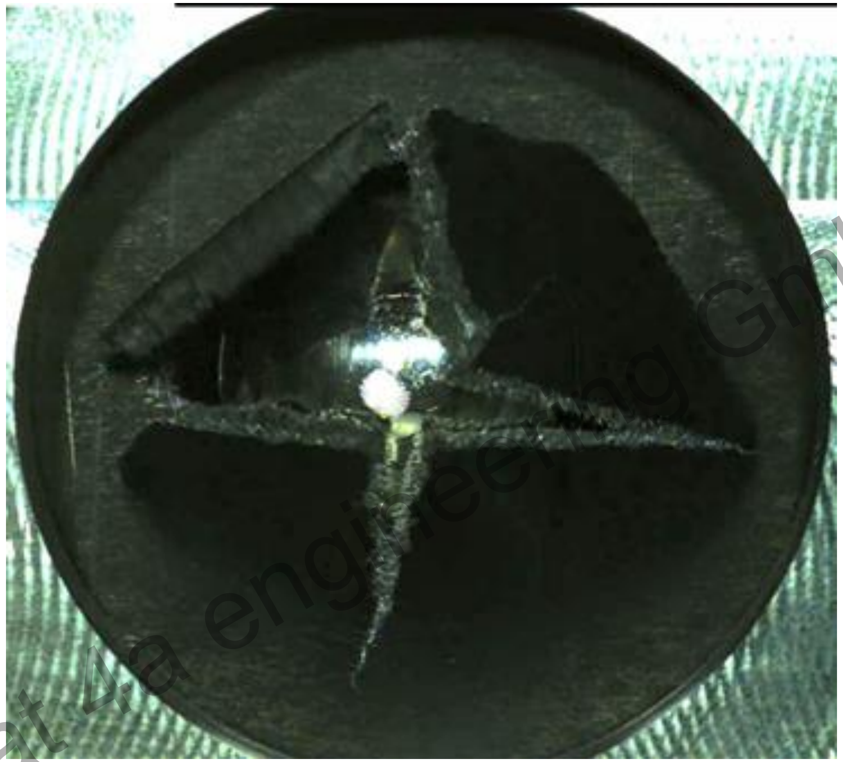


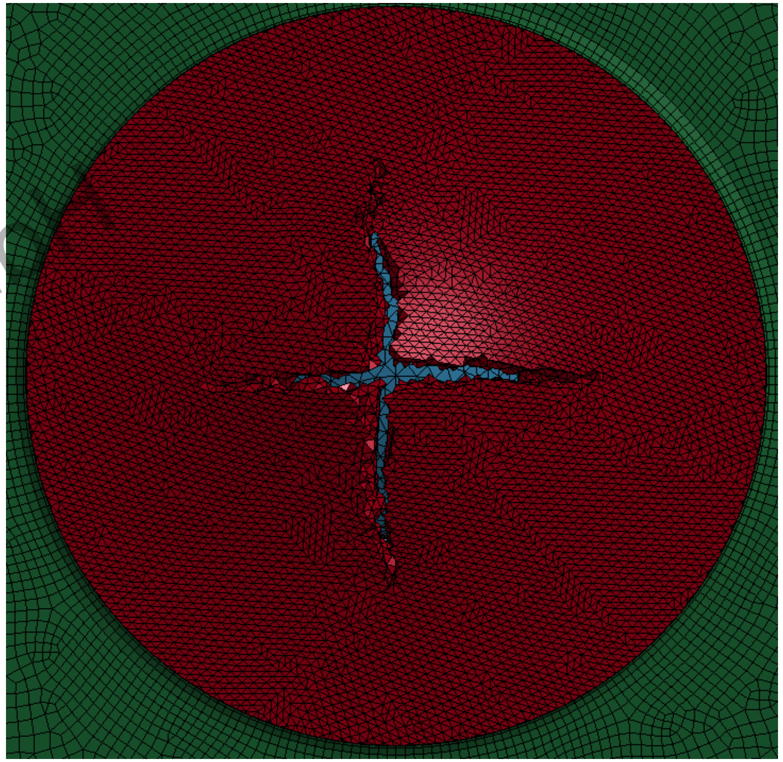
···· averaged test curves
— result of simulation

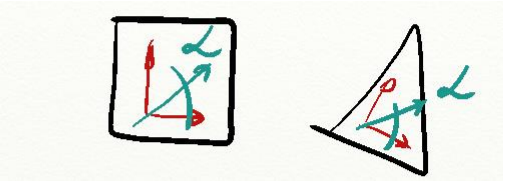
Source: P Reithofer, failure criteria SFRT and LFRT

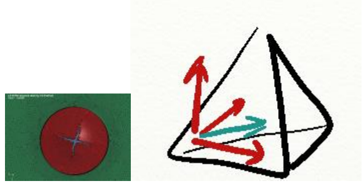
From test to material card – PP LGF30 *MAT_215





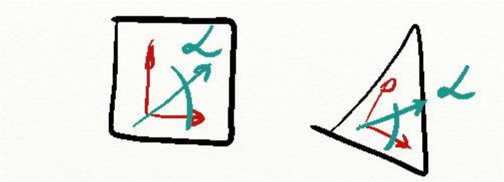


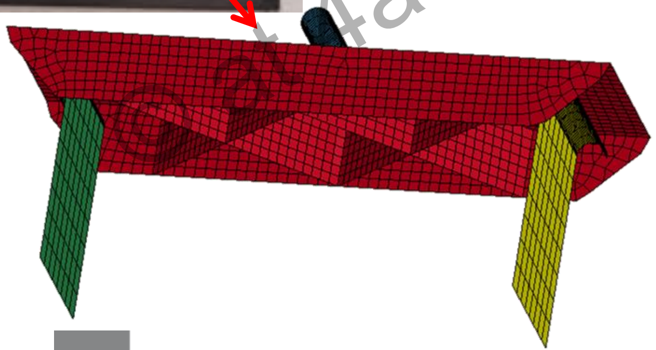


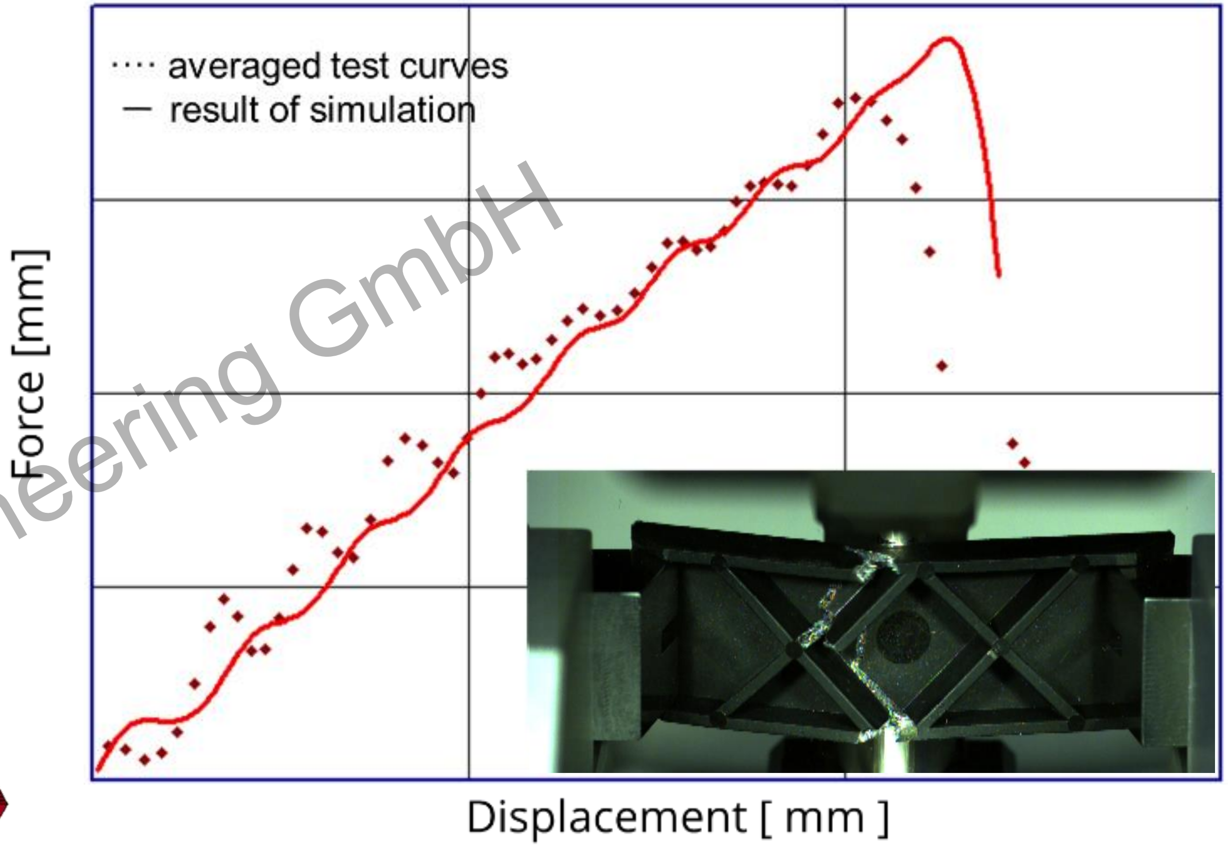


Source: P Reithofer, failure criteria SFRT and LFRT

Validation for PP LGF30



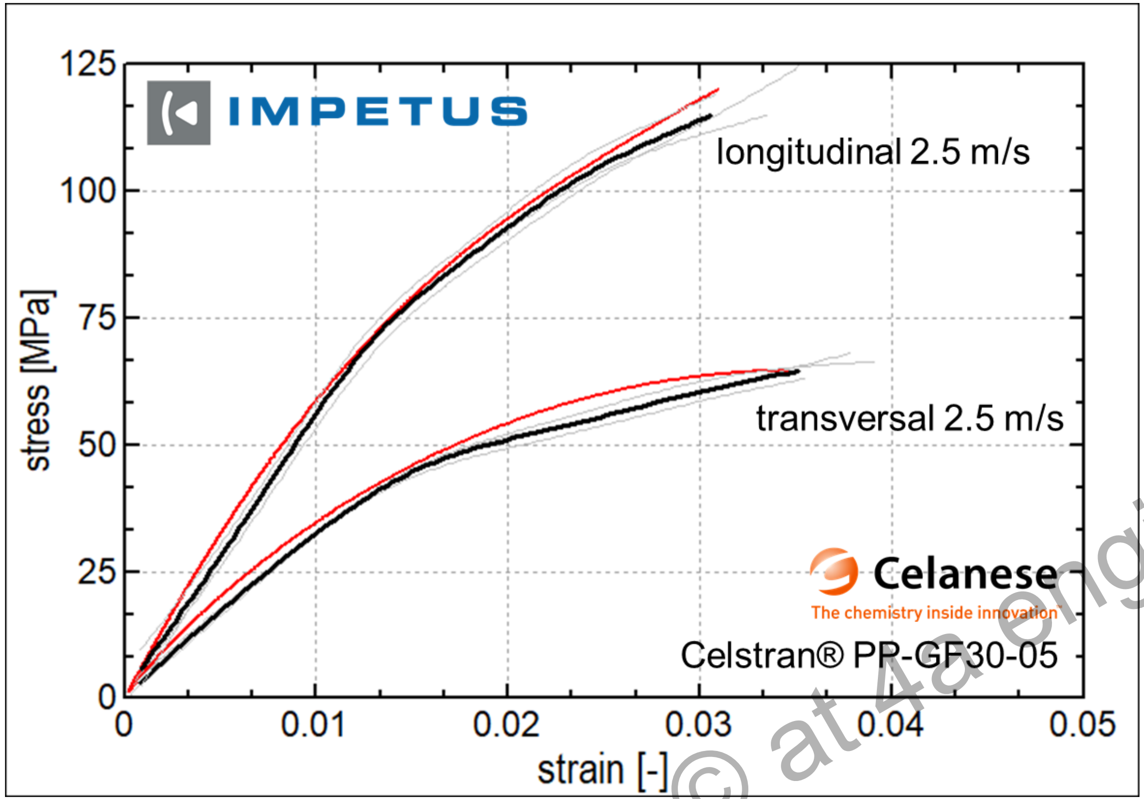


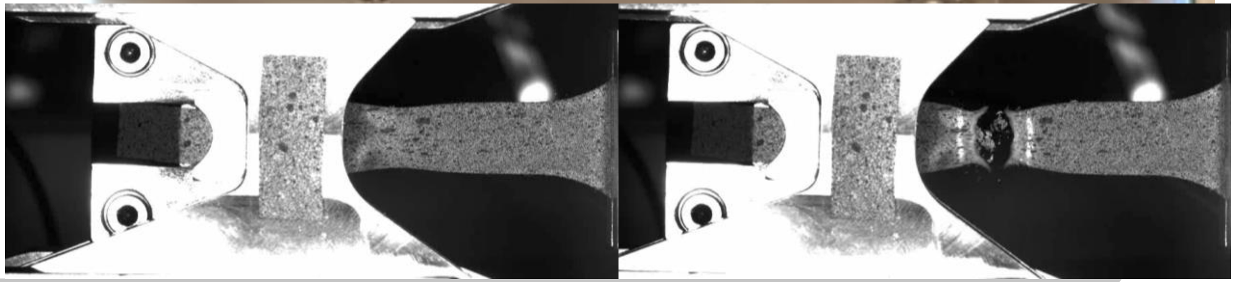


FIBERMAP

Source: P Reithofer, failure criteria SFRT and LFRT

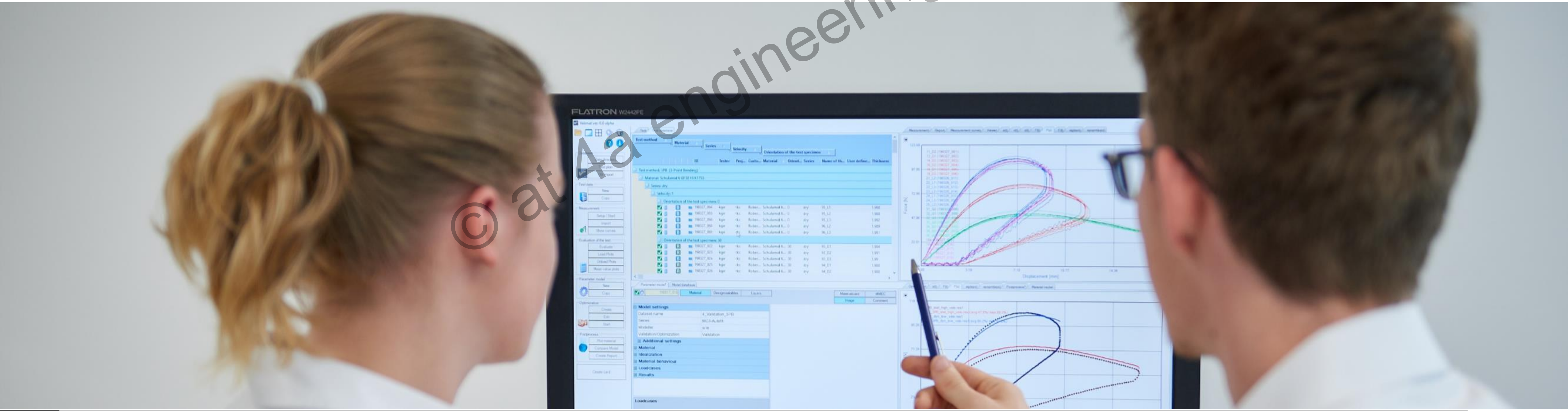
Dynamic tensile testing





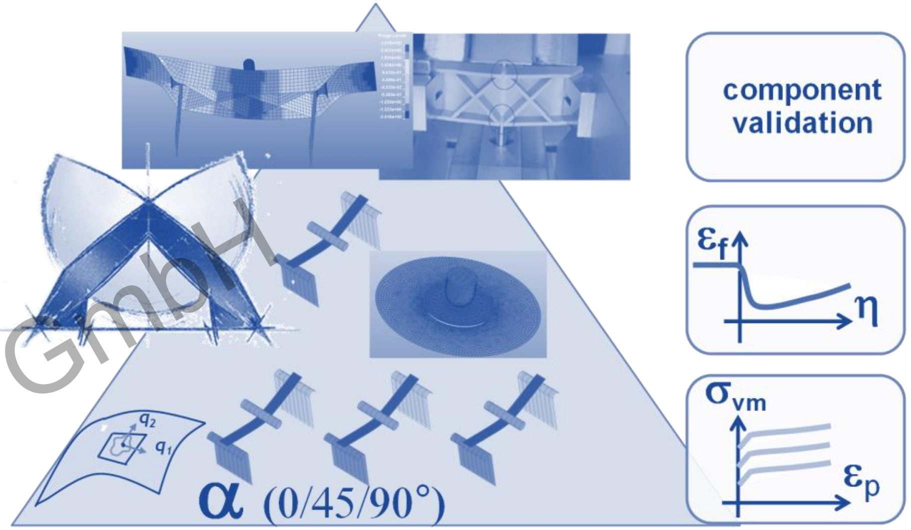
comparison
IMPETUS™ impact tensile versus
classical servo hydraulic test

How to get **MAT_157* or **MAT_215* ?



How to get *MAT_215 ?

VALIMAT



fiber

- mechanical properties
- fiber content
- aspect ratio
- fiber orientation

literature

engineering judgement

tests (µCT, ...)

matrix

- pseudo mechanical properties
  - yield
  - hardening
  - failure

REVERSE ENG.

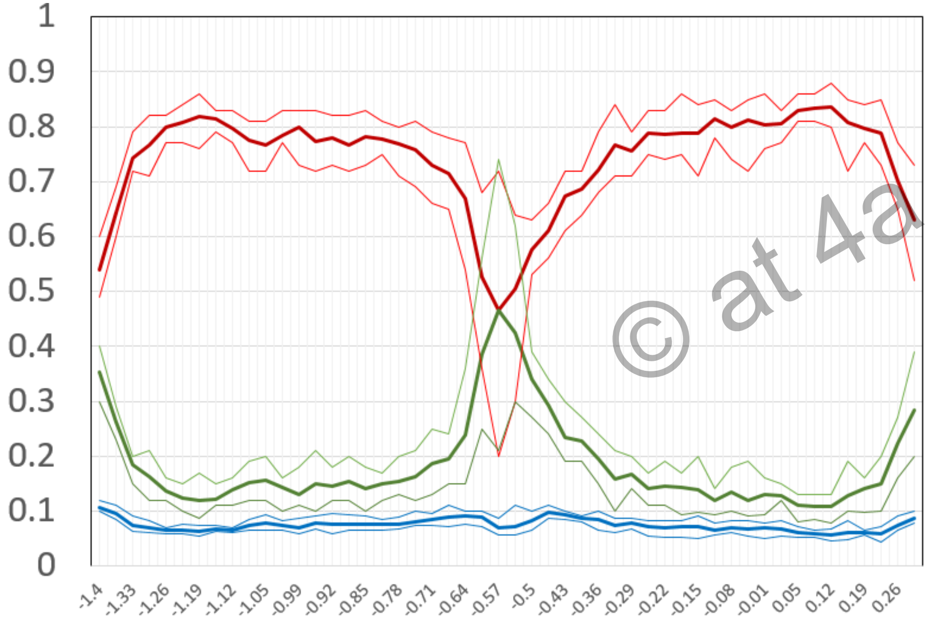
tests

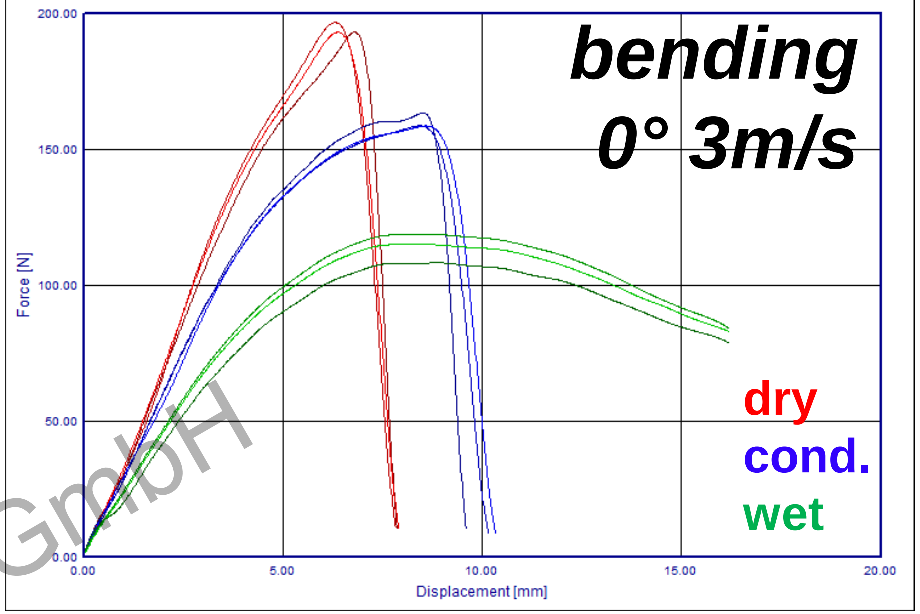
- bending and/or tensile
  - testing in different directions
    0°, 30° (45°), 90° sample orientation
- uniaxial and biaxial
- static and dynamic

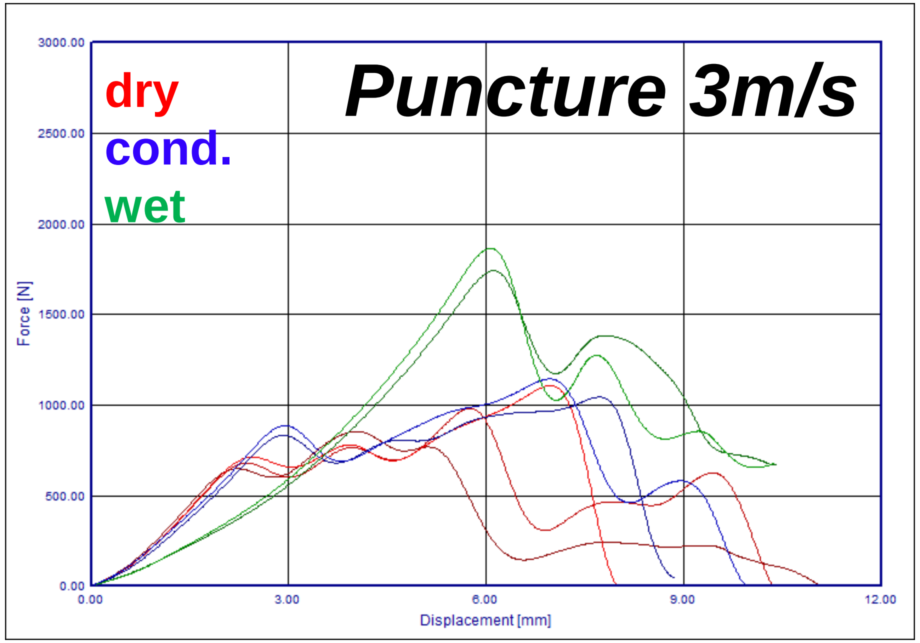
How to get *MAT_215 – case study PA6 GF30 I*

Provided by consortium (PCCL, HILTI, Hirtenberger)

- plaques for puncture tests
- bending samples (0°, ~30°, 90°)
- different moisture contents (dry, cond., wet)
- µCT measurements





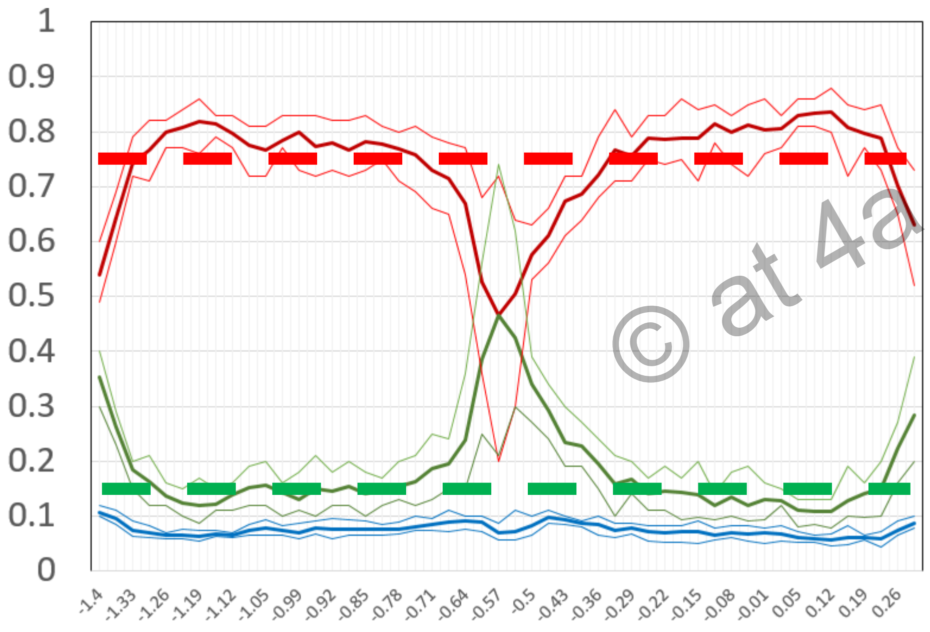


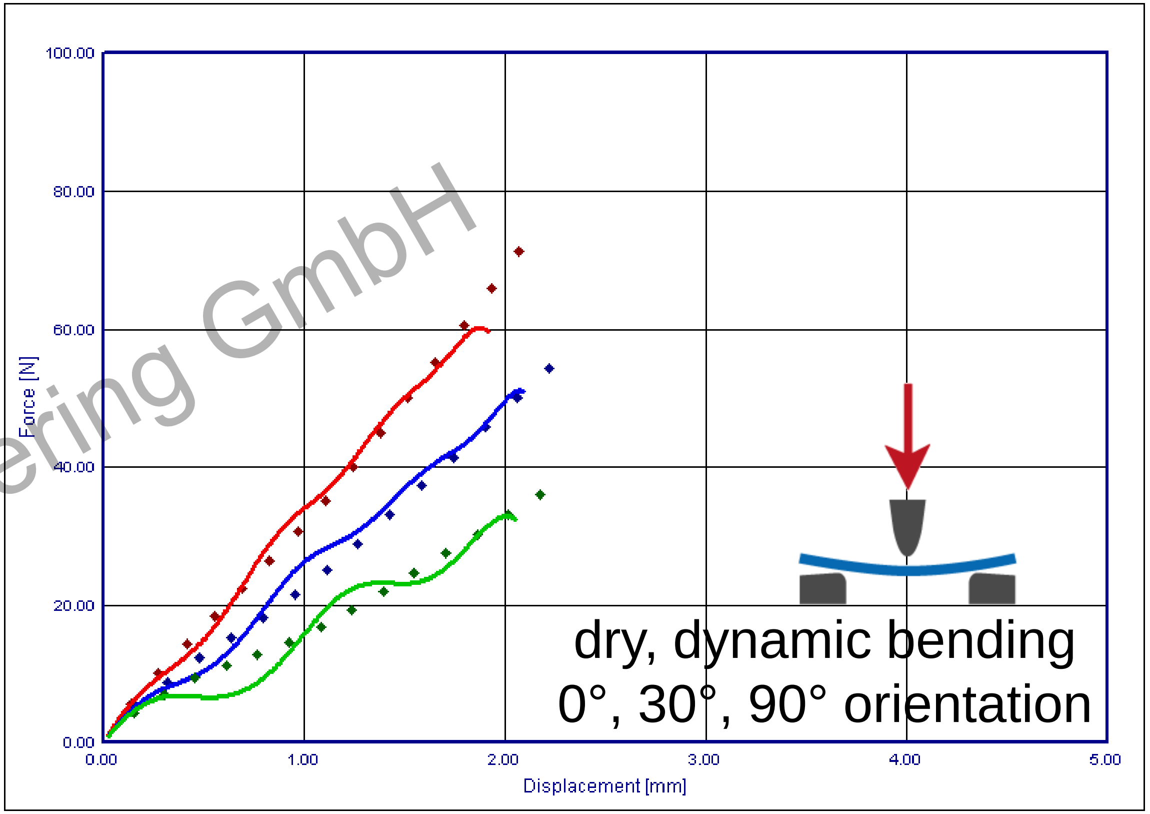
Source: P Reithofer, failure criteria SFRT and LFRT

How to get *MAT_215 – case study PA6 GF30 I

1st step: set up the composite

- Fiber properties from literature
- Fiber content 30%wt → **-0,3**
- Aspect ratio typical for short fibers l/d=20
- µCT measurements → average



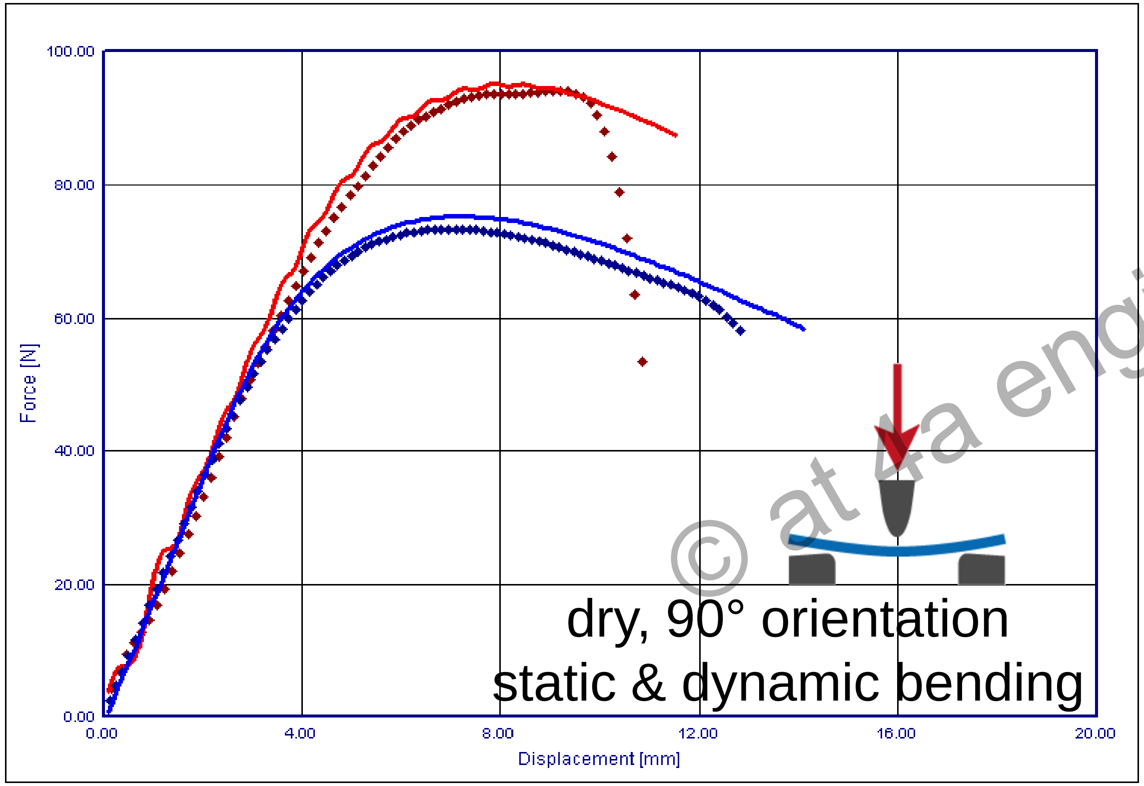


Source: P Reithofer, et.al., failure criteria SFRT and LFRT

How to get **MAT_215 – case study PA6 GF30 I*

2nd step: matrix hardening

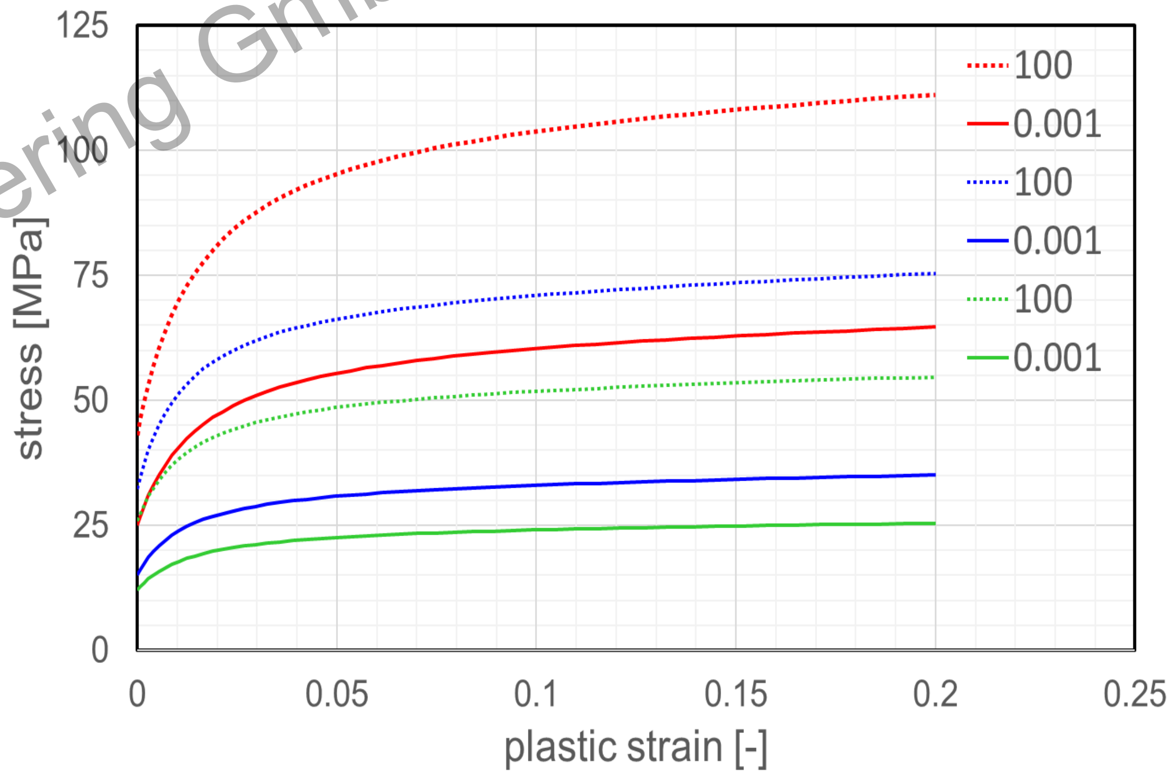
- parameter identification of hardening law



Source: P Reithofer, failure criteria SFRT and LFRT

Matrix in dependence of moisture

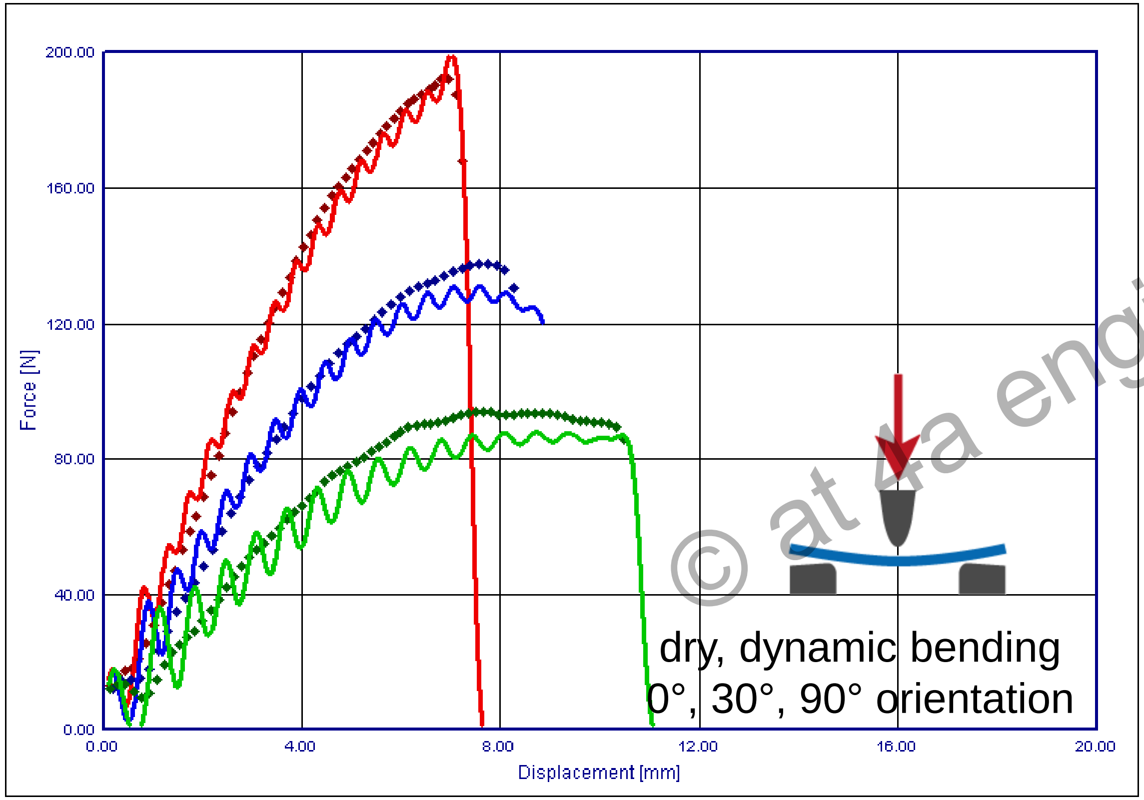
Young's Mod.	dry	cond.	wet
[MPa]	2500	1600	1450



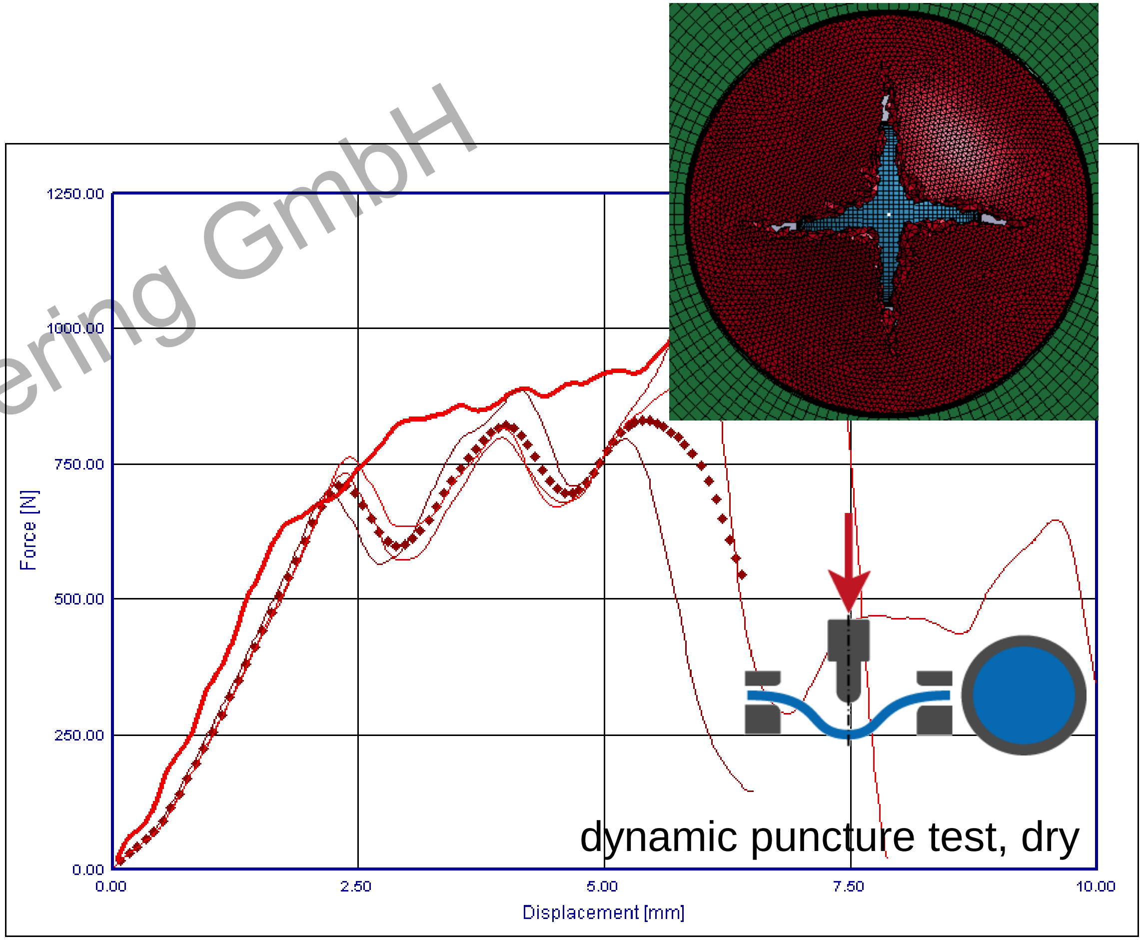
How to get *MAT_215 – case study PA6 GF30 I

3rd step: validation on dynamic bending

4th step: failure strains



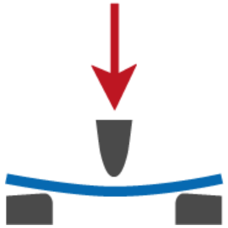
5th step: validation on dynamic puncture



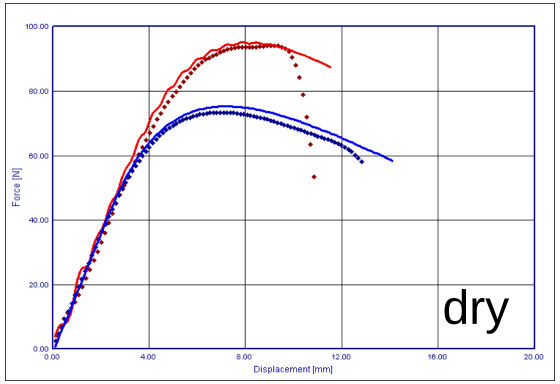
Source: P Reithofer, failure criteria SFRT and LFRT

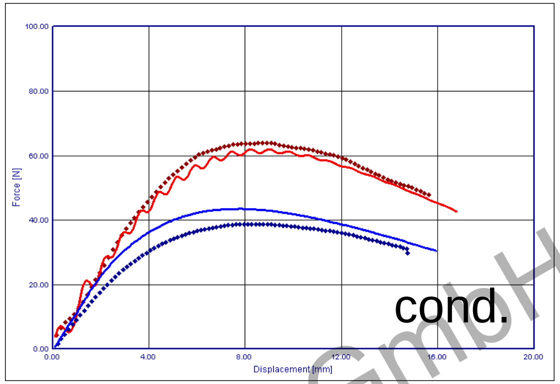
Second material - PA6 GF30 different moisture contents

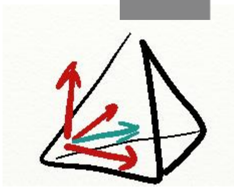
VALIMAT



90° orientation
static & dynamic bending

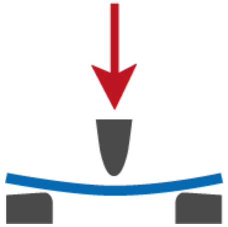




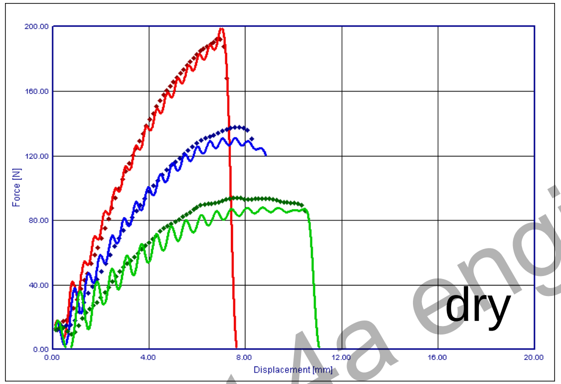


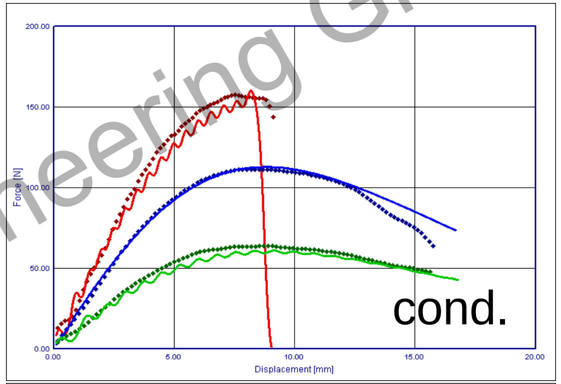
ELTYP4
0.5 mm

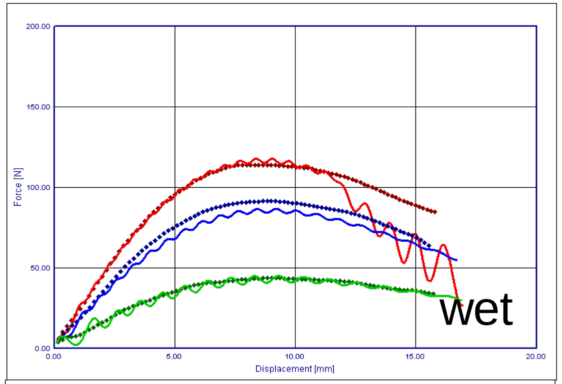
···· averaged test curves
— result of simulation

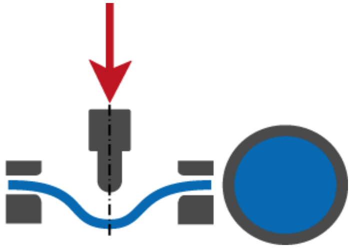


dynamic bending
0°, 30°, 90° orientation

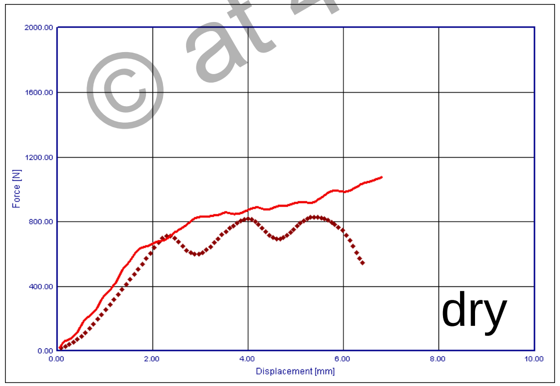


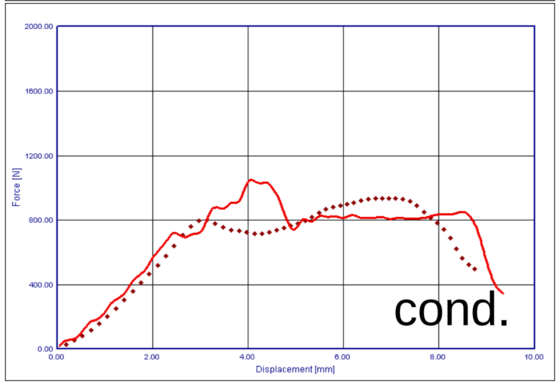


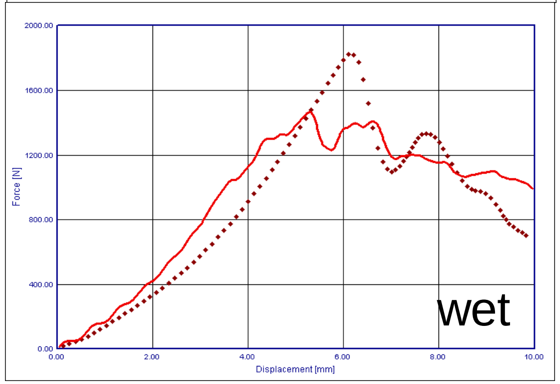




dynamic puncture test

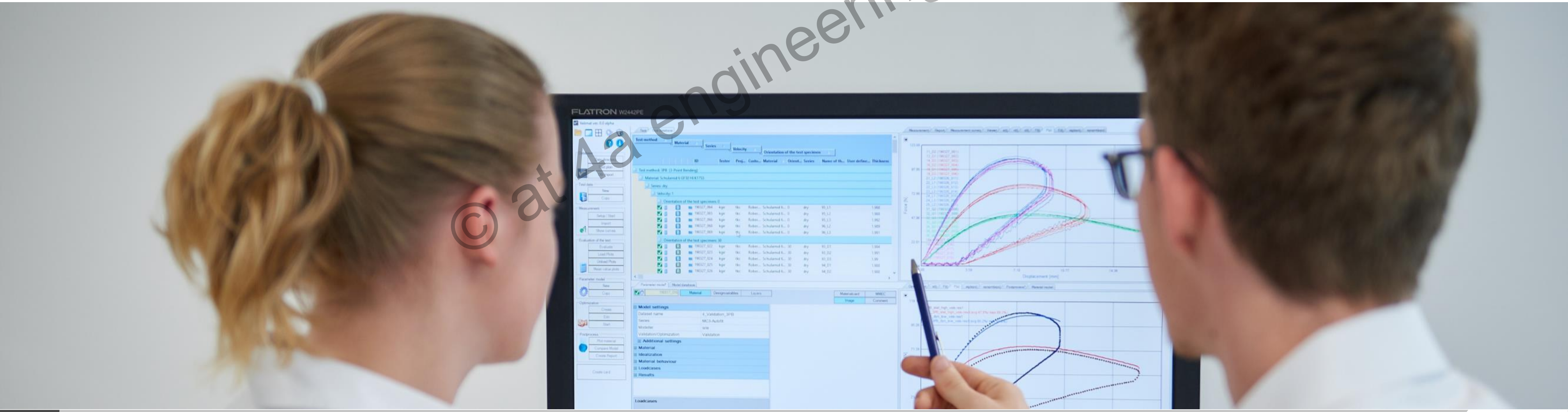






Source: P Reithofer, failure criteria SFRT and LFRT

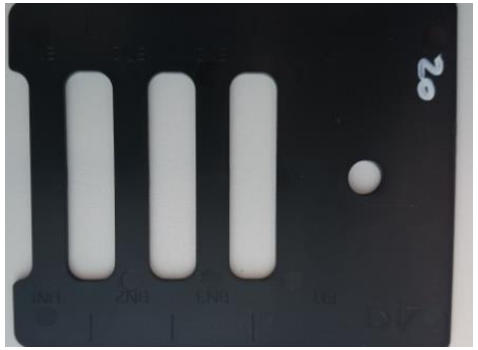
What else ?



injection mold for material characterization

DOM & Wall thickness

Melt- & Weldlines



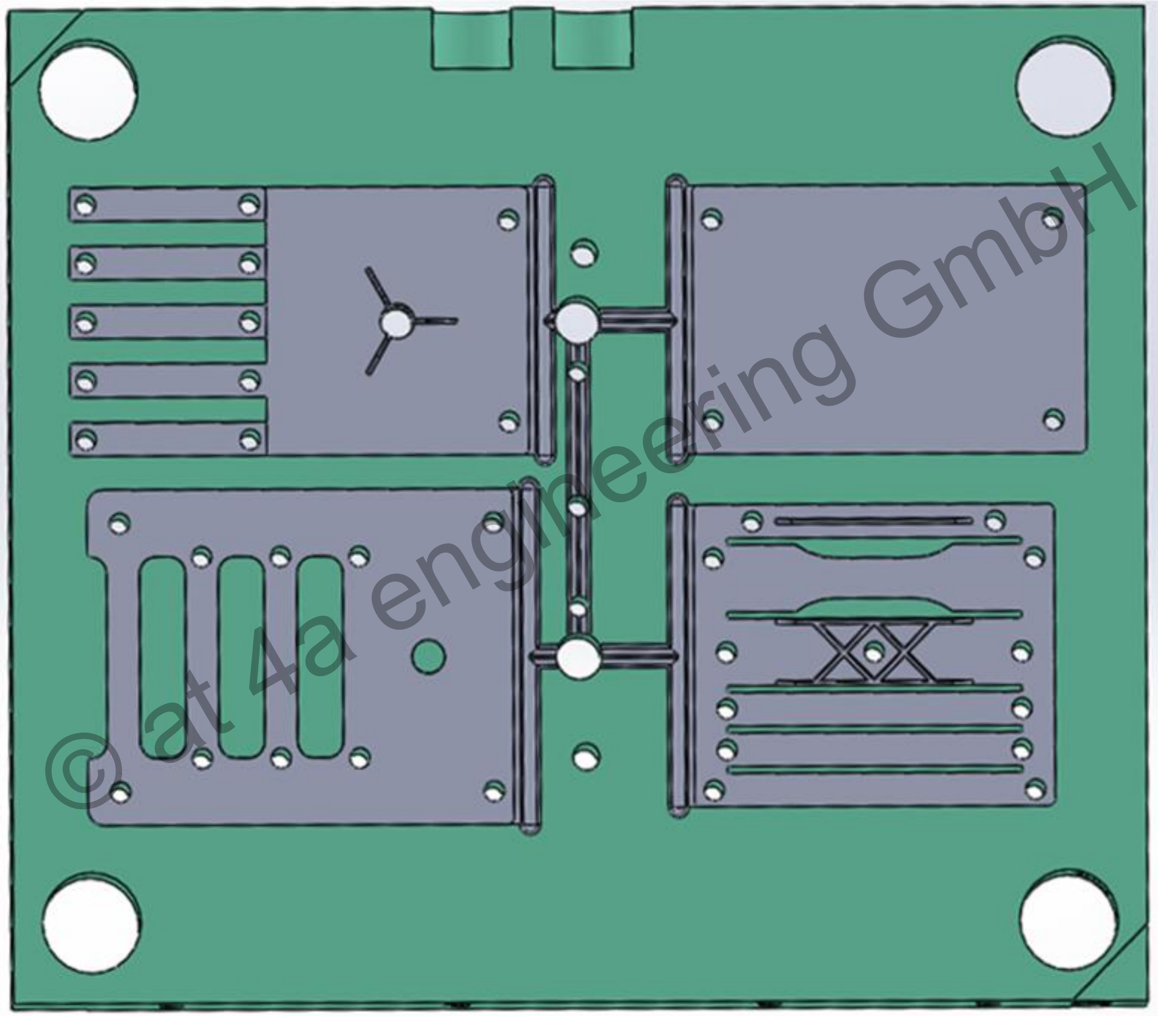
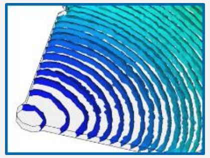


Plate 120 x 80 x 2 mm

Multi-Specimen &
Rib & Component

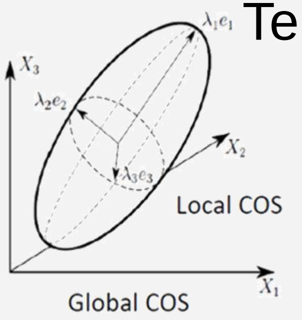
Material models – present approaches

Process simulation



$$a_{ij} = \begin{bmatrix} a_{xx} & a_{xy} & a_{xz} \\ & a_{yy} & a_{yz} \\ & & a_{zz} \end{bmatrix}$$

Tensor 2nd order

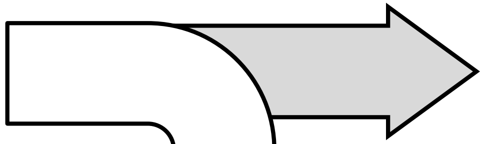


CADMOULD 3D-F SIMULATION

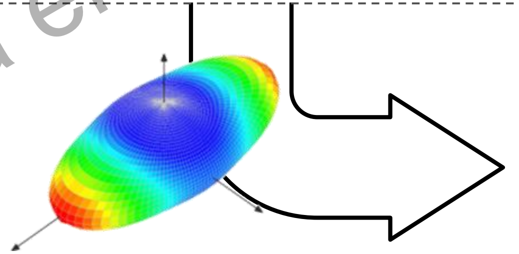
Moldex3D MOLDING INNOVATION

MOLDFLOW

FIBERMAP

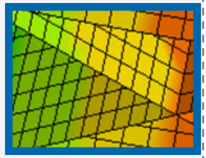


$$C^{-1} = \begin{bmatrix} \frac{1}{E_1} & -\frac{\nu_{21}}{E_2} & -\frac{\nu_{31}}{E_3} & 0 & 0 & 0 \\ -\frac{\nu_{12}}{E_1} & \frac{1}{E_2} & -\frac{\nu_{32}}{E_3} & 0 & 0 & 0 \\ -\frac{\nu_{13}}{E_1} & -\frac{\nu_{23}}{E_2} & \frac{1}{E_3} & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{1}{G_{23}} & 0 & 0 \\ 0 & 0 & 0 & 0 & \frac{1}{G_{31}} & 0 \\ 0 & 0 & 0 & 0 & 0 & \frac{1}{G_{21}} \end{bmatrix}$$



MICROMEC

Structural simulation

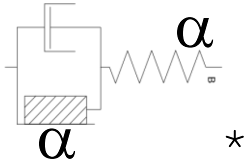


Homogenization (Micro Scale)
Mean Field Theory

$$\overline{\sigma}^C = \varphi \overline{\sigma}^F + (1-\varphi)\overline{\sigma}^M$$

*MAT_215

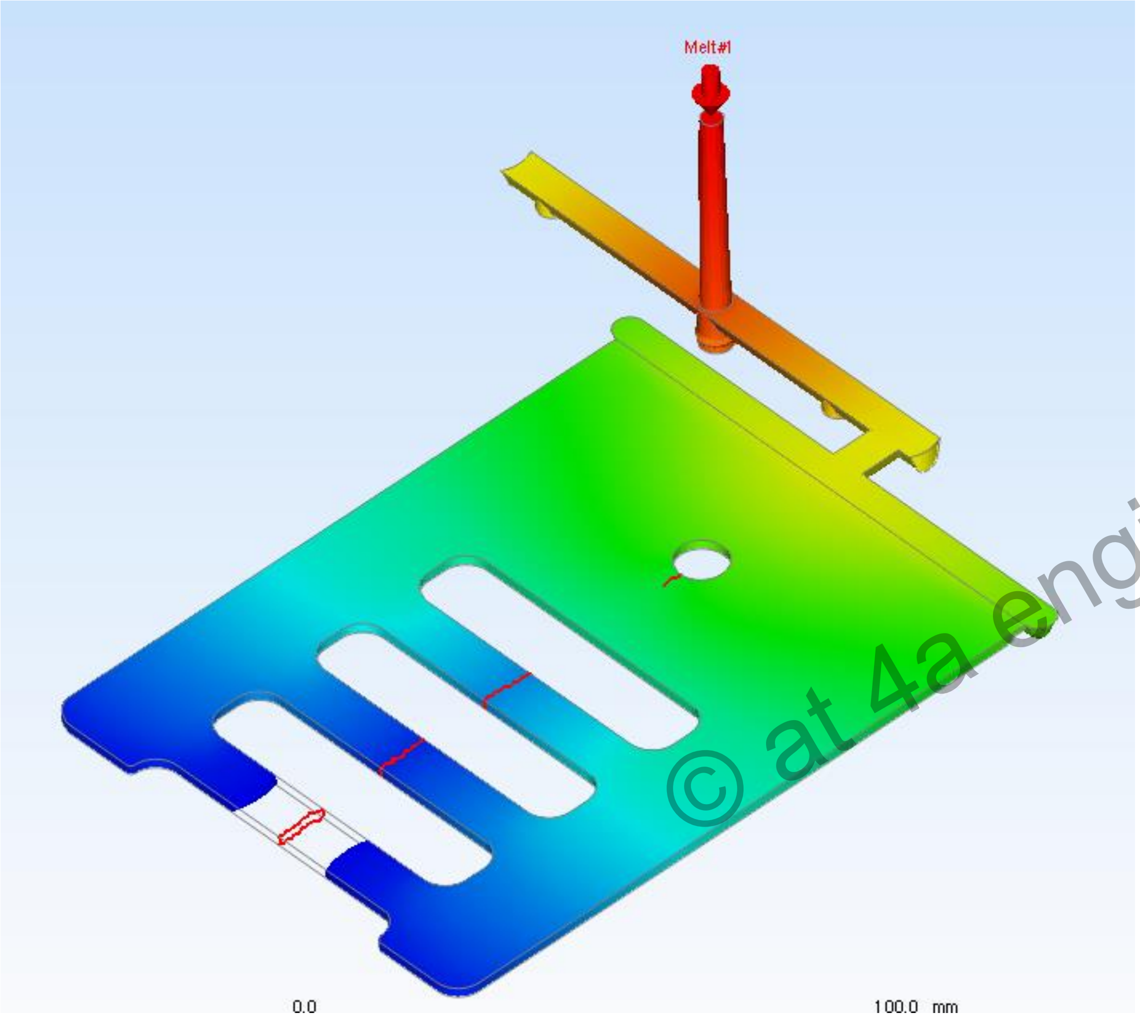
Composite (Macro Scale)
Hill Plasticity

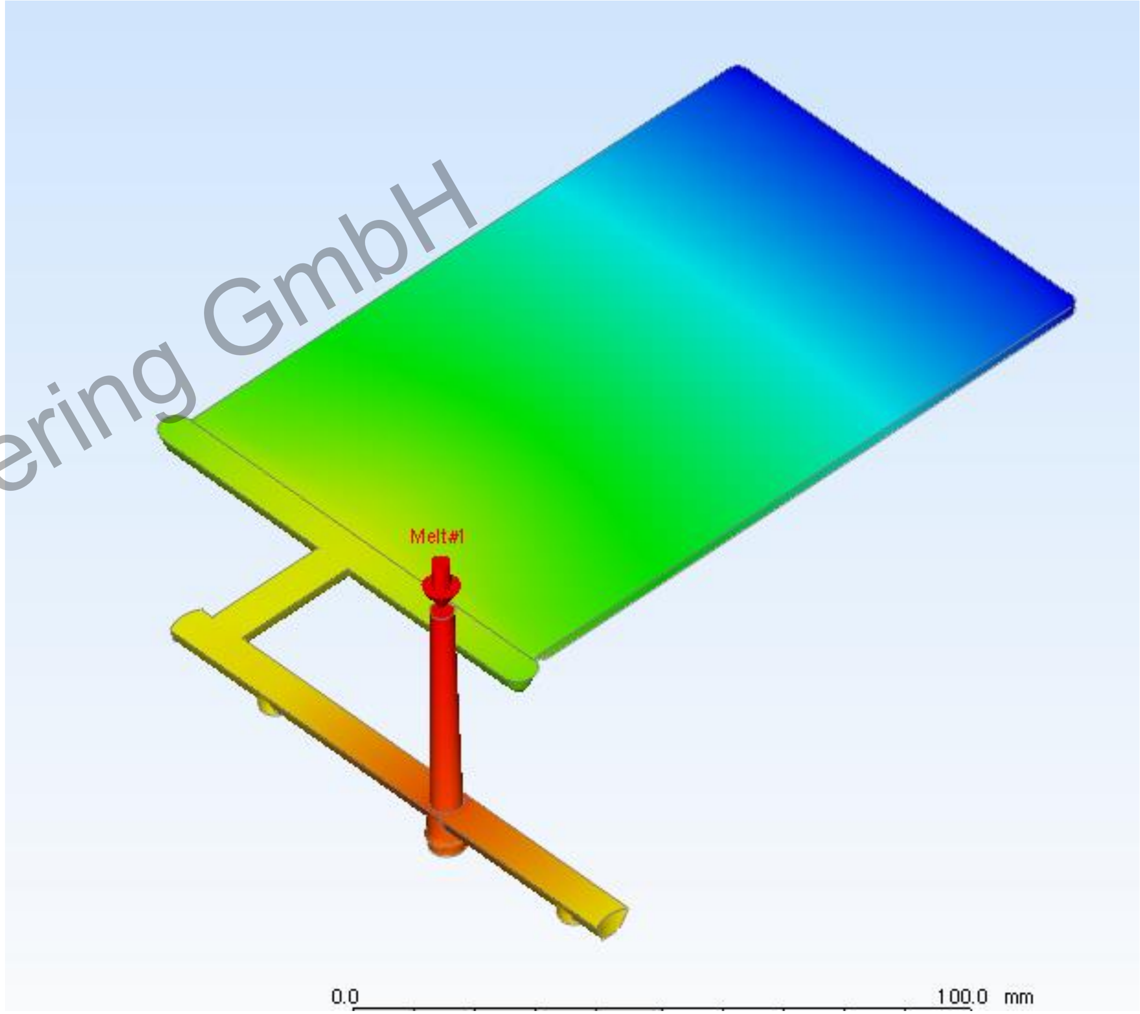


*MAT_157

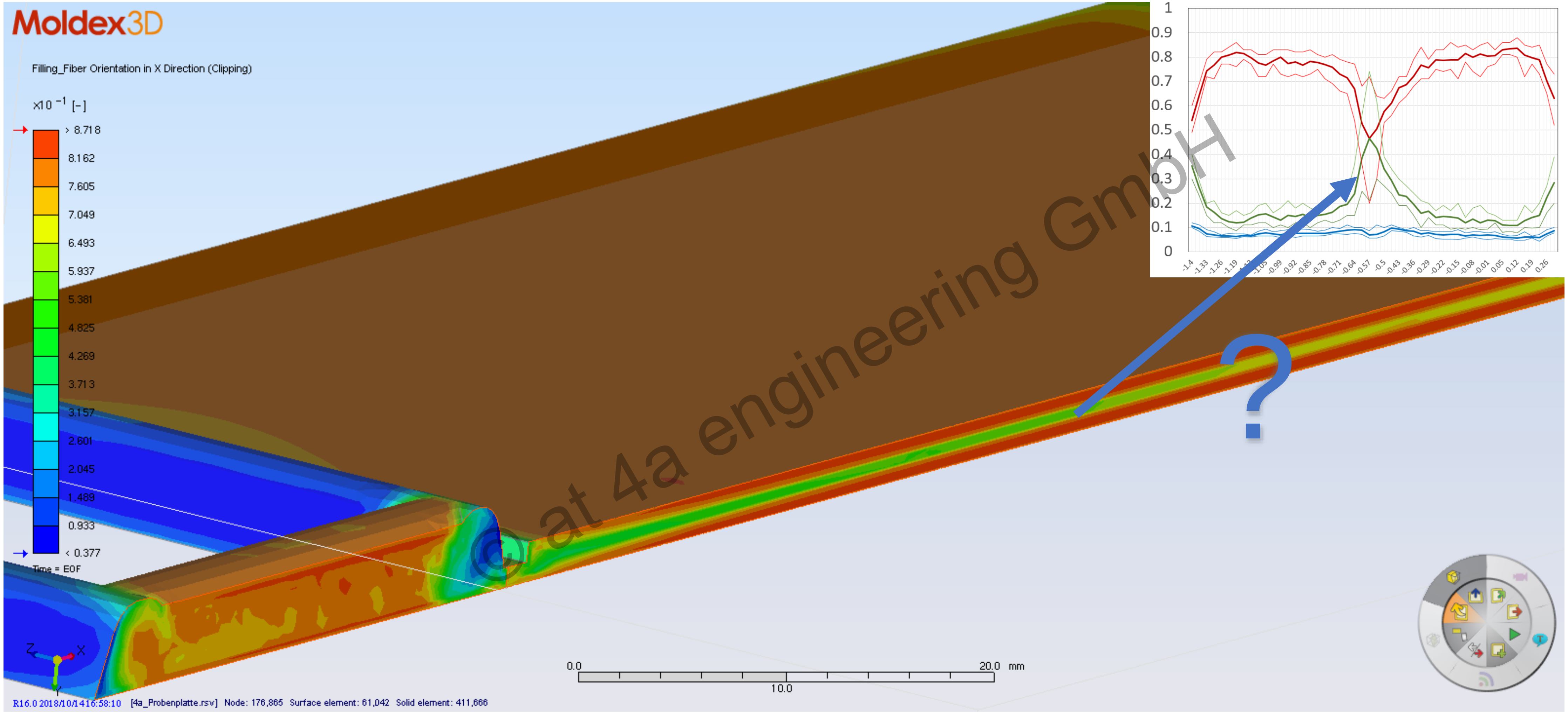
LSTC Livermore Software Technology Corp.
LS-DYNA®

injection mold – process simulation

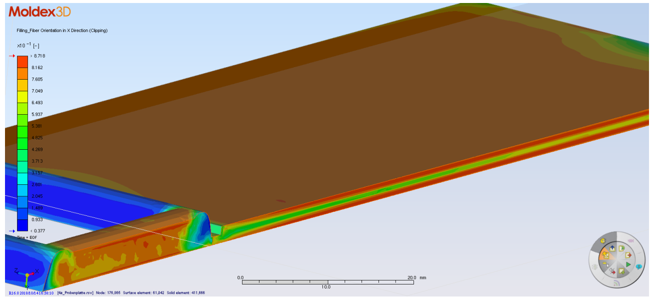


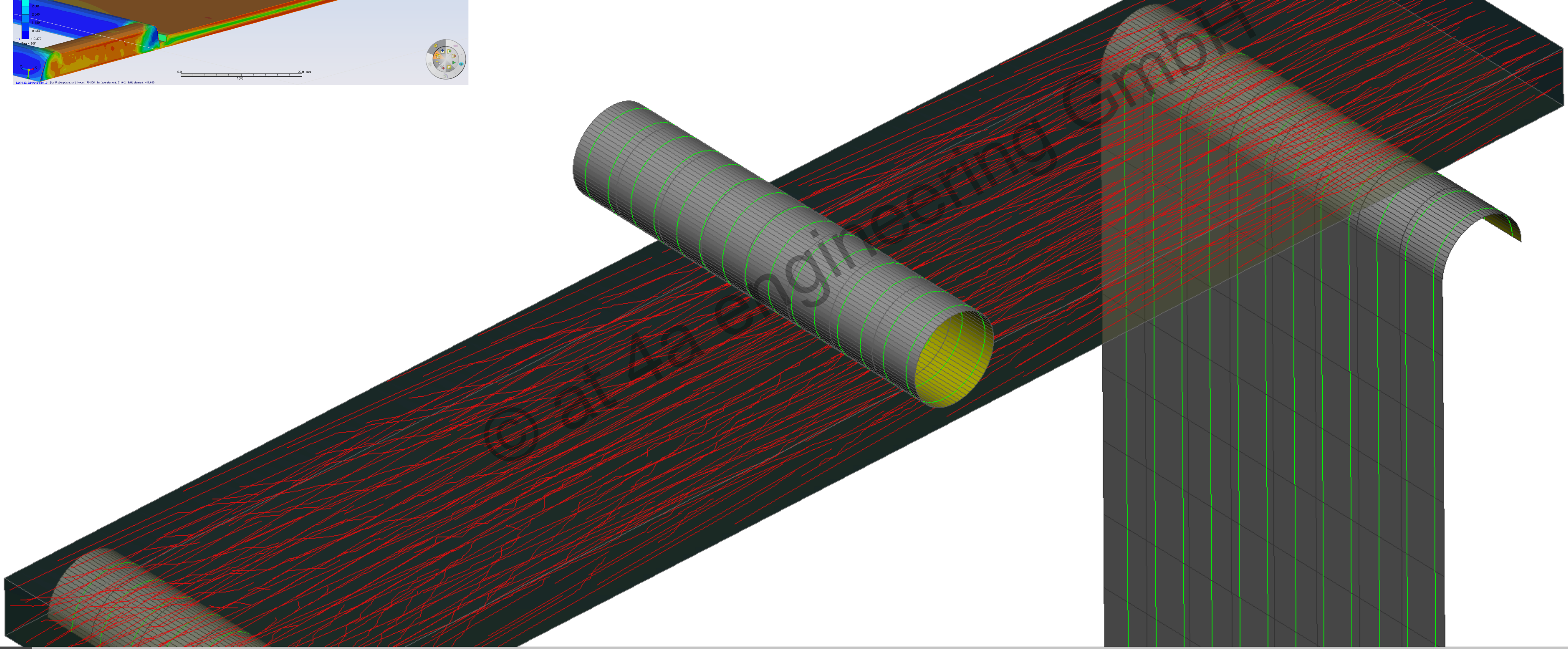


injection mold – process simulation fiber orientation



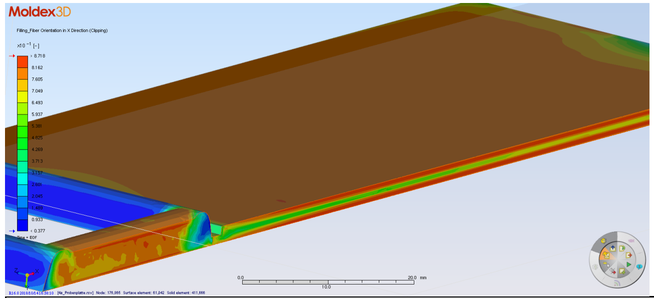
injection mold – process simulation & mapping

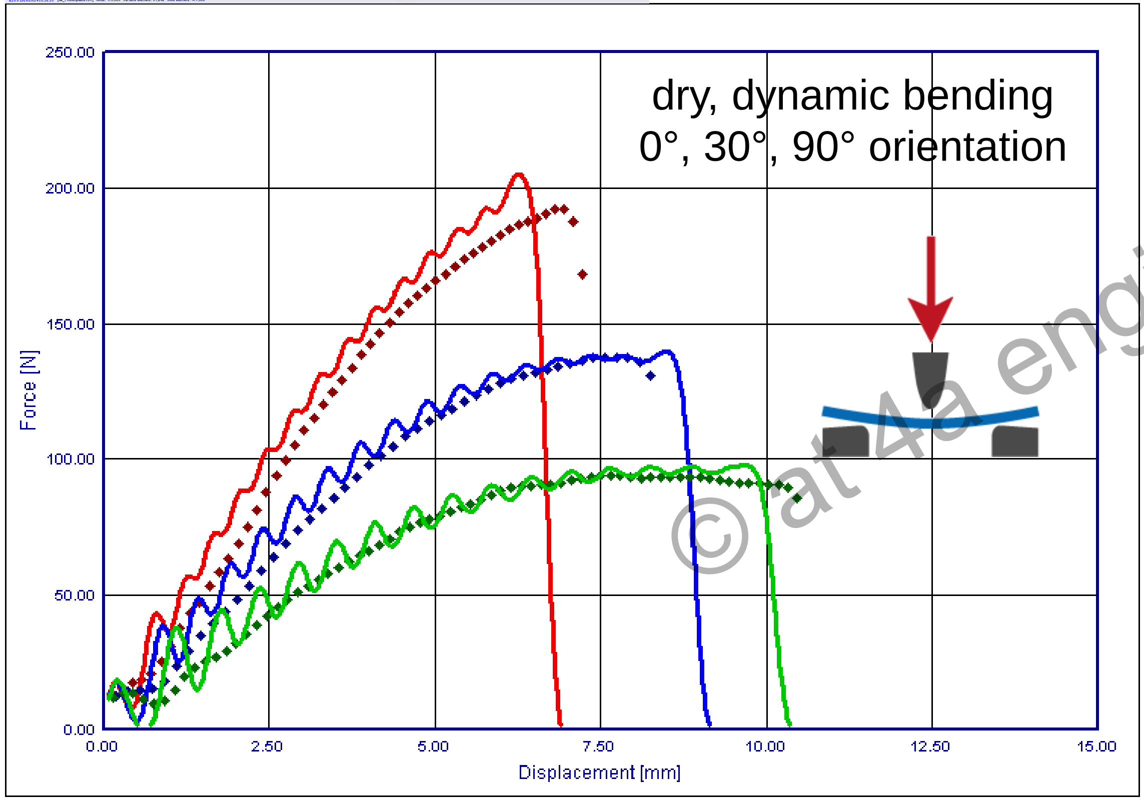


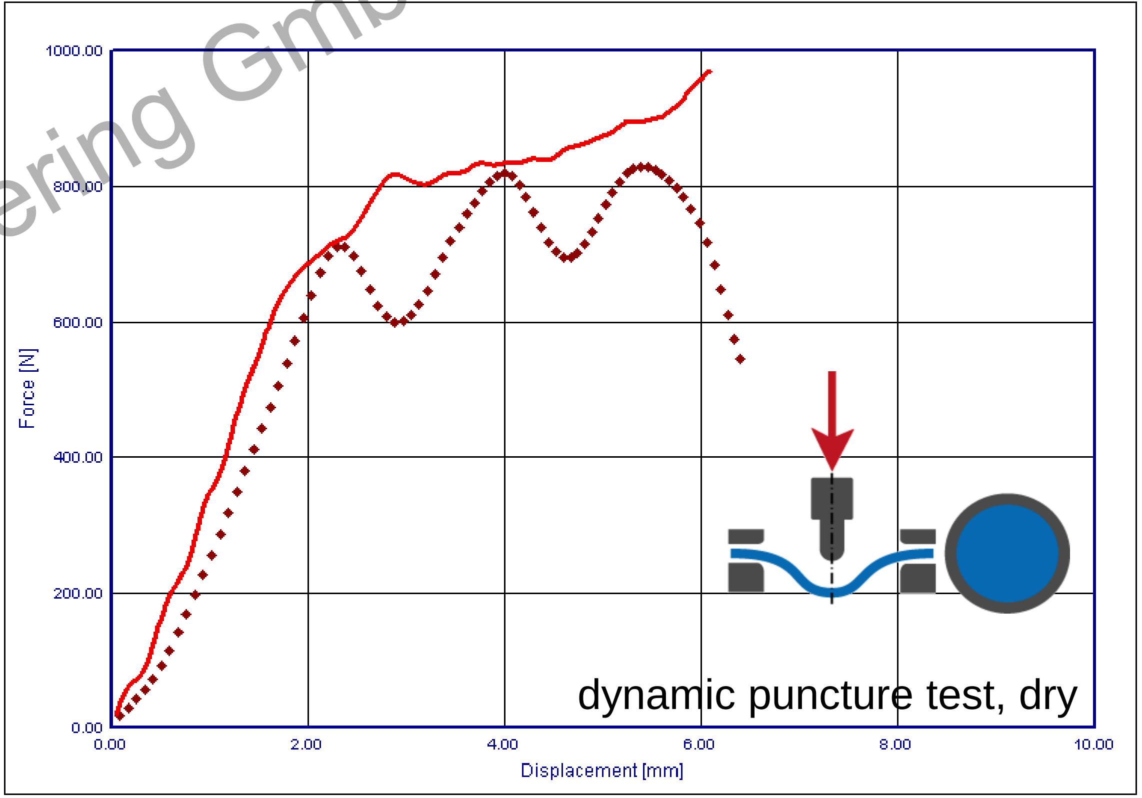


injection mold – process simulation & mapping

Scale of hardening curve ~20%



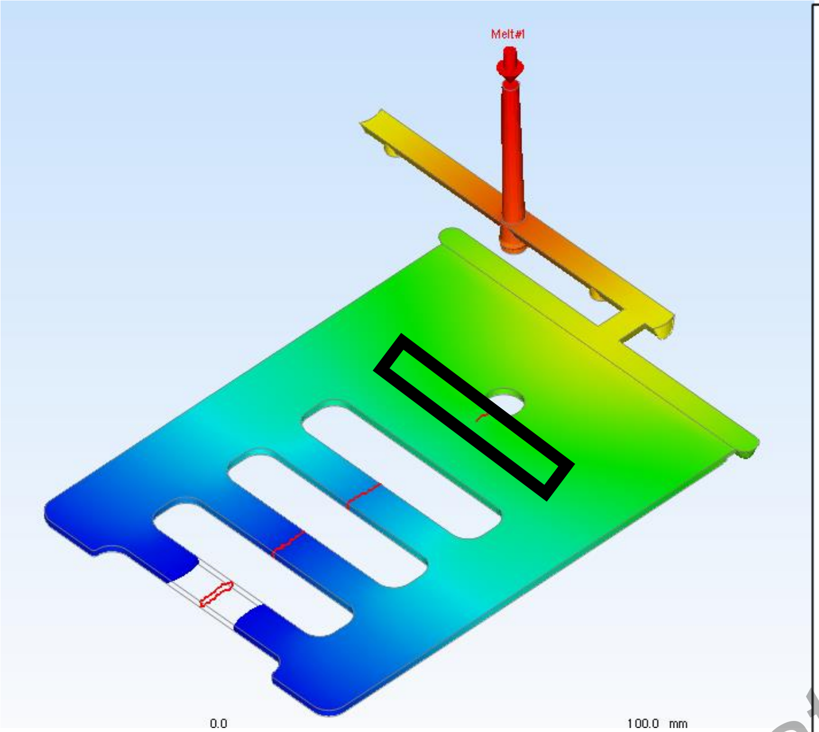


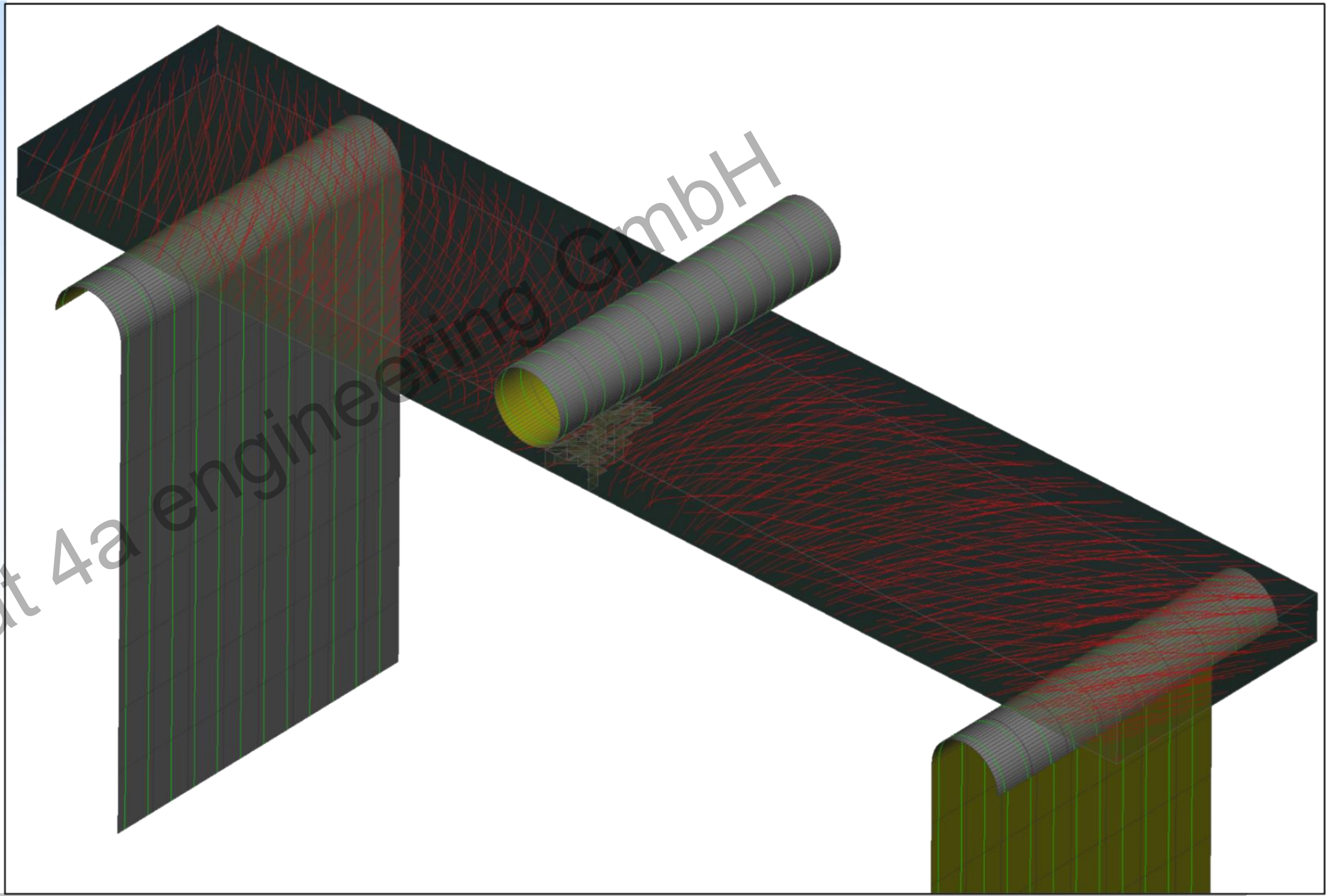


Source: P Reithofer, failure criteria SFRT and LFRT

injection mold – process simulation & mapping

FIBERMAP

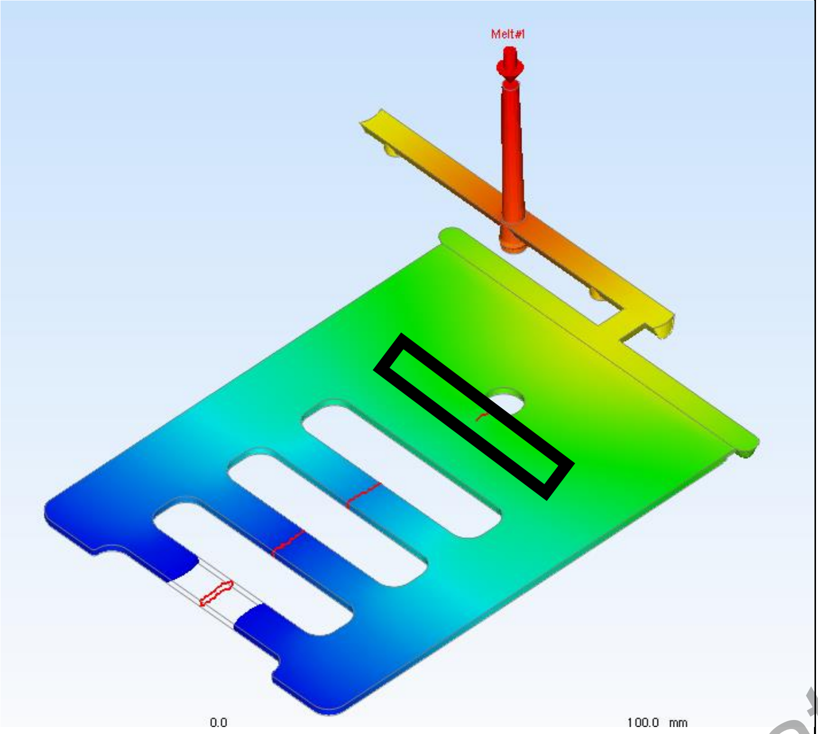




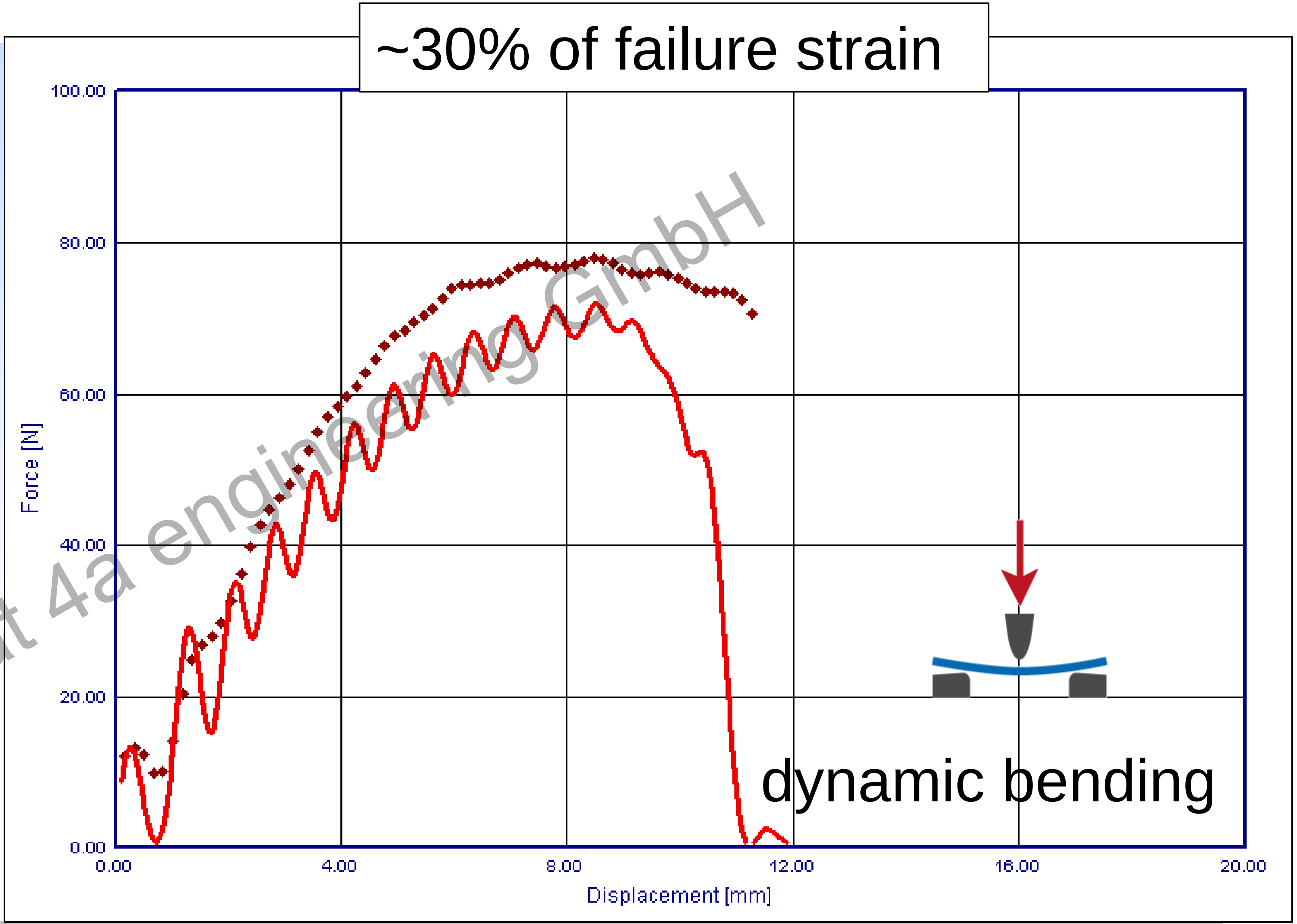
meltline

Source: P Reithofer, failure criteria SFRT and LFRT

injection mold – process simulation & mapping



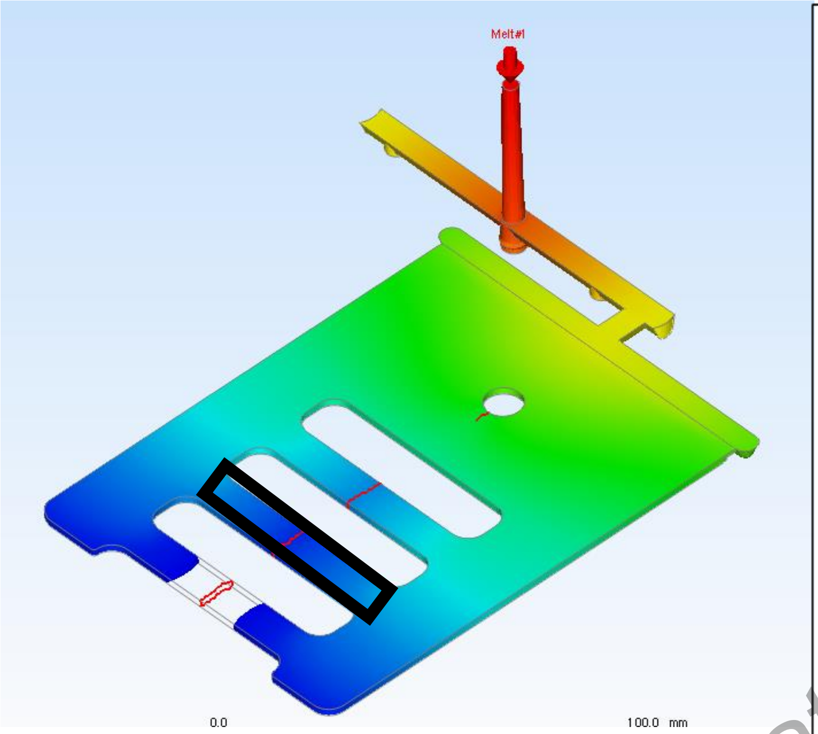
meltline



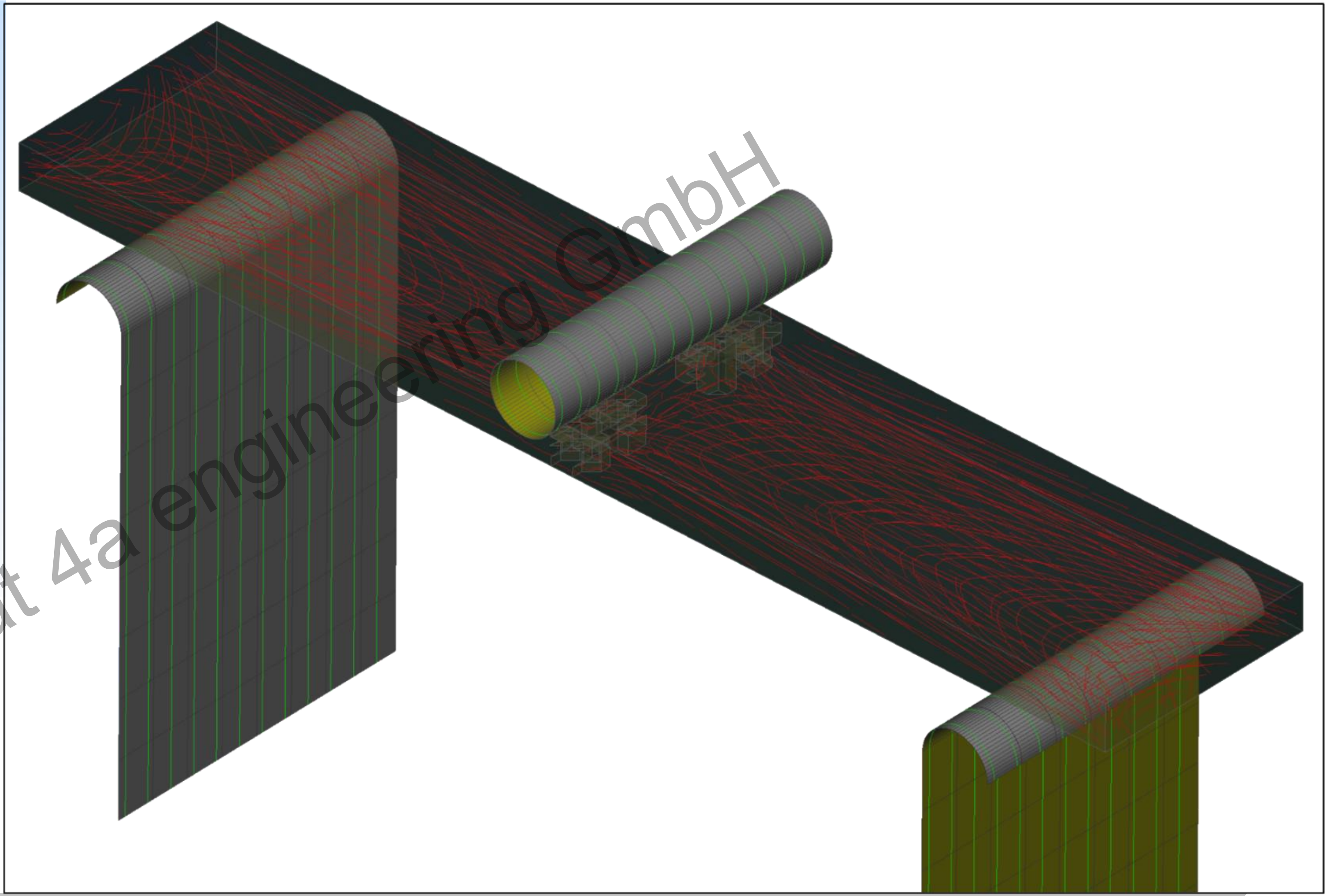
Source: P Reithofer, failure criteria SFRT and LFRT

injection mold – process simulation & mapping

FIBERMAP



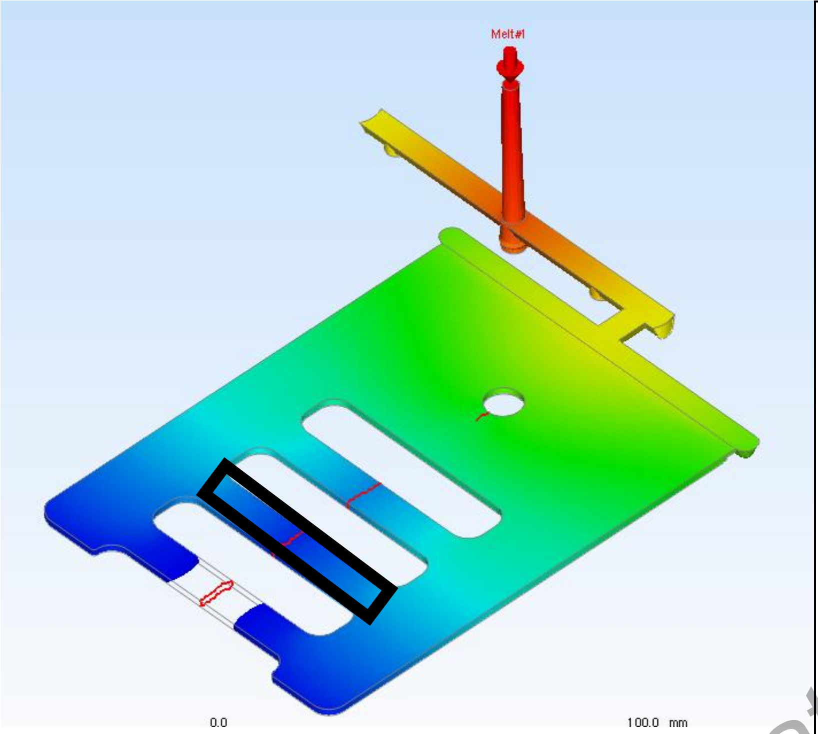
weldline



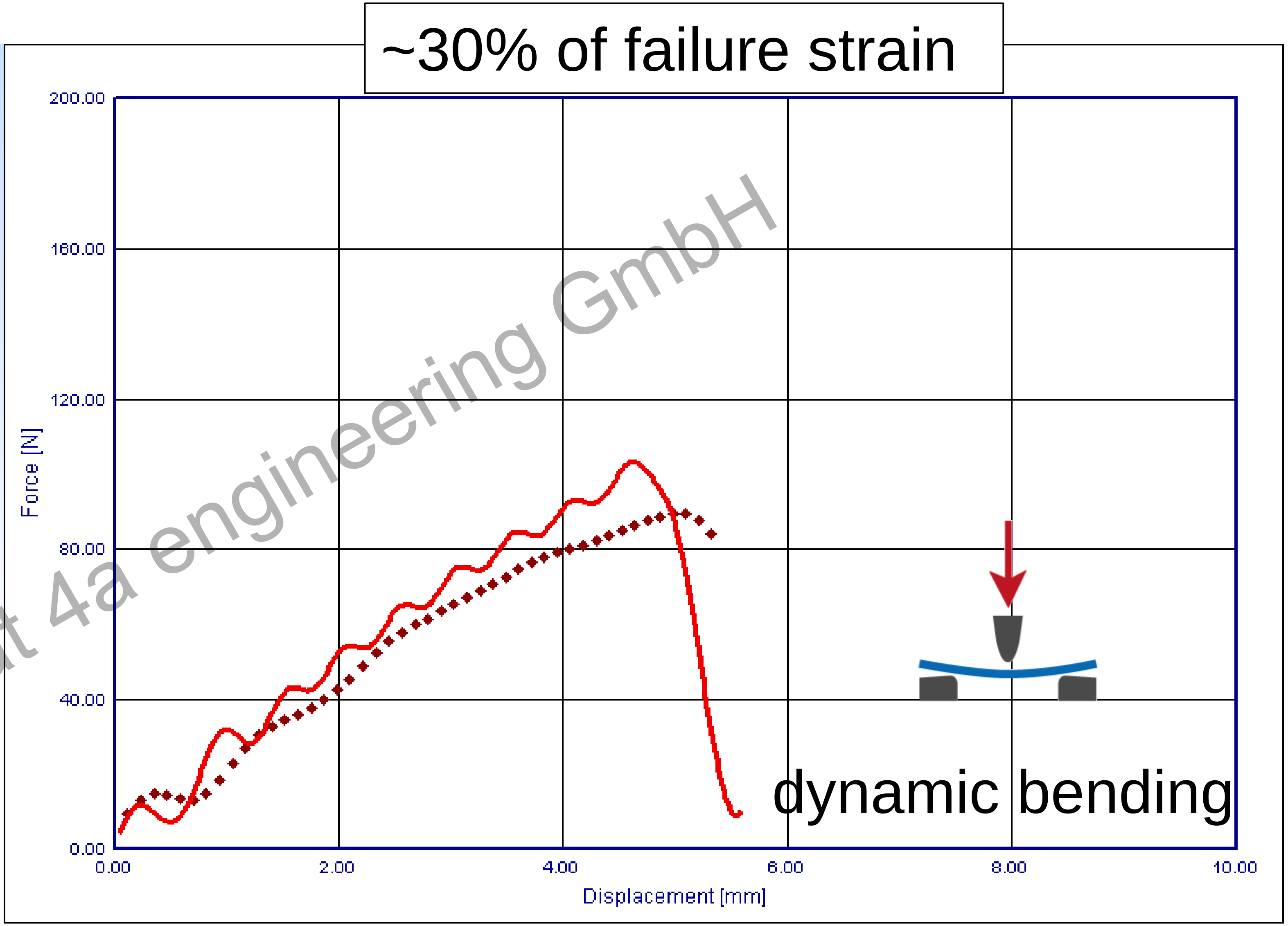
Source: P Reithofer, failure criteria SFRT and LFRT

injection mold – process simulation & mapping

FIBERMAP

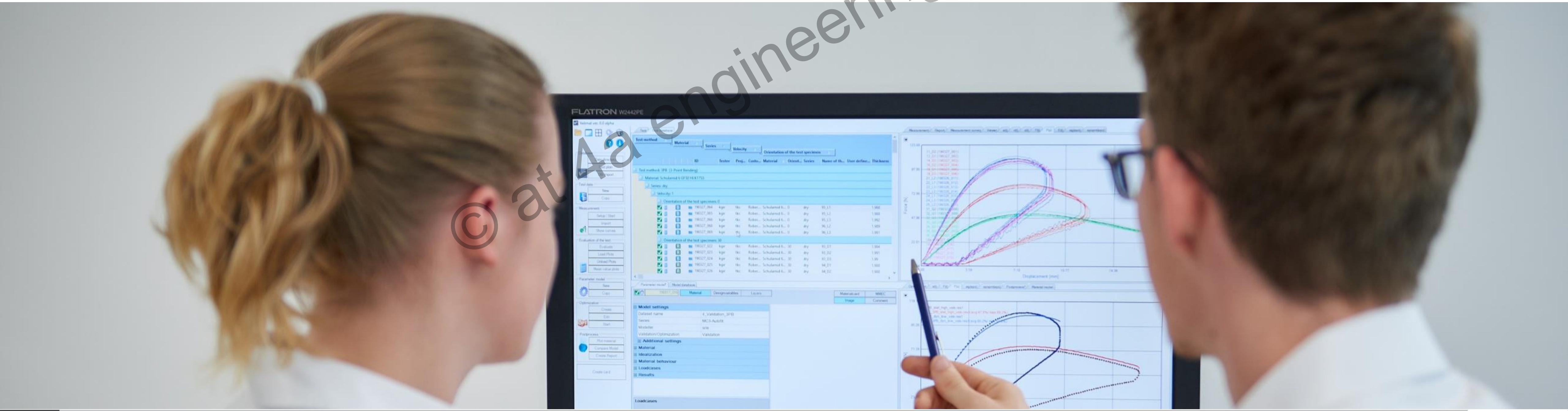


weldline

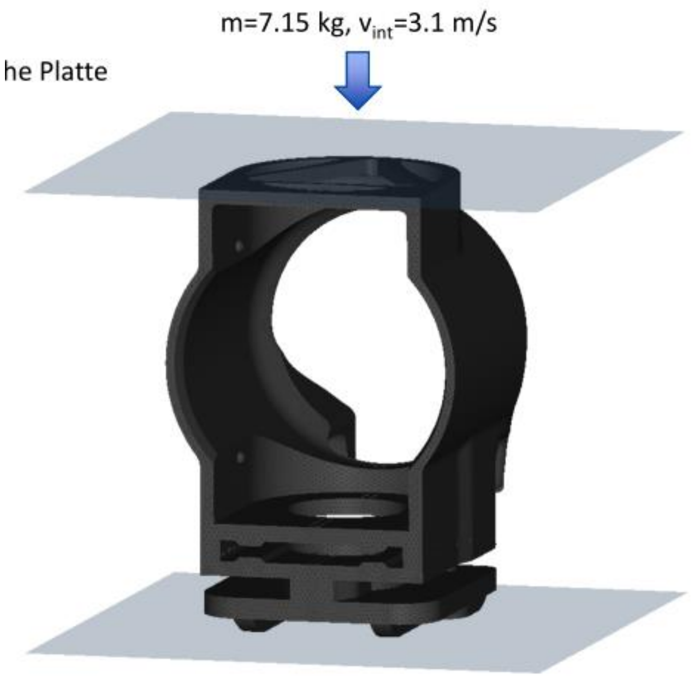


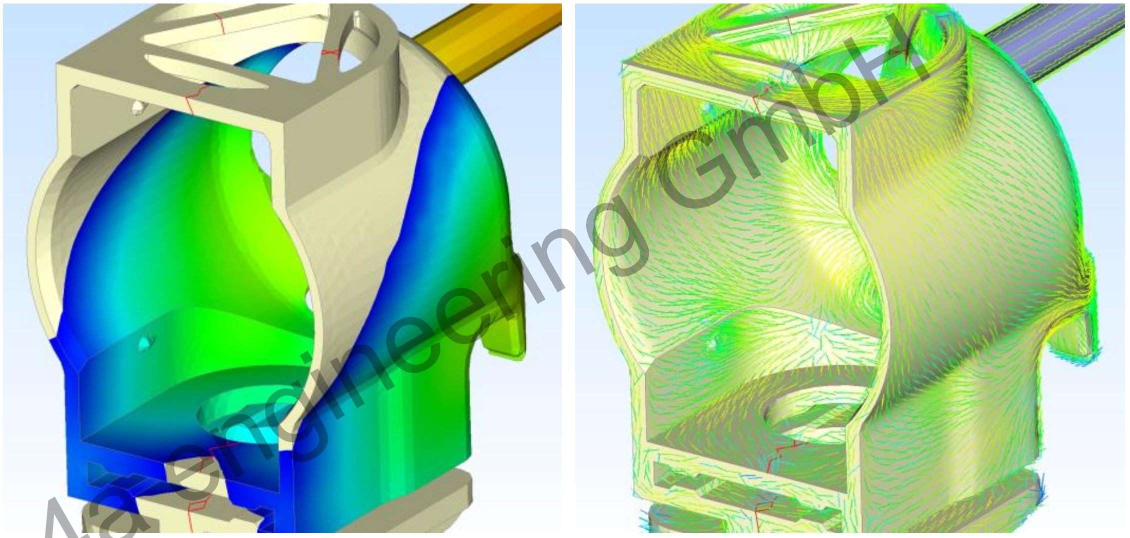
Source: P Reithofer, failure criteria SFRT and LFRT

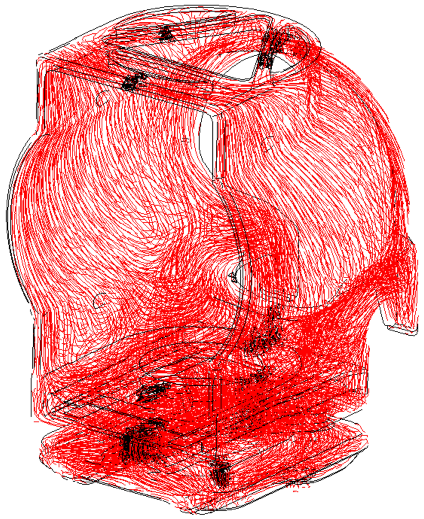
Case Study



Casestudy - sleeve



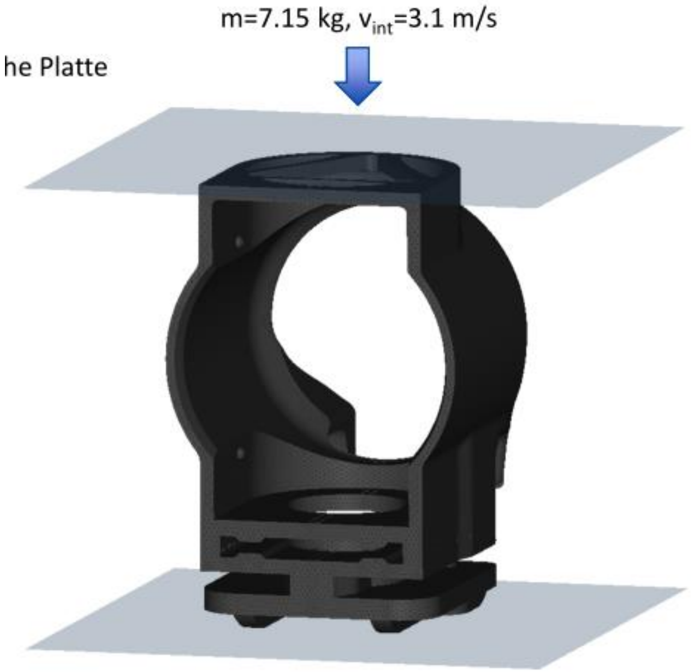




Typische Elementgröße: 0.25mm
Elementtyp: Tetrahedron Type 10
Elementanzahl: 469 470

See more: R. Steinberger, et.al. Hirtenberger Automotive Group – *Considering the Local Anisotropy of Short Fiber Reinforced Plastics, European Dynaforum 2017*

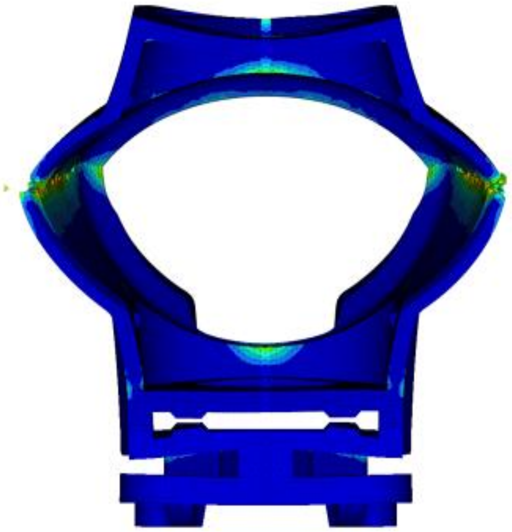
Casestudy - sleeve



test

*MAT_157/215
local anisotropy

*MAT_24
isotropic



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Intelligent reliable solutions for plastics, composites, metals, foams, ...

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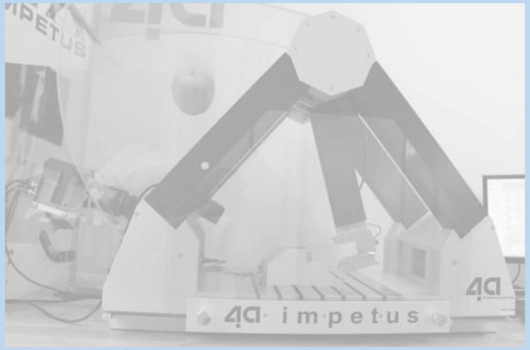
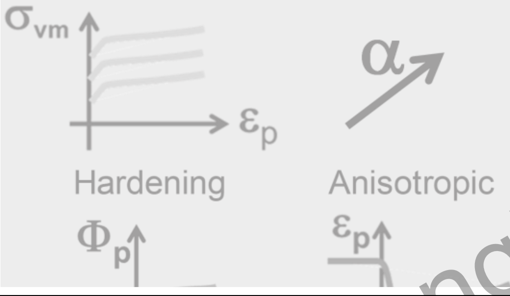


efficient
dynamic testing

VALIMAT



from test to validated
material cards

MICROMEC

3D anisotropic
material cards

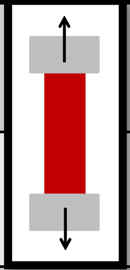
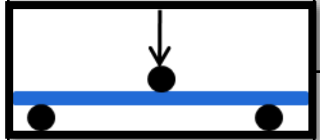
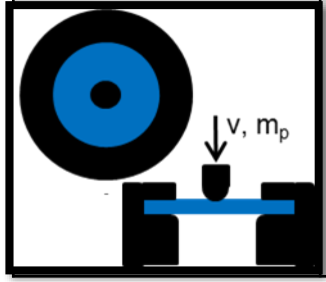
FIBERMAP

individual mapping
process information

Composites (Carbon)

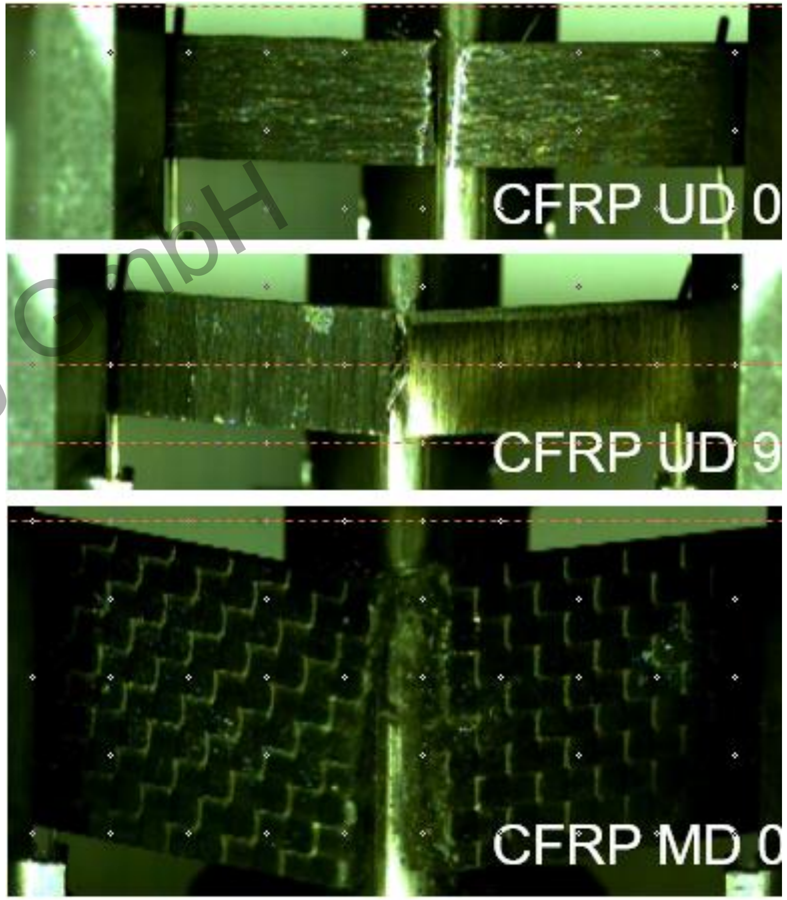
Composites – typical test setup

IMPETUS

	specimen		0°	45°	90°
	═	UD		static	
	╫	MD		static, cyclic	
	═	UD		static, dynamic	
	╫	MD		static, dynamic	
	╫	MD		Puncture	

Material Card

Validation



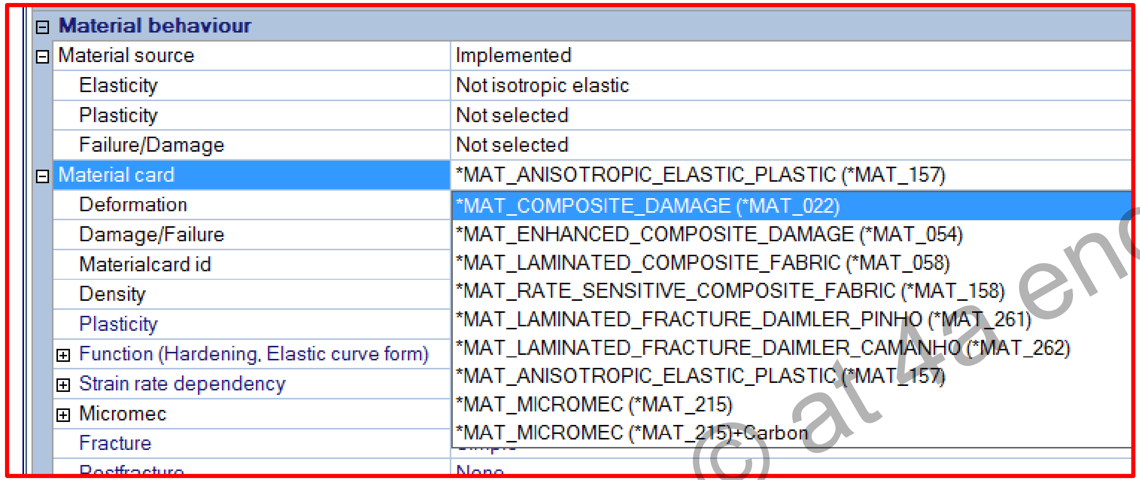
Composites – available LS-DYNA material models

VALIMAT

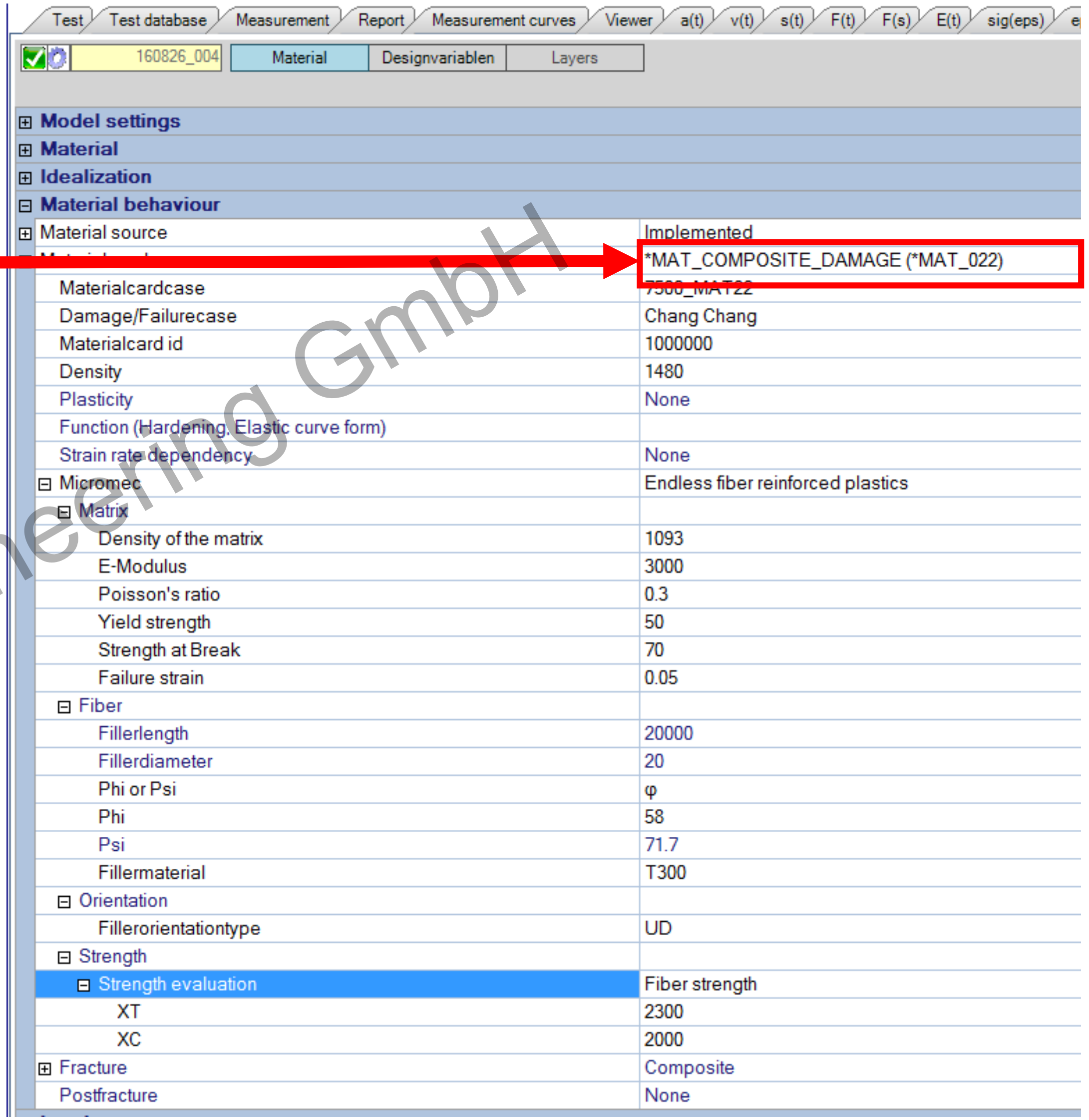
No.	Elastic	Plastic	Damage	Strain rate	Failure	
22	Orthotropic	None	None	None	Orientation dependent	**Carbon, Glass, Kevlar endless & fabric**
54/55	Orthotropic	None	Elastic Orthotropic	Strength	Chang-Chang/ Tsai-Wu Orientation dependent	
58	Orthotropic	None	Elastic Orthotropic	Strength, Stiffness	mod. Hashin Orientation dependent	
158	Orthotropic	None	Elastic Orthotropic	Visco-elasticity	Orientation dependent	
261	Orthotropic	None	Elastic Orthotropic	None	failure Pinho (Puck) Orientation dependent	
262	Orthotropic	None	Elastic Orthotropic	None	failure Camanho (Puck) Orientation dependent	

Composites – micro mechanical approach in VALIMAT

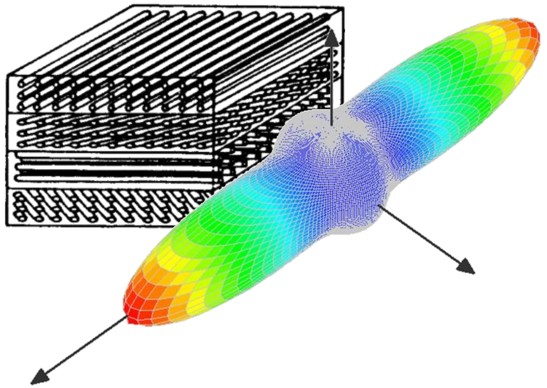
***Part_Composite**



Available LS-DYNA materialcards in VALIMAT™

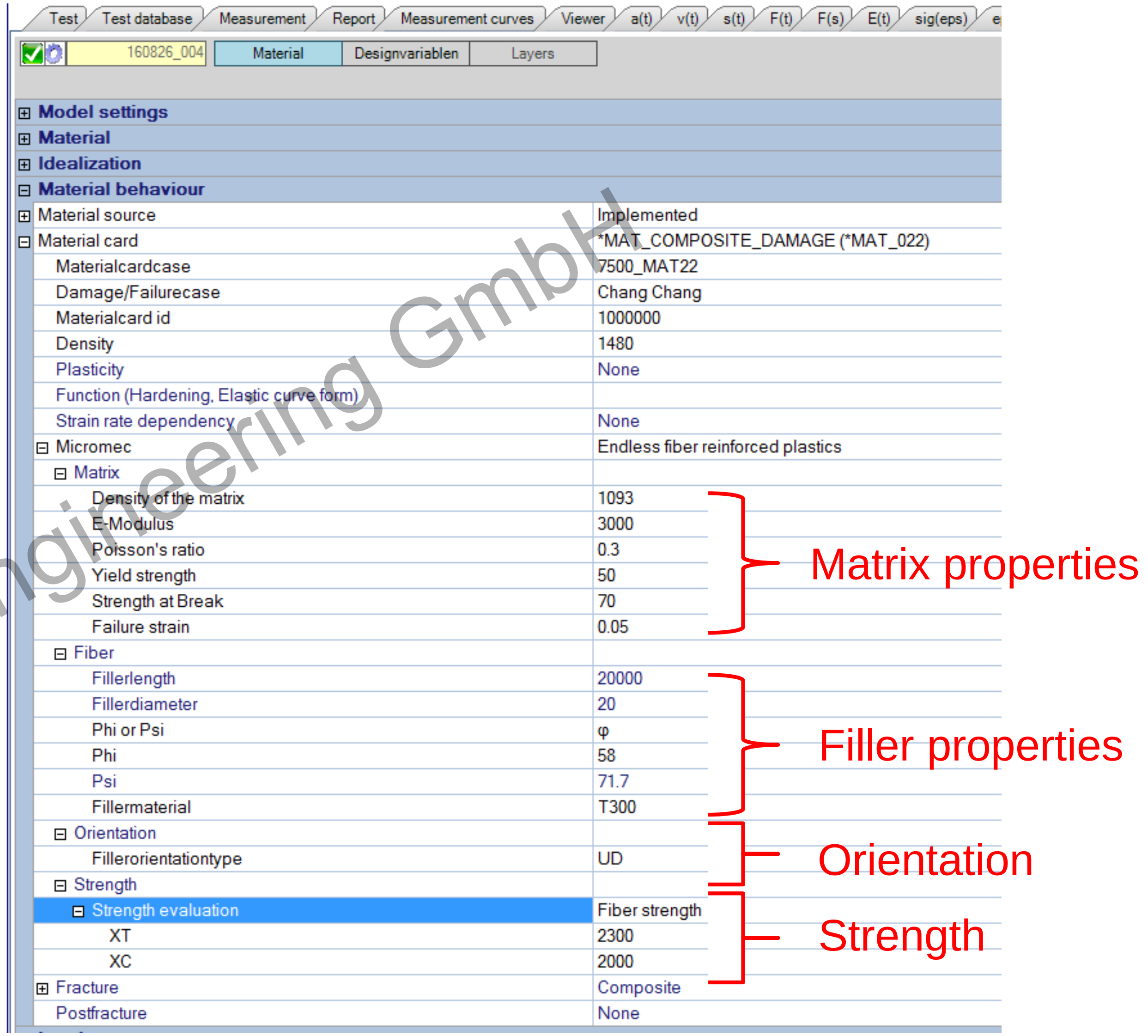


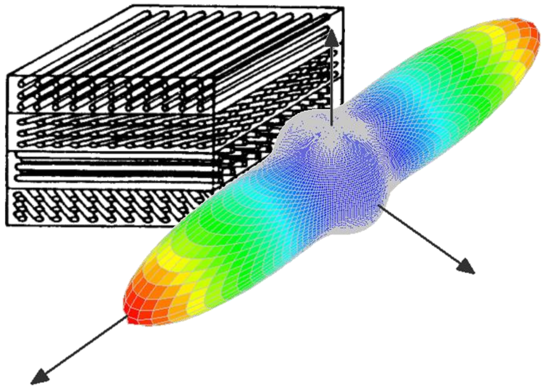
Composites – micro mechanical approach in VALIMAT



$$\overline{\sigma}^{C} = \varphi\overline{\sigma}^{F} + (1-\varphi)\overline{\sigma}^{M}$$

C...composite, F...fiber, M...matrix





$$\overline{\sigma}^{C} = \varphi \overline{\sigma}^{F} + (1-\varphi)\overline{\sigma}^{M}$$

C...composite, F...fiber, M...matrix

Typical Design Variables for `*MAT_022`

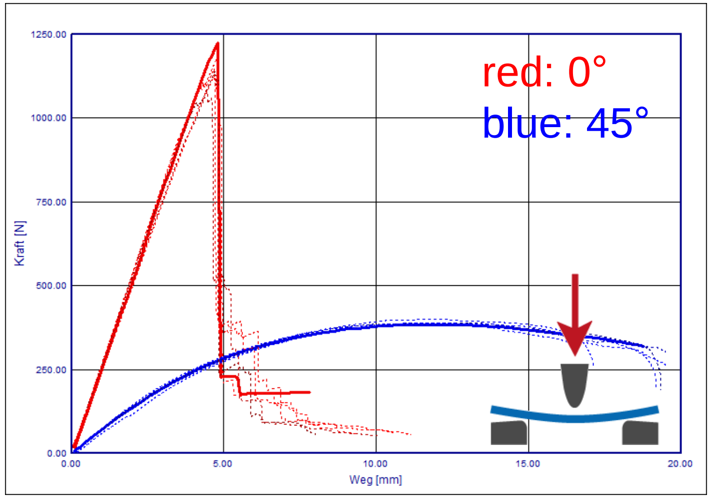
160826_004 | Material | Designvariablen | Layers

Name	Start	const...	from	to	Variance	Condi...	Description
GroupName: 10_elasticity							
c_E11	MMEC	☐	100000	180000	(NULL)		young modulus tensile in 1 direction
c_E22	MMEC	☑	(NULL)	(NULL)	(NULL)		young modulus tensile in 2 direction
c_E33	MMEC	☑	(NULL)	(NULL)	(NULL)		young modulus tensile in 2 direction
c_nue21	MMEC	☑	(NULL)	(NULL)	(NULL)		poisson ration in 21 plane
c_nue31	MMEC	☑	(NULL)	(NULL)	(NULL)		poisson ration in 31 plane
c_nue32	MMEC	☑	(NULL)	(NULL)	(NULL)		poisson ration in 32 plane
c_G12	MMEC	☑	(NULL)	(NULL)	(NULL)		shear modulus in 12 plane
c_G23	MMEC	☑	(NULL)	(NULL)	(NULL)		shear modulus in 23 plane
c_G31	MMEC	☑	(NULL)	(NULL)	(NULL)		shear modulus in 31 plane
GroupName: 51_failure							
fc_R11T	MMEC	☑	(NULL)	(NULL)	(NULL)		
fc_R11C	MMEC	☑	(NULL)	(NULL)	(NULL)		
fc_R22T	MMEC	☑	(NULL)	(NULL)	(NULL)		
fc_R22C	MMEC	☑	(NULL)	(NULL)	(NULL)		
fc_R12	MMEC	☑	(NULL)	(NULL)	(NULL)		

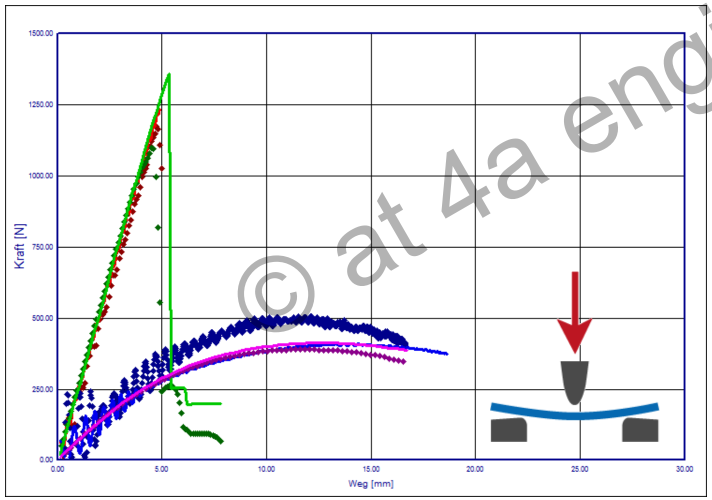
Composites – validation with final material card

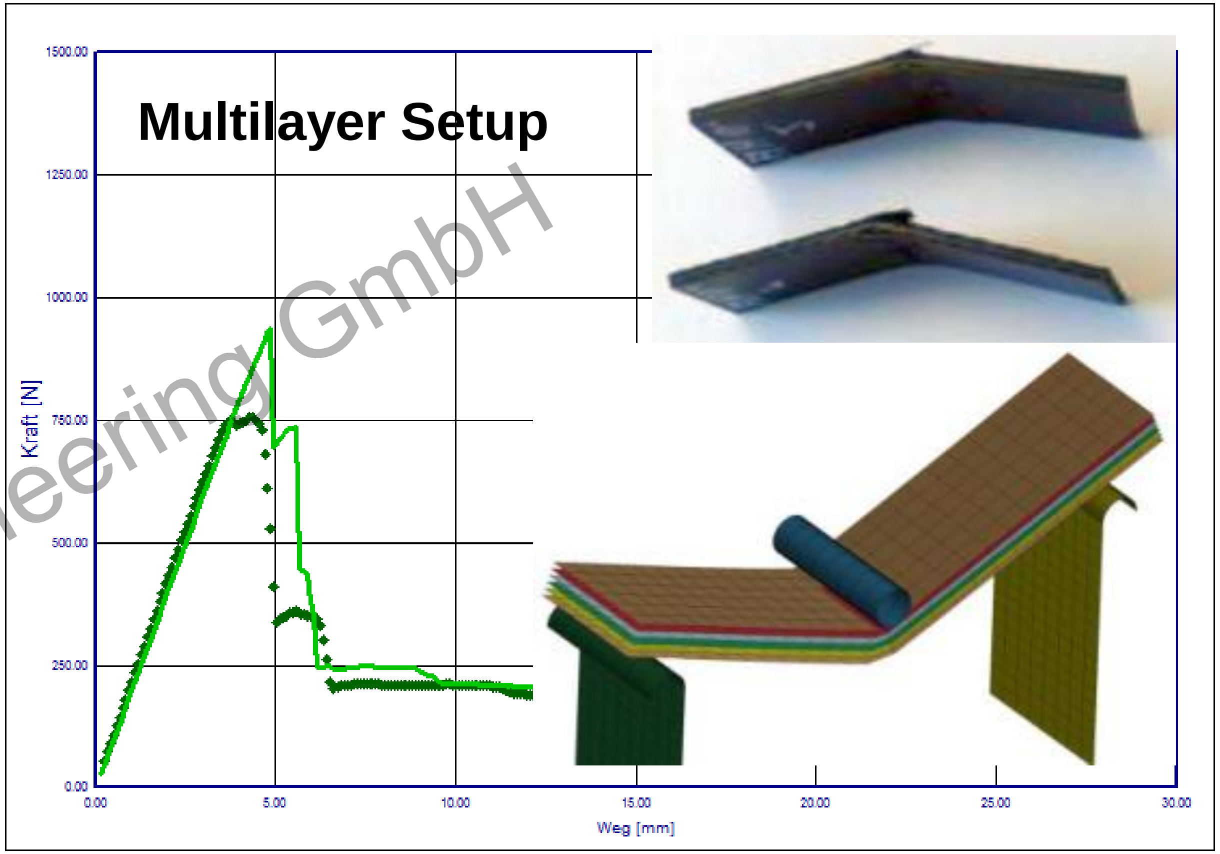
VALIMAT

Orientation



static versus dynamic

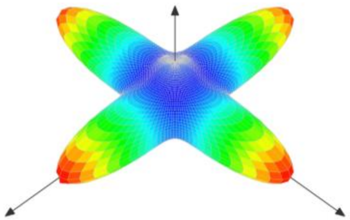




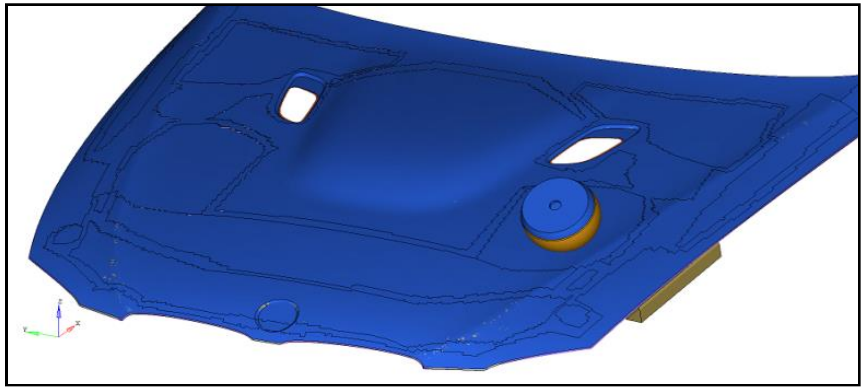
…. test
— simulation

P. Reithofer (4a engineering GmbH) & B. Fellner (MAGNA STEYR Engineering Austria) - Materialcharakterisierung von Composites; 4a Technologietag 2015

Composite – case study



- Front hood
  - Stiffness versus pedestrian safety
- Material card
  - Composite layup with anisotropic material behavior
  - Core material – Honeycomb different compression levels



SOURCE: LINK to PAPER

intelligent reliable solutions for plastics, composites, metals, foams, ...

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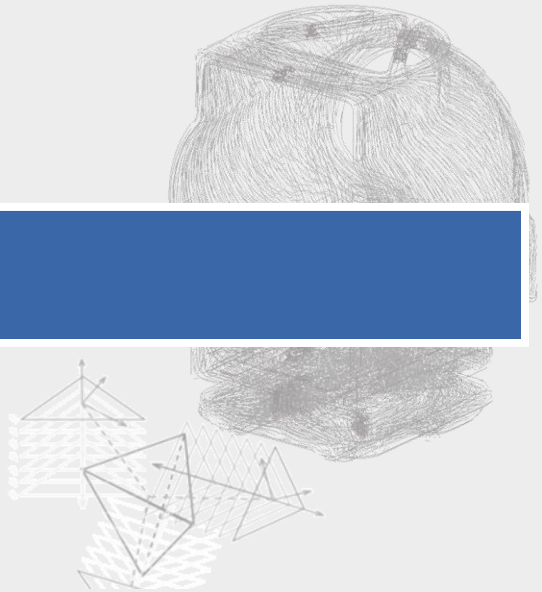
VALIMAT

MICROMEC

FIBERMAP



Thermoplastics

Fiber reinforced Plastics (SFRT & LFRT)

Composites (Carbon)

efficient
dynamic testing

from test to validated
material cards

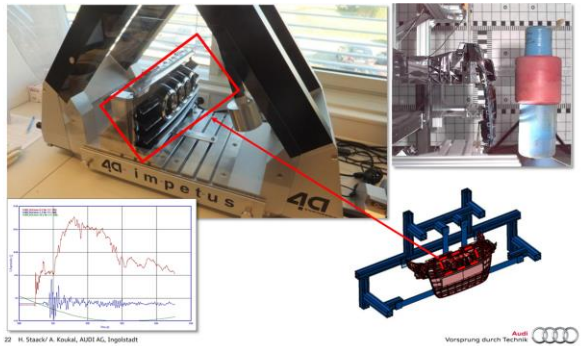
3D anisotropic
material cards

individual mapping
process information

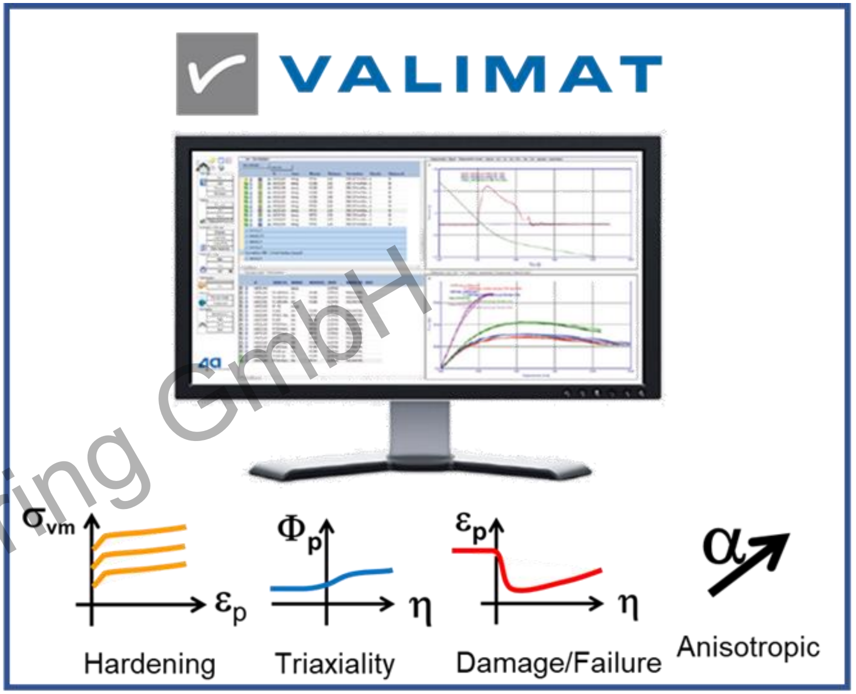
Summary

- different models needed for different materials
  - COMPOSITE (higher fiber content) → elastic + damage
  - SFRT, LFRT (medium fiber content) → viscoplasticity also of importance
- Two main approaches
  - Macro scale – composite behavior
  - Micro scale – distinguish between fiber and resin/matrix behavior
- Differences
  - Flexibility in usage (Micro ++)
  - Computational effort (Macro ++)

DAY 8 – 17th July 2020



User-defined specimen/input decks
User-defined material cards



Possibilities in VALIMAT®
with Python

Thank you for your Attention!

4a summer-school - webinar and training
Evaluating and checking test data
Interpretation of typical results

SAVE THE DATE
17th **Python: a powerful tool with VALIMAT®, user defined material cards/specimen**

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