

Integrative Simulation von kurz- und langglasfaserverstärkten Kunststoffen

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Deutsches LS-DYNA Forum
10. – 12. Oktober 2016, Bamberg

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Einleitung

- Wie verhalten sich SFRT/LFRT Kunststoffe
- Welche Simulationstools gibt es
- Wie sieht eine Simulationsprozesskette aus

Materialmodelle in LS-DYNA

- Welche Modelle sind für Composites verfügbar
- Wie kann die Orientierung berücksichtigt werden

Materialcharakterisierung

- Welche Prüfmethoden bietet 4a impetus
- Wie funktioniert eine Materialkartenerstellung (LIVE)

Mapping

- Wie aufwendig ist das Mapping (LIVE)
- Auf was sollte geachtet werden

Diskussion

4a technology group

4a technology-group: founded in 2002

Location: Traboch, Austria

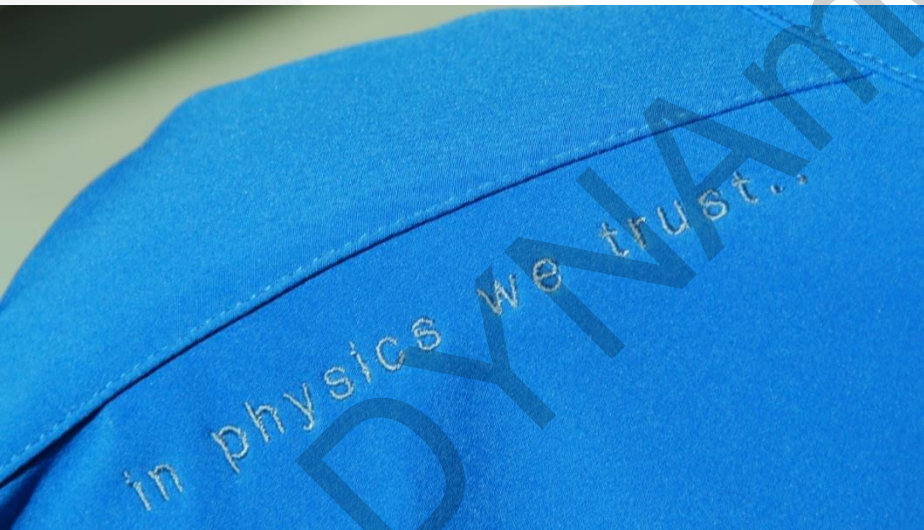
Number of employees > 80

Field of operation: global

Certificates: ISO 9001

more than 2000 projects

more than 400 customers





Group of Companies

4a Group
Philosophy
People
Products
Press
Contact
Directions

>>> **JOBS**

Company details
Terms & Conditions

DE|EN



IN PHYSICS WE TRUST

Business units



Engineering
and simulation
for plastic
products
and components



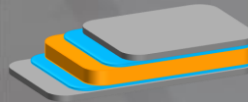
Multi-layer
composites and
sandwich
materials for
cost-efficient



Testing
facilities
generating
material data
suitable for
the dynamic
simulation of
plastics



Dummies and
testing
facilities for
active vehicle
safety



to unit webpage

to unit webpage



to unit webpage

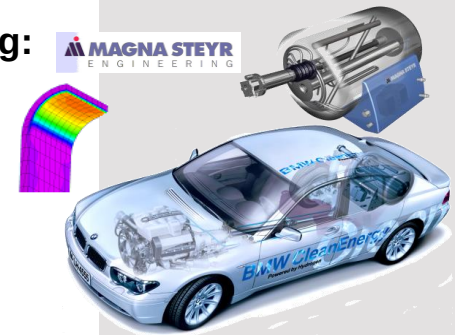
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- polymer and materials science
- numerical simulation methods
- fiber reinforced plastics and composites
- method and software development
- material characterization
- product development

strut bar:



LH₂ – tank mounting:

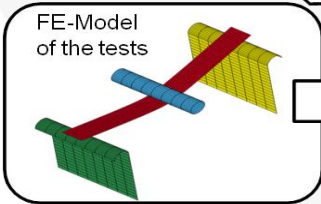


highspeed
measurement

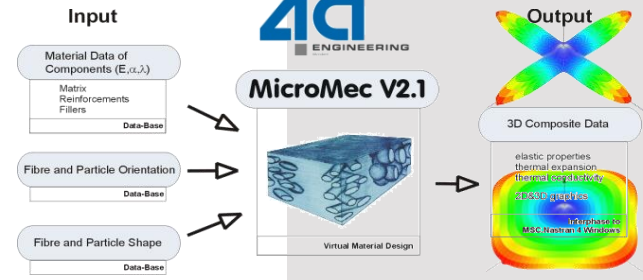
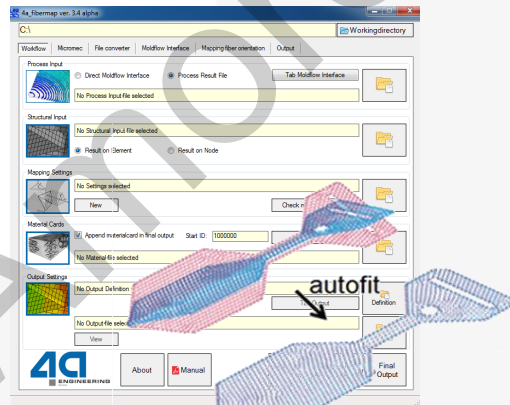
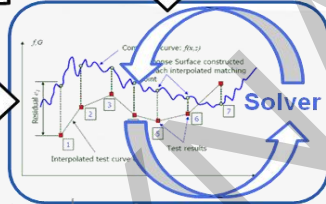
parameterized
materialcard

$$\sigma = \sigma_0 + E \cdot \varepsilon_p \cdot \frac{1}{\left[1 - \frac{E}{H} \cdot \varepsilon_p\right]}$$

$$\sigma = \sigma_0(\varepsilon) \left[1 + C \ln \frac{\dot{\varepsilon}}{\dot{\varepsilon}_0}\right]$$



FE-Model
of the tests



Einleitung

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Diskussion

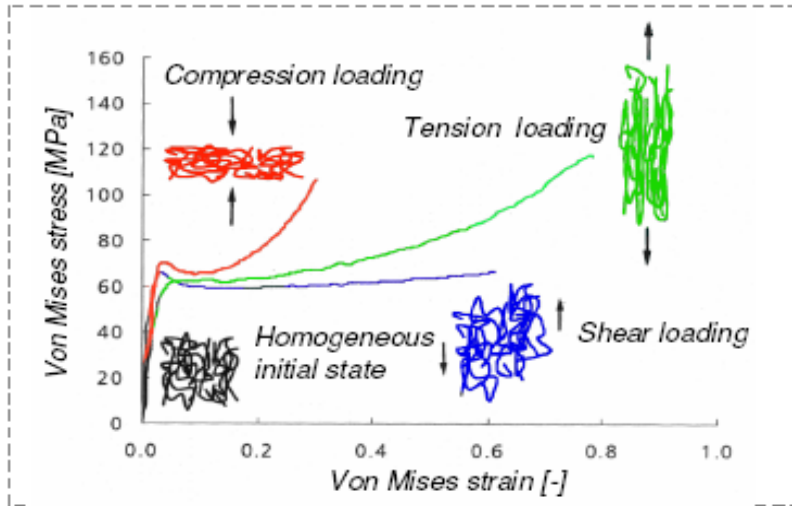
- Matrix
 - Thermoplast
 - Duroplast
- Partikel oder Faser (Verstärkung)
 - Talkum (Plättchen)
 - Glaskugeln
 - **Glasfaser (isotrop)**
 - Aramid, Carbon (transversal isotrop)
 - Naturfasern, Holz, Stahl, ...



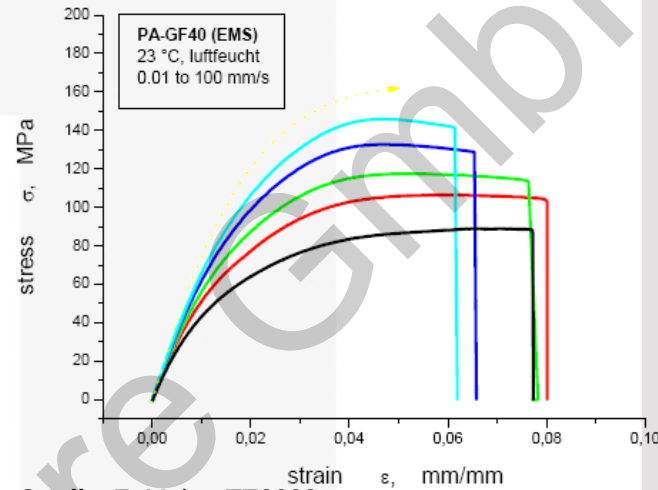
elastisch/plastisch
Belastungsart
Zeit / Temperatur

Einleitung

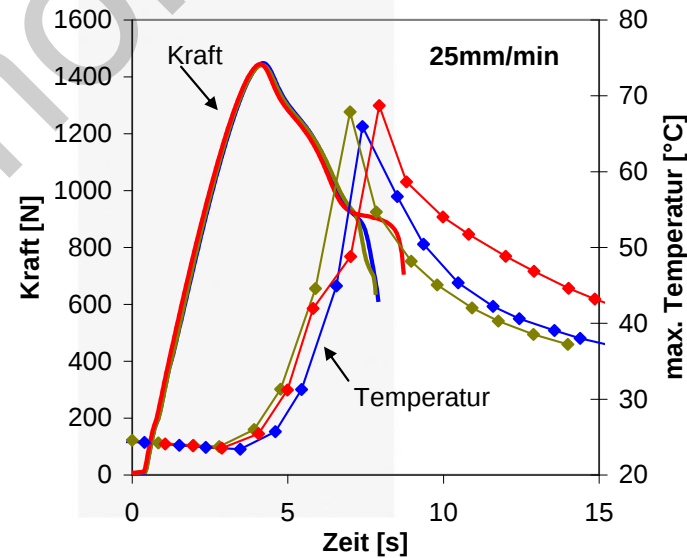
Matrixverhalten



Quelle: Mechanik der Kunststoffe, W. Retting, Hanser Verlag 1991

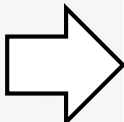


Quelle: Z. Major, TT2008



Quelle: J. Strauch, TT2012

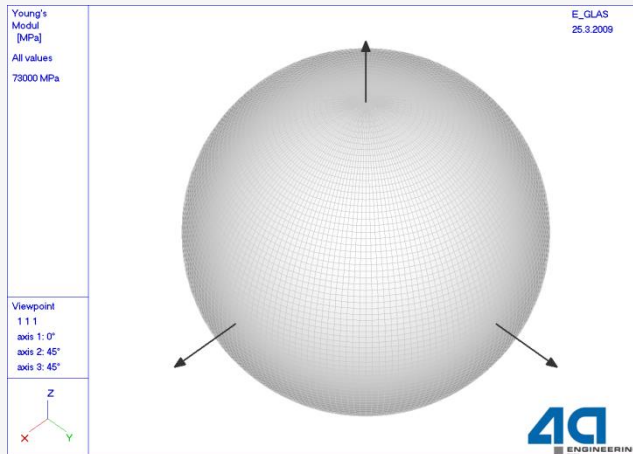
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- Matrix
 - **Thermoplast**
 - Duroplast
 - Partikel oder Faser (Verstärkung)
 - Talkum (Plättchen)
 - Glaskugeln
 - Glasfaser (isotrop) 
 - Aramid, Carbon (transversal isotrop)
 - Naturfasern, Holz, Stahl, ...
- Elastisch
Anisotropie**

Anisotropie

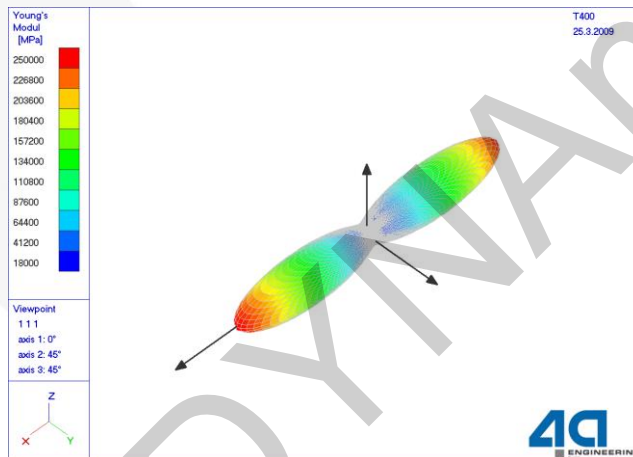
Sonderformen der Anisotropie

Glasfaser (isotrop)



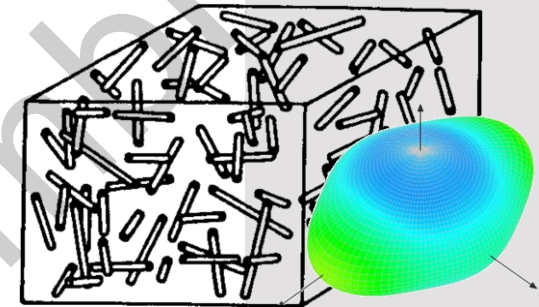
$$C^{-1} = \begin{bmatrix} \frac{1}{E} & -\frac{\nu}{E} & -\frac{\nu}{E} & 0 & 0 & 0 \\ -\frac{\nu}{E} & \frac{1}{E} & -\frac{\nu}{E} & 0 & 0 & 0 \\ -\frac{\nu}{E} & -\frac{\nu}{E} & \frac{1}{E} & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{2(1+\nu)}{E} & 0 & 0 \\ 0 & 0 & 0 & 0 & \frac{2(1+\nu)}{E} & 0 \\ 0 & 0 & 0 & 0 & 0 & \frac{2(1+\nu)}{E} \end{bmatrix}$$

T400 (transversal isotrop)

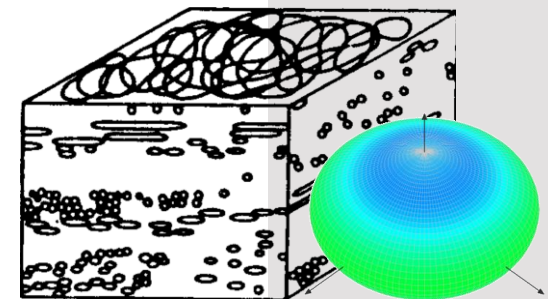


$$C^{-1} = \begin{bmatrix} \frac{1}{E_1} & -\frac{\nu_{12}}{E_2} & -\frac{\nu_{13}}{E_2} & 0 & 0 & 0 \\ -\frac{\nu_{21}}{E_1} & \frac{1}{E_2} & -\frac{\nu_{23}}{E_2} & 0 & 0 & 0 \\ -\frac{\nu_{31}}{E_1} & -\frac{\nu_{32}}{E_2} & \frac{1}{E_2} & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{2(1+\nu_{23})}{E_2} & 0 & 0 \\ 0 & 0 & 0 & 0 & \frac{1}{G_{31}} & 0 \\ 0 & 0 & 0 & 0 & 0 & \frac{1}{G_{21}} \end{bmatrix}$$

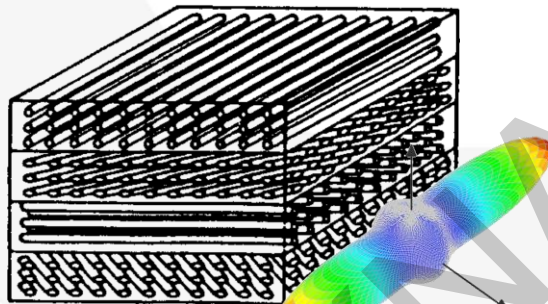
- unverstärkt
- Teilchen- oder partikelverstärkt ($l/d < 1$)
- Kurzfaserverstärkt (l/d 20-40, $d \sim 10\mu\text{m}$)
- Langfaserverstärkt (l/d 100-200, $d \sim 20\mu\text{m}$)
- Endlosfaserverstärkt ($l/d \gg 1000$)



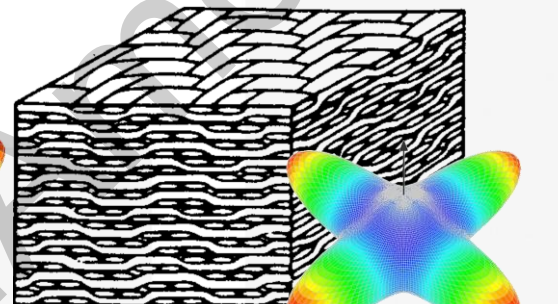
Kurz- bzw. Langfasern



Fasermatten



unidirektionale
Faserschichten



Gewebe

Bildquelle: Physik und Werkstoffkunde der Kunststoffe VO02/03, Montanuniversität Leoben

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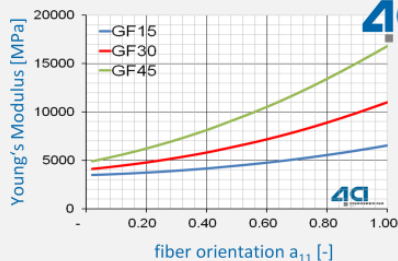
Kurz- und langfaserverstärkte Kunststoffe

typische Materialien

H1

**SFRT / LFRT –
fiber orientation**

PA6 GF30
polyamide short glass fiber reinforced



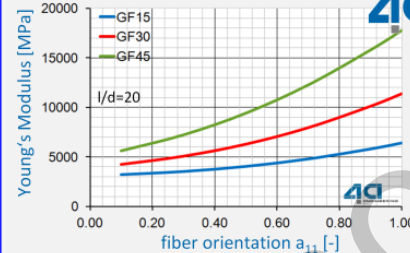
P: 3.4 €/kg **ρ:** 1.4 g/cm³
E₁: 9700 MPa **α₁:** 64·10⁻⁶ 1/K
σ_y: 140 MPa **ε_B:** 4%
T_G: 50 °C **a_C:** 100(15) kJ/m²

PA6GF30

H2

**SFRT / LFRT –
fiber orientation**

PBT GF30
polybutylene terephthalate short glass fiber reinforced



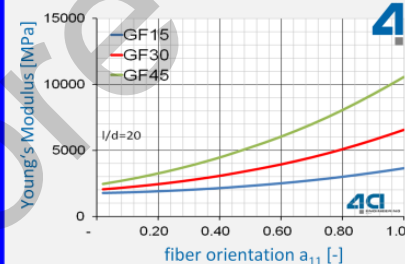
P: 3 €/kg **ρ:** 1.5 g/cm³
E₁: 9500 MPa **α₁:** 25·10⁻⁶ 1/K
σ_y: 92 MPa **ε_B:** 3%
T_G: 30 °C **a_C:** 67(11) kJ/m²

PBTGF30

H3

**SFRT / LFRT –
fiber orientation**

PP GF30
polypropylene short glass fiber reinforced



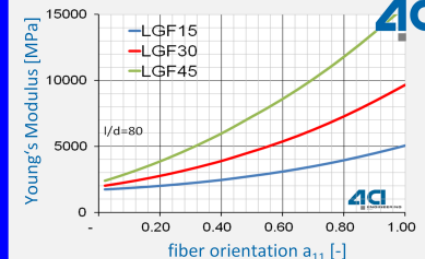
P: 2.3 €/kg **ρ:** 1.1 g/cm³
E₁: 6000 MPa **α₁:** 38·10⁻⁶ 1/K
σ_y: 70 MPa **ε_B:** 4%
T_G: -10 °C **a_C:** 20(5) kJ/m²

PPGF30

H4

**SFRT / LFRT –
fiber orientation**

PP LGF30
polypropylene long glass fiber reinforced

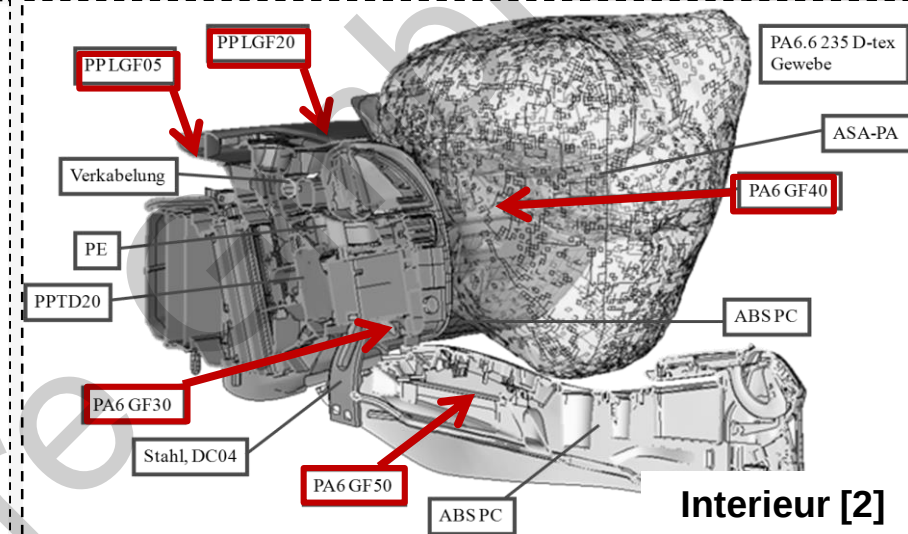
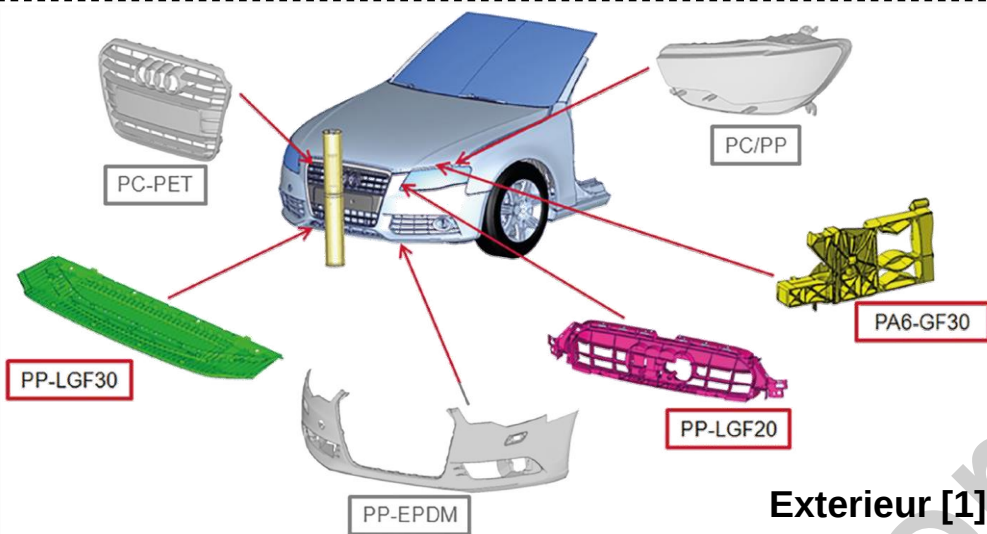


P: 2.5 €/kg **ρ:** 1.1 g/cm³
E₁: 6900 MPa **α₁:** 40·10⁻⁶ 1/K
σ_y: 76 MPa **ε_B:** 5%
T_G: -10 °C **a_C:** 70(18) kJ/m²

PPLGF30

Kurz- und langfaserverstärkte Kunststoffe

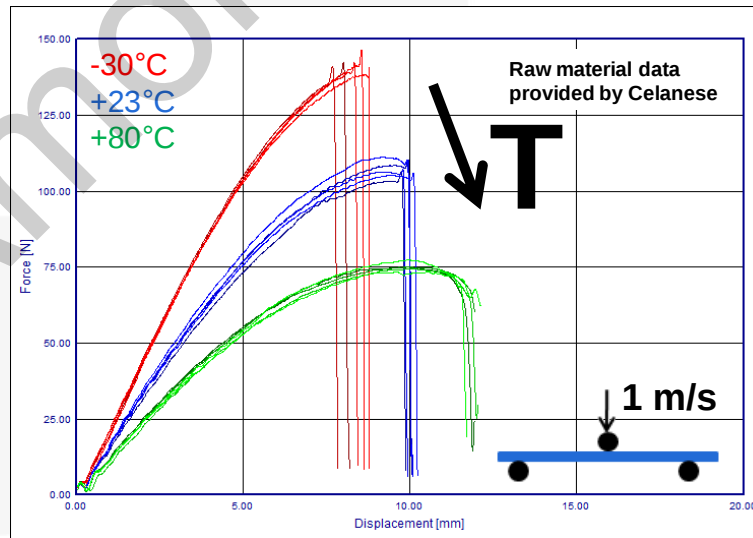
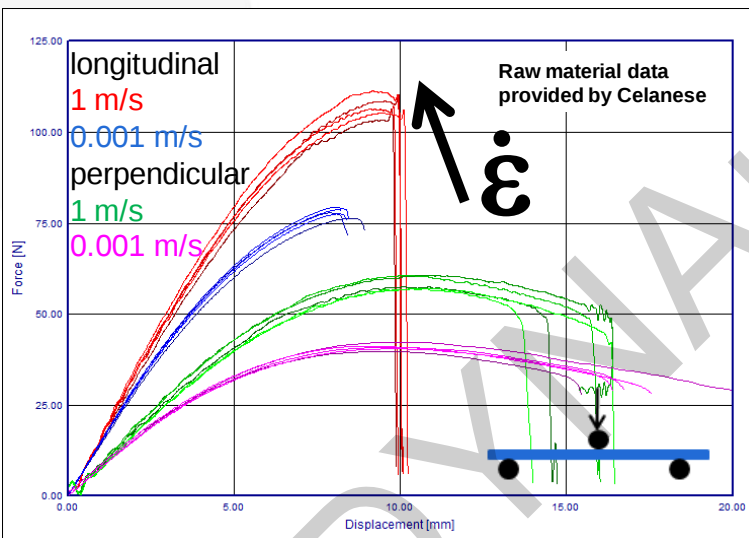
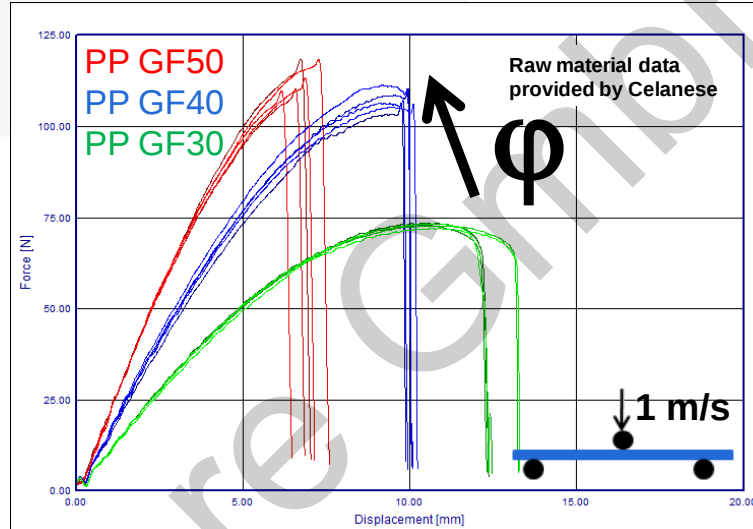
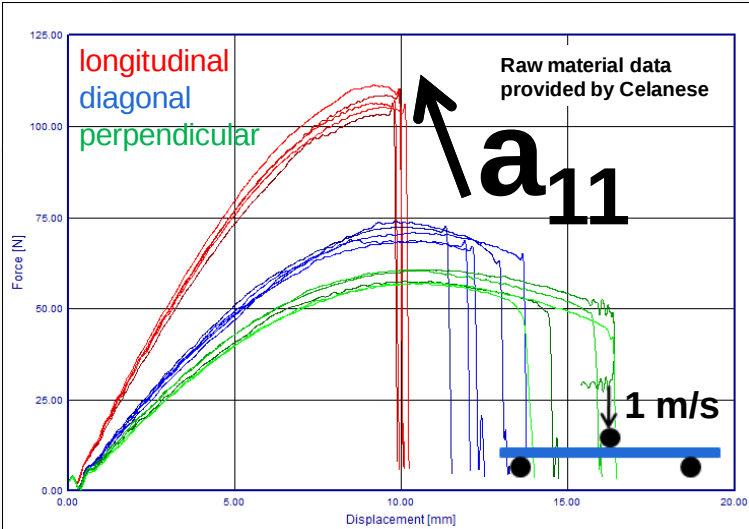
typische Anwendungen



- Consumer goods
- Power Tools
-

Kurz- und langfaserverstärkte Kunststoffe

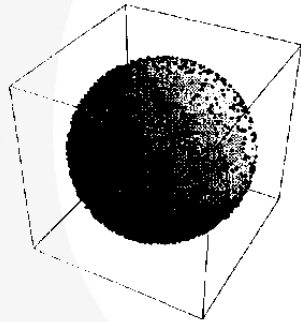
typische Materialverhalten



Wahrscheinlichkeit eine Faser im Raum anzutreffen
typische Beschreibungsformen

Dichteanhäufung

$$a_{ij} = \oint \psi(p) p_i p_j dp$$



Tensor Global

$$a_{xx} + a_{yy} + a_{zz} = 1$$

$$\vec{x} \times \vec{y} = \vec{z}$$

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

Eigenwerte/-vektoren

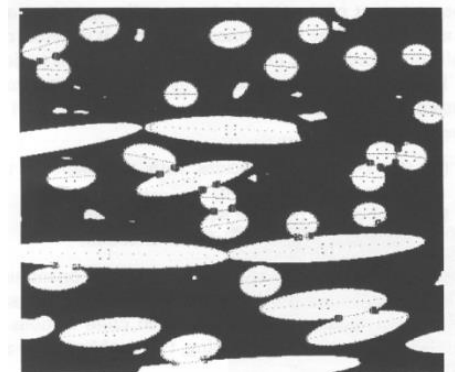
$$a_I + a_{II} + a_{III} = 1$$

$$\vec{v}_I \times \vec{v}_{II} = \vec{v}_{III}$$

$$a_{ij} = \begin{bmatrix} a_I & 0 & 0 \\ & a_{II} & 0 \\ \text{symm.} & & a_{III} \end{bmatrix}$$

Messung der Faserorientierung

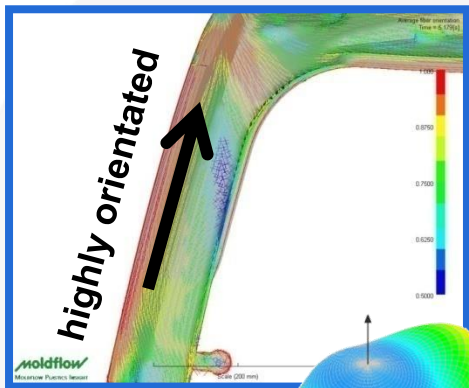
- Schliffbilder (mehrere 1000 Fasern pro Messung)
- REM
- μ -CT



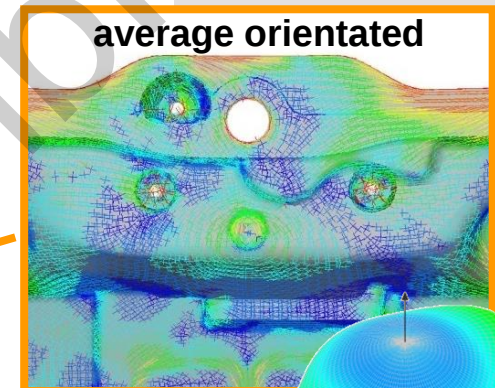
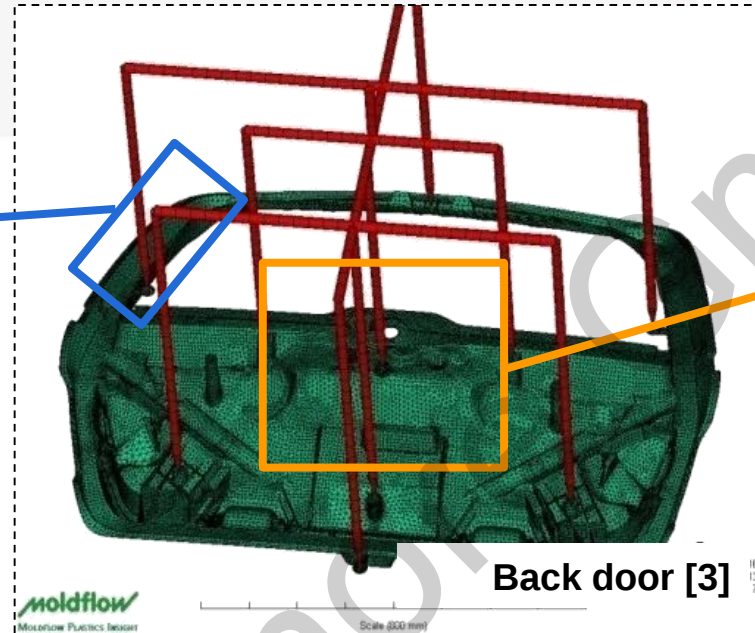
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Kurz- und langfaserverstärkte Kunststoffe

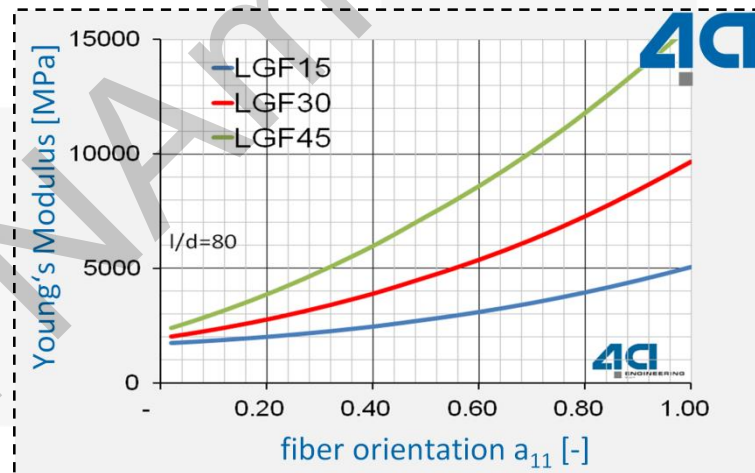
Faserorientierung



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



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

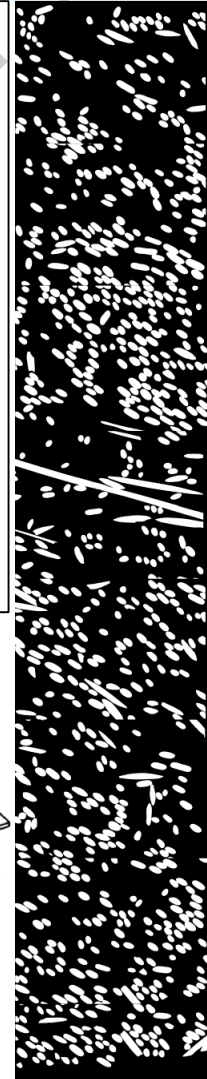
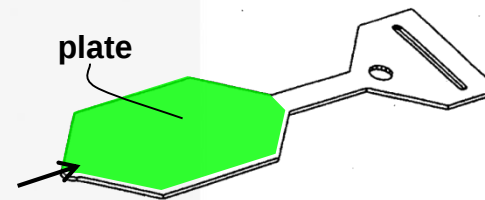
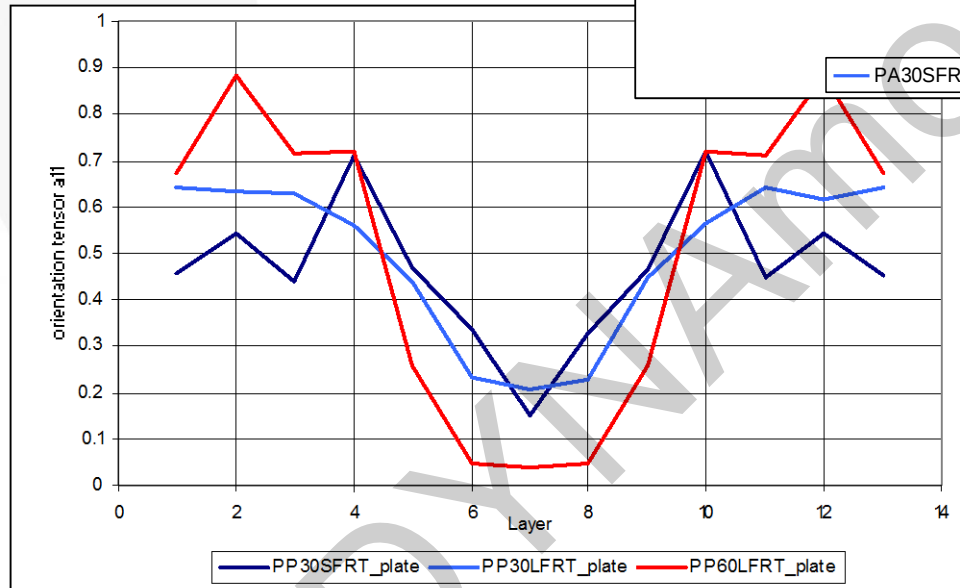
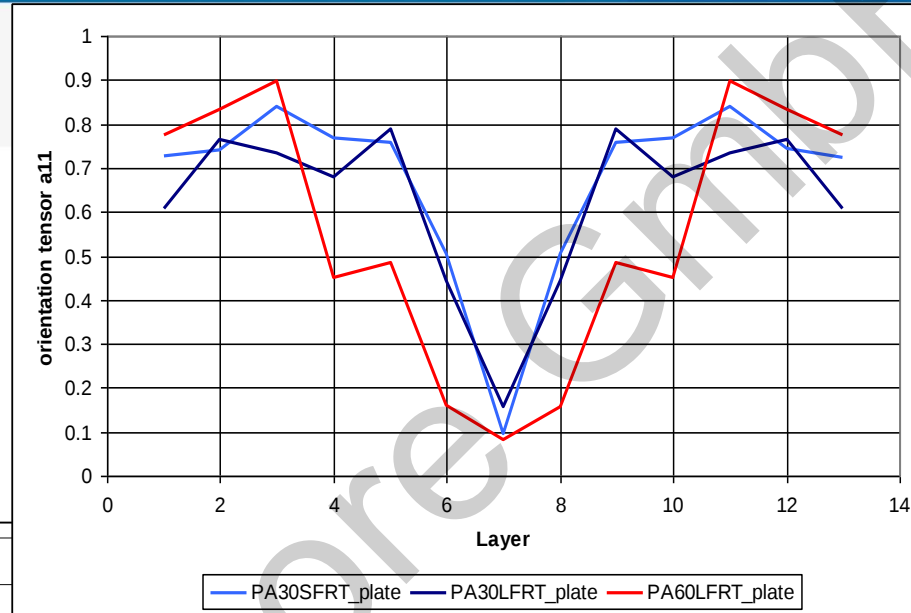


Kurz- und langfaserverstärkte Kunststoffe

Vergleich gemessene Faserorientierung

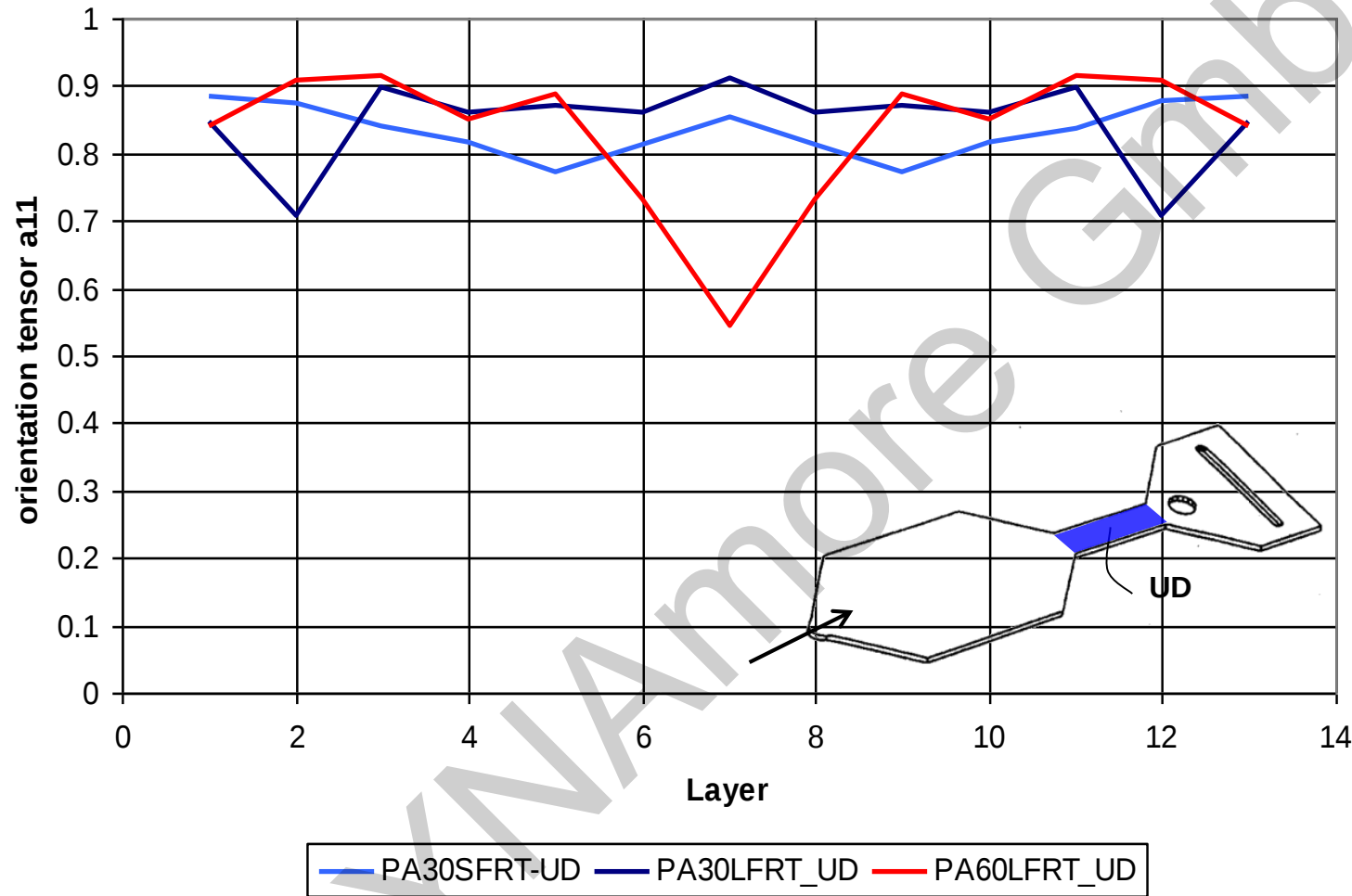
Wechselwirkung

- Geometrie
(Scher- vs. Quellströmung)
- Faserlänge
- Matrix (Viskosität)
- Fasergehalt (Interaktion)



Kurz- und langfaserverstärkte Kunststoffe

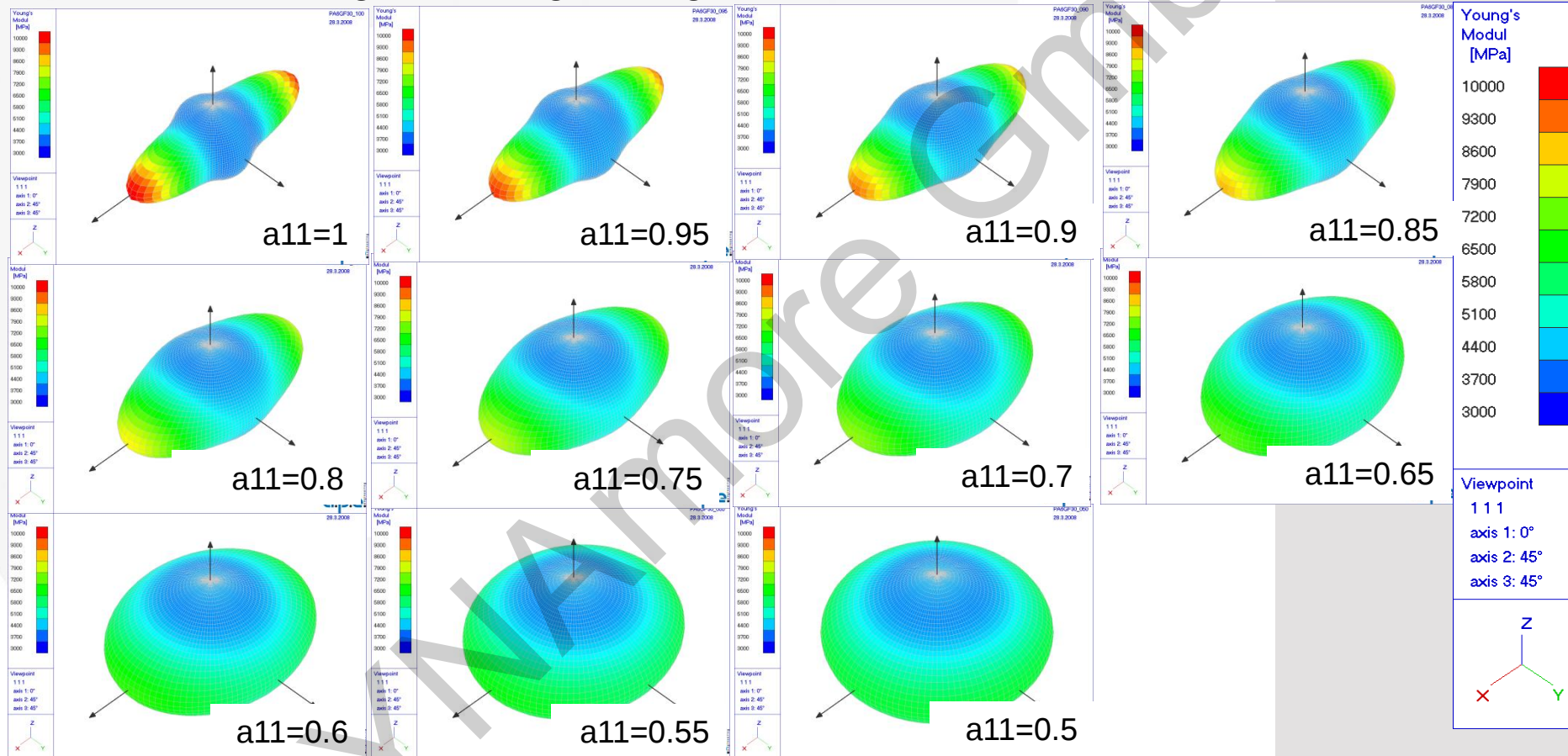
Vergleich gemessene Faserorientierung



Kurz- und langfaserververstärkte Kunststoffe

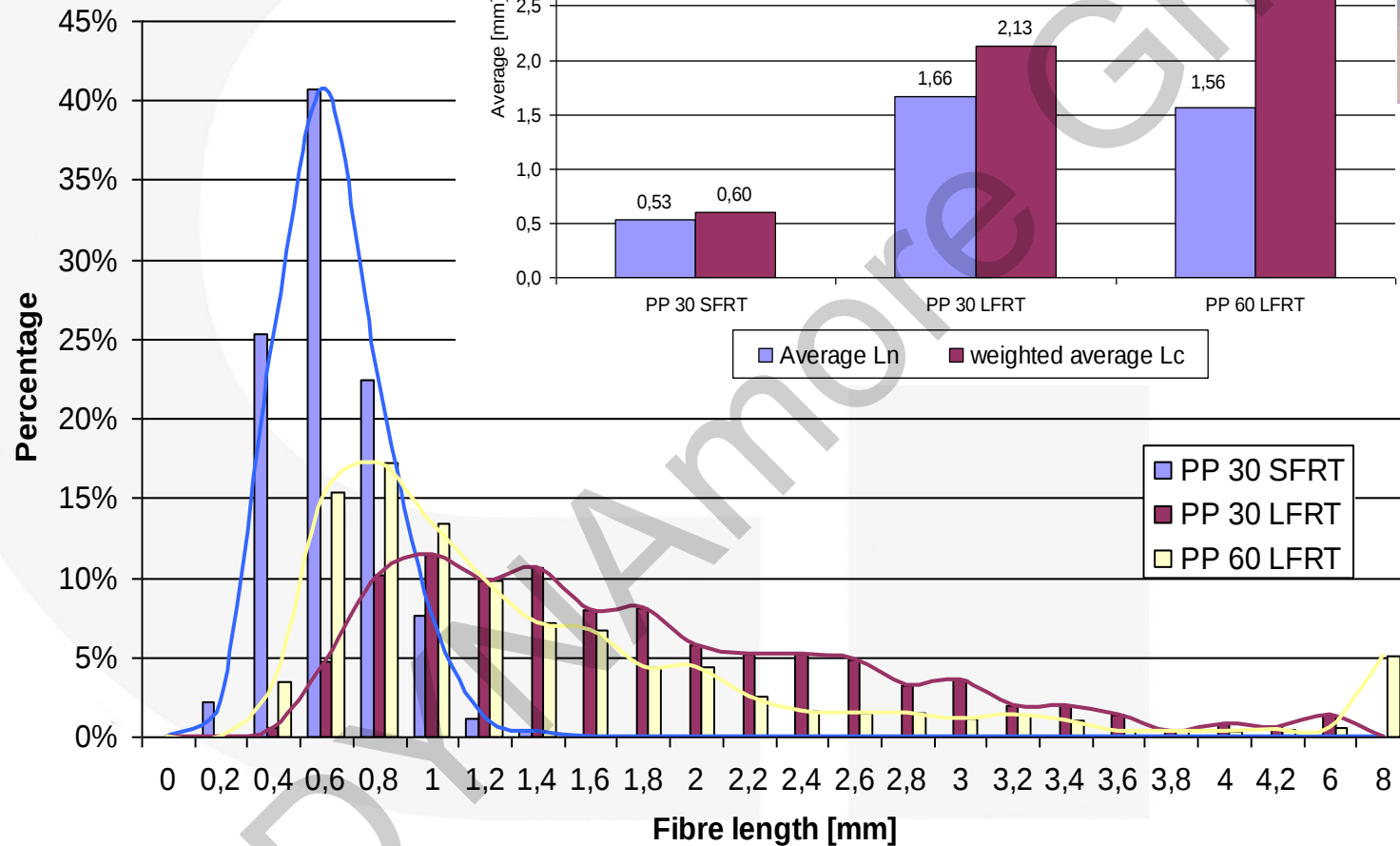
Einfluss Faserorientierung

- Anisotropes Verhalten - 3D Plot der Steifigkeit für unterschiedliche Faserorientierungsverteilungen dargestellt.



Kurz- und langfaserverstärkte Kunststoffe

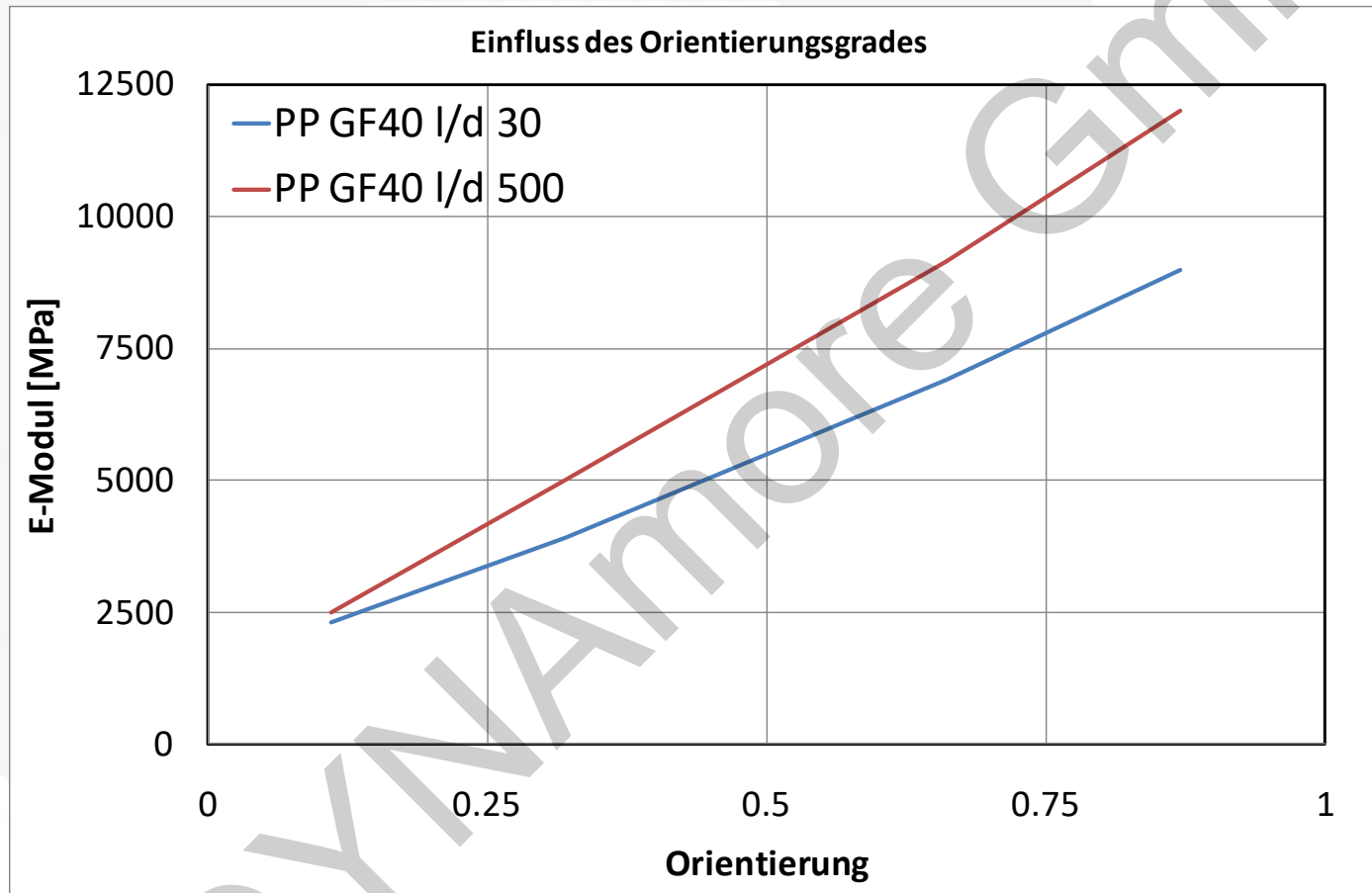
Vergleich gemessene Faserlänge



Kurz- und langfaserverstärkte Kunststoffe

Einfluss Faserlänge

Einfluss der Faserlänge auf den E-Modul abhängig vom Orientierungsgrad

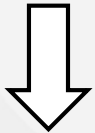
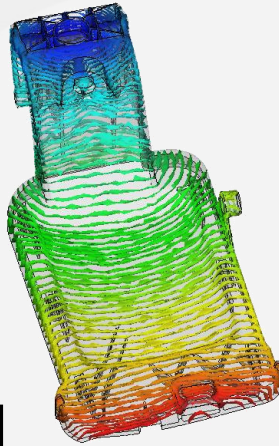


Prozesssimulation

Füllung

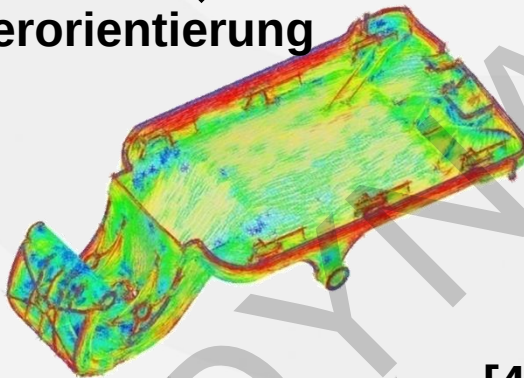
Fill time
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[s]
1.736
1.302
0.8678
0.4339
0.0000



Faserorientierung

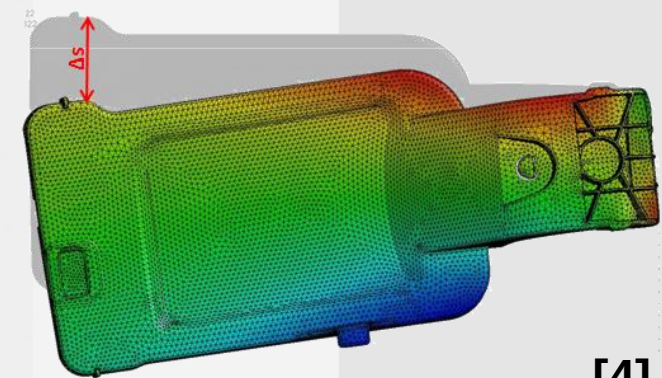
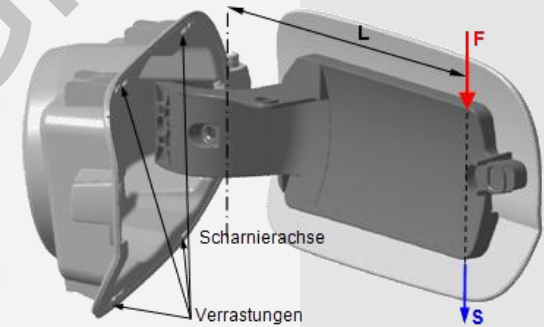
1.000
0.8750
0.7500
0.6250
0.5000



[4]

Struktursimulation

Biegung



[4]

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Integrative Simulation

Simulationsprozess

Prozesssimulation

CADMOULD®
3D-F SIMULATION

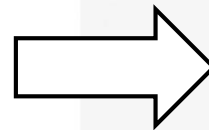
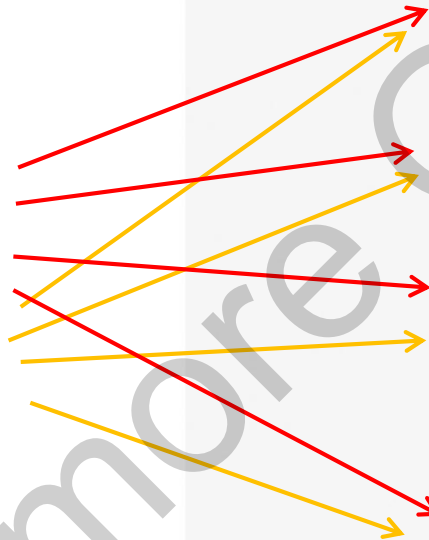
Moldex3D
MOLDING INNOVATION

 **MOLDFLOW**


SOLIDWORKS
PLASTICS

SIGMASOFT®

Schnittstellen
am gleichen Netz



Übertragung der
lokalen Richtungen
oder Steifigkeiten

Struktursimulation

ANSYS®

 **LSTC**
Livermore Software
Technology Corp.
LS-DYNA®

MSC Nastran

NX
NASTRAN

 **AUTODESK**
NASTRAN

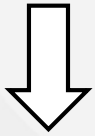
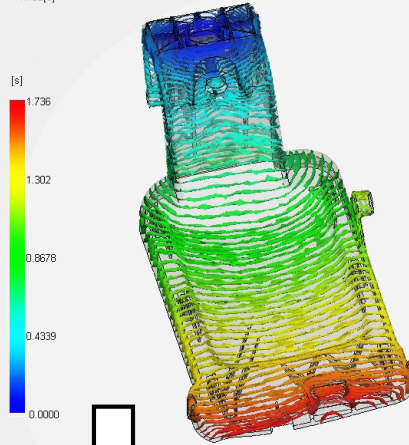
 **SIMULIA**

 **Virtual
Performance
Solution**

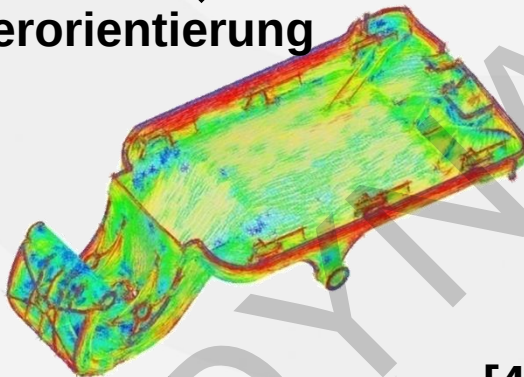
Prozesssimulation

Füllung

Fill time
= 1.736[s]

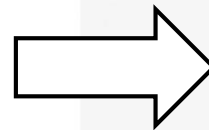
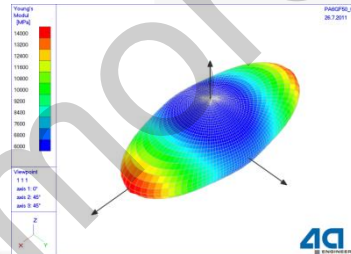


Faserorientierung



[4]

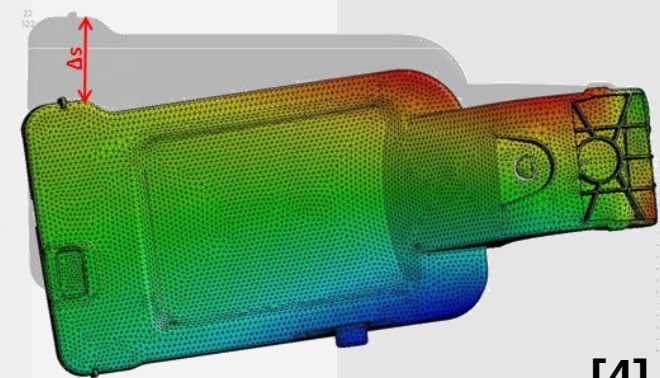
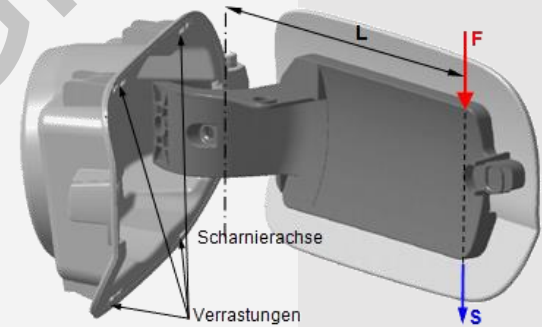
Mapping



Übertragung der
lokalen
Anisotropien

Struktursimulation

Biegung

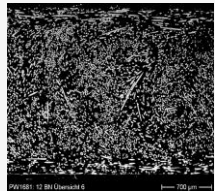


[4]

Simulationsprozesskette

Für Spritzgussteile

Injection molding (Moldflow, Moldex, ...)

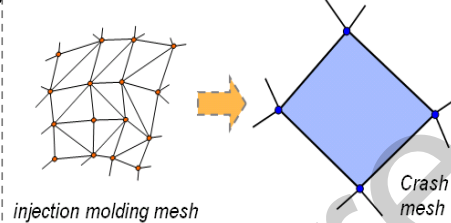


$$a_{ij} = \begin{bmatrix} 0,66 & 0 & 0 \\ 0 & 0,32 & 0 \\ 0 & 0 & 0,02 \end{bmatrix}$$

fiber orientation

Mapping (4a fibermap, ...)

In plane mapping



Mapping in thickness direction



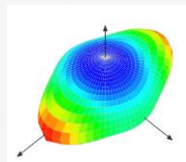
Material Model

Mean Field
homogenization

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

***MAT_215**

micromechanics modeling (4a micromec, ...)

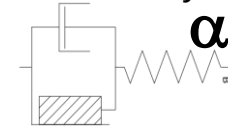


$$C = \begin{bmatrix} C_{11} & C_{12} & C_{13} & C_{14} & C_{15} & C_{16} \\ & C_{22} & C_{23} & C_{24} & C_{25} & C_{26} \\ & & C_{33} & C_{34} & C_{35} & C_{36} \\ & & & C_{44} & C_{45} & C_{46} \\ & & & & C_{55} & C_{56} \\ & & & & & C_{66} \end{bmatrix}$$

anisotropy

Standard Material Model

Hill Plasticity



***MAT_157**

Structural Simulation



Einleitung

- Wie verhalten sich SFRT/LFRT Kunststoffe
- Welche Simulationstools gibt es
- Wie sieht eine Simulationsprozesskette aus

Materialmodelle in LS-DYNA

- Welche Modelle sind für Composites verfügbar
- Wie kann die Orientierung berücksichtigt werden

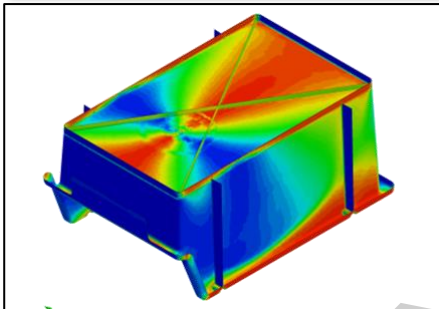
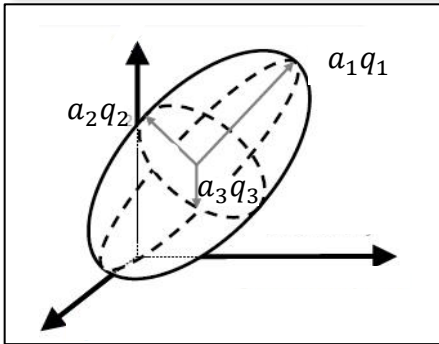
Materialcharakterisierung

- Welche Prüfmethoden bietet 4a impetus
- Wie funktioniert eine Materialkartenerstellung (LIVE)

Mapping

- Wie aufwendig ist das Mapping (LIVE)
- Auf was sollte geachtet werden

Diskussion



Material models in LS-DYNA for the integrative simulation of fiber reinforced plastics

Andrea Erhart, Christian Liebold,
André Haufe, **Stefan Hartmann**
DYNAmore GmbH, Stuttgart, Germany

Peter Reithofer
4a engineering GmbH, Traboch, Austria



14th GERMAN LS-DYNA FORUM

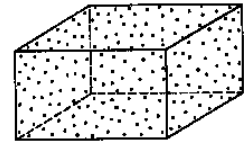
10 – 12 October 2016, Bamberg, Germany

Outline

- Integrative Simulation:
 - Motivation
 - Fiber orientation
 - Homogenization
 - Procedure
- Material models in LS-DYNA
 - continuous filaments/fabrics
 - long and short fibers
 - *MAT_215 / *MAT_4A_MICROMECH
- Mapping
 - Tools: 4a fibermap (4a engineering) – Envyo (DYNAmore)
 - procedure for *MAT_157
 - procedure for *MAT_215
- Examples
- Summary and Outlook

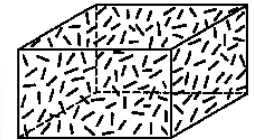
Integrative Simulation: – Motivation

- particulate composites:

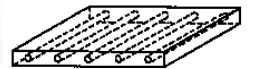
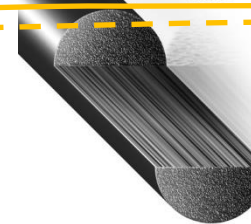


- fibrous composites:

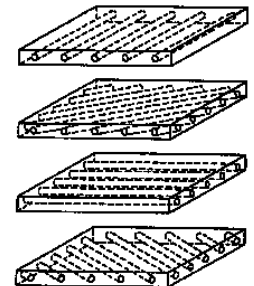
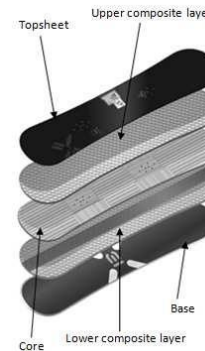
- short/long fibers:



- continuous filaments:



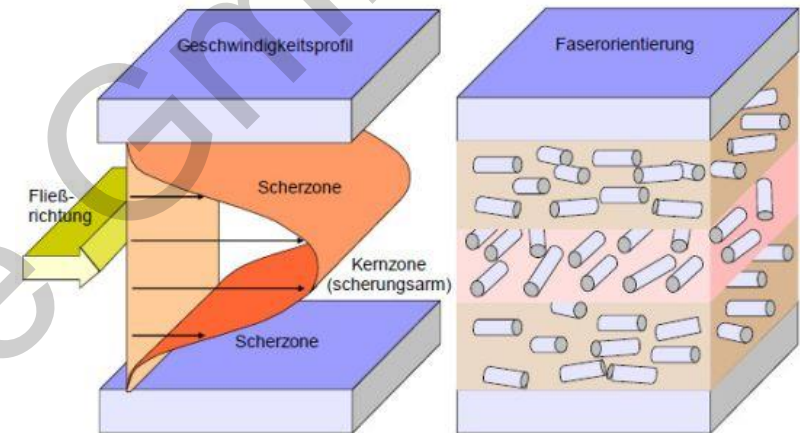
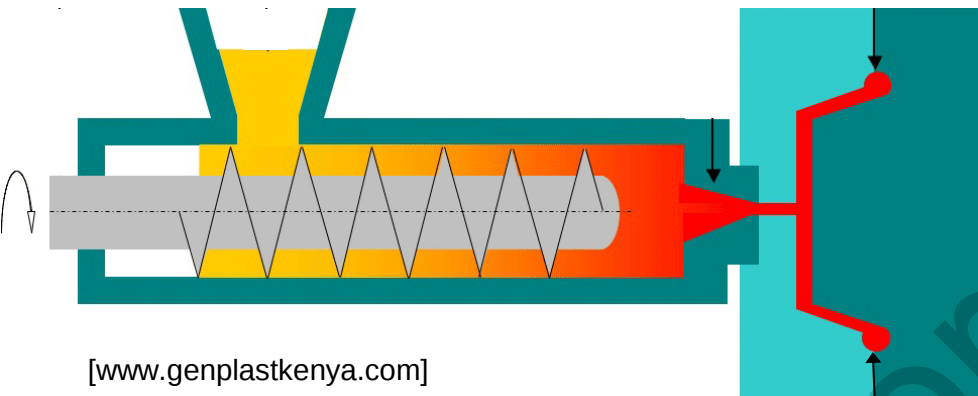
- laminated composites:



Integrative Simulation: – Motivation

Aim:

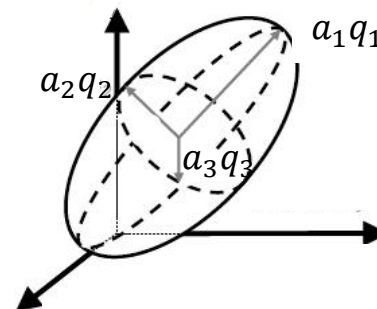
- Include production process in simulation model for mechanical behavior



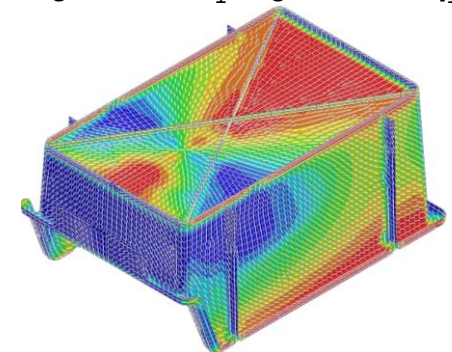
[wiki.polymerservice-merseburg.de]

Orientation tensor 2nd order a : Mapped from process simulation as

- eigenvectors q_i (main fiber directions)
- eigenvalues a_i (orientation probability)

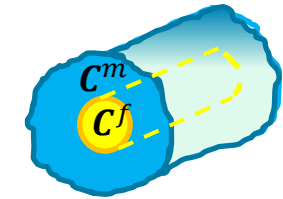


eigen value a_1 , eigen vector q_1



Integrative Simulation: – Homogenization

1st step: Effective properties of unidirectional (UD) composite

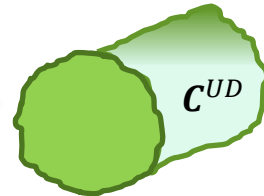


fiber in matrix

Analytical homogenization:



- Eshelby + Mori-Tanaka
- empirical equations
- upper/lower bounds



equivalent
homogeneous
UD-medium

Eshelby + Mori-Tanaka:

strain concentration tensor:

$$\mathbf{A} = \left(\mathbf{I} + \mathbf{E} : \mathbf{S}^m : (\mathbf{C}^f - \mathbf{C}^m) \right)^{-1}$$

unidirectional stiffness matrix :

$$\mathbf{C}^{UD} = \mathbf{C}^m + \nu_f (\mathbf{C}^f - \mathbf{C}^m) : \mathbf{A}$$

2nd step: Orientation averaging: Effective properties of (real) unaligned composite

homogenized stiffness matrix :

$$\mathbf{C}_{ijkl} = \int \mathbf{C}^{UD} \psi(\theta, \phi) d\Omega$$

Advani & Tucker:

$$\begin{aligned} \mathbf{C}_{ijkl} = & B_1 \mathbf{a}_{ijkl} + B_2 (\mathbf{a}_{ij} \delta_{kl} + \mathbf{a}_{kl} \delta_{ij}) + B_3 (\mathbf{a}_{ik} \delta_{jl} + \mathbf{a}_{il} \delta_{jk} + \mathbf{a}_{jl} \delta_{ik} + \mathbf{a}_{jk} \delta_{il}) \\ & + B_4 (\delta_{ij} \delta_{kl}) + B_5 (\delta_{ik} \delta_{jl} + \delta_{il} \delta_{jk}) \end{aligned}$$

Closure approximation $\mathbf{a}_4$

with fiber orientation tensors: $\mathbf{a}_{2,ij} = \int p_i p_j \psi(\theta, \phi) d\Omega$ and $\mathbf{a}_{4,ijkl} = \int p_i p_j p_k p_l \psi(\theta, \phi) d\Omega$

$$B_1 = C_{1111}^{UD} + C_{2222}^{UD} - 2C_{1122}^{UD} - 4C_{1212}^{UD}$$

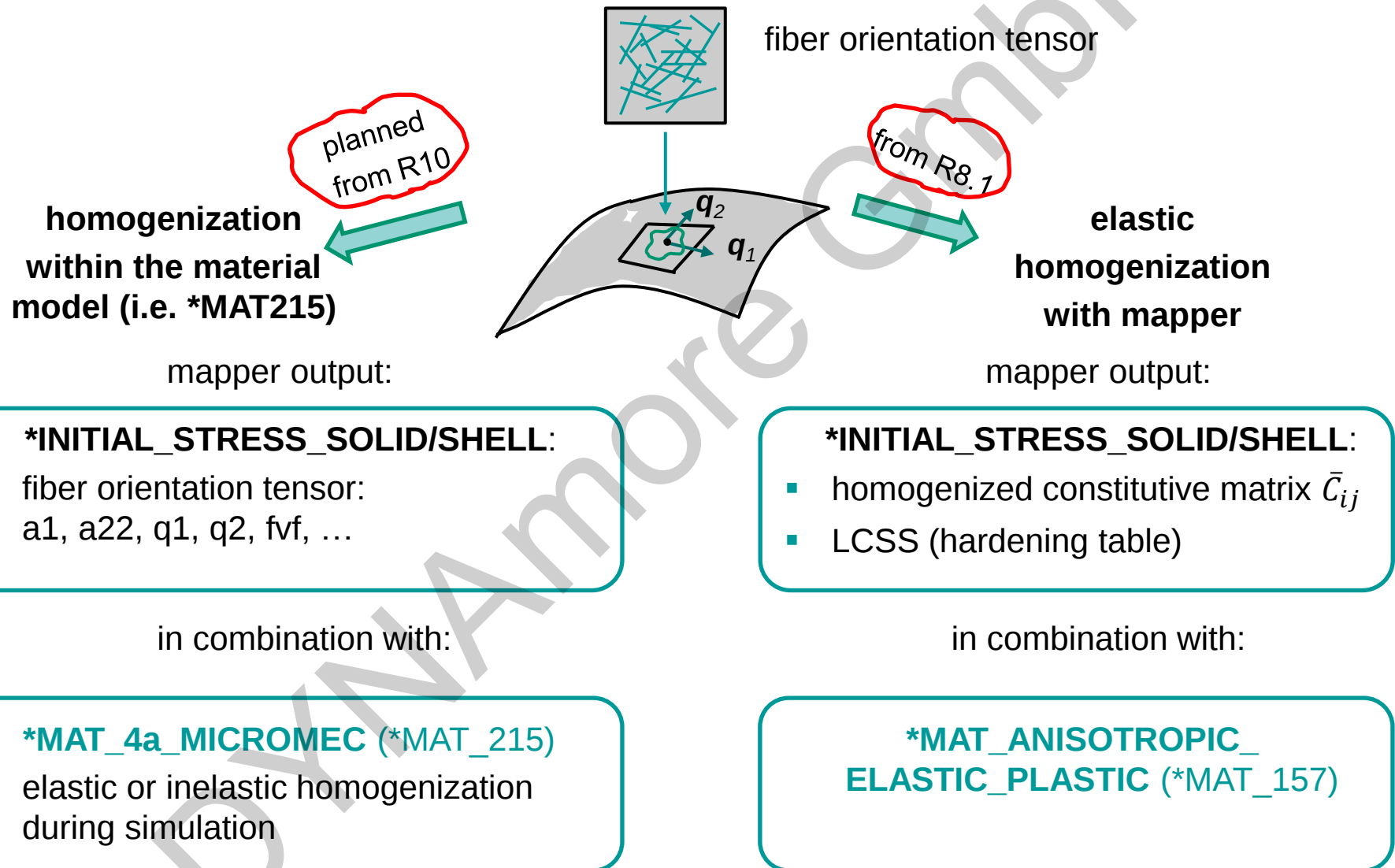
$$B_3 = C_{1212}^{UD} + \frac{1}{2} (C_{2233}^{UD} - C_{2222}^{UD})$$

$$B_4 = C_{2233}^{UD}$$

$$B_2 = C_{1122}^{UD} + C_{2233}^{UD}$$

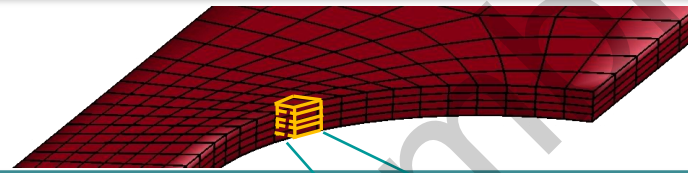
$$B_5 = \frac{1}{2} (C_{2222}^{UD} - C_{2233}^{UD})$$

Integrative Simulation: – Procedure



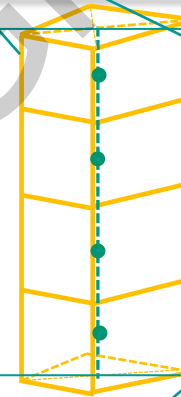
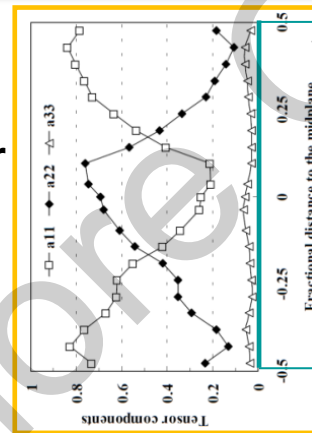
Integrative Simulation: – Procedure

- Injection molding simulation:
fiber orientation / fiber content

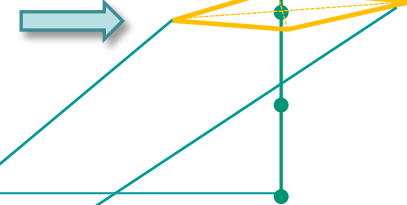


molding
discretization

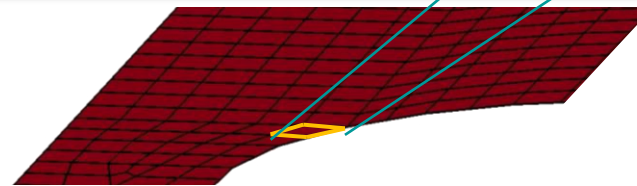
- Mapping of fiber orientation tensor
(main values und main directions)
- fiber content



a_{11}, a_{22}, q_1, q_2



- Computation of homogenized
(elastic) material properties



structural analysis
discretization

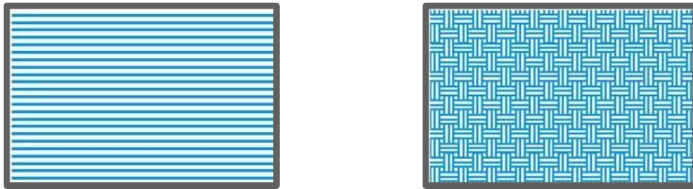
- Analysis using homogenized anisotropic material model (i.e.: *MAT_157)
- Analysis with homogenization in the material model (*MAT_215)

Outline

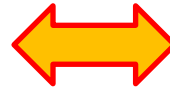
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Material models in LS-DYNA: – continuous vs. discontinuous

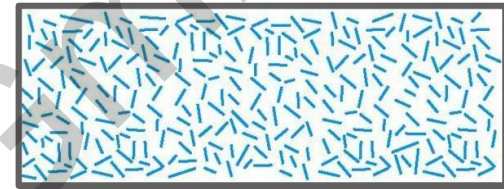
Continuous filaments / fabrics



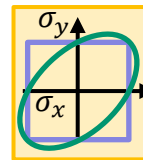
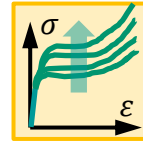
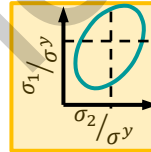
- **Non-varying anisotropy in region:** orthotropic / transversal isotropic
- One material card for **part**
- orthotropic elastic
- anisotropic plastic (e.g. Hill48)
- rate dependent hardening
- failure for fibrous composites (e.g. Chang-Chang, Tsai-Wu, Hashin)



long or short fibers (injection moulded)



- **Local varying anisotropy**
- One 'material card' for **every IP**
- orthotropic elastic
- anisotropic plastic (e.g. Hill48)
- rate dependent hardening
- failure for fibrous composites (e.g. Chang-Chang, Tsai-Wu, Hashin)



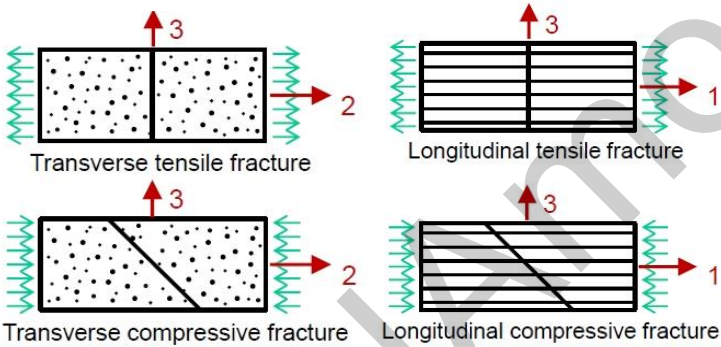
Material models in LS-DYNA: – continuous filaments/fabrics

Anisotropic material models:

*MAT_002	$\begin{bmatrix} \sigma_{11} \\ \sigma_{22} \\ \sigma_{33} \\ \sigma_{23} \\ \sigma_{31} \\ \sigma_{12} \end{bmatrix} = \begin{bmatrix} C_{11} & C_{12} & C_{13} & C_{14} & C_{15} & C_{16} \\ C_{21} & C_{22} & C_{23} & C_{24} & C_{25} & C_{26} \\ C_{31} & C_{32} & C_{33} & C_{34} & C_{35} & C_{36} \\ C_{41} & C_{42} & C_{43} & C_{44} & C_{45} & C_{46} \\ C_{51} & C_{52} & C_{53} & C_{54} & C_{55} & C_{56} \\ C_{61} & C_{62} & C_{63} & C_{64} & C_{65} & C_{66} \end{bmatrix} \begin{bmatrix} \varepsilon_{11} \\ \varepsilon_{22} \\ \varepsilon_{33} \\ \varepsilon_{23} \\ \varepsilon_{31} \\ \varepsilon_{12} \end{bmatrix}$	anisotropic / orthotropic elastic
*MAT_157		anisotropic elastic, orthotropic plastic (Hill48)

Material models with failure criteria for fibrous composites

different failure modes: fiber in tension/compression, matrix failure, mixed modes

*MAT_022		orthotr.elast + Chang-Chang failure
*MAT_054		orthotr.elast + pl.+ failure Chang-Chang
*MAT_055		orthotr.elast + pl. + fail. f:Chang m:Tsai-Wu
*MAT_058		orthotr.elast, damage + failure mod. Hashin
*MAT_158		orthotr.elast, damage + failure, rate depend.
*MAT_261		orthotr.elast, damage + failure Pinho
*MAT_262		orthotr.elast, damage + failure Camanho

Material models for draping of fabrics / thermoplastic pre-pregs

*MAT_249		thermoplastic matrix + hyperelastic fabric (R8)
*MAT_277		visco-thermo-elastic, curing (from R9)

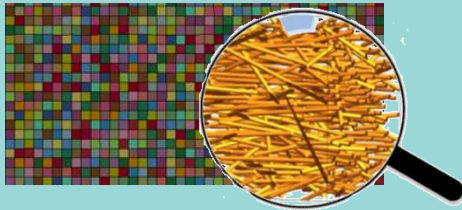
Material models in LS-DYNA: – long and short fibers

fiber orientation (and homogenized material data) as

input data in material card

only useful for continuous, aligned fibers

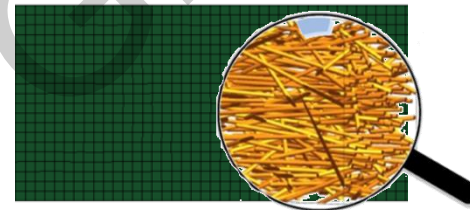
else:



inhomogeneous fiber distribution needs individual
part / material card for every element

fiber orientation (and homogenized material data) as
history variables. Can be initialized for each
integration point individually using

***INITIAL_STRESS_SOLID / SHELL**



one part / material card for whole component

***MAT_ANISOTROPIC_ELASTIC (*MAT_002) or *MAT_215 or**

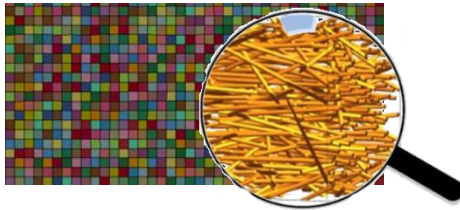
***MAT_ANISOTROPIC_ELASTIC_PLASTIC (*MAT_157)**

Material models in LS-DYNA: – long and short fibers

fiber orientation (and homogenized material data) as

input data in material card

only useful for continuous, aligned fibers
else:



inhomogeneous fiber distribution needs individual
part / material card for every element

fiber orientation (and homogenized material data) as
history variables. Can be initialized for each
integration point individually using

*INITIAL_STRESS_SOLID / SHELL



one part / material card for whole component

*MAT_157

$$IHIS = 8a_3 + 4a_2 + 2a_1 + a_0$$

with $a_0 \dots a_3$ each either 0 or 1

*INITIAL_STRESS_SOLID:

$$NHISV = 6a_0 + 21a_1 + 6a_2 + a_3$$

*INITIAL_STRESS_SHELL:

$$NHISV = 2a_0 + 21a_1 + 3a_2 + a_3$$

flag	description	variables	number
a_0	material directions	q_1, q_2	6
a_1	aniso. el. stiffness	C_{ij}	21
a_2	anisotropic plasticity	F, G, H, L, M, N	6
a_3	hardening curve	LCSS	1

flag	description	variables	number
a_0	material directions	q_1, q_2	2
a_1	aniso. el. stiffness	C_{ij}	21
a_2	anisotropic plasticity	r_{00}, r_{45}, r_{90}	3
a_3	hardening curve	LCSS	1

Material models in LS-DYNA: – long and short fibers

- *MAT_215 - *MAT_4A_MICROMECH
 - Micro Mechanic Based Material Model
 - fiber: (transversal) isotropic elastic
 - matrix: isotropic elastic, viscoplastic (like *MAT_024)
 - Mori-Tanaka Mean Field Theory
- more about this new material model in:

Dienstag, 11. Oktober

10:20 - 11:00 Uhr

11:00 - 12:20 Uhr

Raum 1

SDM /
Compression

Raum 2

Materials
[SFR Polymers]

MATERIALS [SHORT FIBER-REINFORCED POLYMERS] S. 111 - 119

Chair: B. Lauterbach (Adam Opel)

Some Aspects on Characterizing and Modeling of Unreinforced and Short Fiber Reinforced Polymers in Crashworthiness Applications

M. Vogler, G. Oberhofer, H. Dell

(Matfem Partnerschaft Dr. Gese & Oberhofer)

Potential of MAT_157 for Short-Fiber-Reinforced Injection Molded Plastic Components

W. Korte, S. Pazour, M. Stojek (PART Engineering)

Modeling of Fiber-Reinforced Plastics Taking into Account the Manufacturing Process

C. A. T. Reclusado (Fraunhofer EMI); S. Nagasawa (Fuji Heavy Industries)

***MAT_4a_micromec – Micro Mechanic Based Material Model**

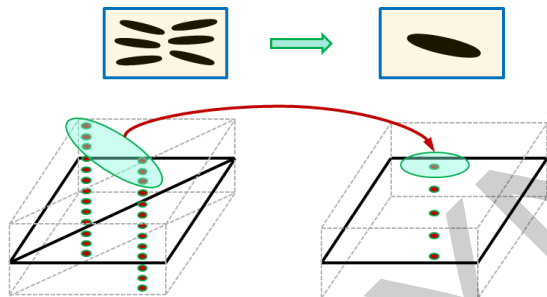
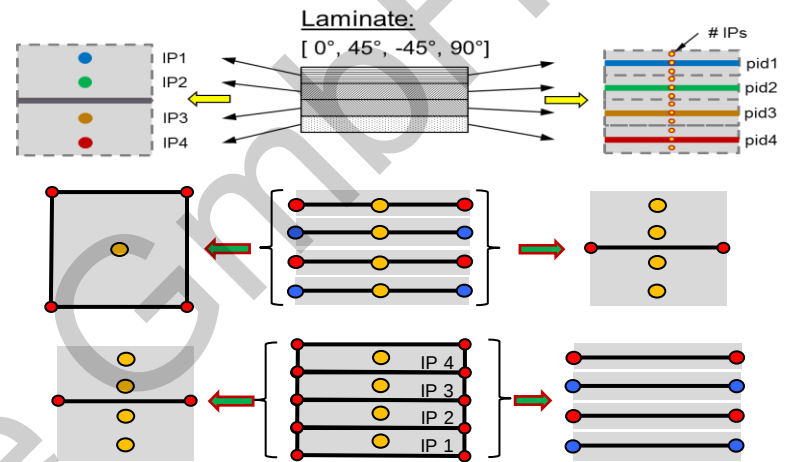
A. Erhart, S. Hartmann (DYNAmore); B. Jilka, P. Reithofer
(4a engineering)

Outline

- Integrative Simulation:
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 - Fiber orientation
 - Homogenization
 - Procedure
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Mapping: – tools

- 4a fibermap (4a engineering)
 - more about that later in this workshop
- Envyo (DYNAmore)
 - fiber orientations
 - homogenization
 - mapping between various modeling techniques
 - ...
 - more about Envyo in:



AGENDA – MITTWOCH, 12. OKTOBER 2016

RAUM 4

WORKSHOP

Leitung: C. Liebold (DYNAmore)

Mapping Tool Envyo

The workshops feature both informative and how-to knowledge with demonstrations of the latest features from experts.

The aim is to provide the attendees with insights, limits and merits of the topic. It facilitates the understanding by showcasing simple examples that explain the methods. Besides the presentation there will be time for interactions between the presenters and the audience.

PARALLEL

11:00

11:20

11:40

12:00

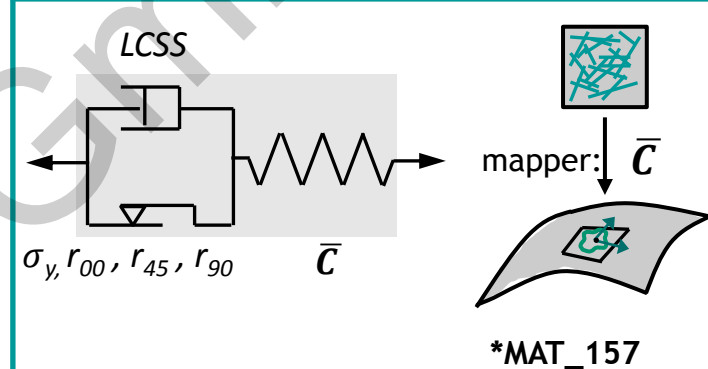
12:20

Mapping: – Procedure for *MAT_157

*MAT_ANISOTROPIC_ELASTIC_PLASTIC (*MAT_157)

- material card is input of user
- elastic homogenization done with *Envyo*
→ c11 ... c66 in *INITIAL_STRESS_SHELL
- aopt=0: q1 and q2 in *INITIAL_STRESS_SHELL
- evaluation of **ihis=3** see above
- for damage / failure: *MAT_ADD_EROSION
from R9: Tsai-Wu failure criterion

homogenised elastic -
macroscopic visco-plastic



\$CARD 1	mid 1	ro 1.52E-06	sigy 0.018	lcss 999	qr1	cr1	qr2	cr2
\$CARD 2	C11	C12	C13	C14	C15	C16	C22	C23
\$CARD 3	C24	C25	C26	C33	C34	C35	C36	C44
\$CARD 4	C45	C46	C55	C56	C66	R00 0.95	R45 0.8	R90 1.0
\$CARD 5	s11	s22	s33	s12	aopt 0	vp		macf
\$CARD 6	xp	yp	zp	a1	a2	a3		
\$CARD 7	v1	v2	v3	d1	d2	d3	beta	ihis 3

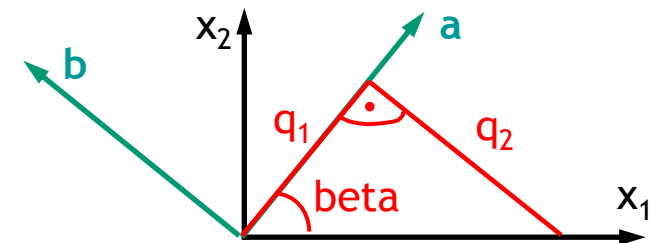
Mapping: – Procedure for *MAT_157

*INITIAL_STRESS_SHELL is generated automatically by Envyo

Integration point 1 IP 2	\$CARD 1	eid 1	nplane 1 or 4	nthick e.g. 5	nhisv 23	ntensr	large	nthhint	nthhisv
	\$CARD 2	t 0.0e+00	sigxx 0.0	sigyy 0.0	sigzz 0.0	sigxy 0.0	sigyz 0.0	sigzx 0.0	eps 0.0
	\$CARD 3	q1 8.84e-01	q2 1.09e-01	C11 1.1e+01	C12 4.9e+00	C13 2.4e+00	C14 0.0e+00	C15 0.0e+00	C16 0.0e+00
	\$CARD 4	C22 4.6e+00	C23 8.6e-01	C24 0.0e+00	C25 0.0e+00	C26 0.0e+00	C33 4.3e+00	C34 7.2e-01	C35 0.0e+00
	\$CARD 5	C36 0.0e+00	C44 1.5e+00	C45 0.0e+00	C46 0.0e+00	C55 5.6e-01	C56 0.0e+00	C66 8.7e-01	
	\$CARD 6	t -0.9062	sigxx 0.0	sigyy 0.0	sigzz 0.0	sigxy 0.0	sigyz 0.0	sigzx 0.0	eps 0.0

For shells:

Material direction (main fiber orientation): Only first eigenvector necessary:
described by direction $q_1 = \cos\beta$, $q_2 = -\sin\beta$



Mapping: – Procedure for *MAT_215

*MAT_4A_MICROMECH (*MAT_215)

- material card is input of user
- homogenization done within *MAT_215
- fiber orientation tensor by mapper and written to *INITIAL_STRESS_SOLID/*INITIAL_STRESS_SHELL
- for solids and shells

planned
from R10

\$CARD 1	mid	mmopt	bupd			failm	failf	numint
\$CARD 2	aopt	macf	xp	yp	zp	a1	a2	a3
\$CARD 3	v1	v2	v3	d1	d2	d3	beta	
\$CARD 4	fvf		f1	fd		a11	a22	
\$CARD 5	rof	el	et	glt	prtl	prtt		
\$CARD 6	xt						slimxt	ncyred
\$CARD 7	rom	e	pr					
\$CARD 8	sigyt	etant			eps0	c		
\$CARD 9	lcidt				lcdi	upf		

homogenization

mat. main direction
or via:

*INITIAL_STRESS_X

fiber geometry

fiber properties

matrix material

Mapping: – Procedure for *MAT_215

*INITIAL_STRESS_SHELL

Integration point 1

\$CARD 1	eid 1	nplane 1 or 4	nthick e.g. 5	nhisv 12	ntensr	large	nthhint	nthhisv
\$CARD 2	t 0.0e+00	sigxx 0.0	sigyy 0.0	sigzz 0.0	sigxy 0.0	sigyz 0.0	sigzx 0.0	eps 0.0
\$CARD 3	Hisv1	Hisv2	Hisv3	Hisv4	Hisv5	Hisv6	Hisv7	Hisv8
\$CARD 4	Hisv9=q1	Hisv10=q2	Hisv11=a11	Hisv12=a22				

Integration point 2

\$CARD 5	t -0.9062	sigxx 0.0	sigyy 0.0	sigzz 0.0	sigxy 0.0	sigyz 0.0	sigzx 0.0	eps 0.0
\$CARD 6	see *SECTION_ SHELL							
\$CARD 7	q1 ..	q2 ..	a11 ..	a22 ..				

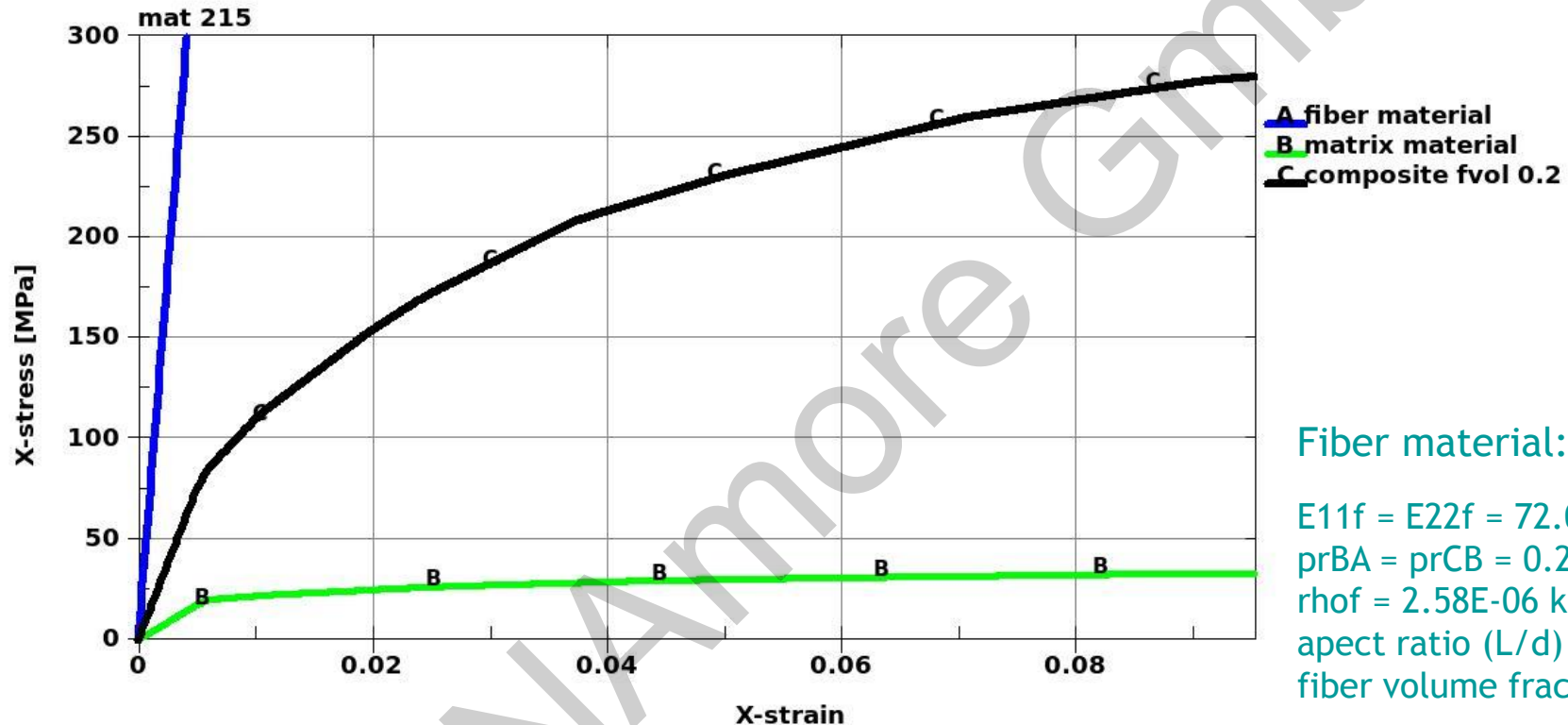
IP 3 ... 5

\$CARD 8	t -0.5385	sigxx ..	sigyy ..	sigzz ..	sigxy ..	sigyz ..	sigzx ..	eps ..
ff								

Outline

- Integrative Simulation:
 - Motivation
 - Fiber orientation
 - Homogenization
 - Procedure
- Material models in LS-DYNA
 - continuous filaments/fabrics
 - long and short fibers
 - *MAT_215 / *MAT_4A_MICROMECH
- Mapping
 - Tools: 4a fibermat (4a engineering) – Envyo (DYNAmore)
 - procedure for *MAT_157
 - procedure for *MAT_215
- Examples
- Summary and Outlook

*MAT_215 (stress-strain behavior): matrix – fiber - composite

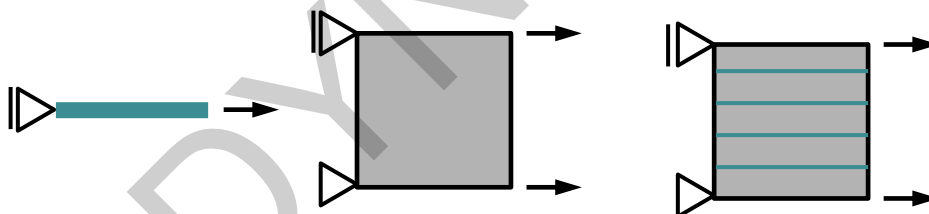


Fiber material:

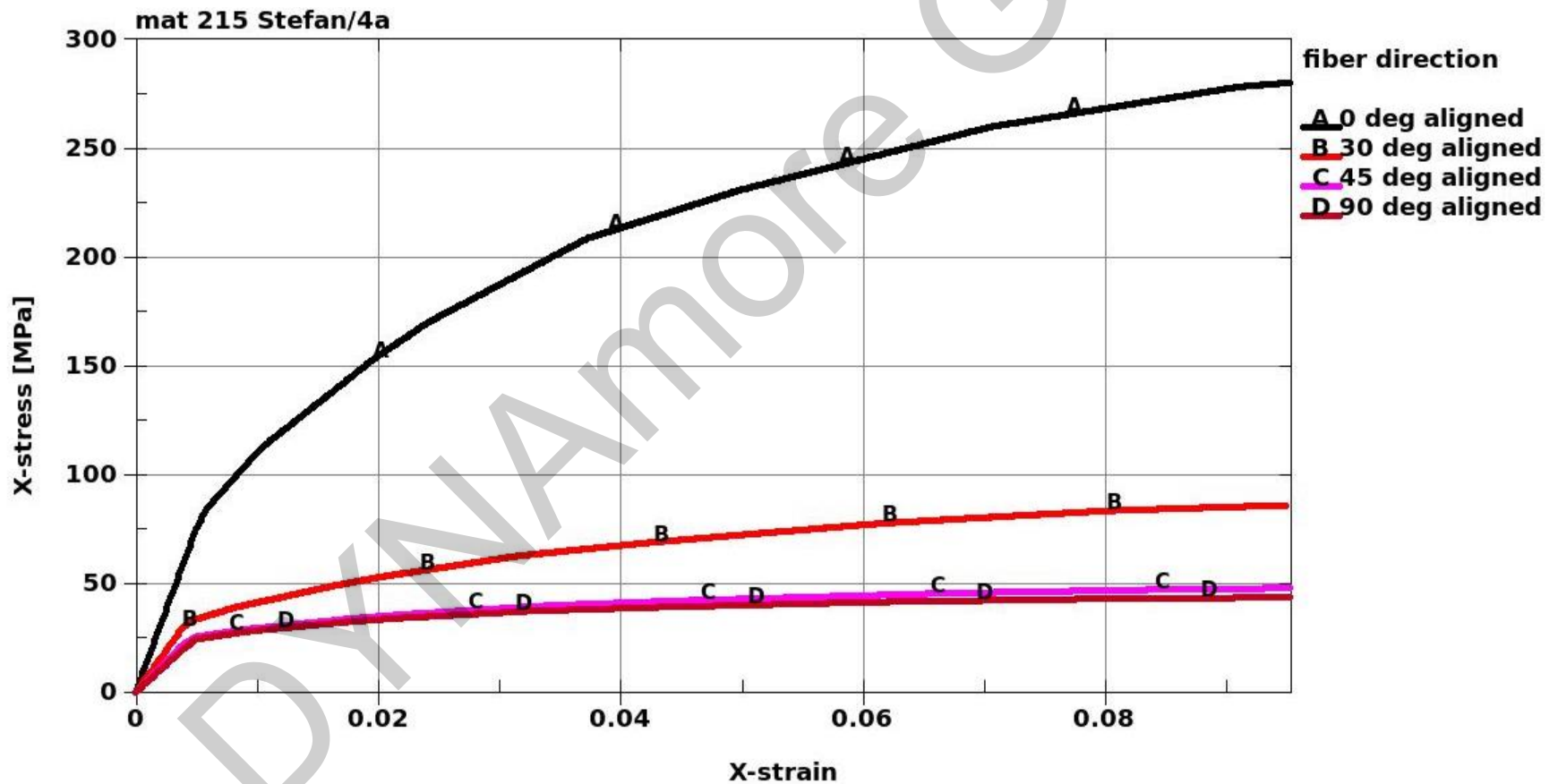
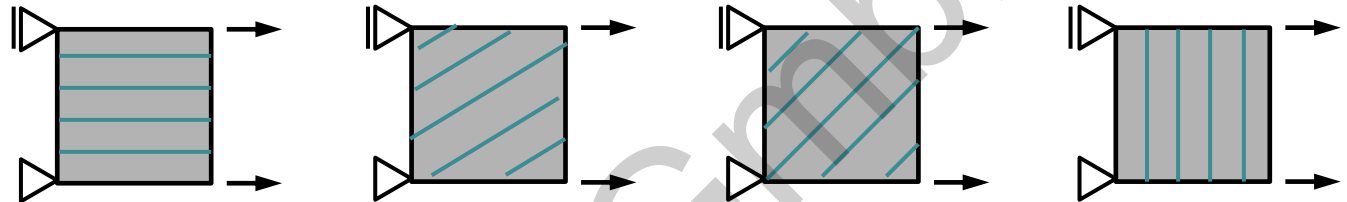
$E_{11f} = E_{22f} = 72.0 \text{ GPa}$
 $pr_{BA} = pr_{CB} = 0.20$
 $\rho_{hf} = 2.58E-06 \text{ kg/mm}^3$
 aspect ratio (L/d) = 25
 fiber volume fraction = 20%

Matrix material:

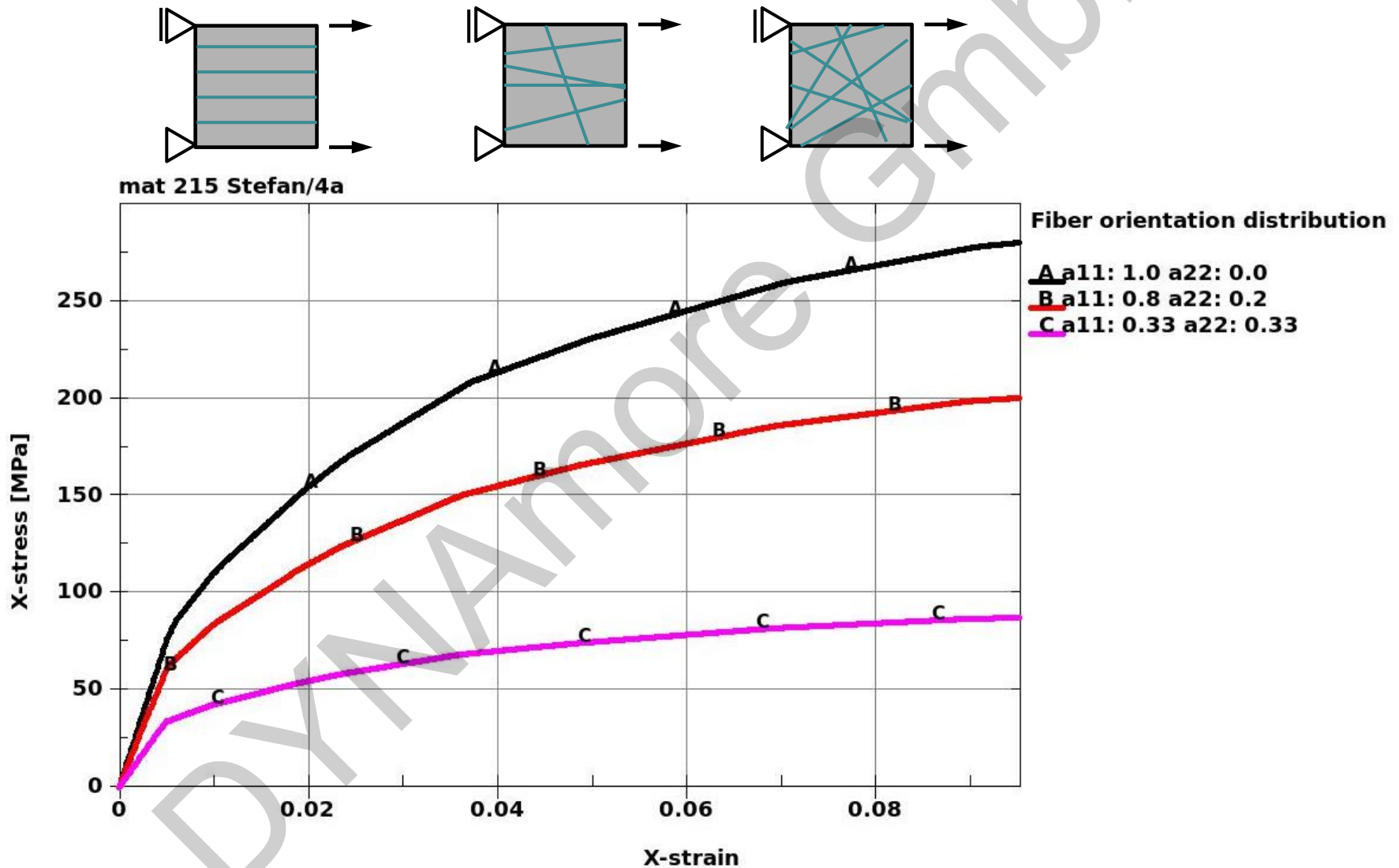
$EM = 3.5 \text{ GPa}$
 $pr_M = 0.32$
 $\rho_{hm} = 1.2E-06 \text{ kg/mm}^3$



*MAT_215: Influence of fiber direction

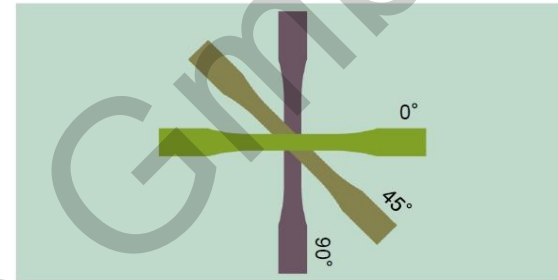
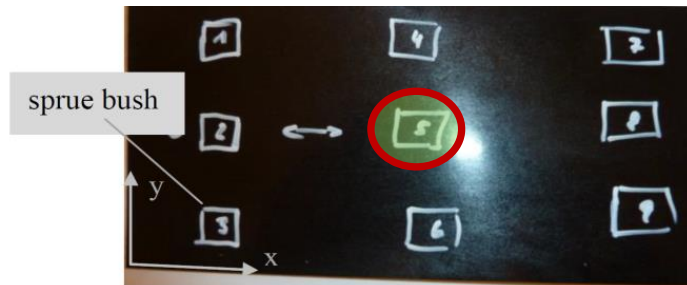


*MAT_215: Influence of fiber alignment



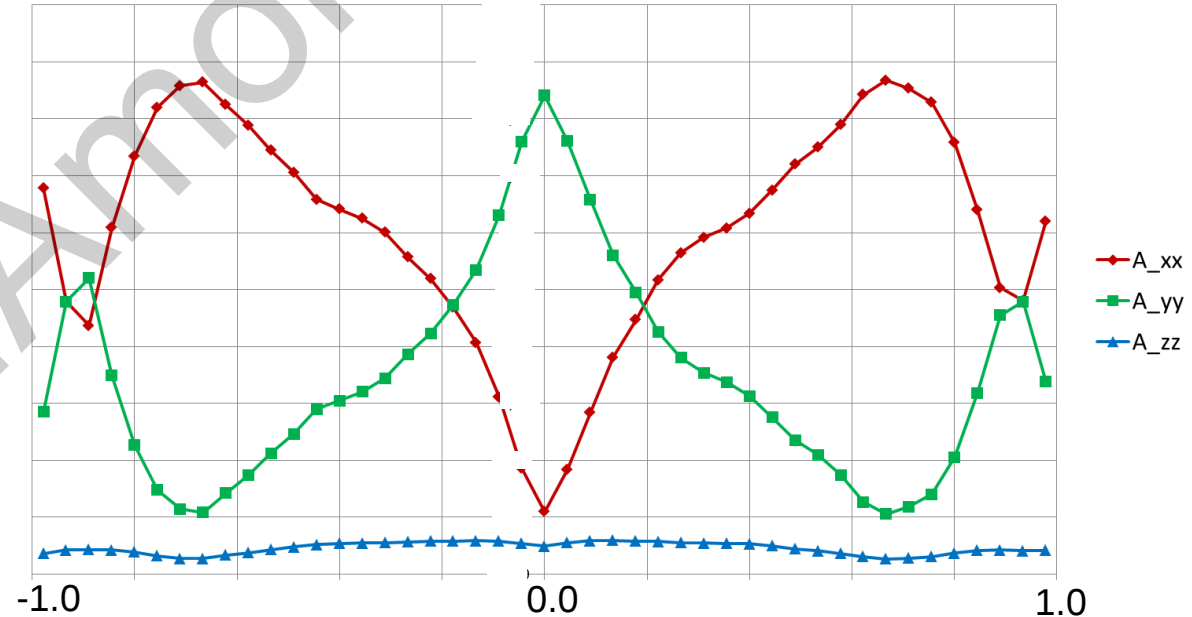
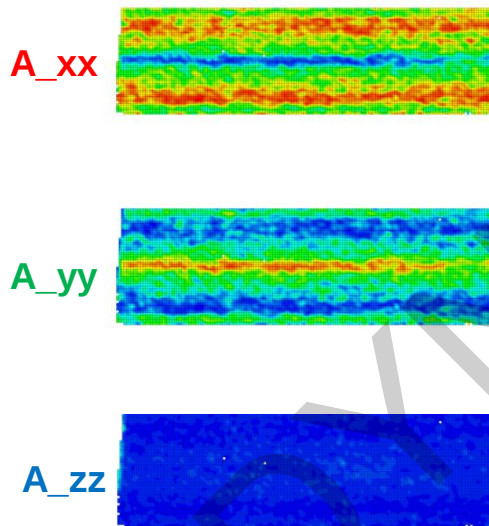
Tensile test: fiber orientation distribution

- Tensile specimen in 0°, 45°, 90° cut out in middle of injection moulded plate



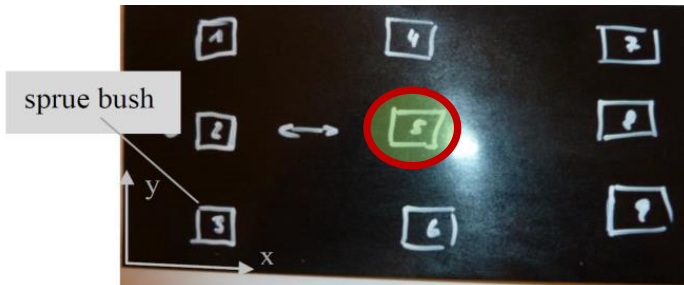
- Fiber orientation of 0°- specimen over thickness (μ CT-Scan):

Tensor data A_{ij} vs. rel. thickness - specimen 5

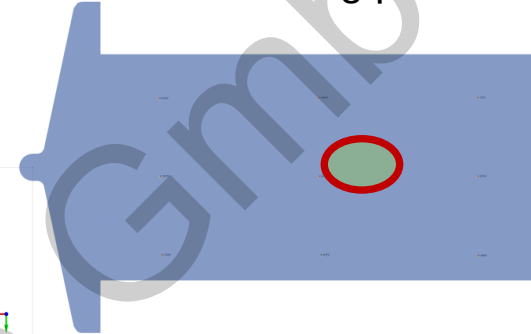


Tensile test: fiber orientation distribution

moulded plate

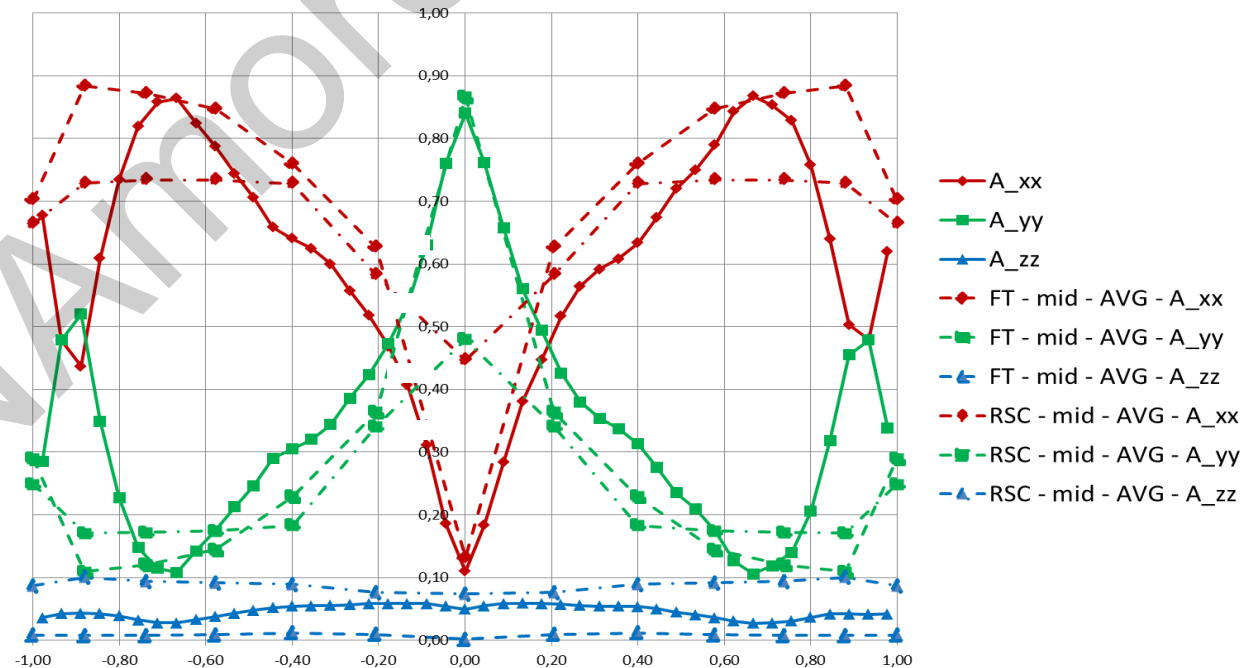


simulation of moulding process



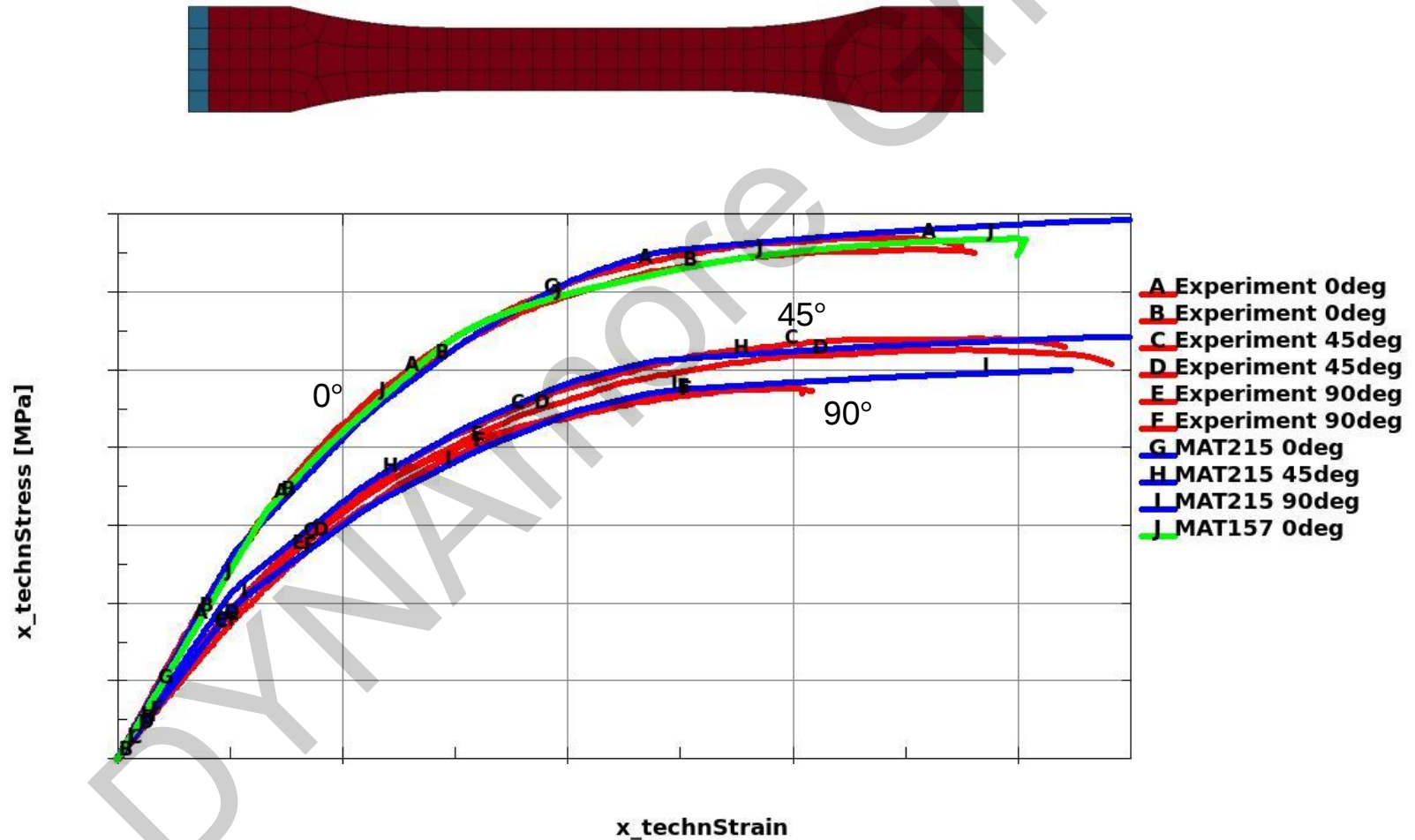
- Fiber orientation of 0°- specimen over thickness μ CT-Scan vs. simulation results

Tensor data A_{ii} vs. rel. thickness - specimen 5



Tensile test: simulation vs. experimental results

- Experimental tensile tests carried out by DYNAmore (here: quasi-static loading)



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 - procedure for *MAT_215
- Examples
- Summary and Outlook

Summary and Outlook

- various material models available in LS-DYNA
 - for short/long fiber reinforced plastics
 - for continuous fiber reinforced composites
- integrative simulation needs mapping
- homogenization can be done
 - in the mapper (i.e. *MAT_157)
 - in the material model (i.e. *MAT_215 – based on micro mechanics)
- more possibilities will be added depending on user requests
 - material models / features in LS-DYNA
 - mapping capabilities
 - ...
- Thank you!

Einleitung

- Wie verhalten sich SFRT/LFRT Kunststoffe
- Welche Simulationstools gibt es
- Wie sieht eine Simulationsprozesskette aus

Materialmodelle in LS-DYNA

- Welche Modelle sind für Composites verfügbar
- Wie kann die Orientierung berücksichtigt werden

Materialcharakterisierung

- Welche Prüfmethoden bietet 4a impetus
- Wie funktioniert eine Materialkartenerstellung (LIVE)

Mapping

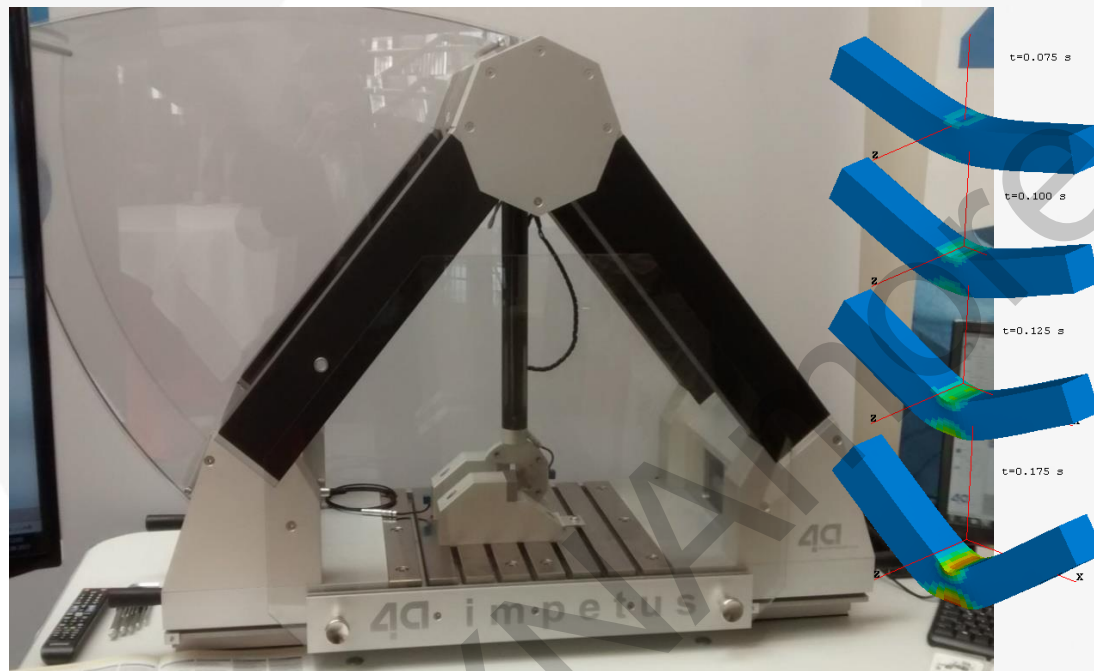
- Wie aufwendig ist das Mapping (LIVE)
- Auf was sollte geachtet werden

Diskussion

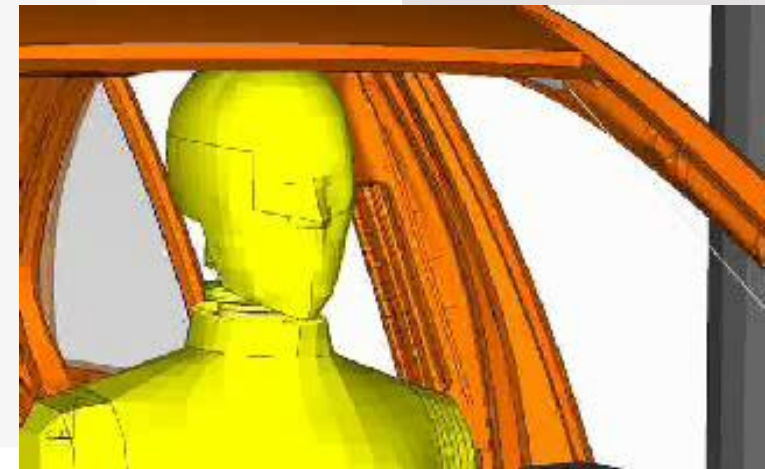
4a impetus dynamische Prüfungen

Prüfsystem

- efficient high-dynamic testing
- crash-behaviour of plastics
- material data for simulation



source: <http://gm-volt.com/>



source: Dynamore GmbH

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**4a impetus - intelligent testing systems
powered by 4a engineering GmbH**



static

dynamic

External Testing

4a impetus Hardware

4a impetus Software

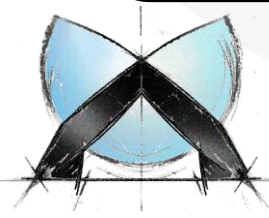
Testresults

Reports

Workflow

Postprocess

Materialcards



4a impetus - intelligent testing systems

powered by 4a engineering GmbH

LS-OPT®

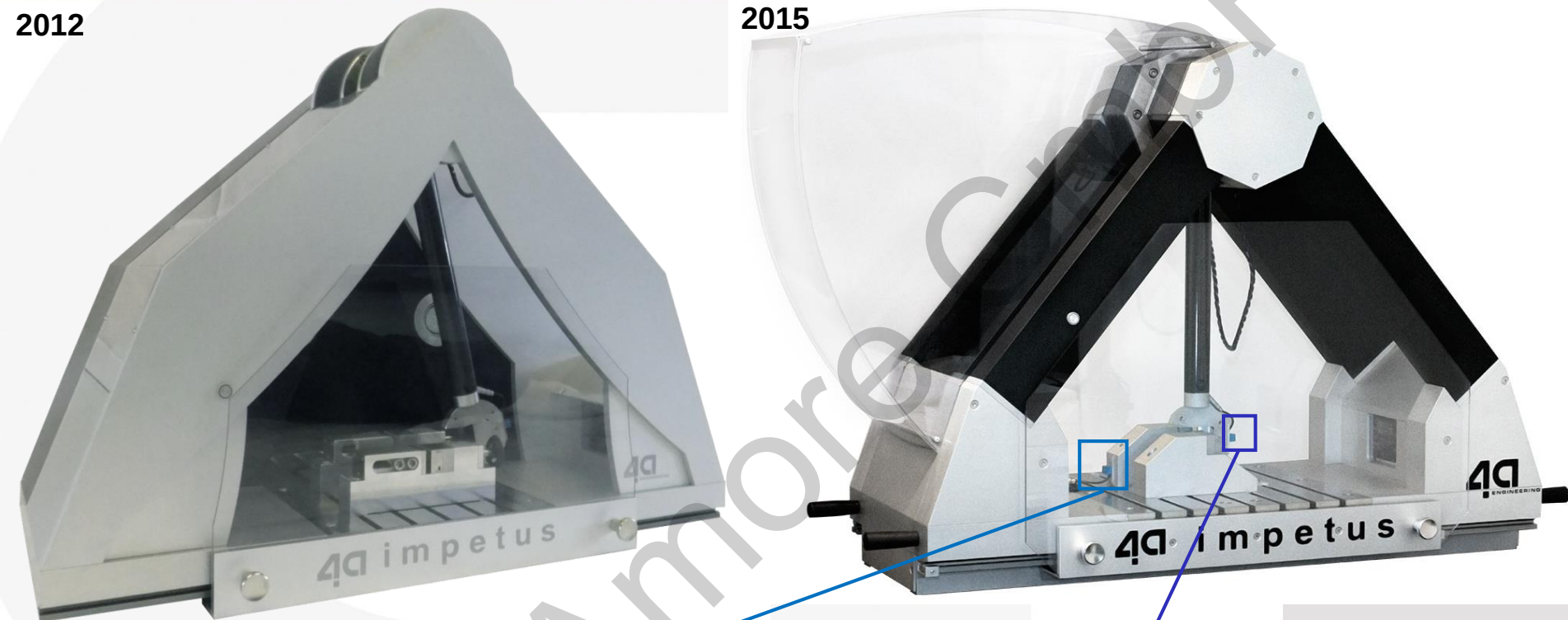
Reverse Engineering Optimierer

4a impetus dynamische Prüfungen

Prüfsystem

2012

2015



g-Sensor am Widerlager und g-Sensor am Pendelkopf

Pendelkopfmasse: 500 - 2000 g (Zusatzgewichte)

Prüfgeschwindigkeit: 1 – 4.4 m/s

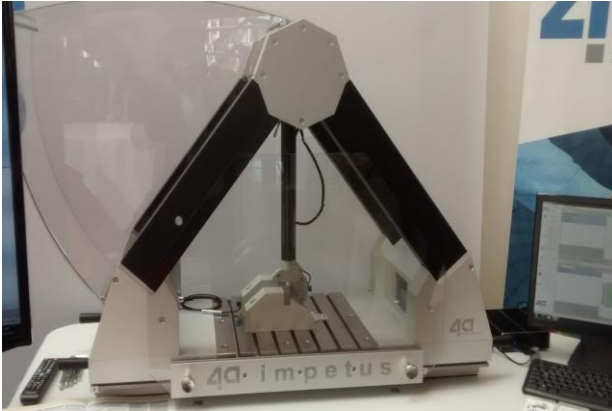
Finnen- und Widerlagerradius: 2 bzw. 5 mm

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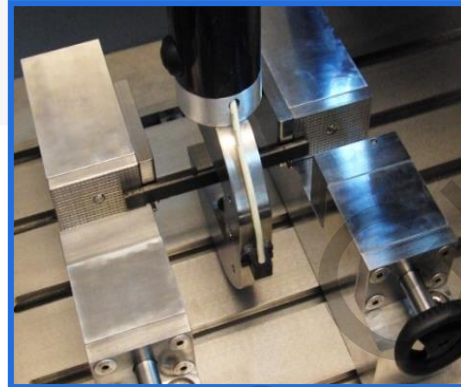
4a impetus dynamische Prüfungen

Prüfsystem

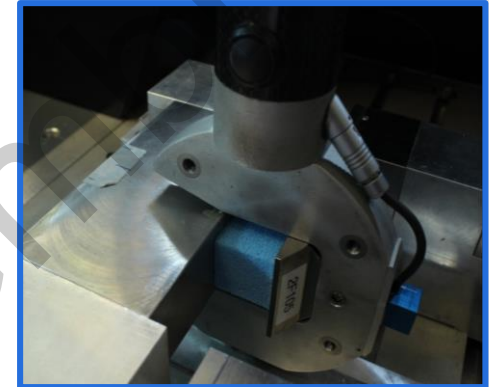
4a impetus Hardware



- single pendulum up to 4.5 m/s
- double pendulum up to 8 m/s
- **standard test methods**
- **specialized test methods**



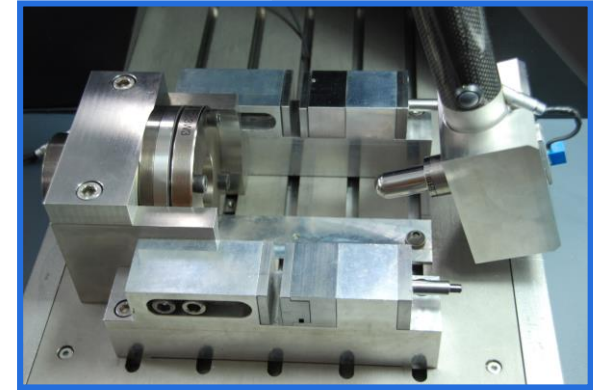
bending test



compression test



Fixed bending test

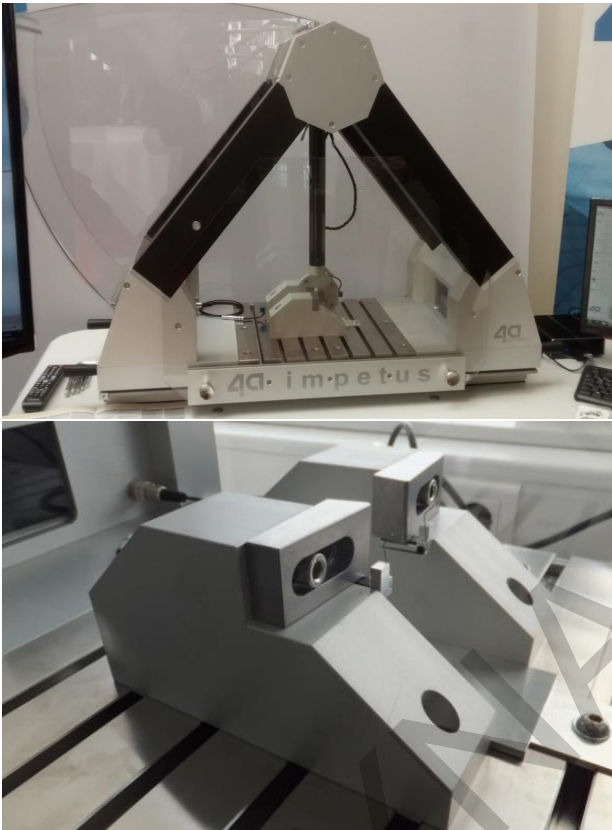


Puncture test

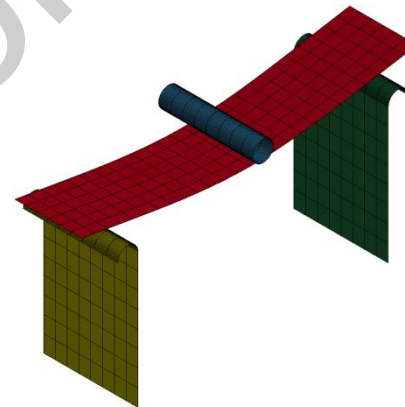
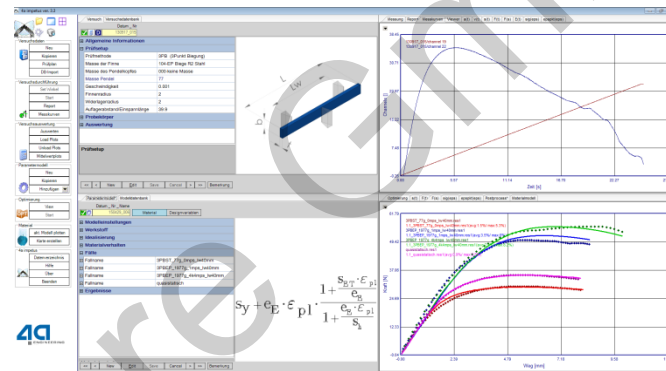
4a impetus dynamische Prüfungen

3-Punkt-Biegung

4a impetus Hardware



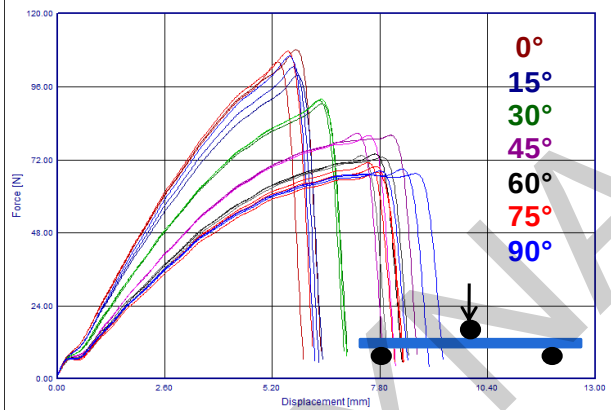
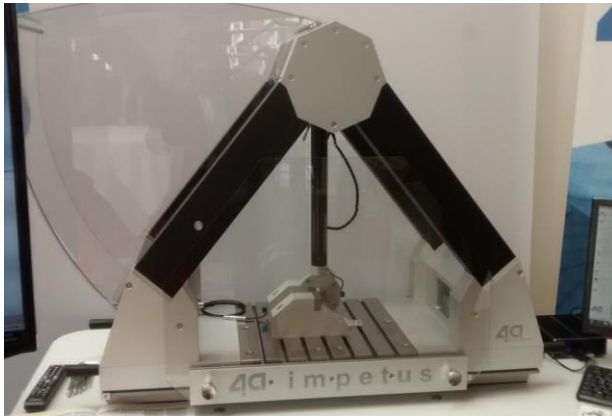
4a impetus Software



4a impetus dynamische Prüfungen

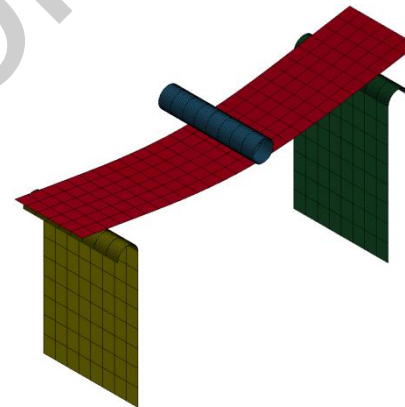
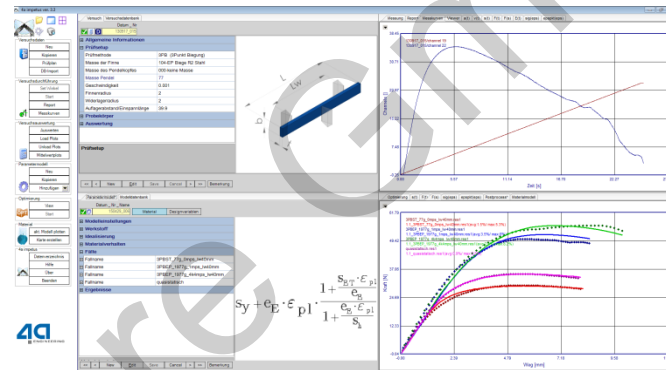
3-Punkt-Biegung

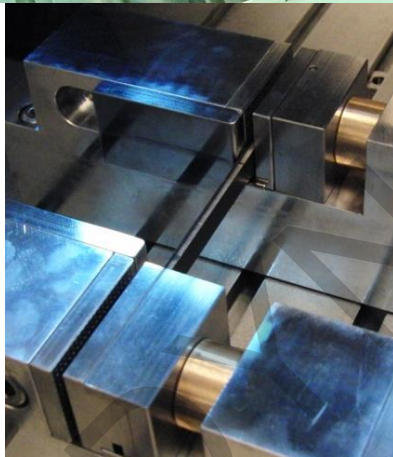
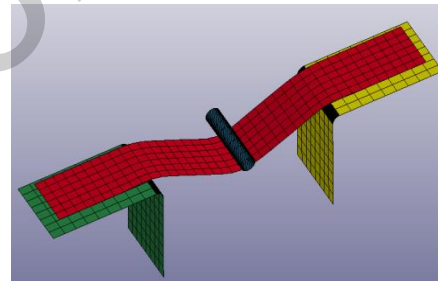
4a impetus Hardware



0° 90°

4a impetus Software



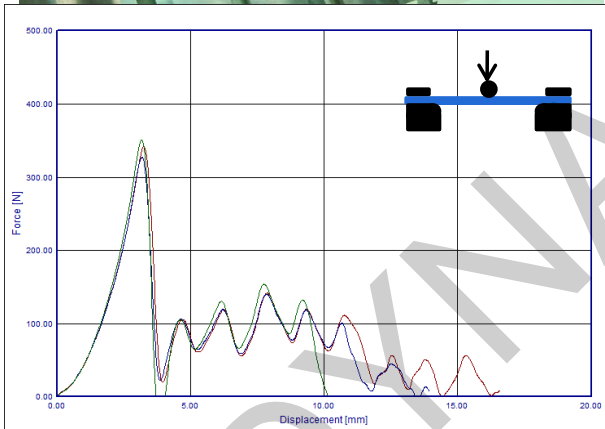
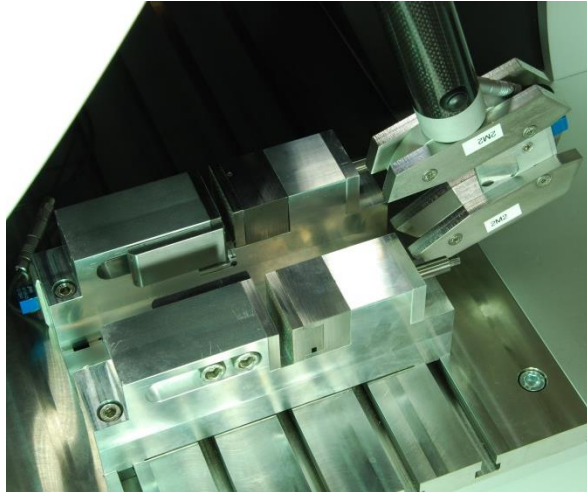
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DYNA
MORE

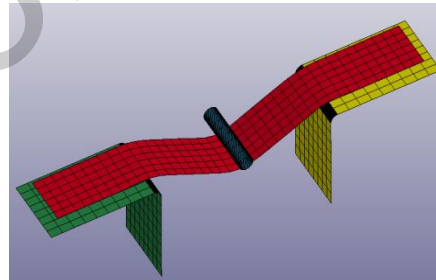
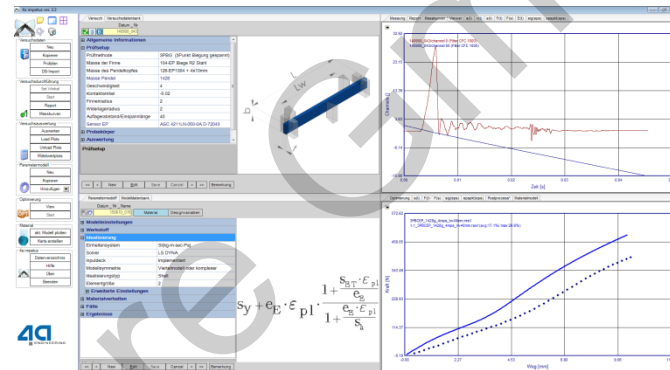
4a impetus dynamische Prüfungen

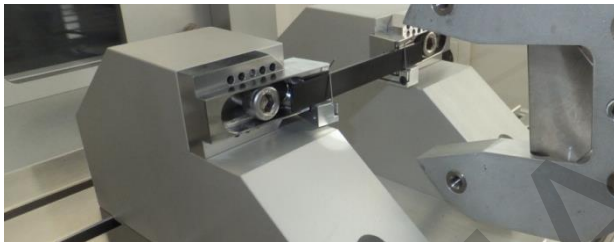
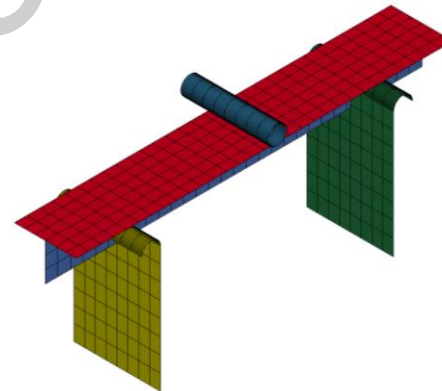
gespannte 3-Punkt-Biegung

4a impetus Hardware



4a impetus Software



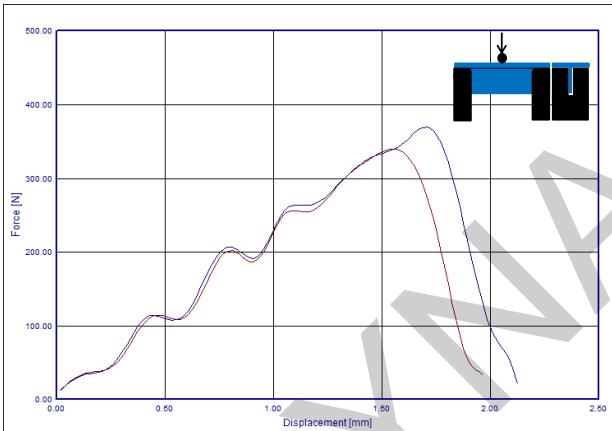
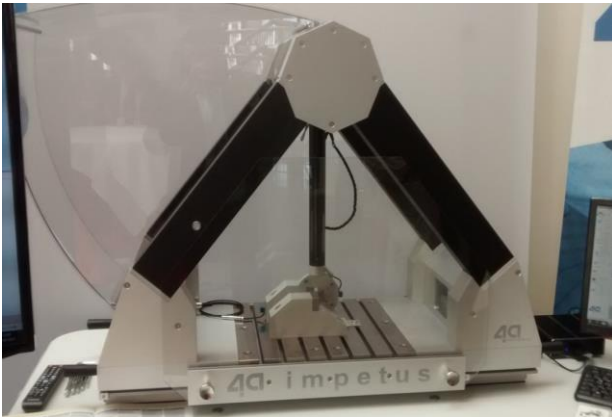
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DYNA
MORE

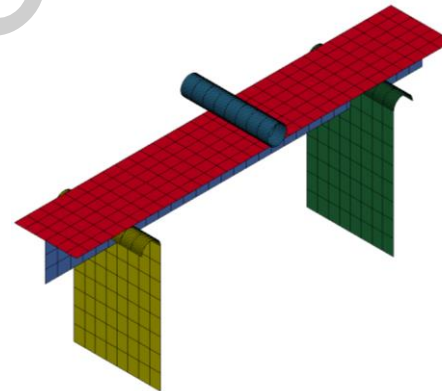
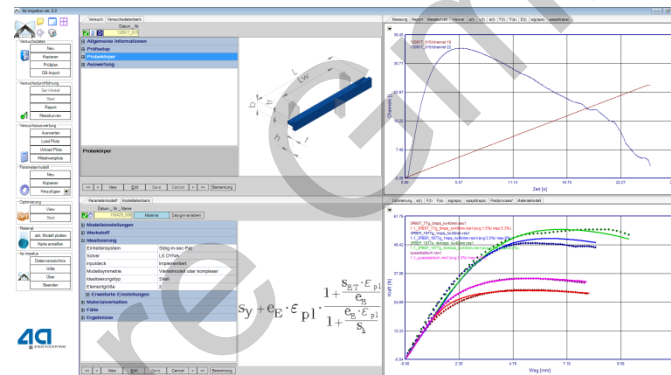
4a impetus dynamische Prüfungen

Komponentenprüfung T-Probe

4a impetus Hardware



4a impetus Software



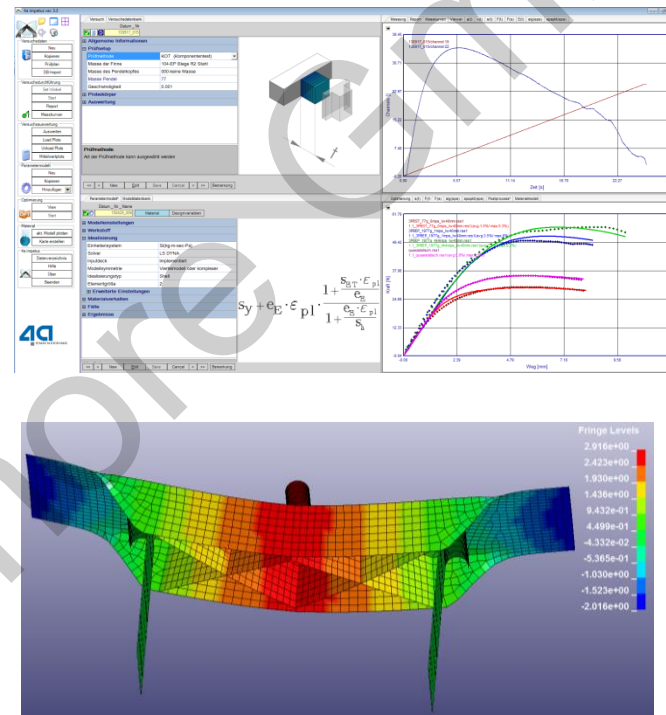
4a impetus dynamische Prüfungen

Komponentenprüfung Doppelrippe

4a impetus Hardware



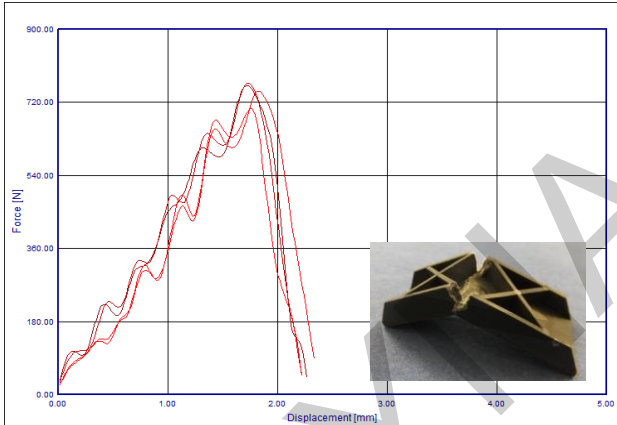
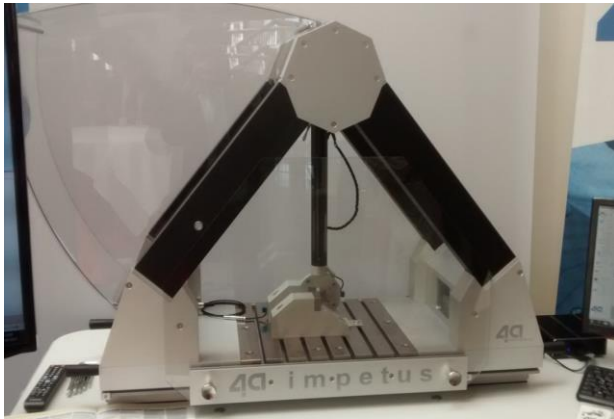
4a impetus Software



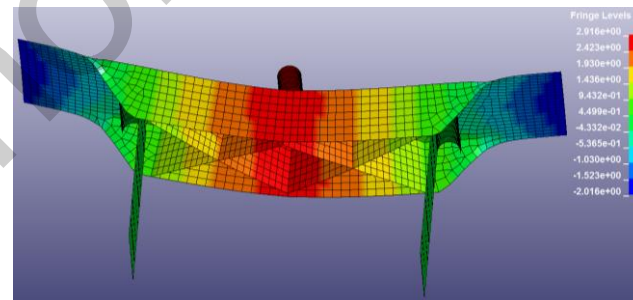
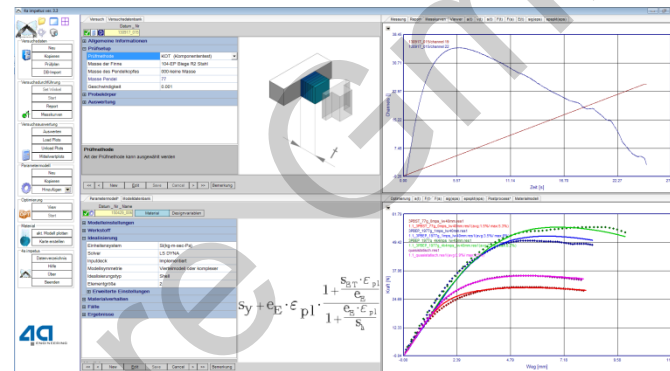
4a impetus dynamische Prüfungen

Komponentenprüfung Doppelrippe

4a impetus Hardware



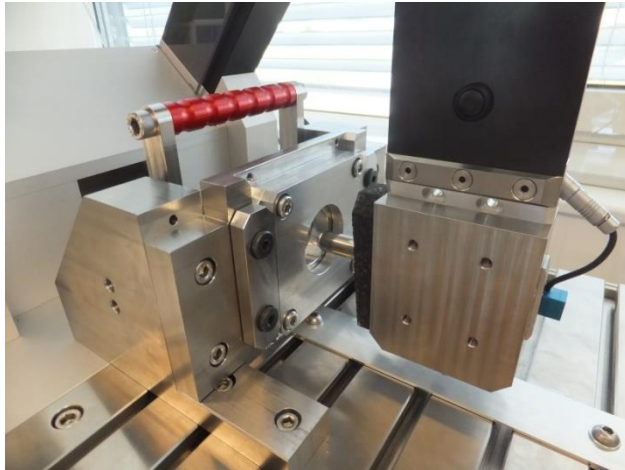
4a impetus Software



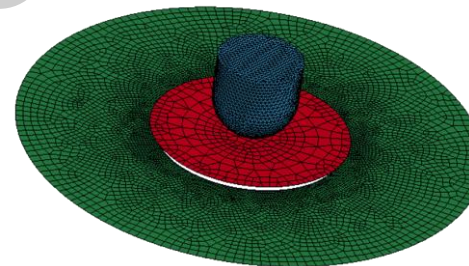
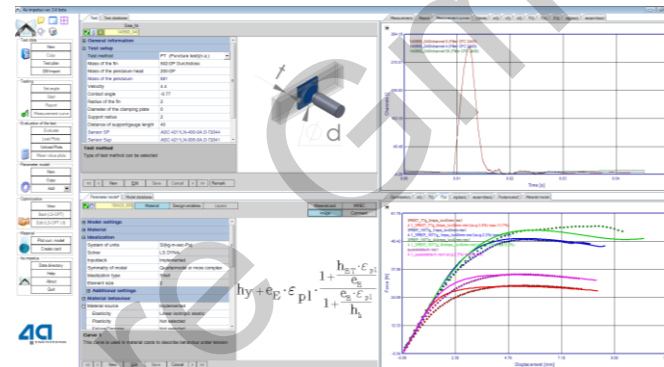
4a impetus dynamische Prüfungen

Durchstoßaufbau

4a impetus Hardware



4a impetus Software



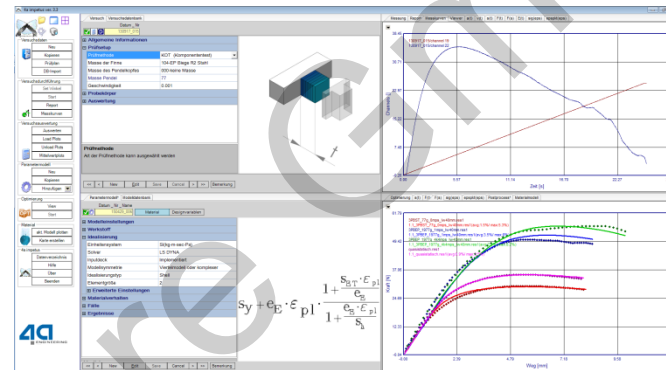
4a impetus dynamische Prüfungen

Komponenten

4a impetus Hardware

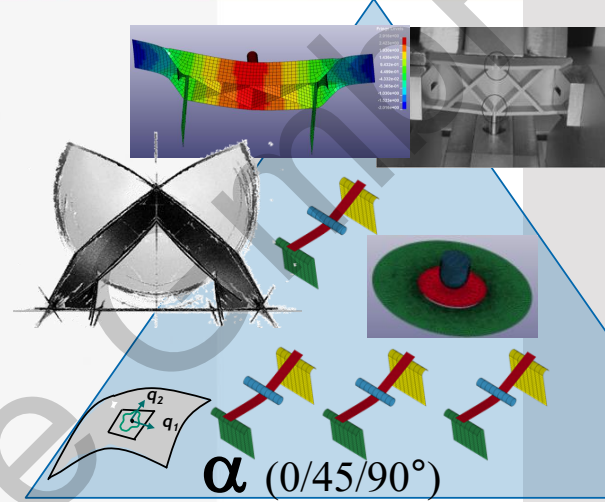
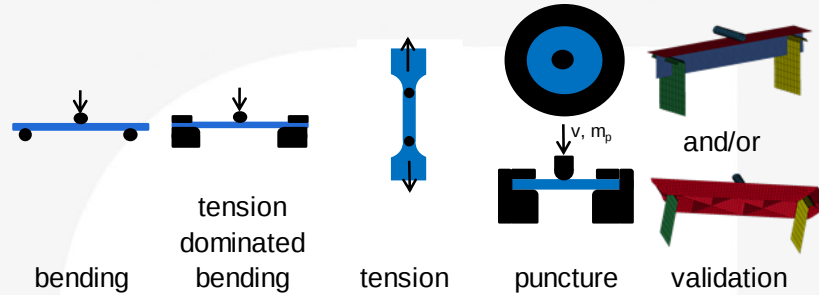


4a impetus Software

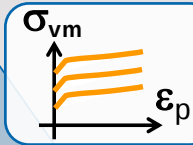
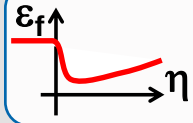


4a impetus

Material characterization

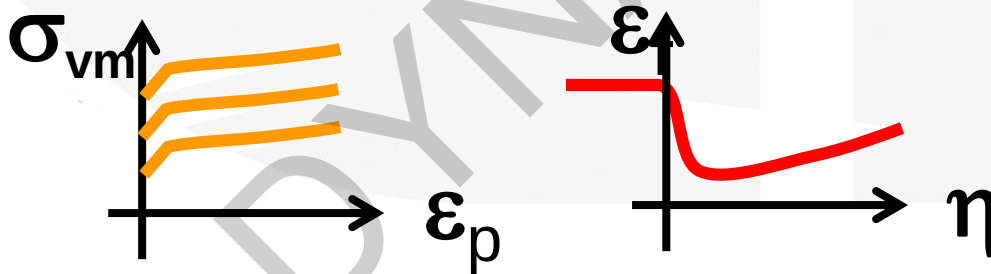


component validation



comment

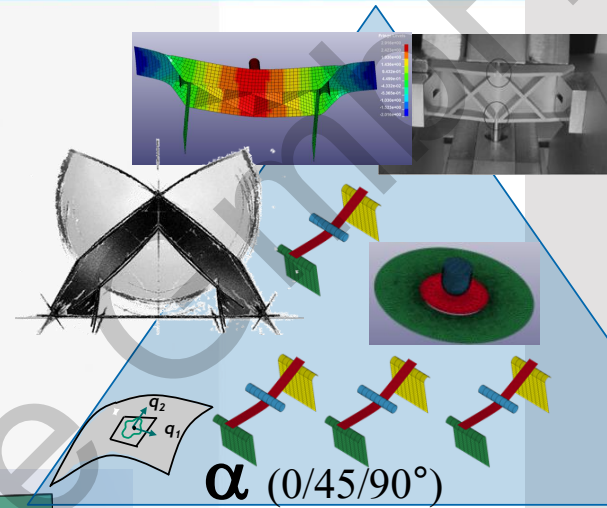
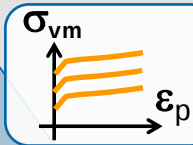
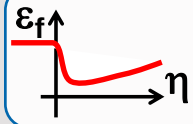
	static	dynamic	dynamic	static	dynamic	static	dynamic	static	dynamic	comment
*MAT_024	☒	☒								Materialcard for each direction
*MAT_157	☒	☒		☒	☒	☒	☒	☒	☒	μCT
*MAT_215	☒	☒		☒	☒	☒	☒	☒	☒	



4a impetus

Material characterization

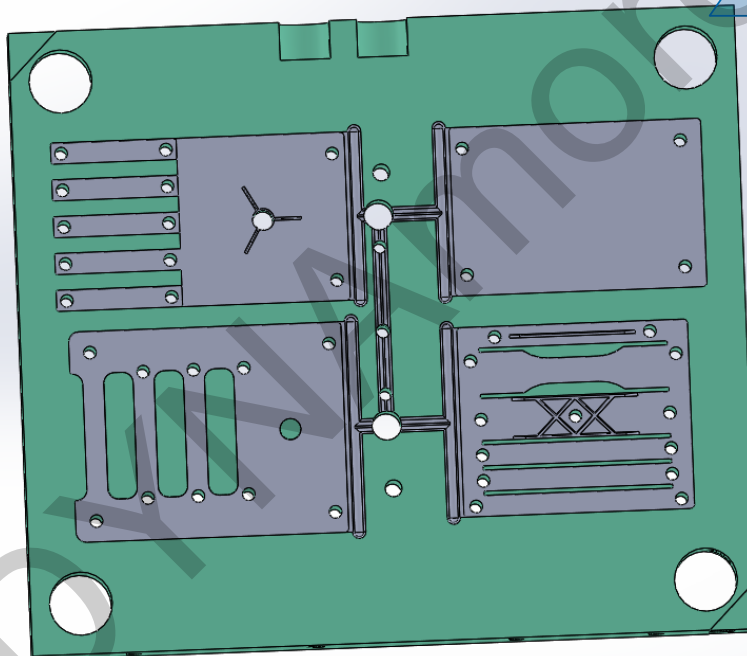
component
validation



Validation DOM &
wall thickness



melt & welt lines



Upcoming ISO
Plate 120 x 80 x 2 mm



injected samples

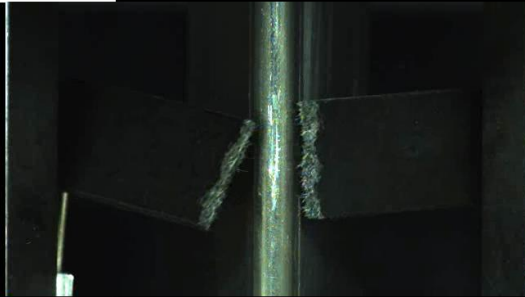


4a impetus

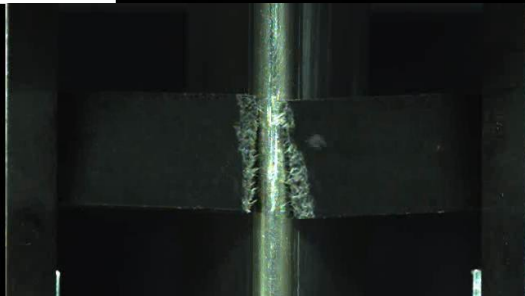
Material characterization



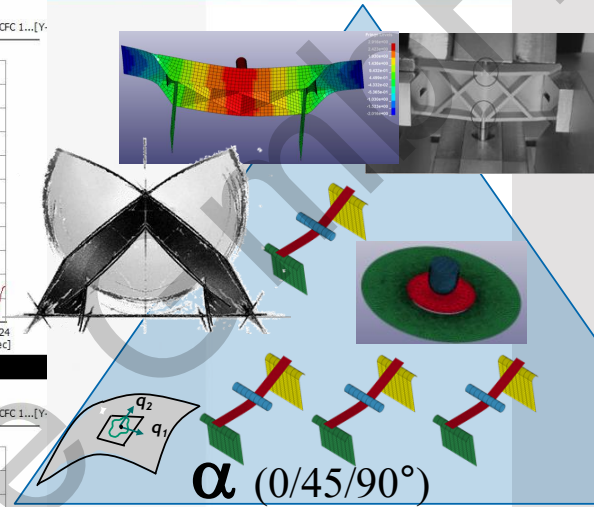
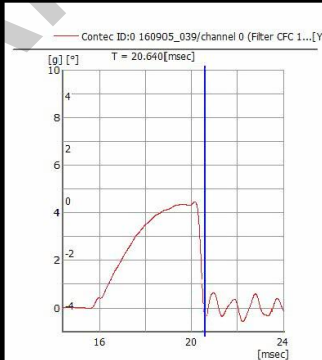
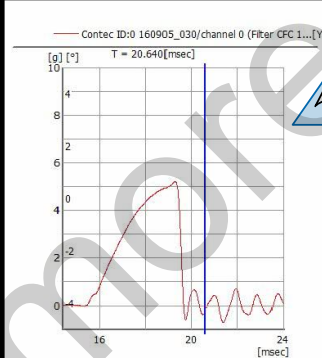
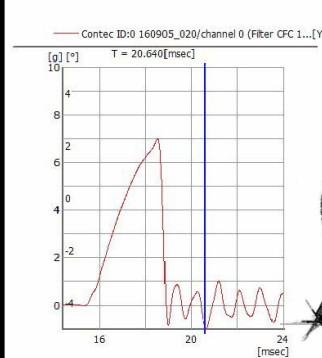
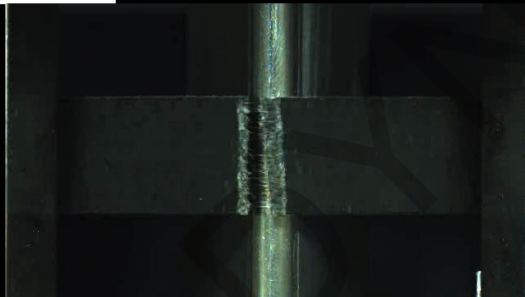
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1/12500 sec
Start
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Date : 2016/9/8



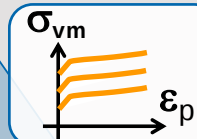
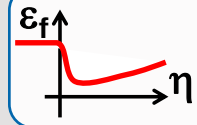
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12500 fps
1/12500 sec
Start
+20.64 ms
Date : 2016/9/8



FASTCAM Mini AX100 type 540K-C-16GB
12500 fps
1/12500 sec
Start
+20.64 ms
Date : 2016/9/8

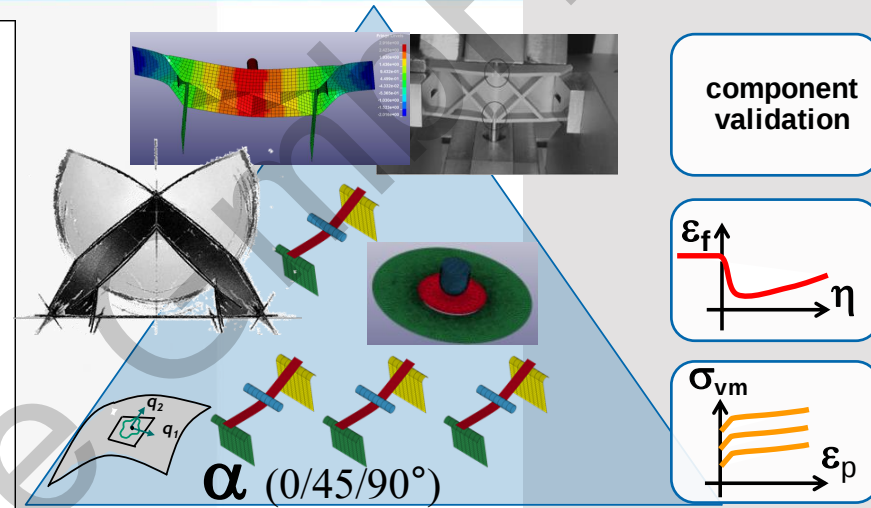
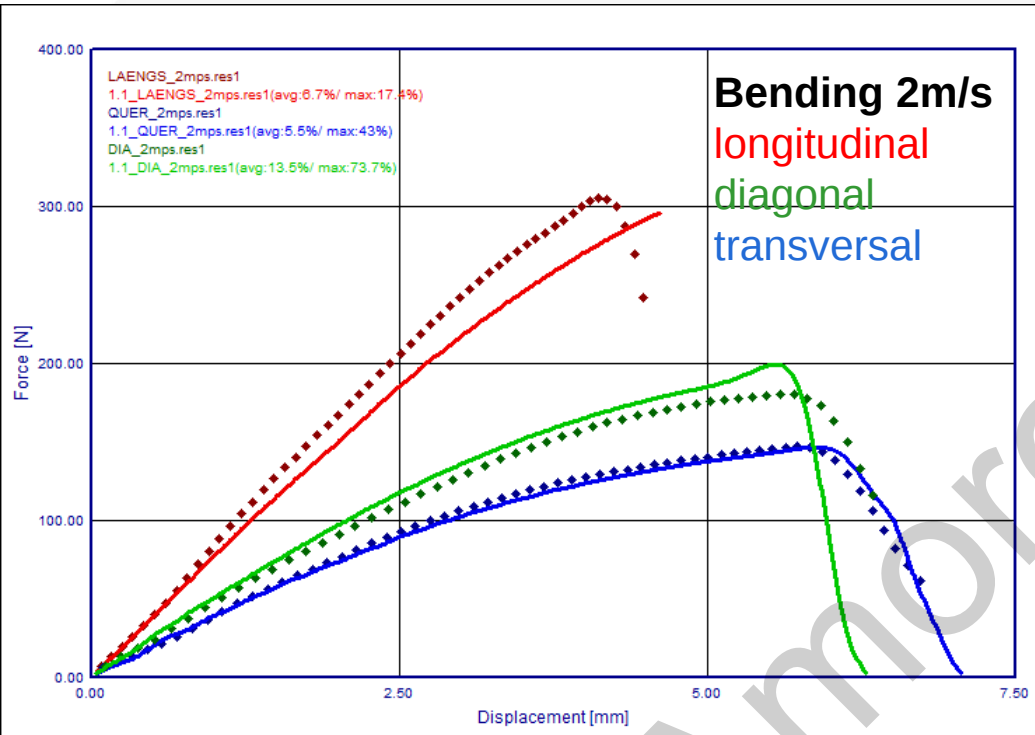


component
validation



4a impetus

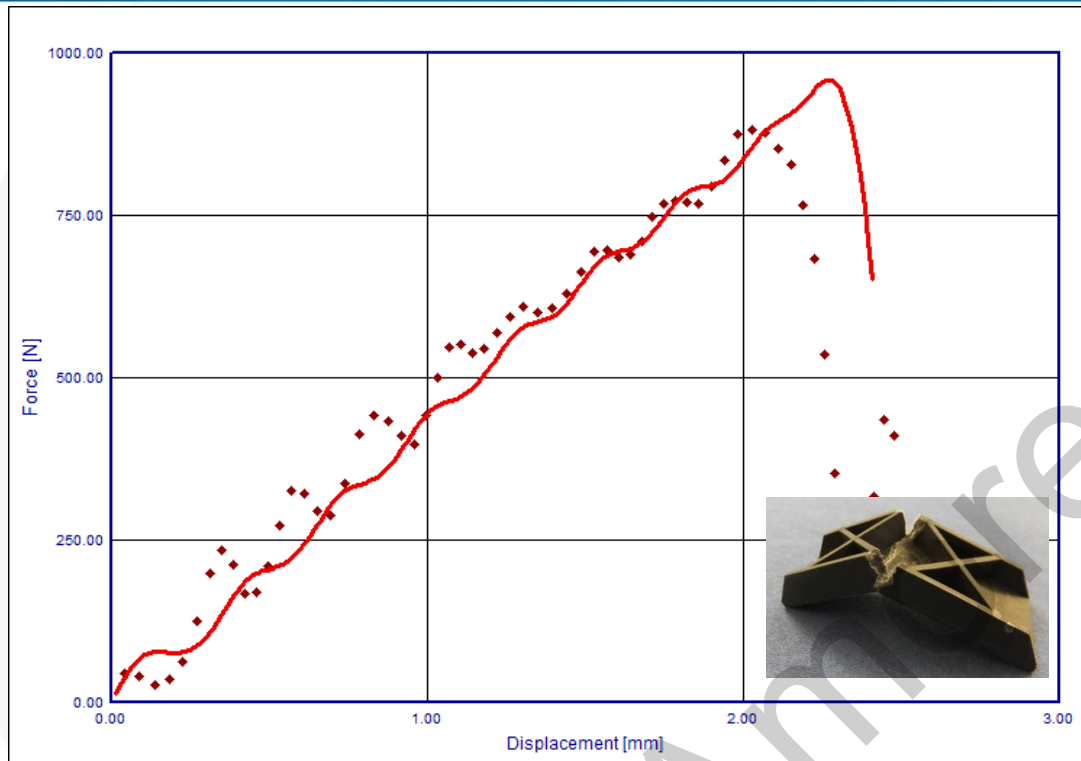
Material characterization



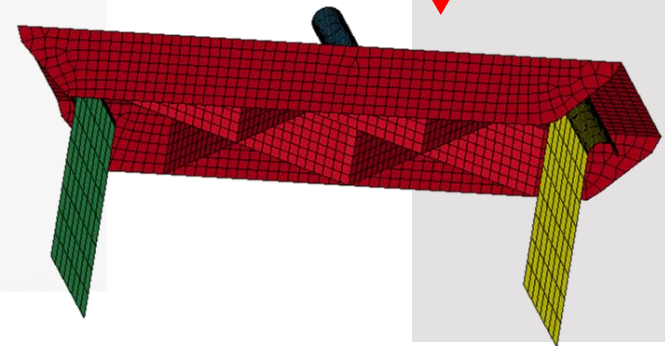
LIVE

Case study Doublecrossrib

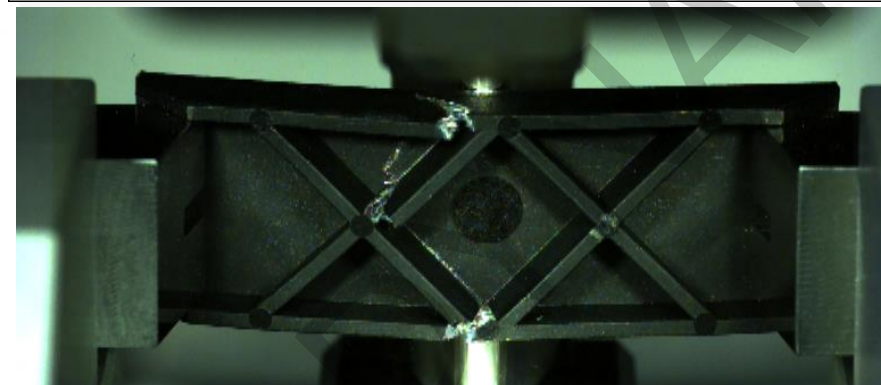
Using *MAT_215



4a
FIBERMAP



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Einleitung

- Wie verhalten sich SFRT/LFRT Kunststoffe
- Welche Simulationstools gibt es
- Wie sieht eine Simulationsprozesskette aus

Materialmodelle in LS-DYNA

- Welche Modelle sind für Composites verfügbar
- Wie kann die Orientierung berücksichtigt werden

Materialcharakterisierung

- Welche Prüfmethoden bietet 4a impetus
- Wie funktioniert eine Materialkartenerstellung (LIVE)

Mapping

- Wie aufwendig ist das Mapping (LIVE)
- Auf was sollte geachtet werden

Diskussion

- Es wird gezeigt, wie von einem Spritzgussbauteil auf eine daraus entnommene Probe (Doppelkreuzrippe)
 - die Faserorientierung mittels 4a fibermap gemappt wird
 - und im Anschluss eine dynamische 3-Punkt-Biegung in 4a impetus simuliert wird (LS-Dyna).
 - Die Faserorientierung wird als ***INITIAL_STRESS_SHELL** übertragen.
- Material: Stamax 30YM 240 (PP LGF30)
- Notwendige Daten:
 - Spritzgussimulation Versuchsbauteil (Autodesk Moldflow®)
 - FEM-Modell des Probekörpers (Shell-Idealisierung, Elementkantenlänge 1 mm)
 - Entsprechendes Materialmodell (z.B. ***MAT_157** oder ***MAT_215**)

Fallbeispiel (4a fibermap)

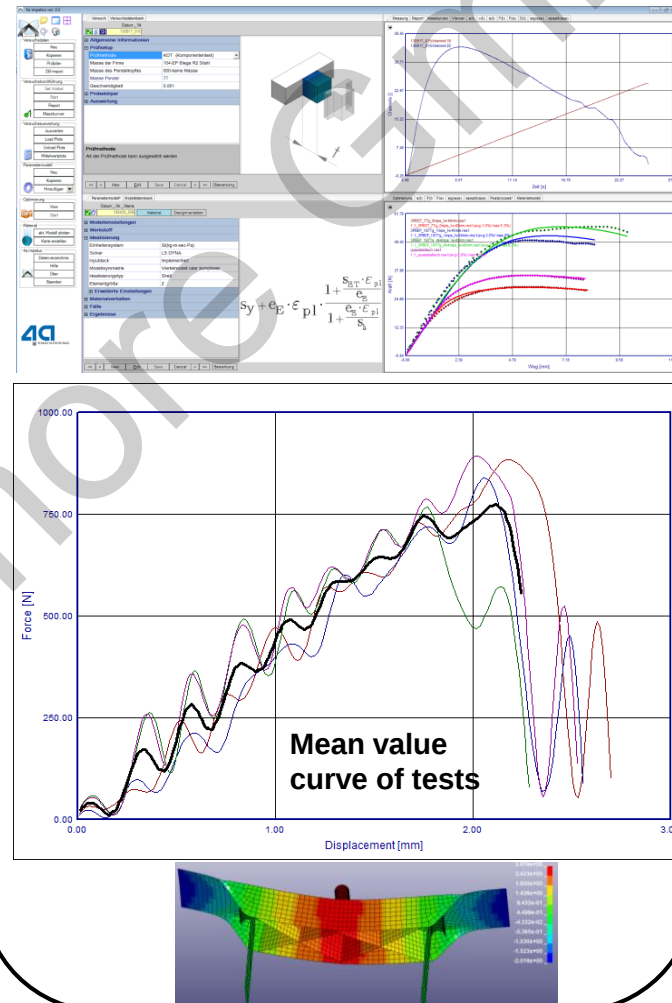
Aufgabenstellung

- 3-Punkt-Biegung der Doppelkreuzrippe:

4a impetus Hardware



4a impetus Software

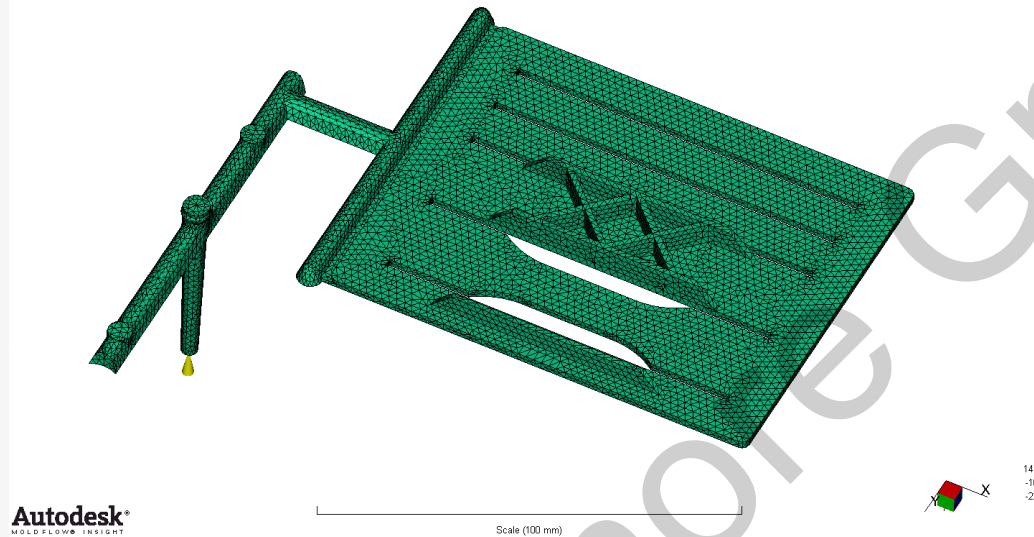


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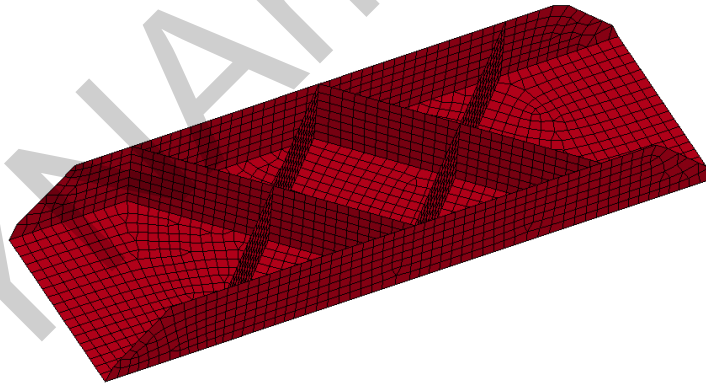
Fallbeispiel (4a fibermap)

Aufgabenstellung

- Modell in Autodesk Moldflow®:



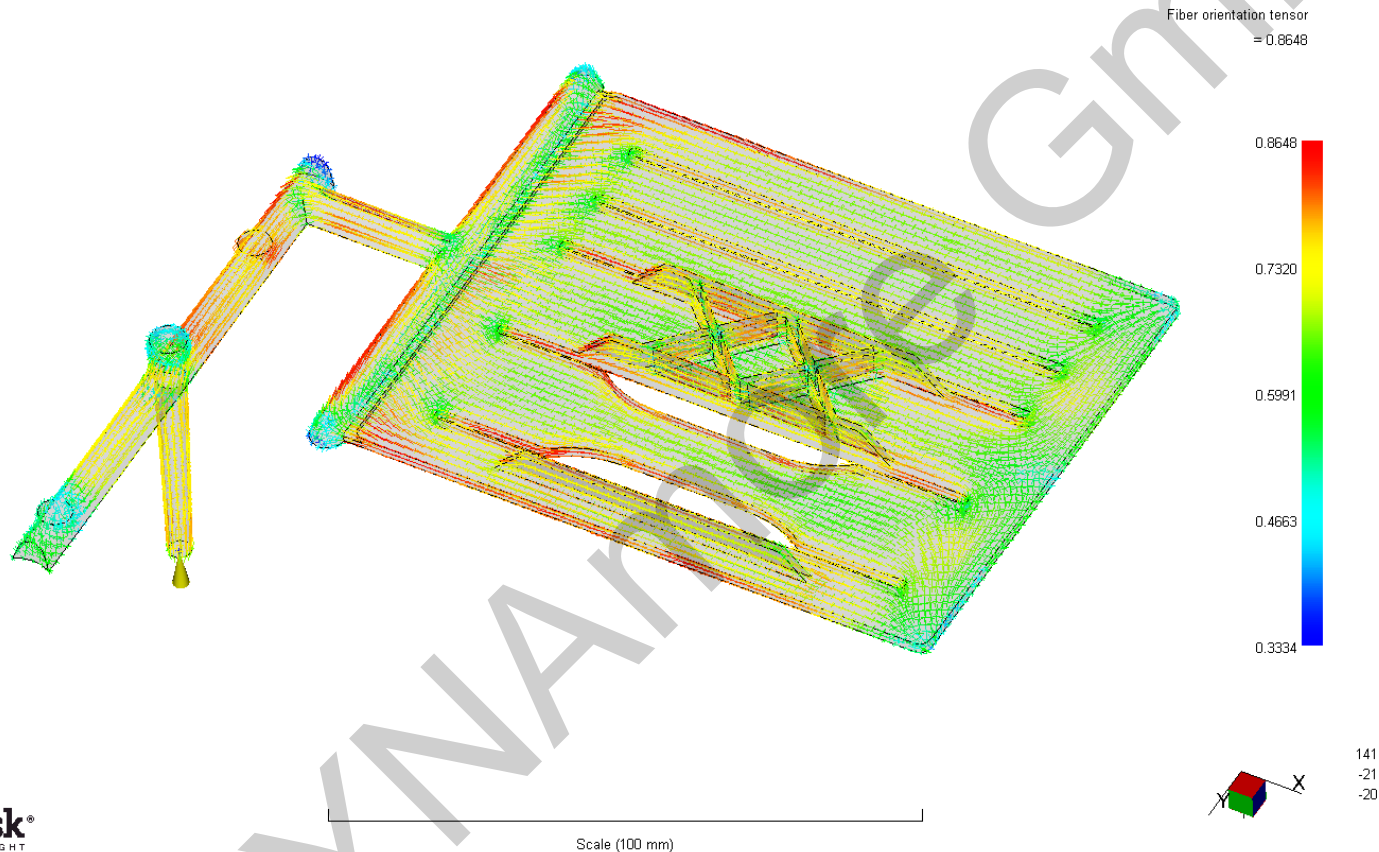
- FEM-Modell:



Fallbeispiel (4a fibermap)

Aufgabenstellung

- Ergebnis Faserorientierungstensor aus Autodesk Moldflow®:



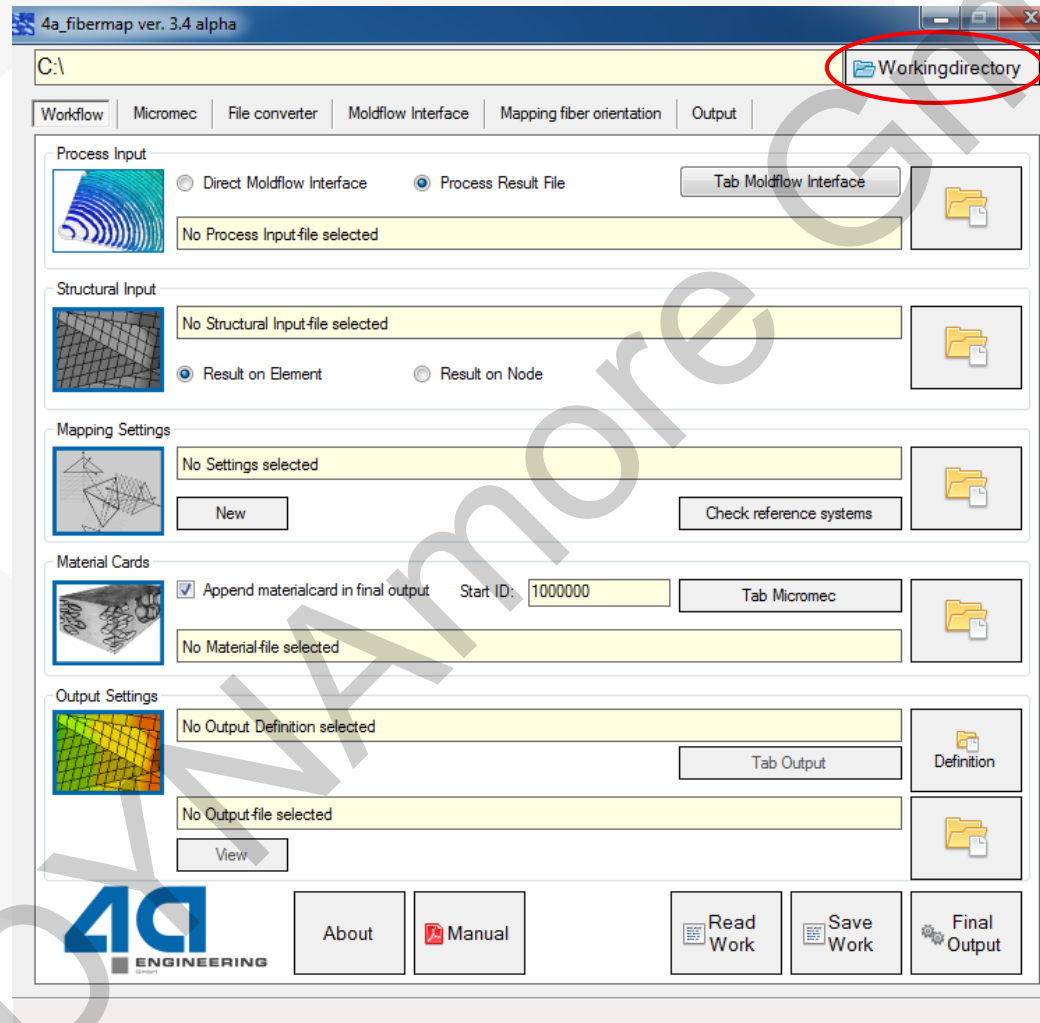
Die prinzipielle Vorgehensweise des Mapping-Prozesses ist im folgenden aufgeführt:

- 1. Spritzgusssimulation durchführen (z.B. Autodesk Moldflow®) und Ergebnisse exportieren (XML)
- 2. FEM-Modell erstellen (z.B. mit ANSA®)
- 3. Mapping mit 4a fibermap durchführen (Workflow)
 - 3a. 4a fibermap starten
 - 3b. Autodesk Moldflow®-Ergebnisse importieren
 - 3c. Mapping durchführen
 - 3d. Export der gemittelten gemappten Eigenschaften
- 4. FEM-Berechnung (z.B. mit LS-DYNA®) durchführen

Fallbeispiel (4a fibermap)

3. Mapping mit 4a fibermap durchführen (Workflow)

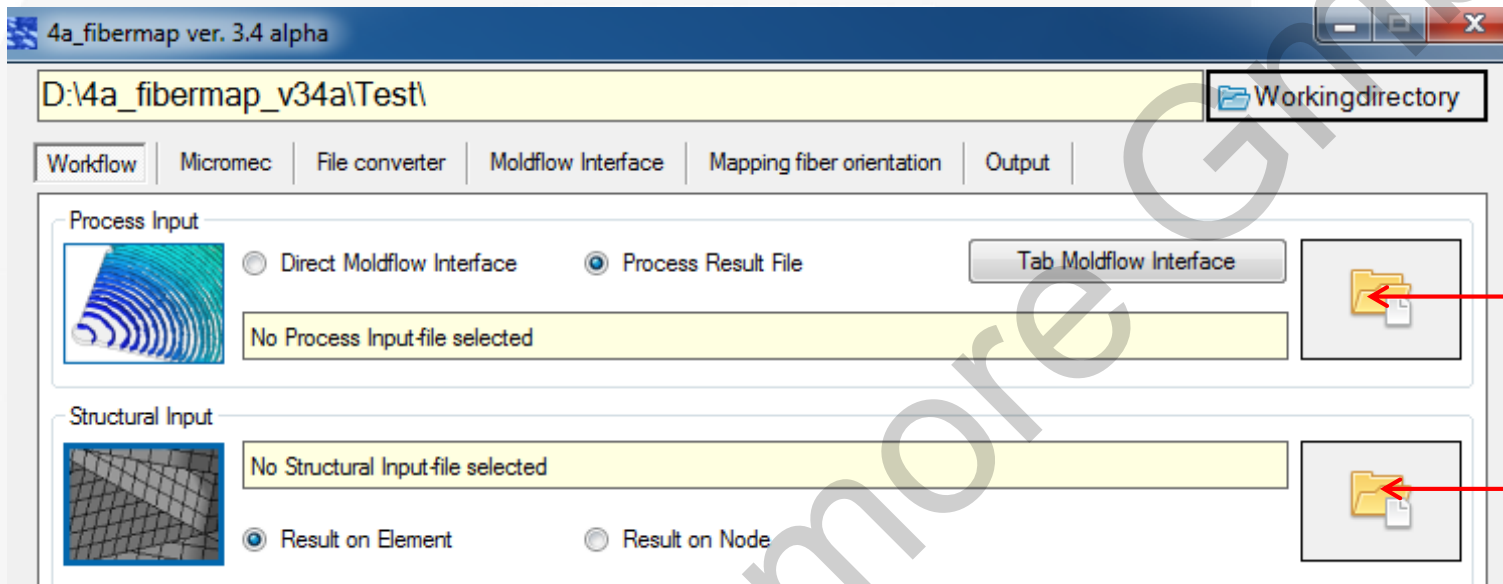
- Zuerst muss 4a fibermap gestartet und das Arbeitsverzeichnis angegeben werden.



Fallbeispiel (4a fibermap)

3. Mapping mit 4a fibermap durchführen (Workflow)

- Danach müssen die entsprechenden Dateien angegeben werden:



**Moldflow-Ergebnis
(XML)**

**FEM-Modell
(LS-Dyna / Abaqus
/ ...)**

Fallbeispiel (4a fibermap)

3. Mapping mit 4a fibermap durchführen (Workflow)

- Danach müssen die entsprechenden Dateien angegeben werden:

The screenshot displays the 4a fibermap software interface with the following sections:

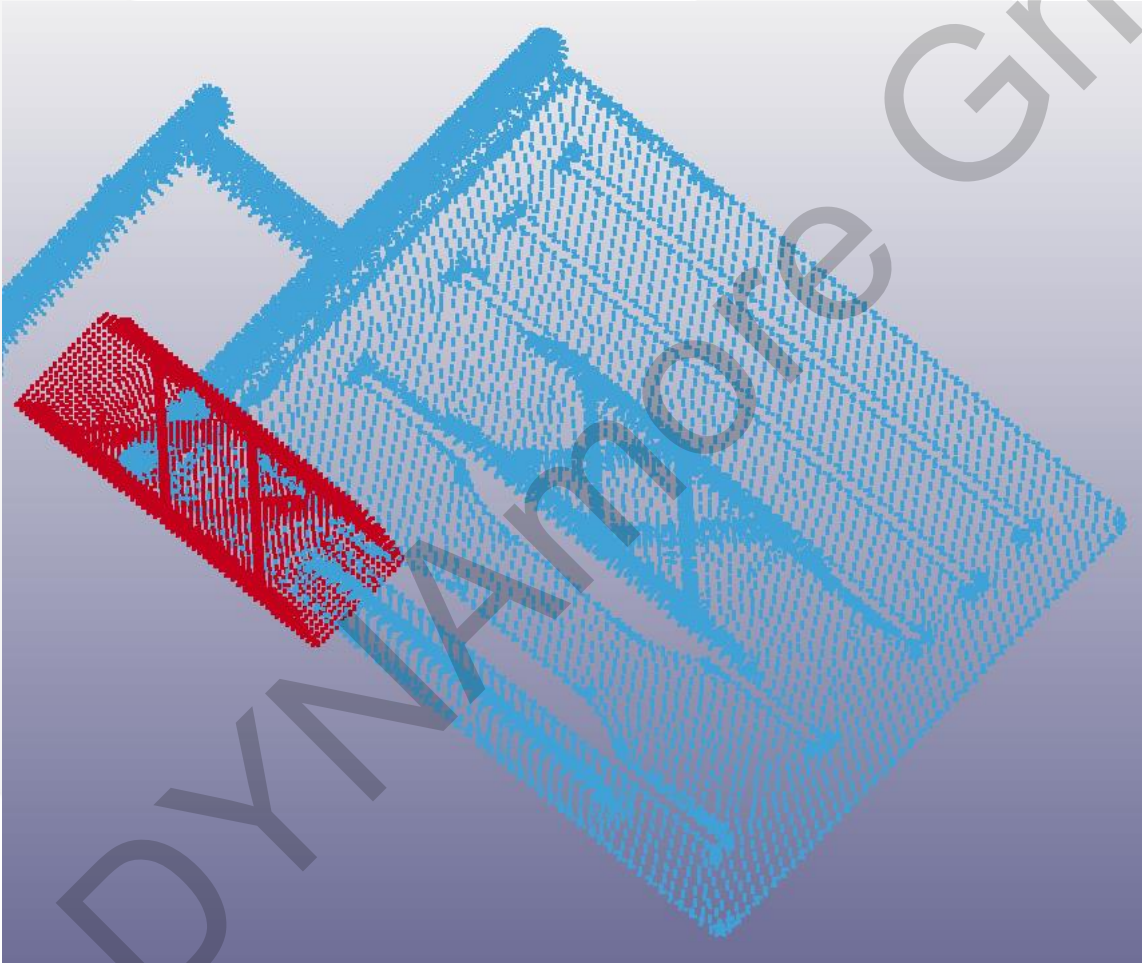
- Structural Input:** A yellow box indicates "No Structural Input-file selected". Below it are radio buttons for "Result on Element" (selected) and "Result on Node". A folder icon is on the right.
- Mapping Settings:** A yellow box indicates "No Settings selected". Below it is a "New" button and a "Check reference systems" button. A folder icon is on the right.
- Material Cards:** A checkbox "Append materialcard in final output" is checked. The "Start ID" is set to "1000000". A "Tab Micromec" button is present. A yellow box indicates "No Material-file selected". A folder icon is on the right.
- Output Settings:** A yellow box indicates "No Output Definition selected". Below it is a "Tab Output" button. A "Definition" button with a folder icon is on the right. Another yellow box indicates "No Output-file selected". A "View" button and a folder icon are at the bottom.

Mapping Settings
(wenn vorhanden)

Optional:
Materialkarte

3c. Mapping durchführen

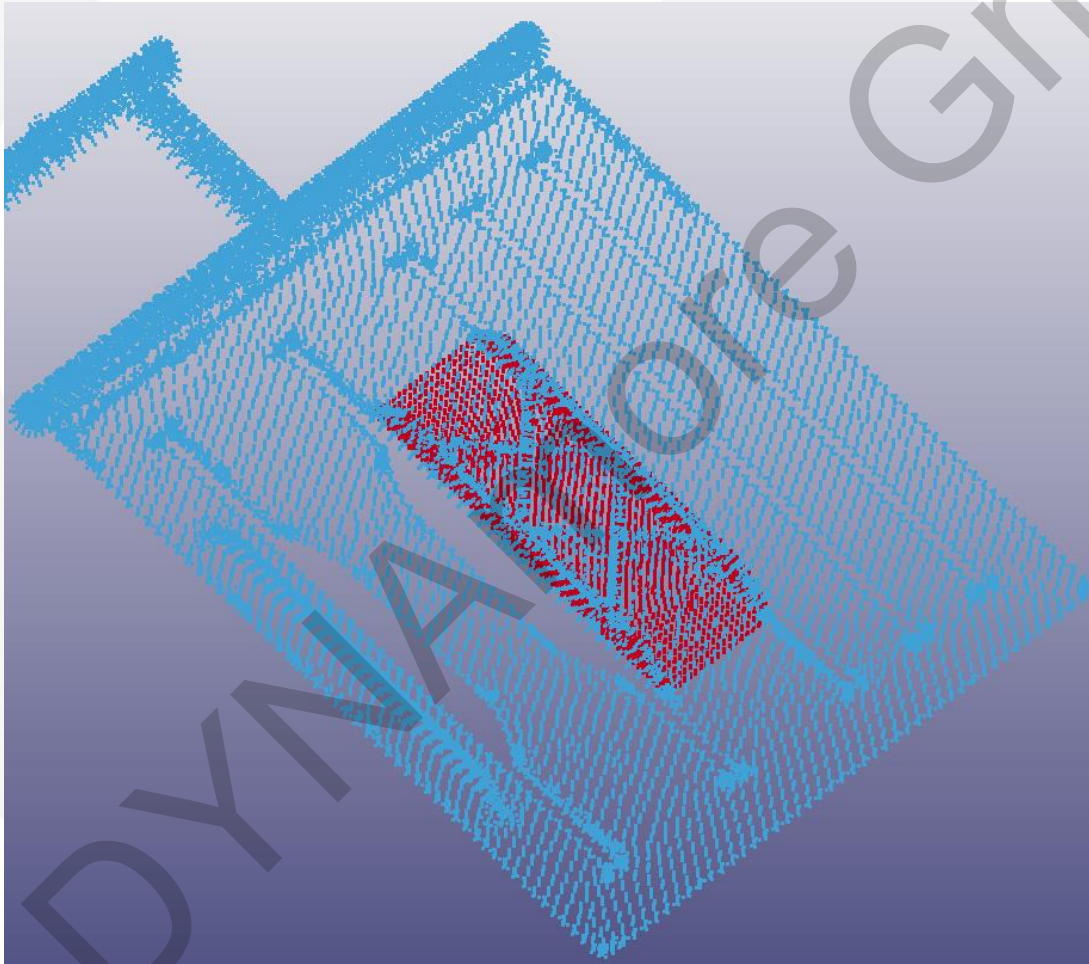
- Lage des Bauteils (blau) und der Probengeometrie (rot) zueinander aufgrund der Einstellungen in den Referenzsystemen. Die Probengeometrie muss noch verschoben werden.



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3c. Mapping durchführen

- Die Probengeometrie wurde durch Anpassung der Werte im Referenzsystem der Probe in die richtige Lage gebracht, sodass sie sich mit dem Bauteil deckt.



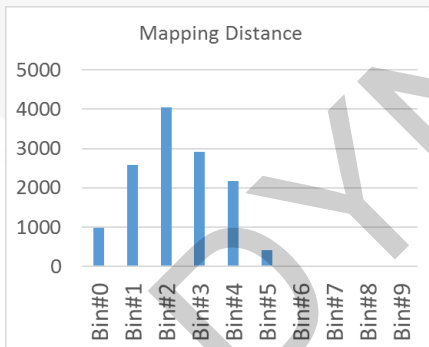
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3c. Mapping durchführen

Qualitätscheck

- Automatisch wird eine Statistik als CSV ausgegeben und ein weiteres LS-DYNA File das die durchschnittliche „Mappingdistance“ anzeigt.
- Damit lässt sich sehr gut die Qualität des Mappings überprüfen.

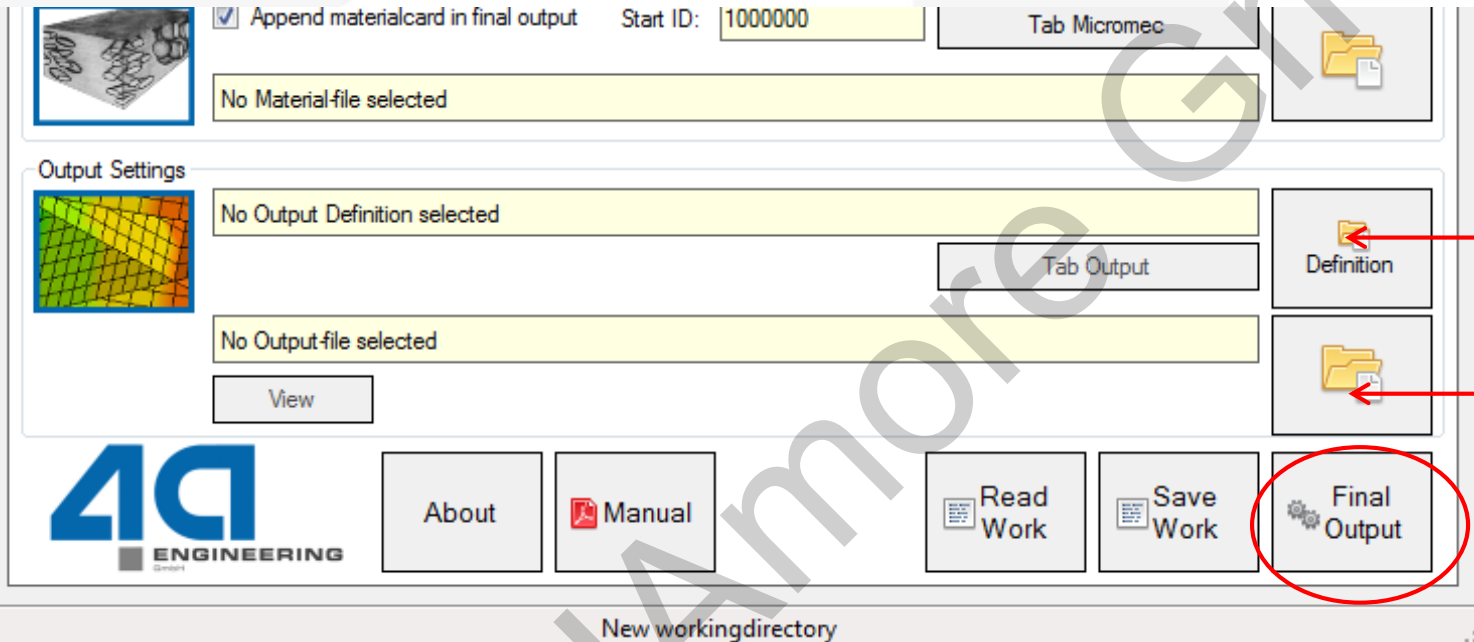
Bin-Name	Lower-limit	Upper-limit	Count
	mm	mm	-
Bin#0	0	0.2	982
Bin#1	0.2	0.4	2580
Bin#2	0.4	0.6	4047
Bin#3	0.6	0.8	2911
Bin#4	0.8	1	2162
Bin#5	1	1.2	408
Bin#6	1.2	1.4	5
Bin#7	1.4	1.6	0
Bin#8	1.6	1.8	0
Bin#9	1.8	2	0



Fallbeispiel (4a fibermap)

3. Mapping mit 4a fibermap durchführen (Workflow)

- Danach müssen die entsprechenden Dateien angegeben werden:



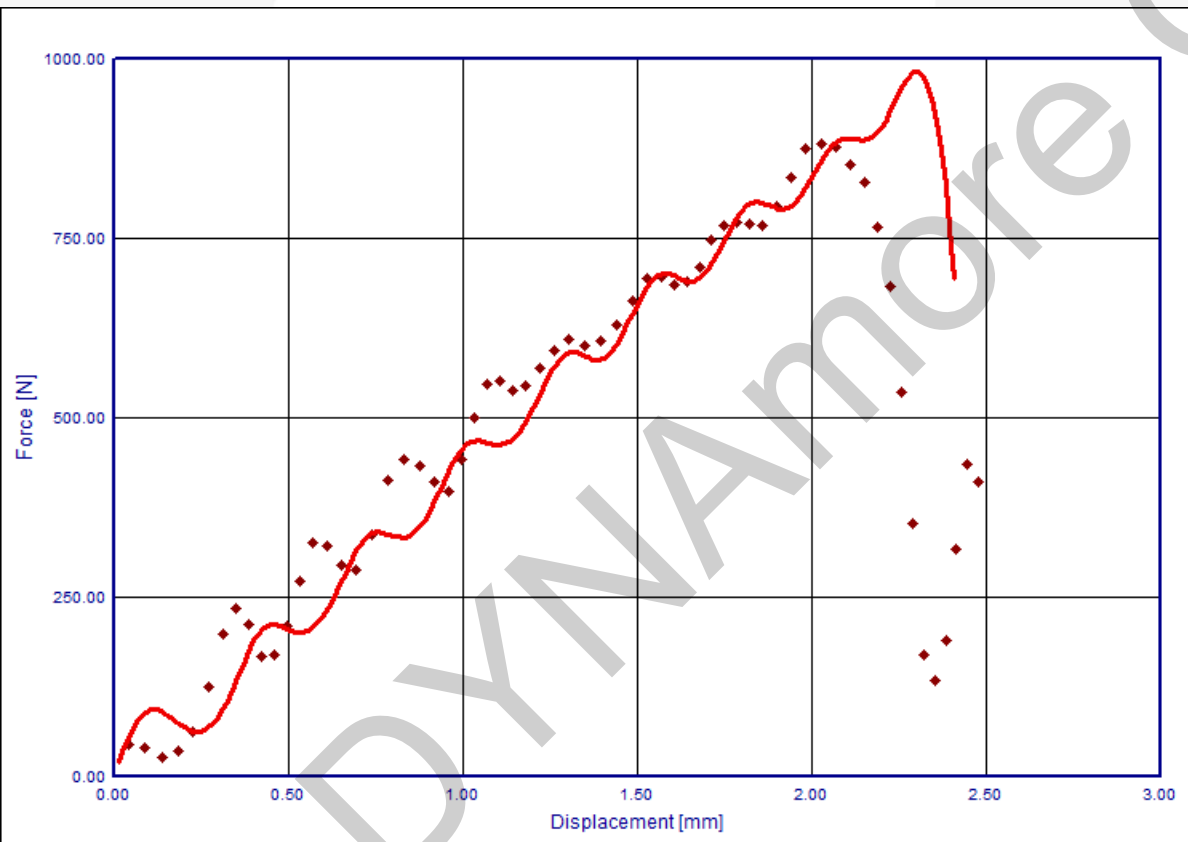
Template für das Mapping (für z.B. *Element_Shell_Beta)

Ausgabe-Datei

- Mit Klick auf „Final Output“ wird das Mapping durchgeführt und das Ergebnis in die Ausgabe-Datei geschrieben.

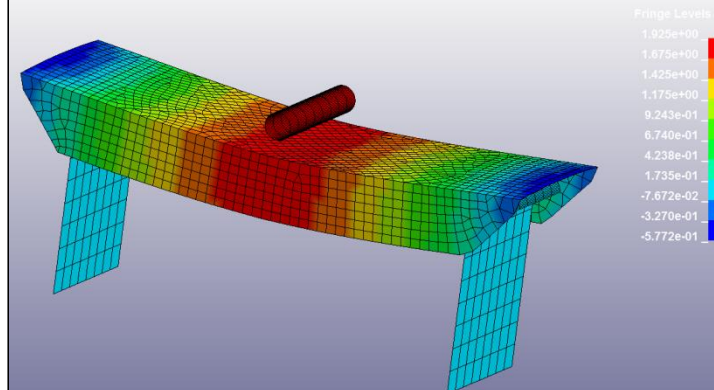
4. FEM-Berechnung durchführen - Ergebnis

- Ergebnis: Die rote durchgezogene Kurve zeigt das Kraft-Weg-Verhalten in der Simulation für die gemappte Doppelkreuzrippe. Deutlich ist die gute Übereinstimmung zwischen Versuch (gepunktete Kurve) und Simulation zu erkennen.



..... Mittelwertkurve Versuch
_____ Ergebnis Simulation

Verschiebung in z-Richtung:



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Integrative Simulation

Simulationsprozess

Prozesssimulation

CADMOULD[®]
3D-F SIMULATION

Moldex3D
MOLDING INNOVATION

 **MOLDFLOW**


SOLIDWORKS
PLASTICS

SIGMASOFT[®]

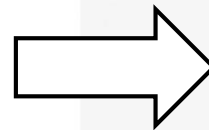
Mapping

4a
FIBERMAP

 **digimat**

EIGENE
TOOLS

UNIVERSITÄRE
TOOLS



Übertragung der
lokalen
Anisotropien

Struktursimulation

ANSYS[®]

 **LSTC**
Livermore Software
Technology Corp.
LS-DYNA[®]

MSC Nastran

NX
NASTRAN

 **AUTODESK**
NASTRAN

 **SIMULIA**

 **Virtual
Performance
Solution**

Prozesssimulation

Idealisierung

- 2 ½ D Mittelfläche
- 2 ½ D Oberfläche
- 3D Volumen

Strömung

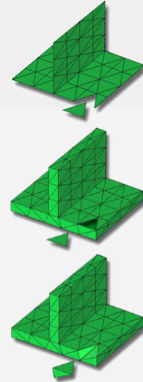
- Viskosität
- pVT

Faser

- Faserlänge
- Faserdurchmesser

Faserorientierungsmodell

- Closure Approximations $OT^2 \rightarrow OT^4$
- Faserinteraktion (RSC, Ci, ARD, ..)
- Faserbruch



Mapping

Mittelungsverfahren

- Unterschiedliche Idealisierung
- Anzahl der Stützstellen

Schnittstellen

- Unterschiedlichste Softwarelösungen sowohl **prozess-** als auch **strukturseitig**

Transformationen

- Koordinatensysteme
 - Ergebnisse (Vektor, Tensor)
-

Struktursimulation

Idealisierung

- Shell
- Solid
- Netzfeinheit, Integrationspunkte

Anwendung

- Verzug
- Bauteil (Steifigkeit, Festigkeit)
- Crash (Energie, Versagen)

Materialmodell

- SOLVER, USERMATERIALS
- Geschwindigkeit, Feuchte, Temp.

Orientierung

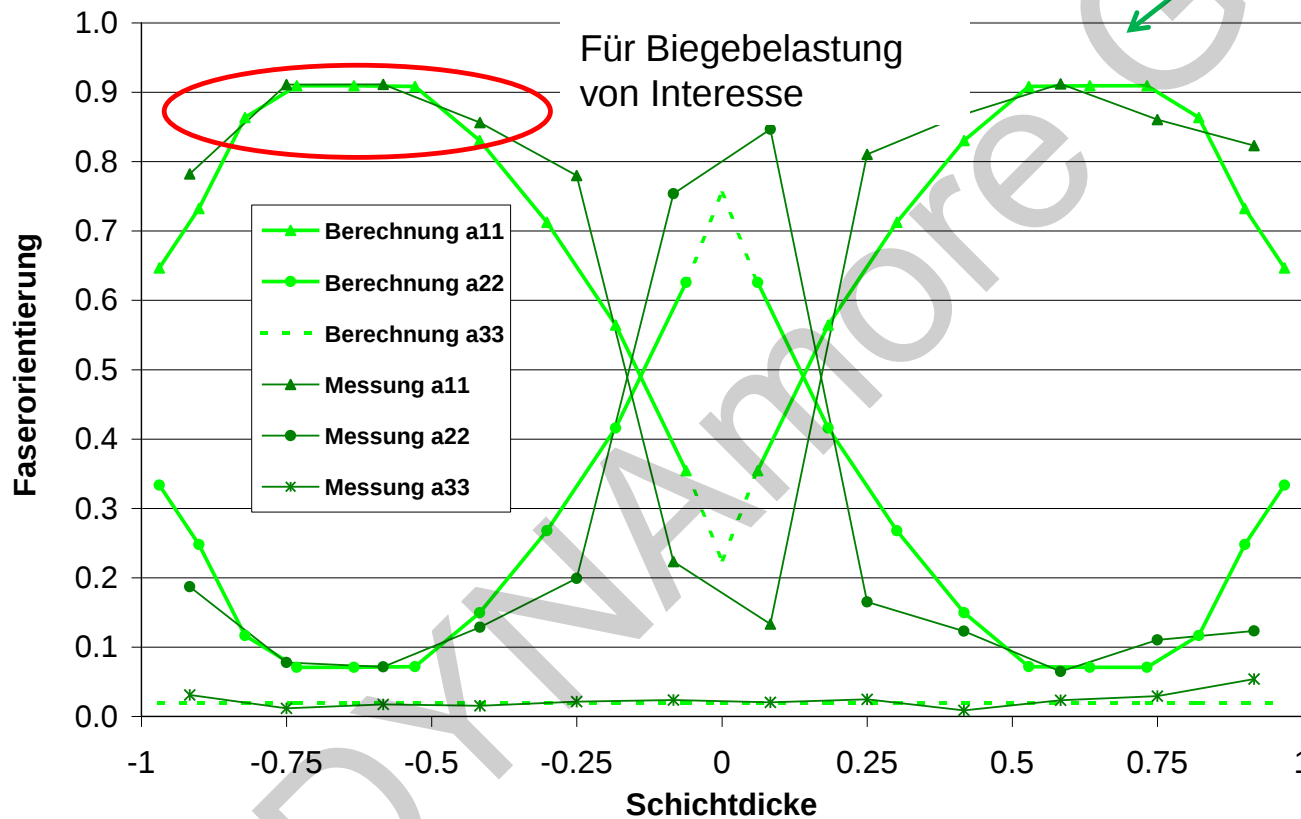
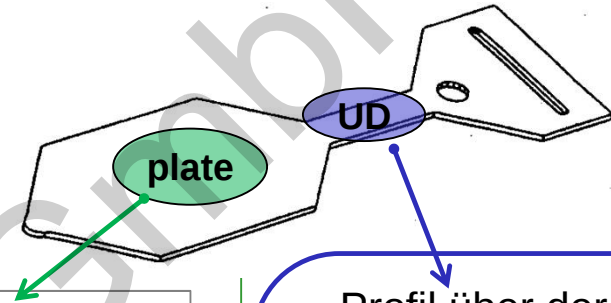
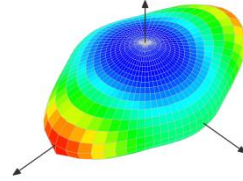
- Global
- Elementweise

Vielzahl an Vorgehensweisen & Einstellmöglichkeiten

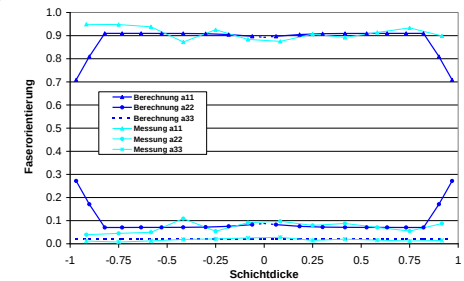
Validierung der gesamten Prozesskette erforderlich

Mittlere FO in Tensorform

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

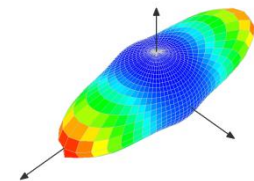


Profil über der Dicke



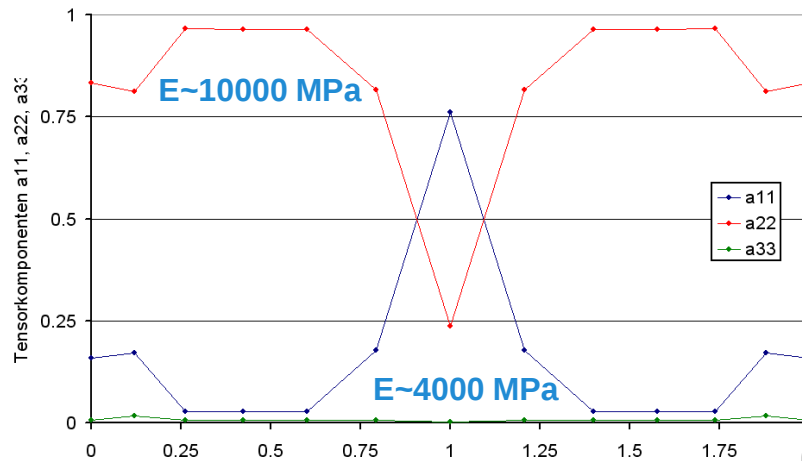
Mittlere FO in Tensorform

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

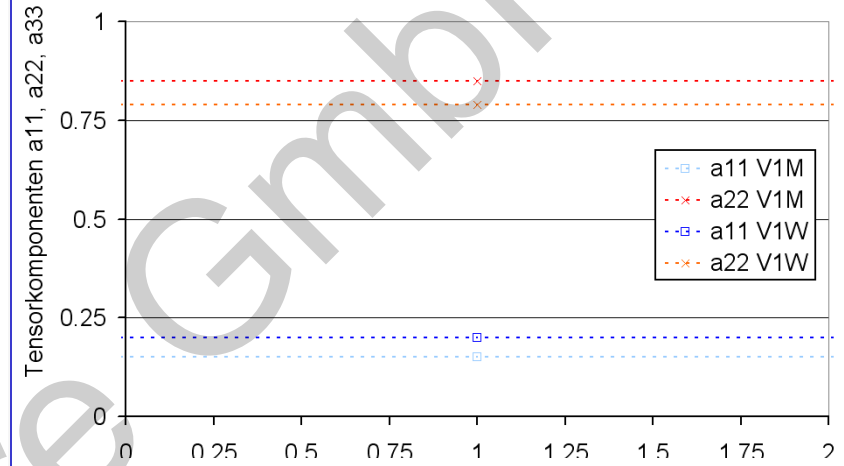


Mapping

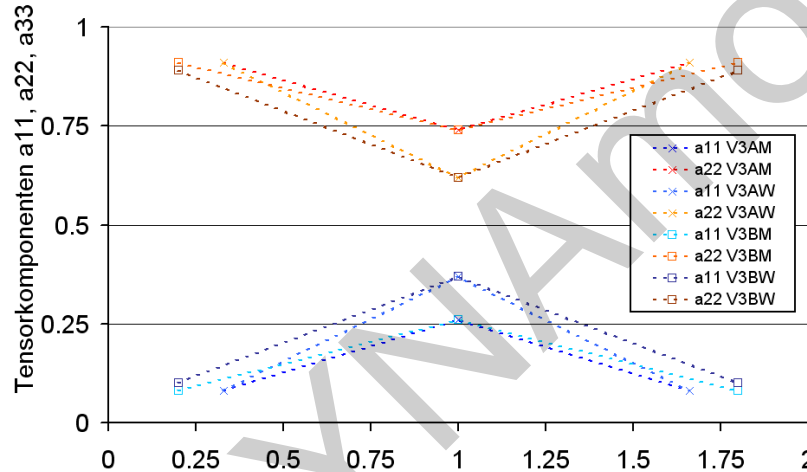
Verteilung Integrationspunkte - Informationstransfer



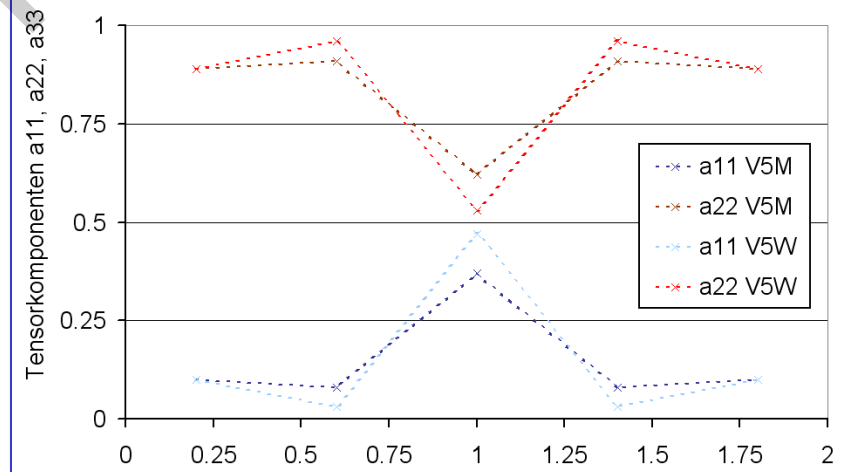
Result injection process simulation



Only 1 material point over wall thickness



3 material points over wall thickness

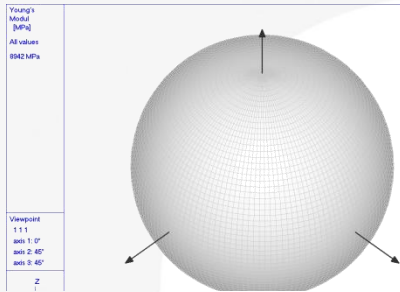


5 material points over wall thickness

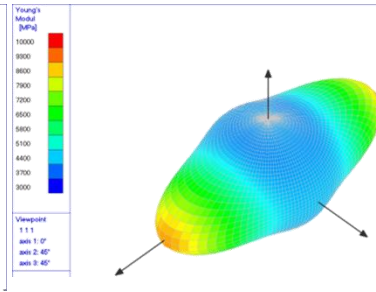
Mapping

Vergleich Biegesteifigkeit einer Platte

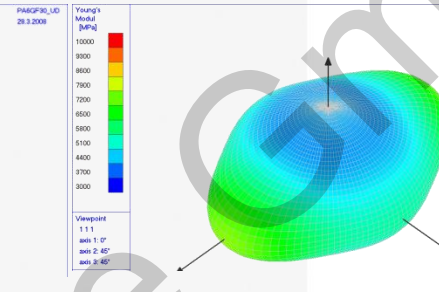
Herstellerangabe
isotrop



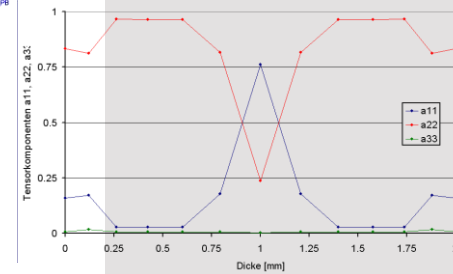
UD-Bereich im Mittel
orthotrop



Platten-Bereich im
Mittel orthotrop



Platten FO Verteilung
orthotrop



längs

3.0 mm

3.2 mm

3.5 mm

3.3 mm

3.0 mm

6.7 mm

5.4 mm

6.5 mm

quer

Gesamtverschiebung [mm]

all=0.68
 $\alpha=0^\circ$

$$fo^{(2)} = \begin{bmatrix} 0,68 & 0 & 0 \\ 0 & 0,32 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

$$fo^{(2)} = \begin{bmatrix} 0,8 & 0 & 0 \\ 0 & 0,2 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

all=0.8
 $\alpha=0^\circ$

$$fo^{(2)} = \begin{bmatrix} 0,8 & 0 & 0 \\ 0 & 0,2 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

all=0.8
 $\alpha=0^\circ$

$$fo^{(2)} = \begin{bmatrix} 0,2 & 0 & 0 \\ 0 & 0,8 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

all=0.8
 $\alpha=90^\circ$

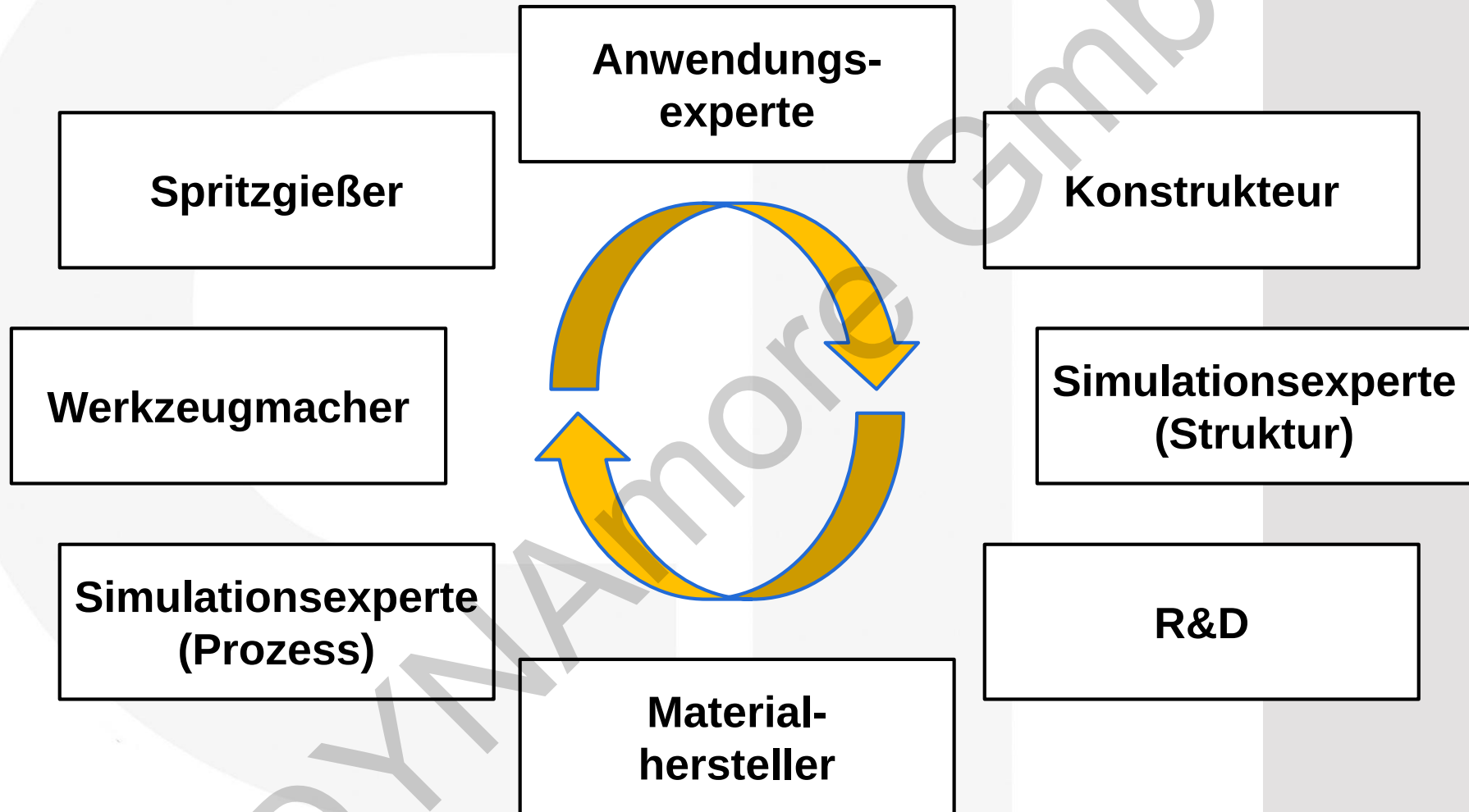
$$fo^{(2)} = \begin{bmatrix} 0,8 & 0 & 0 \\ 0 & 0,2 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

all=0.8
 $\alpha=0^\circ$

$$fo^{(2)} = \begin{bmatrix} 0,8 & 0 & 0 \\ 0 & 0,2 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

all=0.8
 $\alpha=0^\circ$

all=0.8
 $\alpha=18^\circ$



Einleitung

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- Wie sieht eine Simulationsprozesskette aus

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- Wie funktioniert eine Materialkartenerstellung (LIVE)

Mapping

- Wie aufwendig ist das Mapping (LIVE)
- Auf was sollte geachtet werden

Diskussion

Session: MATERIALS (PARAMETER IDENTIFICATION)

- Dienstag um 09:40 in Raum 2
- 4a impetus Dynamische Materialcharakterisierung von Kunststoffen – Entwicklung in den letzten 10 Jahren

Session: MATERIALS (SHORT FIBER-REINFORCED POLYMERS)

- Dienstag um 12:00 in Raum 2
- *MAT_4a_micromec – Micro Mechanic Based Material Model

Session: CRASH (COMPOSITES)

- Dienstag um 15:50 in Raum 1
- Closed Simulation Process Chain for Short Fiber Reinforced Plastic Components with LS-DYNA

Session: ARENA 2036

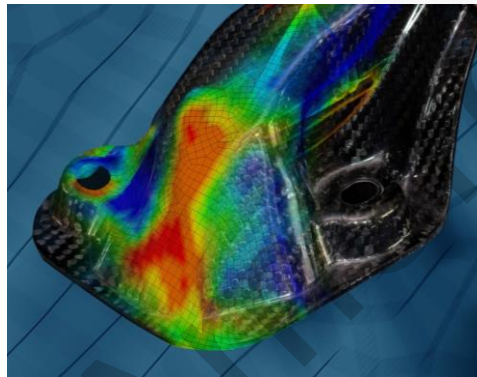
- Dienstag um 18:40 in Raum 1
- Closing the Simulation Process Chain using a Solver Independent Data Exchange Platform: The Digital Prototype

Session: Mapping Tool ENVYO Workshop

- Mittwoch um 11:00 in Raum 4

- [1] R. Luijkx - *Kunststoffmaterialien in der Interieur Funktionsauslegung bei Audi AG*, 4a Technologietag 2010 ([Link](#))
- [2] H. Staack, A. Koukal (Audi AG) – *Anforderungsgerechte Material und Bruchmodellierung für die Fahrzeugsicherheit*, 4a Technologietag 2016 ([Link](#))
- [3] P. Reithofer, B. Jilka, A. Fertschej (4a engineering GmbH) – *4a micromec für die integrative Simulation faserverstärkter Kunststoffe*, NAFEMS Deutschsprachige Konferenz 2014, Bamberg ([Link](#))
- [4] M. Gramling, V. Carrillo-Gonzalez (Audi AG), P. Reithofer, C. Wüster (4a engineering GmbH) - *Integrative Simulation von kurzfaserverstärkten Thermoplasten am Beispiel einer Tankklappe*, 4a Technologietag 2012 ([Link](#))

Thank you for your attention!



14th **4a**
TECHNOLOGIETAG

23.- 24. March 2017
in Schladming, Austria

„Light weight applications & Composites”
More information: <http://technologietag.4a.co.at/>

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