

# Short and long fiber reinforced thermoplastics – material models in LS-DYNA

P. Reithofer<sup>1</sup>, B. Jilka<sup>1</sup>, S. Hartmann<sup>2</sup>, T. Erhart<sup>2</sup>, A. Haufe<sup>2</sup>

<sup>1</sup>4a engineering GmbH, Austria

<sup>2</sup>DYNAMore GmbH, Germany

## 1 Fiber reinforced thermoplastics

In the last years the demand on weight reduction in the automotive industry has led to a strong interest for various composite applications. Due to the complexity of those usually highly anisotropic materials virtual product development is one of the key factors to understand the load carrying behavior of such parts. Furthermore enhanced CAE tools and models are necessary to ensure an efficient and robust product development.

Especially fiber size and geometry have a significant influence on the part performance. Orthotropic properties increase with increasing fiber content while at the same time the effect of strain rate diminishes due to the lesser content of matrix material (figure 1 and 2). Also a strong dependence on the temperature can be seen (figure 3) especially also for the failure behavior; the test specimens become more brittle with decreasing temperatures.

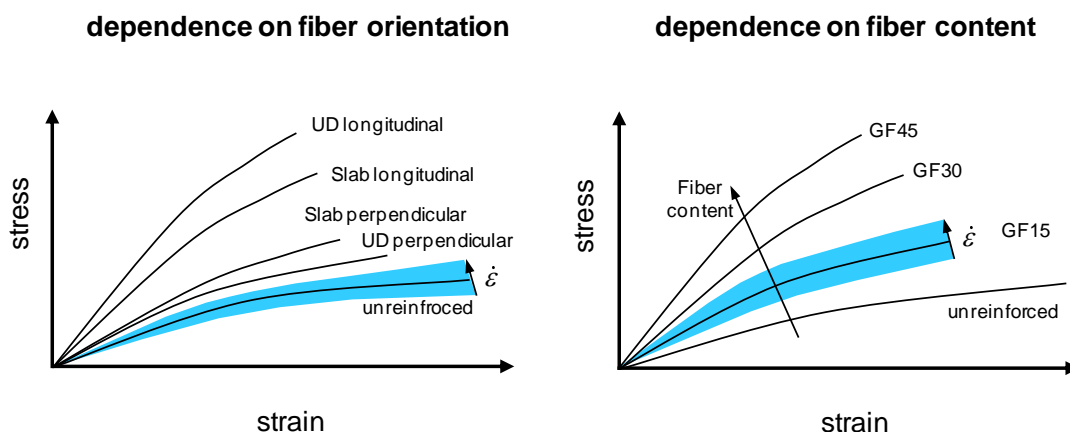


Fig.1: Influence of fiber orientation, content and strain rate on the stress-strain-behavior [1].

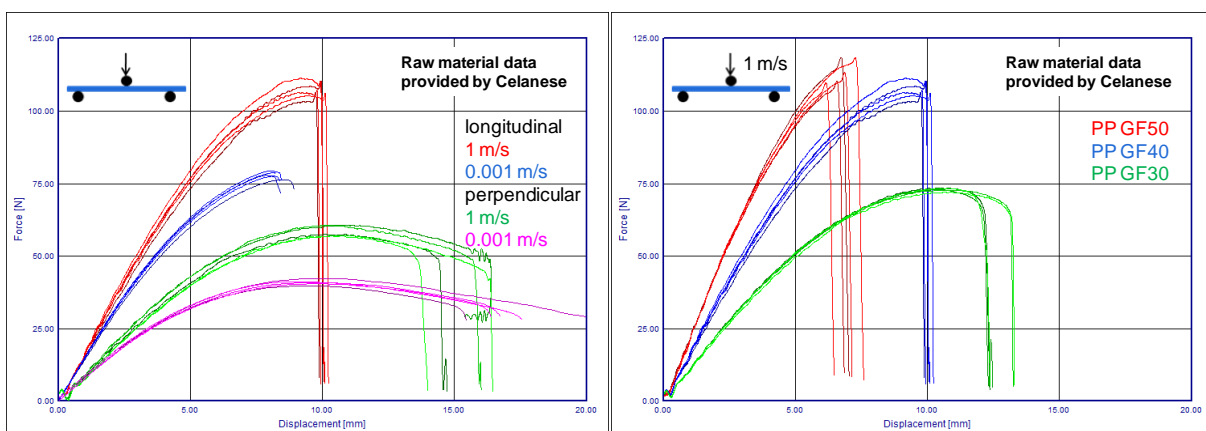


Fig.2: Influence of test velocity (left) and fiber content (right) shown on the force-displacement curves for a PP GF tested in a 3-point-bending test using 4a impetus [1].

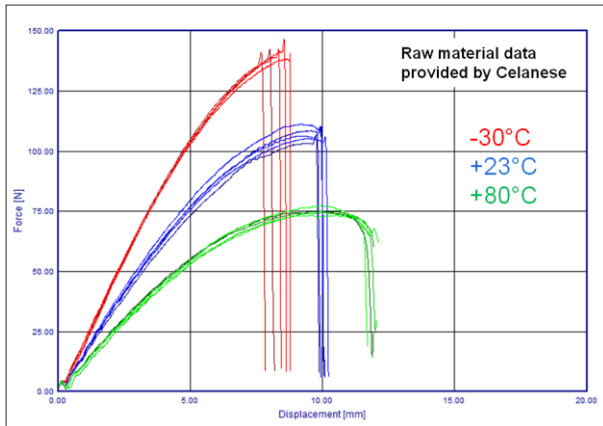


Fig.3: Influence of temperature shown on the force-displacement curves for a PP GF40 longitudinal tested in a 3-point-bending test at a velocity of 1 mps using 4a impetus [1].

LS-DYNA offers a great number of constitutive models for anisotropic materials. These models are able to consider anisotropic influences to some extent (e.g. \*MAT\_002, \*MAT\_022, \*MAT\_054/055, MAT\_058, \*MAT\_103, \*MAT\_108, \*MAT\_157, etc.), shown in table 1.

The aforementioned currently available constitutive models may not be able to fulfil all of the many effects and requirements to describe the real material behavior, however most of these models are well suited to resemble the main anisotropic influence of the fiber reinforcement.

No.	Elastic	Plastic	Damage	Strain rate	Failure
2	Orthotropic / Anisotropic	None	None	None	*MAT_ADD_EROSION
22	Orthotropic	None	None	None	Orientation dependent
54	Orthotropic	None	Elastic Orthotropic	Strength	Orientation dependent
58	Orthotropic	None	Elastic Orthotropic	Strength, Stiffness	Orientation dependent
103	Isotropic	Hill	None	Plasticity	*MAT_ADD_EROSION
108	Orthotropic	Hill	None	None	*MAT_ADD_EROSION
157	Anisotropic	Hill	None	Plasticity	*MAT_ADD_EROSION
158	Orthotropic	None	Elastic Orthotropic	Viscoelasticity	Orientation dependent

Table 1: Material models in LS-DYNA for anisotropic materials [2].

Of course LS-Dyna permanently works on improvements on the existing material models. For example, for material \*MAT\_002 new features were recently implemented with the option \*MAT\_002\_ANIS (see figure 4):

- Hyperelastic (total) formulation using Green-Lagrange strain
- Elastic-anisotropic behavior, stiffness matrix with 21 independent coefficients
- Several possibilities to define material directions, e.g. AOPT, ELEMENT\_SOLID\_ORTHO, etc.
- Use invariant node numbering is recommended

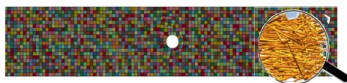
CARD #1	mid	ro	c11	c12	c22	c13	c23	c33
CARD #2	c14	c24	c34	c44	c15	c25	c35	c45
CARD #3	c55	c16	c26	c36	c46	c56	c66	aopt
CARD #4	xp	yp	zp	a1	a2	a3	macf	ihis
CARD #5	v1	v2	v3	d1	d2	d3	beta	ref

➤  $C_{ij}$ : constants in the 6x6 anisotropic constitutive matrix  $\sigma_{ij} = C_{ijkl} \epsilon_{kl}$

➤ AOPT: usual options to define the material's coordinate system

➤ ihis: flag for element-wise definition of the stiffness tensor with \*INITIAL\_STRESS\_SOLID. This allows mapping of locally anisotropic data.

Old approach: each element one material card



New approach: one property \*INITIAL\_STRESS\_SHELL (SOLID)

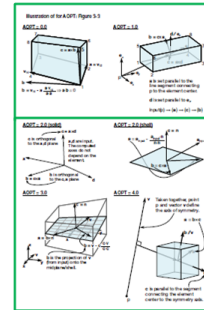
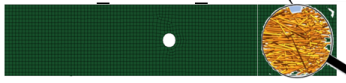


Fig.4: New features for \*MAT\_002 [2].

Also the material model \*MAT\_157 offers new features such as the IP-wise Initialization (figure 5).

\*MAT\_157: Selective mapping IHIS

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

FLAG	Description	Variables	#
$a_0$	Material directions	$q_{11}, q_{12}, q_{13}, q_{31}, q_{32}, q_{33}$	6
$a_1$	Anisotropic stiffness	$C_{ij}$	21
$a_2$	Anisotropic constants	$F, G, H, L, M, N$	6
$a_3$	Stress-strain curve	$LCSS$	1

\*INITIAL\_STRESS\_SOLID: NHISV

- In addition to 6 stress values and eps NHISV history variables can be initialized
- NHISV must correspond to the  $a_i$  that define IHIS in \*MAT\_157

$$NHISV = 6a_0 + 21a_1 + 6a_2 + 1a_3$$

Fig.5: New features for \*MAT\_157 [2].

Furthermore 4a has developed a user material in LS Dyna, based on micro-mechanics (mori tanaka meanfield theory). Results and a comparison to classical material models are presented. Advantages are

- the description of the mechanical composite behavior by a matrix and fiber phase, not only in elasticity but also in visco-plasticity up to a matrix failure.
- the simplified usage in the complete simulation process chain, due to the direct usage of process induced fiber orientation and content as input parameter for the material model.

To get the best simulation results not only the best material model has to be used but also the influence of the process chain has to be considered. The fiber orientation (see figure 1 and 2) has a significant influence on the material behavior. Using 4a micromec [6] the elastic properties of a fiber reinforced material can be calculated very quick and using 4a fibermap [7] the resulting fiber orientation can be mapped from the rheological simulation into the FEM-simulation. The benefits of implementing these applications in the simulation process chain (figure 6) are clearly visible.

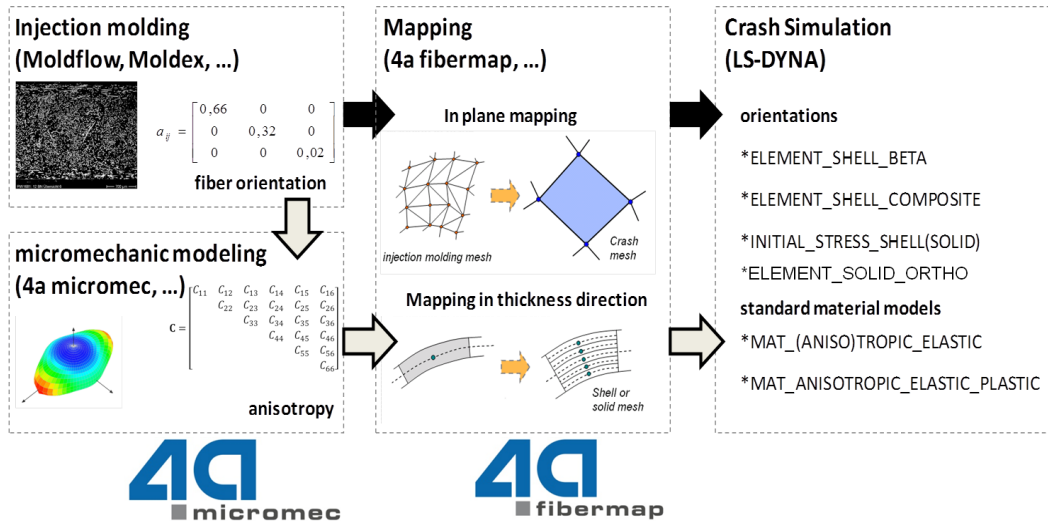


Fig.6: Available simulation process chain for injection molded parts [3].

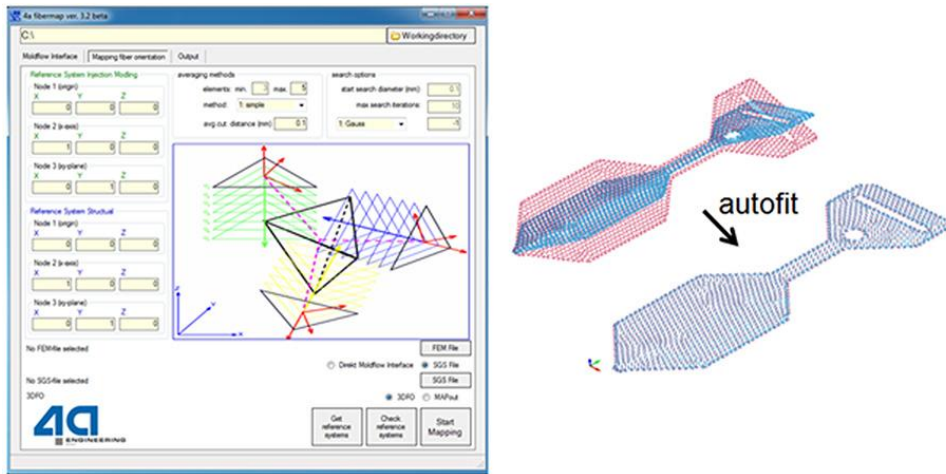


Fig.7: 4a fibermap for mapping informations like fiber orientation, temperature, ...  
Autofit feature - to find automatically coordinate transformation from process to structural mesh

Figure 8 shows a comparison of the test results to the simulation results on PP GF40. The orthotropic material model without plasticity or damage (\*MAT\_002) can reproduce the longitudinal direction, but is too stiff in perpendicular direction.

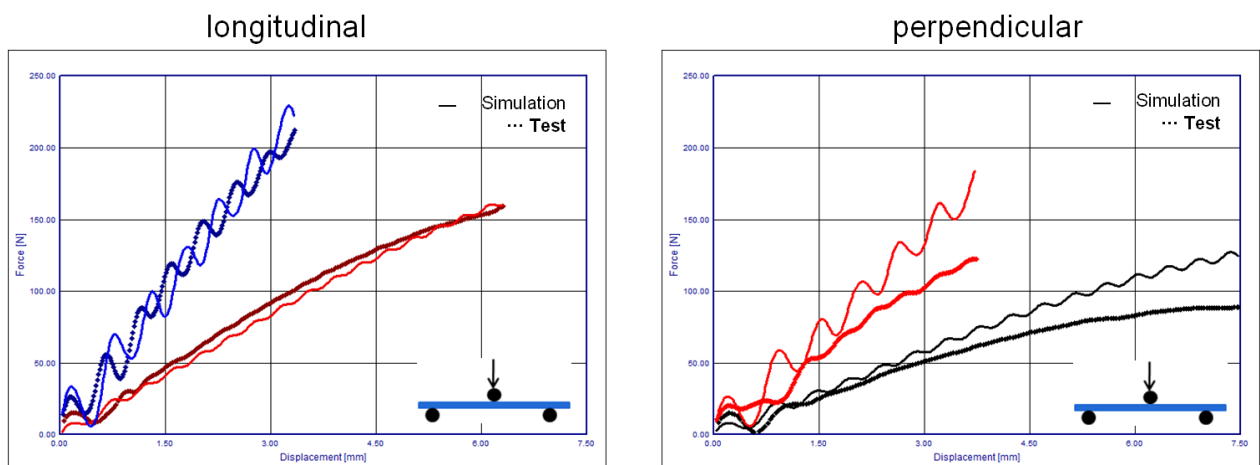


Fig.8: Comparison of test and simulation results on PP GF40 (3-point-bending, two velocities, \*MAT\_002) [1].

Figure 9 shows the results for \*MAT\_157, which is an orthotropic material model with visco plasticity based on a HILL yield function, this material model can reproduce both directions.

For this example

- the resulting fiber orientation of the test specimens were mapped by using 4a fibermap,
- the elastic properties were calculated by using 4a micromec and
- the visco plasticity and failure behavior were determined by reverse engineering with 4a impetus.

The implementation of the process chain (shown in figure 6) into the 4a impetus process is shown in figure 10 and leads to very good and near to reality results.

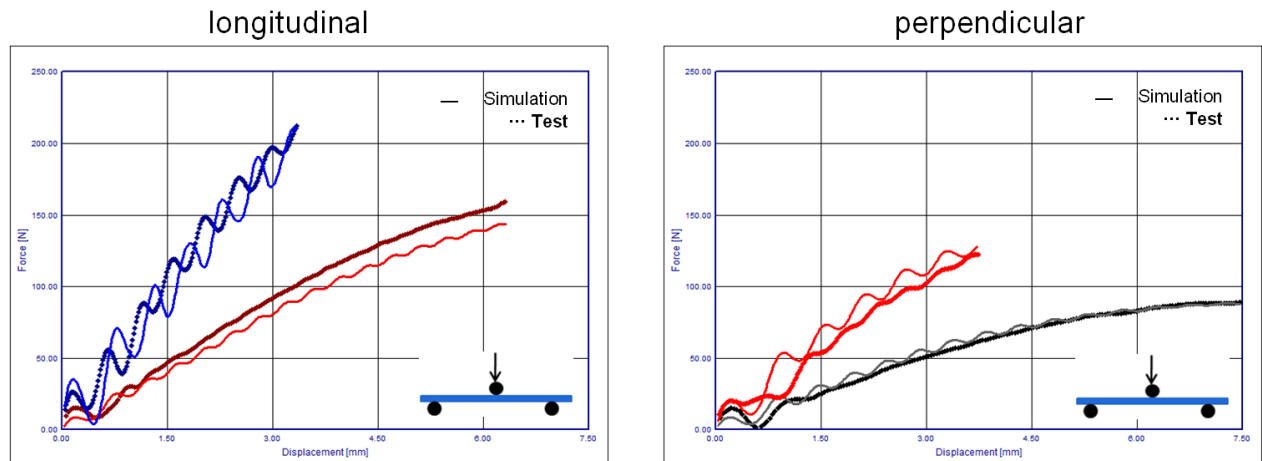


Fig.9: Comparison of test and simulation results on PP GF40 (3-point-bending, two velocities, \*MAT\_157) [1].

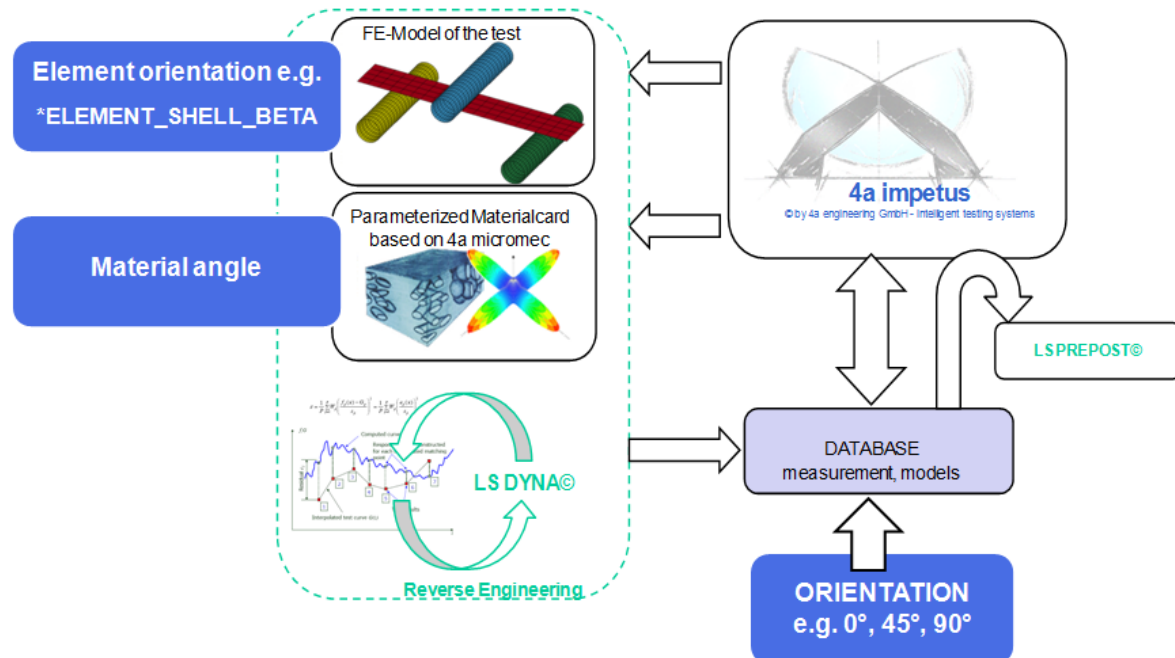


Fig.10: 4a impetus process for fiber materials [4].

Figure 11 shows a casestudy of the so called "Nutini box". As mentioned before the fiber orientation was mapped on the LS-DYNA simulation model, by using the LS-DYNA input key **\*ELEMENT\_SHELL\_BETA**. Together with one average \*MAT\_157 the simulation results including the consideration of failure were quite accurate.



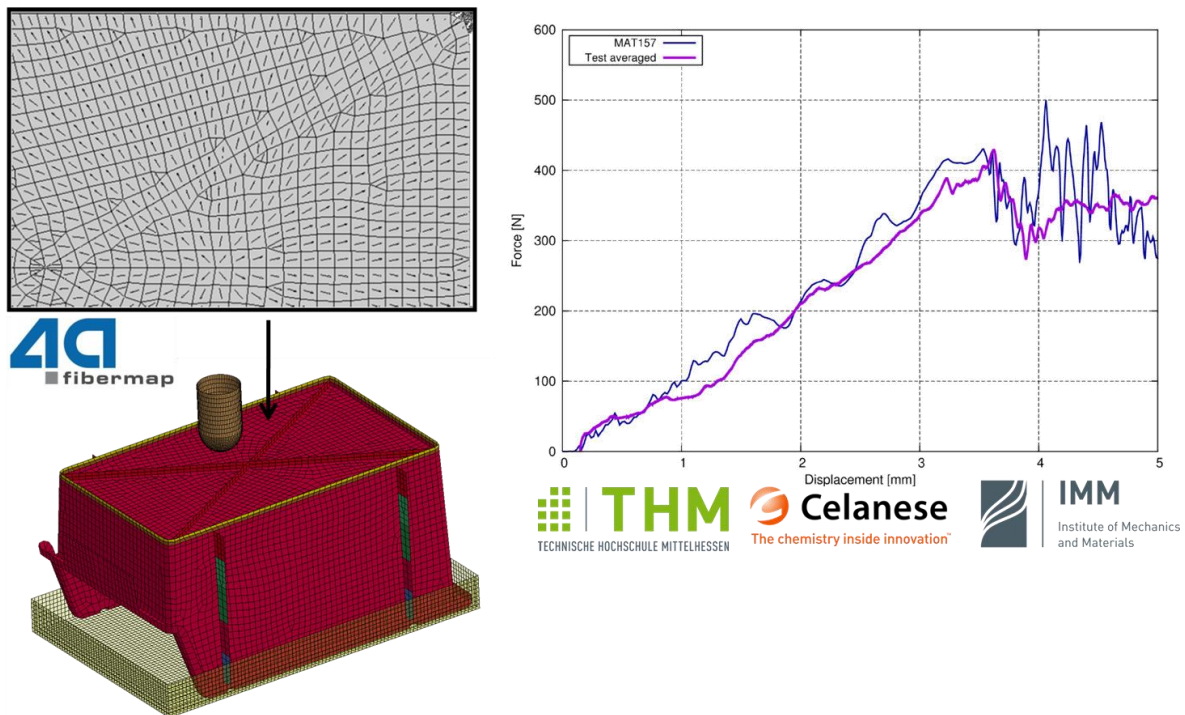


Fig.11: Crash of the Nutini box; results were achieved using the 4a impetus process [5].

## 2 Summary

LS-DYNA offers a great number of constitutive models for anisotropic materials, but they may not be able to fulfil all of the many effects and requirements to describe the real material behavior. So permanent improvements on the existing material models are done.

Orthotropic material models without plasticity or damage (\*MAT\_002, \*MAT\_022) can reproduce the longitudinal direction, but are too stiff in perpendicular direction. Orthotropic material models with plasticity (\*MAT\_108) can reproduce both directions, but since plastics are rate dependent there is a need to take an average strain rate for the material parameters. Orthotropic material models with plasticity and rate dependence (\*MAT\_157) can reproduce both directions and are the optimal choice to describe the mechanical composite behavior. To separate matrix and fiber phase especially a micro mechanical material model is needed for describing effects like matrix failure. Considering the complete process chain in the 4a impetus process leads to accurate and near to reality results.

## 3 Literature

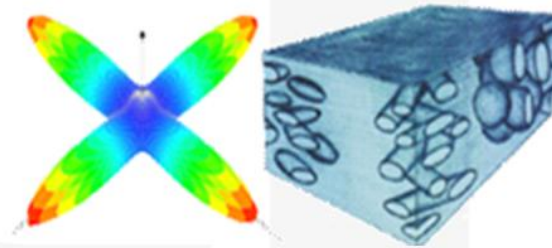
- [1] P. Reithofer, B. Jilka (4a engineering GmbH); S. Hartmann, T. Erhart, A. Haufe (DYNAmore GmbH) - Short and long fiber reinforced thermoplastics material models in LS-DYNA; 13. LS-DYNA Anwenderforum, Bamberg 2014
- [2] A. Haufe (DYNAmore GmbH) – Zum aktuellen Stand der Simulation von Kunststoffen mit LS-DYNA, 11. 4a Technologietag - 2014
- [3] P. Reithofer, B. Jilka, A. Fertschej (4a engineering GmbH) – 4a micromec für die integrative Simulation faserverstärkter Kunststoffe, 11. LS-DYNA Anwenderforum, Ulm 2012
- [4] P. Reithofer, A. Fertschej, B. Jilka (4a engineering GmbH) - Möglichkeiten und Grenzen der integrativen Simulation von kurz- und langglasfaserverstärkten Kunststoffen; NAFEMS 2014, Leipzig
- [5] R. Jennrich, M. Roth, Prof. S. Kolling (Technische Hochschule Mittelhessen); C. Liebold (DYNAmore GmbH); G. Weber (Celanese GmbH) – Experimentelle und numerische Untersuchung eines kurzglasfaserverstärkten Kunststoffes, 13. LS-DYNA Forum 2014, Bamberg
- [6] [http:// micromec.4a.co.at](http://micromec.4a.co.at)
- [7] <http:// fibermap.4a.co.at>

## Short and long fiber reinforced thermoplastics material models in LS-DYNA

S. Hartmann<sup>1</sup>, P. Reithofer<sup>2</sup>, B. Jilka<sup>2</sup>

<sup>1</sup>DYNAmore GmbH

<sup>2</sup>4a engineering GmbH



4a engineering GmbH  
Industriepark 1  
A-8772 Traboch  
reithofer@4a.co.at  
++43 (0) 664 80106 601

**10<sup>th</sup> EUROPEAN LS-DYNA CONFERENCE**  
15 - 17 JUNE 2015 – WÜRZBURG, GERMANY

Seite: 1 / 28

Autor: Peter Reithofer, Bernhard Jilka, Artur Fertschej

Datum: 150616

Titel: rep\_15061602\_pr\_bj1a\_afer\_gga\_FiberMaterialModels.ppt

I N P H Y S I C S W E T R U S T

© 4a engineering GmbH, all rights reserved

## Content

- Introduction
- Exemplary material behavior  
fiber orientation and content – strain rate - temperature
- \*MAT\_24 – typical approach
- Available material models in LS DYNA
- Micro mechanic based model
- Simulation process chain
- Case study
- Conclusion

Seite: 2 / 28

Autor: Peter Reithofer, Bernhard Jilka, Artur Fertschej

Datum: 150616

Titel: rep\_15061602\_pr\_bj1a\_afer\_gga\_FiberMaterialModels.ppt

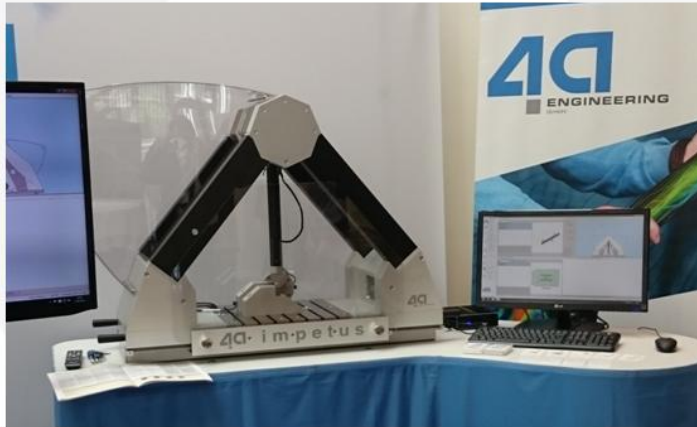
I N P H Y S I C S W E T R U S T

© 4a engineering GmbH, all rights reserved

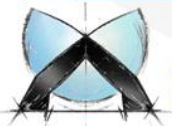
## 4a impetus



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



bending test on 4a impetus



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



Seite: 3 / 28  
Autor: Peter Reithofer, Bernhard Jilka, Artur Fartschej  
Datum: 150616  
Titel: rep\_15061602\_pr\_bj1a\_afer\_gga\_FiberMaterialModels.ppt

I N P H Y S I C S W E T R U S T

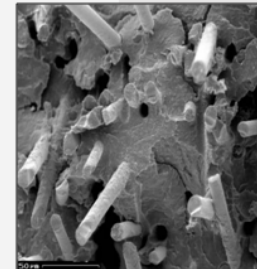
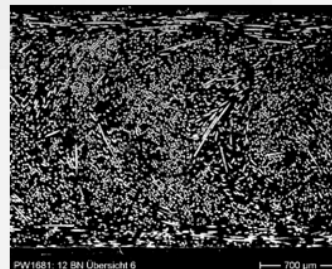
© 4a engineering GmbH, all rights reserved

## Introduction

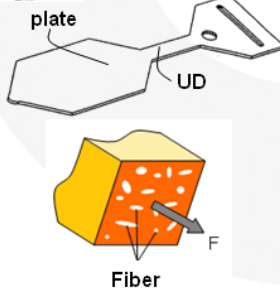
### Characteristic structure of reinforced plastics



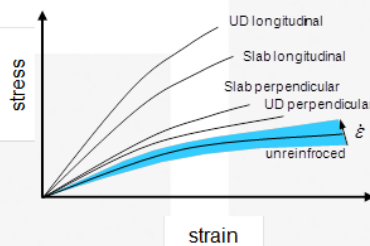
**Fiber size and geometry have significant influence on the part performance. Orthotropic properties increase with increasing fiber content while at the same time the effect of strain rate diminishes due to the less content of matrix material.**



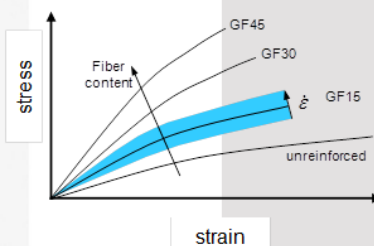
4a experimental tool



dependence on fiber orientation



dependence on fiber content



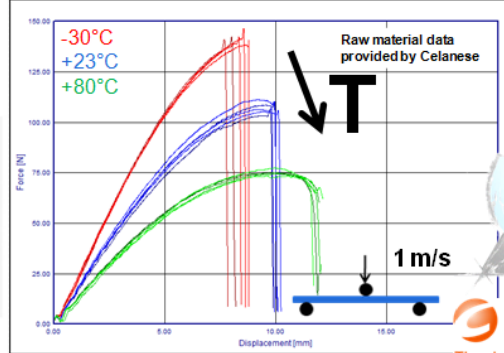
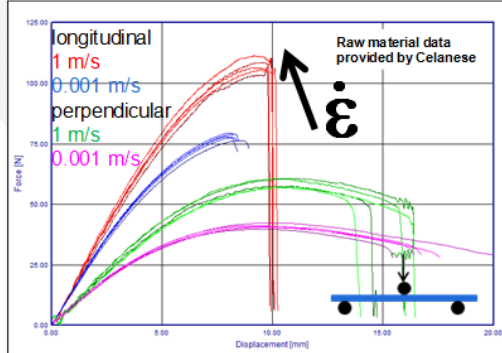
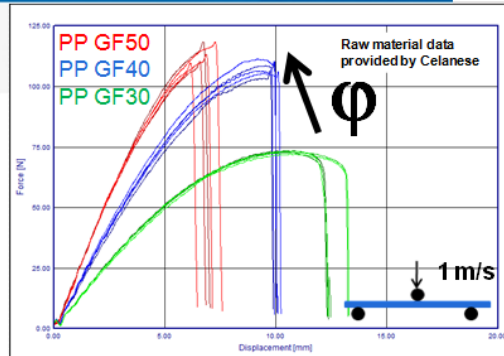
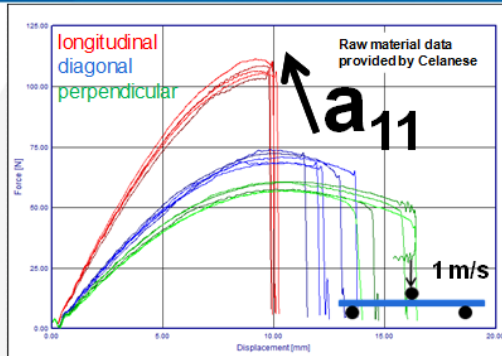
Seite: 4 / 28  
Autor: Peter Reithofer, Bernhard Jilka, Artur Fartschej  
Datum: 150616  
Titel: rep\_15061602\_pr\_bj1a\_afer\_gga\_FiberMaterialModels.ppt

I N P H Y S I C S W E T R U S T

© 4a engineering GmbH, all rights reserved



# fiber reinforced thermoplastics 3-point-bending, support distance 50 mm

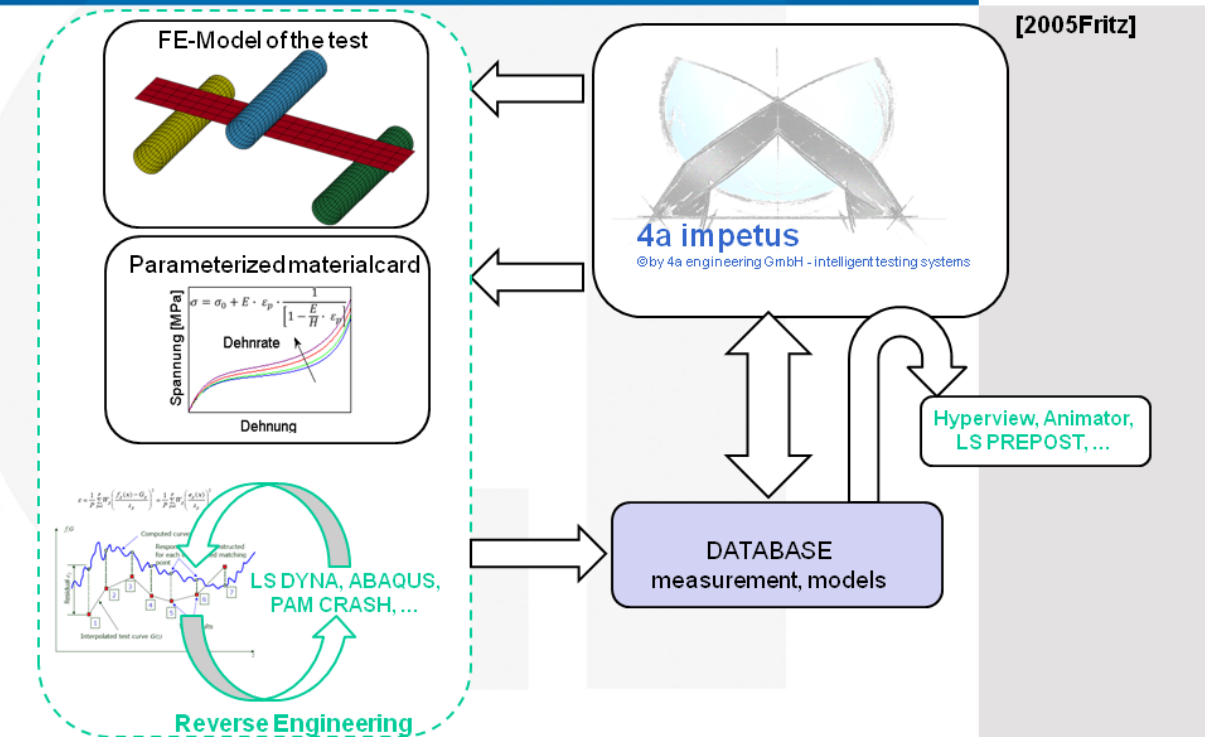


Seite: 5 / 28  
 Autor: Peter Reithofer, Bernhard Jilka, Artur Fertschej  
 Datum: 150616  
 Titel: rep\_15061602\_pr\_bj1a\_ater\_gga\_FiberMaterialModels.ppt

I N P H Y S I C S W E T R U S T

© 4a engineering GmbH, all rights reserved

## \*MAT\_24 – typical approach separate for each direction



Seite: 6 / 28  
 Autor: Peter Reithofer, Bernhard Jilka, Artur Fertschej  
 Datum: 150616  
 Titel: rep\_15061602\_pr\_bj1a\_ater\_gga\_FiberMaterialModels.ppt

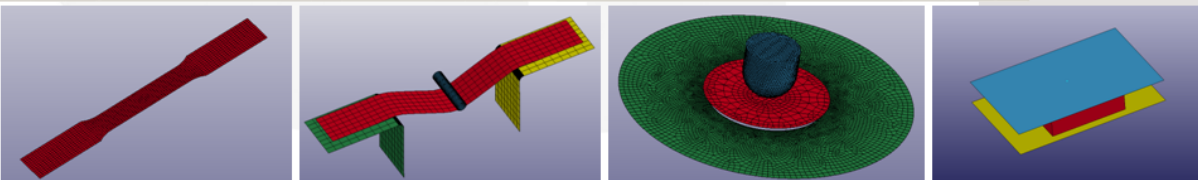
I N P H Y S I C S W E T R U S T

© 4a engineering GmbH, all rights reserved

# 4a impetus



**Complete system from the test to the validated material card**

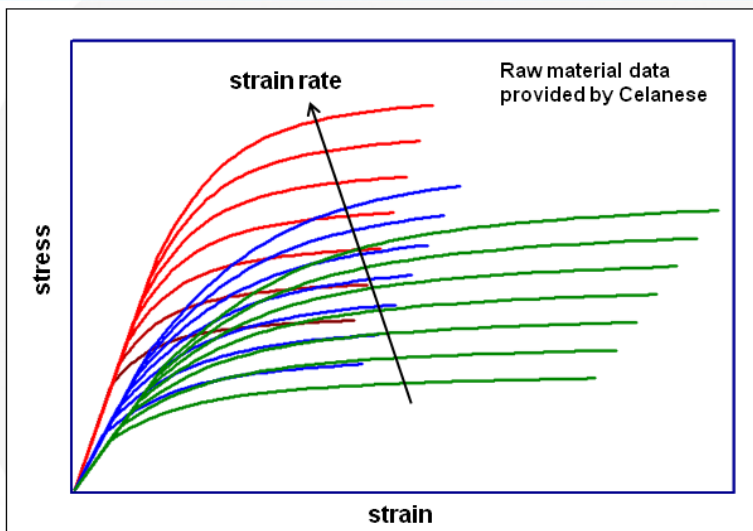


Seite: 7 / 28  
 Autor: Peter Reithofer, Bernhard Jilka, Artur Fertschej  
 Datum: 150616  
 Titel: rep\_15061602\_pr\_bj1a\_ater\_gga\_FiberMaterialModels.ppt

I N P H Y S I C S W E T R U S T

© 4a engineering GmbH, all rights reserved

## \*MAT\_24 – typical approach separate for each direction



PP GF40

longitudinal  
 diagonal  
 perpendicular

This diagram shows the calculated material models for PP GF40 using \*MAT\_24. The different Young's Moduli and stress levels for the orientations are clearly visible. The high fiber content leads to quick failure in the tests with just a small amount of plastic strain, especially for the longitudinal direction.



Seite: 8 / 28  
 Autor: Peter Reithofer, Bernhard Jilka, Artur Fertschej  
 Datum: 150616  
 Titel: rep\_15061602\_pr\_bj1a\_ater\_gga\_FiberMaterialModels.ppt

I N P H Y S I C S W E T R U S T

© 4a engineering GmbH, all rights reserved

## Material models in LSDYNA

### Overview



No.	Elastic	Plastic	Damage	Strain rate	Failure
24	Isotropic	J2 Plasticity	None	Plasticity	*MAT_ADD_EROSION
2	Orthotropic / Anisotropic	None	None	None	*MAT_ADD_EROSION
22	Orthotropic	None	None	None	Orientation dependent
54	Orthotropic	None	Elastic Orthotropic	Strength	Orientation dependent
58	Orthotropic	None	Elastic Orthotropic	Strength, Stiffness	Orientation dependent
103	Isotropic	Hill	None	Plasticity	*MAT_ADD_EROSION
108	Orthotropic	Hill	None	None	*MAT_ADD_EROSION



Seite: 9 / 28

Autor: Peter Reithofer, Bernhard Jilka, Artur Fertschej

Datum: 150616

Titel: rep\_15061602\_pr\_bj1a\_afer\_gga\_FiberMaterialModels.ppt

I N P H Y S I C S W E T R U S T

© 4q engineering GmbH, all rights reserved

## Material models in LSDYNA

### combination of material models



#### Approaches in literature

##### ➤ MAT54 + MAT108

- Spritzgussbauteile aus kurzfaserverstärkten Kunststoffen: Methoden der Charakterisierung und Modellierung zur nichtlinearen Simulation von statischen und crashrelevanten Lastfällen, Julian Schöpfer, Institut für Verbundwerkstoffe GmbH, PhD thesis 2011
- Julian Schöpfer: Charakterisierung und Modellierung von kurzfaserverstärkten Kunststoffen - Teil 2: Simulationen mit LS-DYNA, Dynaforum 2010, Bamberg

[Link](#)

##### ➤ MAT\_002 + MAT\_103

→ MAT\_157

ANISOTROPIC ELASTICITY + HILL VISCOPLASTICITY

FAILURE ADD\_EROSION HILL PLASTIC STRAIN

- André Haufe: Zum aktuellen Stand der Simulation von Kunststoffen mit LS-DYNA, 4a Technologietag 2014, Schladming

[Link](#)

- R. Jennrich: Experimentelle und numerische Untersuchung eines kurzglasfaserverstärkten Kunststoffes, Dynaforum 2014, Bamberg

[Link](#)



Seite: 10 / 28

Autor: Peter Reithofer, Bernhard Jilka, Artur Fertschej

Datum: 150616

Titel: rep\_15061602\_pr\_bj1a\_afer\_gga\_FiberMaterialModels.ppt

I N P H Y S I C S W E T R U S T

© 4q engineering GmbH, all rights reserved

## Material models in LSDYNA new features MAT\_157



[2014Haufe]



### IP-wise Initialization

\*MAT\_157: Selective mapping IHIS

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

FLAG	Description	Variables	#
$a_0$	Material directions	$q_{11}, q_{12}, q_{13}, q_{31}, q_{32}, q_{33}$	6
$a_1$	Anisotropic stiffness	$C_{ij}$	21
$a_2$	Anisotropic constants	$F, G, H, L, M, N$	6
$a_3$	Stress-strain curve	$LCSS$	1

\*INITIAL\_STRESS\_SOLID:NHISV

- In addition to 6 stress values and eps NHISV history variables can be initialized
- NHISV must correspond to the  $a_i$  that define IHIS in \*MAT\_157

$$NHISV = 6a_0 + 21a_1 + 6a_2 + 1a_3$$



Seite: 11 / 28  
 Autor: Peter Reithofer, Bernhard Jilka, Artur Fertschej  
 Datum: 150616  
 Titel: rep\_15061602\_pr\_bj1a\_ater\_gga\_FiberMaterialModels.ppt

I N P H Y S I C S W E T R U S T

© 4q engineering GmbH, all rights reserved

## Material models in LSDYNA Overview



No.	Elastic	Plastic	Damage	Strain rate	Failure
2	Orthotropic / Anisotropic	None	None	None	*MAT_ADD_EROSION
22	Orthotropic	None	None	None	Orientation dependent
54	Orthotropic	None	Elastic Orthotropic	Strength	Orientation dependent
58	Orthotropic	None	Elastic Orthotropic	Strength, Stiffness	Orientation dependent
103	Isotropic	Hill	None	Plasticity	*MAT_ADD_EROSION
108	Orthotropic	Hill	None	None	*MAT_ADD_EROSION
157	Anisotropic	Hill	None	Plasticity	*MAT_ADD_EROSION
158	Orthotropic	None	Elastic Orthotropic	Viscoelasticity	Orientation dependent

### USERMAT → Micro mechanic based material models



Seite: 12 / 28  
 Autor: Peter Reithofer, Bernhard Jilka, Artur Fertschej  
 Datum: 150616  
 Titel: rep\_15061602\_pr\_bj1a\_ater\_gga\_FiberMaterialModels.ppt

I N P H Y S I C S W E T R U S T

© 4q engineering GmbH, all rights reserved

## Material models in LSDYNA MAT\_157 material



- material model based on **composites properties**

\*MAT\_157: Selective mapping IHIS

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

FLAG	Description	Variables	#
$a_0$	Material directions	$q_{11}, q_{12}, q_{13}, q_{31}, q_{32}, q_{33}$	6
$a_1$	Anisotropic stiffness	$C_{ij}$	21
$a_2$	Anisotropic constants	$F, G, H, L, M, N$	6
$a_3$	Stress-strain curve	$LCSS$	1

$$C_{ij}(a_{ij}, \varphi, C^M, C^F)$$

$$f(a_{ij}, \varphi, \sigma^M, \sigma^F)$$

$$f(a_{ij}, \varphi)$$

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

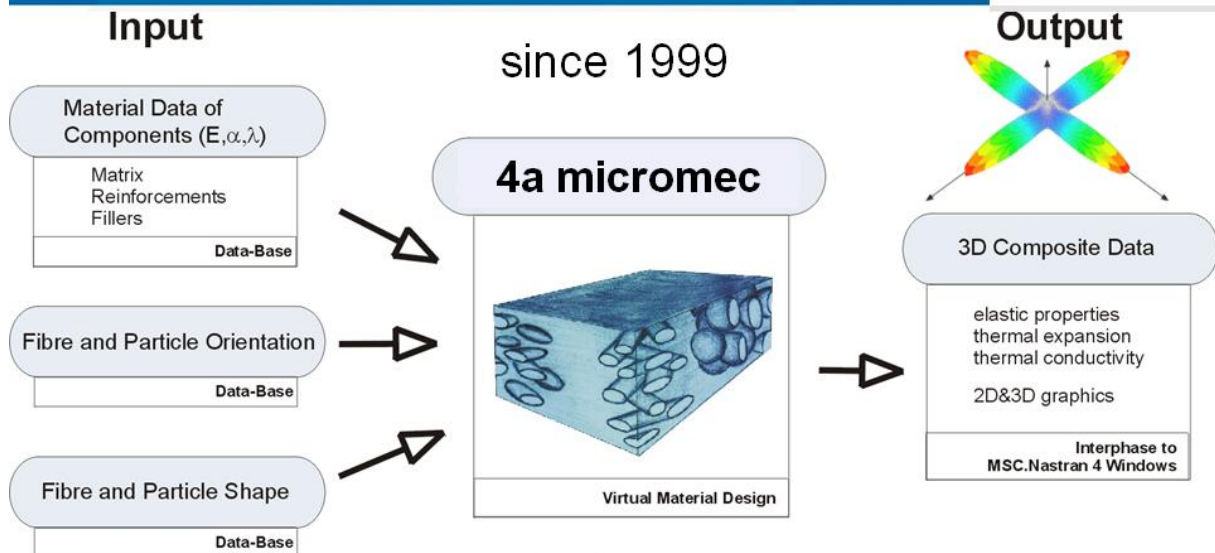
➔ **Micro mechanical model is needed**



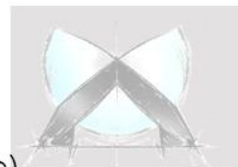
Seite: 13 / 28  
 Autor: Peter Reithofer, Bernhard Jilka, Artur Fertschej  
 Datum: 150616  
 Titel: rep\_15061602\_pr\_bj1a\_ater\_gga\_FiberMaterialModels.ppt

I N P H Y S I C S W E T R U S T

## Micro mechanic based material models Stand-alone product - calculating the elastic values



- Usage for SFRT, LFRT, CFRP, GFRP, ....
- Stand-alone-solution available (3D thermo-elastic properties)
- User material (orthotropic elastic visco-plastic including failure)

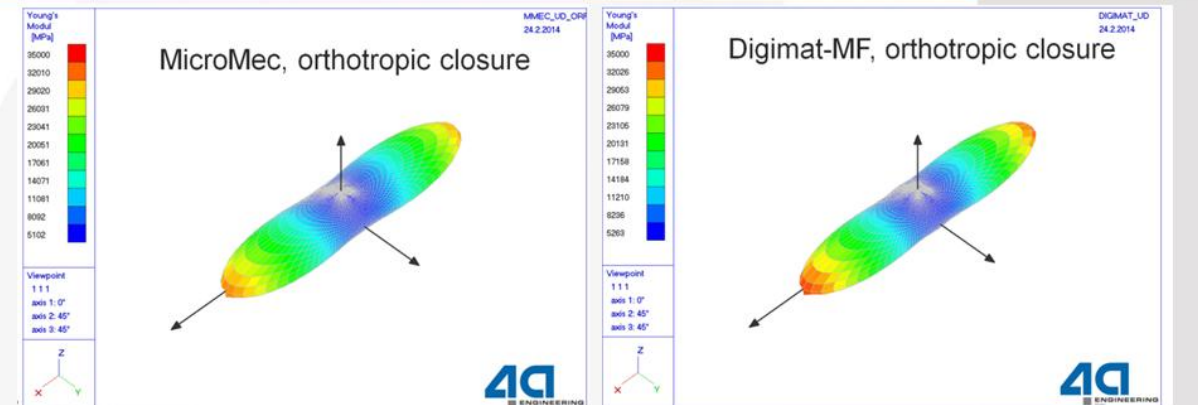


Seite: 14 / 28  
 Autor: Peter Reithofer, Bernhard Jilka, Artur Fertschej  
 Datum: 150616  
 Titel: rep\_15061602\_pr\_bj1a\_ater\_gga\_FiberMaterialModels.ppt

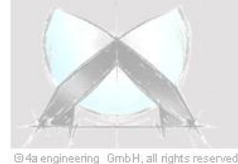
I N P H Y S I C S W E T R U S T



## Micro mechanic based material models Stand-alone product - calculating the elastic values



- Comparison by University of Leoben between Digimat-MF and 4a micromec
- User material (orthotropic elastic visco-plastic including failure)

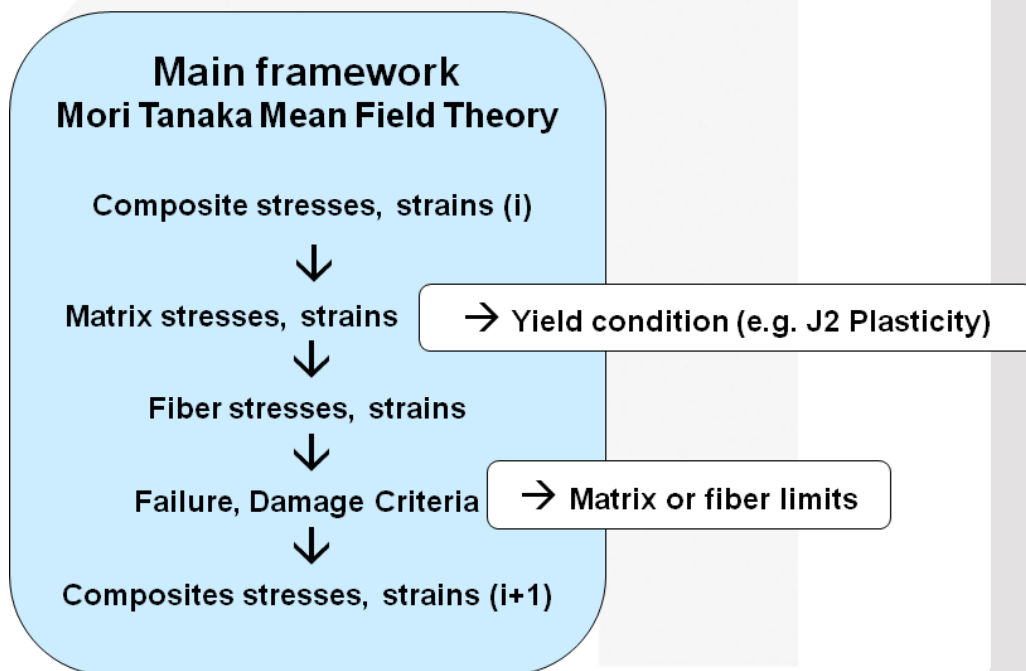


©4a engineering GmbH, all rights reserved

Seite: 16 / 28  
 Autor: Peter Reithofer, Bernhard Jilka, Artur Fertschej  
 Datum: 150616  
 Titel: rep\_15061602\_pr\_bj1a\_ater\_gga\_FiberMaterialModels.ppt

I N P H Y S I C S W E T R U S T

## Micro mechanic based material models User materials - framework

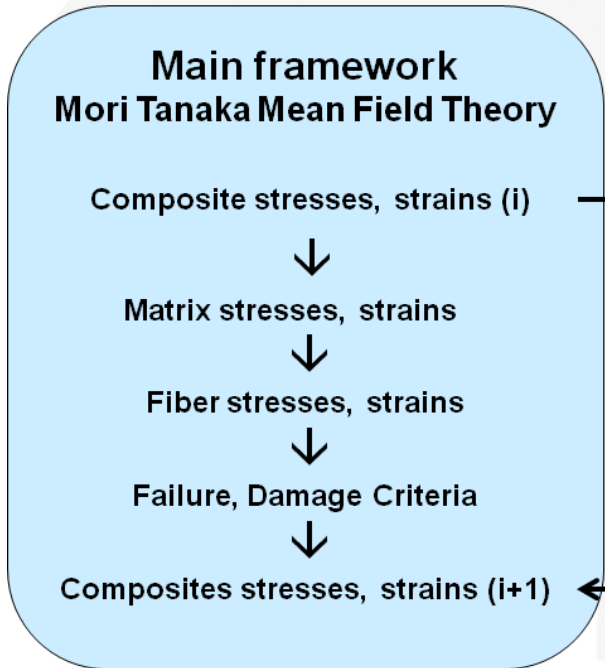


©4a engineering GmbH, all rights reserved

Seite: 16 / 28  
 Autor: Peter Reithofer, Bernhard Jilka, Artur Fertschej  
 Datum: 150616  
 Titel: rep\_15061602\_pr\_bj1a\_ater\_gga\_FiberMaterialModels.ppt

I N P H Y S I C S W E T R U S T

## Micro mechanic based material models User materials – general workflow



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

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

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

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

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

$$\bar{B}_{i+1} = f(f\sigma^{(4)}, E_M^T, l/d)$$

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

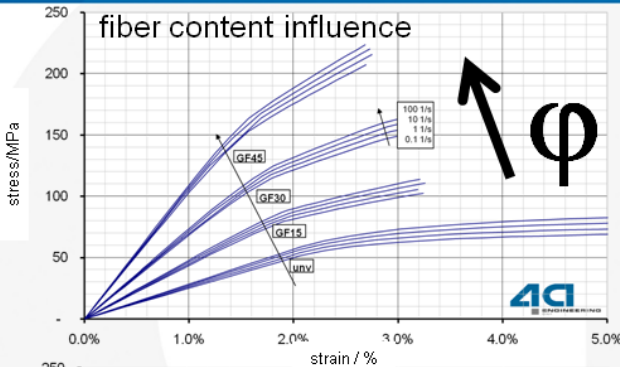
$$\Delta \sigma^C = [\varphi \bar{A} + (1 - \varphi)I] \Delta \sigma^M$$

©4a engineering GmbH, all rights reserved

Seite: 17 / 28  
Autor: Peter Reithofer, Bernhard Jilka, Artur Fertschej  
Datum: 150616  
Titel: rep\_15061602\_pr\_bj1a\_ater\_gga\_FiberMaterialModels.ppt

I N P H Y S I C S W E T R U S T

## Micro mechanic based material models Results of 1-element tests

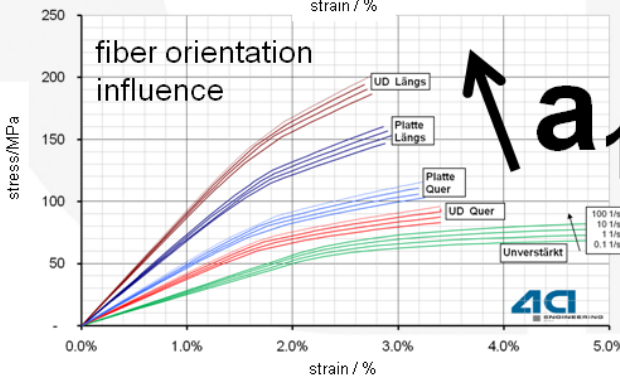


material behavior is

- orthotropic
- visco elastic
- visco plastic

Failure

- $\varepsilon^M(\eta, \varepsilon)$



©4a engineering GmbH, all rights reserved

Seite: 18 / 28  
Autor: Peter Reithofer, Bernhard Jilka, Artur Fertschej  
Datum: 150616  
Titel: rep\_15061602\_pr\_bj1a\_ater\_gga\_FiberMaterialModels.ppt

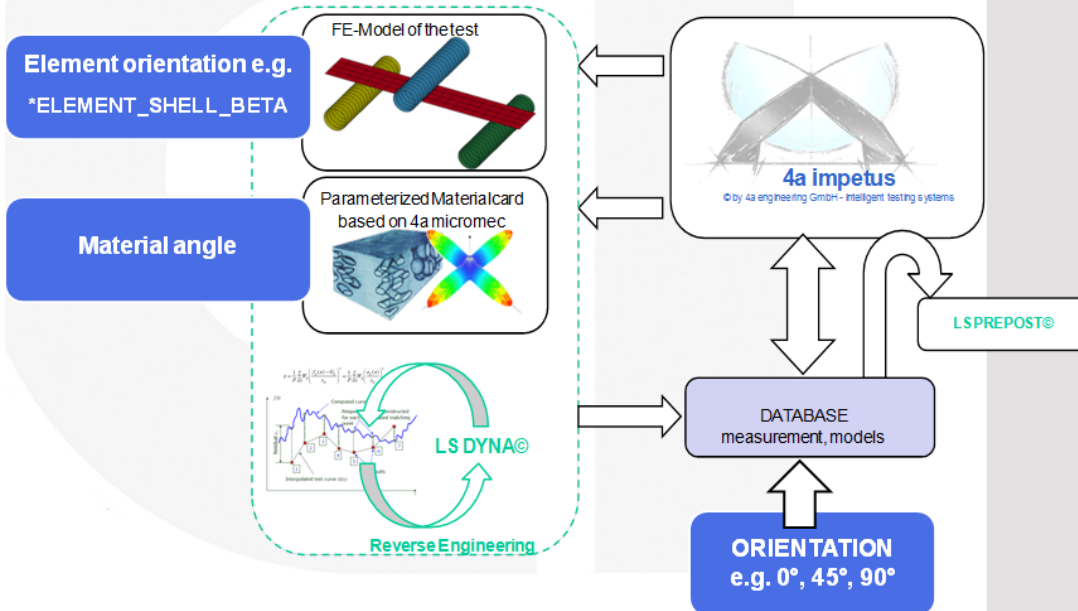
I N P H Y S I C S W E T R U S T

## Material models in LSDYNA 4a impetus process



[2012Reithofer]

- The influence of the manufacturing process on the material behavior (fiber orientation) is included in the process chain.

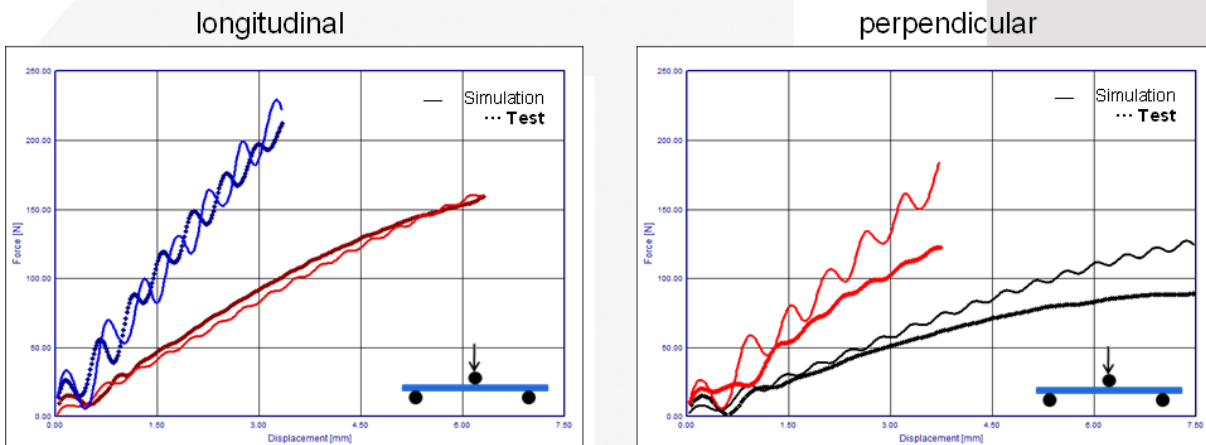


Seite: 19 / 28  
 Autor: Peter Reithofer, Bernhard Jilka, Artur Fertschej  
 Datum: 150616  
 Titel: rep\_15061602\_pr\_bj1a\_ater\_gga\_FiberMaterialModels.ppt

I N P H Y S I C S W E T R U S T

© 4a engineering GmbH, all rights reserved

## Material models in LSDYNA Comparison on PPGF40 (MAT\_002)



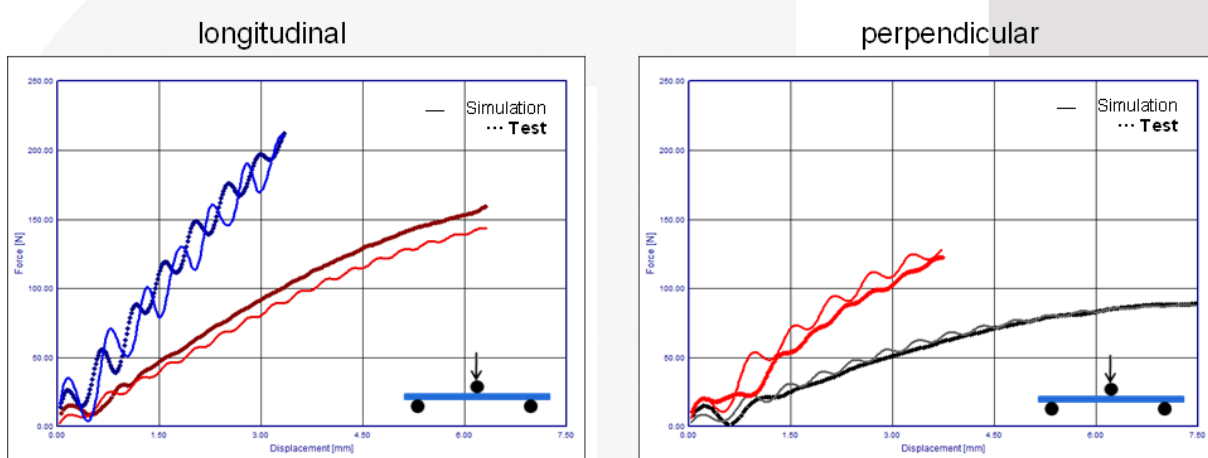
- Orthotropic material models **without plasticity or damage** (MAT\_002, MAT\_022) can reproduce the **longitudinal direction**, but are too **stiff in perpendicular** direction.

Seite: 20 / 28  
 Autor: Peter Reithofer, Bernhard Jilka, Artur Fertschej  
 Datum: 150616  
 Titel: rep\_15061602\_pr\_bj1a\_ater\_gga\_FiberMaterialModels.ppt

I N P H Y S I C S W E T R U S T

© 4a engineering GmbH, all rights reserved

# Material models in LSDYNA Comparison on PPGF40 (MAT\_157)



- Orthotropic material models with **plasticity and rate dependence (MAT\_157)** can reproduce both directions.



Seite: 21 / 28  
 Autor: Peter Reithofer, Bernhard Jilka, Artur Fertschej  
 Datum: 150616  
 Titel: rep\_15061602\_pr\_bj1a\_ater\_gga\_FiberMaterialModels.ppt

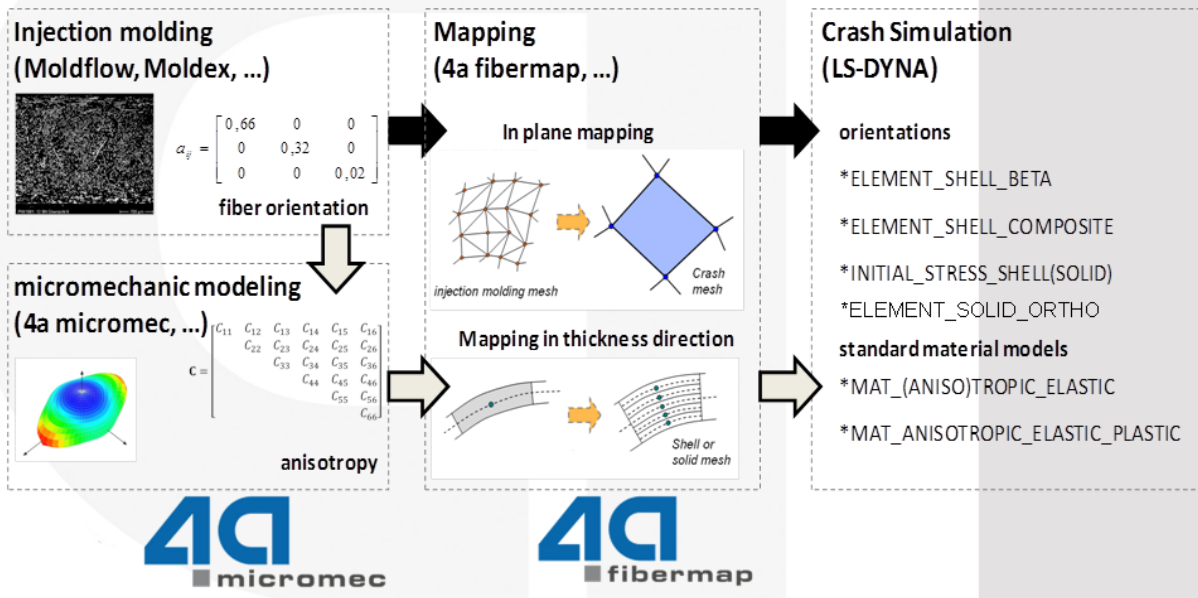
I N P H Y S I C S W E T R U S T

© 4Q engineering GmbH, all rights reserved

# Simulation process chain for injection molded parts



[2012Reithofer]

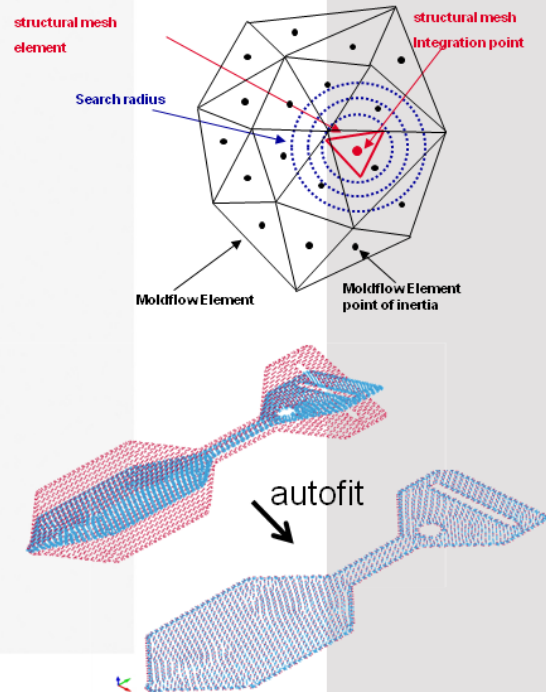
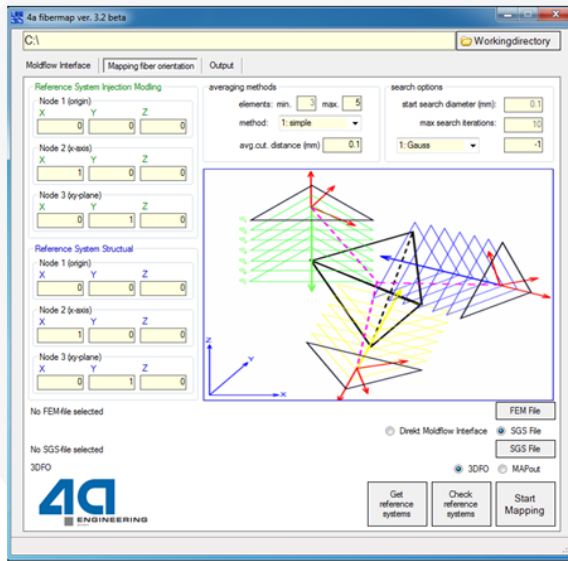


Seite: 22 / 28  
 Autor: Peter Reithofer, Bernhard Jilka, Artur Fertschej  
 Datum: 150616  
 Titel: rep\_15061602\_pr\_bj1a\_ater\_gga\_FiberMaterialModels.ppt

I N P H Y S I C S W E T R U S T

© 4Q engineering GmbH, all rights reserved

## Simulation process chain 4a fibermap - mapping



Seite: 23/28  
 Autor: Peter Reithofer, Bernhard Jilka, Artur Fertschej  
 Datum: 150616  
 Titel: rep\_15061602\_pr\_bj1a\_ater\_gga\_FiberMaterialModels.ppt

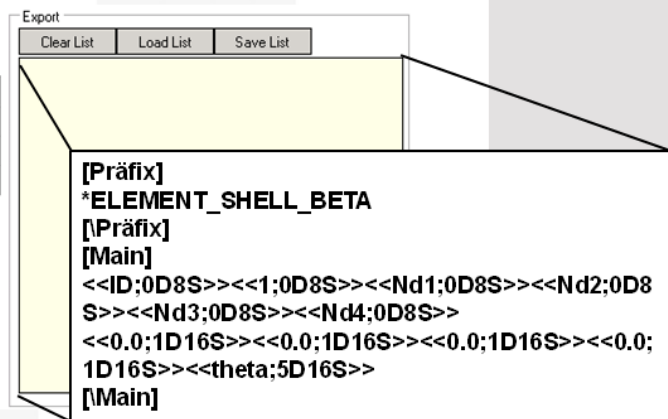
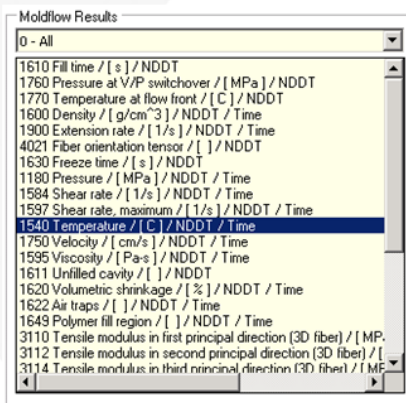
I N P H Y S I C S W E T R U S T



## Simulation process chain 4a fibermap – interface

- Moldex - fiber orientation
- Moldflow - fiber orientation and further results could be mapped

[2012Reithofer]



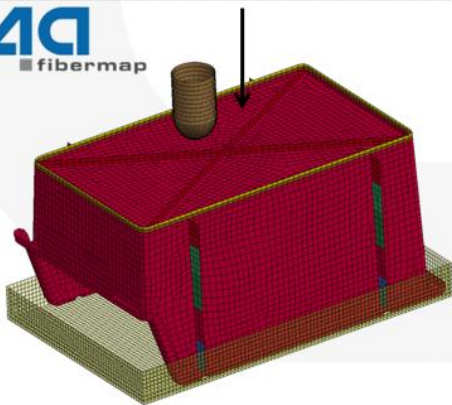
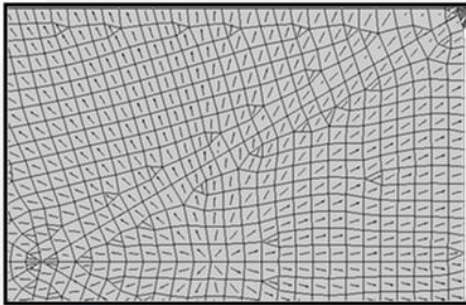
Seite: 24/28  
 Autor: Peter Reithofer, Bernhard Jilka, Artur Fertschej  
 Datum: 150616  
 Titel: rep\_15061602\_pr\_bj1a\_ater\_gga\_FiberMaterialModels.ppt

I N P H Y S I C S W E T R U S T





## Casestudy Nutini Box with MAT\_157



Seite: 26 / 28  
Autor: Peter Reithofer, Bernhard Jilka, Artur Fertschej  
Datum: 150616  
Titel: rep\_15061602\_pr\_bj1a\_afer\_gga\_FiberMaterialModels.ppt

I N P H Y S I C S W E T R U S T

## Conclusion



- Orthotropic material models **without plasticity or damage** (MAT\_002, MAT\_022) can reproduce the **longitudinal direction**, but are too **stiff in perpendicular** direction.
- Orthotropic material models with **plasticity and rate dependence** (MAT\_157) can **reproduce both directions**.
- Orthotropic material models with damage (MAT\_054, MAT\_058, MAT\_158) could be also an alternative.
- **Only micro mechanic based material models have the capability to cover all effects in an easy approach.**



Seite: 26 / 28  
Autor: Peter Reithofer, Bernhard Jilka, Artur Fertschej  
Datum: 150616  
Titel: rep\_15061602\_pr\_bj1a\_afer\_gga\_FiberMaterialModels.ppt

I N P H Y S I C S W E T R U S T

Thank you for your attention!



Seite: 27 / 28  
Autor: Peter Reithofer, Bernhard Jilka, Artur Fertschej  
Datum: 150616  
Titel: rep\_15061602\_pr\_bj1a\_ater\_gga\_FiberMaterialModels.ppt

I N P H Y S I C S W E T R U S T

© 4a engineering GmbH, all rights reserved

## Literature



- [2008Reithofer]** P. Reithofer, M. Fritz, T. Wimmer (4a engineering GmbH) – *Kurzfaserverstärkte Kunststoffbauteile - Einfluss der prozessbedingten Faserorientierung auf die Strukturmechanik*, 7. LS-DYNA Anwenderforum, Bamberg 2008 ([Link](#))
- [2012Reithofer]** P. Reithofer, B. Jilka, A. Fertschej (4a engineering GmbH) – *4a micromec für die integrative Simulation faserverstärkter Kunststoffe*, 11. LS-DYNA Anwenderforum, Ulm 2012 ([Link](#))
- [2014Haufe]** A. Haufe (DYNAmore GmbH) – *Zum aktuellen Stand der Simulation von Kunststoffen mit LS-DYNA*, 11. 4a Technologietag - 2014 ([Link](#))
- [2014Jennrich]** R. Jennrich, M. Roth, Prof. S. Kolling (Technische Hochschule Mittelhessen) C. Liebold (DYNAmore GmbH), G. Weber (Celanese GmbH) – *Experimentelle und numerische Untersuchung eines kurzglasfaserverstärkten Kunststoffes*, 13. LS-DYNA Forum 2014, Bamberg ([Link](#))



Seite: 28 / 28  
Autor: Peter Reithofer, Bernhard Jilka, Artur Fertschej  
Datum: 150616  
Titel: rep\_15061602\_pr\_bj1a\_ater\_gga\_FiberMaterialModels.ppt

I N P H Y S I C S W E T R U S T

© 4a engineering GmbH, all rights reserved