*MAT_4A_MICROMEC – Theory and Application notes

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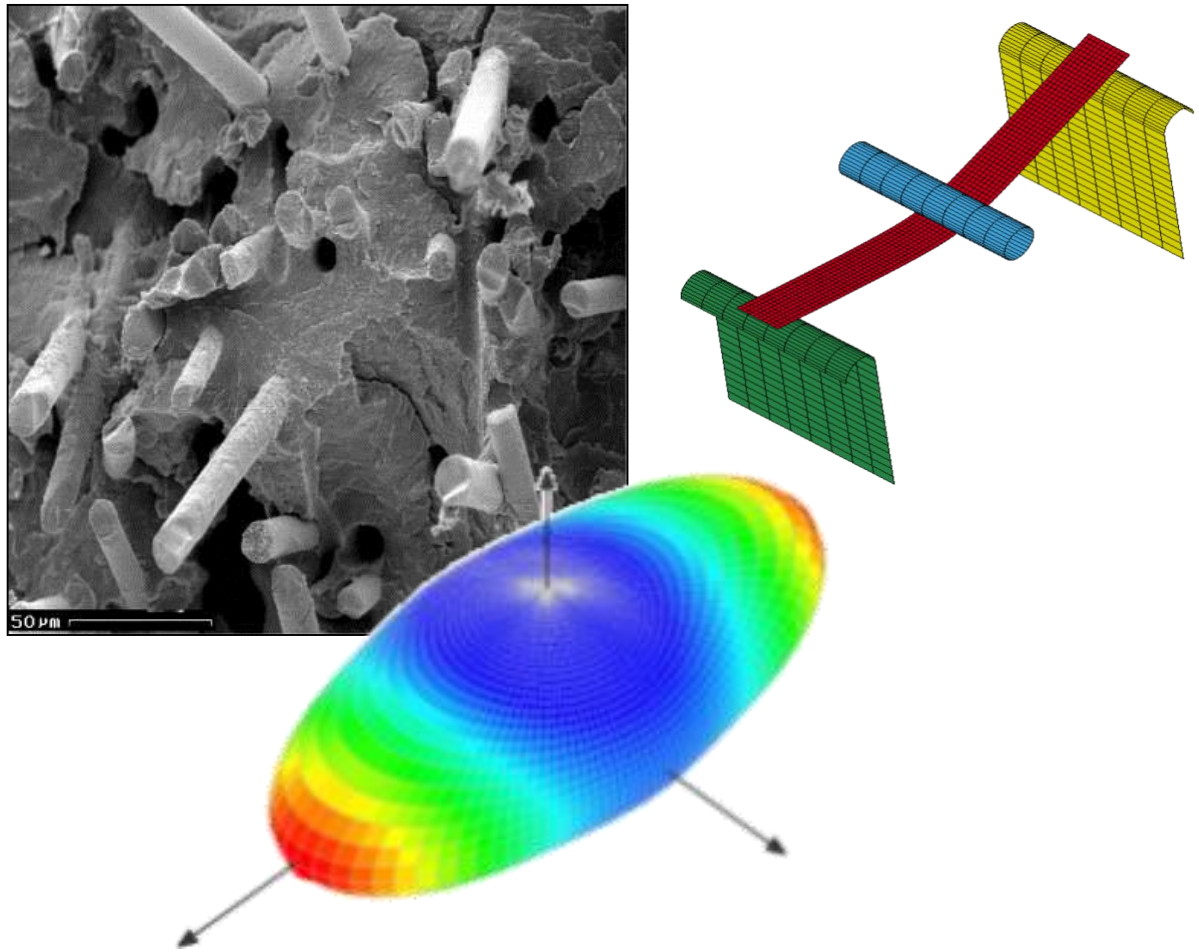
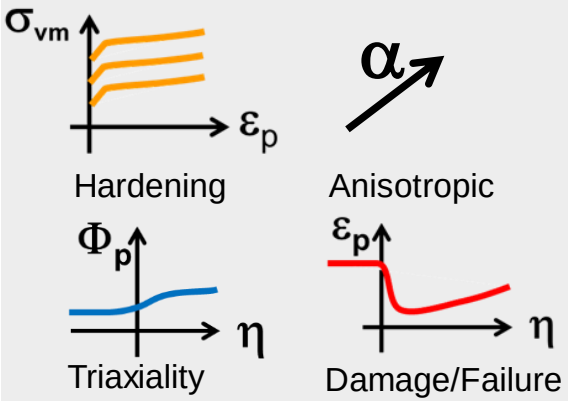
Outline

- Introduction 4a products
- Motivation
- Material models - actual approaches
- Introduction ***MAT_215**
- Material Characterization
- Case Study - Sleeve
- Summary & Outlook



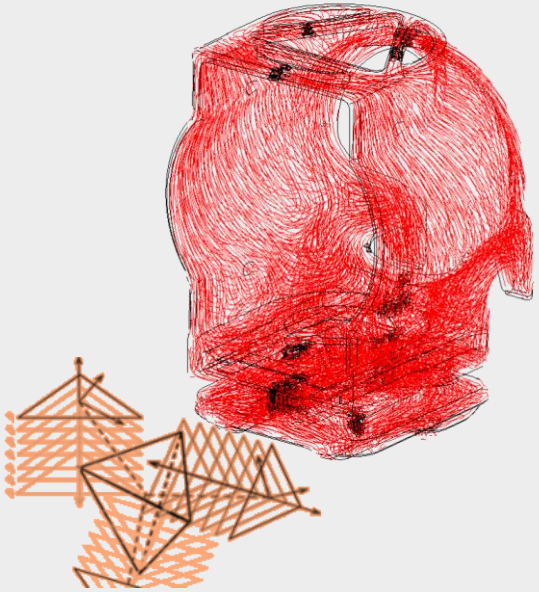
intelligent reliable solutions for plastics, composites, metals, foams, ...

VALIMAT



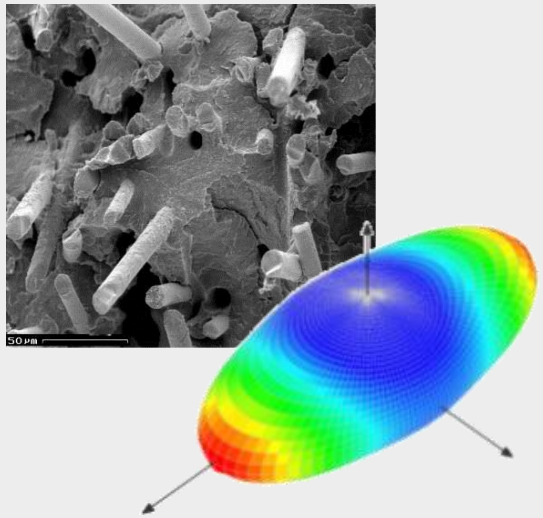
from test to validated material cards

FIBERMAP



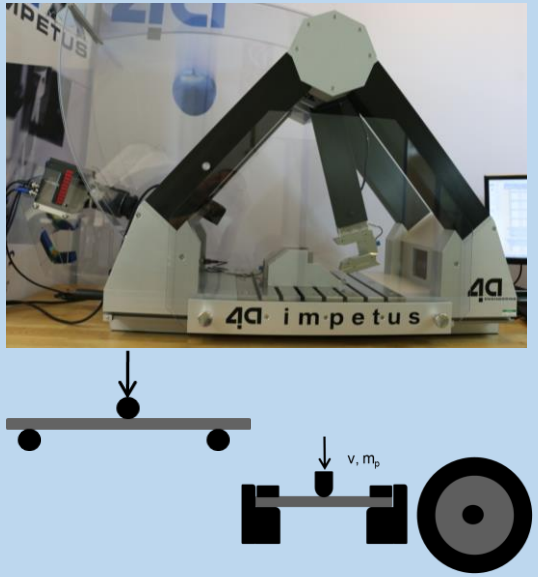
individual mapping process information

MICROMEC



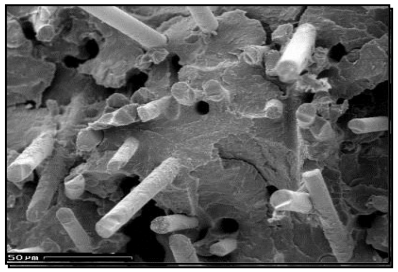
3D anisotropic material cards

IMPETUS

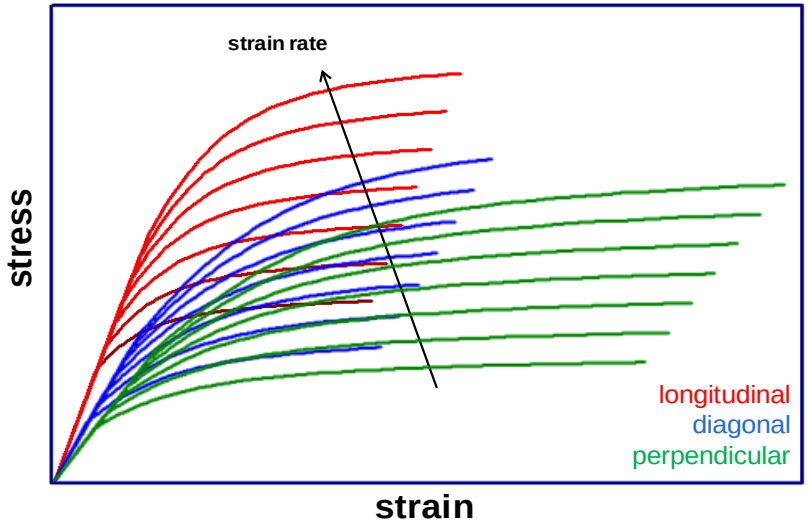


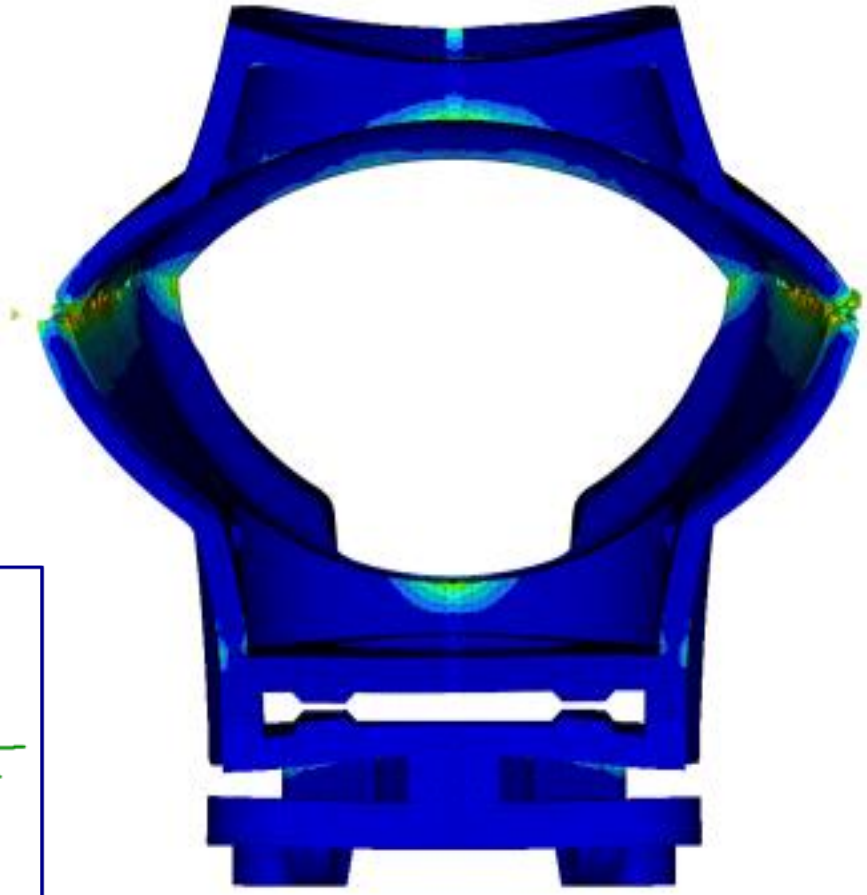
efficient dynamic testing

Motivation – current standard

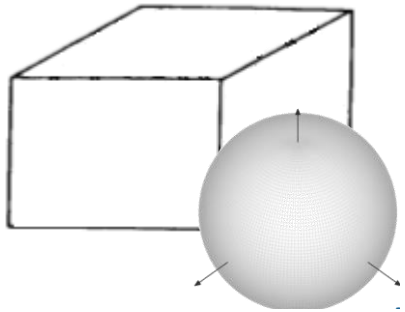


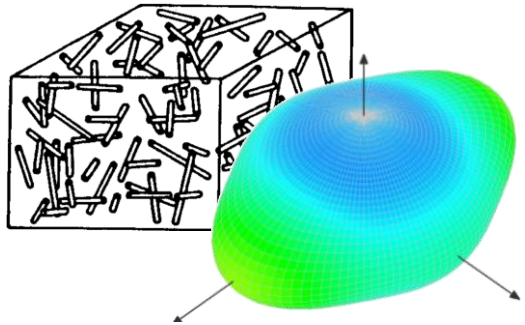
*MAT_024



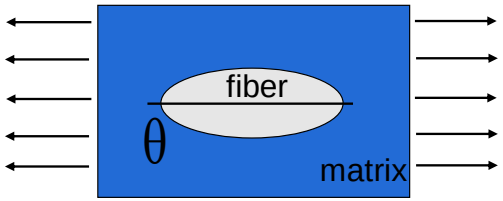


material model - actual approaches





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



Eshelby Tensor

macro scale

constitutiv law → composi

micro scale

homogenizat

Mises plasticity

- quick & d
- criti g
  t
  orientation

elastic

- orthotro
- aniso

elastic tic

- city

M… matrix

- isotropic elas
  viscoplast

F… fiber

- iso tic

*MAT_024

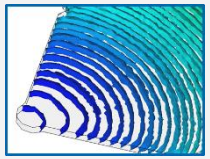
*MAT_157

*MAT_215

α – orientation dependent

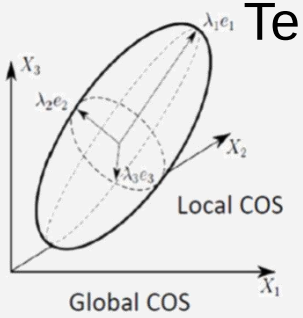
Material models – actual approaches

Process simulation



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

Tensor 2nd order



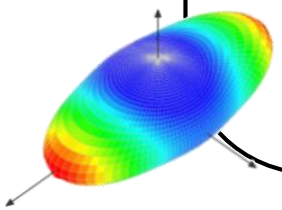
CADMOULD 3D-F SIMULATION

Moldex3D MOLDING INNOVATION

MOLDFLOW

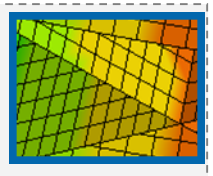
FIBERMAP

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



MICROMEC

Structural simulation

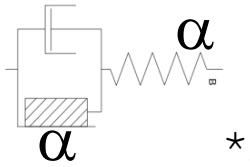


Homogenization (Micro Scale)
Mean Field Theory

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

*MAT_215

Composite (Macro Scale)
Hill Plasticity

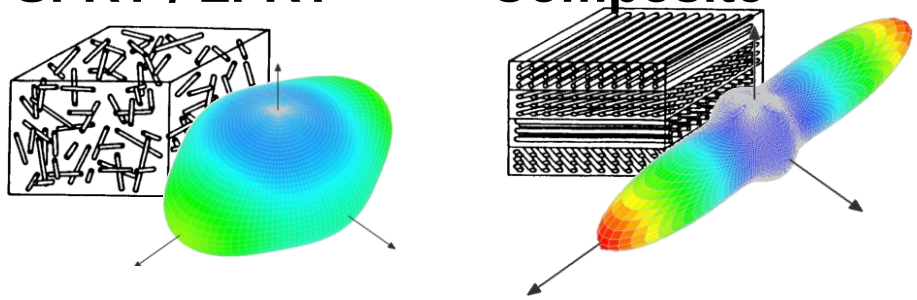


*MAT_157

LSTC Livermore Software Technology Corp.
LS-DYNA®

MICROMEC

SFRT / LFRT **Composite**

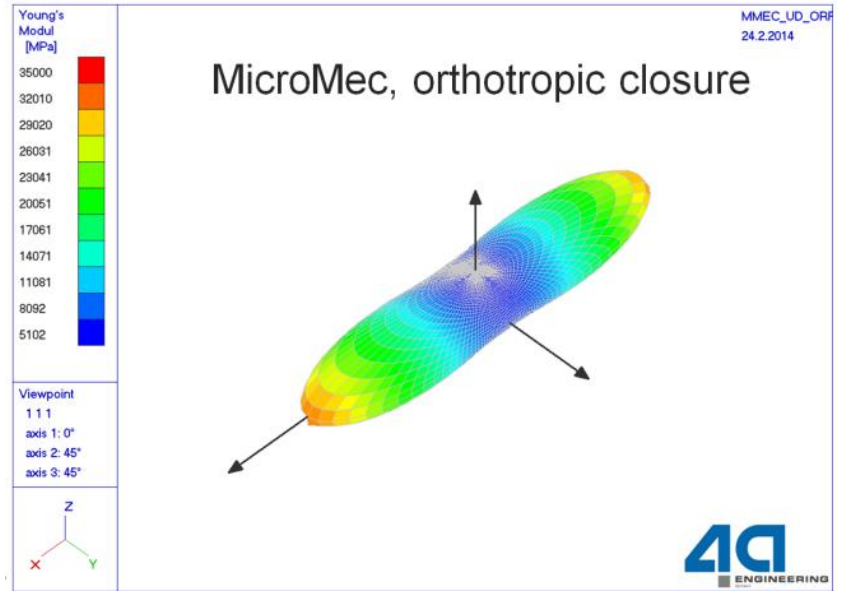


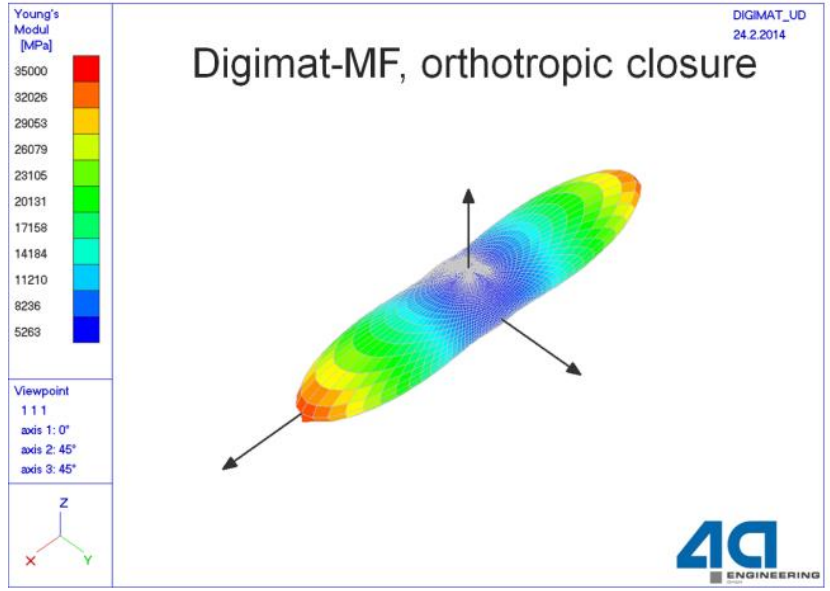
$$\overline{\sigma}^{C} = \varphi\overline{\sigma}^{F} + (1-\varphi)\overline{\sigma}^{M}$$

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

- **Standalone product (2001)**
- **Usermaterial (2007)**
- **Library→4a impetus (2015)**
- **in LSDYNA R10.1 (2018)**

`*MAT_4A_MICROMEC`





Comparison by University of Leoben [Bodor2014]

Material models – *MAT_215 KEYWORD

header
composite
fiber
matrix

```
$=======================================================================
*MAT_4A_MICROMEC
$01     mid      mmopt       bupd         --         --      failm      failf     NUMINT
   1000000        1.0       0.01                               0.         0.      -65.
$02    aopt       macf         xp         yp         zp         a1         a2         a3
          0          0        0.0        0.0        0.0        1.0        0.0        0.0
$03      v1         v2         v3         d1         d2         d3       beta         --
         0.0        0.0        0.0        0.0        0.0        1.0        45.
$04     fvf         --         fl         fd         --        a11        a22         --
        .115                   53.        1.0                   .7        .25
$05     rof         el         et        glt       prtl       prtt         --         --
2.5899e-09    70000.     70000.     28759.      0.217      0.217
$06      xt         --         --         --         --         --     SLIMXT     NCYRED
     2800.                                                          0.01         10
$07     rom          e         pr         --         --         --         --         --
  1.09e-09     1500.        0.3
$08   sigyt       etant         --         --       eps0          c
$09    LCST         --         --         --       LCDI       UPF
   1000000                                       1000020  -1000026
$=======================================================================
```

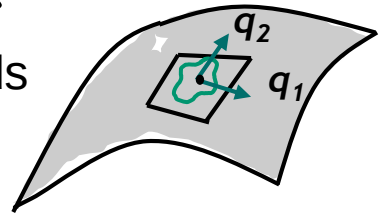
options
direction
definition
transversal i. elasticity
failure
isotropic elasticity
viscoplasticty
damage

Material models – *MAT_215 KEYWORD

CARD 1: General Options / Parameter

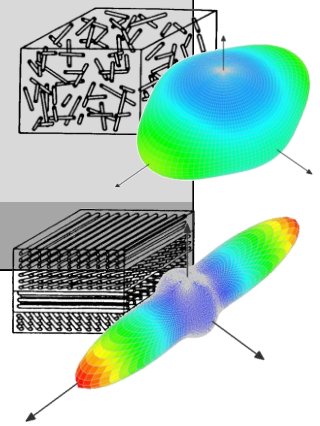
CARD 2-3: Element orientation*

analog to LSDYNA standard anisotropic material cards



CARD 4: Composite Buildup*

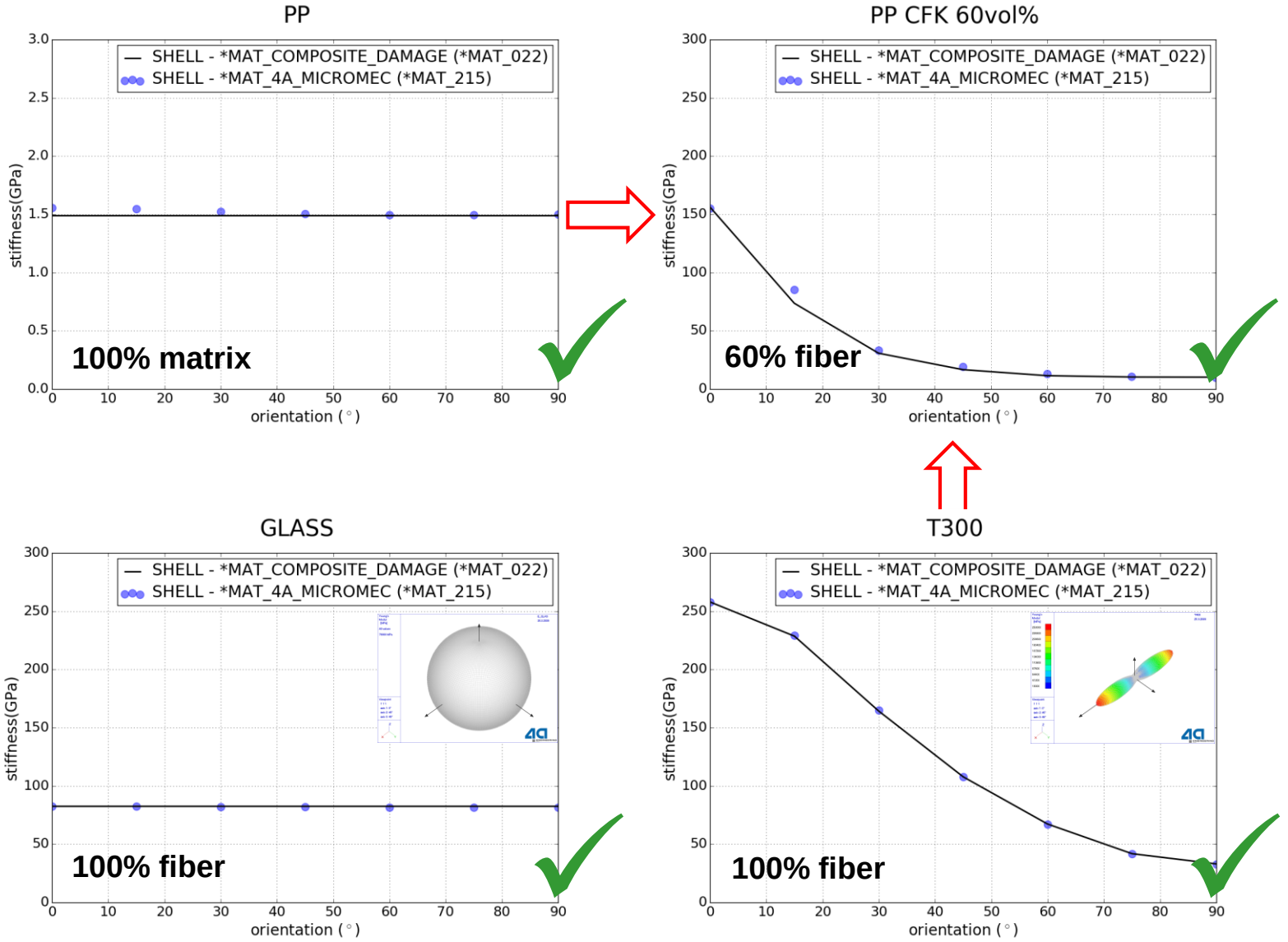
Card 4	1	2	3	4	5	6	7	8
	FVF		FL	FD		A11	A22	
PP GF30	**-0.3**		**200.0**	**10.0**		**0.7**	**0.25**	
PP LGF50	**-0.5**		**1000.0**	**20.0**		**0.65**	**0.30**	
PA6 GF45	**-0.45**		**250.0**	**10.0**		**0.8**	**0.15**	
Carbon UD	**0.6**		**10000.0**	**10.0**		**1.0**	**0.0**	



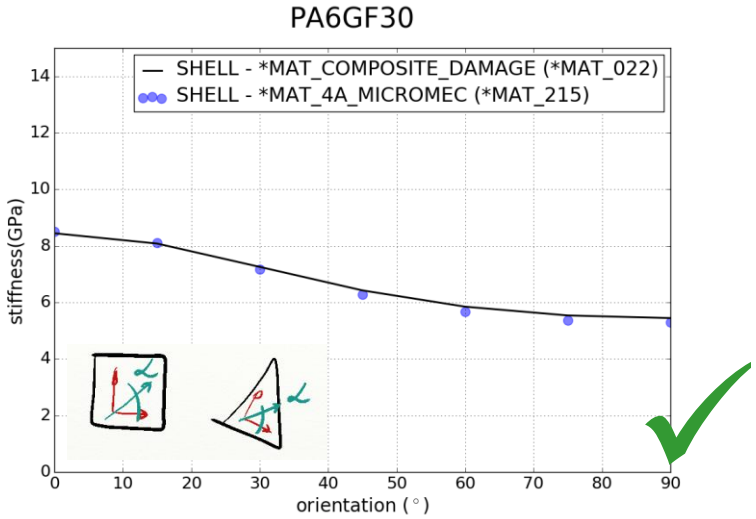
FVF > 0: fiber volume fraction → Composite
FVF < 0: fiber mass fraction → SFRT/LFRT

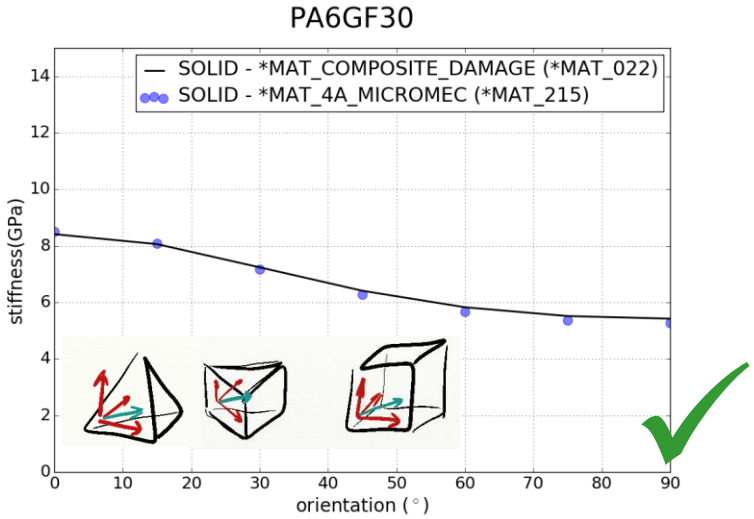
*may be overwritten by
`*INITIAL_STRESS_SHELL/SOLID`

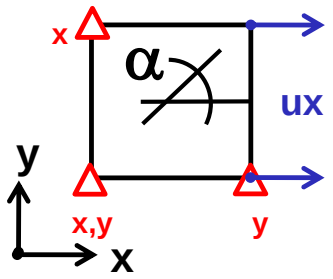
*MAT_215 - Verification

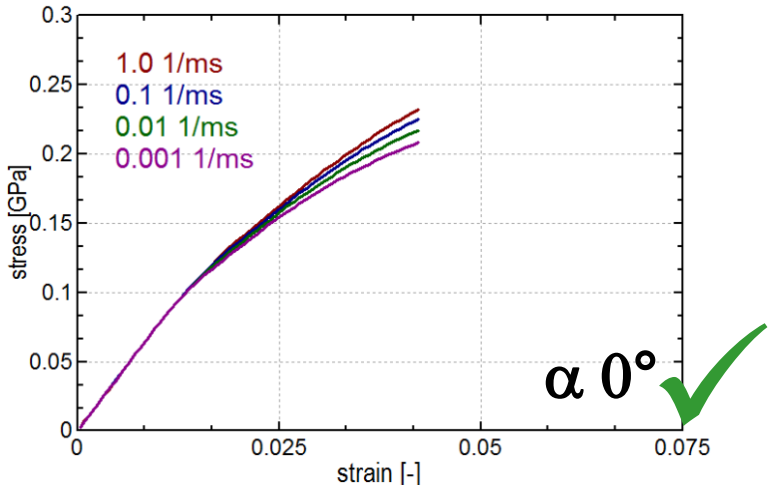


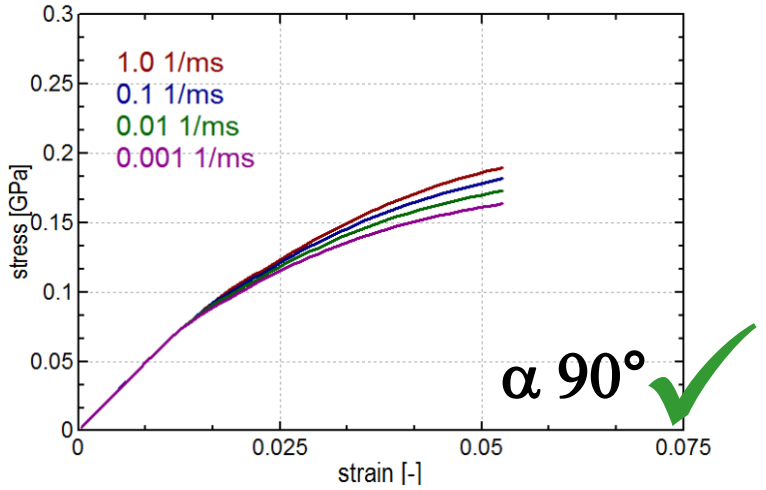
*MAT_215 - Verification



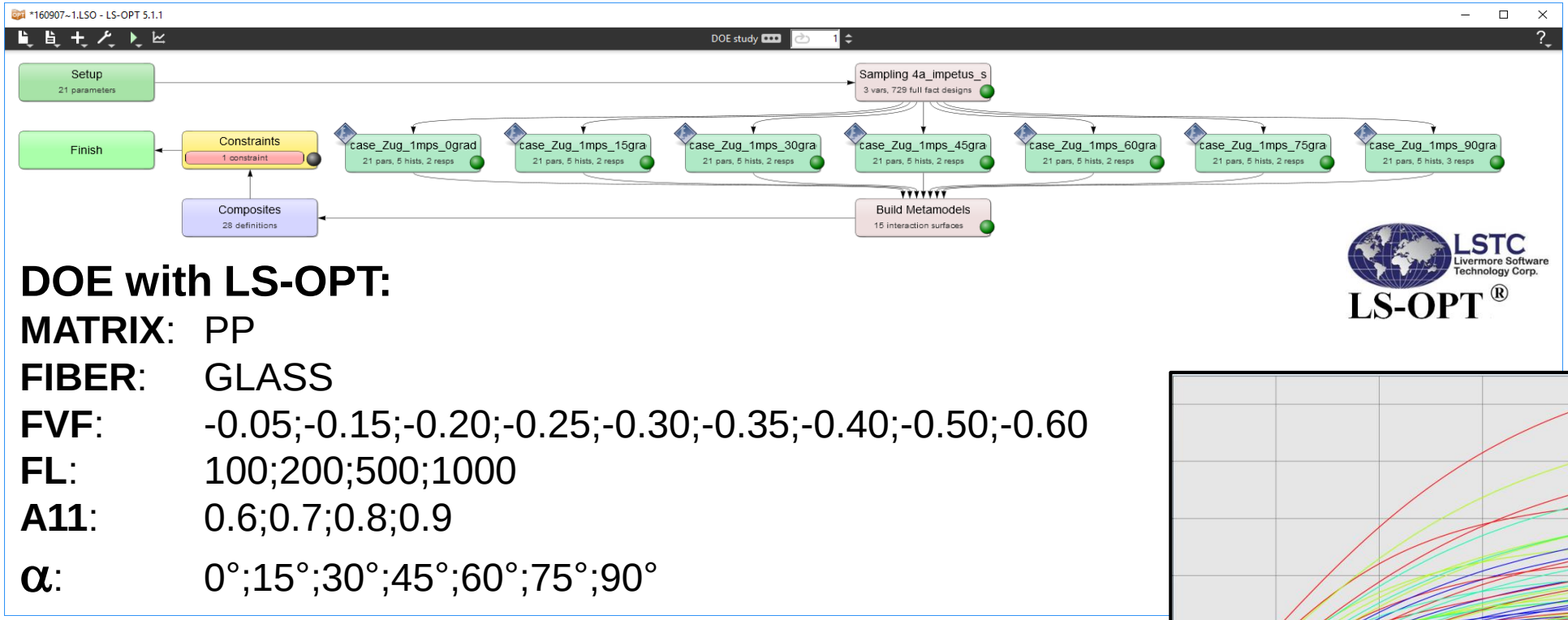


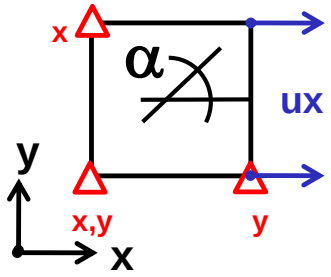






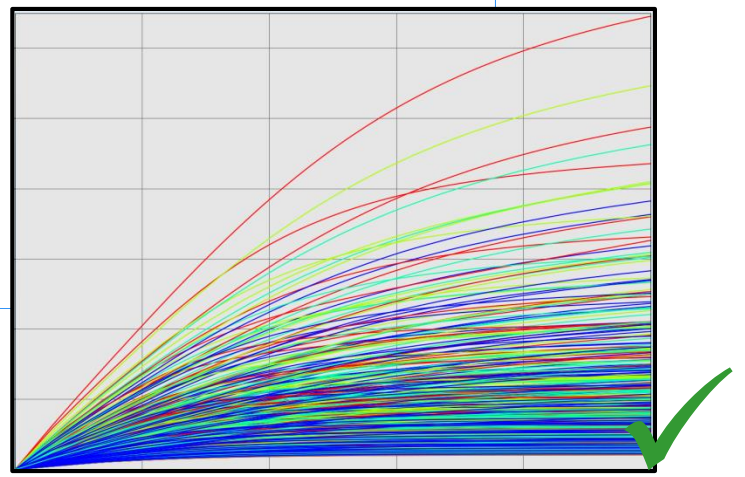
*MAT_215 - Verification





DOE with LS-OPT:

MATRIX: PP
FIBER: GLASS
FVF: -0.05;-0.15;-0.20;-0.25;-0.30;-0.35;-0.40;-0.50;-0.60
FL: 100;200;500;1000
A11: 0.6;0.7;0.8;0.9
α: 0°;15°;30°;45°;60°;75°;90°

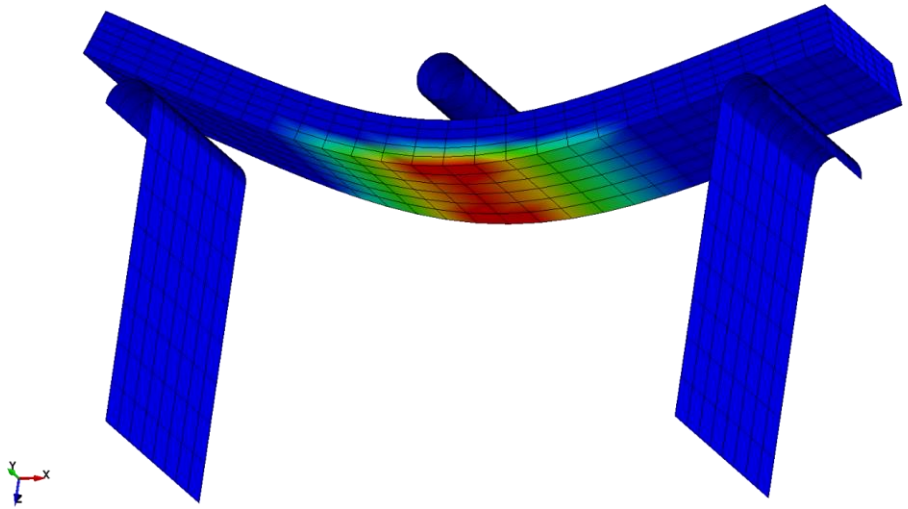


RUNS without an error

Material models – *MAT_215 KEYWORD

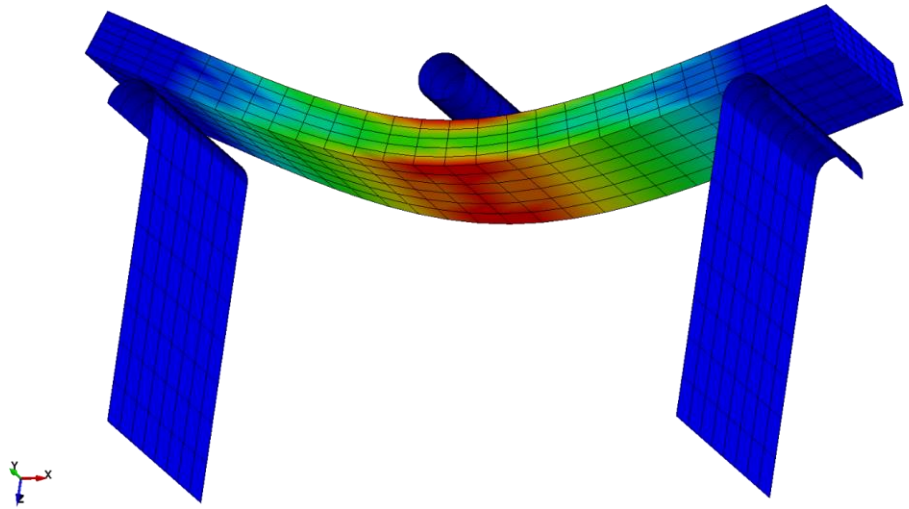
CARD 1: General Options / Parameter

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



History#4 (step8: 0-0.81):

dm - matrix damage init.



History#6 (step8: 0-0.13):

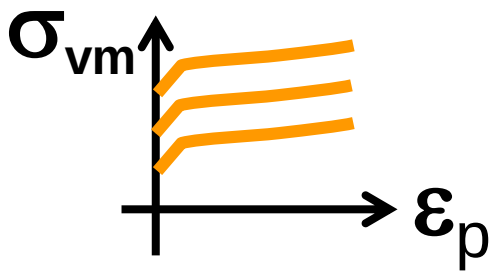
Fiber damage init.

Material models – *MAT_215 KEYWORD

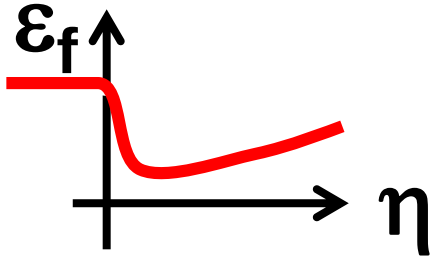
CARD 9: matrix material tables

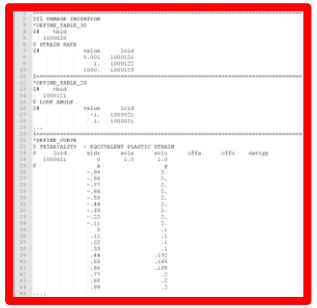
Card 9	1	2	3	4	5	6	7	8
Variable	LCIDT				LCDI	UPF		
Type	F				F	F		
Default	0				0	0.0		

Hardening

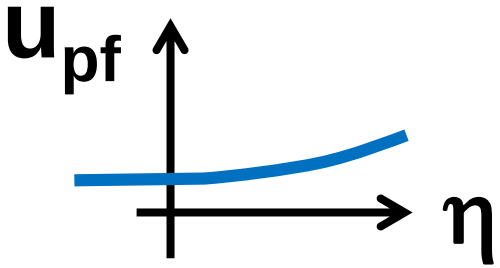


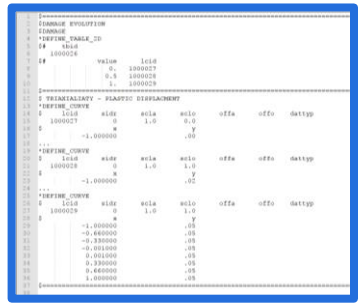
Damage Initiation





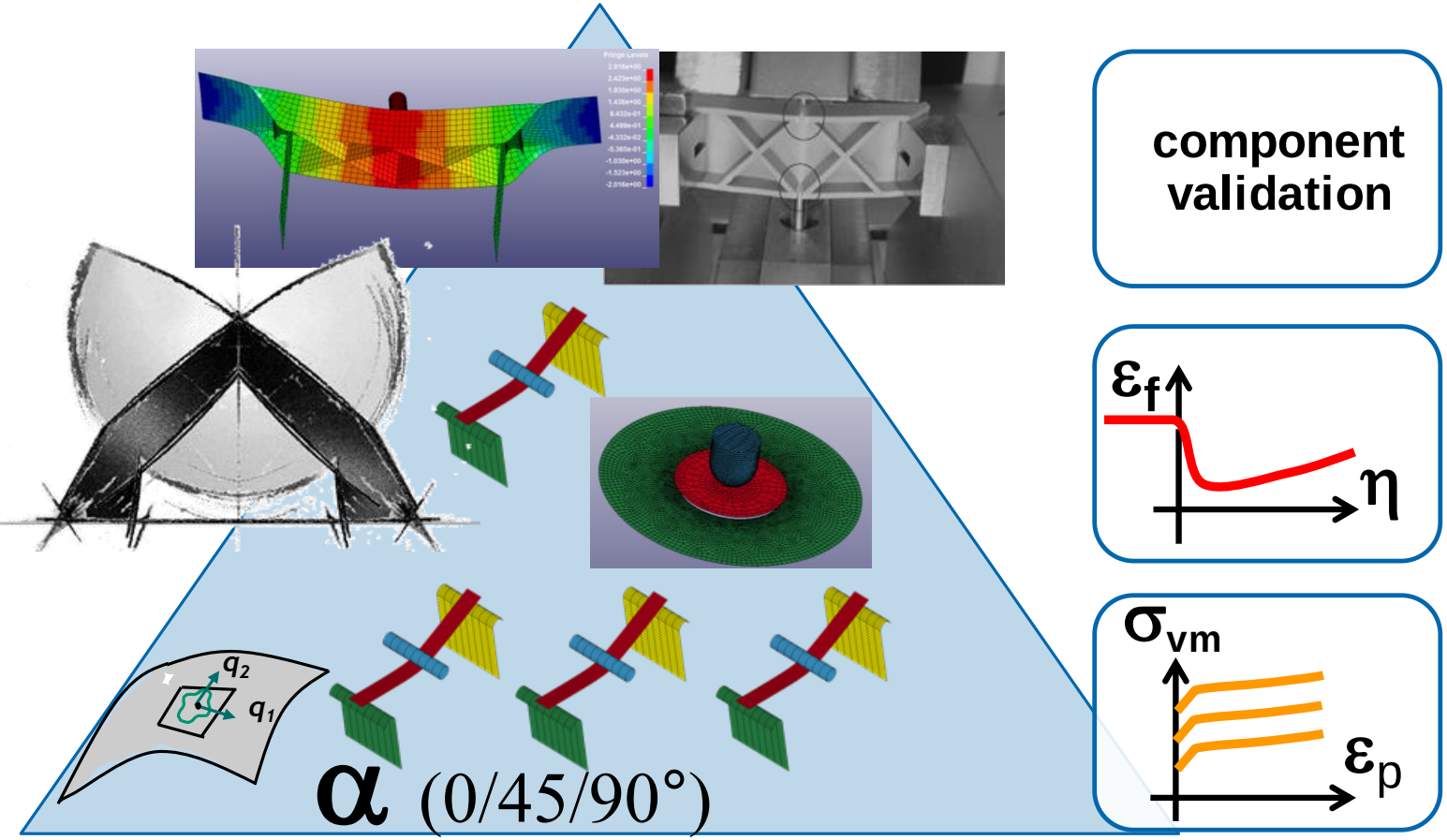
Damage Evolution



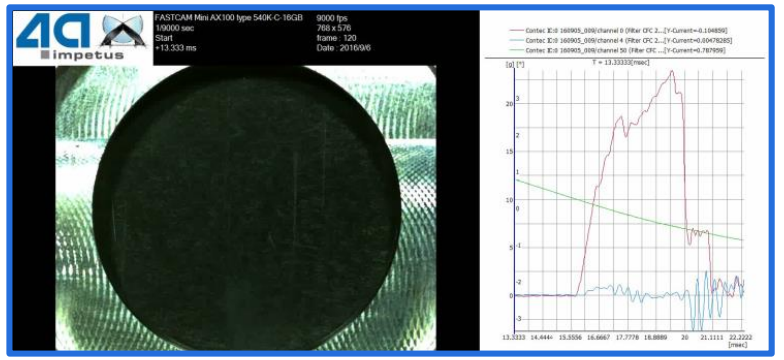


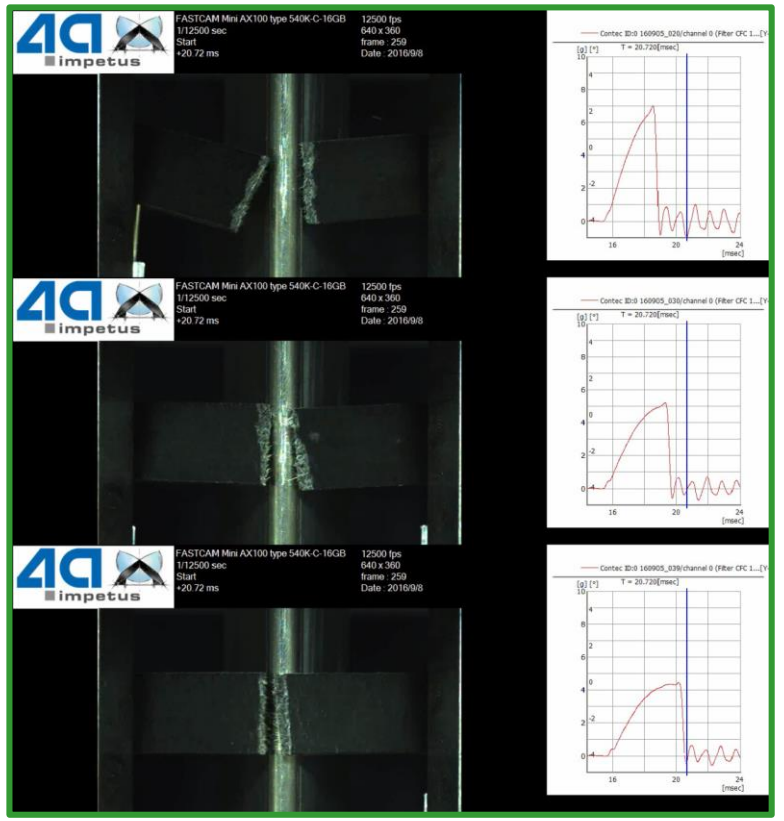
LCIDT	Effective stress (Table)
LCDI	Damage initiation (Table)
UPF	Damage evolution parameter

from test to material card

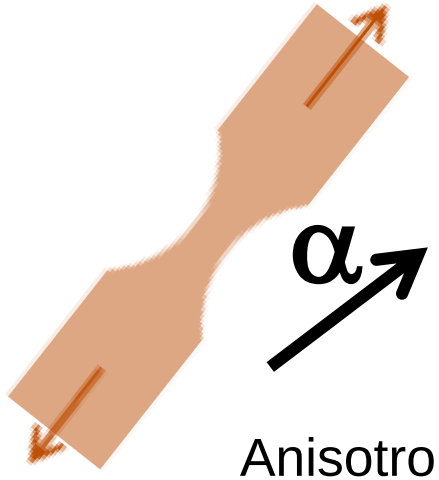


component validation



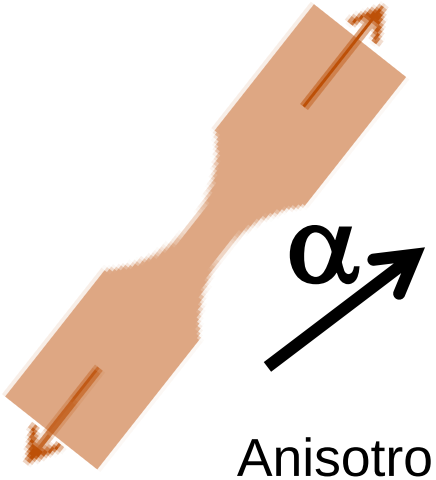


See more: P Reithofer, et.al., Versagen von faserverstärkten Kunststoffen bei dynamischer Beanspruchung, 4a Technologietag -2017



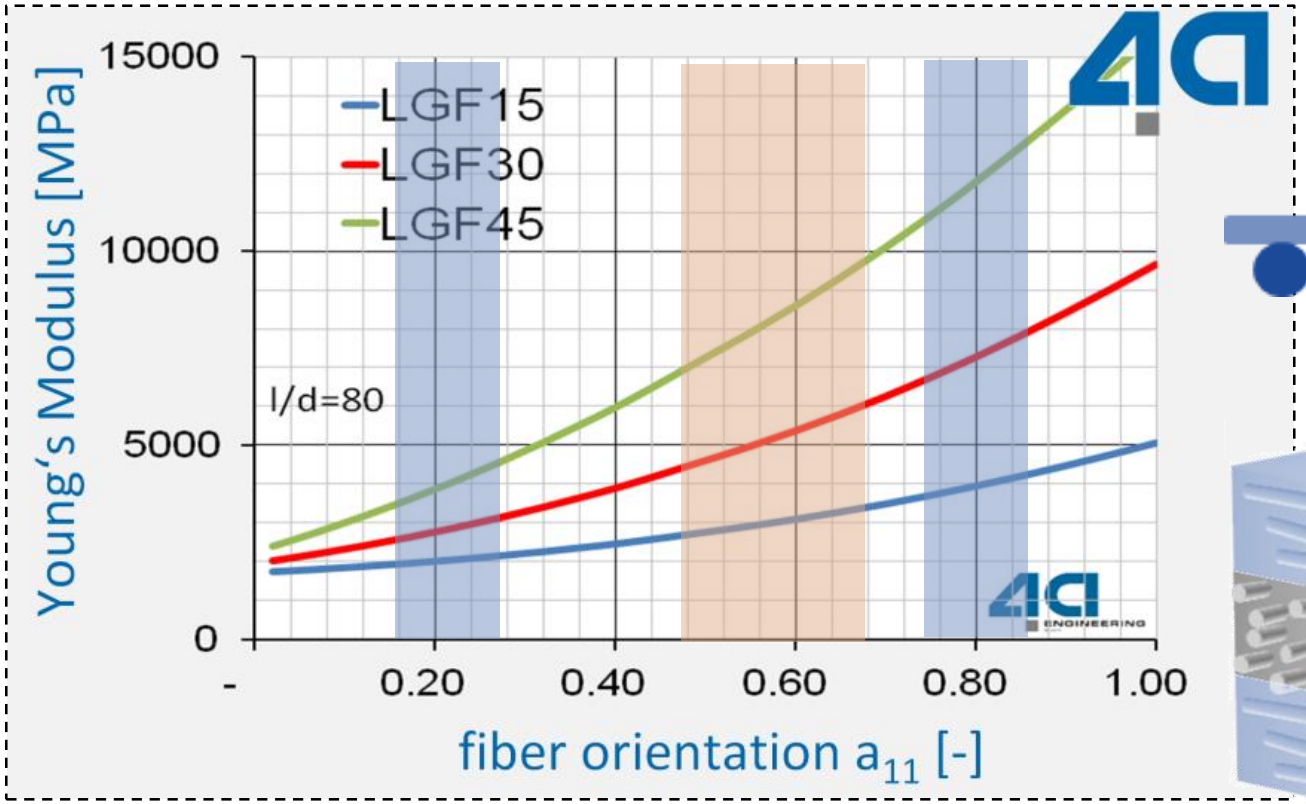
Anisotropic

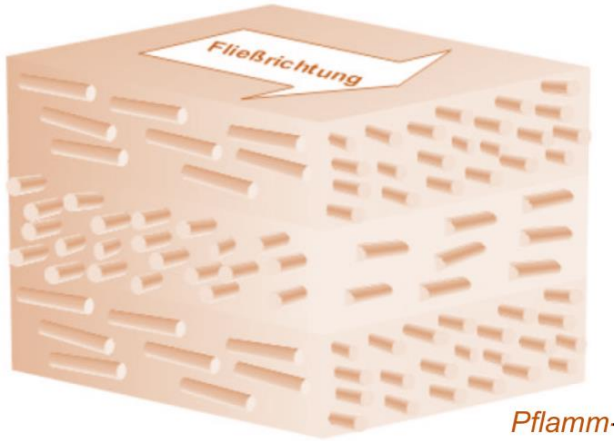
Why not tension (only)?

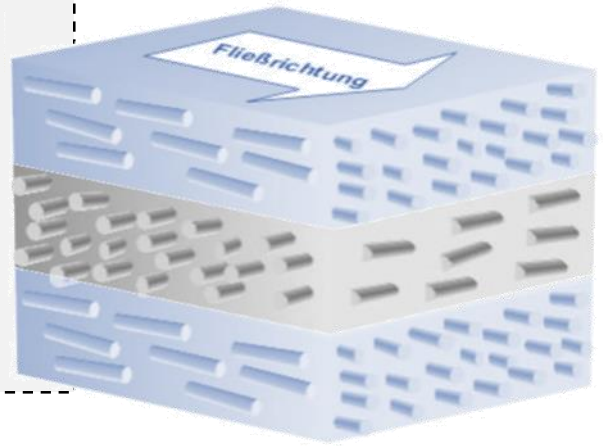


Anisotropic

Why not tension (only)?

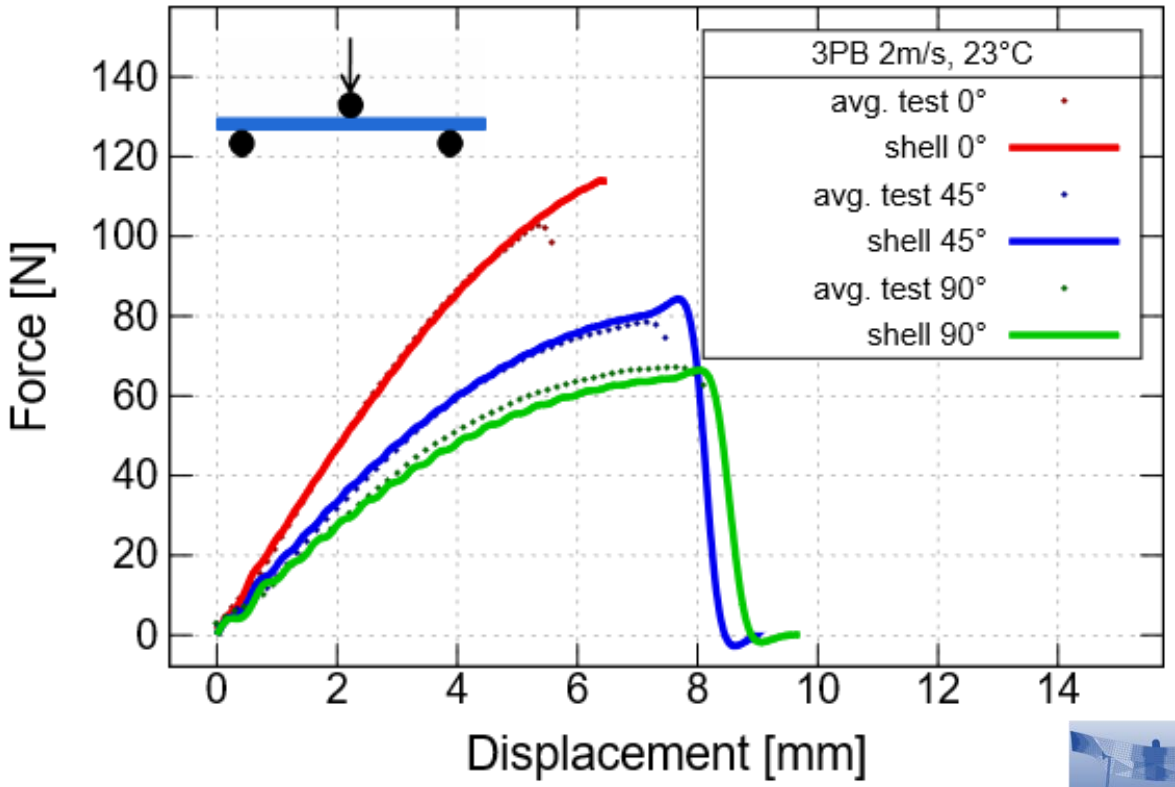


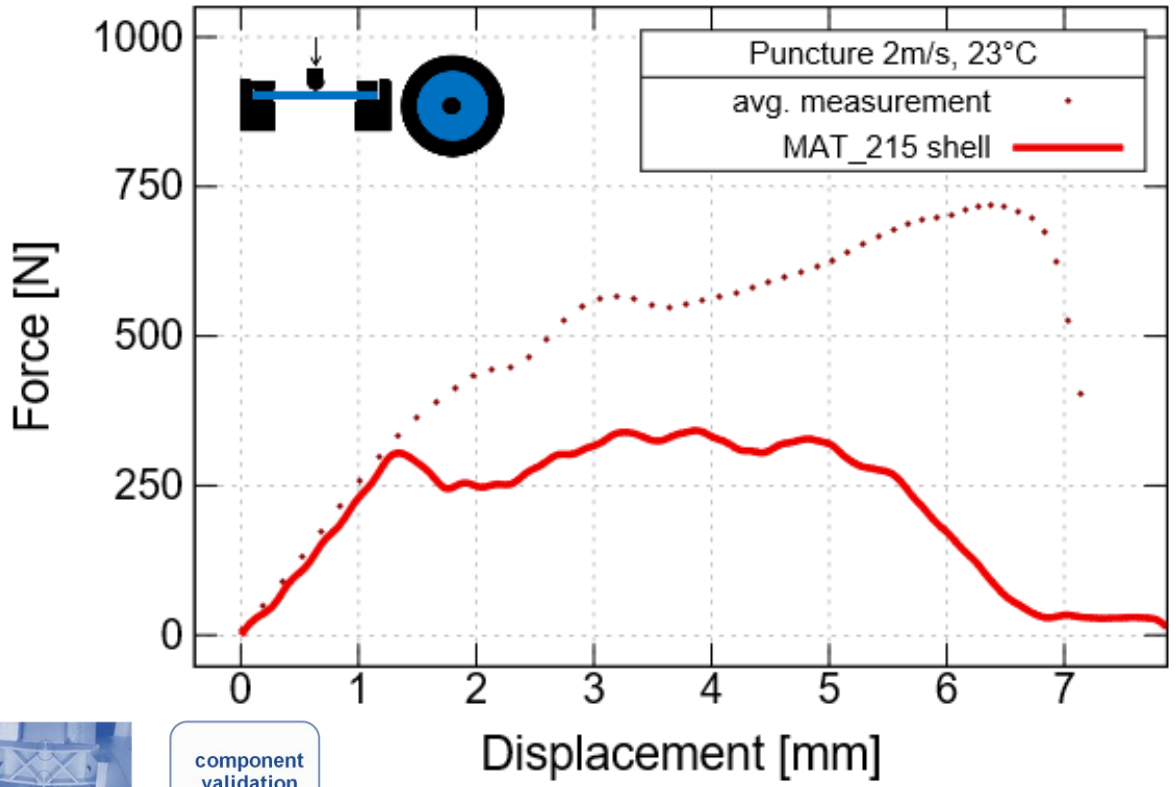


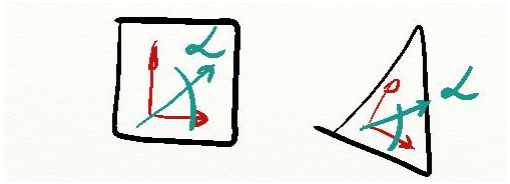


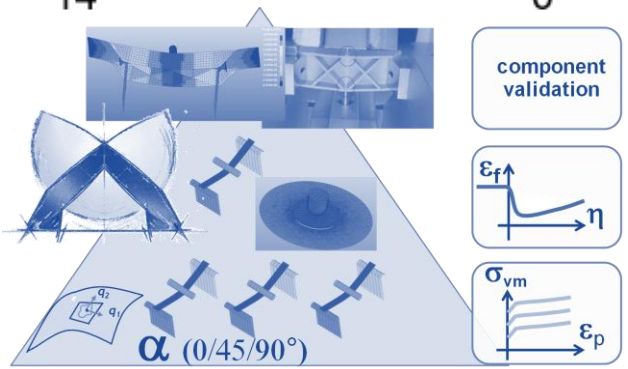
Pflamm-Jonas 2001

from test to material card – PP LGF30 *MAT_215



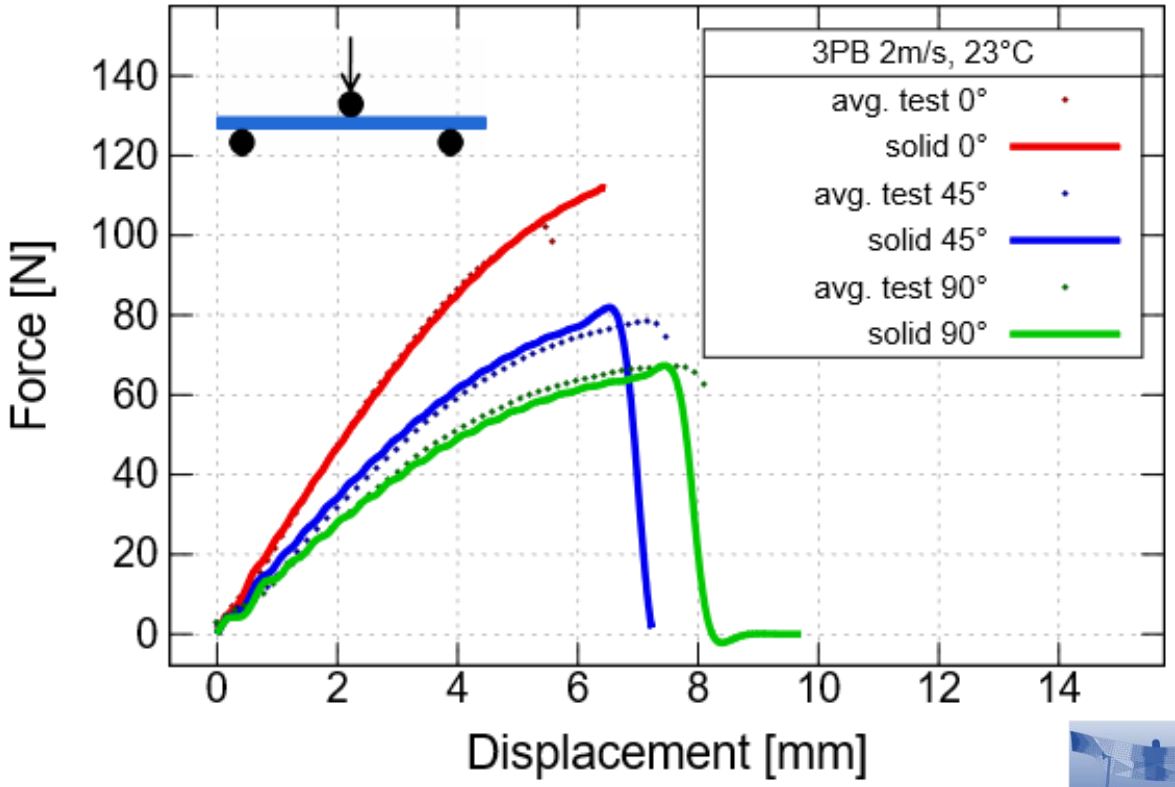


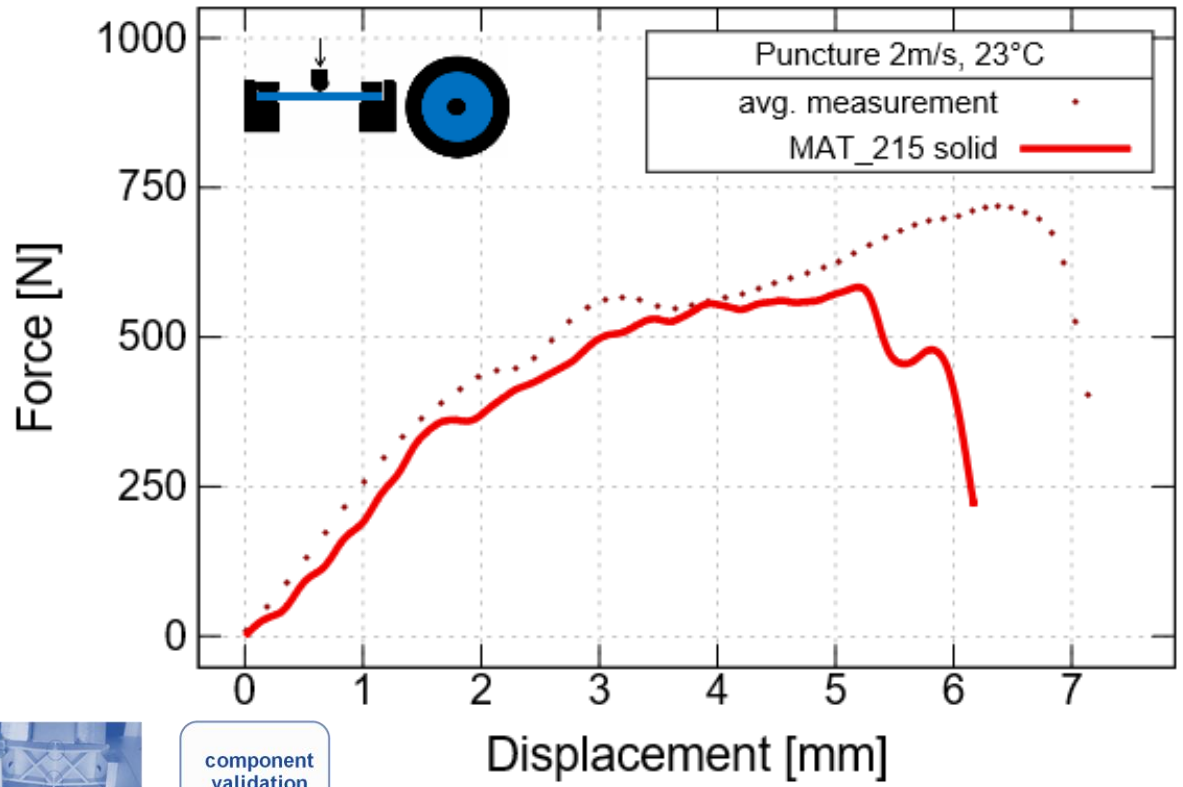


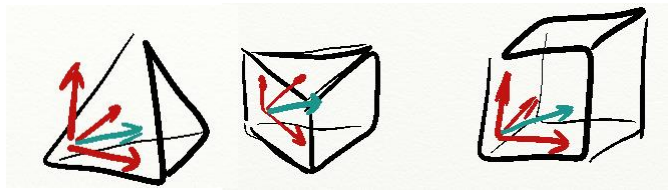


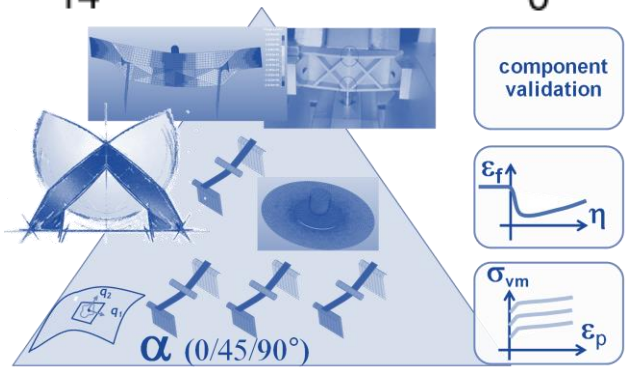
···· averaged test curves
— result of simulation

from test to material card – PP LGF30 *MAT_215









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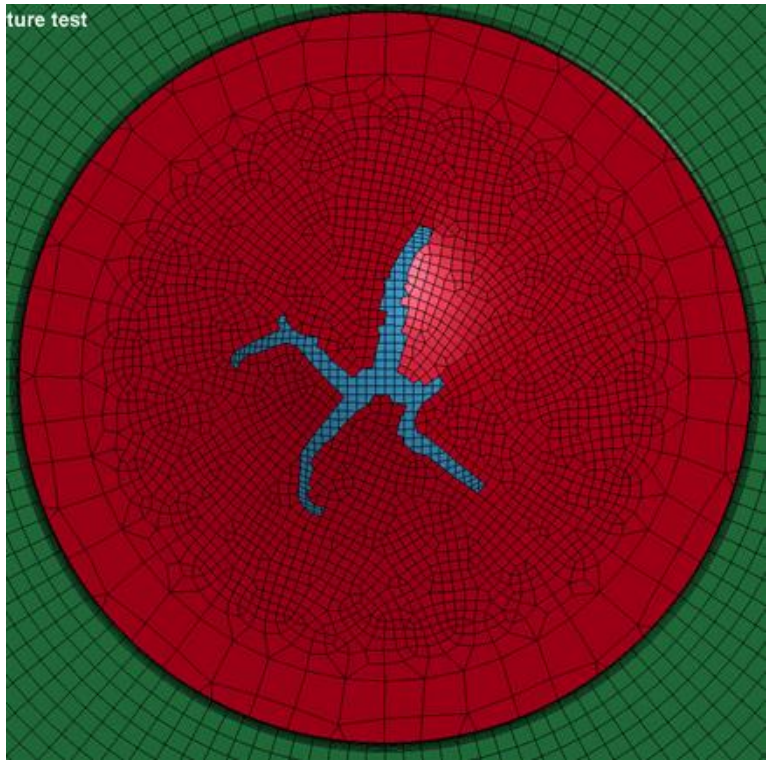
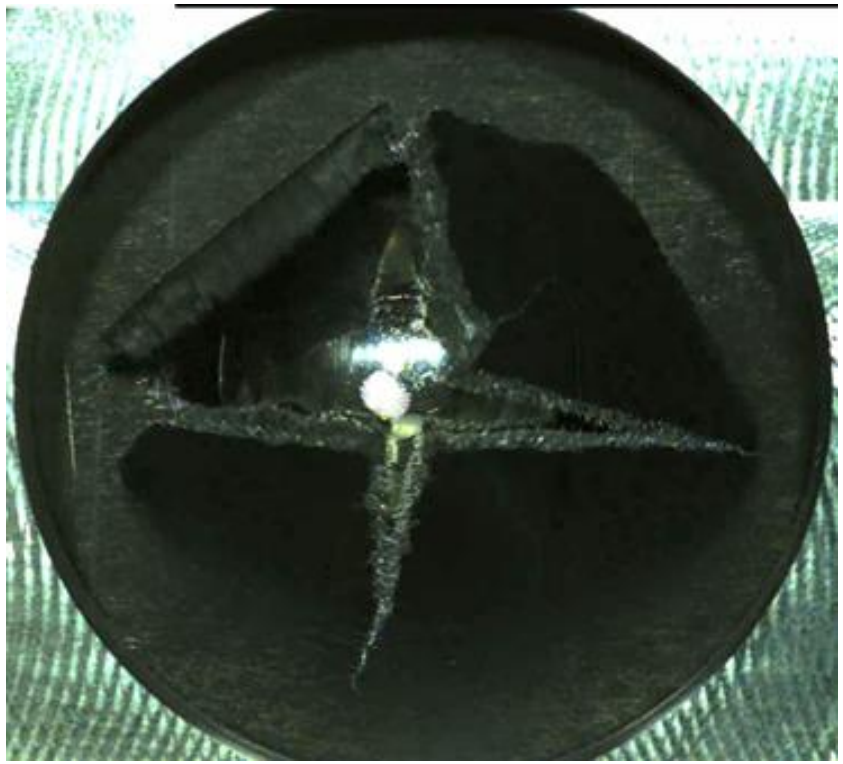
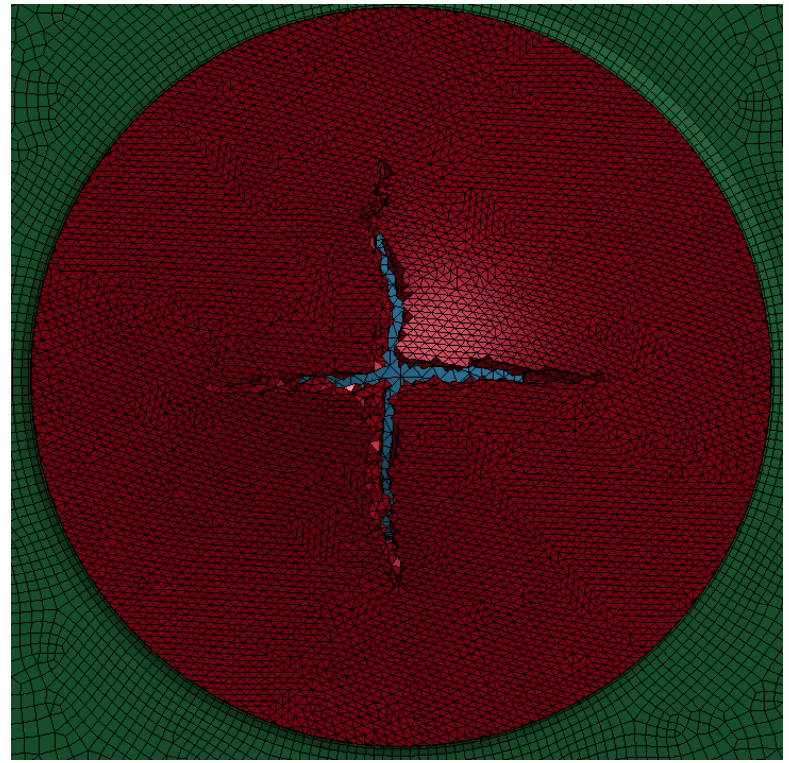
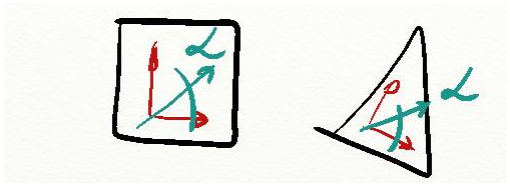
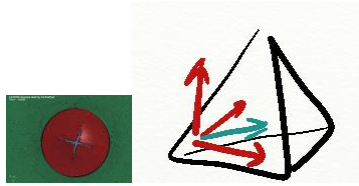
from test to material card – PP LGF30 *MAT_215











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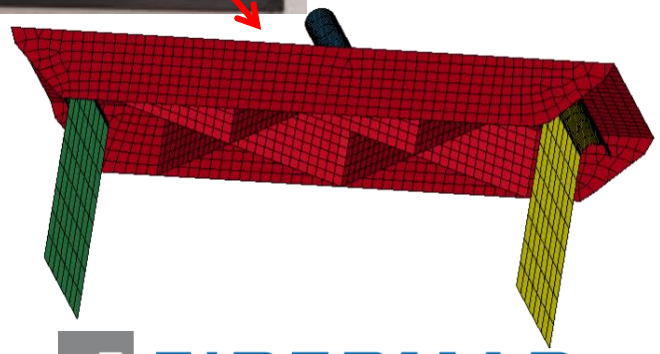
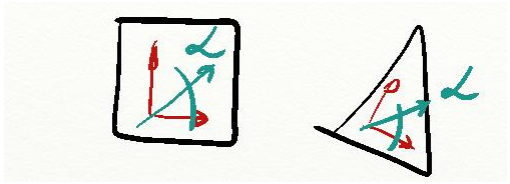
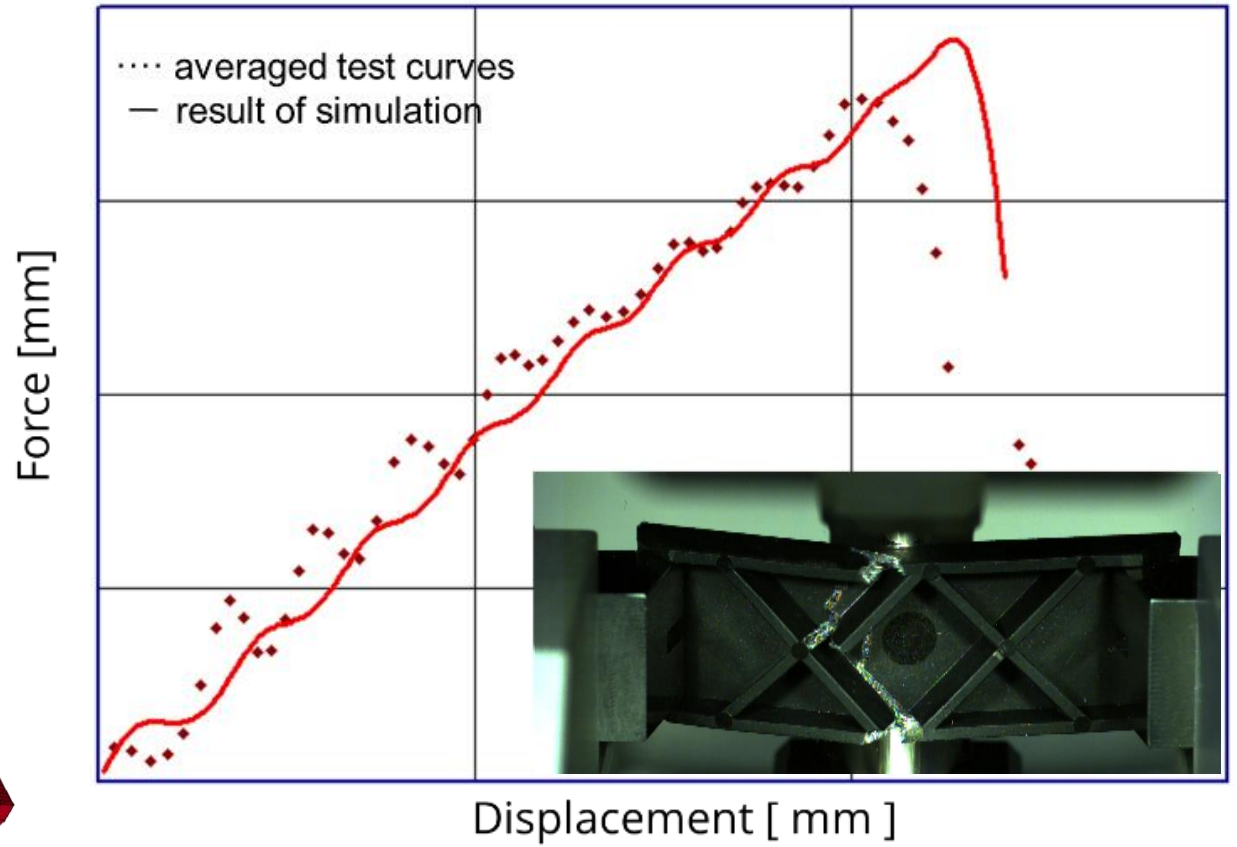
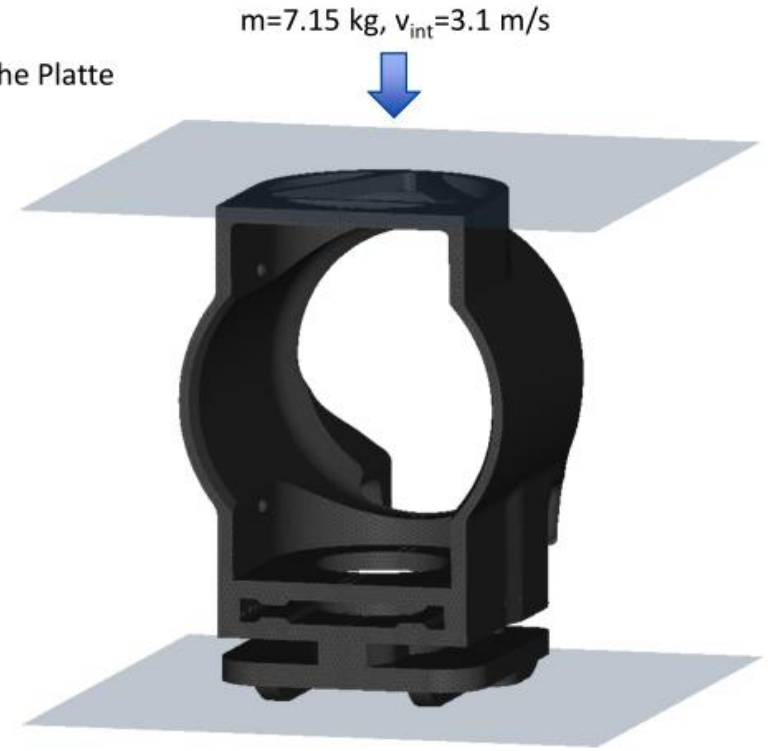


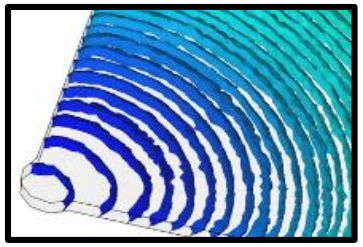




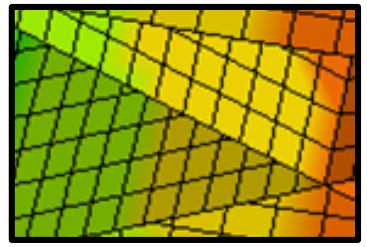
FIBERMAP

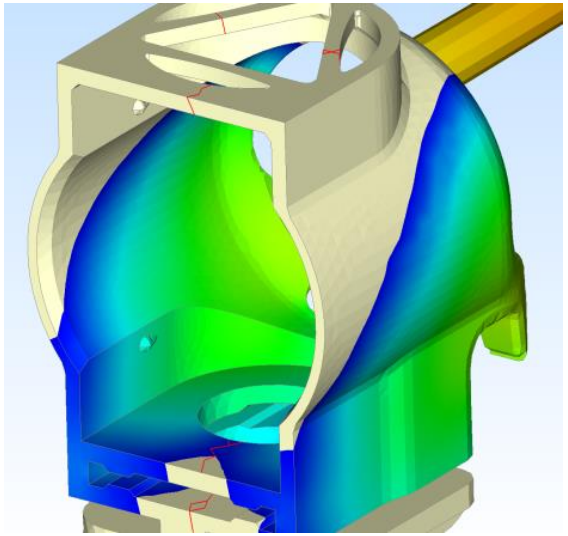
CASESTUDY - SLEEVE

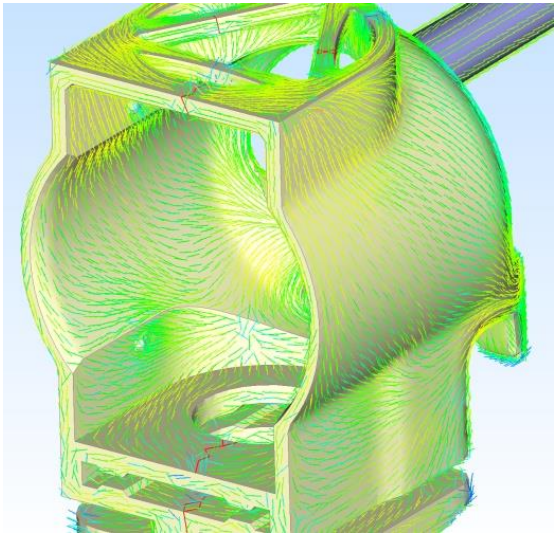


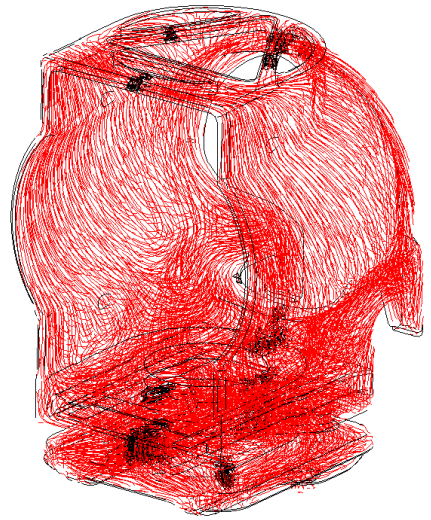


FIBERMAP







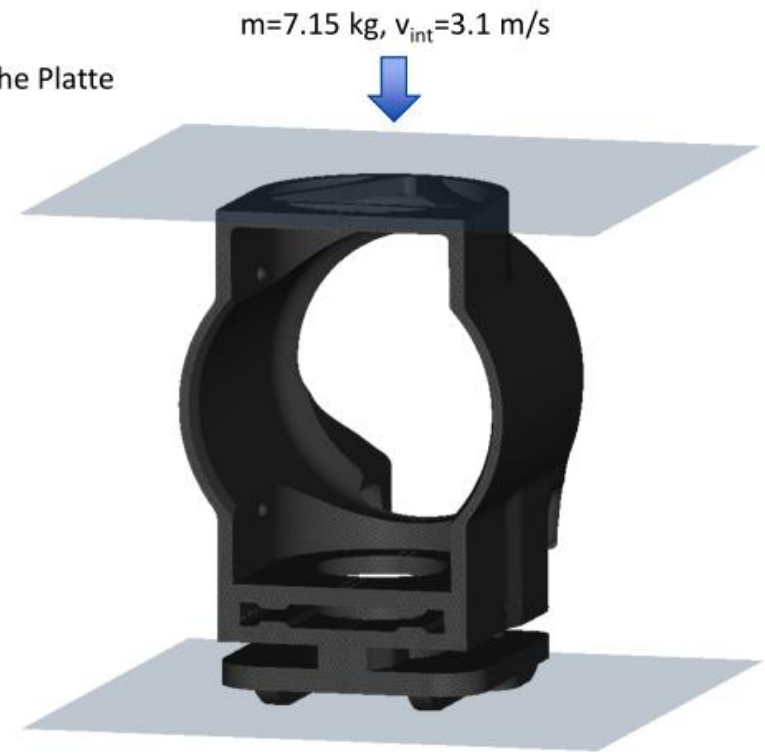


Typische Elementgröße: 0.25mm
Elementtyp: Tetrahedron Type 10
Elementanzahl: 469 470

hirtenberger
Automotive Safety

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

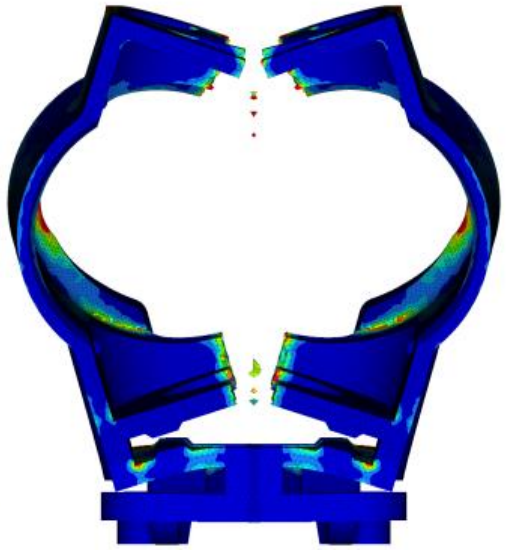
CASESTUDY - SLEEVE



test

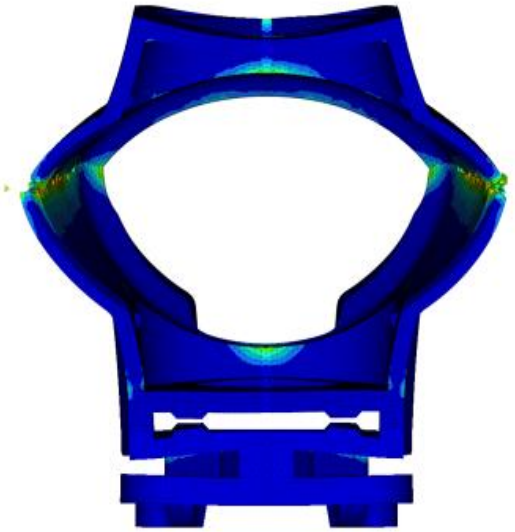
****MAT_157/215***

local anisotropy



****MAT_24***

isotropic



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hirtenberger
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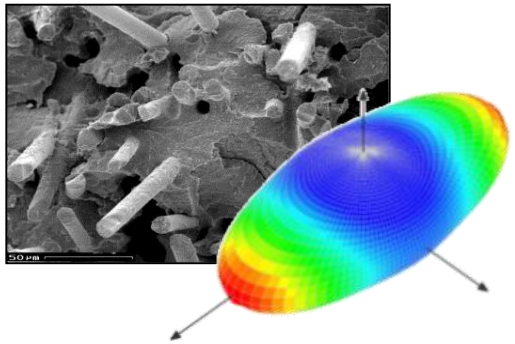
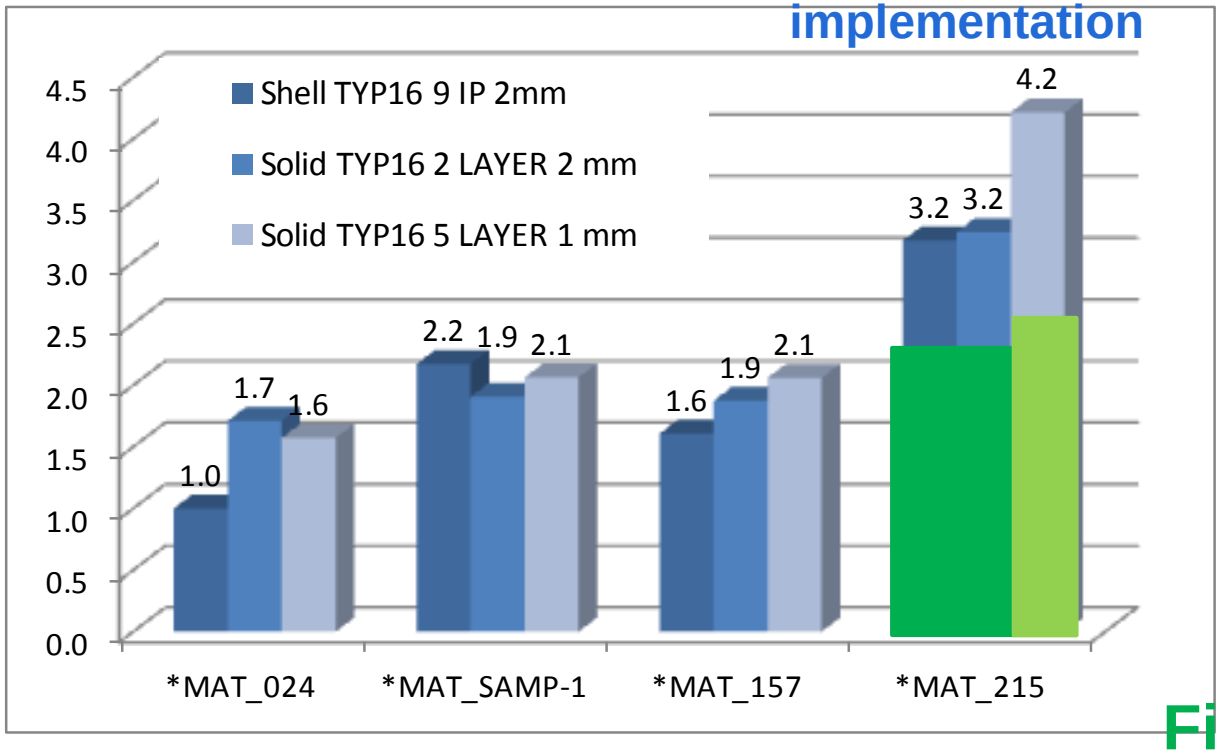
Summary & Outlook



Current implementation



- advantages *`*MAT_215`*
  - micro mechanical approach
    model understands → fiber orientation, aspect ratio
  - simulation process chain considering local anisotropy
    process → structural
- ongoing improvement/development
  - CPU-time consumption
  - failure/damage model
    → further research
- LS-DYNA community
  - benchmark → feedback

First improvements