Plastics and Composites under Dynamic Loading
From Deformation To Failure

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JSOL CORPORATION

7th Resin-Composite Analysis Seminar

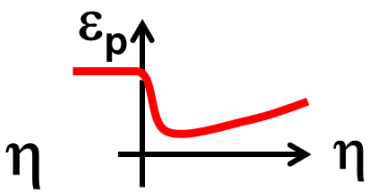
24th January, Nagoya, Japan

Outline

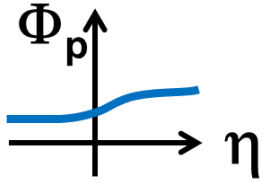
- Introduction
- Thermoplastic materials
- SFRT & LFRT
  short and long fiber reinforced thermoplastics
- Composites
- Outlook / Summary

IMPETUS

VALIMAT

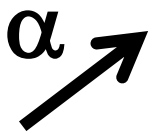


Hardening



Triaxiality

Damage/Failure



Anisotropic

TECHNOLOGY
GmbH

excellence in

plastics&simulation

testing equipment

lightweight products

TECHNOLOGY
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excellence in

plastics&simulation

testing equipment

lightweight products

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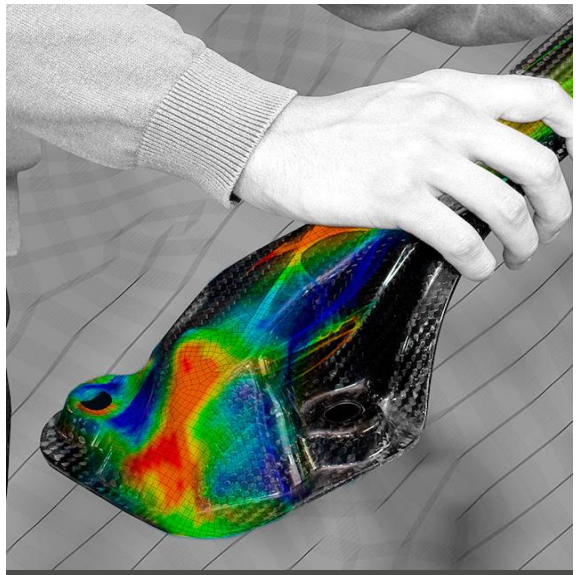
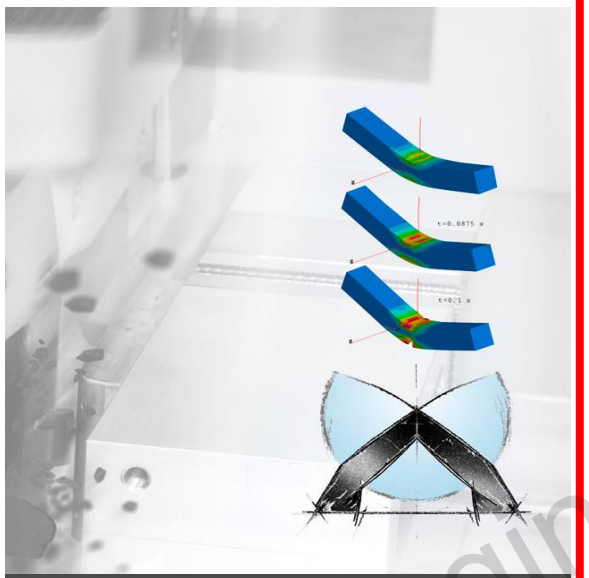
4a business units



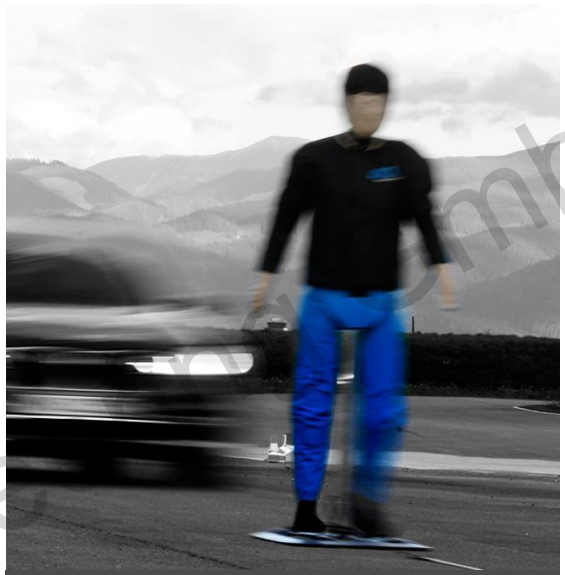
4a engineering

Engineering and simulation for plastic products and composites



Impetus

Testing equipment generating material data for the dynamic simulation of plastics



4activeSystems

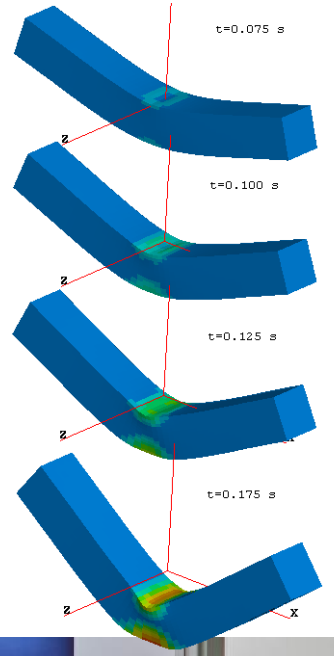
Dummies and testing facilities for active vehicle safety

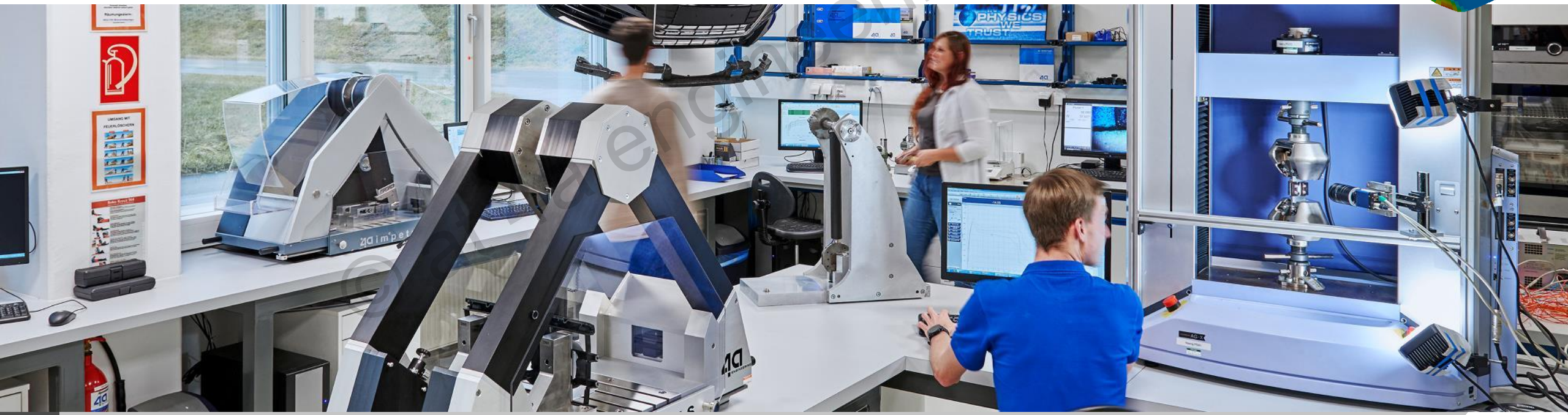
4a manufacturing

Specialized thin foams and multi layer materials

Material characterization - services

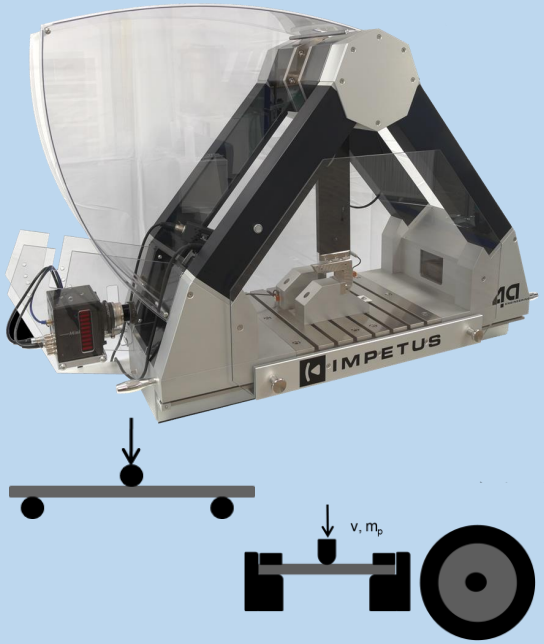
- efficient high-dynamic testing
- dynamic material behaviour
- plastics, foams, composites, …
- **validated material cards ready to use for your crash-simulation**





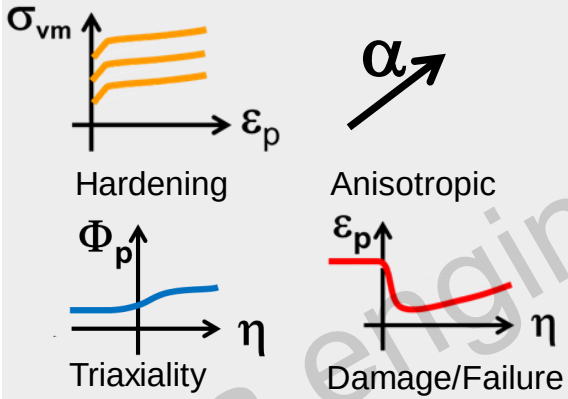
Intelligent reliable solutions for plastics, composites, metals, foams, ...

IMPETUS



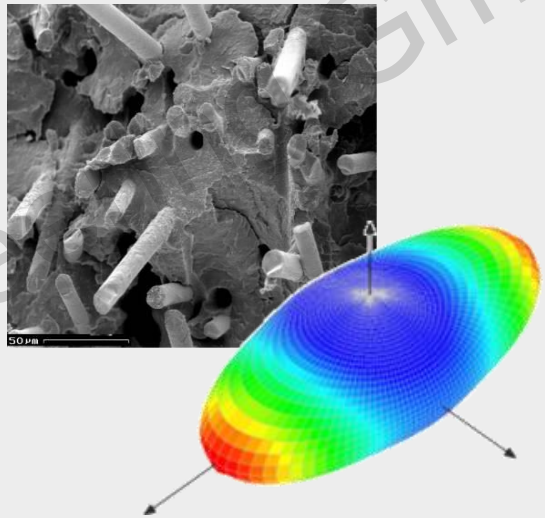
efficient
dynamic testing

VALIMAT



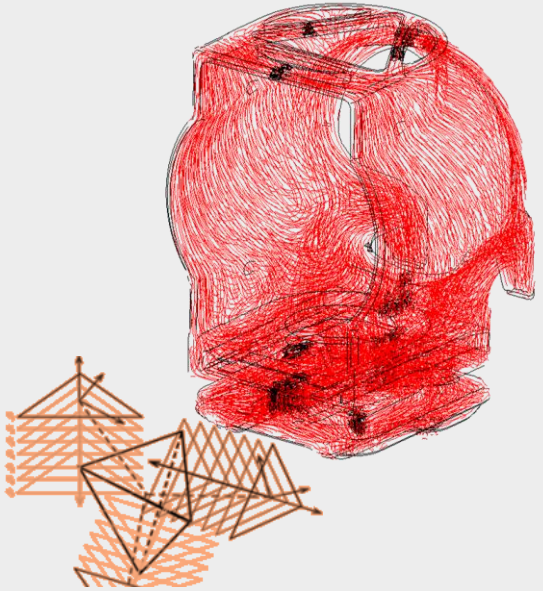
from test to validated
material cards

MICROMEC



3D anisotropic
material cards

FIBERMAP



individual mapping
process information

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

IMPETUS | VALIMAT | MICROMEC | FIBERMAP

Foams

Thermoplastics

Fiber reinforced Plastics (SFRT & LFRT)

Composites (Carbon)

Metals

efficient
dynamic testing

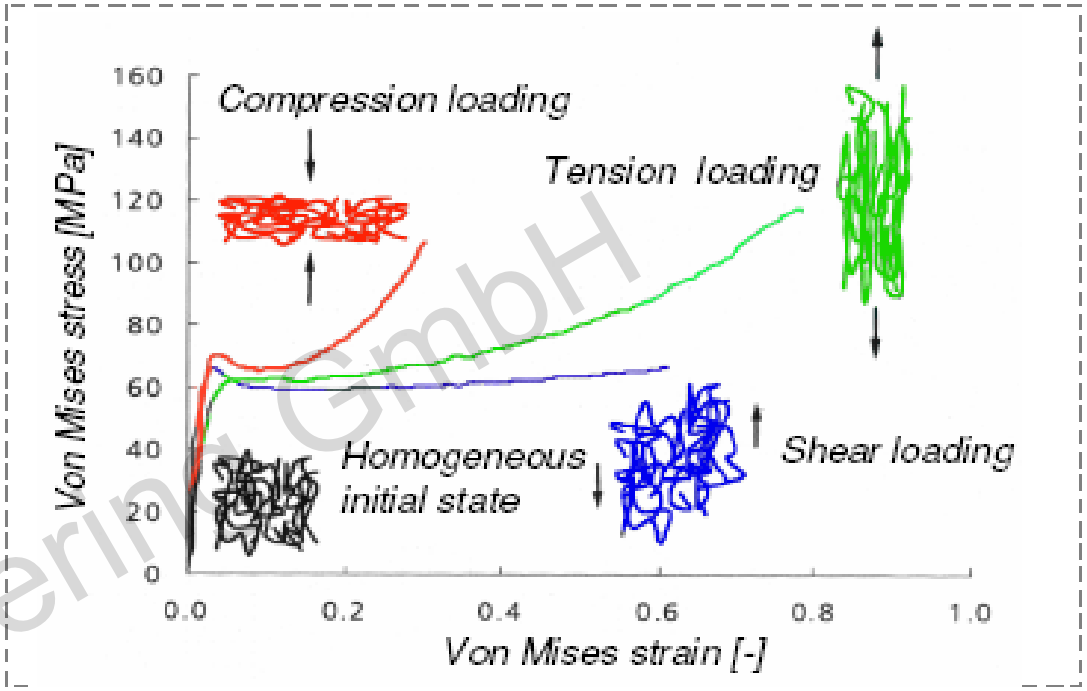
from test to validated
material cards

3D anisotropic
material cards

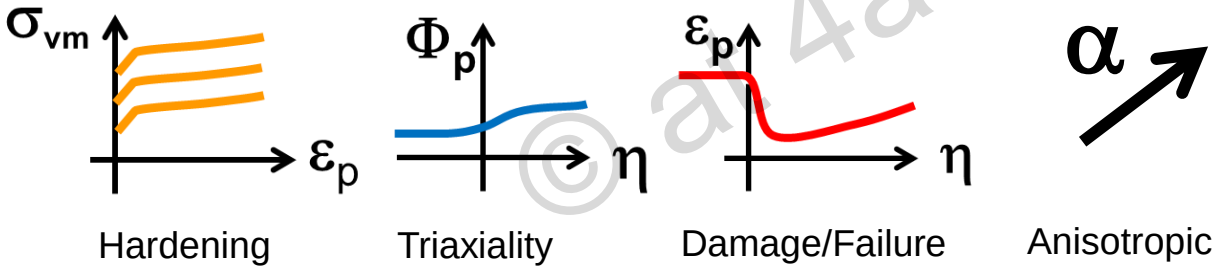
individual mapping
process information

Thermoplastic materials

- Motivation
- Material and failure models
- Material characterization
  - IMPETUS™ - dynamic impact tensile testing
  - typical test results PP T10
- First validation results



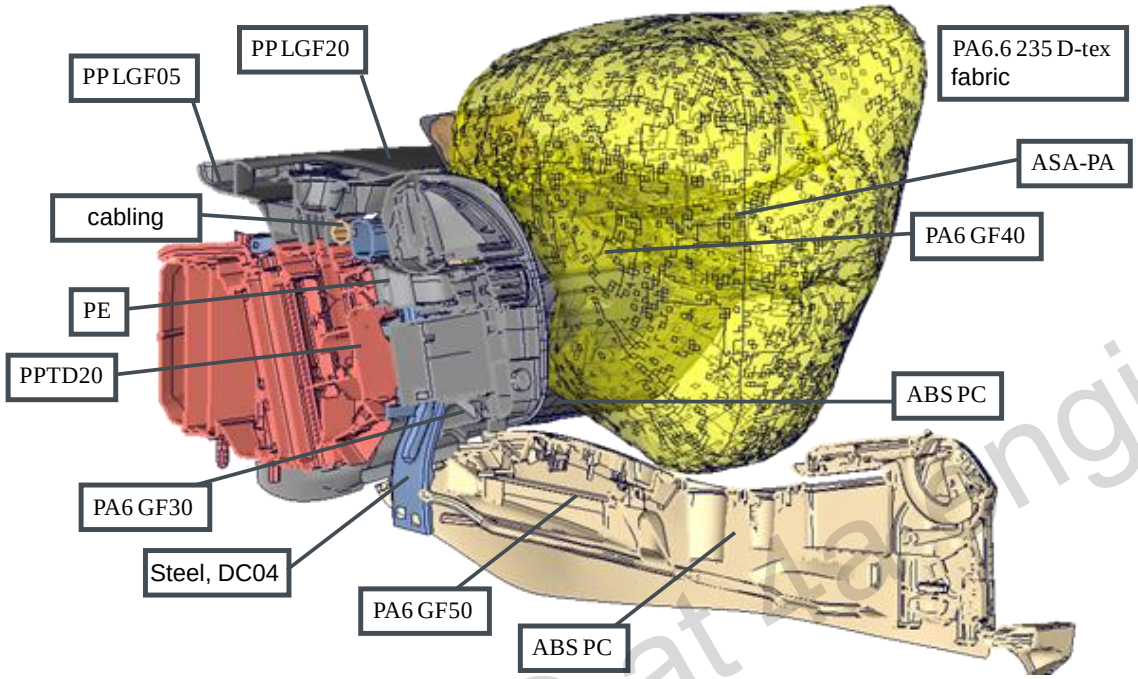
Source: Mechanik der Kunststoffe *W. Retting, Hanser Verlag 1991*



Hardening | Triaxiality | Damage/Failure | Anisotropic

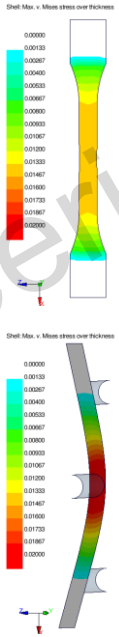
Motivation

material variety

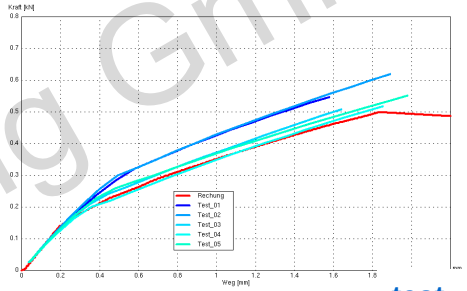


Source: R. Luijkx - *Kunststoffmaterialien in der Interieur Funktionsauslegung bei Audi AG,* 4a Technologietag 2010

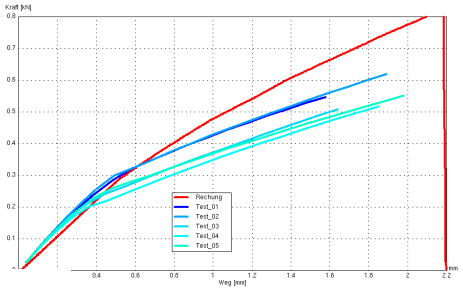
bending load case



original test curve tension

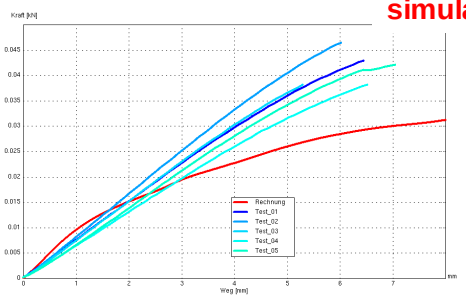


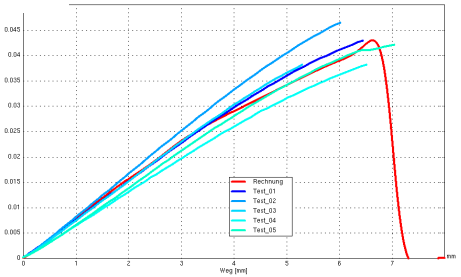
scaling 1.25



test

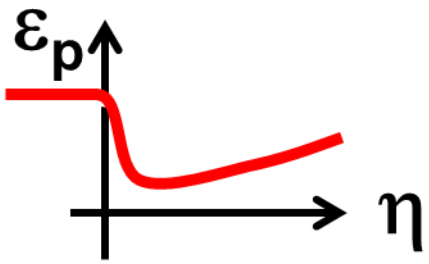
simulation

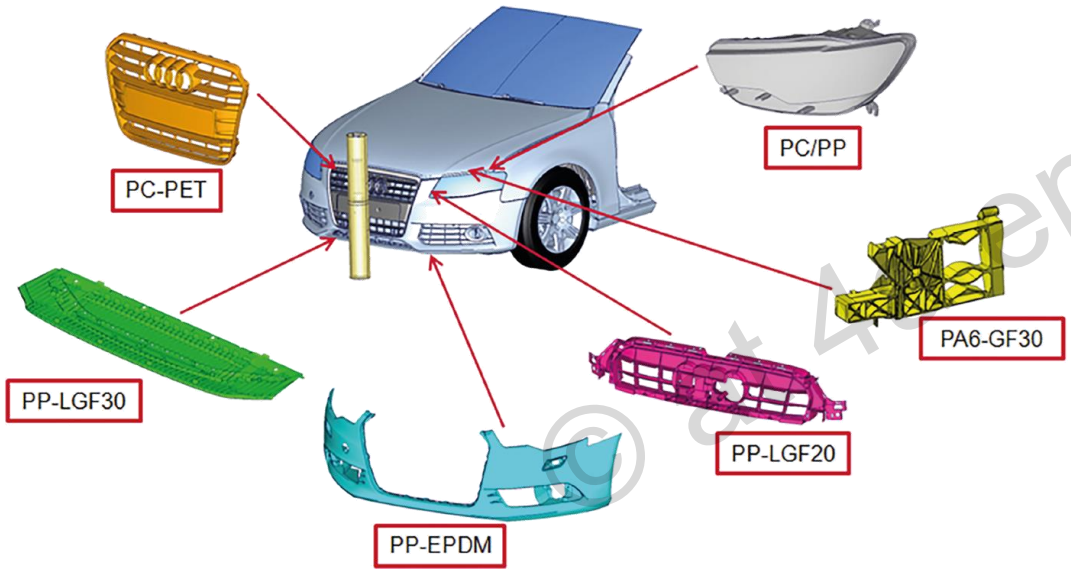


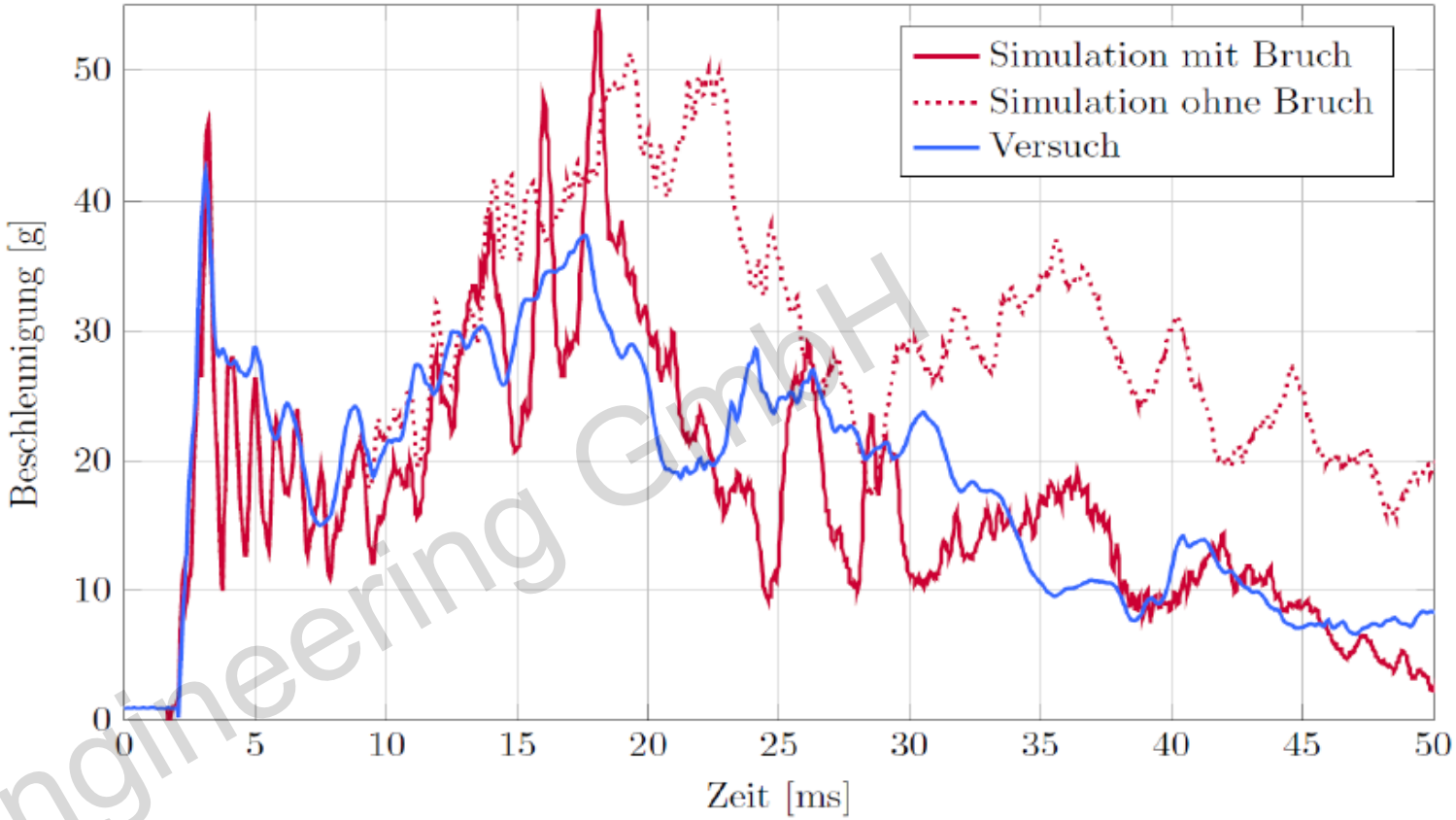


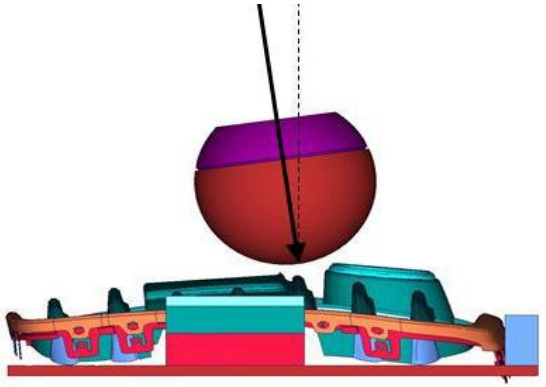
Motivation

Damage/Failure





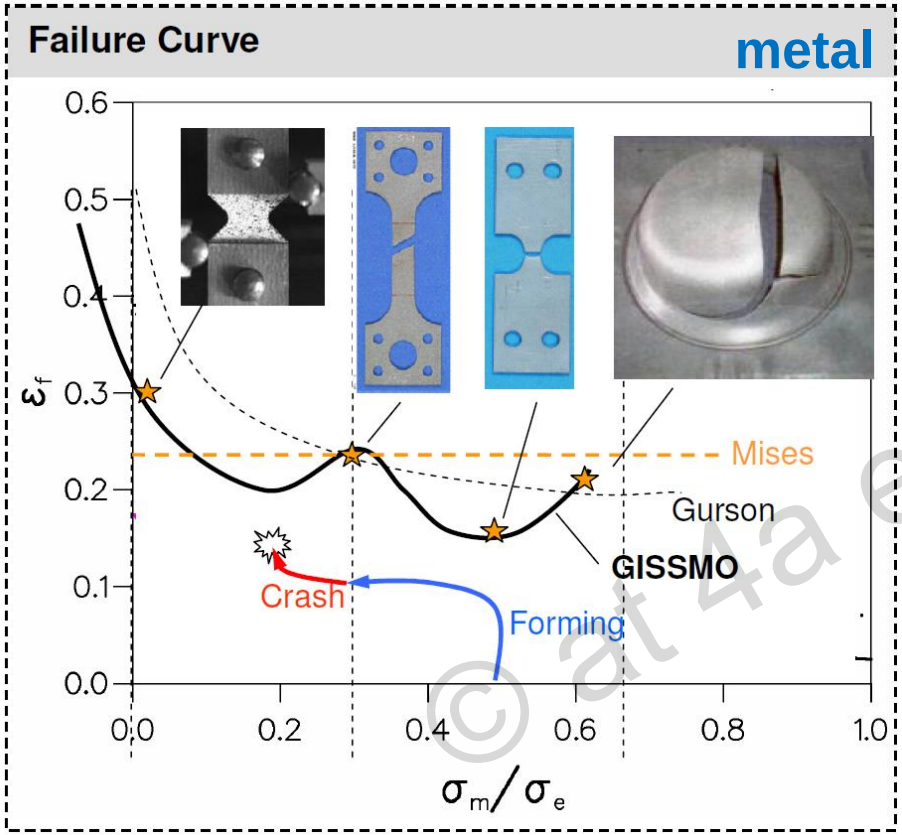




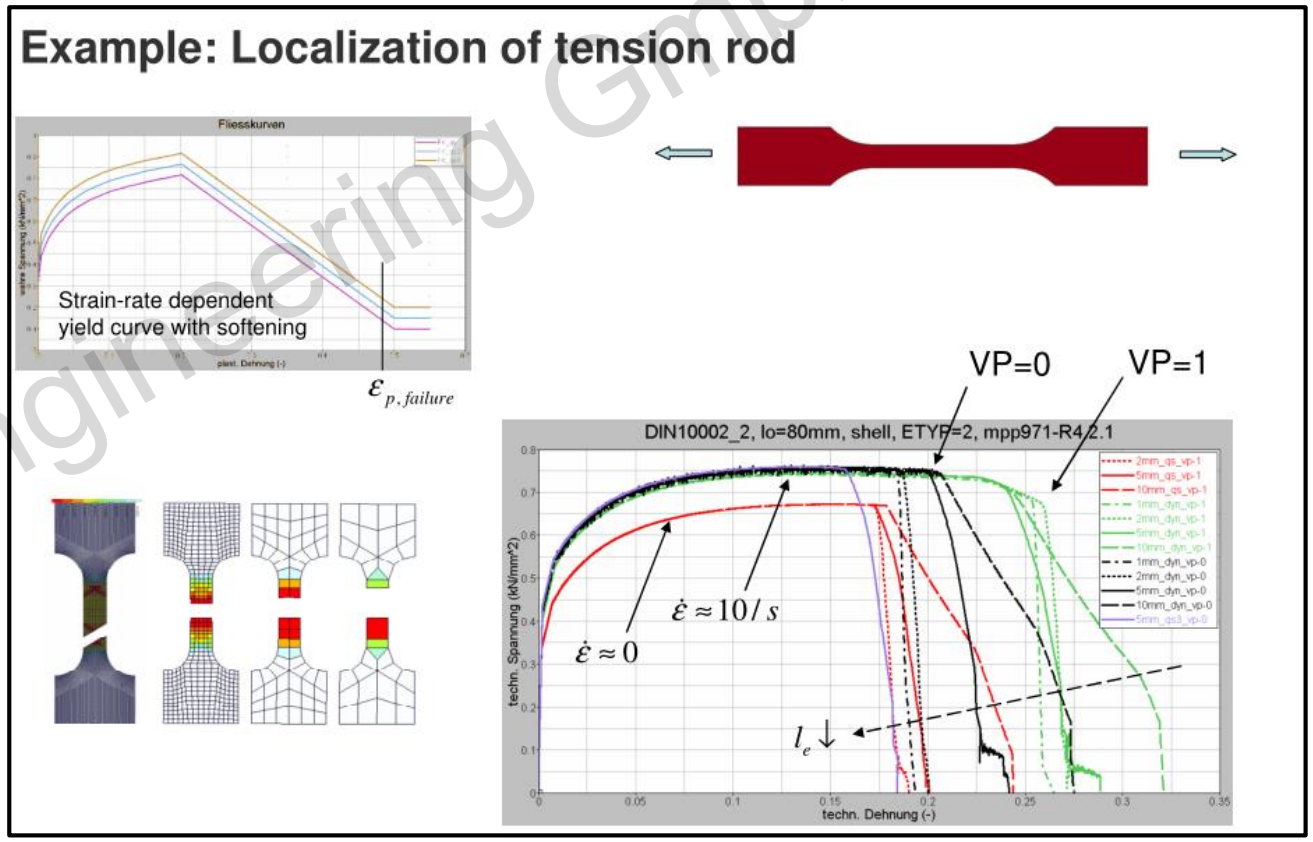
Source: H. Staack, Audi AG: *Anforderungsgerechte Material- und Bruchmodellierung für die Fahrzeugsicherheit*, TT16 Schladming

Motivation

- typical customers request for plastics
  → **GISSMO with *MAT_024 (*MAT_187 internal failure model)**



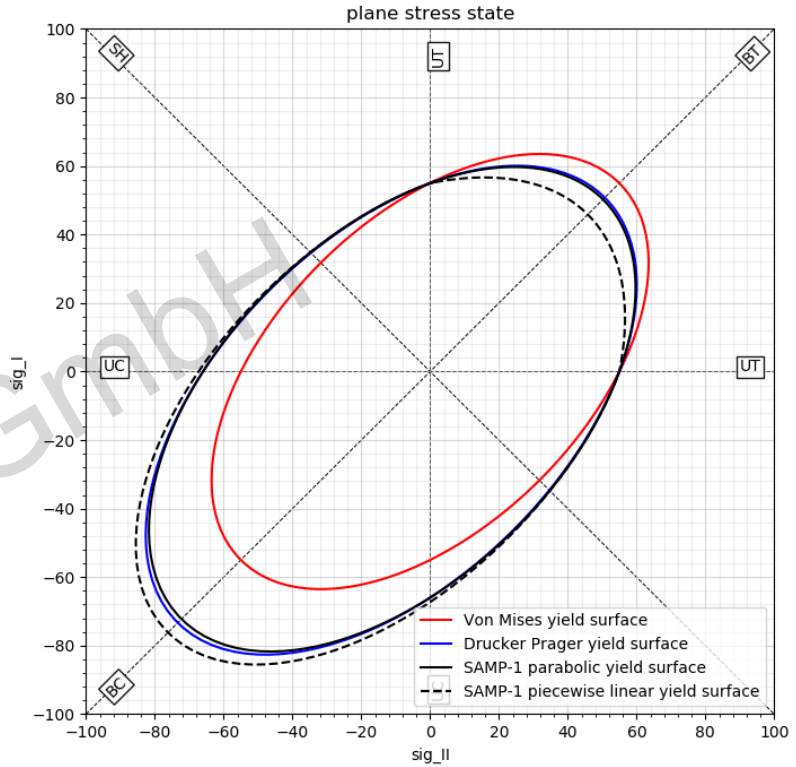
source: F. Neukamm – *GISSMO – Material modeling with a sophisticated failure criteria*, LS-Dyna Developer Forum 2011, Stuttgart



source: Damage and Failure Models in LS-DYNA; M. Feucht; A. Haufe ;(2009)

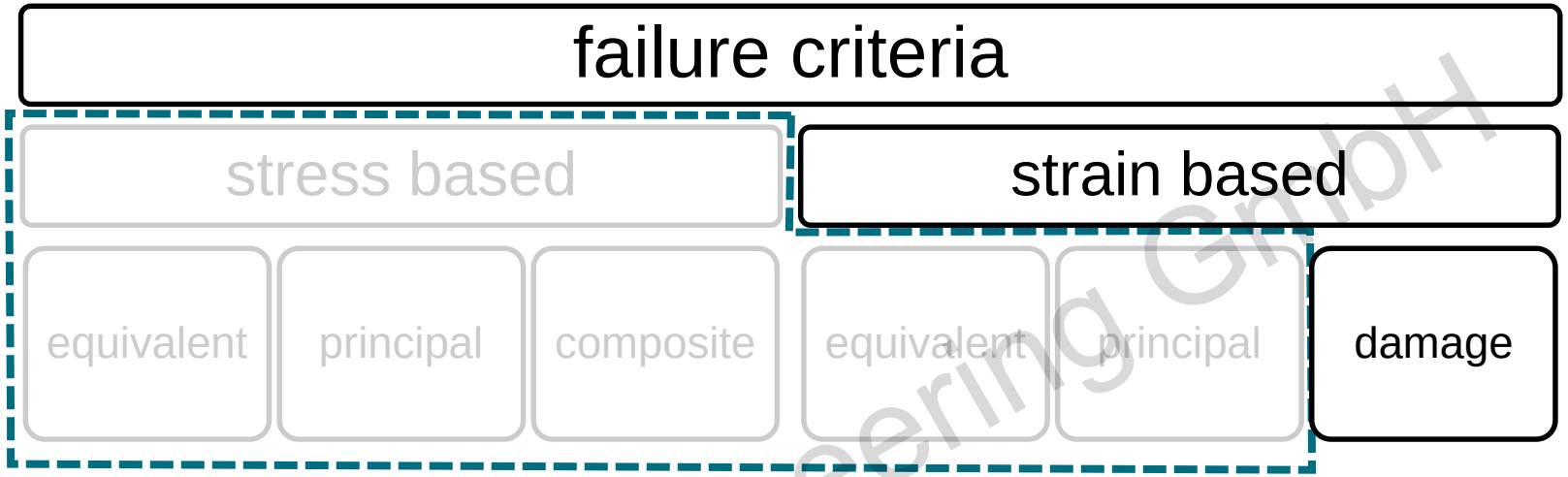
Commonly Used Material Models For Plastics

- ***MAT_024 - The workhorse**
  (*MAT_081,*MAT_089,*MAT_123, …)
- ***MAT_124 - The hidden**
- ***MAT_187 - The plastic expert**
- ***MAT_187L – efficient version (R11)**
- ***MAT_ADD_INELASTIC – promising (R11)**



Material model	yield surface	Visco-elasticity	Visco-plasticity	Comp./tension asymmetry	plastic Poisson's ratio
***MAT_024**	von Mises	✗	✓	✗	0.5
***MAT_124**	2x von Mises	✓ Pronyseries	✓	✓	0.5
***MAT_187L**	linear	✗	✓	✓	✓
***MAT_187**	general	✓ Table	✓	✓	✓

Available failure models in LS-DYNA®



additional failure models

****MAT_ADD_EROSION***

strain damage based

- *before R11 optional DIEM / GISSMO*
- *since R11* ****MAT_ADD_DAMAGE_DIEM***
- *since R11* ****MAT_ADD_DAMAGE_GISSMO***

included damage model in

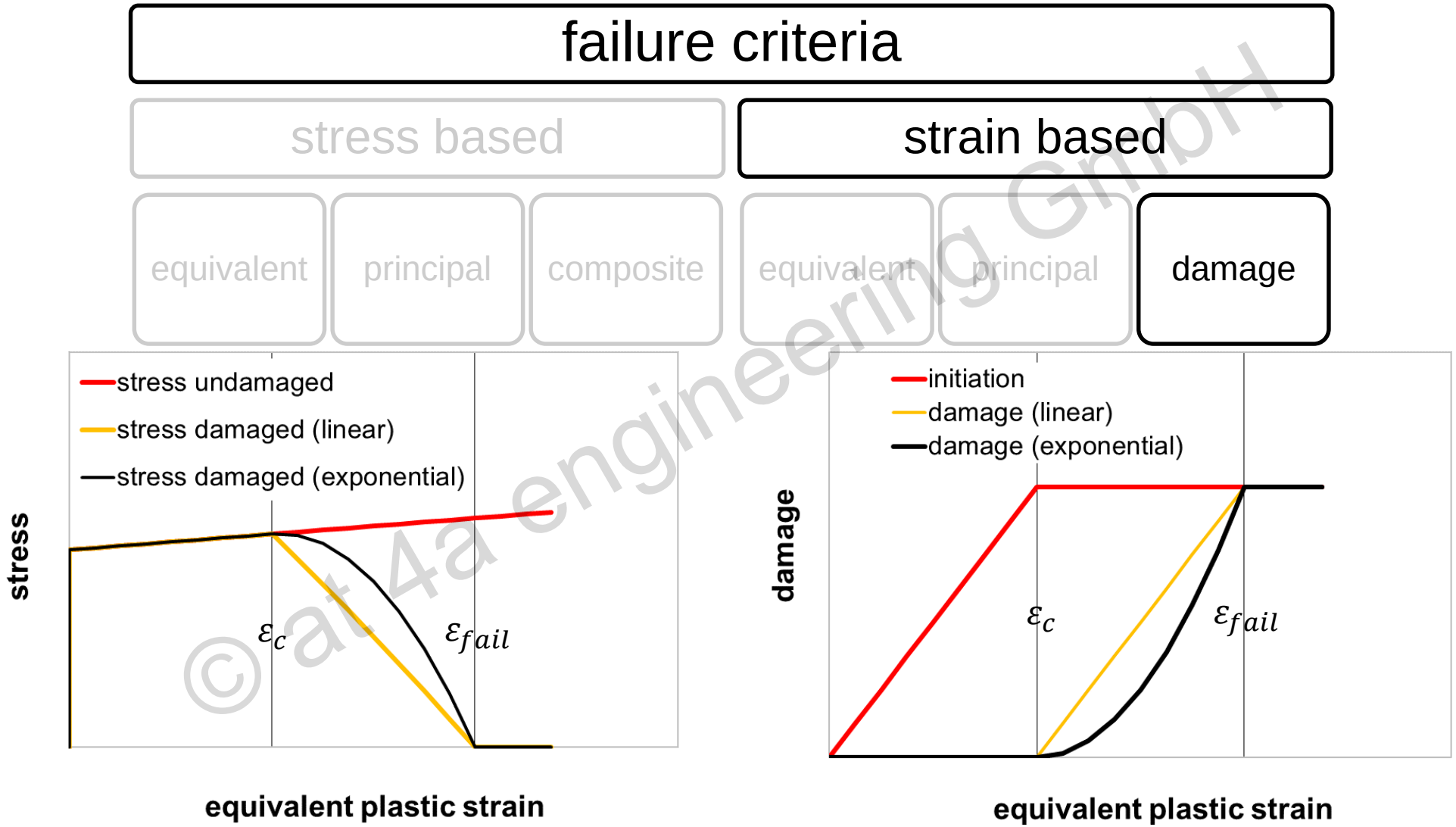
****MAT_SAMP-1***

GISSMO like

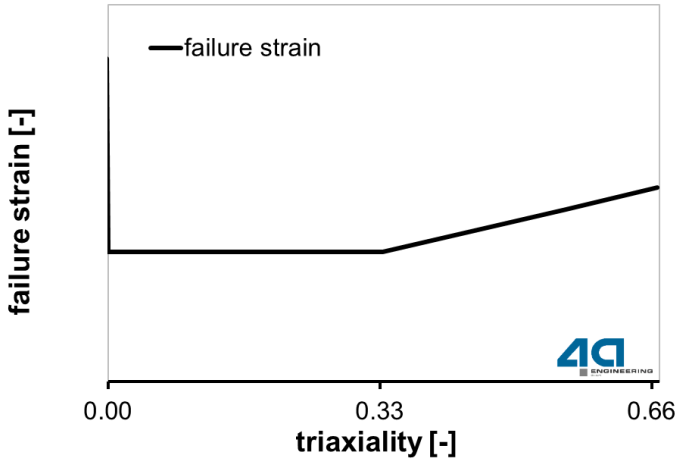
****MAT_4A_MICROMEC***

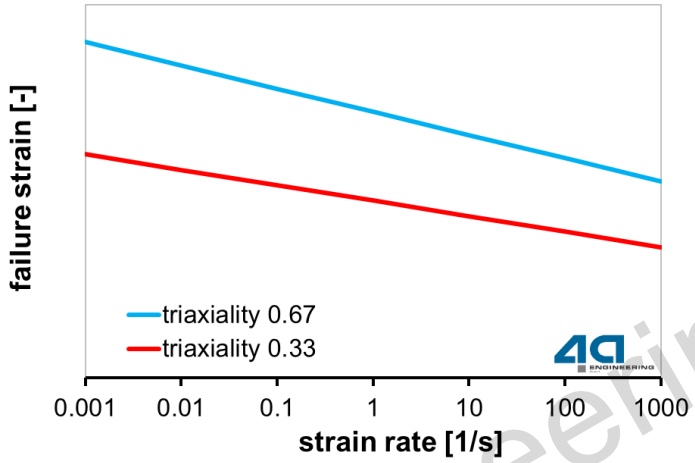
DIEM for matrix failure

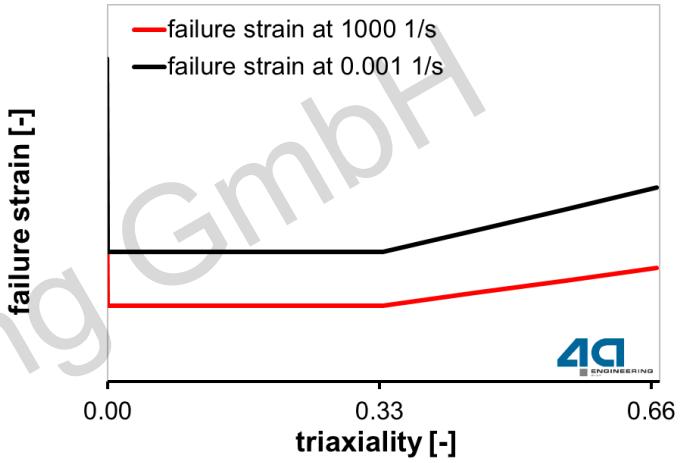
Available failure models – incremental damage formulation



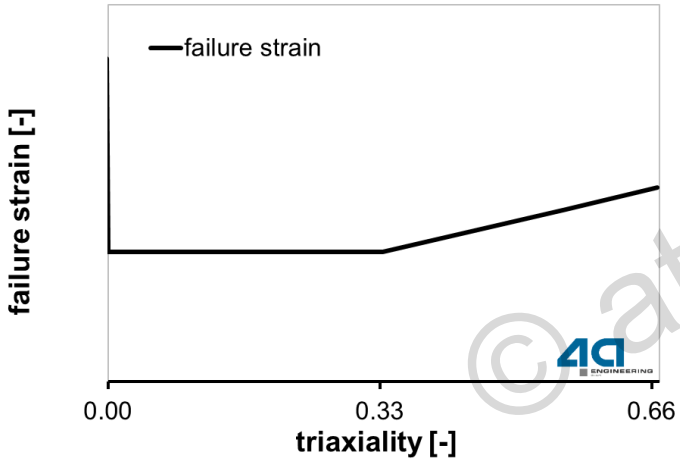
Comparison DIEM-GISSMO visualized

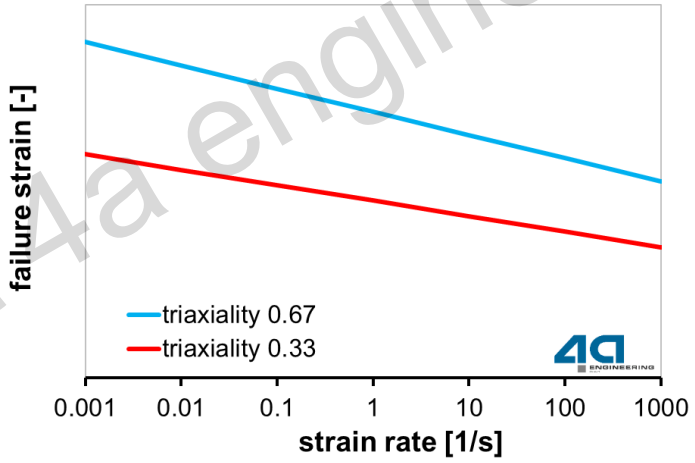


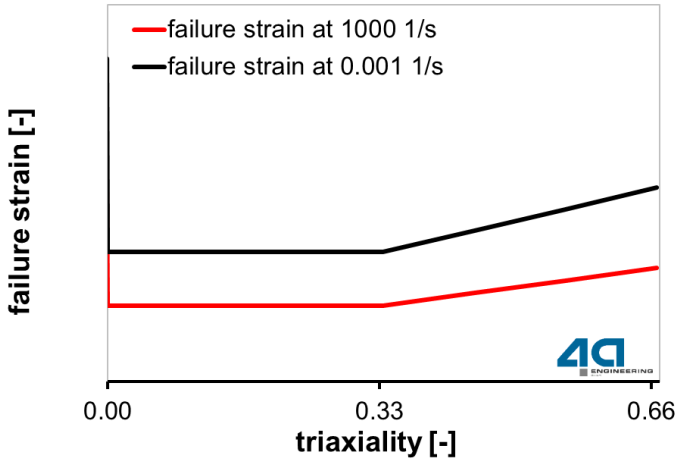




GISSMO

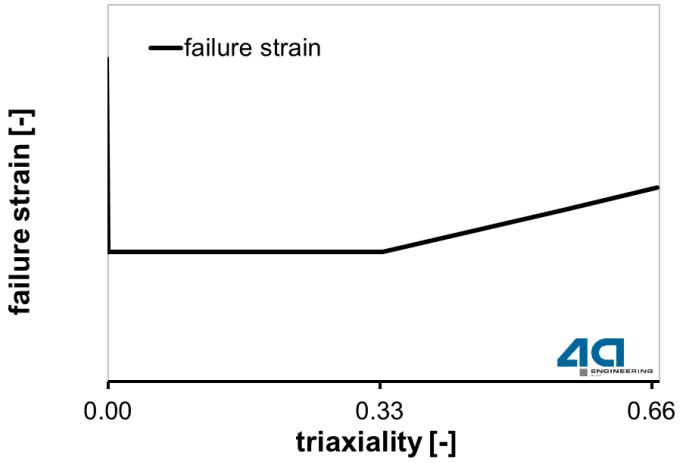


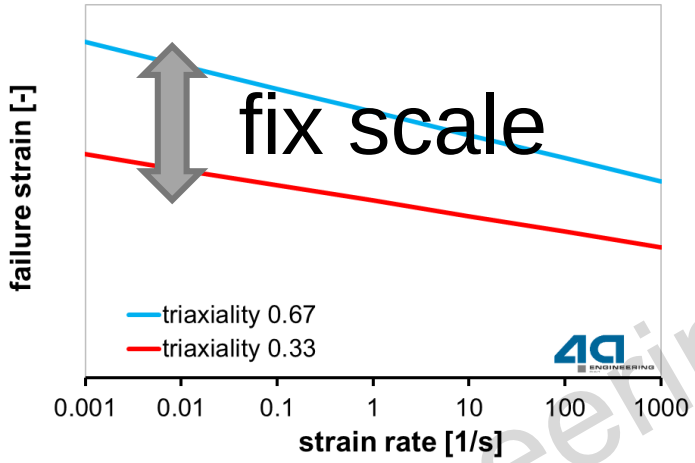


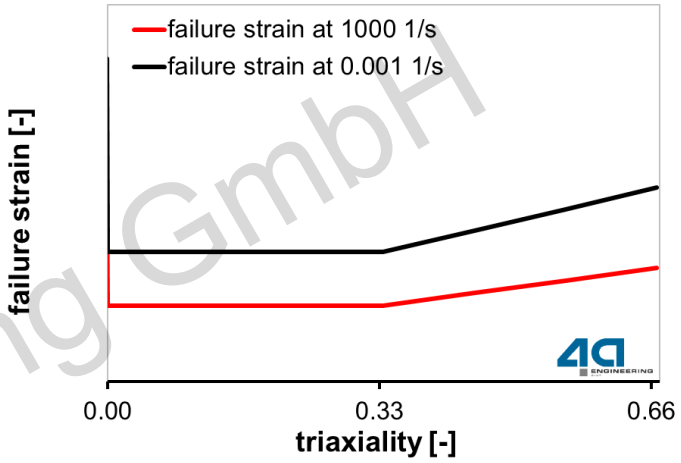


DIEM

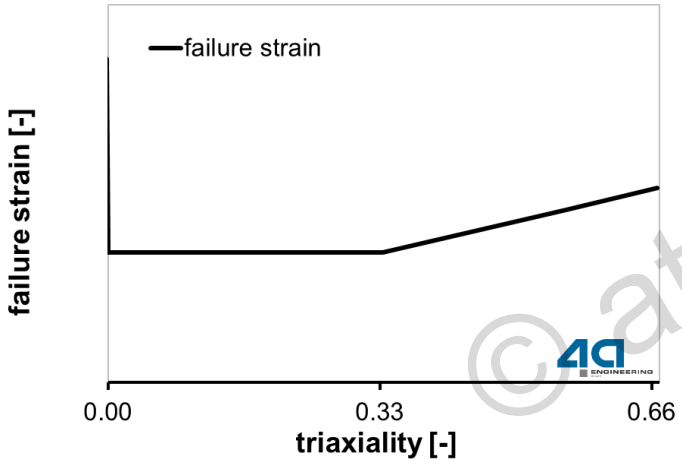
Comparison DIEM-GISSMO visualized

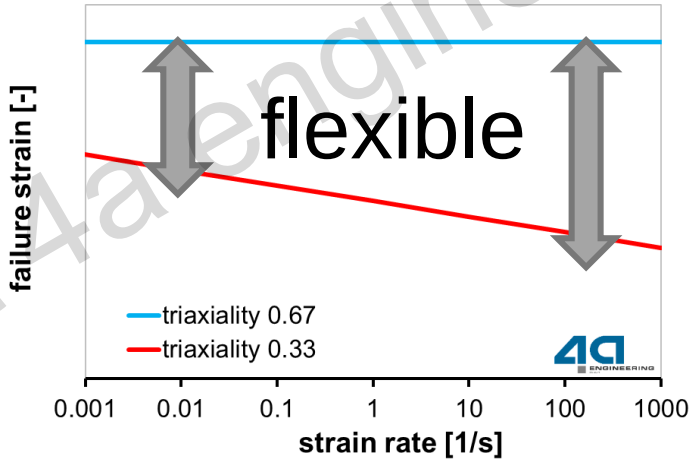


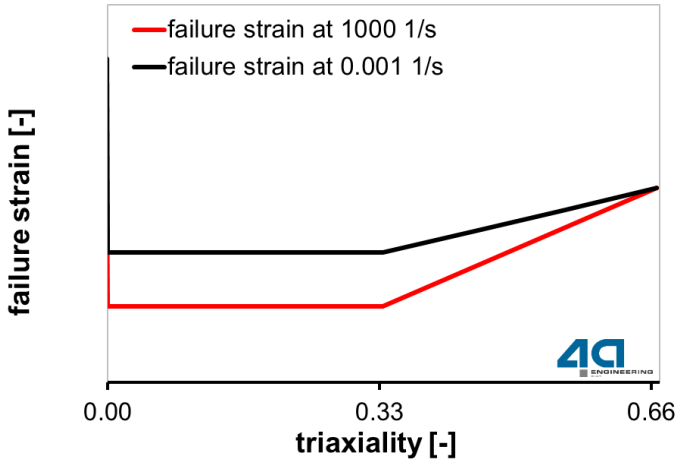




GISSMO



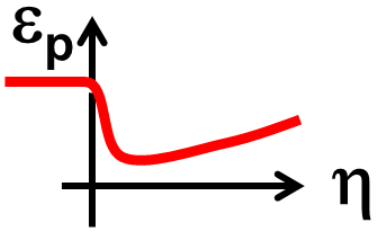




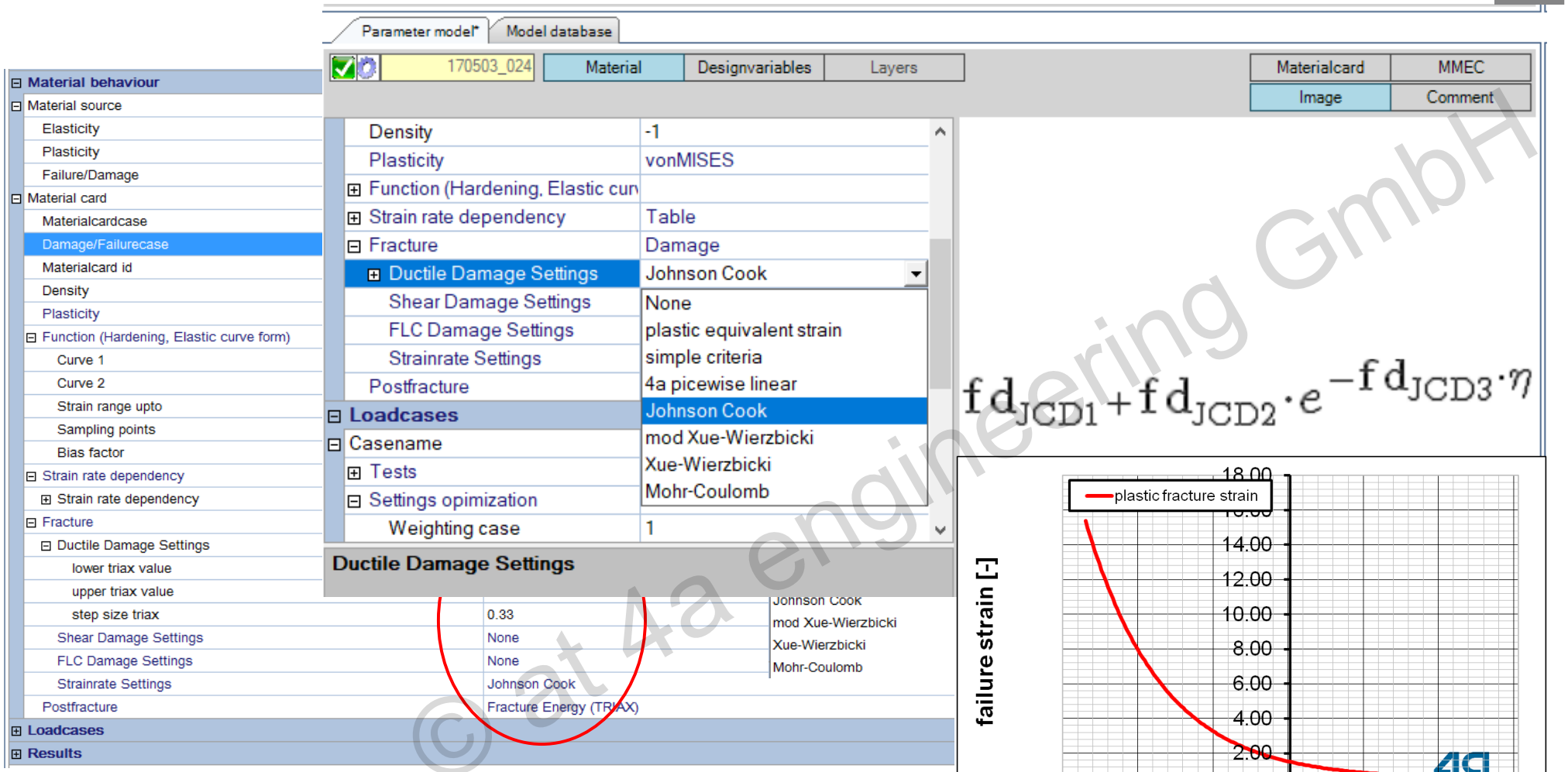
DIEM

Fracture models → *MAT_ADD_EROSION

VALIMAT



Damage/Failure



$$fd_{JCD1} + fd_{JCD2} \cdot e^{-fd_{JCD3} \cdot \eta}$$

Available failure models – typical curves

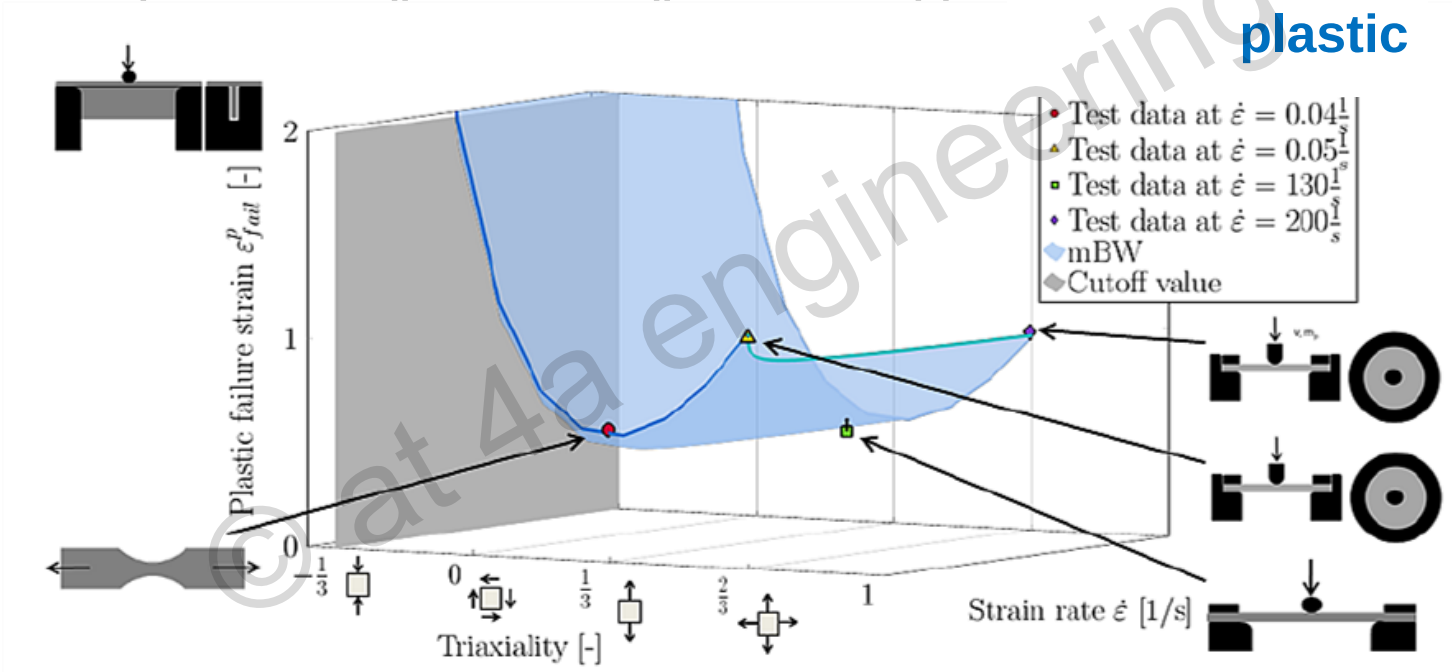
failure criteria

stress based

strain based

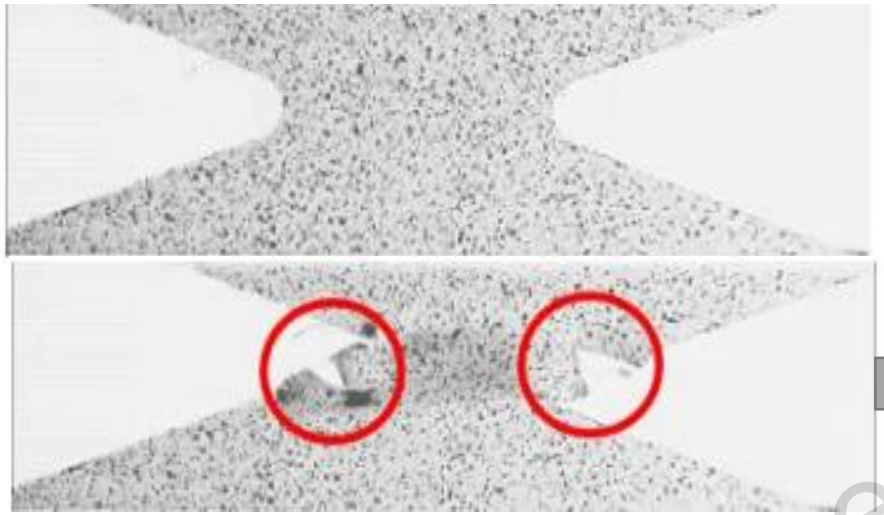
damage

plastic

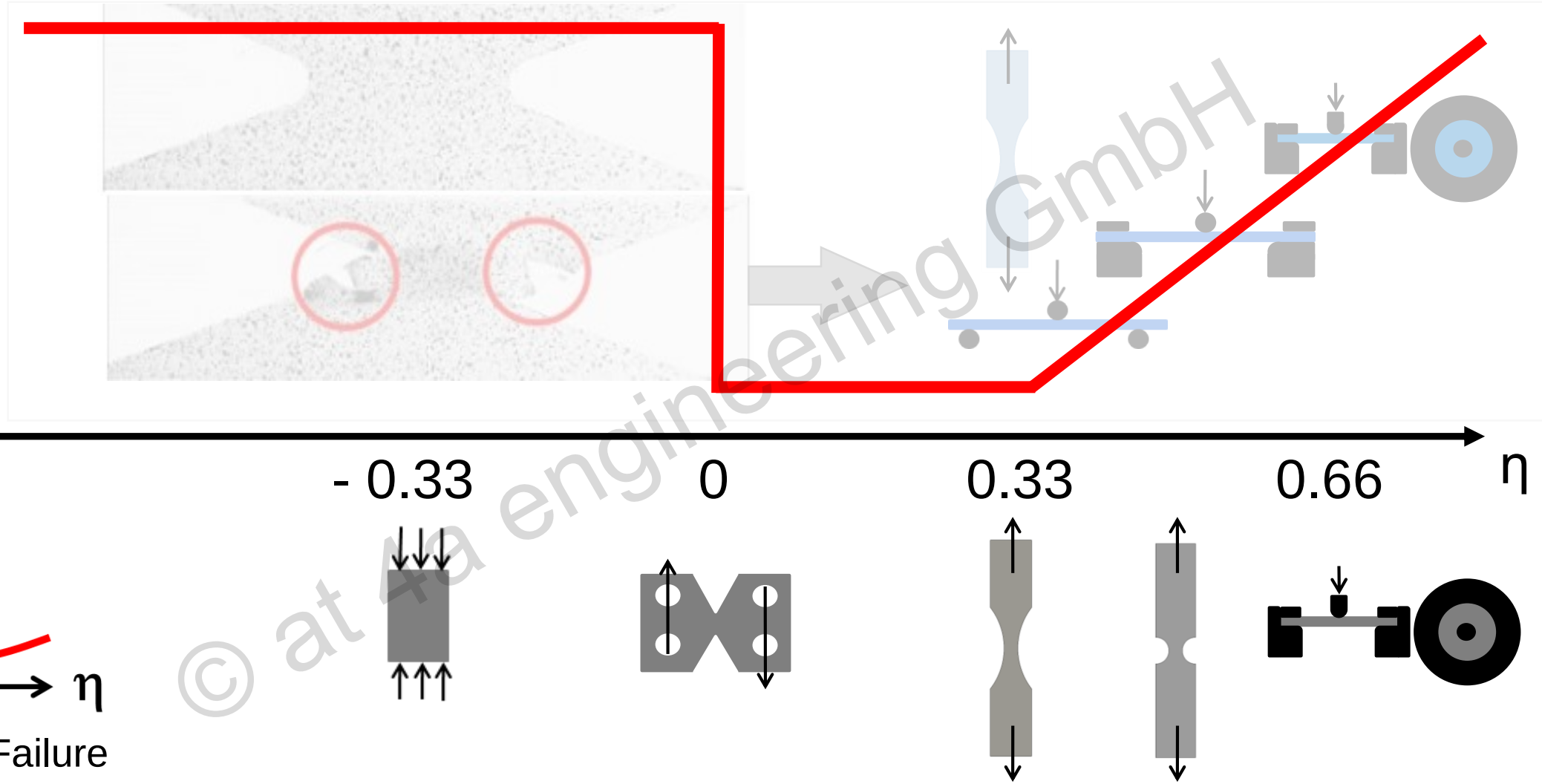


source: H. Staack, - *Application oriented failure modeling and characterization for polymers in automotive pedestrian protection*, COMPLAS 2015, Barcelona

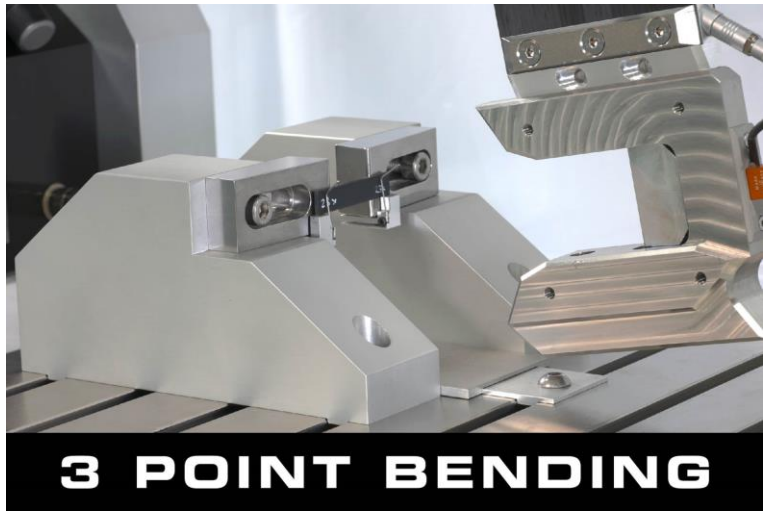
From test to material card

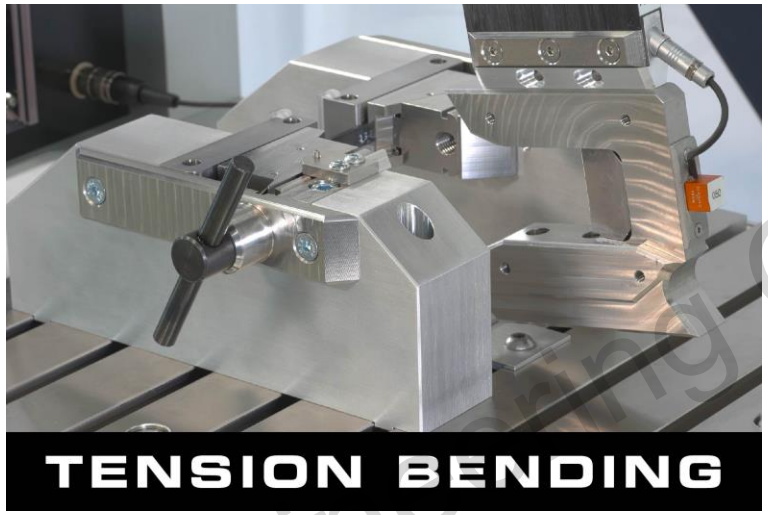


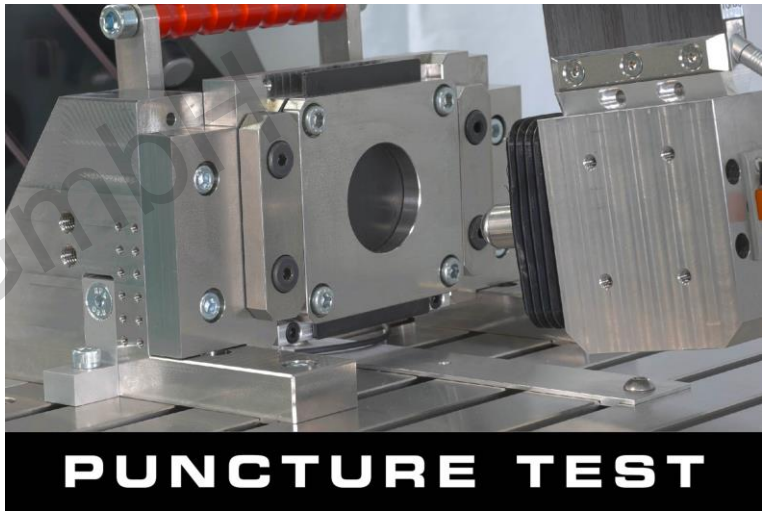
From test to material card

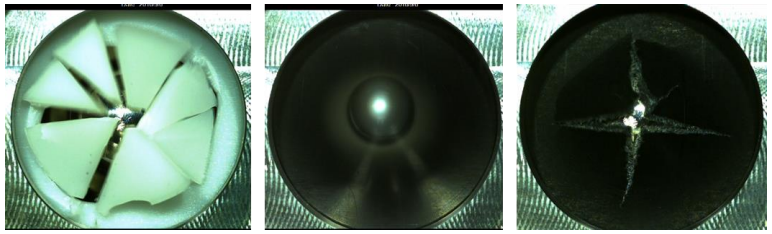


IMPETUS™ - efficient dynamic testing





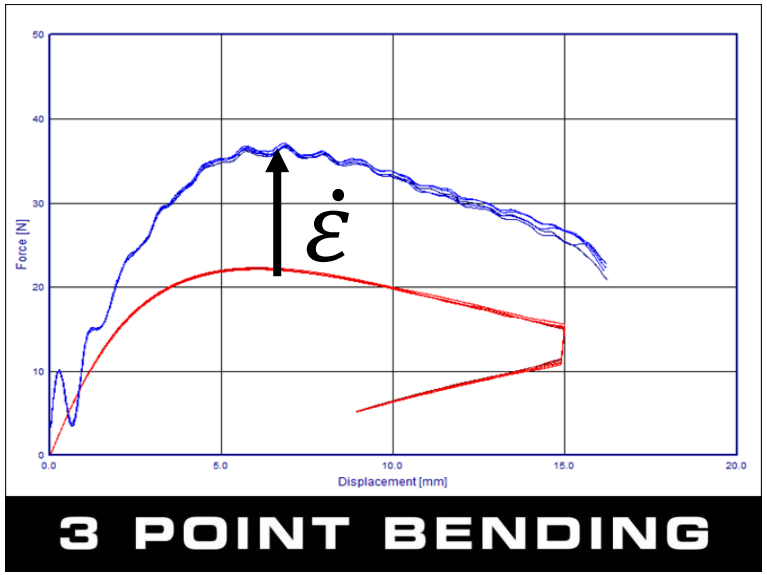




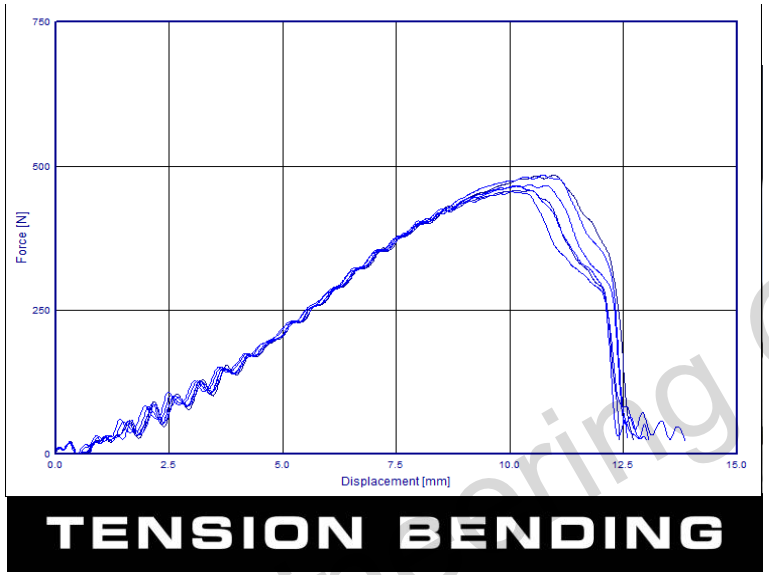
IMPETUS™ ~ 3 m/s

static ~ 1mm/s

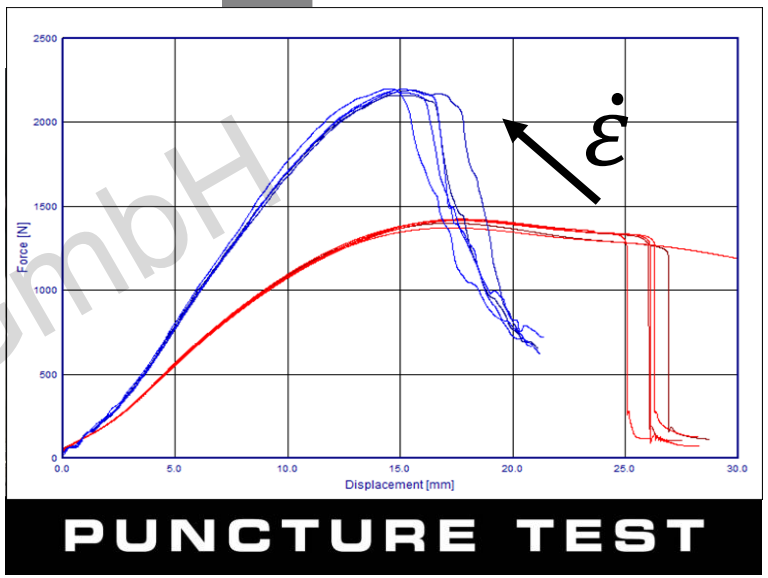
IMPETUS™ - efficient dynamic testing



3 POINT BENDING



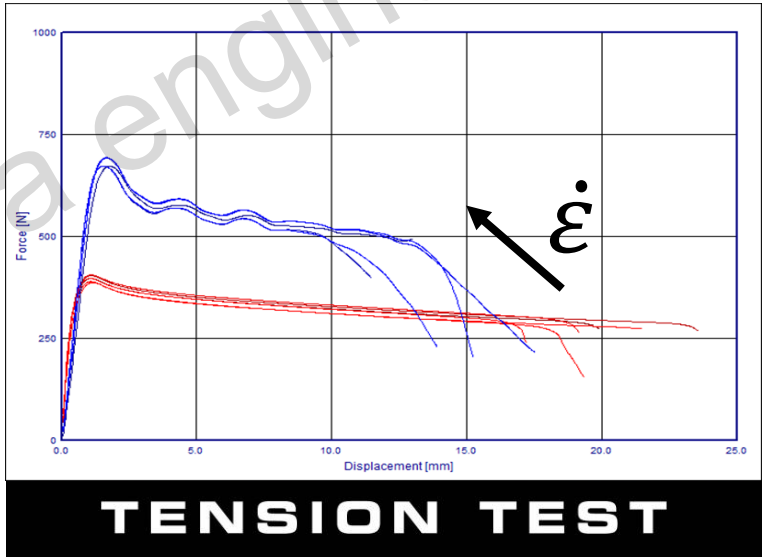
TENSION BENDING



PUNCTURE TEST

IMPETUS™ ~ 3 m/s

static ~ 1mm/s

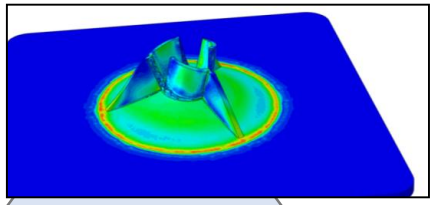


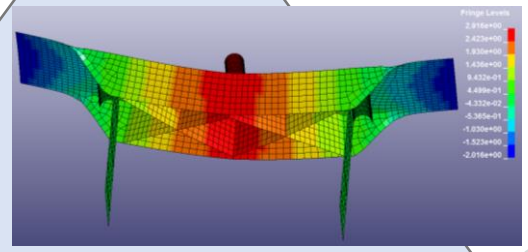
TENSION TEST

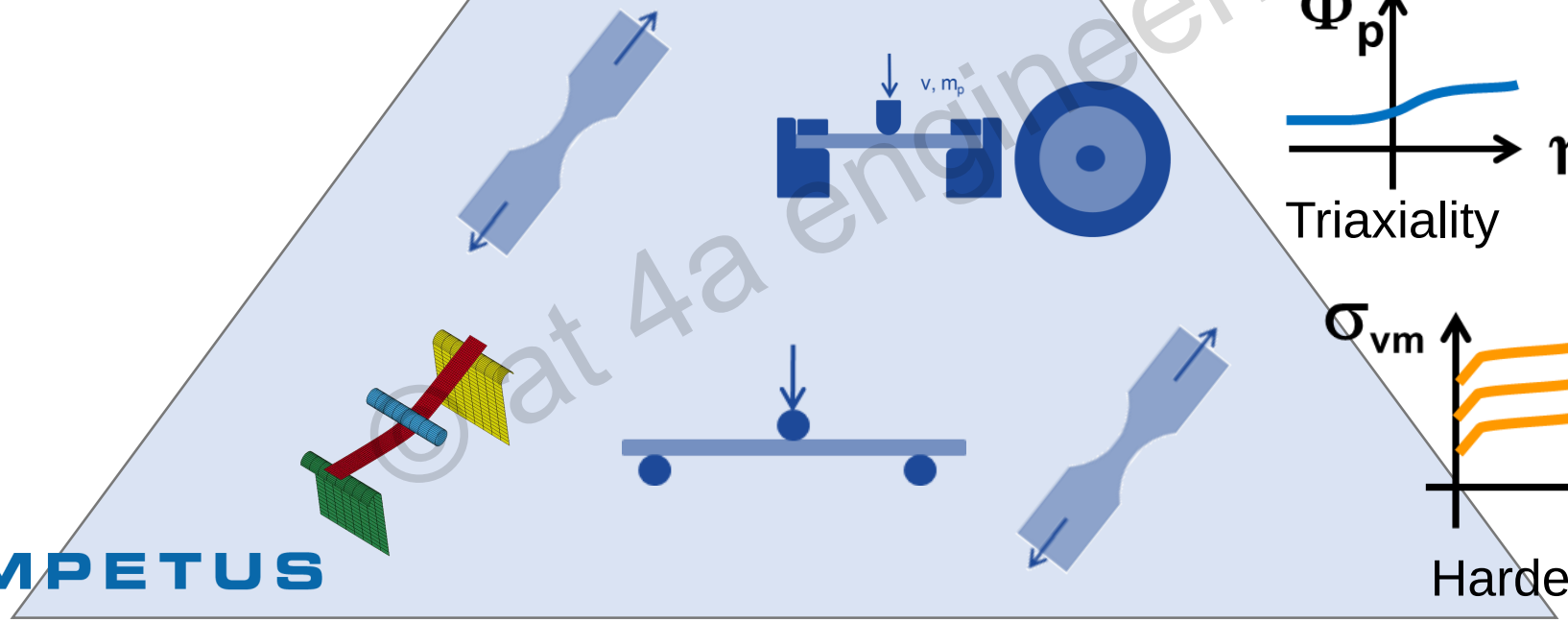
From test to material card

VALIMAT

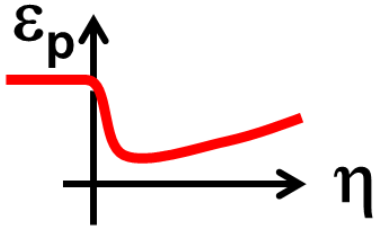
Deformation → Failure
Creep → Static → Crash
ISOTROPIC → ANISOTROPIC





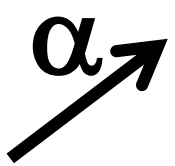


Triaxiality



Damage/Failure

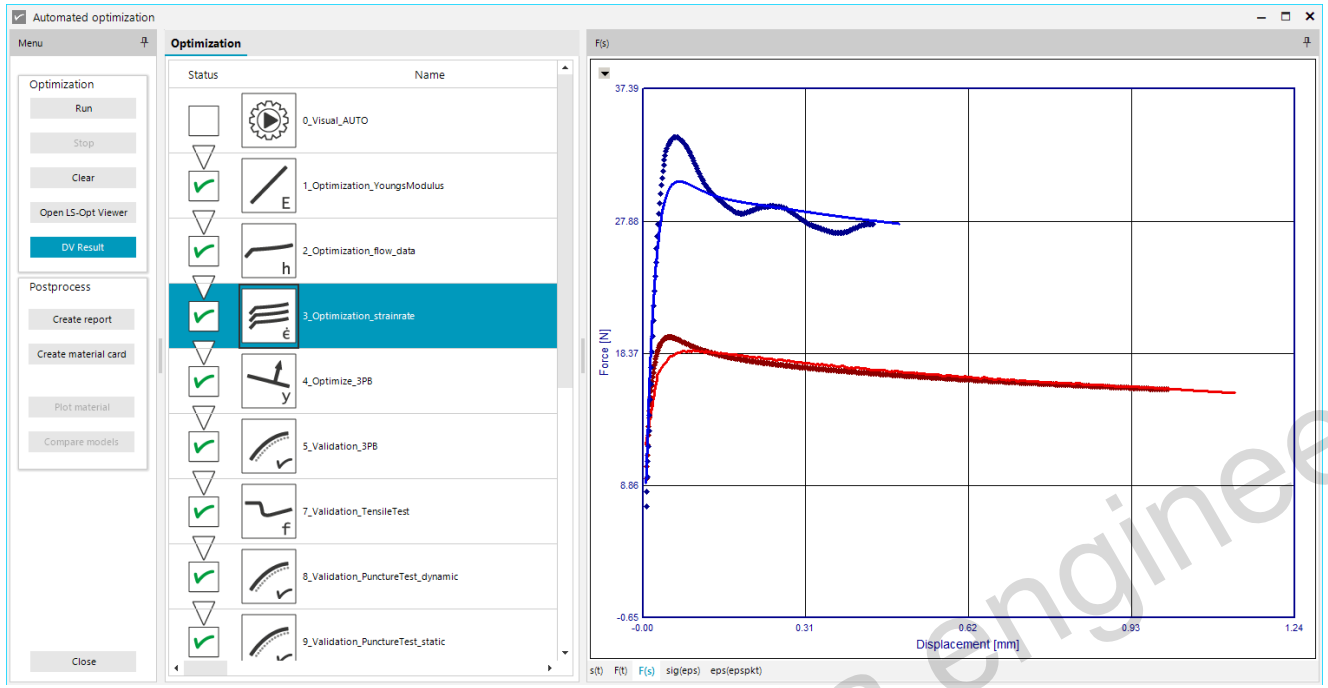
Hardening



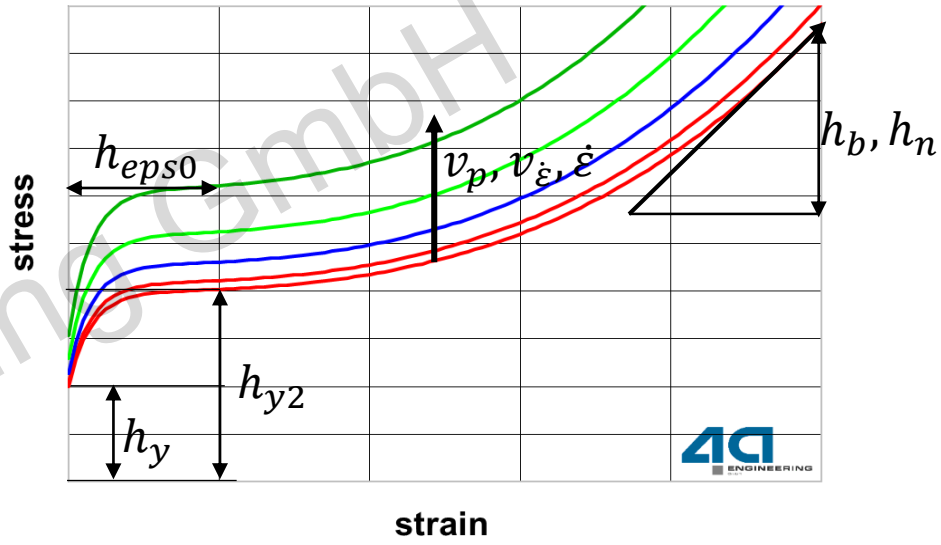
Anisotropic

IMPETUS

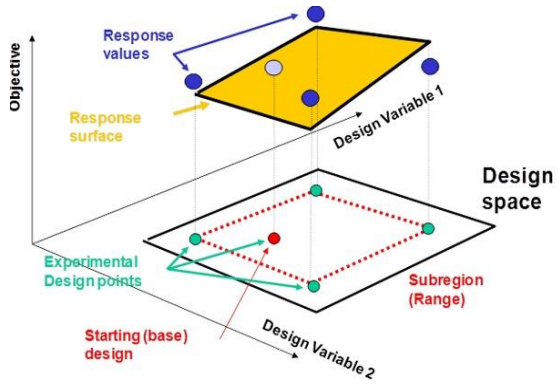
Workflow for material card generation - AUTOFIT

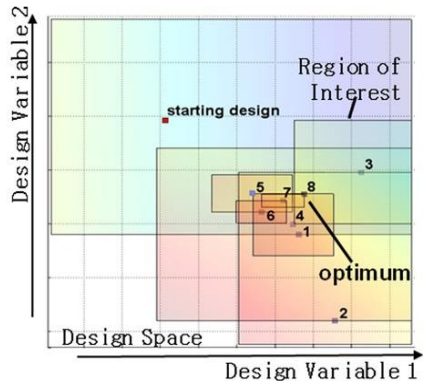


parametrized material card

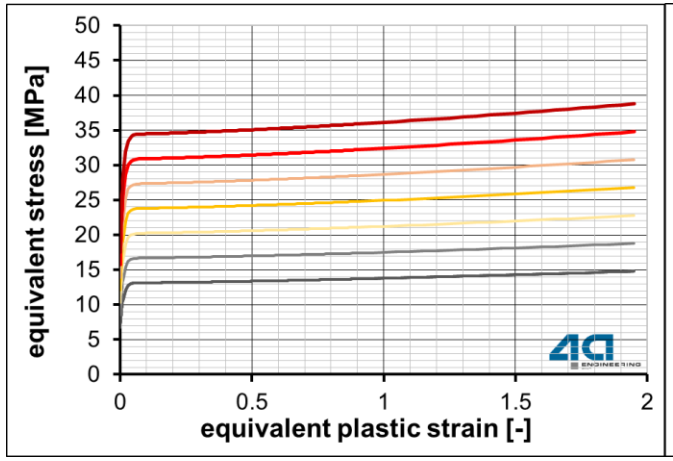


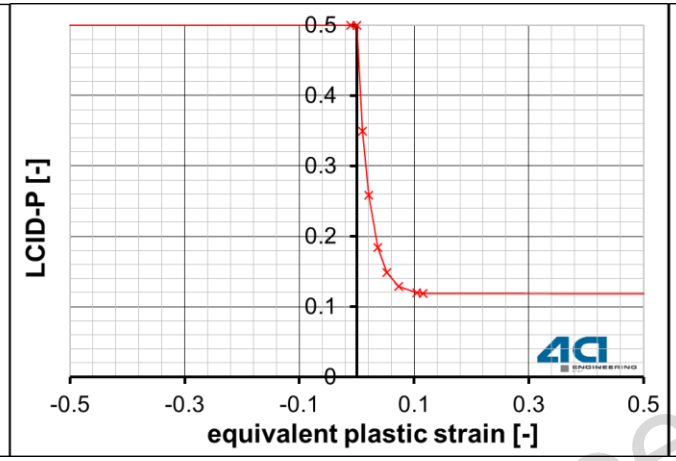
optimization – successive response surface method

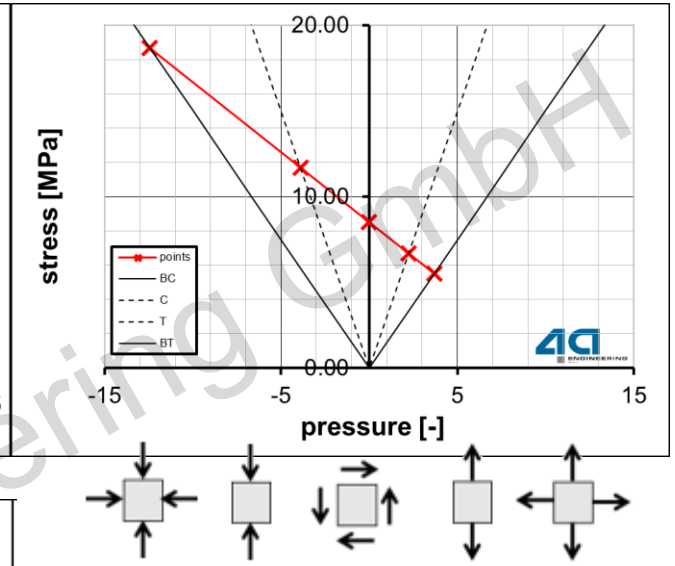


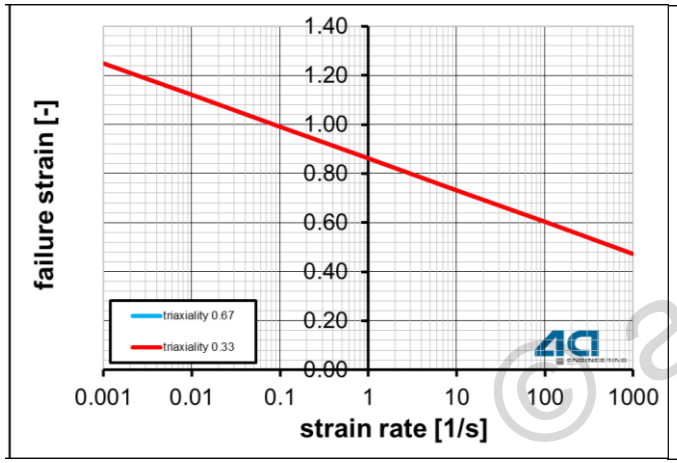


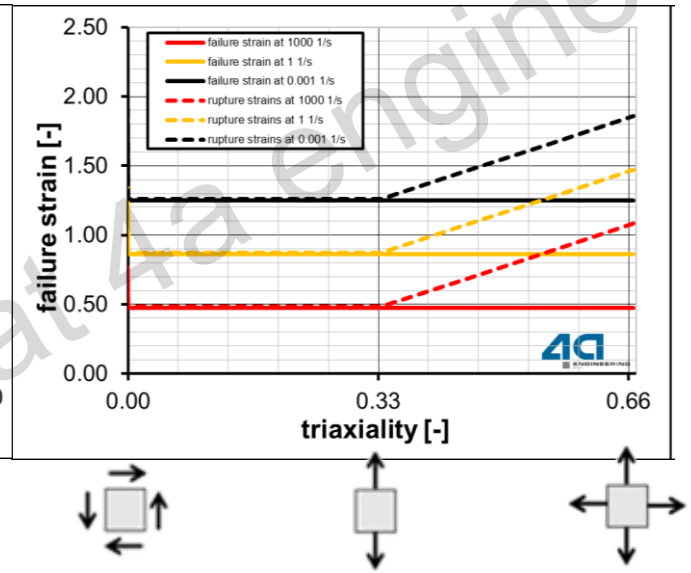
*MAT-SAMP 1 with internal FM – result AUTOFIT

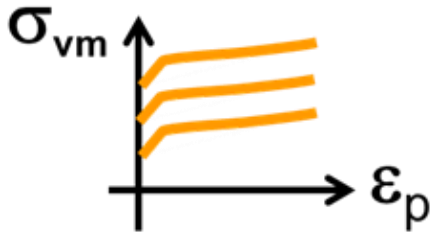




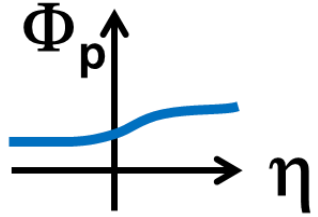




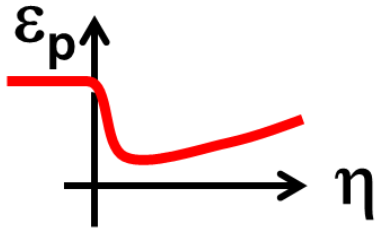




Hardening



Triaxiality

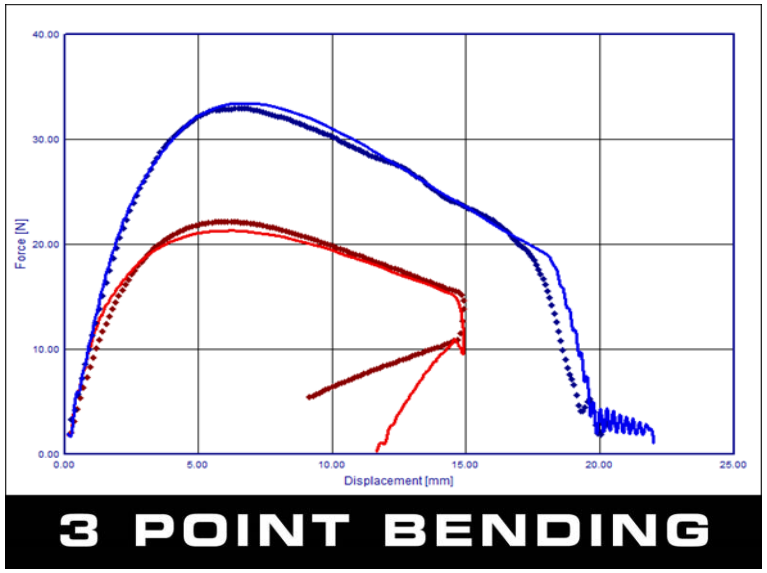


Damage/Failure

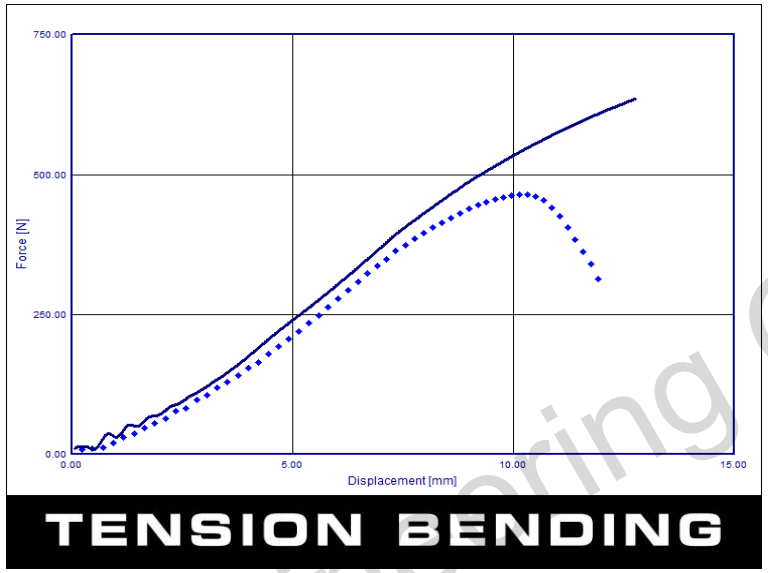
source: Benjamin Hirschmann, master thesis

*MAT-SAMP 1 with internal failure model - validation

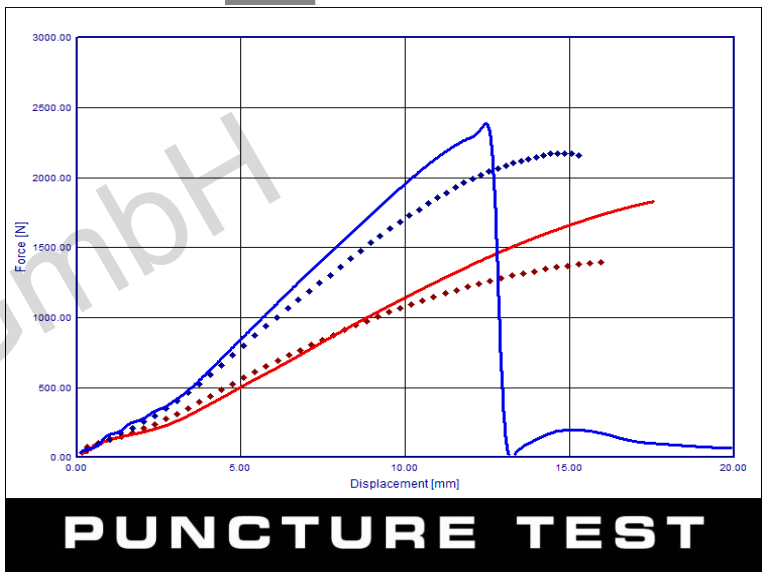
VALIMAT



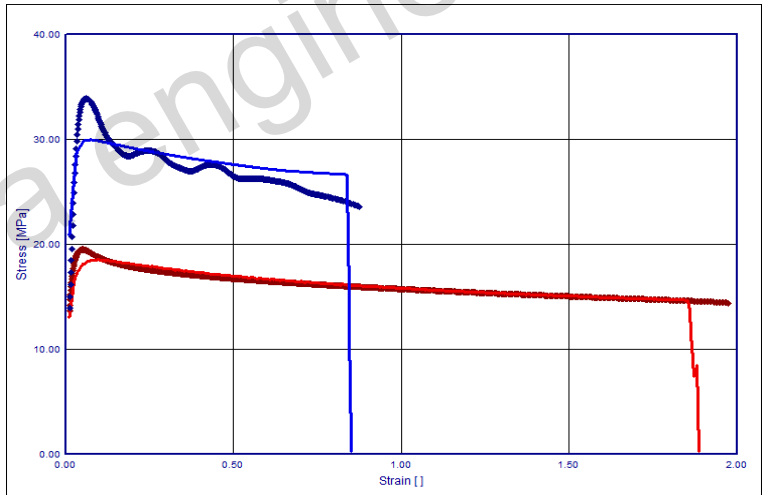
3 POINT BENDING



TENSION BENDING



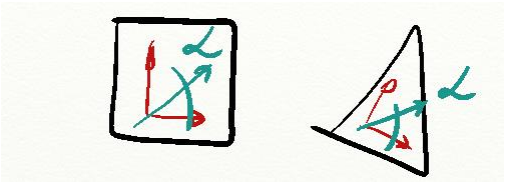
PUNCTURE TEST



TENSION TEST

IMPETUS™ ~ 3 m/s

static ~ 1mm/s

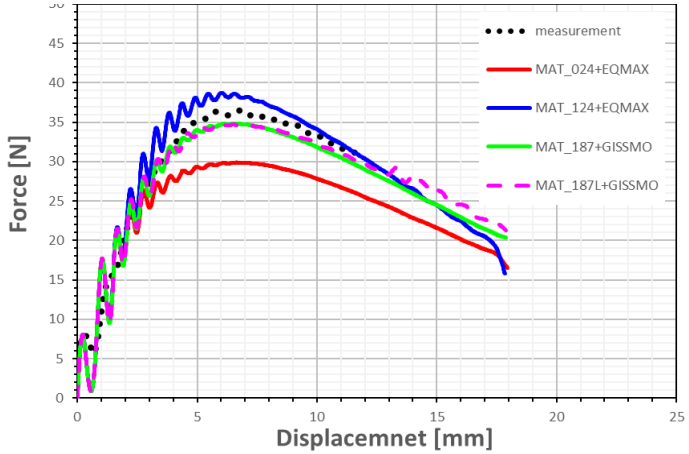


···· averaged test curves

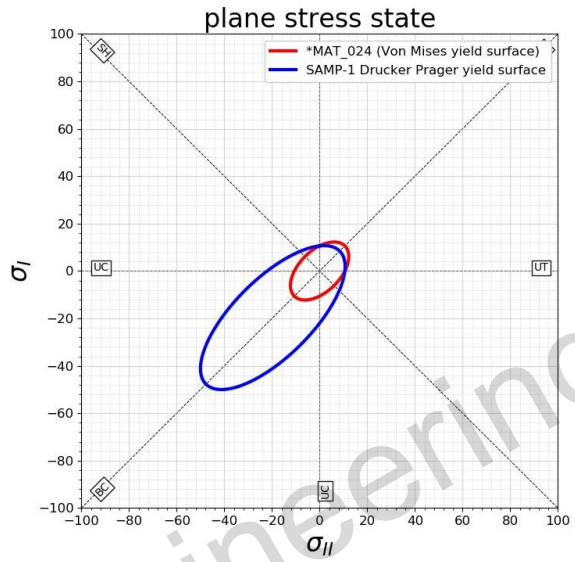
— result of simulation

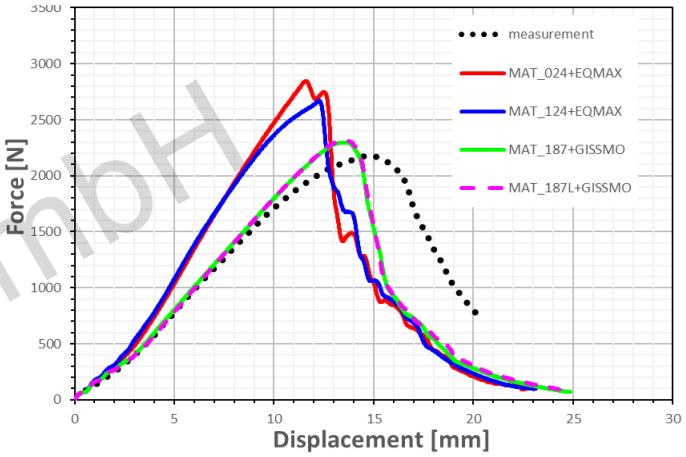
source: Benjamin Hirschmann, master thesis

Comparison of different material models

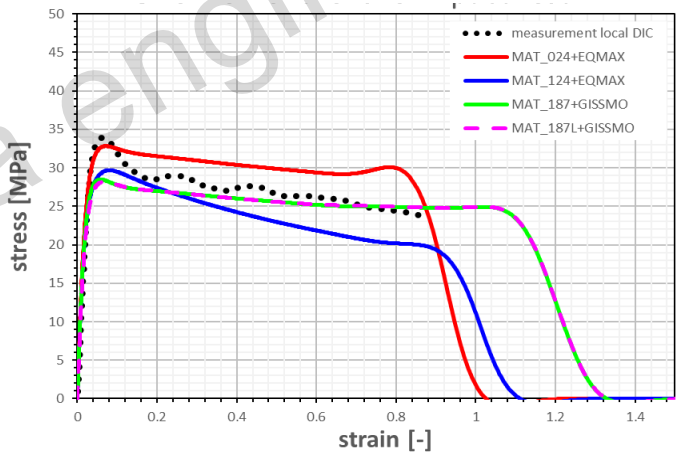


3 POINT BENDING

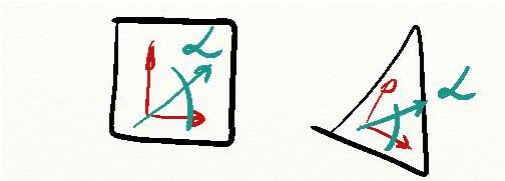




PUNCTURE TEST



TENSION TEST

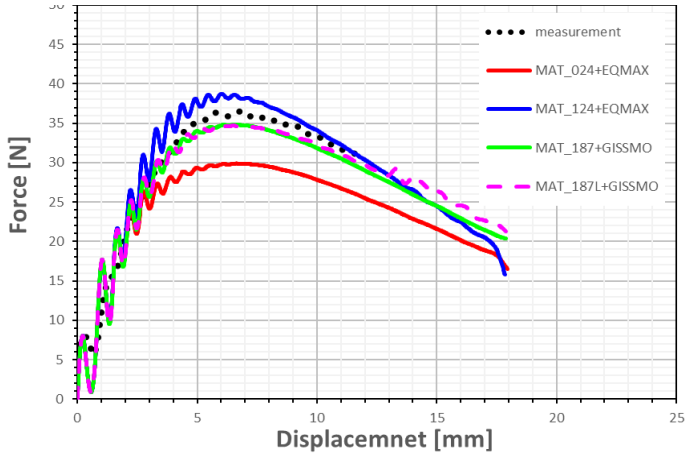


IMPETUS™ ~ 3 m/s

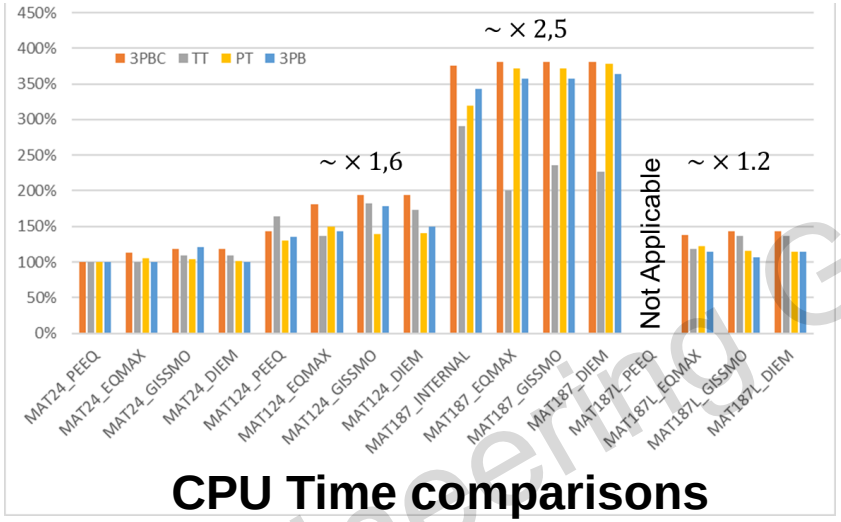
···· averaged test curves
— result of simulation

source: Benjamin Hirschmann, master thesis

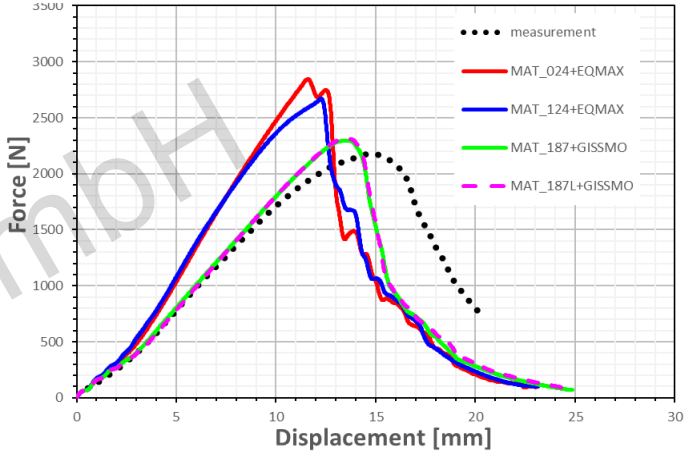
Comparison of different material models



3 POINT BENDING

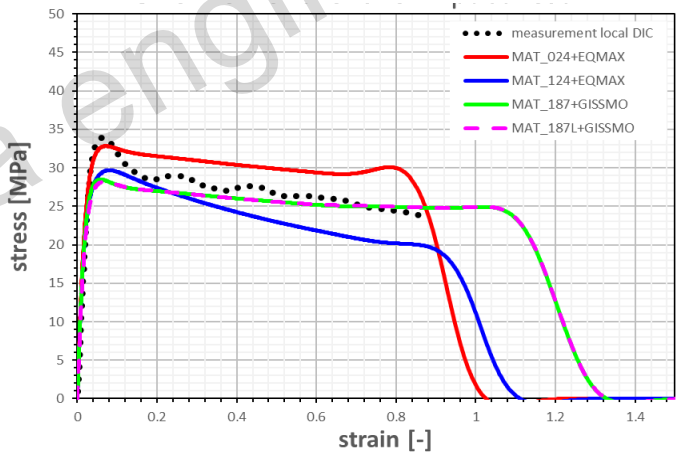


CPU Time comparisons

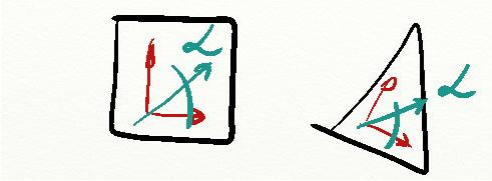


PUNCTURE TEST

IMPETUS™ ~ 3 m/s

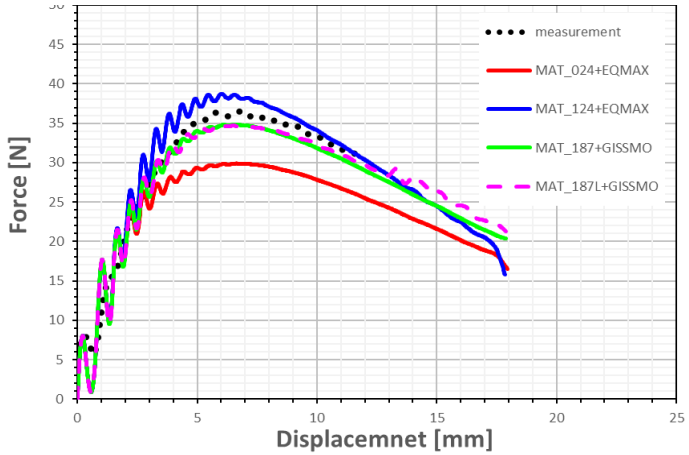


TENSION TEST



source: Benjamin Hirschmann, master thesis

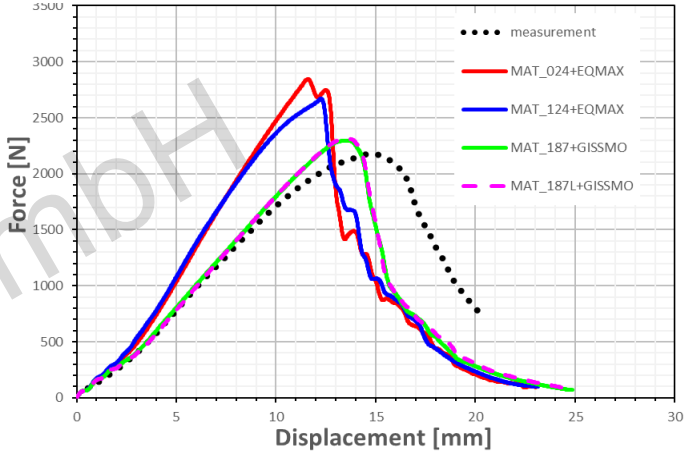
Comparison of different material models



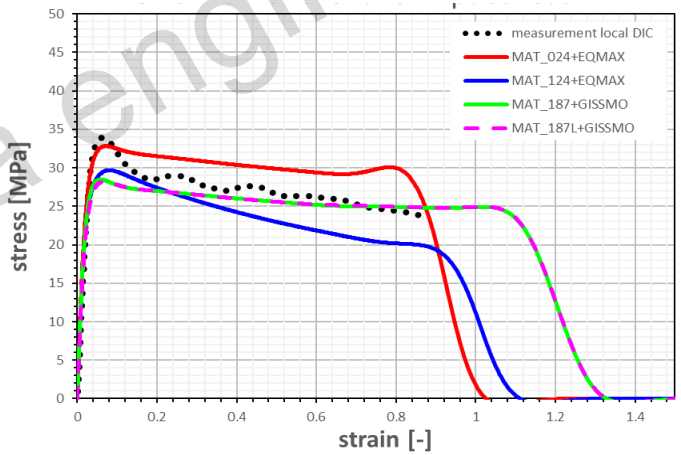
3 POINT BENDING

Material model	CPU Time
*MAT_024	1
*MAT_124	1.6
*MAT_187	2.5
*MAT_187L	1.2

CPU Time comparisons



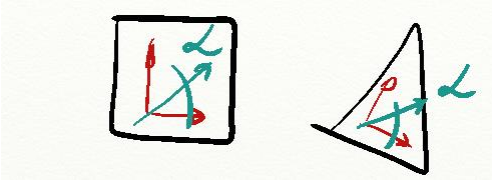
PUNCTURE TEST



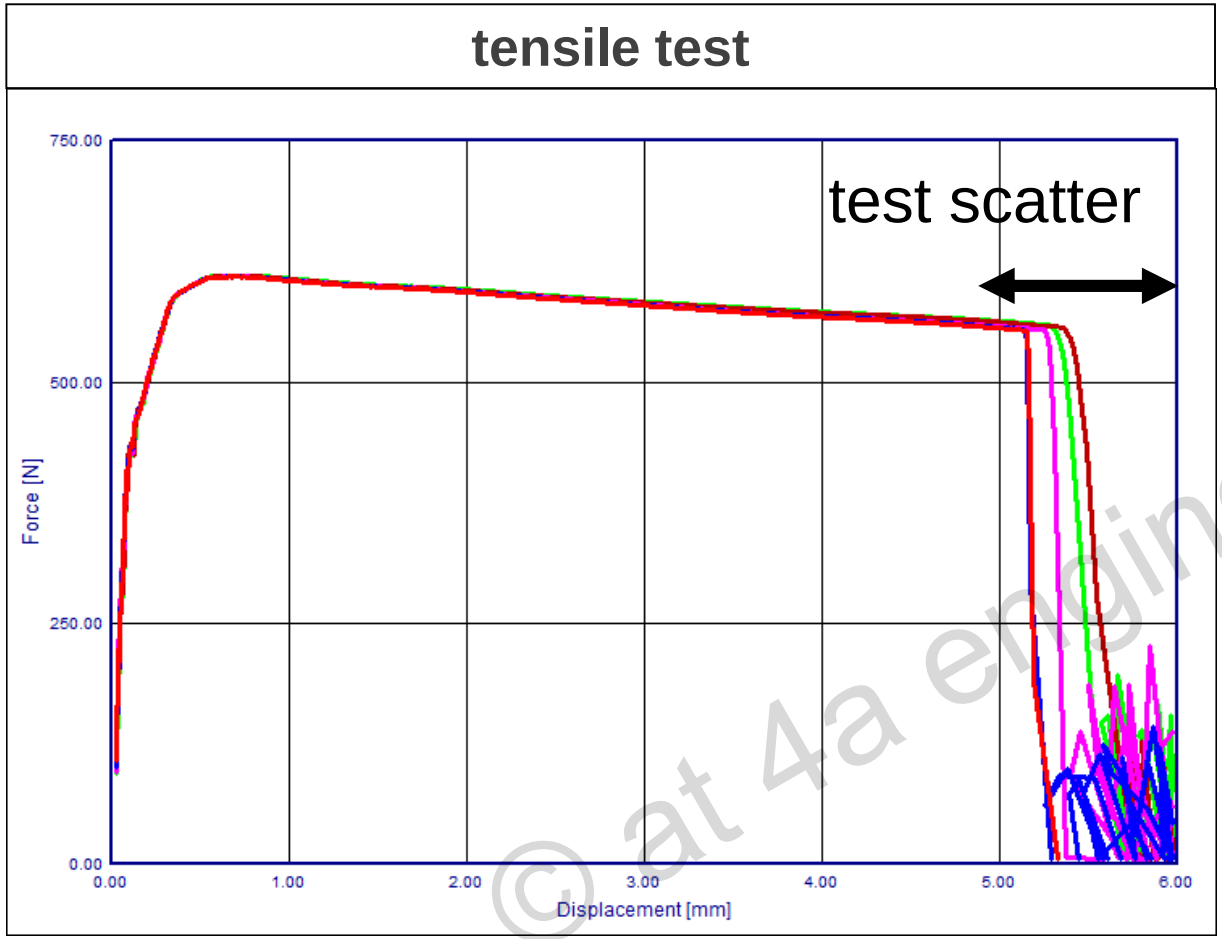
TENSION TEST

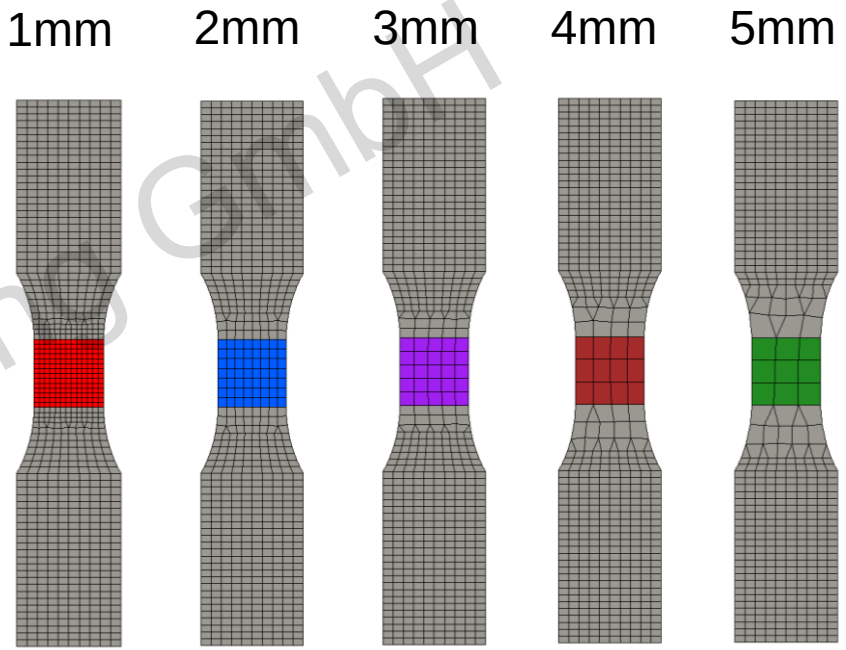
IMPETUS™ ~ 3 m/s

source: Benjamin Hirschmann, master thesis



*MAT-SAMP 1 with internal failure model – influence element size





VALIMAT

source: Benjamin Hirschmann, master thesis

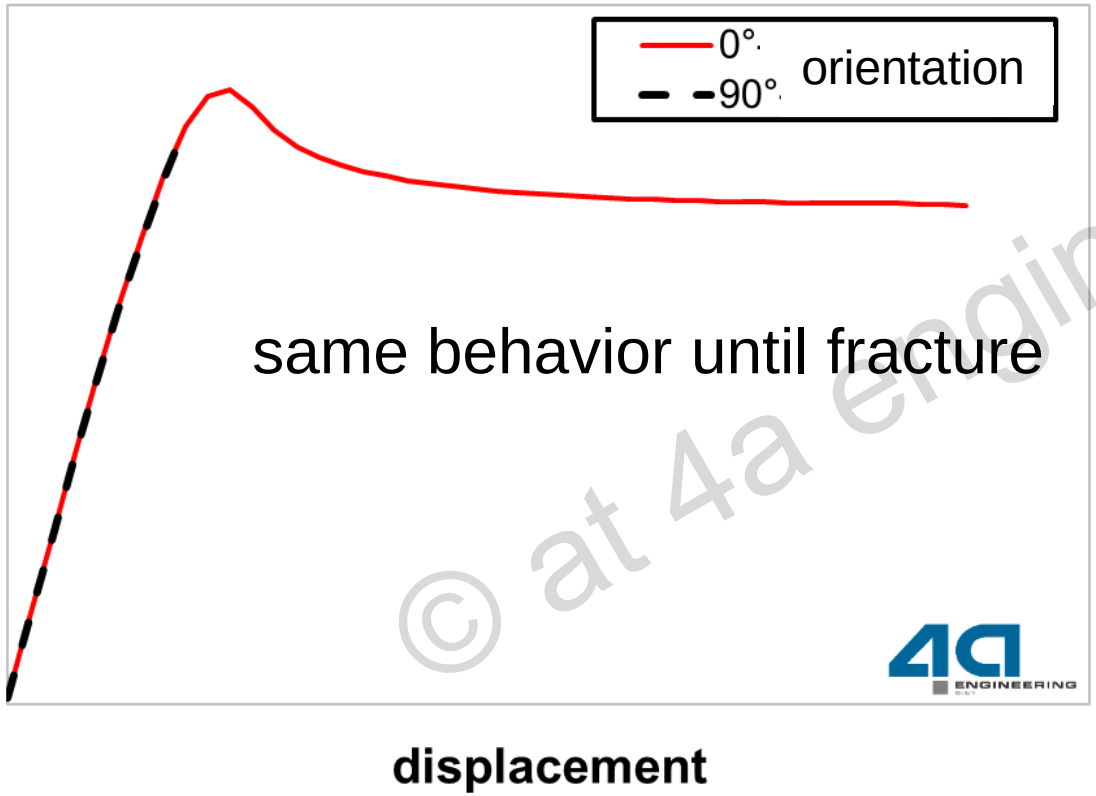
Anisotropic Failure

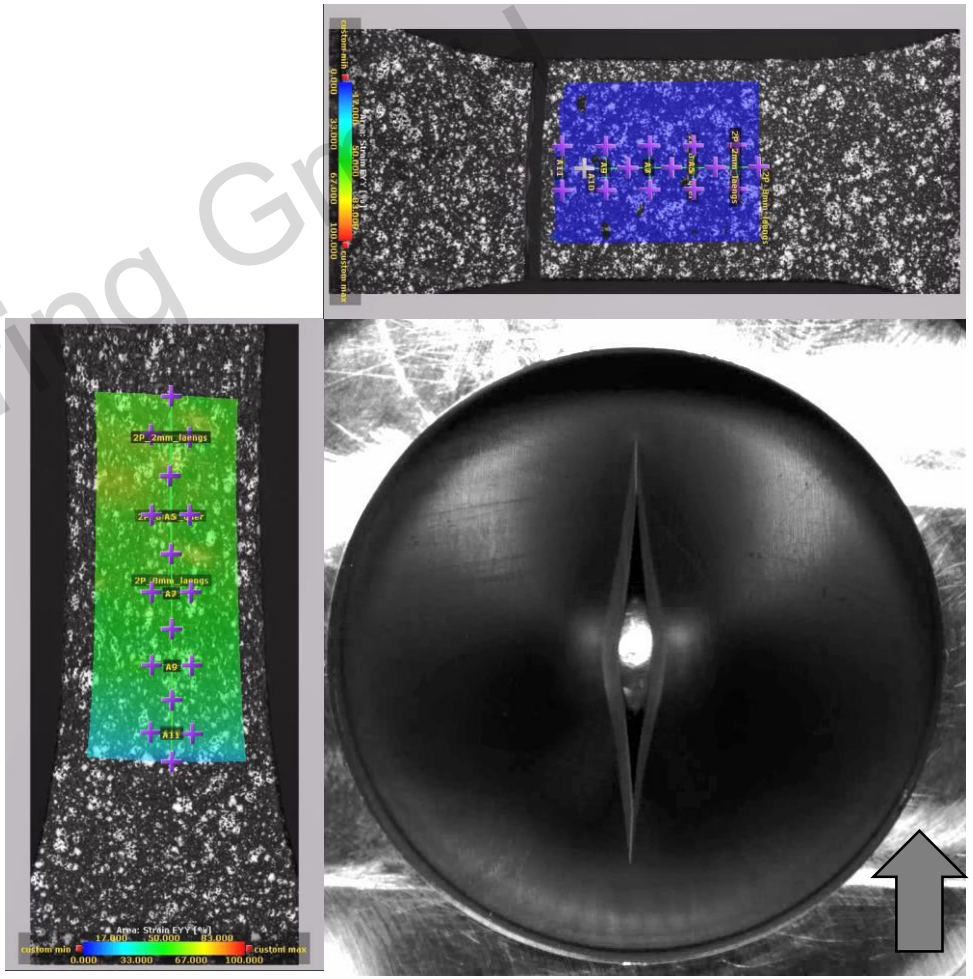
*(*MAT_ADD_GENERALIZED_DAMAGE)*

Plastics ?

Influence of manufacturing process on failure

- example: ABS
  - The induced orientation by the injection molding process leads to an anisotropic failure behavior.





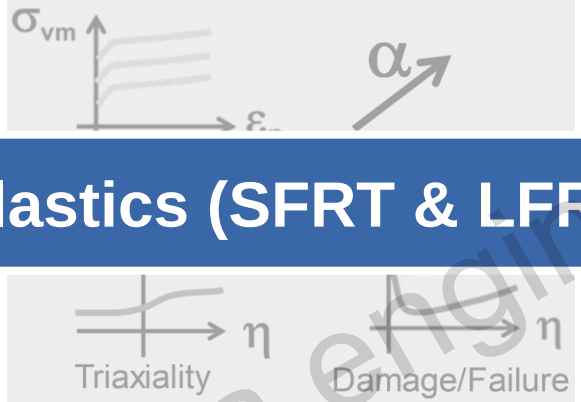
Intelligent reliable solutions for plastics, composites, metals, foams, ...

Fiber reinforced Plastics (SFRT & LFRT)

IMPETUS

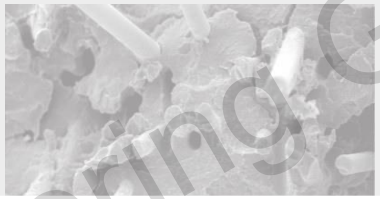
efficient
dynamic testing

VALIMAT



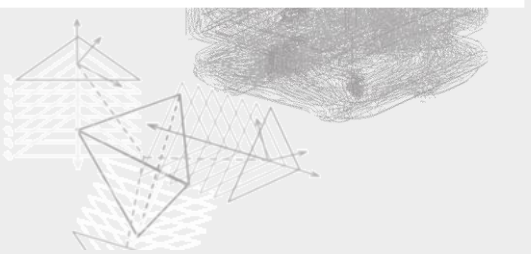
from test to validated
material cards

MICROMEC



3D anisotropic
material cards

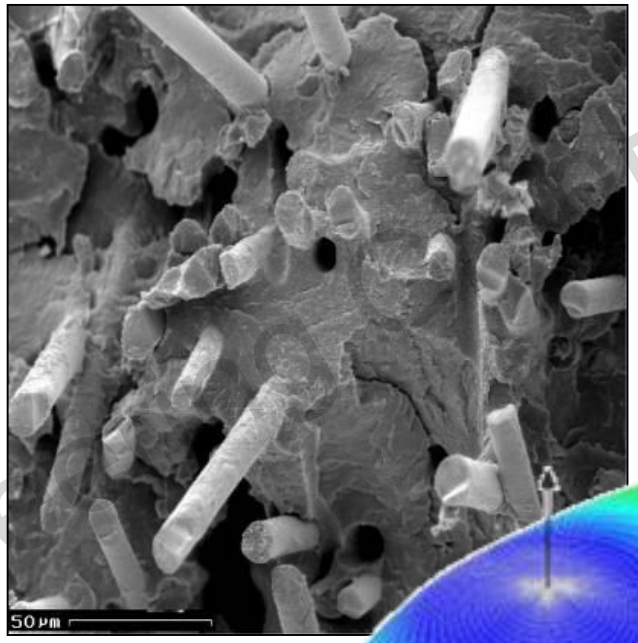
FIBERMAP

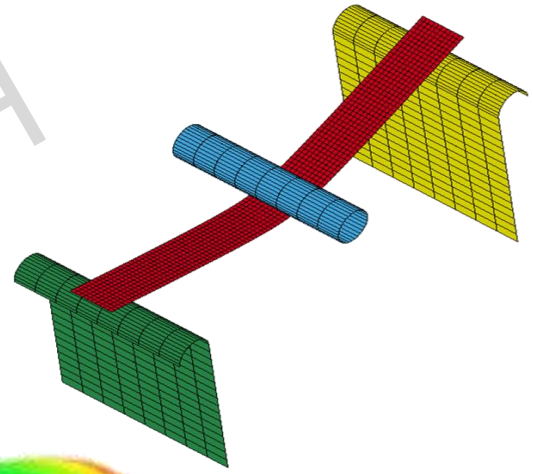


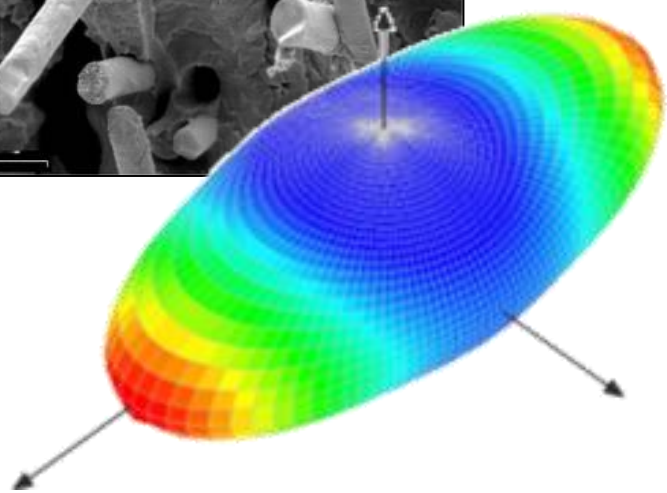
individual mapping
process information

Short and long fiber reinforced thermoplastics

- Motivation
- Manufacturing influence
- Material model approaches
- Material characterization
- Casestudy - sleeve

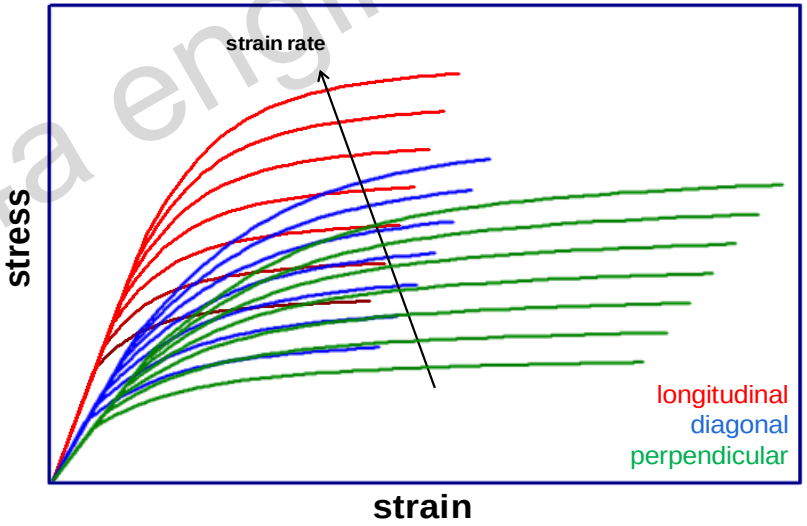


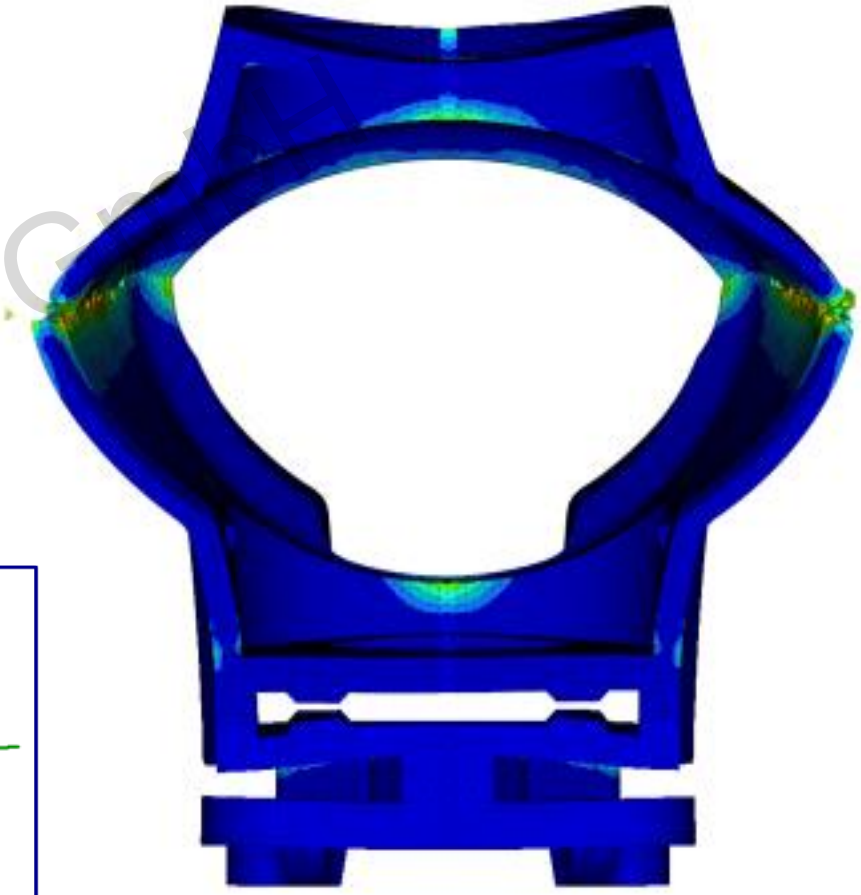




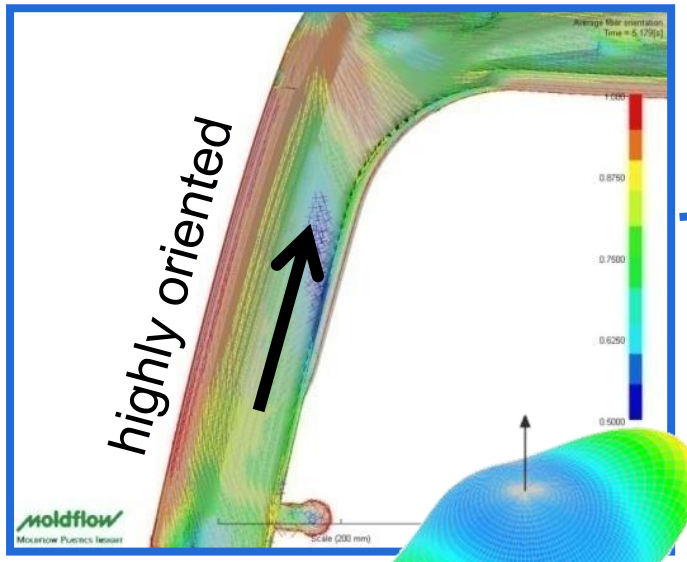
Motivation – current simulation standard

isotropic

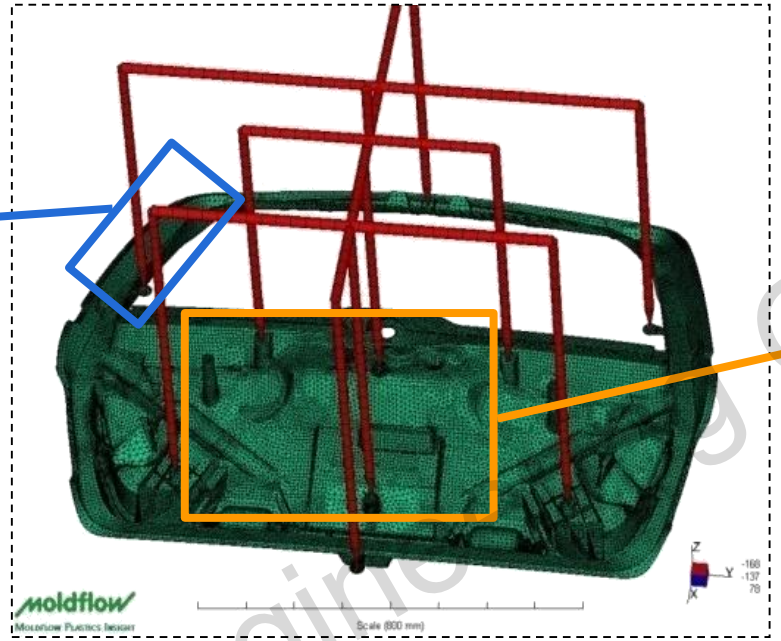


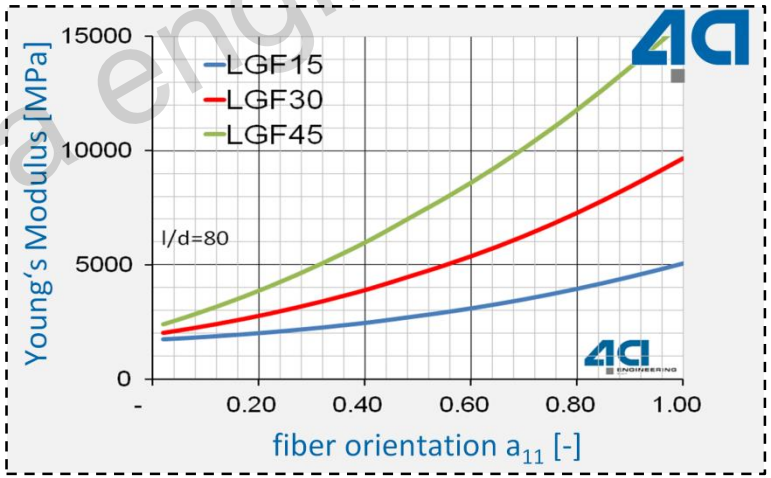


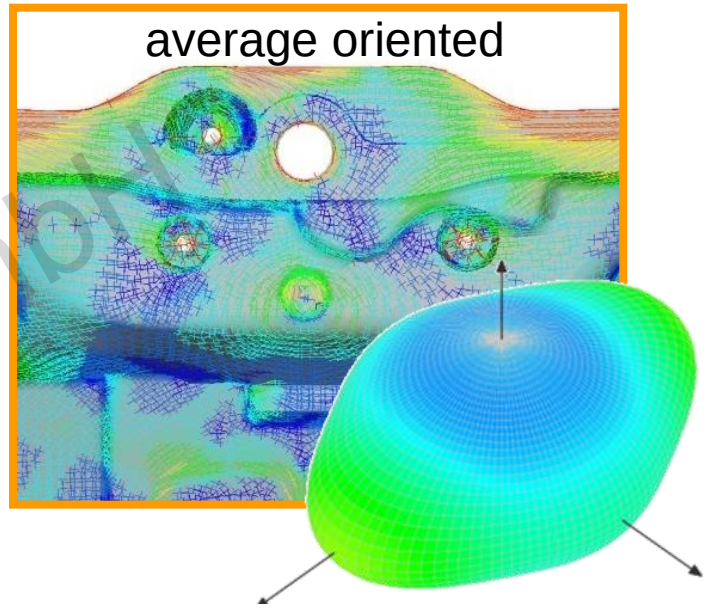
Fiber orientation – development in typical part



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





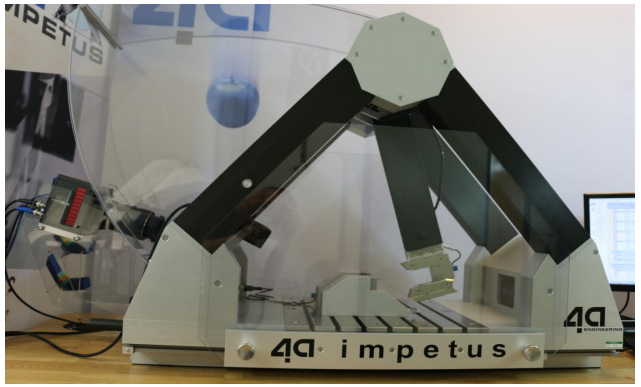


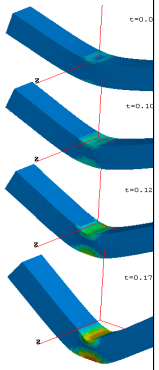
$$a_{ij} = \begin{bmatrix} 0{,}66 & 0 & 0 \\ 0 & 0{,}32 & 0 \\ 0 & 0 & 0{,}02 \end{bmatrix}$$

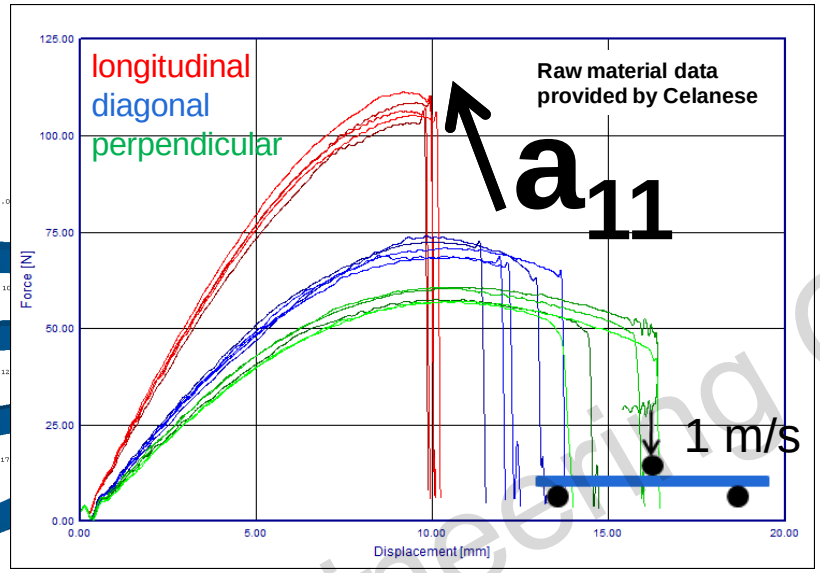
Source: P. Reithofer - *Integrative Simulation – Berücksichtigung der prozessbedingten Anisotropie*, 4a Technologietag 2011

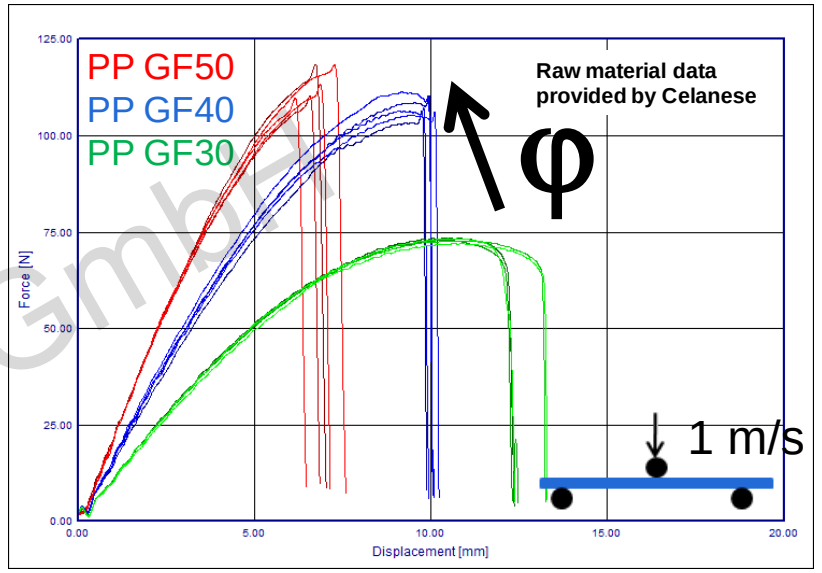
Typical material behavior – SFRT / LFRT

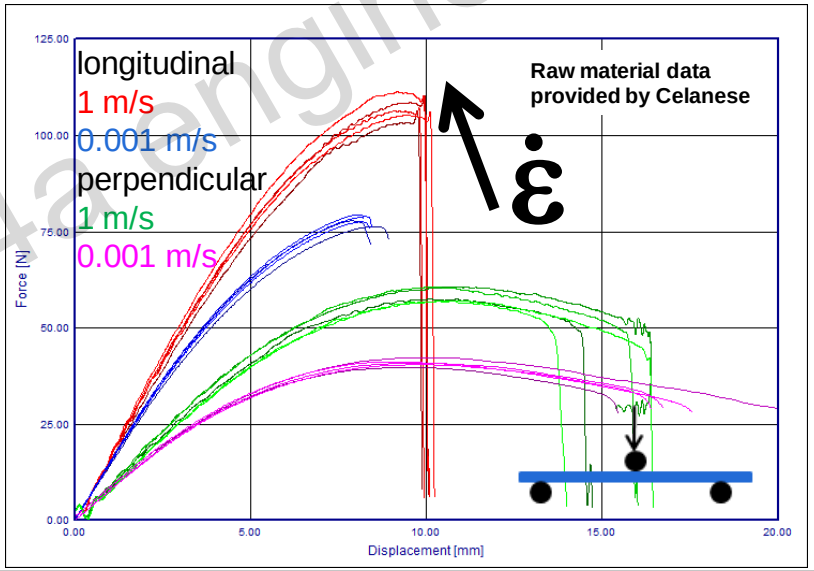
IMPETUS

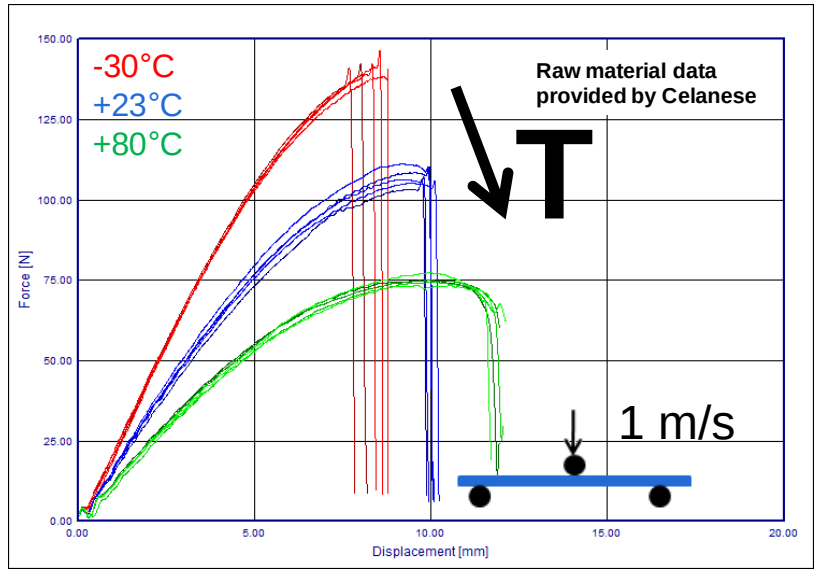




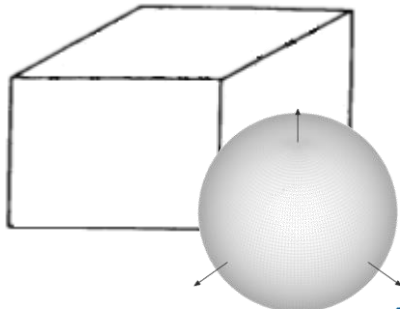


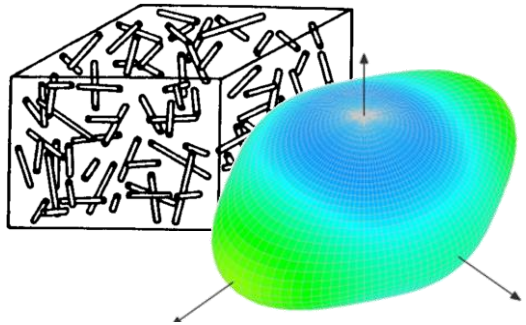




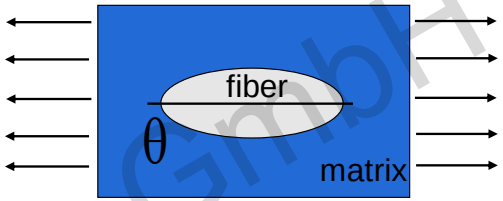


Typical material models in LS-DYNA





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



Eshelby Tensor

macro scale

constitutive law → composi

micro scale

homogenizat

Mises plasticity

- quick & d
- criti g
  t
  orientation

elastic

- orthotro
- aniso

elastic stic

- city

M… matrix

- isotropic elas
  viscoplast

F… fiber

- iso stic

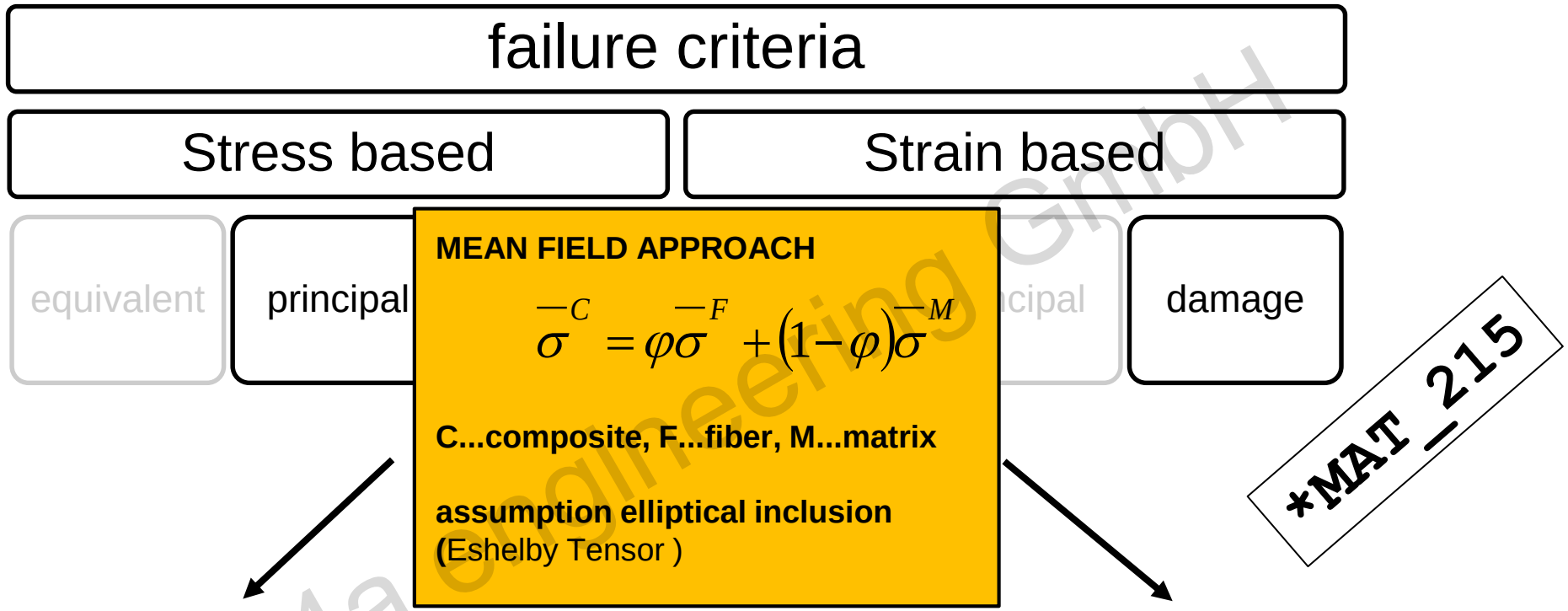
*MAT_024

*MAT_157

*MAT_215

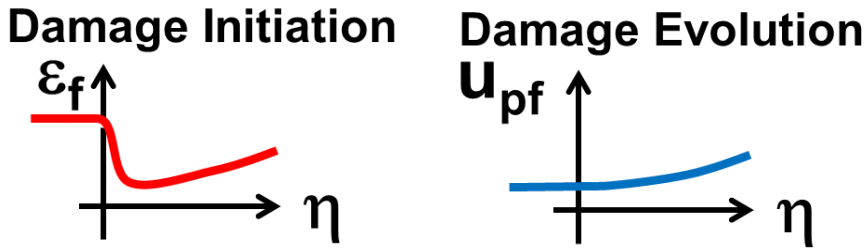
α – orientation dependent

Micro mechanical motivated failure

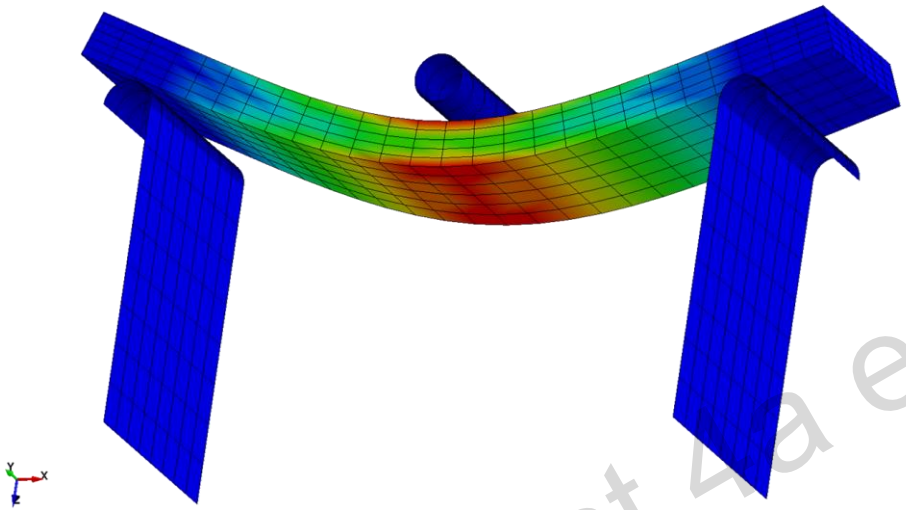


FAILF: Fiber failure

FAILM: Matrix failure – ductile DIEM-Model

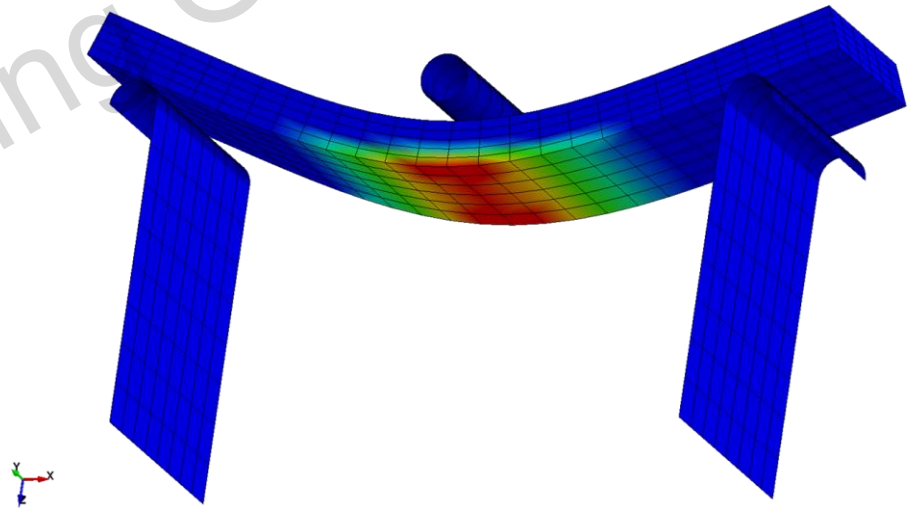


Micro mechanical motivated failure



History#6 (step8: 0-0.13):

Fiber damage init.

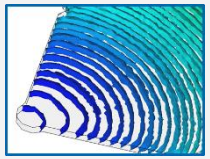


History#4 (step8: 0-0.81):

dm - matrix damage init.

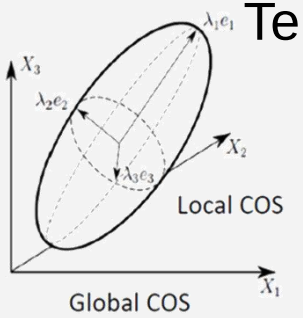
Material models – present approaches

Process simulation



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

Tensor 2nd order



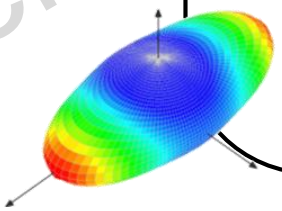
CADMOULD 3D-F SIMULATION

Moldex3D MOLDING INNOVATION

MOLDFLOW

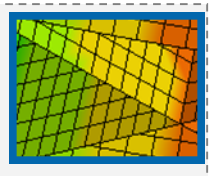
FIBERMAP

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



MICROMEC

Structural simulation

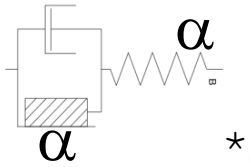


Homogenization (Micro Scale)
Mean Field Theory

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

*MAT_215

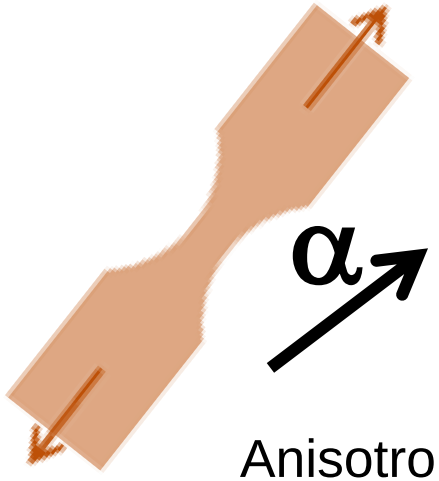
Composite (Macro Scale)
Hill Plasticity



*MAT_157

LSTC Livermore Software Technology Corp.
LS-DYNA®

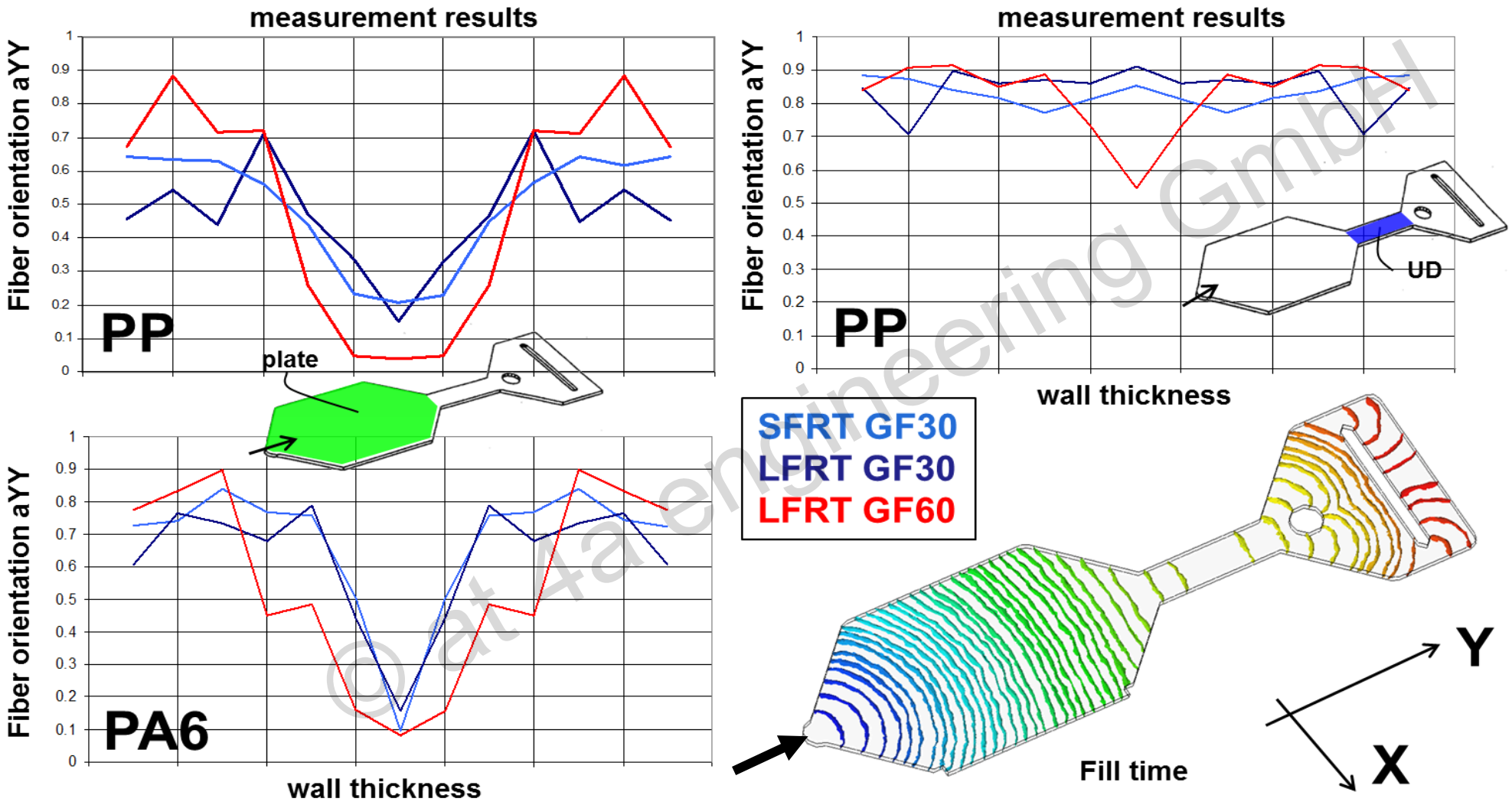
From test to material card



Anisotropic

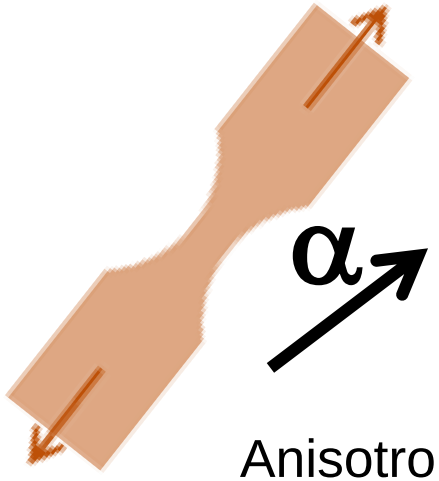
Why not tension (only)?

Fiber orientation – development based on flow / viscosity



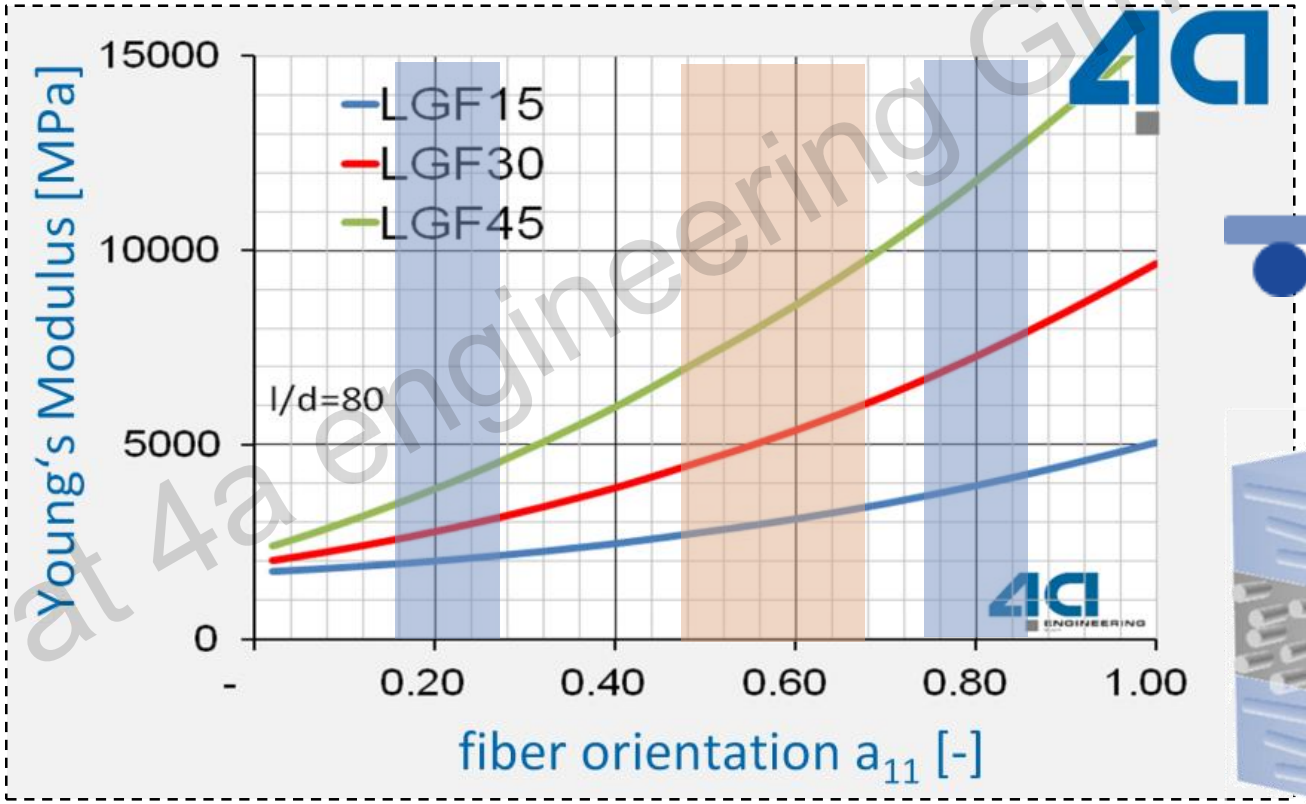
Source: 4a – EU Nelofite project , 2005

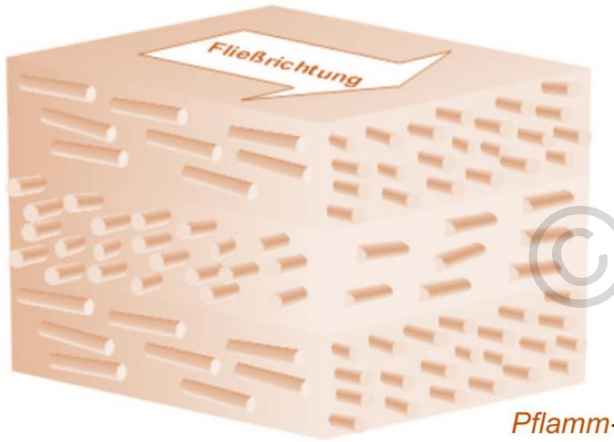
From test to material card



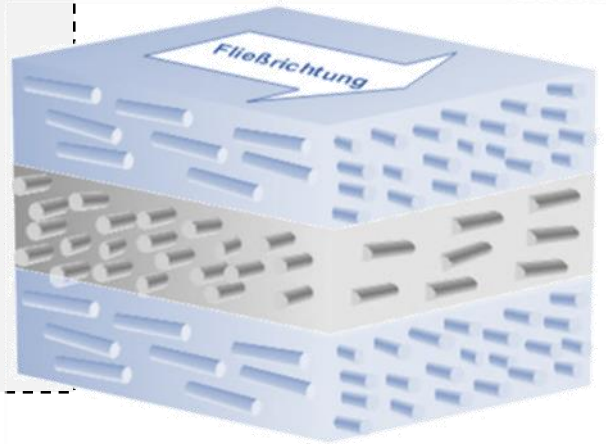
Anisotropic

Why not tension (only)?

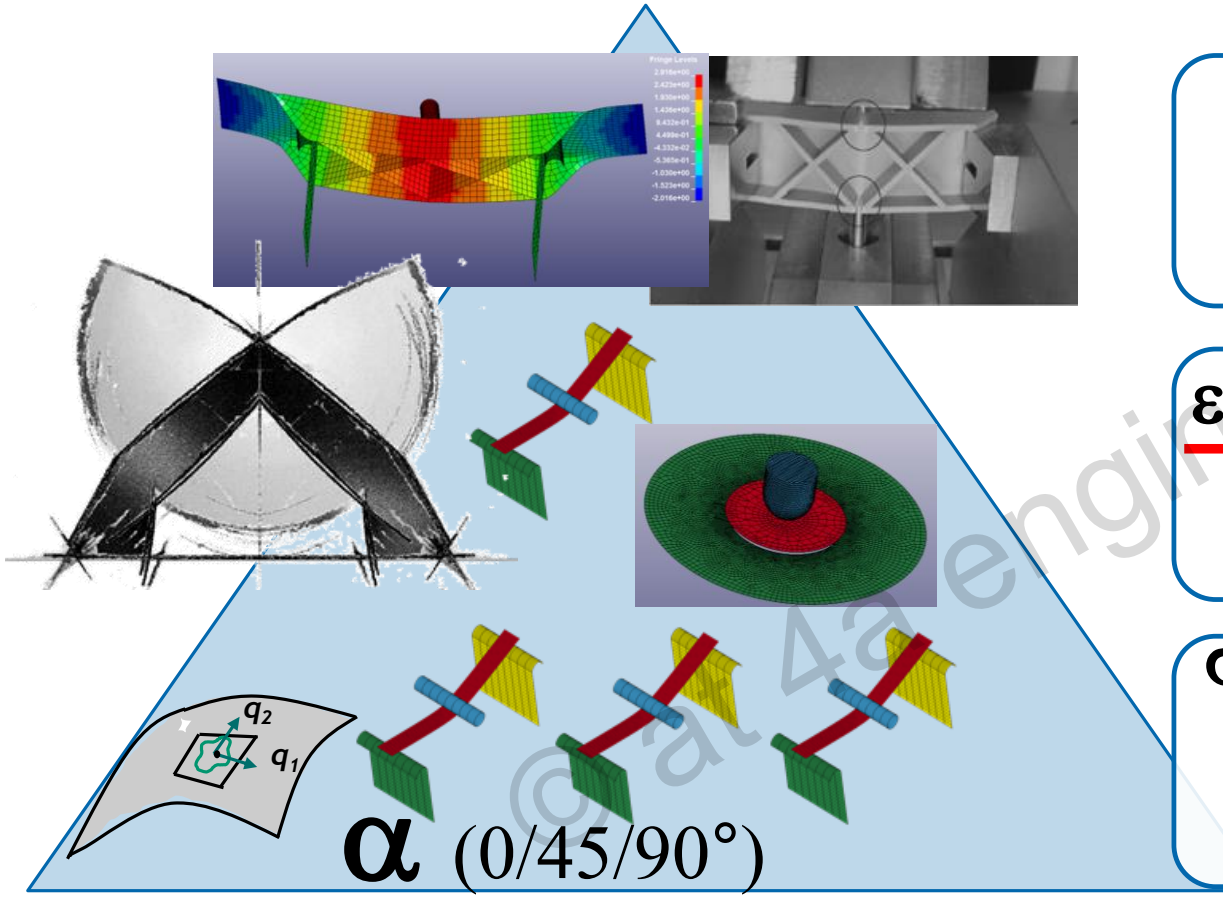




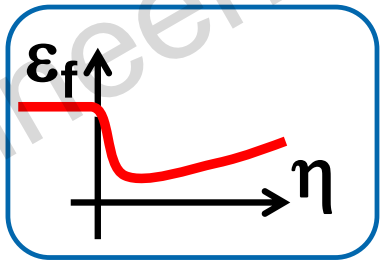
Pflamm-Jonas 2001

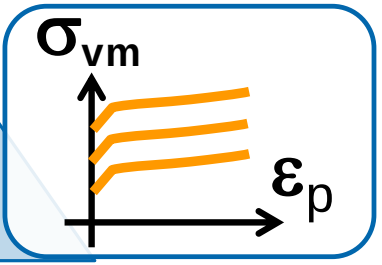


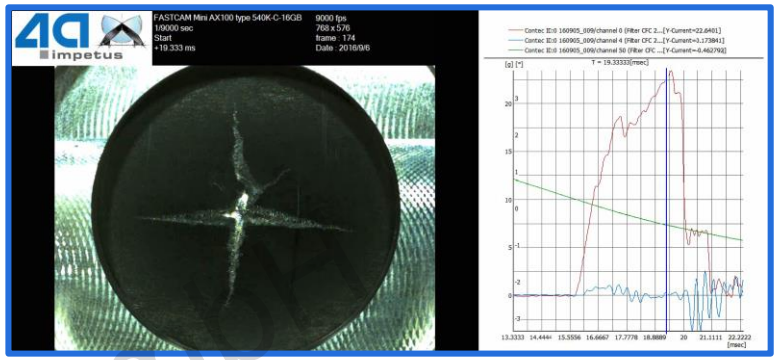
From test to material card

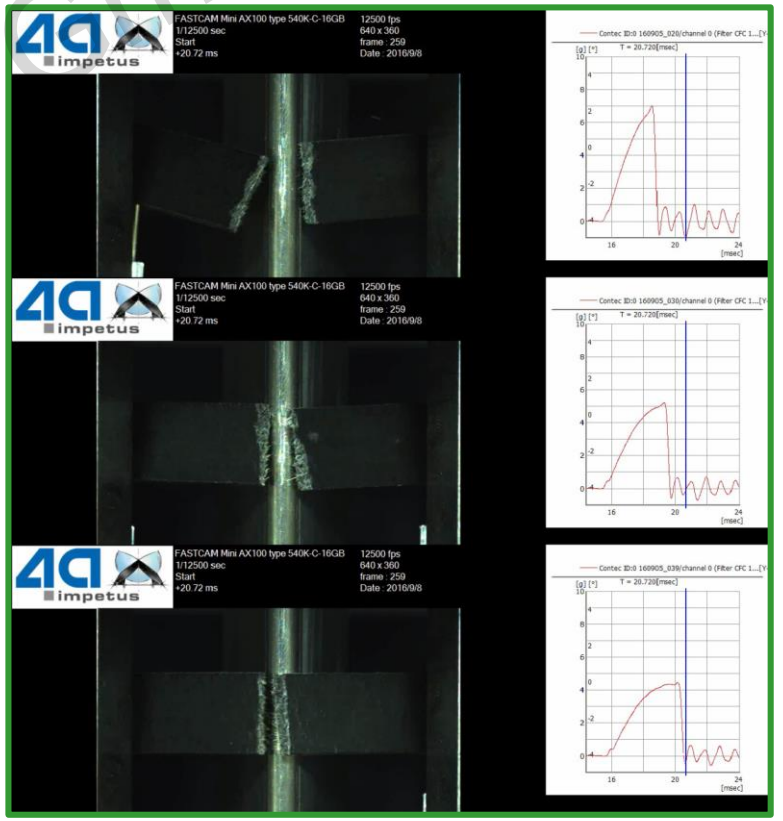


component validation



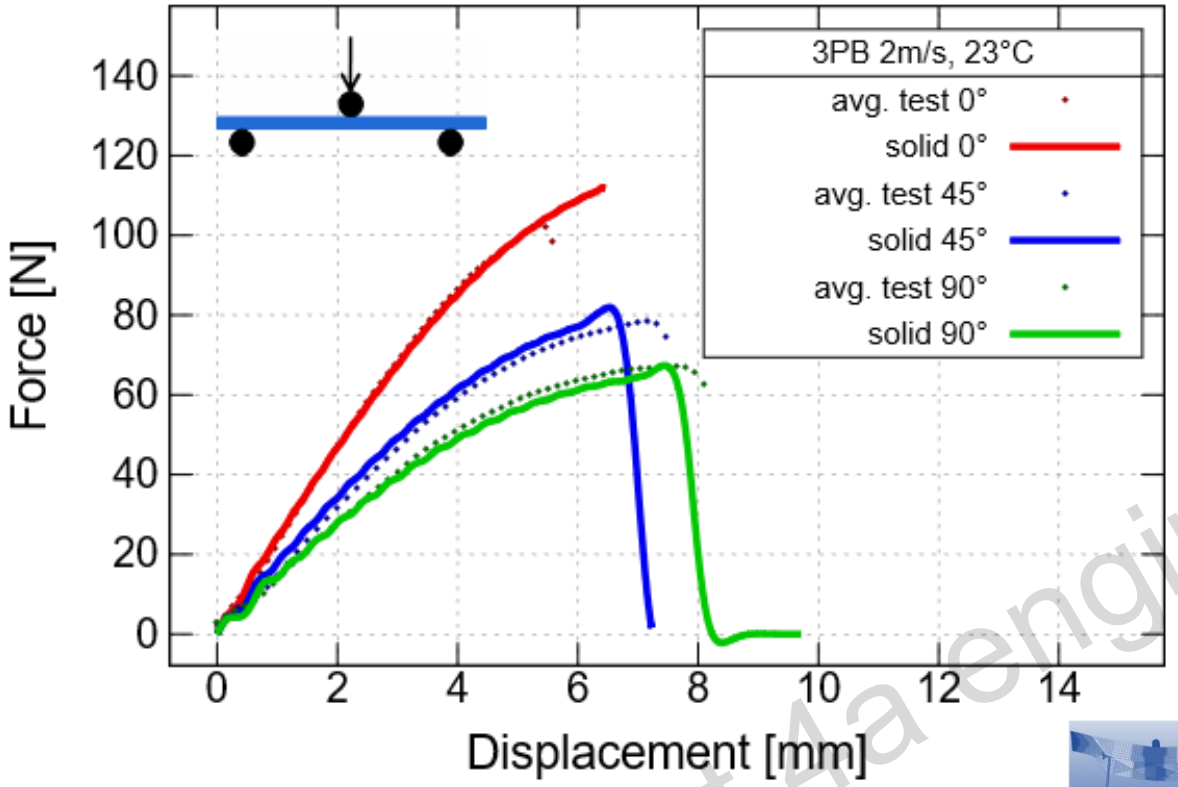


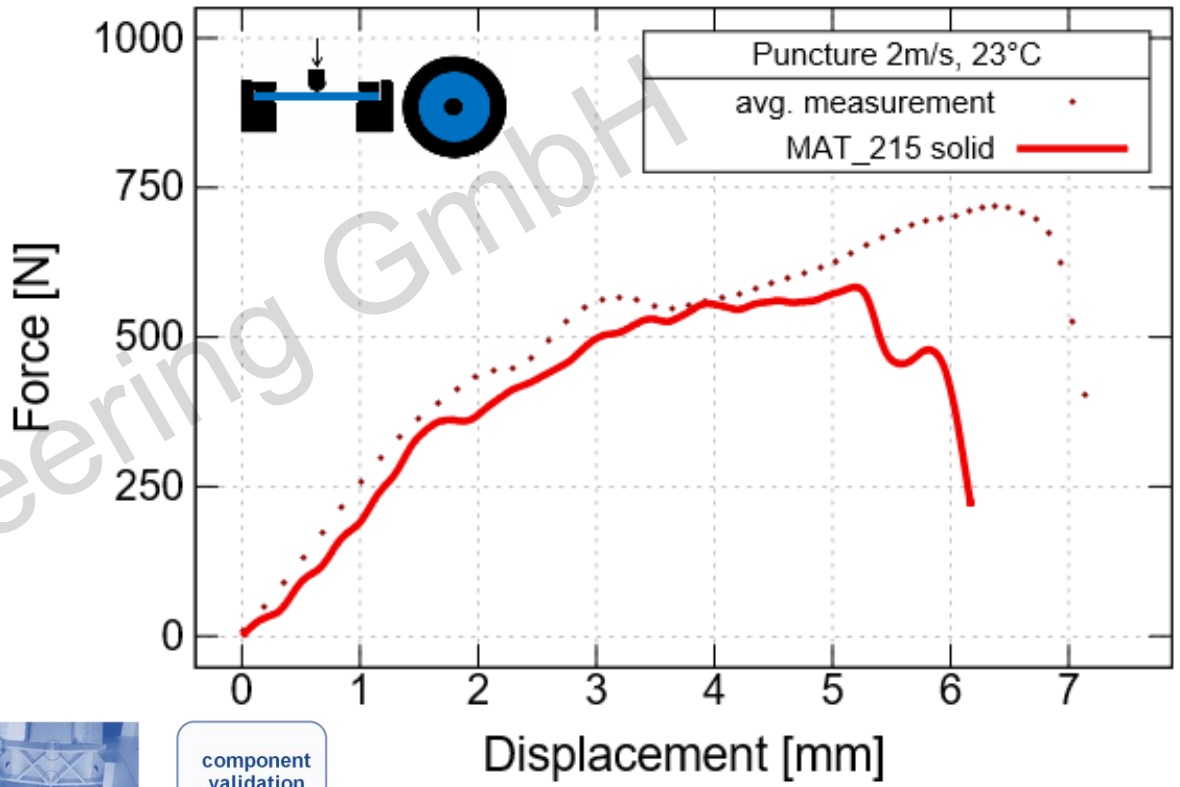


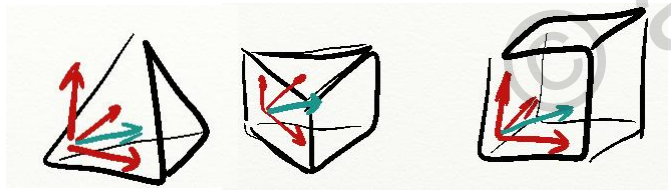


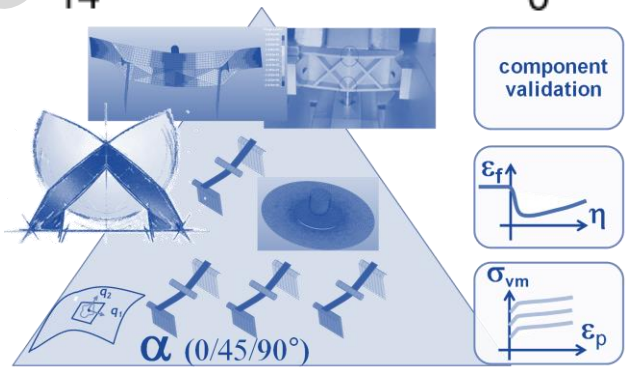
See more: P Reithofer, et.al., Versagen von faserverstärkten Kunststoffen bei dynamischer Beanspruchung, 4a Technologietag -2017

From test to material card: PP LGF30



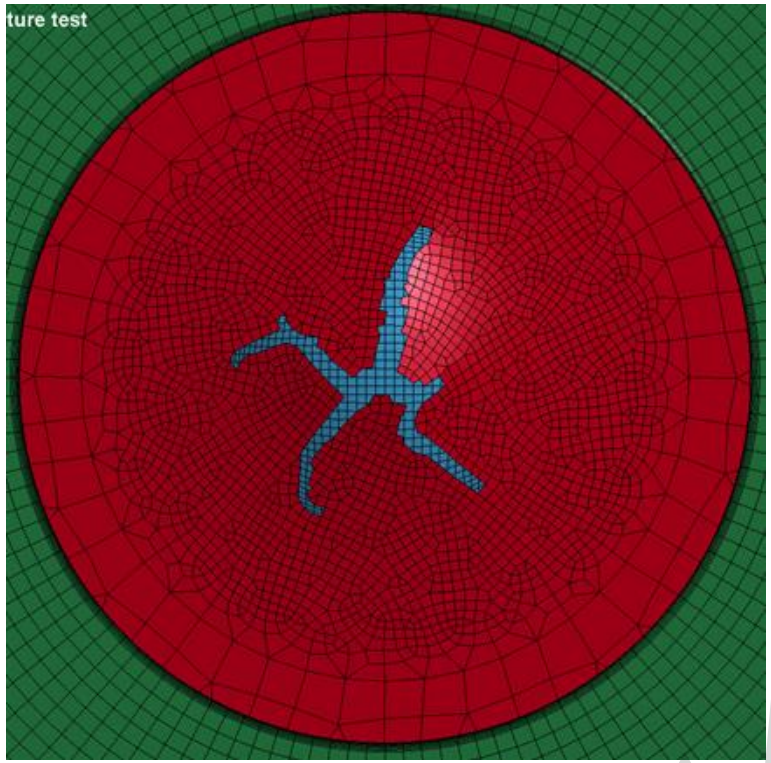


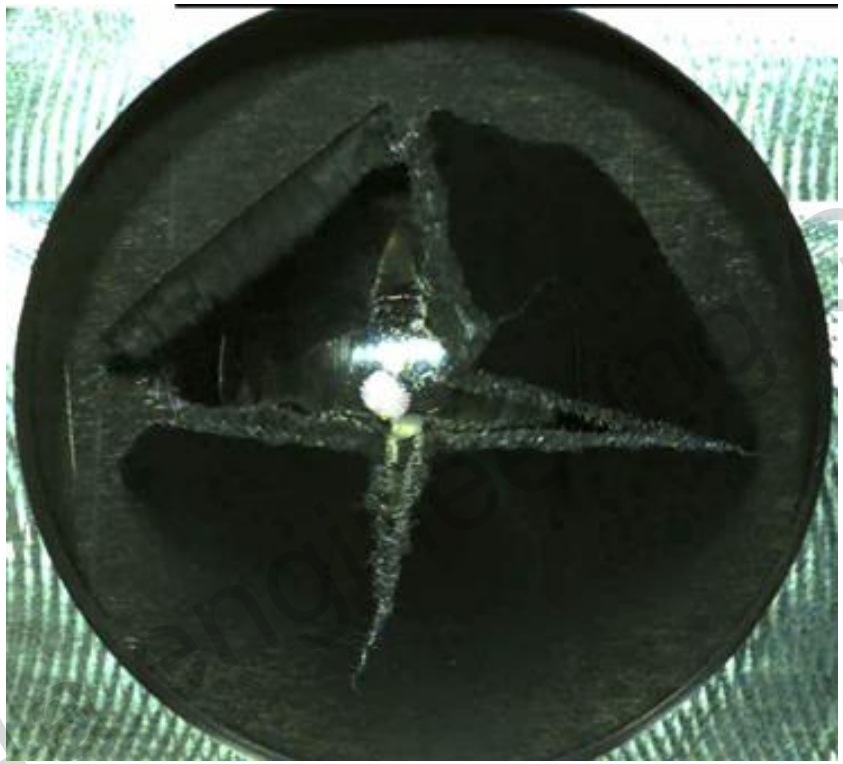


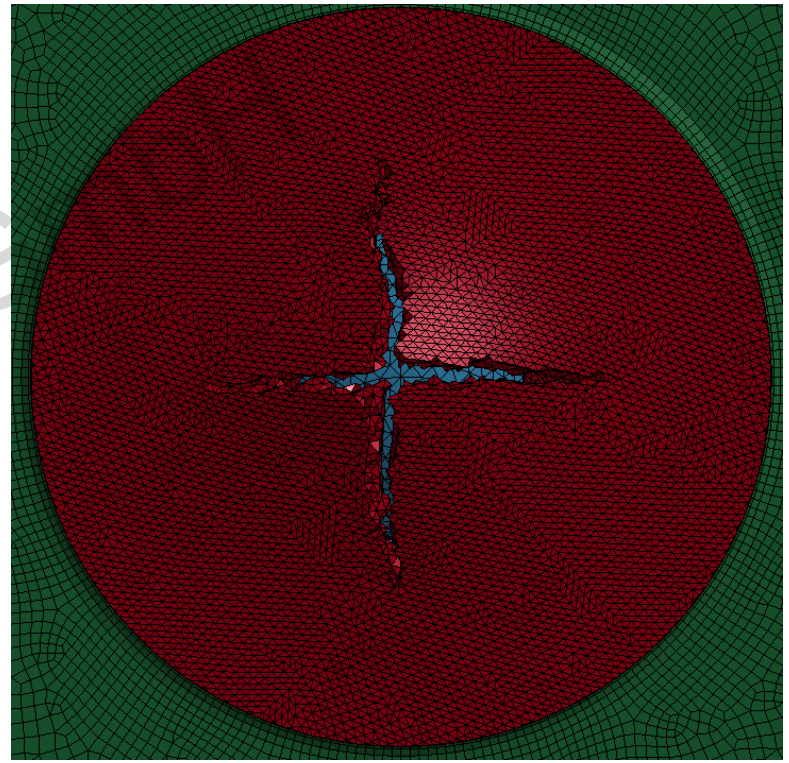


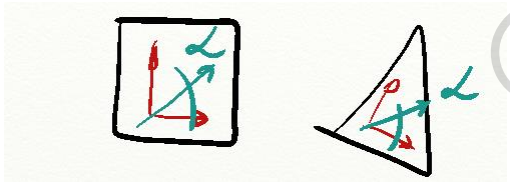
···· averaged test curves
— result of simulation

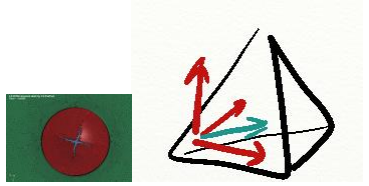
Validation for PP LGF30



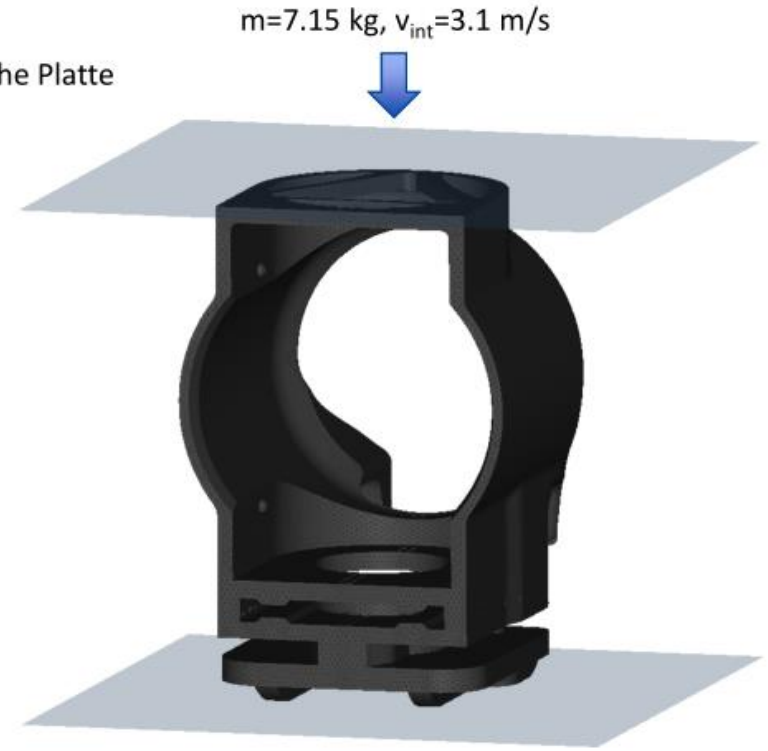


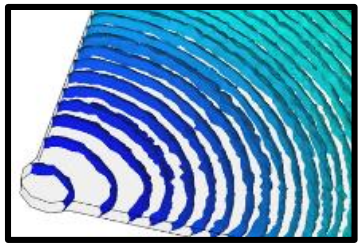




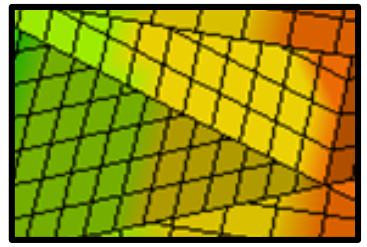


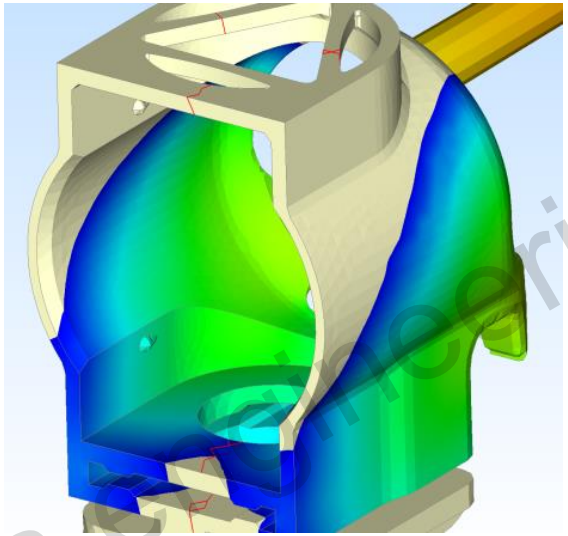
Casestudy - sleeve

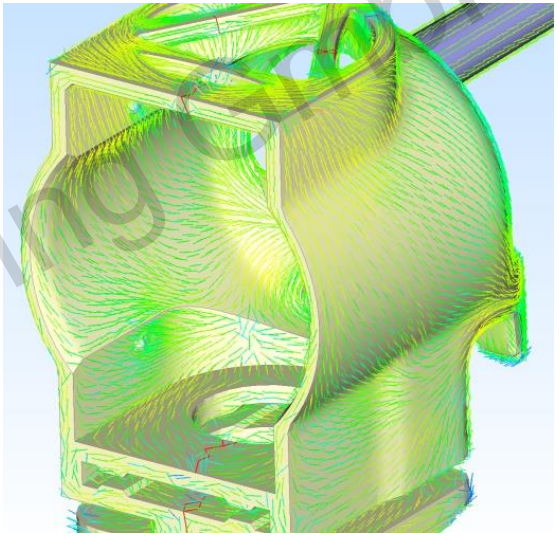


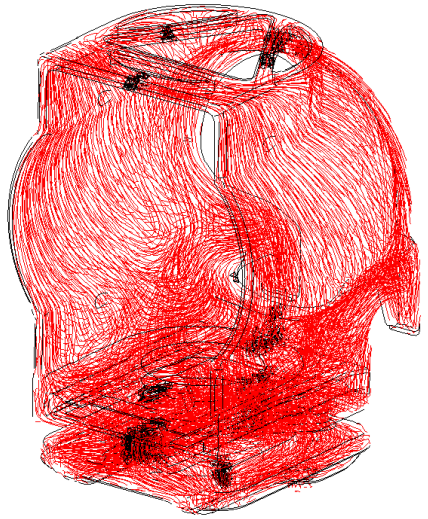


FIBERMAP







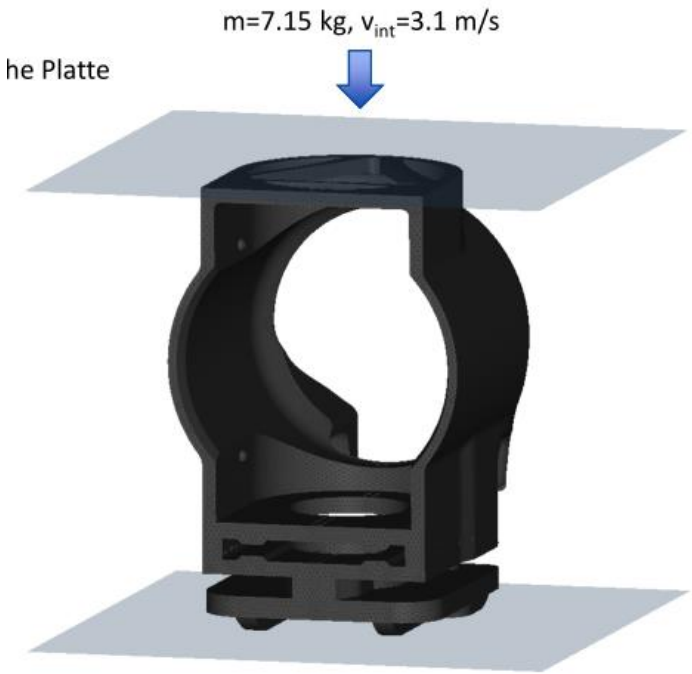


Typische Elementgröße: 0.25mm
Elementtyp: Tetrahedron Type 10
Elementanzahl: 469 470

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



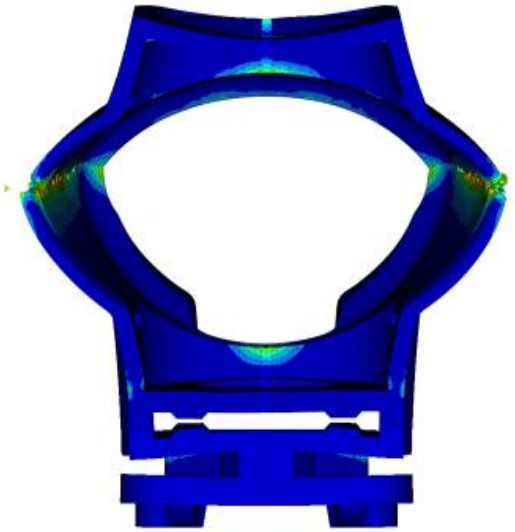
test

****MAT_157/215***

local anisotropy

****MAT_24***

isotropic



Typische Elementgröße: 0.25mm
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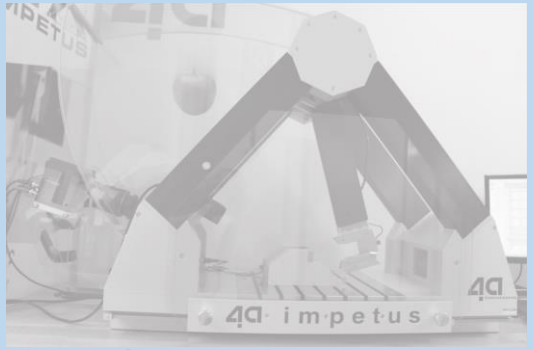
hirtenberger
Automotive Safety

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

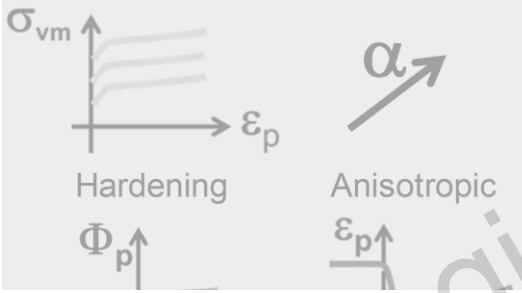
Intelligent reliable solutions for plastics, composites, metals, foams, ...

IMPETUS



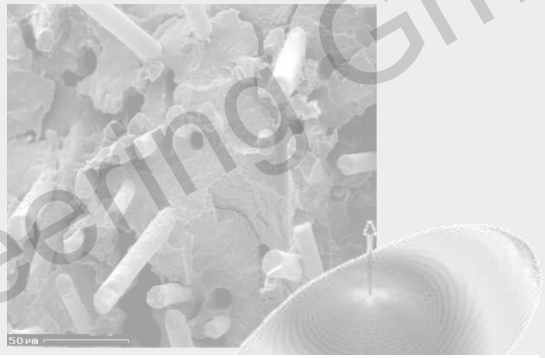
efficient
dynamic testing

VALIMAT



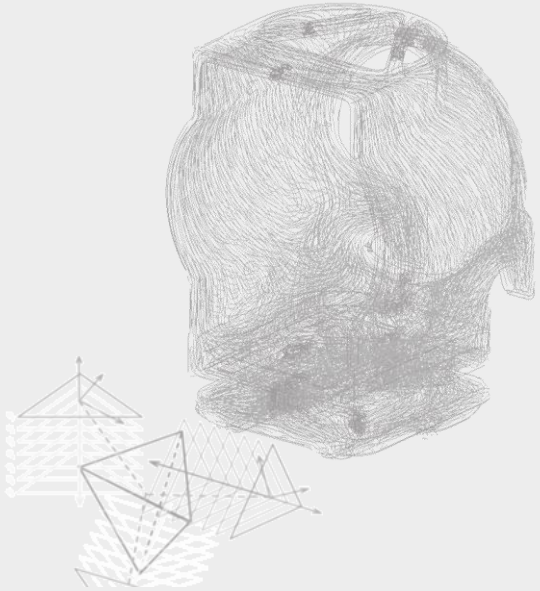
from test to validated
material cards

MICROMEC



3D anisotropic
material cards

FIBERMAP



individual mapping
process information

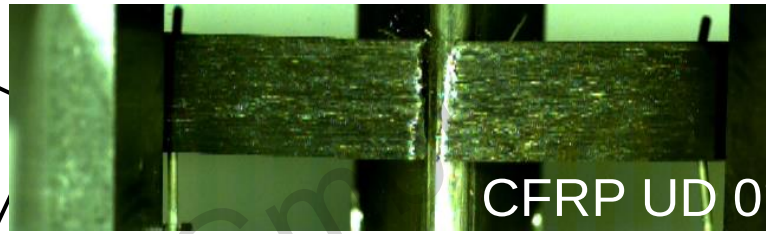
Composites (Carbon)

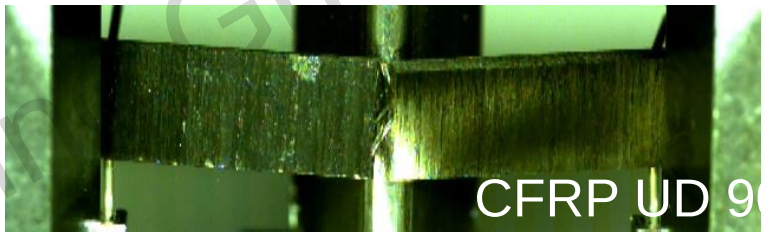
Composites – typical test setup

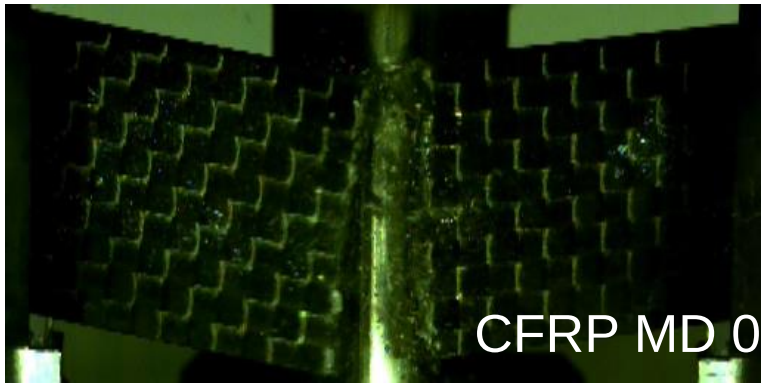
specimen	0°	45°	90°
UD	static		
MD		static, cyclic	
UD	static, dynamic		
MD	static, dynamic		
MD	Puncture		

Material Card

Validation







Composites – available LS-DYNA material models

VALIMAT

22	Orthotropic	None	None	None	Orientation dependent	Carbon, Glass, Kevlar endless & fabric
54/55	Orthotropic	None	Elastic Orthotropic	Strength	Chang-Chang/ Tsai-Wu Orientation dependent	
58	Orthotropic	None	Elastic Orthotropic	Strength, Stiffness	mod. Hashin Orientation dependent	
158	Orthotropic	None	Elastic Orthotropic	Visco-elasticity	Orientation dependent	
261	Orthotropic	None	Elastic Orthotropic	None	failure Pinho (Puck) Orientation dependent	
262	Orthotropic	None	Elastic Orthotropic	None	failure Camanho (Puck) Orientation dependent	

Composites – micro mechanical approach in VALIMAT

```
*Part_Composite
```

Material behaviour	
Material source	Implemented
Elasticity	Not isotropic elastic
Plasticity	Not selected
Failure/Damage	Not selected
Material card	*MAT_ANISOTROPIC_ELASTIC_PLASTIC (*MAT_157)
Deformation	*MAT_COMPOSITE_DAMAGE (*MAT_022)
Damage/Failure	*MAT_ENHANCED_COMPOSITE_DAMAGE (*MAT_054)
Materialcard id	*MAT_LAMINATED_COMPOSITE_FABRIC (*MAT_058)
Density	*MAT_RATE_SENSITIVE_COMPOSITE_FABRIC (*MAT_158)
Plasticity	*MAT_LAMINATED_FRACTURE_DAIMLER_PINHO (*MAT_261)
Function (Hardening, Elastic curve form)	*MAT_LAMINATED_FRACTURE_DAIMLER_CAMANHO (*MAT_262)
Strain rate dependency	*MAT_ANISOTROPIC_ELASTIC_PLASTIC (*MAT_157)
Micromec	*MAT_MICROMEC (*MAT_215)
Fracture	*MAT_MICROMEC (*MAT_215)+Carbon
Postfracture	None

Available LS-DYNA materialcards in VALIMAT™

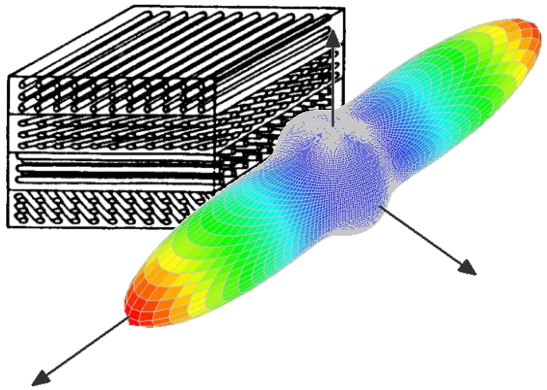
Test | Test database | Measurement | Report | Measurement curves | Viewer | a(t) | v(t) | s(t) | F(t) | F(s) | E(t) | sig(eps) | e

160826_004 | Material | Designvariablen | Layers

Model settings	
Material	
Idealization	
Material behaviour	
Material source	Implemented
	*MAT_COMPOSITE_DAMAGE (*MAT_022)
Materialcardcase	7306_MAT22
Damage/Failurecase	Chang Chang
Materialcard id	1000000
Density	1480
Plasticity	None
Function (Hardening, Elastic curve form)	
Strain rate dependency	None
Micromec	Endless fiber reinforced plastics
Matrix	
Density of the matrix	1093
E-Modulus	3000
Poisson's ratio	0.3
Yield strength	50
Strength at Break	70
Failure strain	0.05
Fiber	
Fillerlength	20000
Fillerdiameter	20
Phi or Psi	φ
Phi	58
Psi	71.7
Fillermaterial	T300
Orientation	
Fillerorientationtype	UD
Strength	
Strength evaluation	Fiber strength
XT	2300
XC	2000
Fracture	Composite
Postfracture	None

Composites – micro mechanical approach

in VALIMAT



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

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

Test | Test database | Measurement | Report | Measurement curves | Viewer | a(t) | v(t) | s(t) | F(t) | F(s) | E(t) | sig(eps) | e

160826_004 | Material | Designvariablen | Layers

Model settings	
Material	
Idealization	
Material behaviour	
Material source	Implemented
Material card	*MAT_COMPOSITE_DAMAGE (*MAT_022)
Materialcardcase	7500_MAT22
Damage/Failurecase	Chang Chang
Materialcard id	1000000
Density	1480
Plasticity	None
Function (Hardening, Elastic curve form)	
Strain rate dependency	None
Micromec	Endless fiber reinforced plastics
Matrix	
Density of the matrix	1093
E-Modulus	3000
Poisson's ratio	0.3
Yield strength	50
Strength at Break	70
Failure strain	0.05
Fiber	
Fillerlength	20000
Fillerdiameter	20
Phi or Psi	φ
Phi	58
Psi	71.7
Fillermaterial	T300
Orientation	
Fillerorientationtype	UD
Strength	
Strength evaluation	Fiber strength
XT	2300
XC	2000
Fracture	Composite
Postfracture	None

Matrix properties

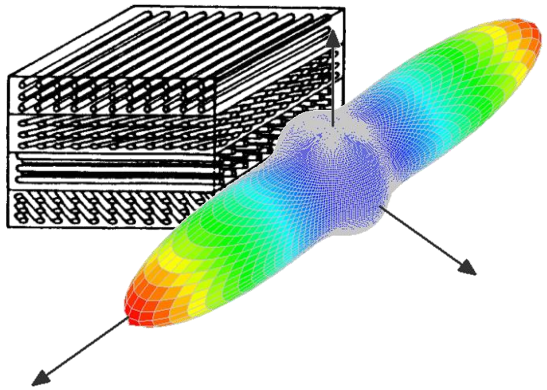
Filler properties

Orientation

Strength

Composites – micro mechanical approach

in VALIMAT



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

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

Typical Design Variables for *MAT_022

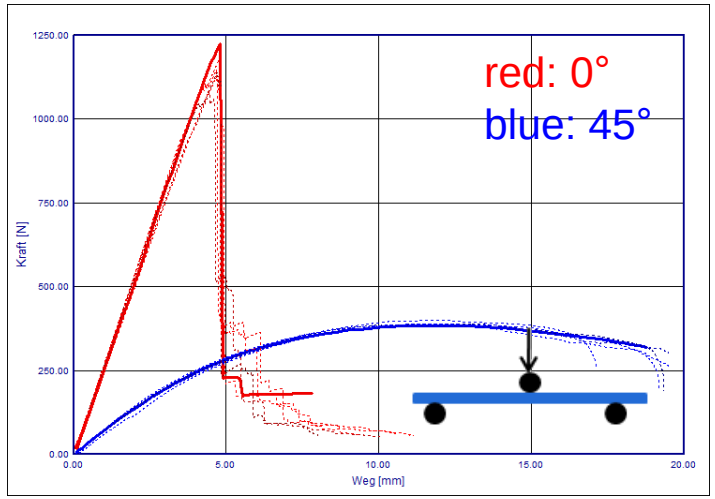
160826_004 | Material | Designvariablen | Layers

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

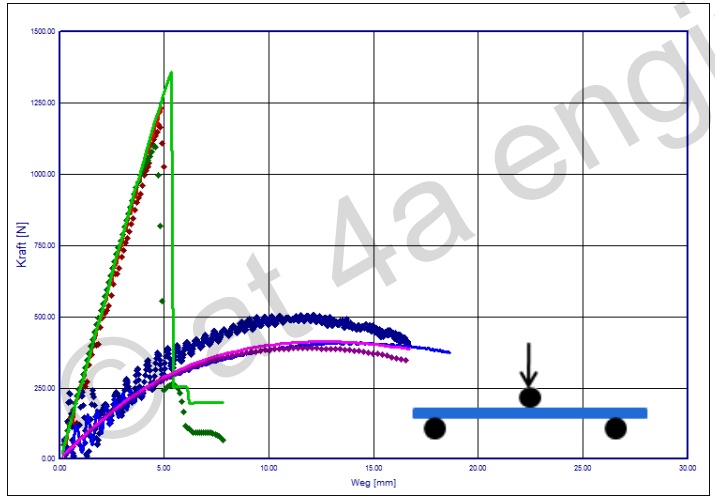
Composites – validation with final material card

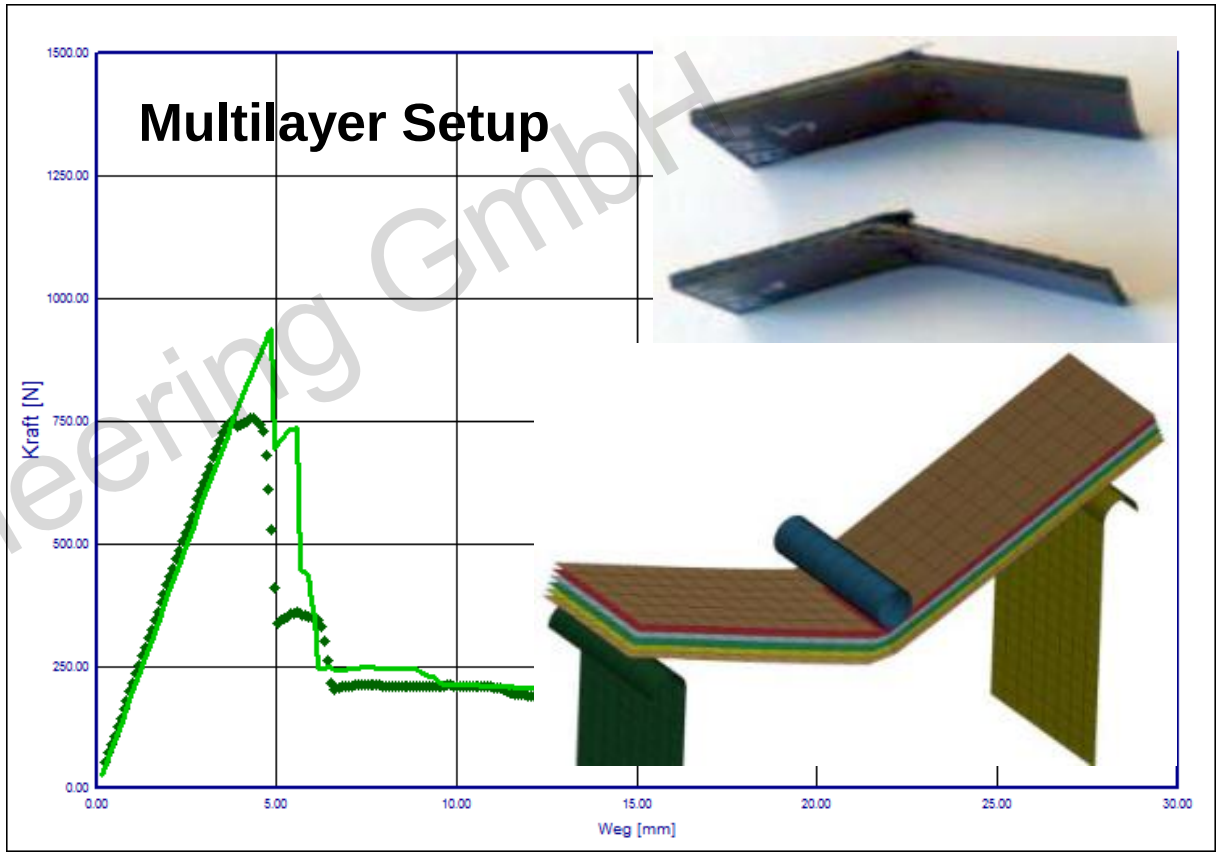
VALIMAT

Orientation



static versus dynamic

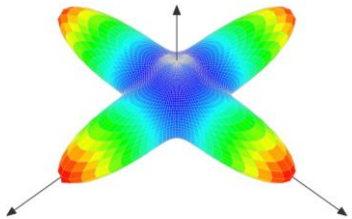




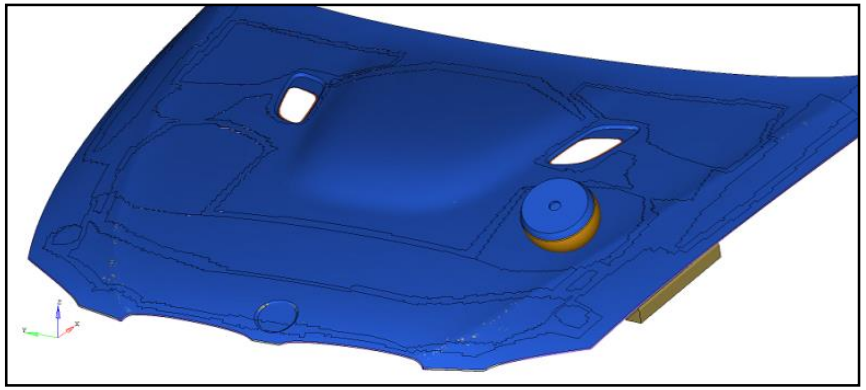
…. test
— simulation

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

Composite – case study



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



SOURCE: LINK to PAPER

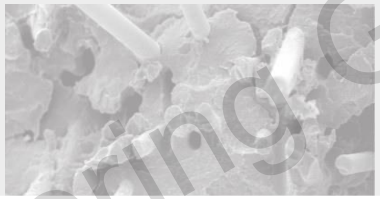
intelligent reliable solutions for plastics, composites, metals, foams, ...

IMPETUS

VALIMAT

MICROMEC

FIBERMAP



Thermoplastics

Fiber reinforced Plastics (SFRT & LFRT)

Composites (Carbon)

efficient
dynamic testing

from test to validated
material cards

3D anisotropic
material cards

individual mapping
process information

Summary

- LS-DYNA offers a lot of different material models for
  - thermoplastic materials
  - short and long fiber reinforced thermoplastics
  - classical composites
- all materials show different mechanical response dependent on different aspects like anisotropy, viscosity, temperature, moisture, …
- material characterization must focus on the main behavior and material card generation must reflect that
- tools are needed to handle data and to fit complex failure models

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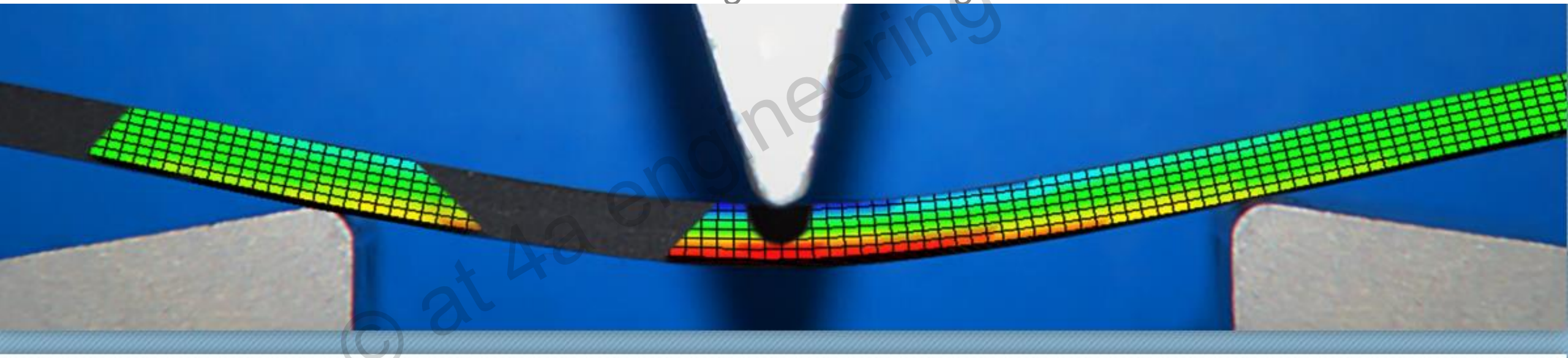
VALIMAT

Thanks for your attention

interested in more …

join us from 2.-4.3.2020

Salzburg Werfenweng



Technology Day 2020 - Plastics on the test rig - Testing and simulation

Appendix
Additional overview

efficient dynamic testing

IMPETUS

plastics

engineering

production

excellence in testing

concepts

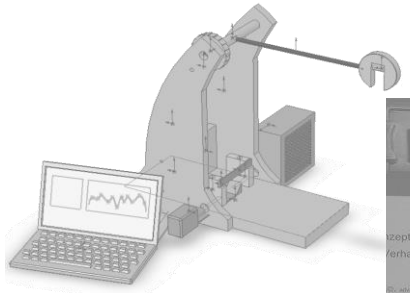
simulation

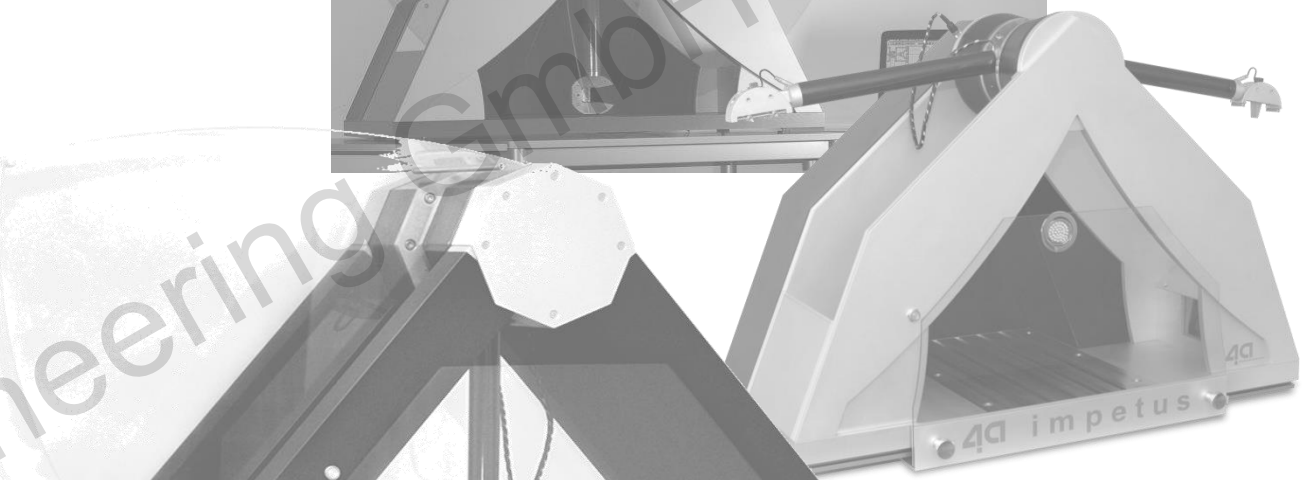
lightweight

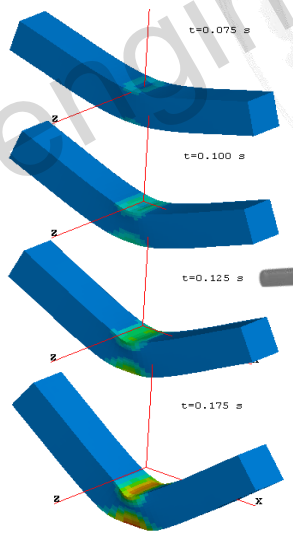
prototypes

Efficient dynamic testing

- desktop testing device
- instrumented high-speed testing
  - acceleration → force / displacement
- impact velocity 0.5 – 4.5 m/s







IMPETUS™ data specification

Highspeed camera is an optional equipment and can be ordered separately.

technical specifications

maximum energy	50J
length of swing arm	500mm
mass of swing arm	1.5 - 3.0kg
impact velocity	0.5 - 4.4m/s

weights and dimensions

L x W x H	1400 x 600 x 850mm
mass	165kg

desk load and dimensions minimum required

L x W x H	1500 x 800 x 800mm
minimum load	250kg

electrical supply data

230 VAC 50 Hz	0.5A
115 VAC 60 Hz	1.0A

5V camera trigger

output level high	>2.5V
output level low	<0.5V

Photron High Speed Camera data specification

Photron

FASTCAM	MINI AX200 540K	NOVA S6 800K	NOVA S9 900K	NOVA S12 1000K	
CMOS Image Sensor	1024 x 1024	1024 x 1024	1024 x 1024	1024 x 1024	px
max. fps full resolution	6400	6400	9000	12800	fps
max. Frame Rate	540000	800000	900000	1000000	fps
Light Sensitivity	40000	64000	64000	64000	ISO
L x W x H	94 x 120 x 120	217.2 x 120 x 120	217.2 x 120 x 120	217.2 x 120 x 120	mm
weight	1.5	3.3	3.3	3.3	kg

Vision Devices lighting data specification

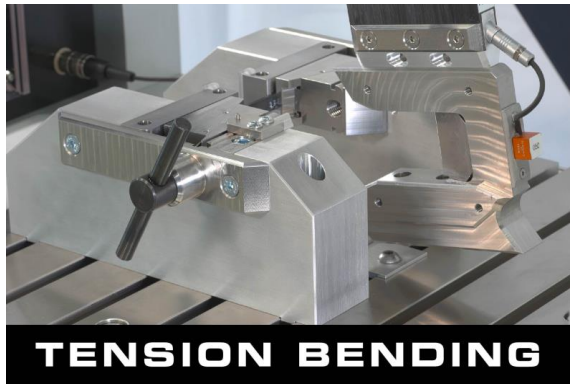
LED VD7000

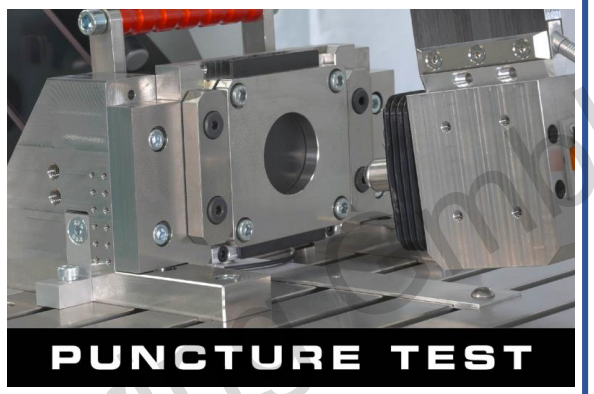
operating voltage	24 - 36	V
rated power	17 - 72	W
Luminous flux	2100	lm
Luminous flux boost	7280	lm
color temperature	6000	K
L x W x H	100 x 46 x 46	mm

VISION DEVICES

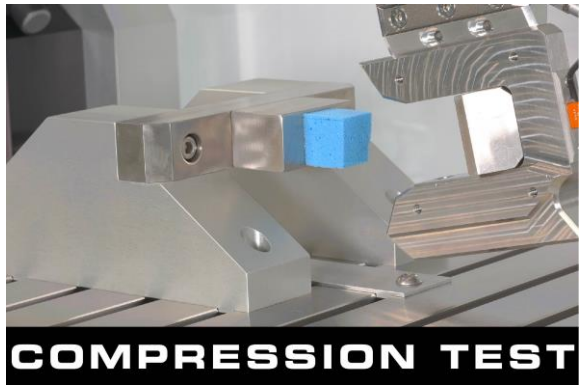
IMPETUS™ - configurations


3 POINT BENDING

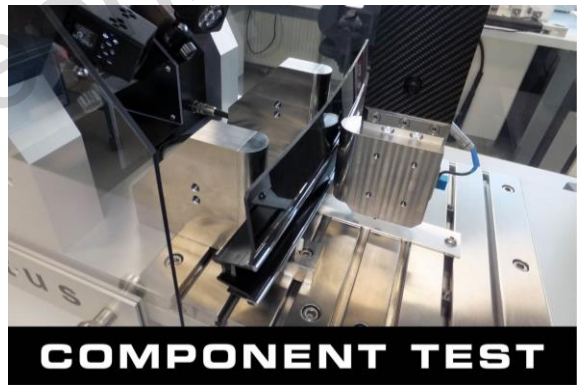

TENSION BENDING

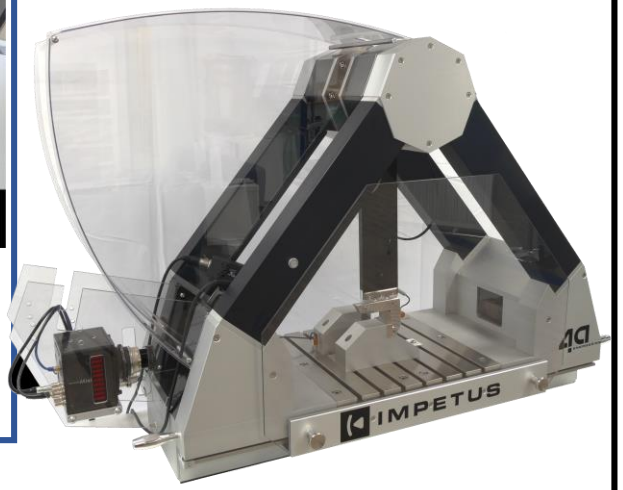

PUNCTURE TEST


TENSION TEST


COMPRESSION TEST


SAMPLE MAGAZIN


COMPONENT TEST

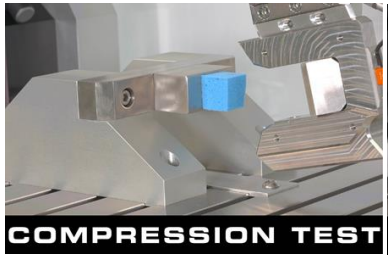
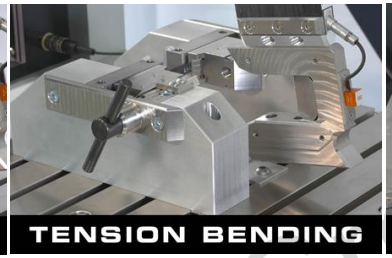
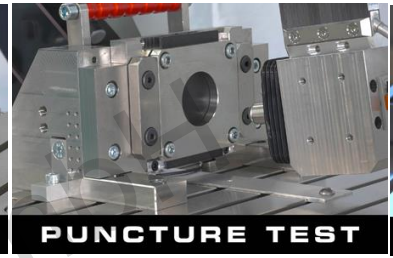


BASIC

STANDARD

PROFESSIONAL

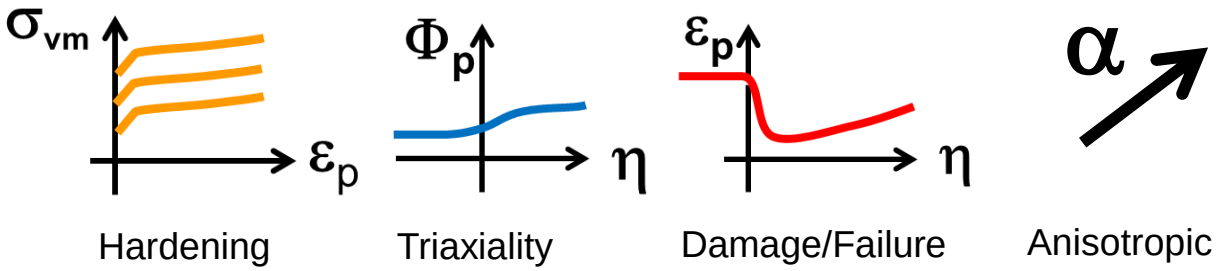
Efficient dynamic testing

Material *(Typical thickness)*	 COMPRESSION TEST	 3 POINT BENDING	 TENSION BENDING	 PUNCTURE TEST	 TENSION TEST
Plastic *(1 - 4 mm)*		✓	✓	✓	✓
Foam *(20 - 30 mm)*	✓	~			
Composite *(1 - 4 mm)*		✓		✓	
Aluminum *(1 – 2.5 mm)*		✓	✓		✓
Metals *(0.5 – 1.5 mm)*		✓			

From test to material card

VALIMAT

plastics
engineering
production
excellence in validation
concepts
simulation
lightweight
prototypes



Hardening | Triaxiality | Damage/Failure | Anisotropic

Material data generation for simulation

Current Situation

- more and more data
- Not only tension
  - Different loadcases (compression, shear, ….)
- More complex simulation models
  Investigations on failure

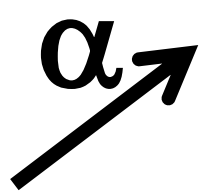
NEEDED

→ Smart USER INTERFACE

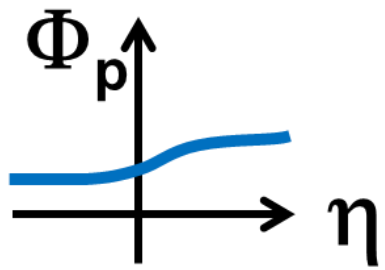
→ Optimization

→ DATABASE handling data

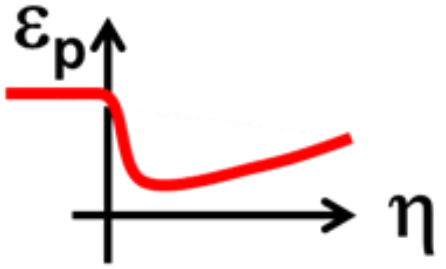
Hardening



Anisotropic



Triaxiality



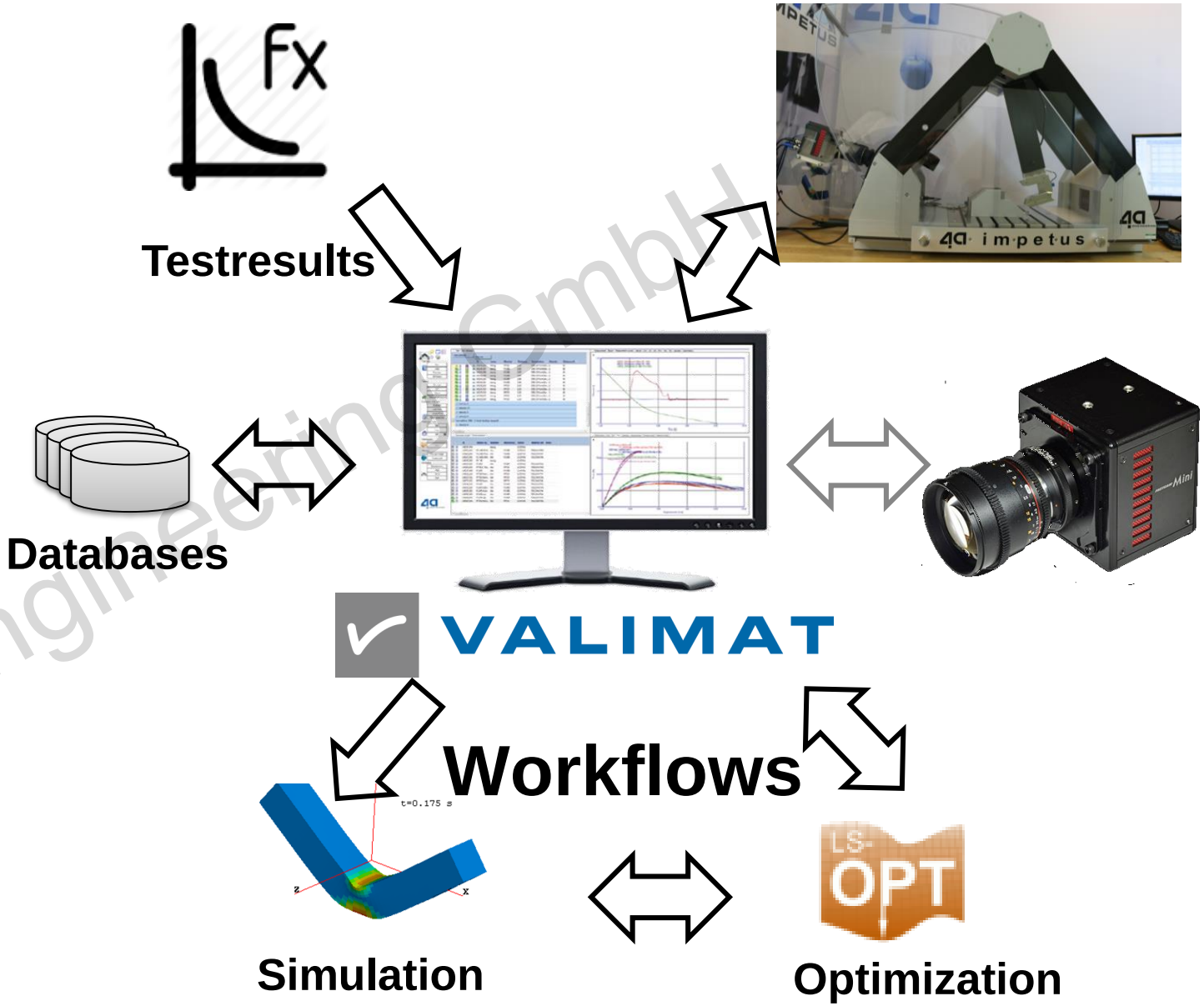
Damage/Failure

From test to material card

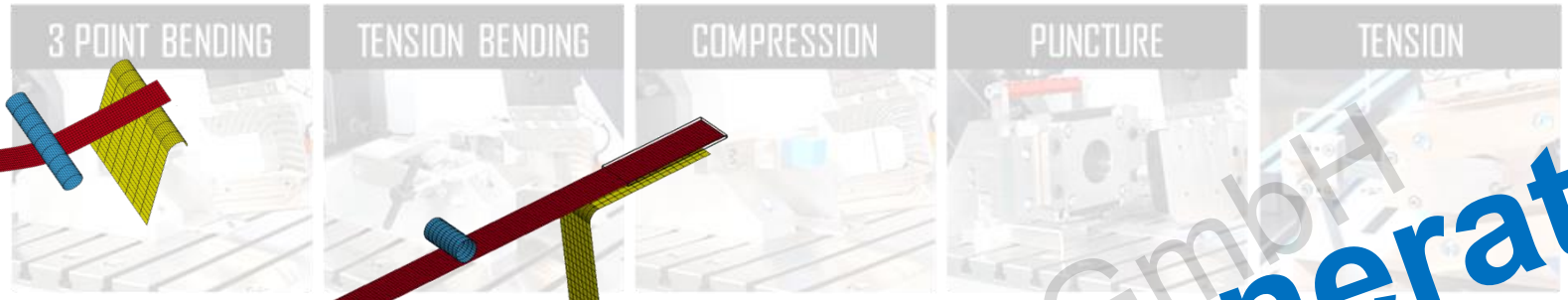
VALIMAT™

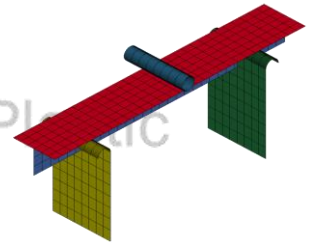
Advantage

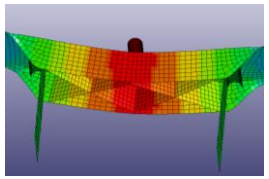
- Handling of bigdata
- Complex models
- Good correlation to simulation

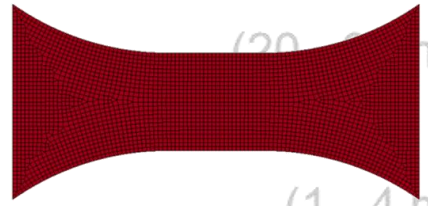


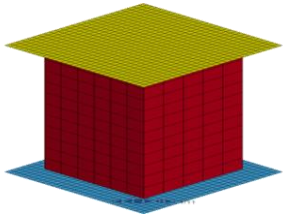
Efficient dynamic testing

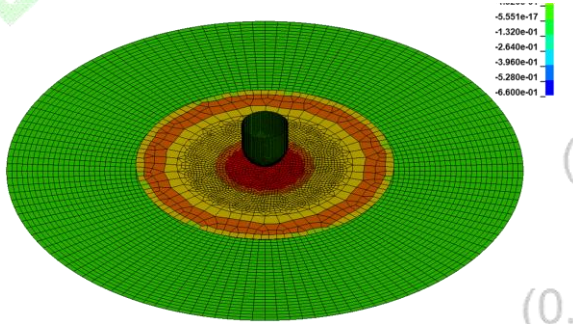












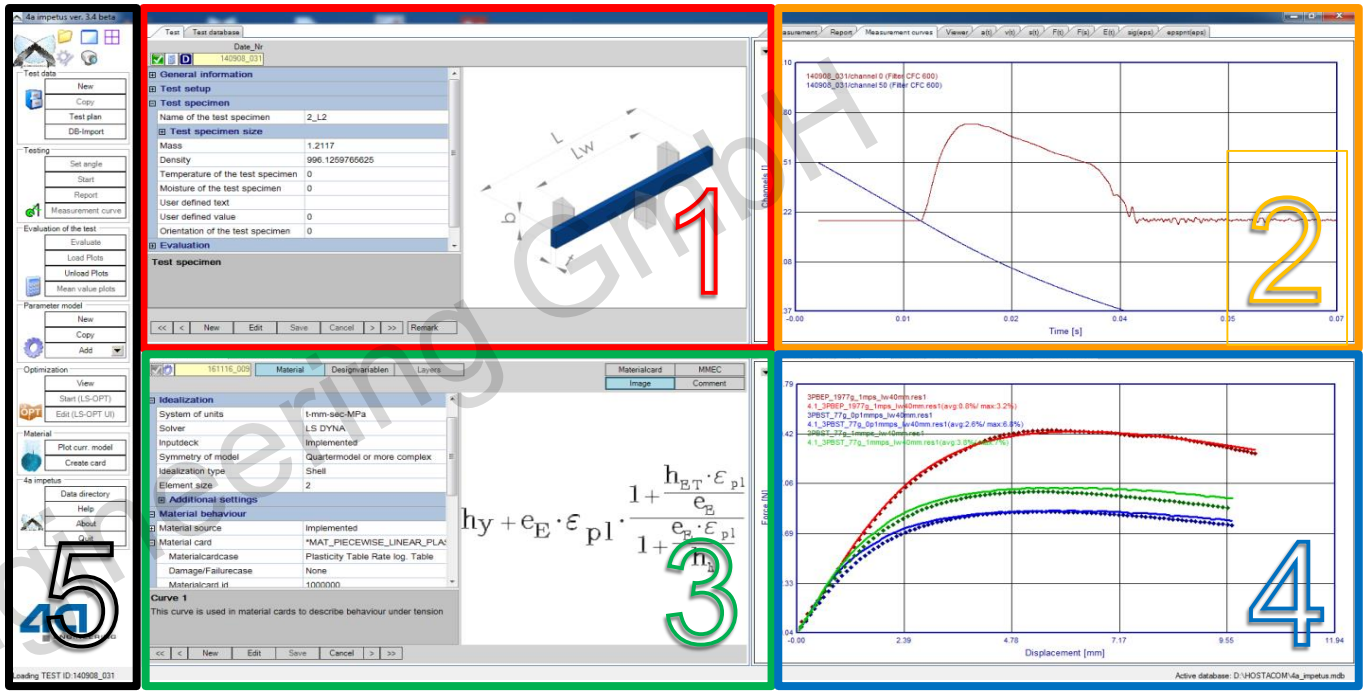
Plastic
Foam
Composite
Aluminum
Metals

typical thickness
(1 - 4 mm)
(20 - 4 mm)
(1 - 4 mm)
(1 – 2.5 mm)
(0.5 – 1.5 mm)

automated FE-model generation

VALIMAT

GUI - the graphic user interface is divided into five parts:

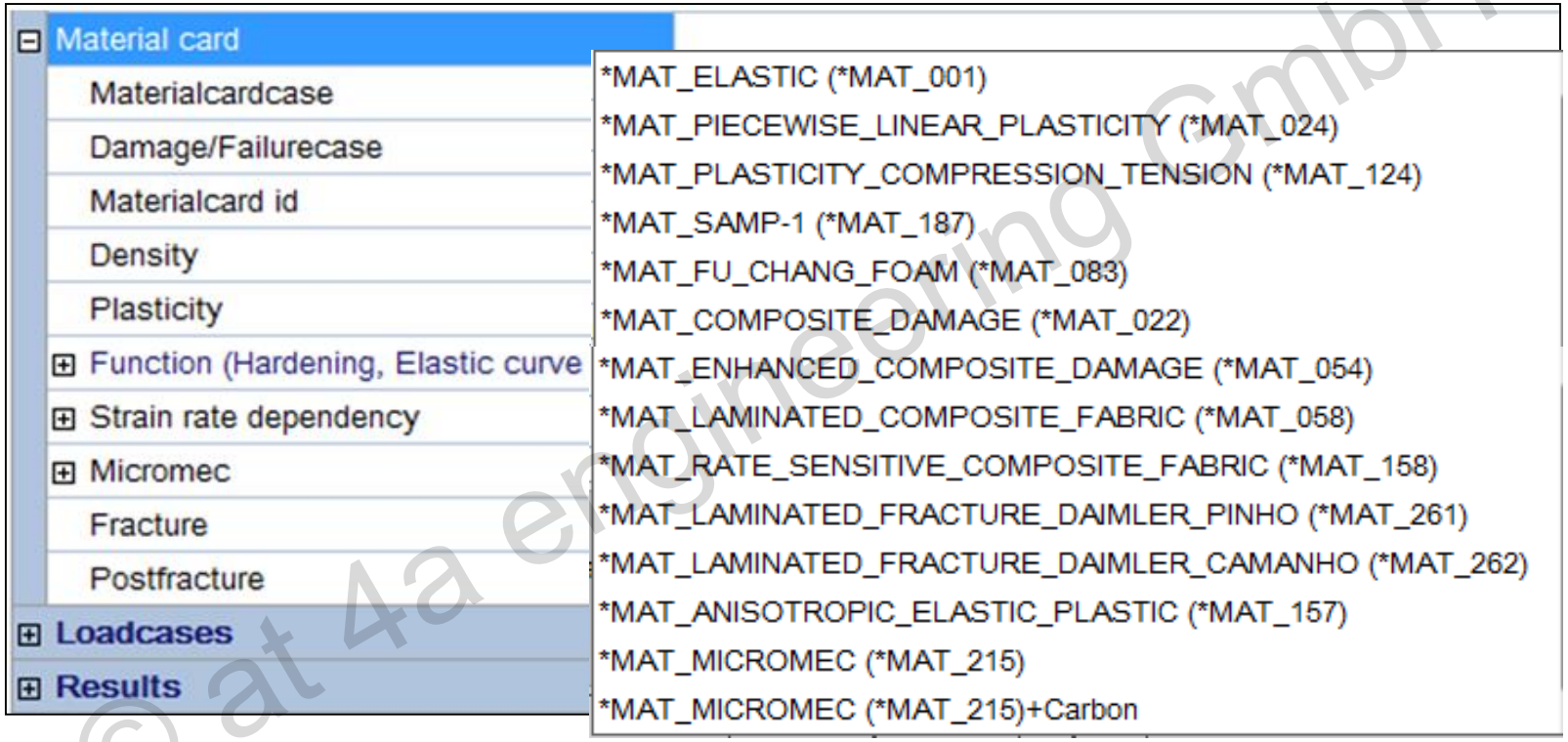


basic menu (left margin, (5))
window top left (1) → test; data base
window top right (2) → measurements; info; measurement results
window bottom left (3) → model parameter; optimization settings
window bottom right (4) → optimization; results of the optimization
the basic menu describes the principal process from the test to the completed material model and allows a simple and fast access of the most important functions.

Material models

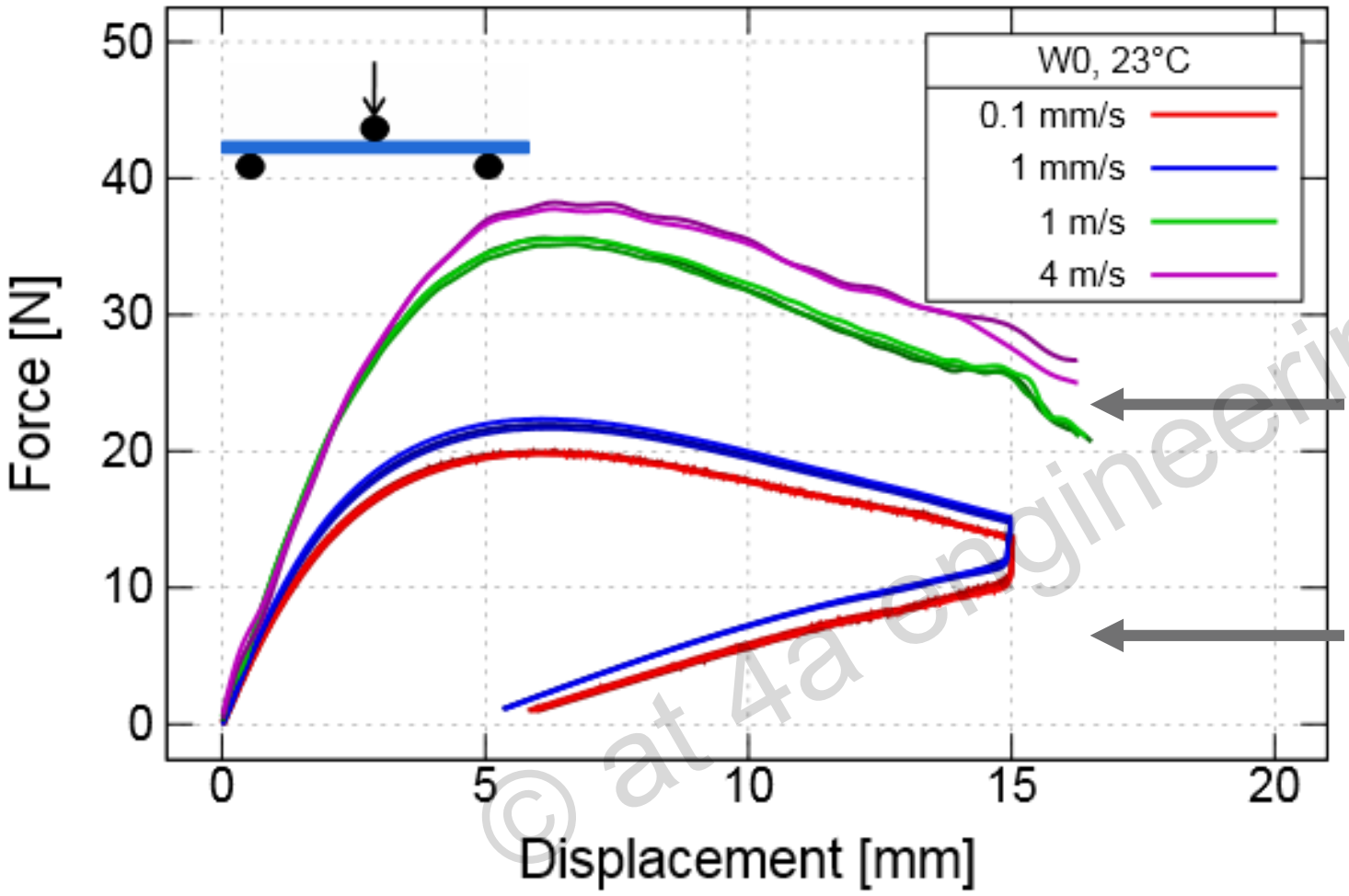
VALIMAT

- Plenty of direct implemented ***LS-Dyna*** material models ***(also Abaqus, PamCrash)***



- ***Whole number*** of LS-Dyna material models is available through ***userdefined material cards***

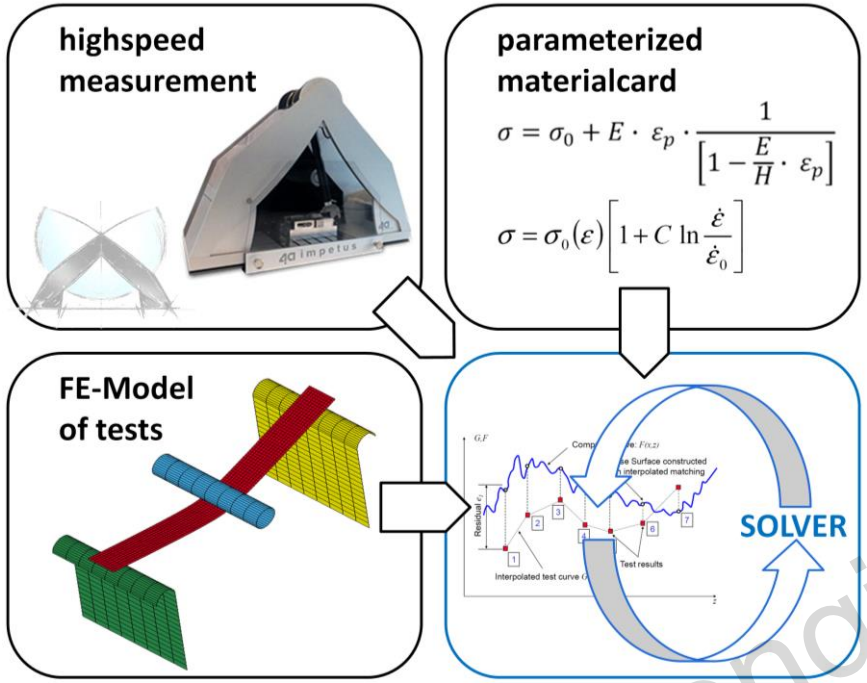
Efficient dynamic testing

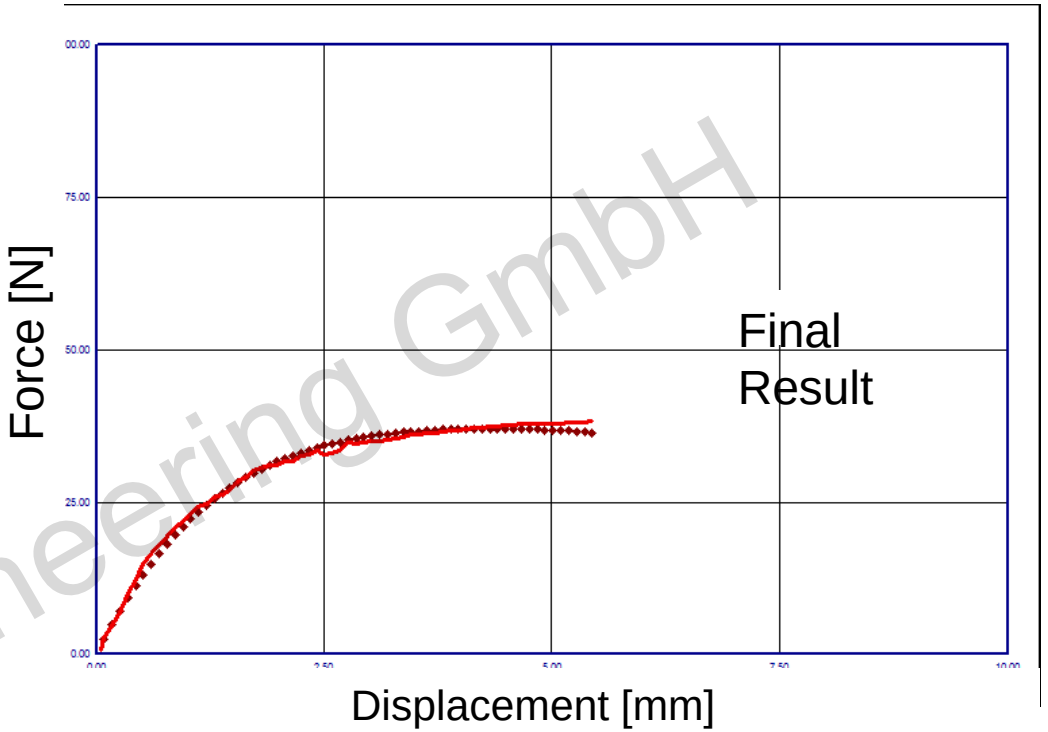


IMPETUS

Universal static testing

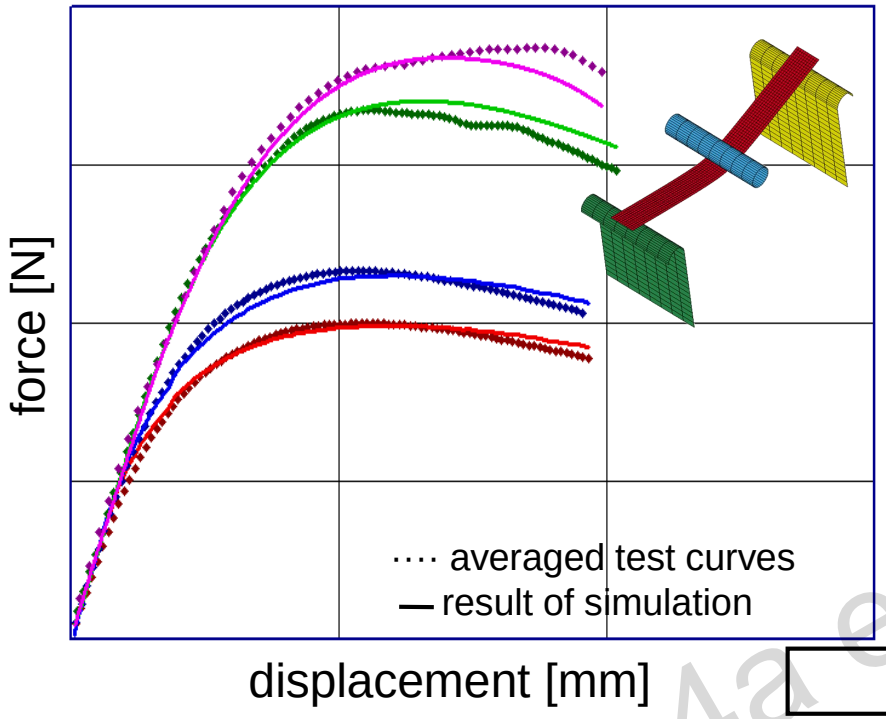
Reverse engineering

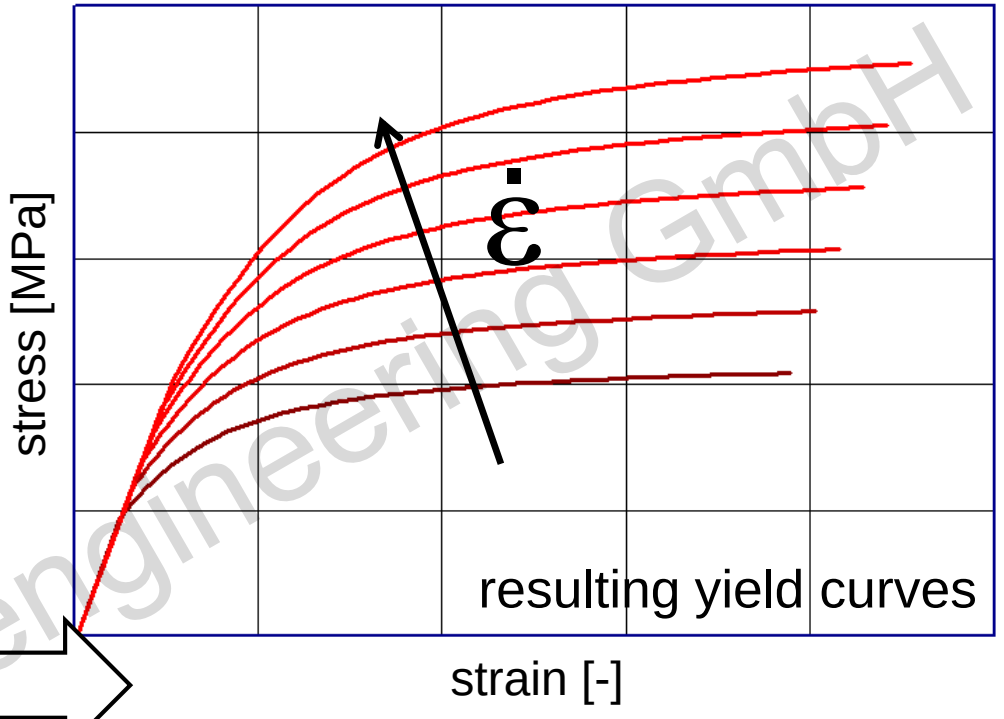




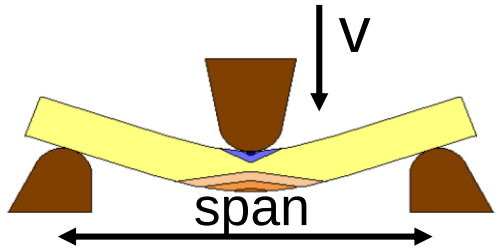
Source: Dynamic Material Characterization Using 4a impetus – PPS Conference 2015, Graz

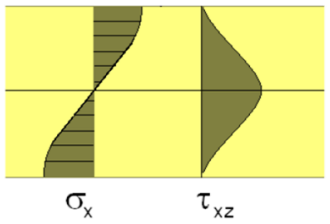
From bending → *MAT_024

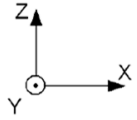


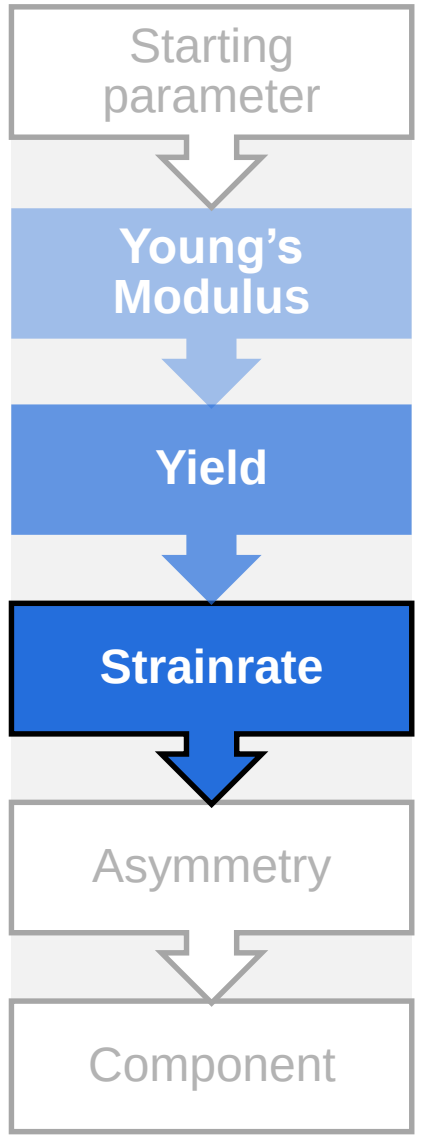


v [m/s]	span [mm]
0.0001	40
0.001	40
1	40
4	40









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

VALIMAT

- manage test results
  (import, export, filter, evaluation)
- statistics
- automatic report
- material card generation
- material card validation

for all material types

from test to validated material cards

IMPETUS

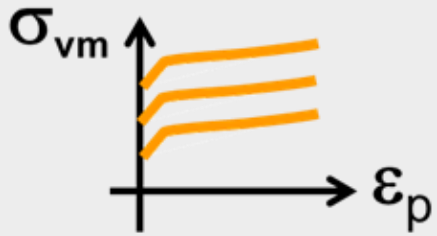
- single pendulum up to 4.5 m/s
- double pendulum up to 8 m/s
- standard test methods
- specialized test methods
- component testing
- advanced measurement

efficient dynamic testing

plastics and composites

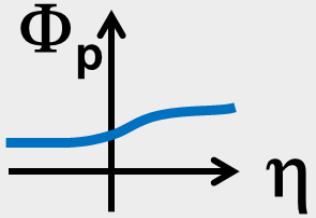
Intelligent reliable solutions for plastics, composites, metals, foams, ...

VALIMAT

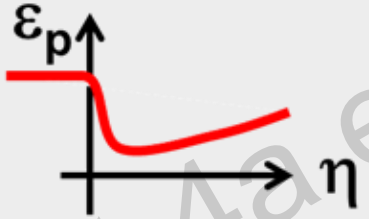


Hardening

Anisotropic



Triaxiality



Damage/Failure

for all material types

from test to validated material cards

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