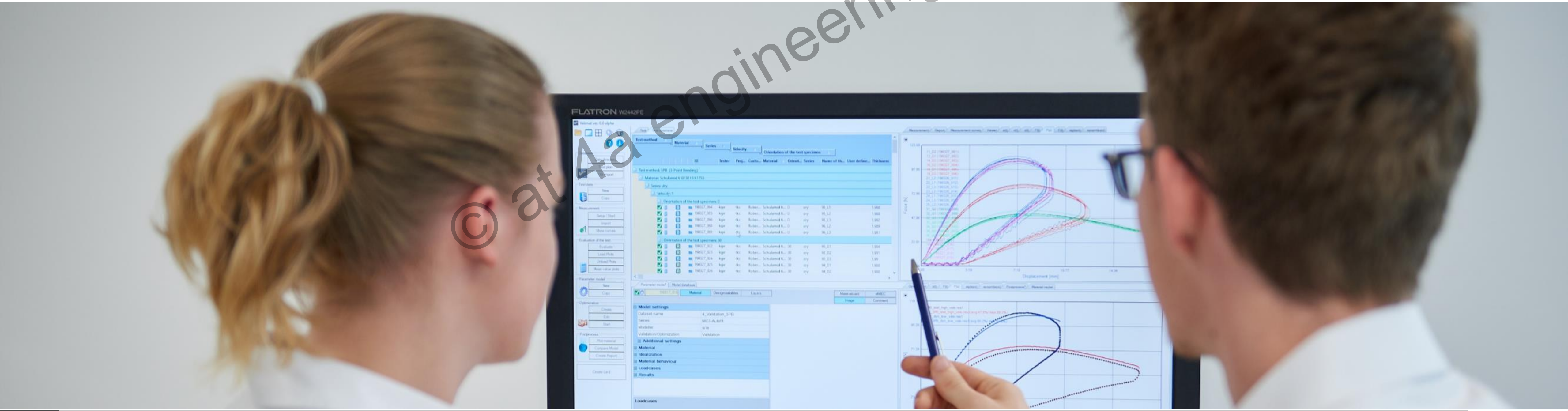
4a Summer School Day 6

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

B. Hirschmann, P. Reithofer, Ch. Schober
Traboch, 15.07.2020



4a Summer School

2^{nd} week - Advanced topics

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

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

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

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

Content of session 6

Overview – material models

general yield surface (***MAT_187**) and

Comprehensive AutoFit setup

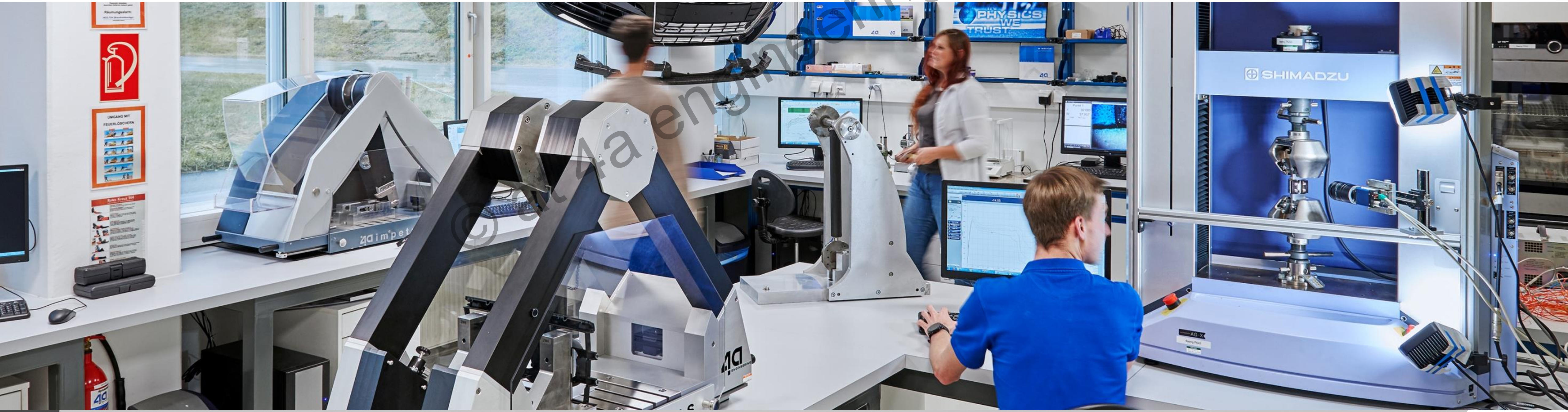
***MAT_024**

***MAT_187**

Overview - failure models

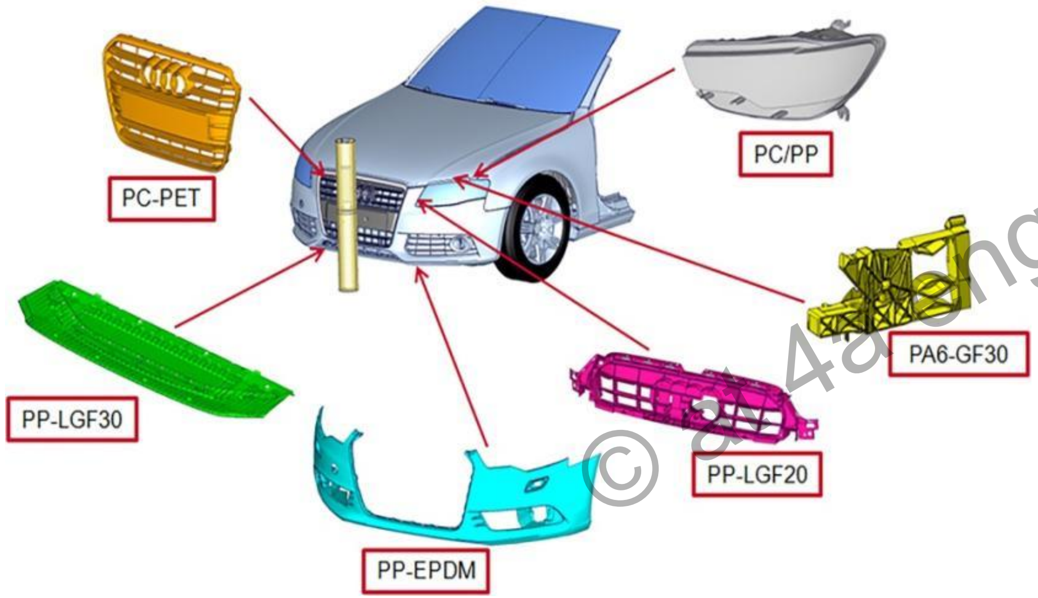
short Outlook 3.8

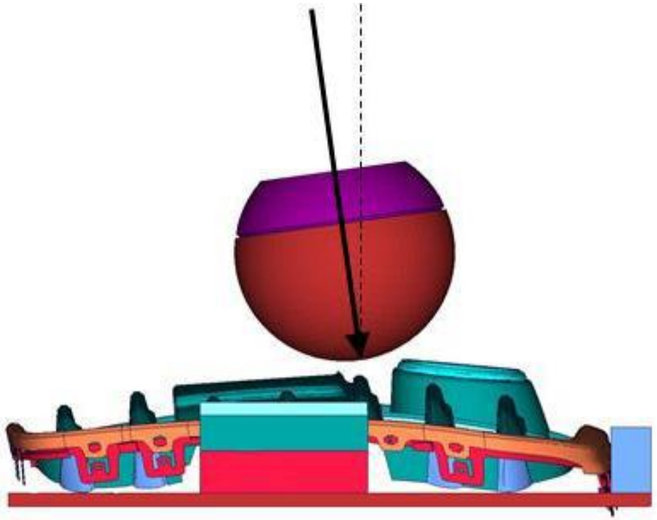
Short Recap what we can measure!

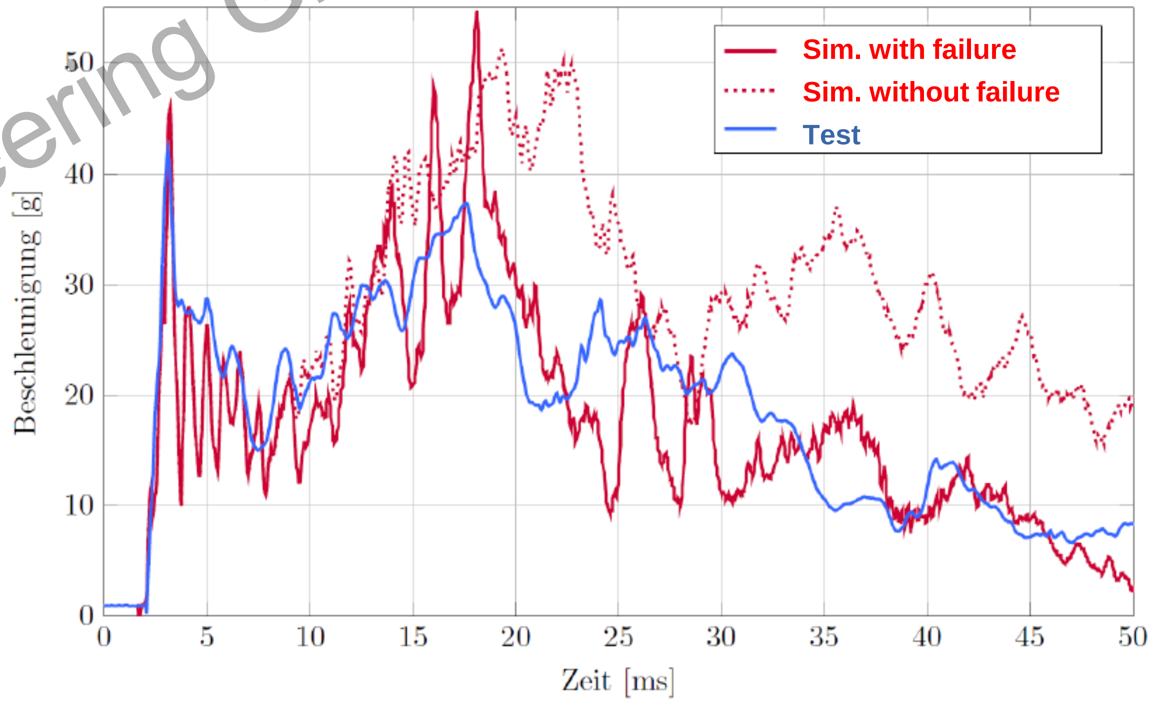


Motivation

- Low Speed Impact behavior
- Plenty of different plastic grades
- Temperature influence -35°C up to 80°C







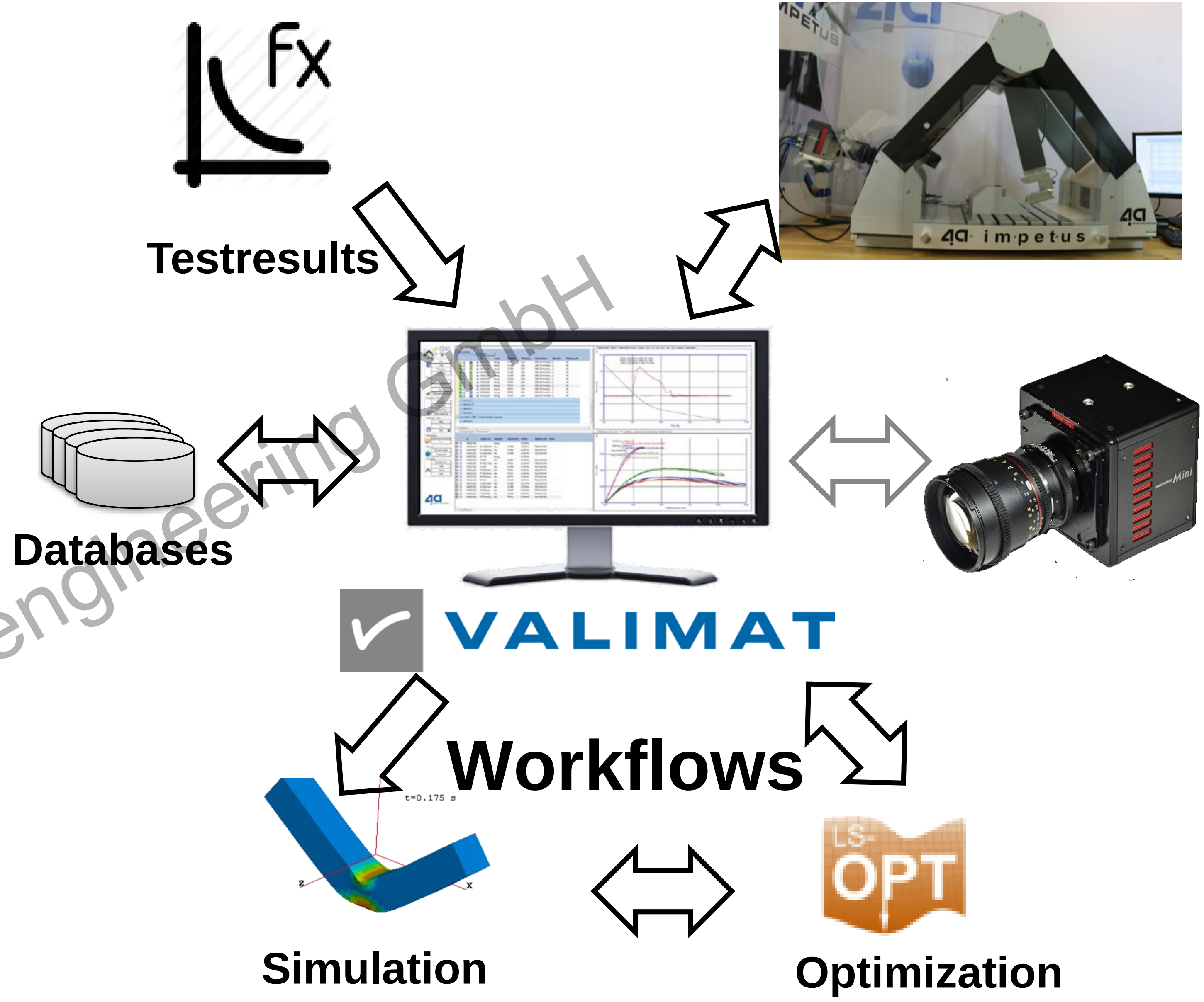
SOURCE: LINK to PAPER

from test to material card

VALIMAT®

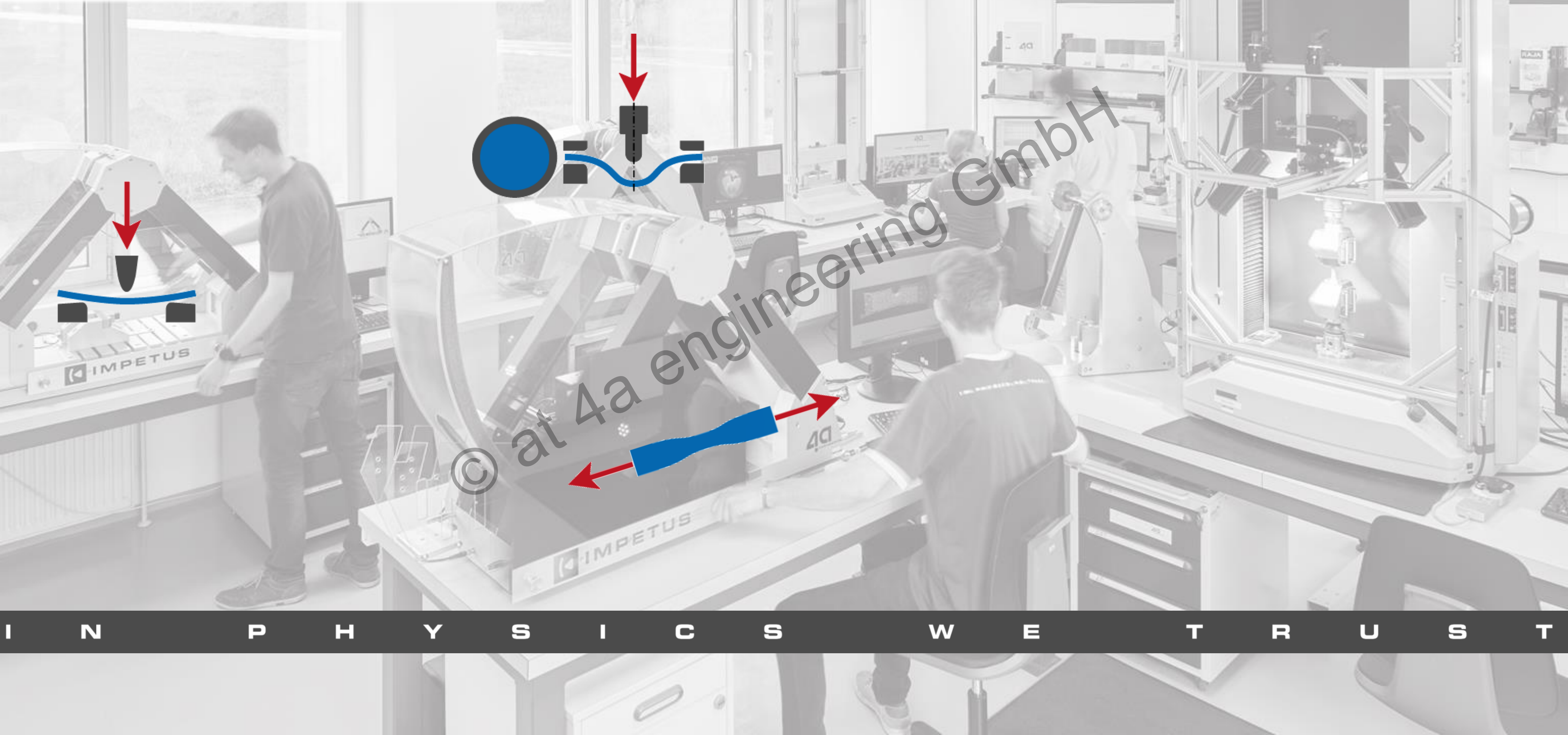
Advantage

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



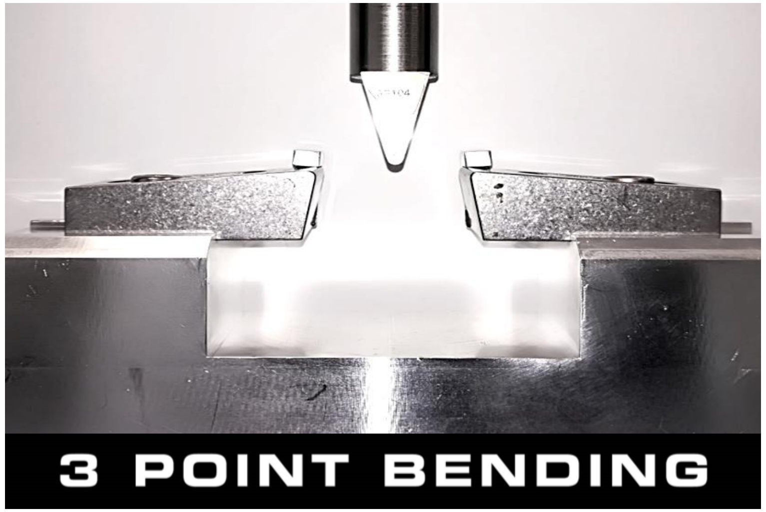
IMPETUS

DAY2 – LIVE



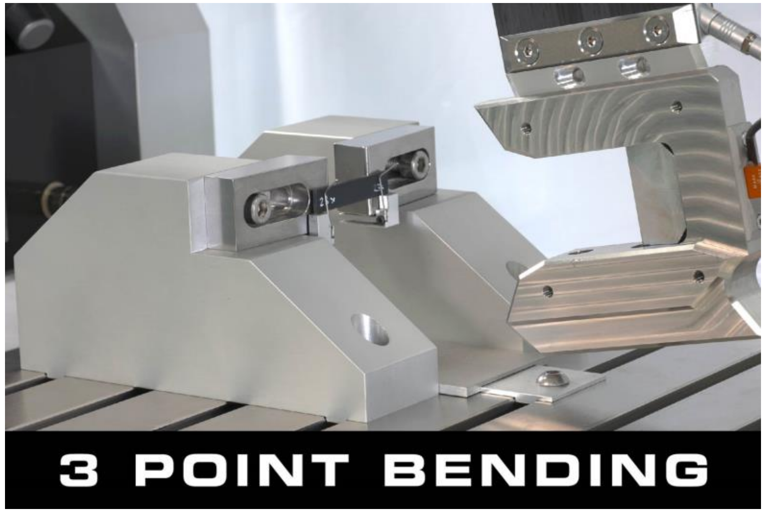
IN PHYSICS WE TRUST

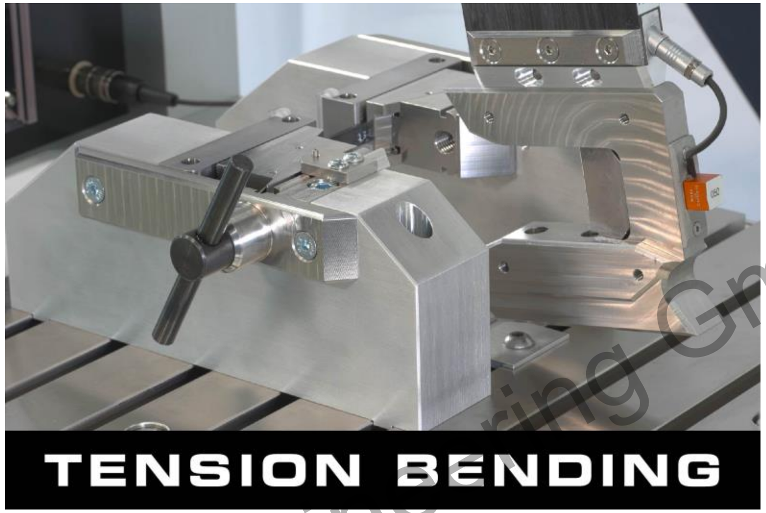
Static Testing

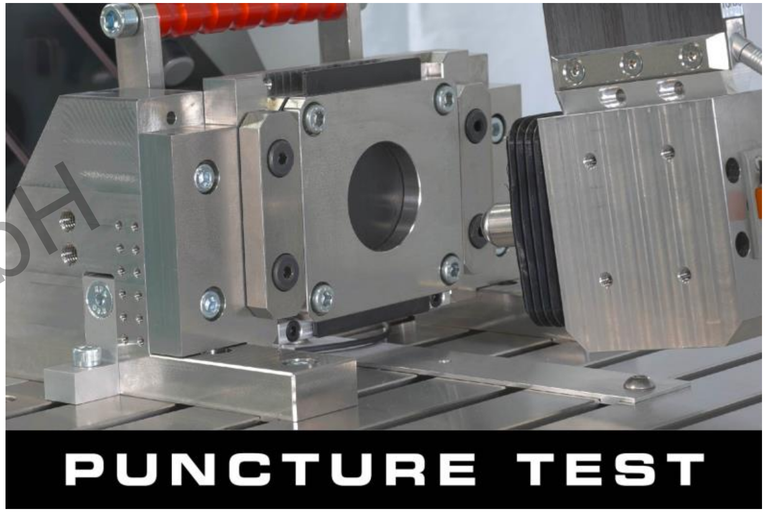


static ~ 1mm/s

IMPETUS® - efficient dynamic testing



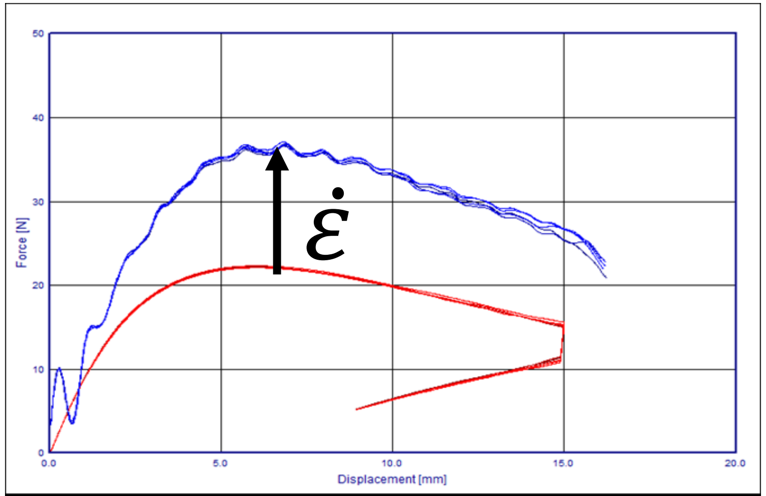




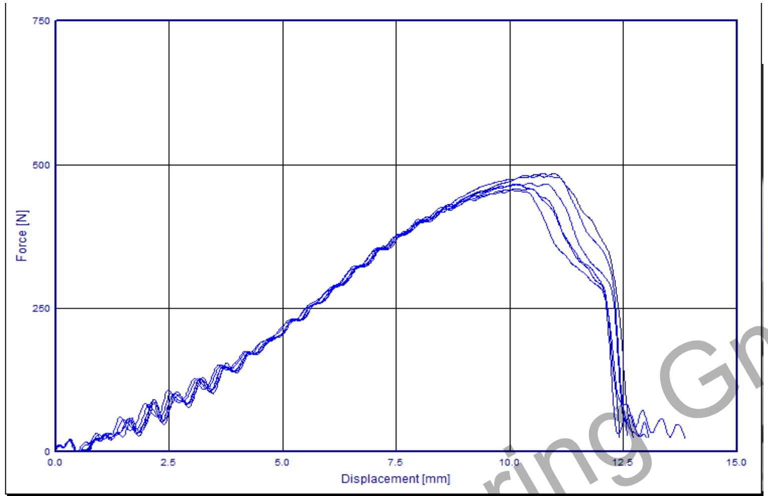
IMPETUS® ~ 3 m/s

Measurement Results ➔ Material Model

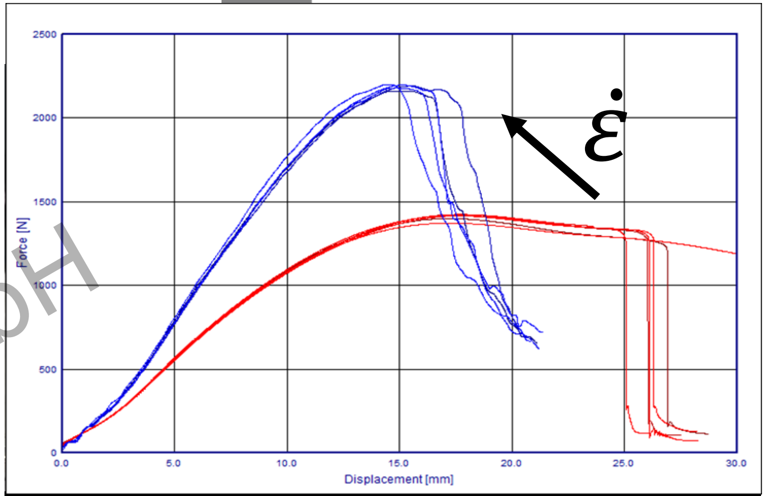
IMPETUS



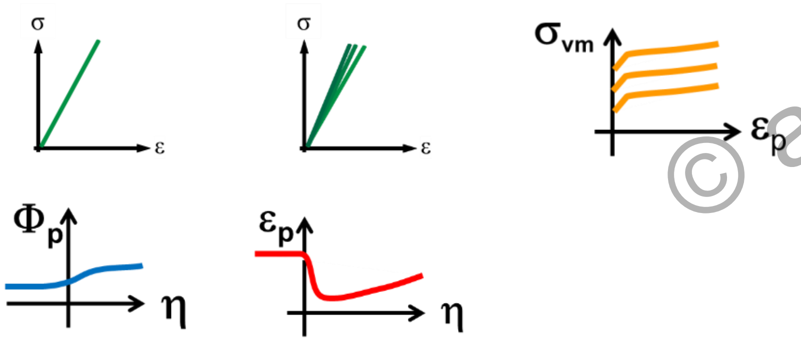
3 POINT BENDING

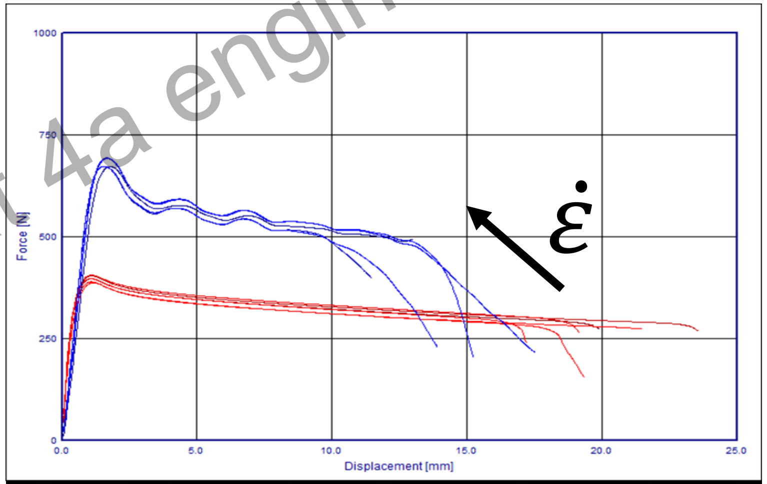


TENSION BENDING

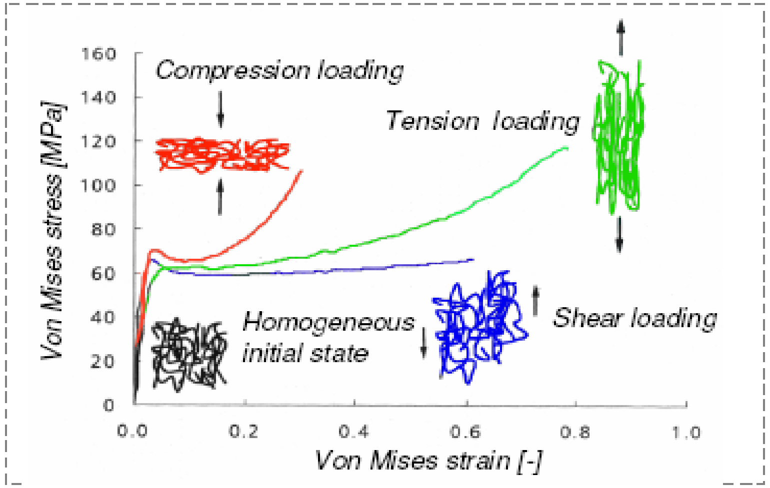


PUNCTURE TEST





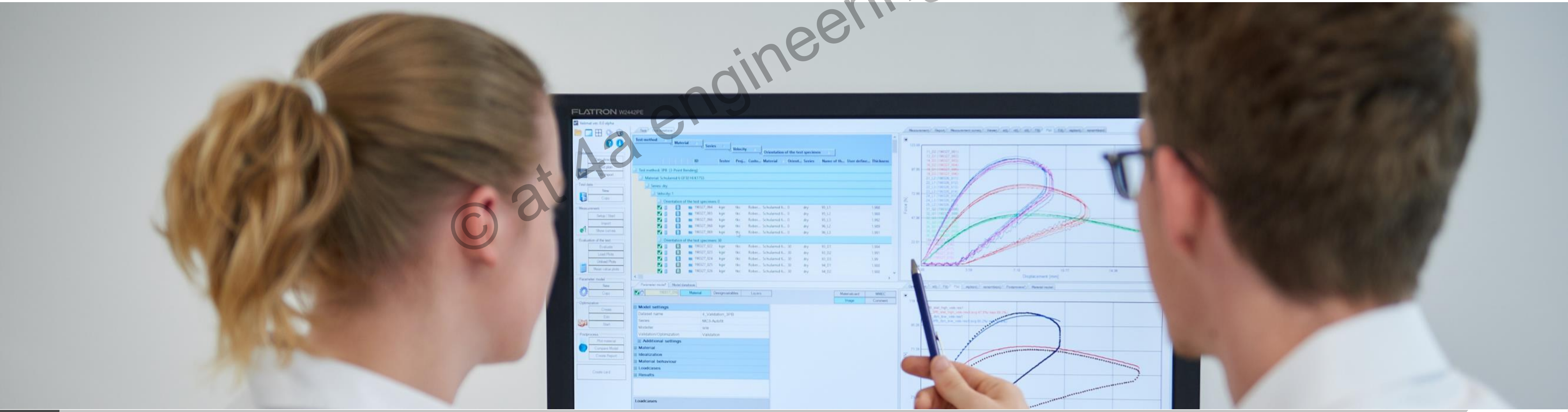
TENSION TEST



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

4a

Short Recap available material models in LS-DYNA®



yield surface – notes about notation

- Stress Tensor:

$$\boldsymbol{\sigma} = \begin{pmatrix} \sigma_x & \tau_{xy} & \tau_{zx} \\ \tau_{xy} & \sigma_y & \tau_{yz} \\ \tau_{zx} & \tau_{yz} & \sigma_z \end{pmatrix} \rightarrow \begin{pmatrix} \sigma_x \\ \sigma_y \\ \sigma_z \\ \tau_{xy} \\ \tau_{yz} \\ \tau_{zx} \end{pmatrix}$$

- Hydrostatic pressure

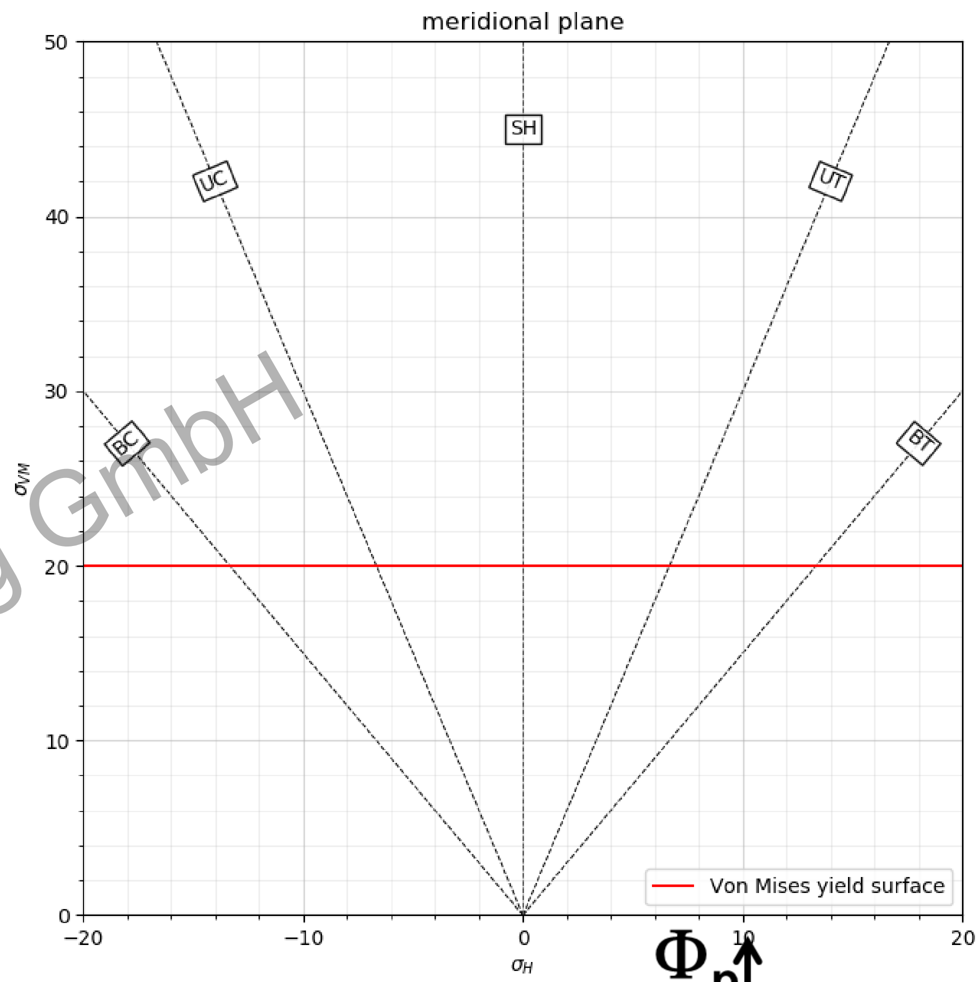
$$p = -\frac{1}{3}(\sigma_x + \sigma_y + \sigma_z)$$

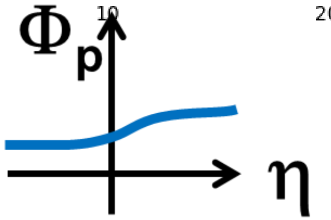
- Von Mises stress:

$$q = \sigma_{VM} = \sqrt{\sigma_x{}^2 + \sigma_y{}^2 + \sigma_z{}^2 - \sigma_x\sigma_y - \sigma_y\sigma_z - \sigma_z\sigma_x + 3(\tau_{xy}{}^2 + \tau_{yz}{}^2 + \tau_{zx}{}^2)}$$

- Triaxiality:

$$\eta = -\frac{p}{q}$$

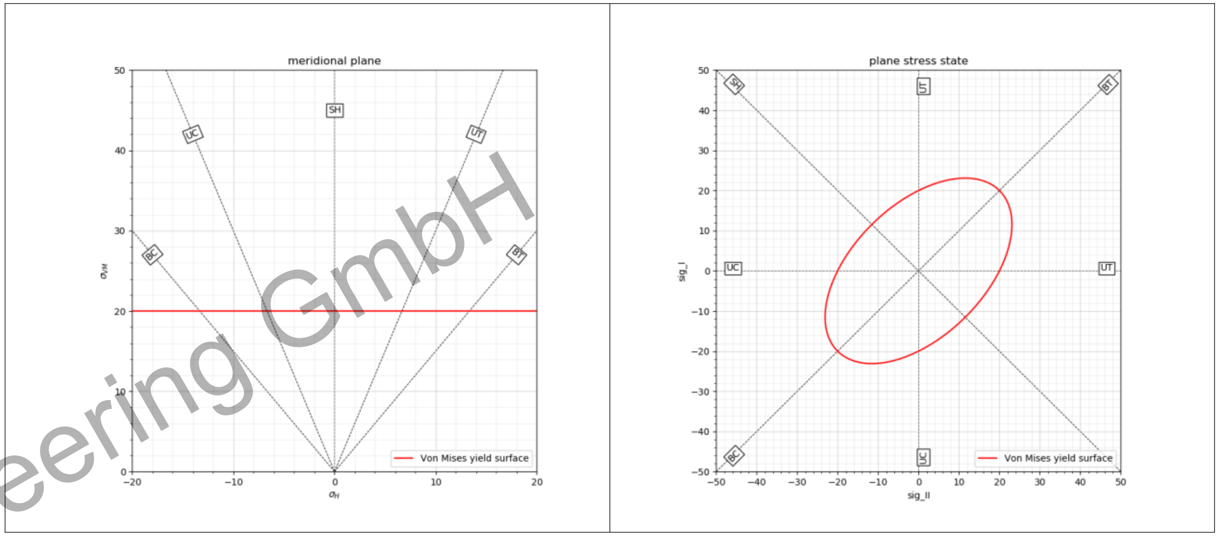




Triaxiality

Commonly Used Material Models For Plastics

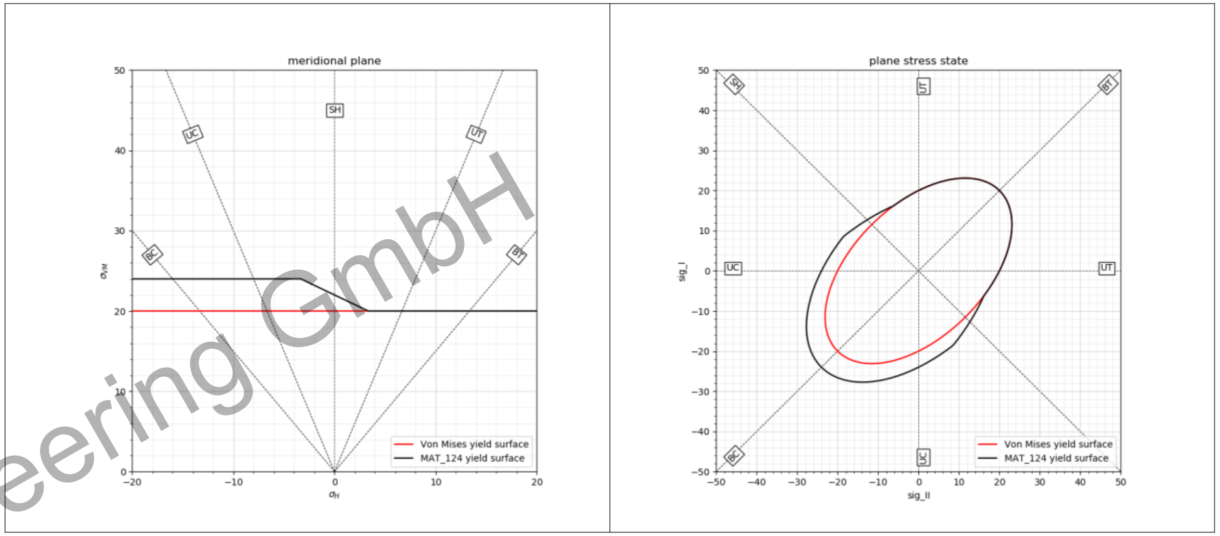
- ***MAT_024** - The workhorse*
  (**MAT_081*, **MAT_089*, **MAT_123*, …)



Material model	yield surface	Visco-elasticity	Visco-plasticity	Comp./tension asymmetry	plastic Poisson's ratio
***MAT_024**	von Mises	✗	✓	✗	0.5

Commonly Used Material Models For Plastics

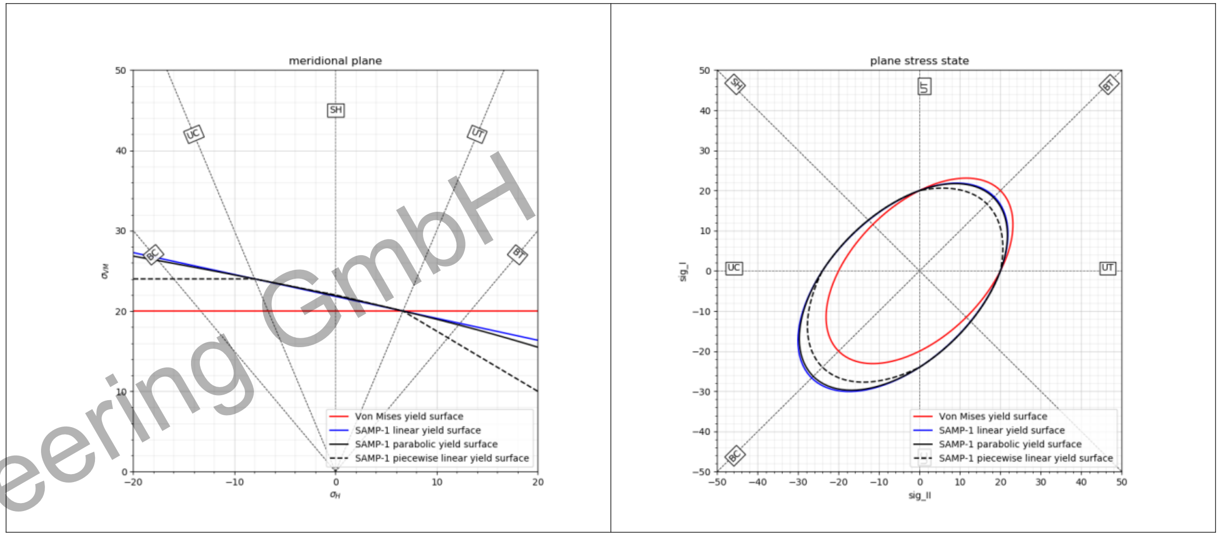
- ***MAT_024* - The workhorse**
  (***MAT_081**, ***MAT_089**, ***MAT_123**, …)
- ***MAT_124 - The hidden***



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

Commonly Used Material Models For Plastics

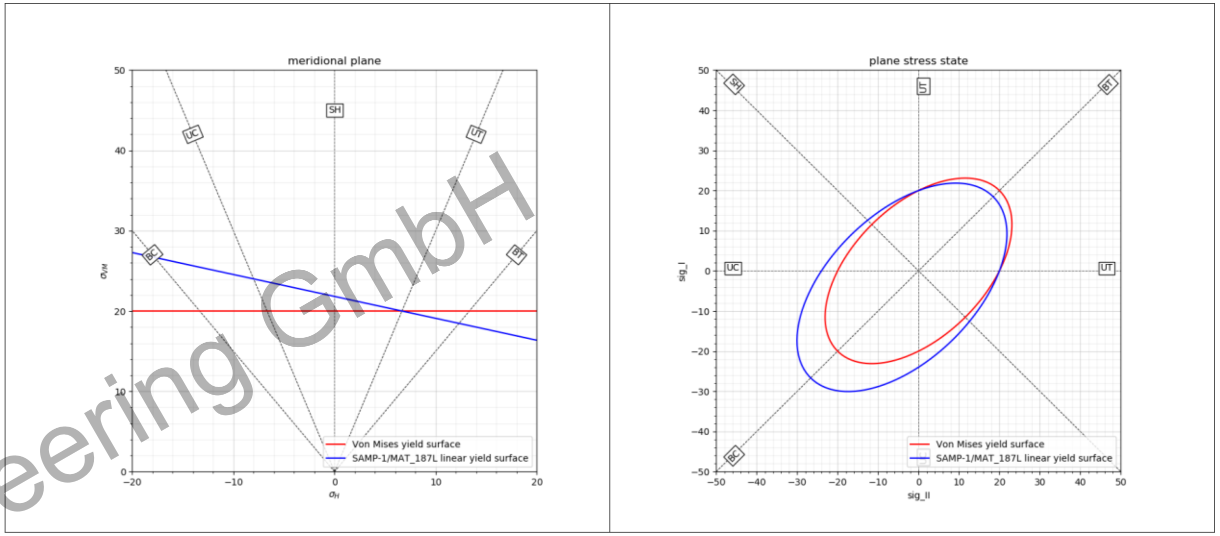
- ***MAT_024* - *The workhorse***
  (***MAT_081**, ***MAT_089**, ***MAT_123**, …)
- ***MAT_124 - The hidden***
- ***MAT_187 - The plastic expert***



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_187	linear; parabolic; piecewise linear	✓ $E(\dot{\varepsilon})$	✓	✓	✓ $\nu_p(\varepsilon)$

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 (R12)**



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_187	linear; parabolic; piecewise linear	✓ $E(\dot{\varepsilon})$	✓	✓	✓ $\nu_p(\varepsilon)$
*MAT_187L	linear	✓ $E(\dot{\varepsilon})$	✓	✓	✓ $\nu_p(\varepsilon)$

From test to material card

VALIMAT

plastics

engineering

production

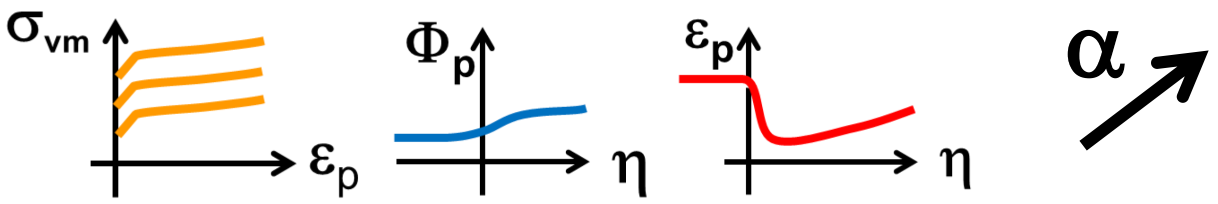
excellence in validation

concepts

simulation

lightweight

prototypes



Hardening | Triaxiality | Damage/Failure | Anisotropic

Material Card - Deformation

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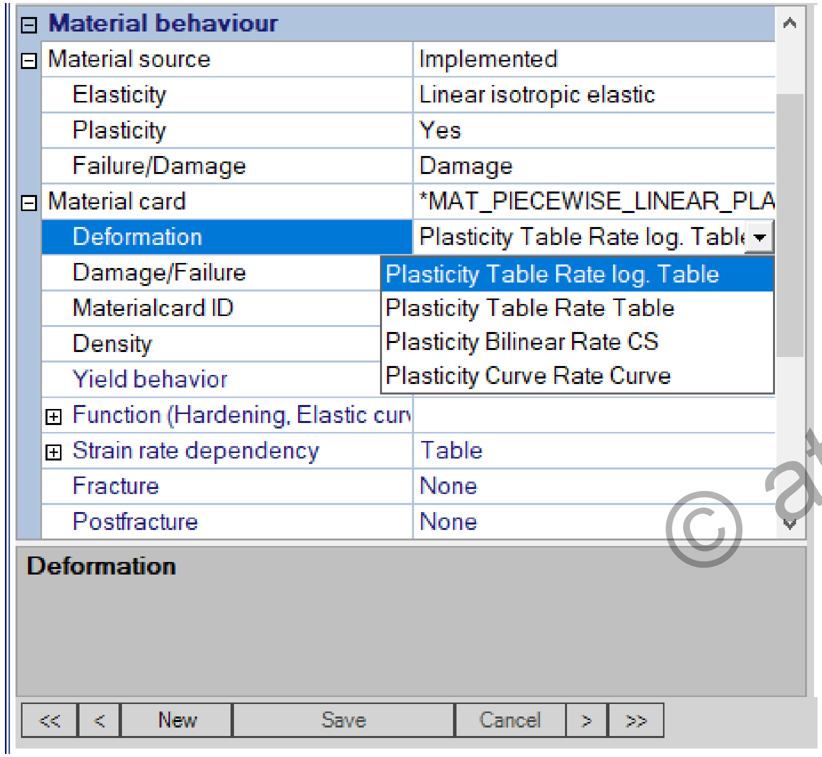
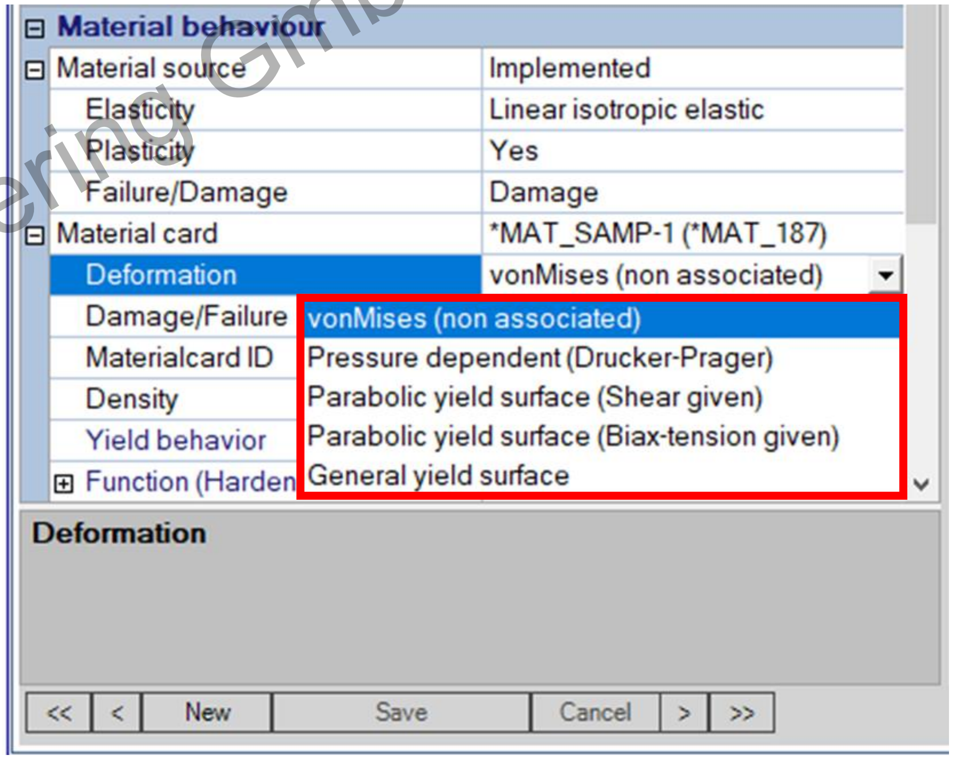
Change of options in the Deformation menu

MAT_024 provides options for the strain rate scaling



MAT_187 provides options for the yield surface shape



Optimization hardening table e.g. 4a model

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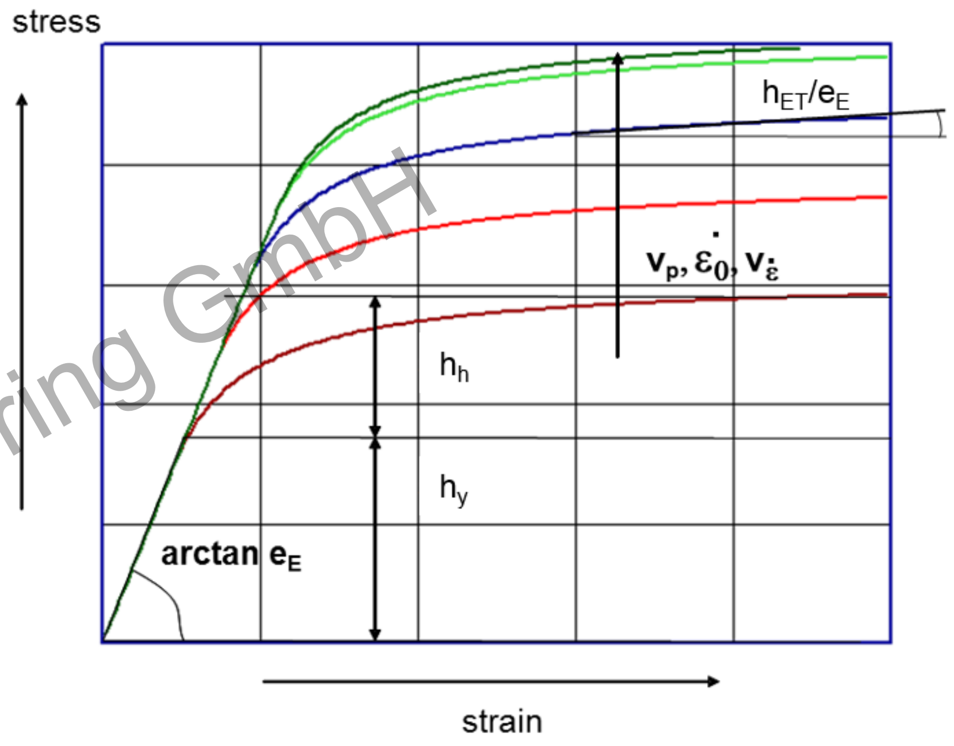
LS DYNA® - ***DEFINE_TABLE***

- plastic behavior described using the meta model of Schmachtenberg

$$h_y + e_E \cdot \varepsilon_{pl} \cdot \frac{1 + \frac{h_{ET} \cdot \varepsilon_{pl}}{e_E}}{1 + \frac{e_E \cdot \varepsilon_{pl}}{h_h}}$$



- hardening linear increased by coefficient h_{ET}/e_E
- strain rate dependency based on Johnson- Cook.

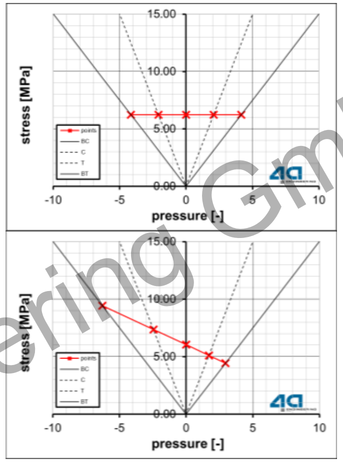
$$1 + \frac{1}{v_p} \cdot \log\left(\frac{\max(\dot{\varepsilon}\ ,\ v_{\dot{\varepsilon}})}{v_{\dot{\varepsilon}}}\right)$$

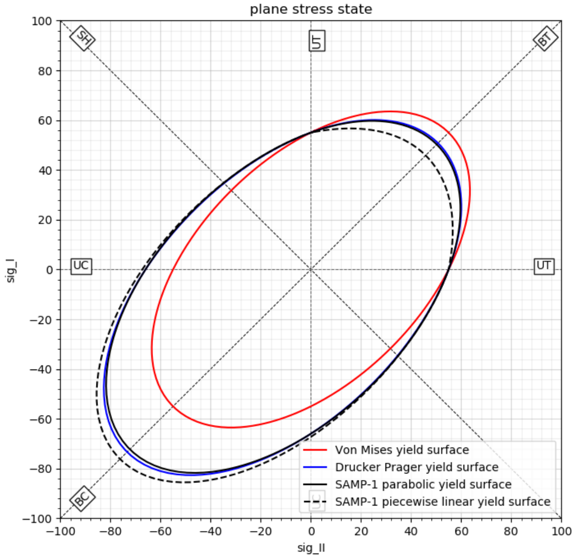
*MAT_187 - options yield surface

Other Criteria

- Von Mises: $f(\boldsymbol{\sigma}) = q - \sigma_0$
- Drucker Prager: $f(\boldsymbol{\sigma}) = q - b \cdot p - a$
- Parabolic: $f(\boldsymbol{\sigma}) = q^2 - c \cdot p^2 - b \cdot p - a$
- piecewise linear yield surface: $f(\boldsymbol{\sigma}) = q - b_i \cdot p - a_i; i = 1 \dots 4$

Meridian Cut:

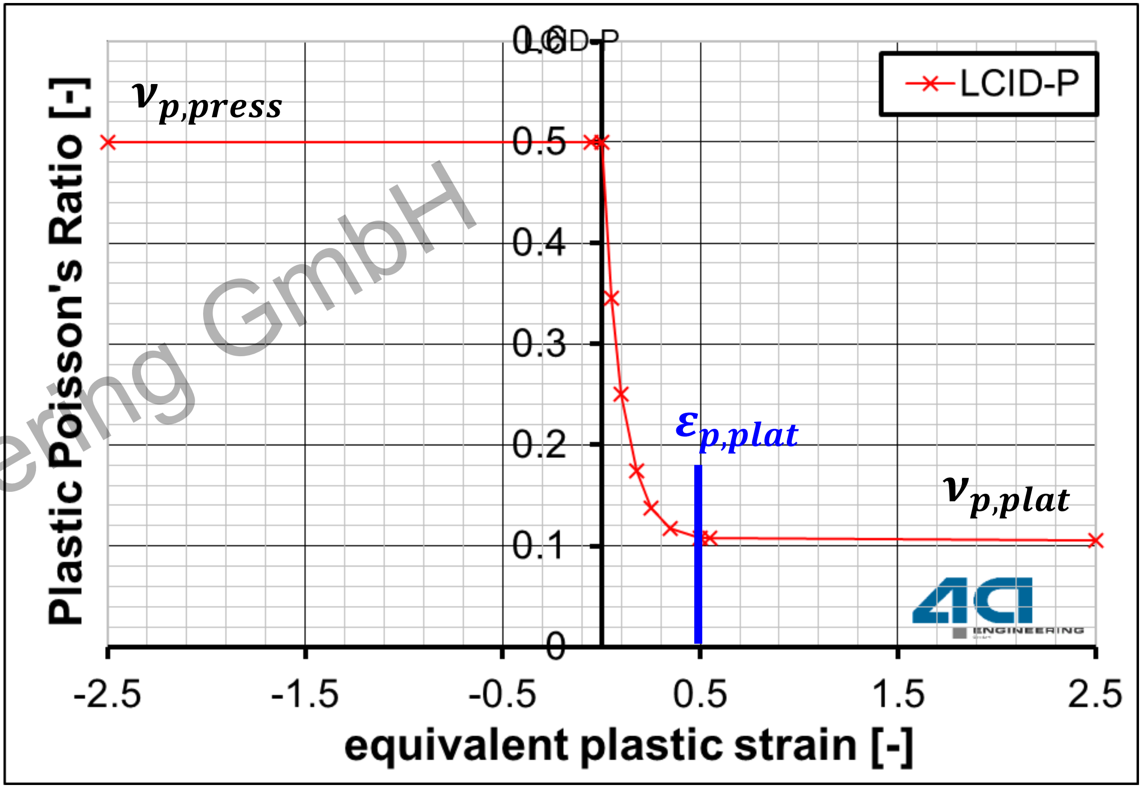




BT: Biaxial Tension
UT: Uniaxial Tension
SH: Shear
UC: Uniaxial Compression
BC: Biaxial Compression

*MAT_187 - plastic poisson's ratio law

- plastic Poisson's ratio over equivalent plastic strain ➔ expressed with a simple model
- Model assumes exponential decay from compression side to a plateau on the tensile side
- $\boldsymbol{\varepsilon_{p,plat}}$ defines the value where ~99% of the difference between compression and tension is subtracted
- $\boldsymbol{\nu_{p,press}}$ Plastic Poisson's Ratio in compression
- $\boldsymbol{\nu_{p,plat}}$ Plastic Poisson's Ratio Plateau in tension



$$\nu_p = \boldsymbol{\nu_{p,plat}} - \left(\boldsymbol{\nu_{p,plat}} - \boldsymbol{\nu_{p,press}}\right) * e^{\min\left(\frac{-5*\varepsilon_p}{\boldsymbol{\varepsilon_{p,plat}}};0\right)}$$

*MAT_187 - plastic poisson’s ratio law

New parameters in Designvariables tab

These parameters define a simple model to describe the relationship between the plastic Poisson’s ratio and the equivalent plastic strain

These parameters are used for the plastic potential

Name	Start	const...	from	to	Variance	Condi...	Description
GroupName: 10_elasticity							
e_E	PRUN	☑	20%	20%	10%		youngs modulus
e_nue	PRUN	☑	(NULL)	(NULL)	(NULL)		poisson ratio
GroupName: 20_yield							
y_0	PRUN	☑	20%	50%	50		yield stress
y_nuep	0.5	☐	0.01	0.5	(NULL)	=xm_...	plastic poisson ratio
y_C	90	☐	5	150	50	=y_T*...	yield stress compression
y_T	NaN	☐	5	150	50	=y_0	yield stress tension
GroupName: 21_hardening							
h_nuep	AUTO	☑	0	0.5	(NULL)		hardening plastic poison ratio
h_scale0	1	☐	0.5	1.0	(NULL)		scalefactor for scaling the yieldcurve, e.g. tension/bending
h_y	AUTO	☑	5	150	50	=y_0	hardening yield stress
h2_scale	1	☑	1	2.999	(NULL)	=2/h_...	scale factor for curve 1
h_ET	PRUN	☑	0	100	(NULL)	<e_E	tangent modulus
h_h	PRUN	☑	5	200	(NULL)		hardening stress plateau
GroupName: 22_hardening							
xm_nuep_eps	AUTO	☑	(NULL)	(NULL)	(NULL)		plastic strain to almost reach nuep_plat $\varepsilon_{p,plat}$
xm_nuep_plat	AUTO	☑	(NULL)	(NULL)	(NULL)		plastic Poissons ratio at infinite tension strain $\nu_{p,plat}$
xm_nuep_meps	AUTO	☑	(NULL)	(NULL)	(NULL)		last point for LCID-P
xm_nuep_pres	AUTO	☑	(NULL)	(NULL)	(NULL)		plastic Poissons ratio in compression domain $\nu_{p,press}$
GroupName: 31_strainrate							
v_p	PRUN	☑	1	1001	(NULL)		strain rate scale (1/vp)
v_epspkt	PRUN	☑	0.0001	1	(NULL)		initial strain rate threshold

plastic Poisson‘s ratio law parameters

True Stress	$\sigma_T = \frac{\sigma'_T}{(1 - \nu' \varepsilon'_T)^2}$
True Strain	$\varepsilon_T = \ln(1 + \varepsilon'_T)$
True Transverse Strain	$\varepsilon_t = \ln(1 + \varepsilon'_t)$
Nominal Poisson’s Ratio	$\nu' = -\frac{\varepsilon'_t}{\varepsilon'_T}$
Young’s Modulus	$E = \frac{\sigma_T}{\varepsilon^e_T}$
True Poisson’s Ratio	$\nu = -\frac{\varepsilon_t}{\varepsilon_T}$
True Plastic Strain	$\varepsilon^P_T = \varepsilon_T - \ln\left(1 + \frac{\sigma_T}{E}\right)$
True Transverse Plastic Strain	$\varepsilon^P_t = \varepsilon_t - \ln\left(1 - \nu' \frac{\sigma_T}{E}\right)$
True Plastic Poisson’s Ratio	$\nu^P = -\frac{\varepsilon^P_t}{\varepsilon^P_T}$

Q: NPL: Manual for the Calculation of Elastic-Plastic Materials Models Parameters, © Crown copyright 2007

*MAT_187 introduction

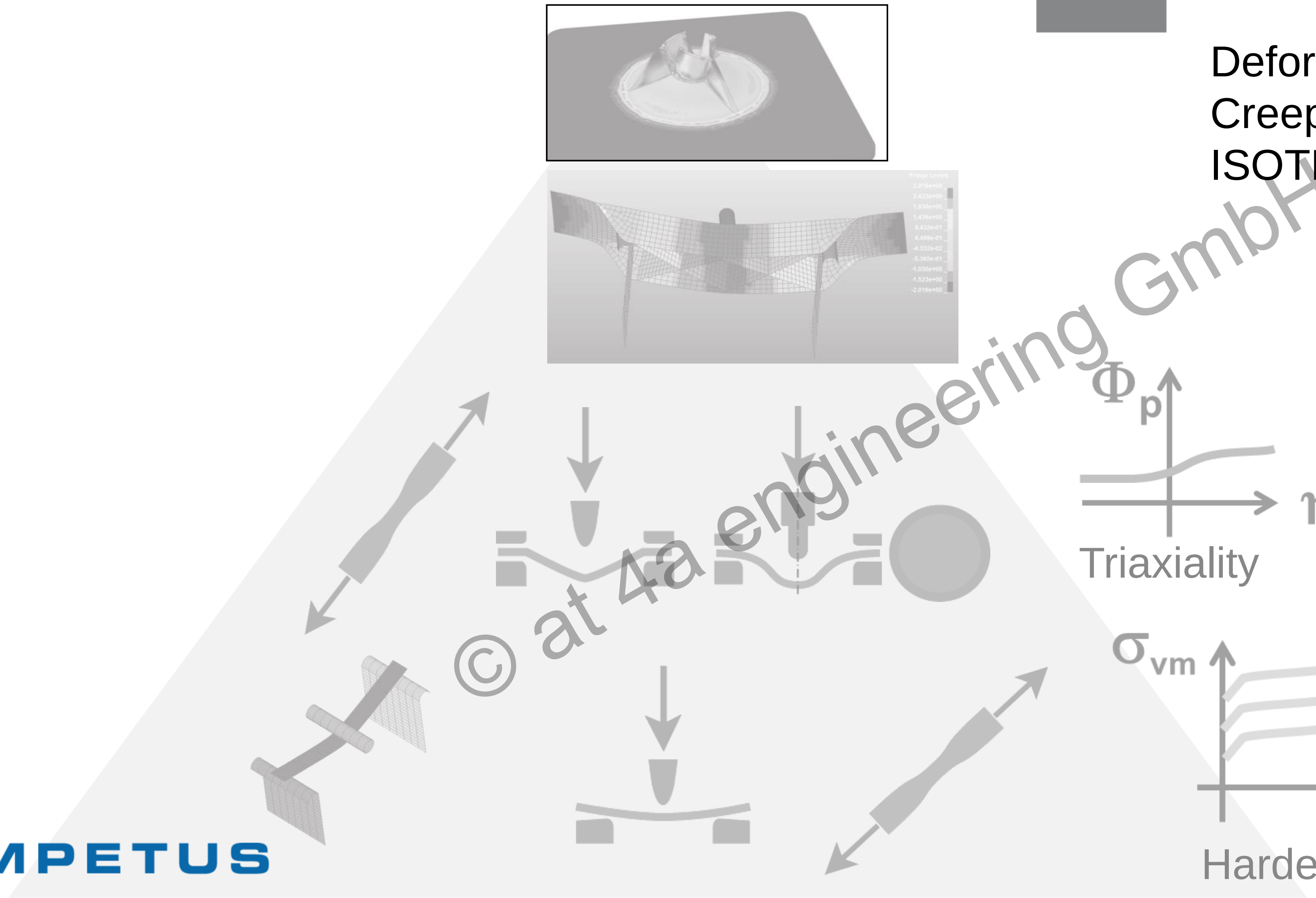
Designvariable

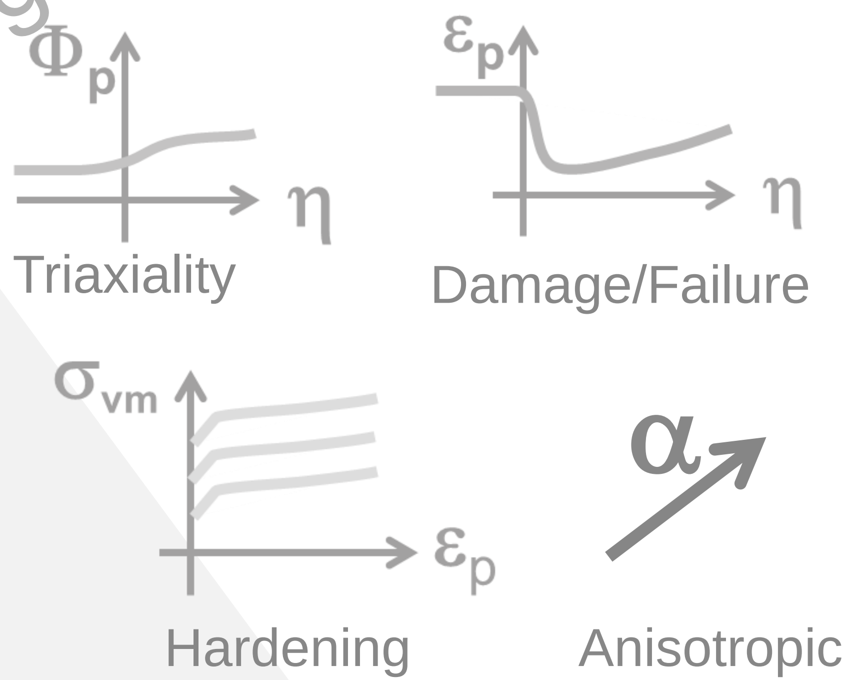
	Name	Start	const...	from	to	Variance	Condi...	Description
	GroupName: 10_elasticity							
	e_E	PRUN	☑	20%	20%	10%		youngs modulus
	e_nue	PRUN	☑	(NULL)	(NULL)	(NULL)		poisson ratio
	GroupName: 20_yield							
	y_0	PRUN	☑	20%	50%	50		yield stress
	y_nuep	0.5	☐	0.01	0.5	(NULL)	=xm_...	plastic poisson ratio
	y_C	90	☐	5	150	50	=y_T*...	yield stress compression
	y_T	NaN	☐	5	150	50	=y_0	yield stress tension
	GroupName: 21_hardening							
	h_nuep	AUTO	☑	0	0.5	(NULL)		hardening plastic poison ratio
	h_scale0	1	☐	0.5	1.0	(NULL)		scalefactor for scaling the yieldcurve, e.g. tension/bending
	h_y	AUTO	☑	5	150	50	=y_0	hardening yield stress
	h2_scale	1	☑	1	2.999	(NULL)	=2/h_...	scale factor for curve 1
	h_ET	PRUN	☑	0	100	(NULL)	<e_E	tangent modulus
	h_h	PRUN	☑	5	200	(NULL)		hardening stress plateau
	GroupName: 22_hardening							
$\varepsilon_{p,plat}$	xm_nuep_eps	AUTO	☑	(NULL)	(NULL)	(NULL)		plastic strain to almost reach nuep_plat
$\nu_{p,plat}$	xm_nuep_plat	AUTO	☑	(NULL)	(NULL)	(NULL)		plastic Poissons ratio at infinite tension strain
	xm_nuep_meps	AUTO	☑	(NULL)	(NULL)	(NULL)		last point for LCID-P
$\nu_{p,press}$	xm_nuep_pres	AUTO	☑	(NULL)	(NULL)	(NULL)		plastic Poissons ratio in compression domain
	GroupName: 31_strainrate							
	v_p	PRUN	☑	1	1001	(NULL)		strain rate scale (1/vp)
	v_epspkt	PRUN	☑	0.0001	1	(NULL)		initial strain rate threshold

from test to material card

VALIMAT

Deformation → Failure
Creep → Static → Crash
ISOTROPIC → ANISOTROPIC





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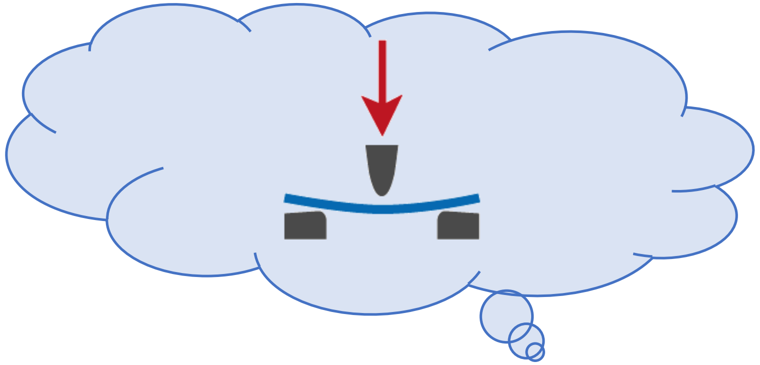
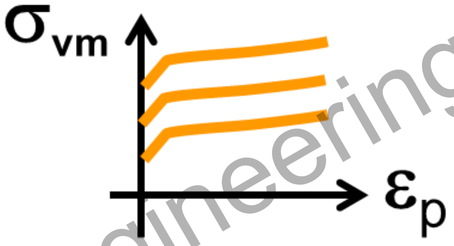
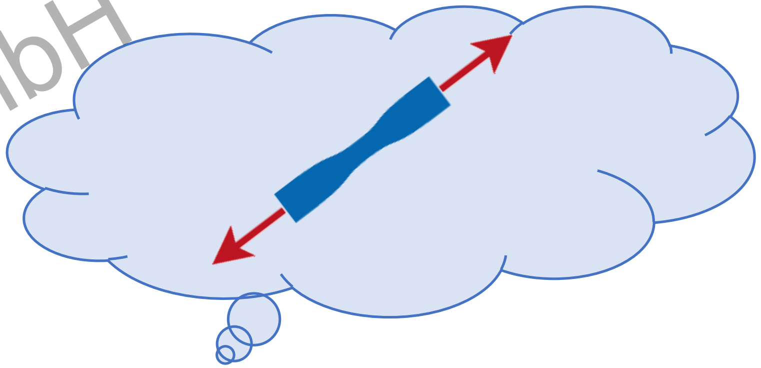
From test to material card – von Mises visco plasticity





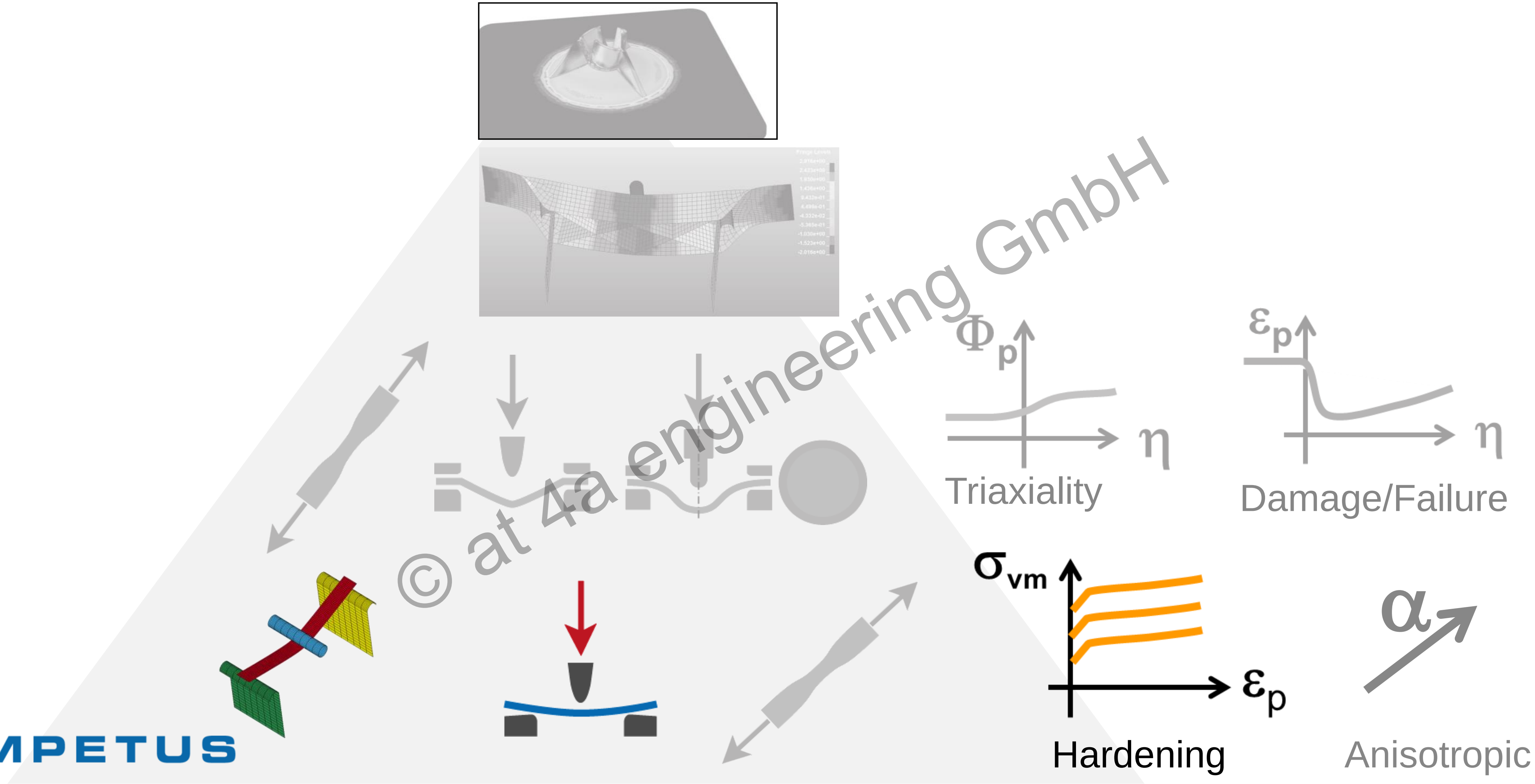
Hardening



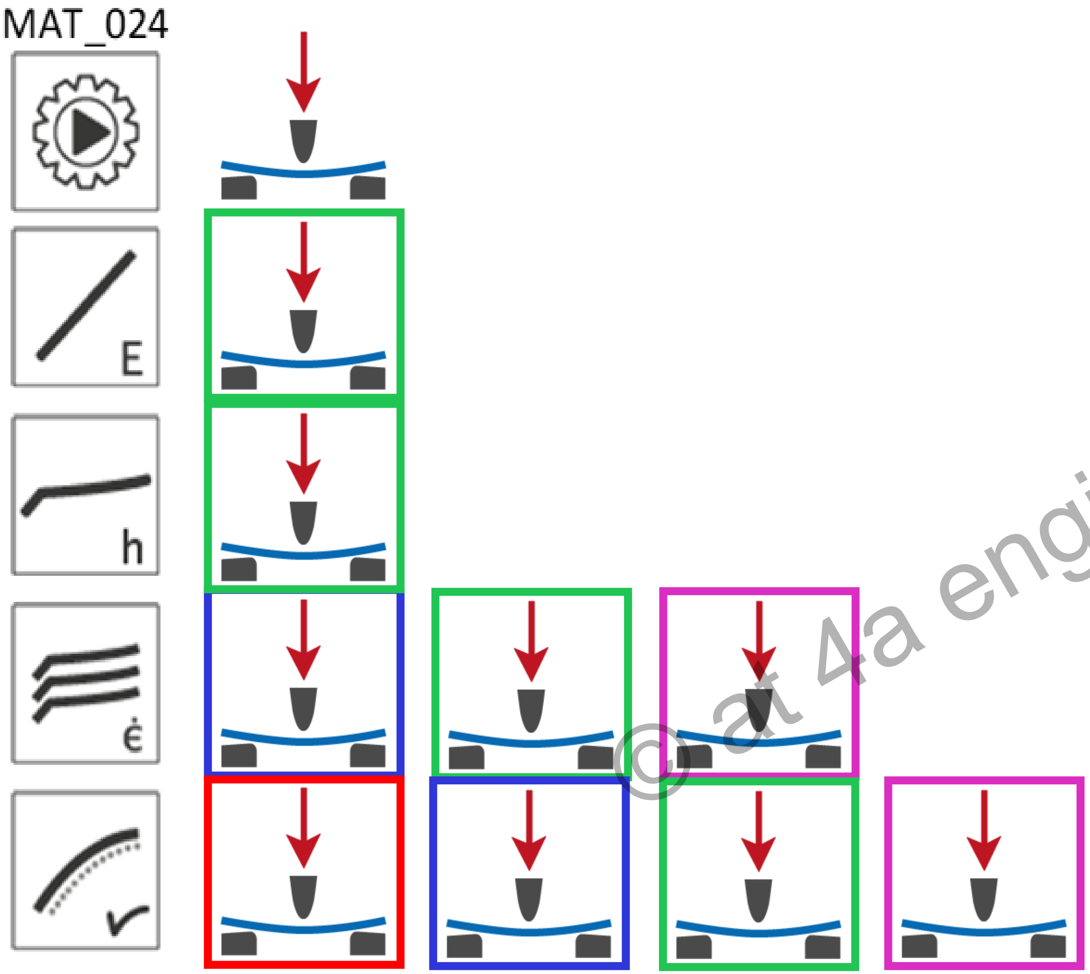
Peter ♡ Bending

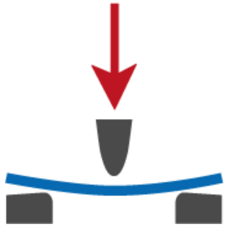
Benjamin ♡ Tension

from test to material card

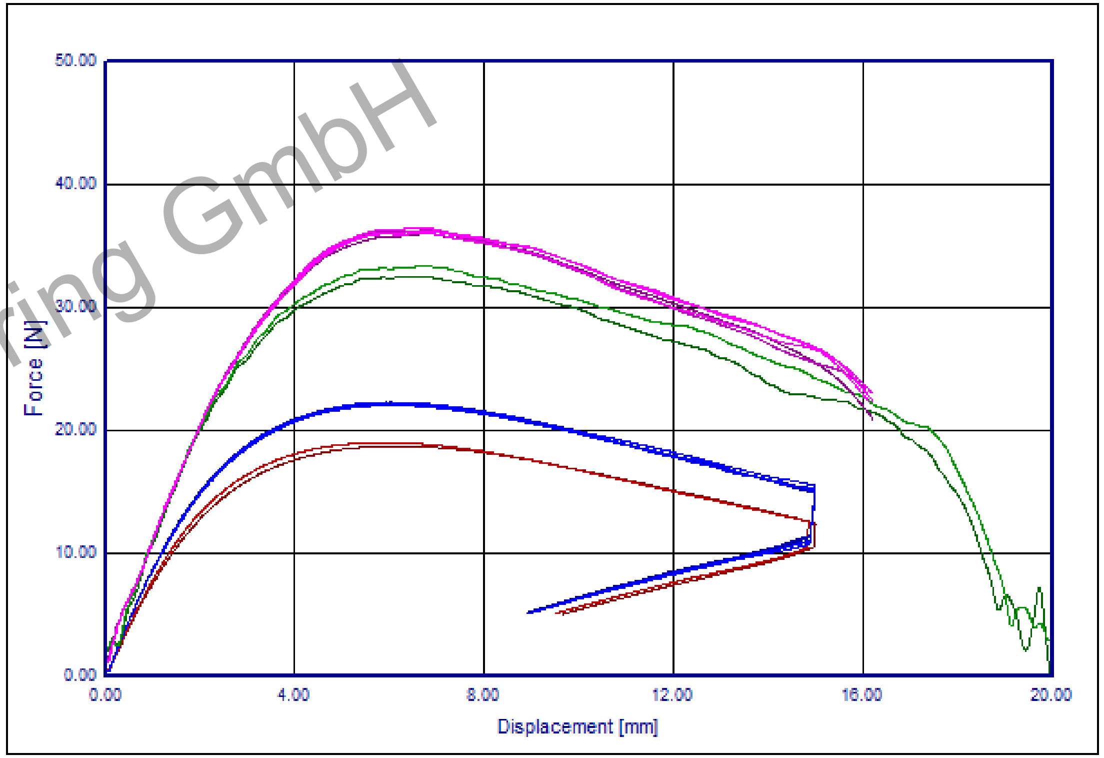


AutoFit Strategy *MAT_024 Bending based



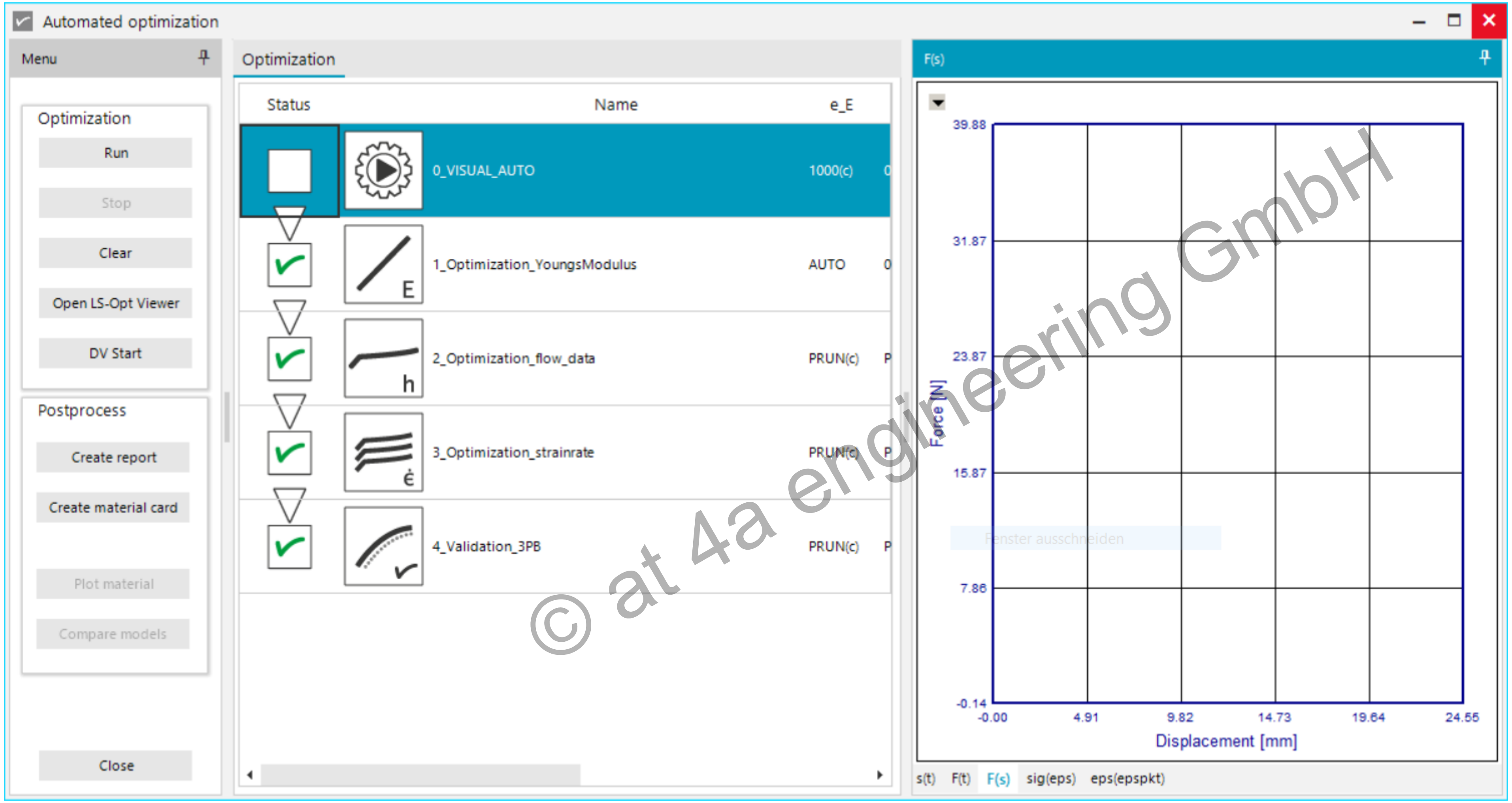


without border all velocities
quasistatic low velocity
quasistatic high velocity
dynamic low velocity
dynamic medium velocity



VALIMAT

Workflow for Material Card Generation - AUTOFIT



Workflow for Material Card Generation - AUTOFIT

Auto Values

VALIMAT

Validation/Optimization: **AutoValues** ➔ Model used for start value generation

- _**EL**: mean value of this case is Young's Modulus e_E
- _**HC**: use this case for hardening curve parameter estimation
- _**VP**: use these cases to evaluate the strain rate dependency v_p
- important **v_epspkt** will be taken from Designvariables this is the reference strain rate

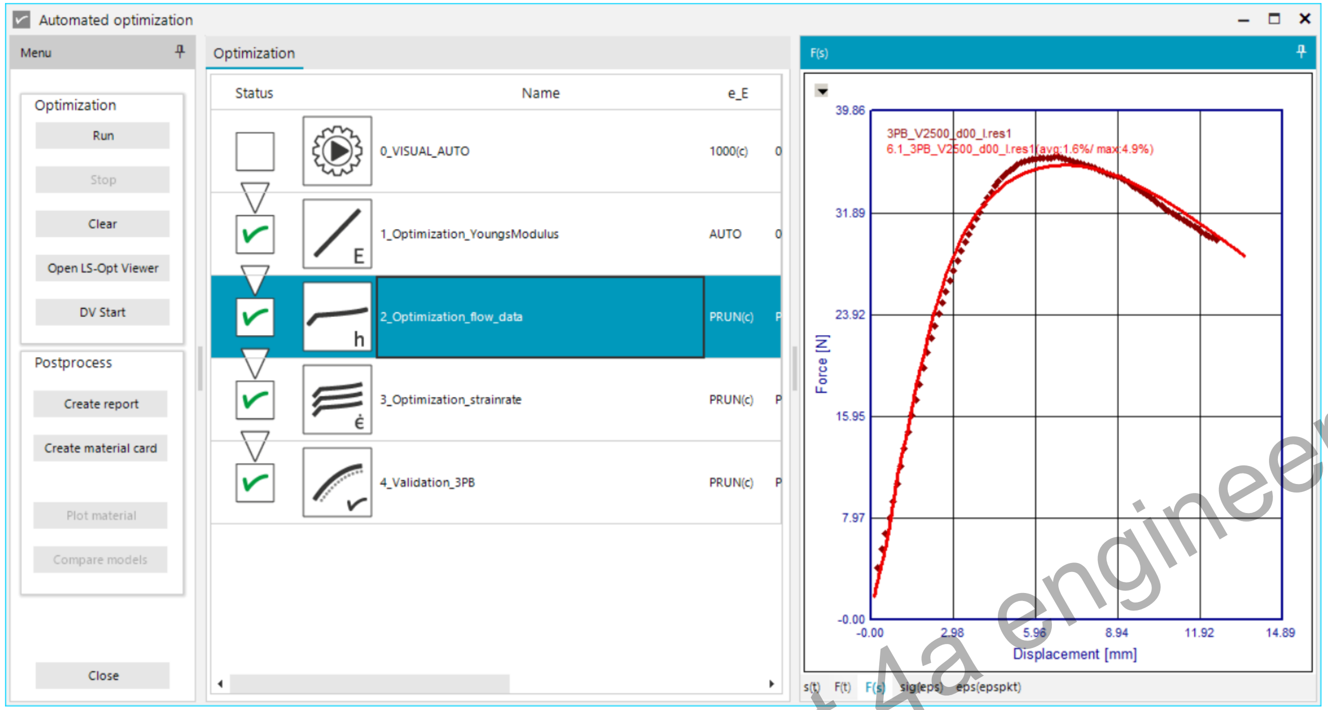
Validation/Optimization	AutoValues
Loadcases	
Casename	3PB_V1_d00_C_VP
Casename	3PB_V2500_d00_C_EL_HC_VP
Casename	TT_V3000_d00_C

Name	Start	const...	from	to	Variance	Condi...	Descri...
GroupName: 31_strainrate							
v_epspkt	0.0001	✓	0.001	1	(NULL)		initial...
Click here to add a new row							

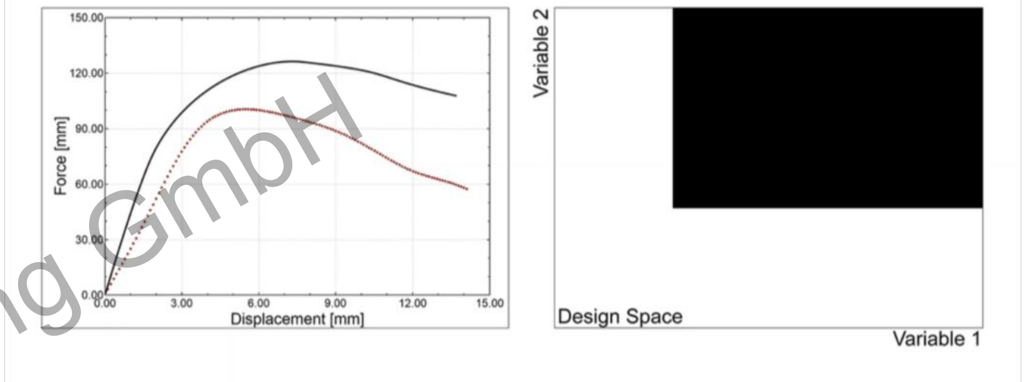
strain range for hardening table

Workflow for Material Card Generation - AUTOFIT

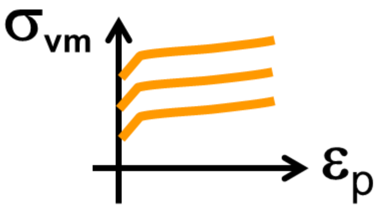
VALIMAT



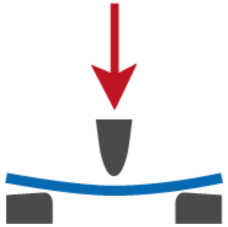
optimization – successive response surface method



$$hardening\ function = f(Variable\ 1, Variable\ 2)$$

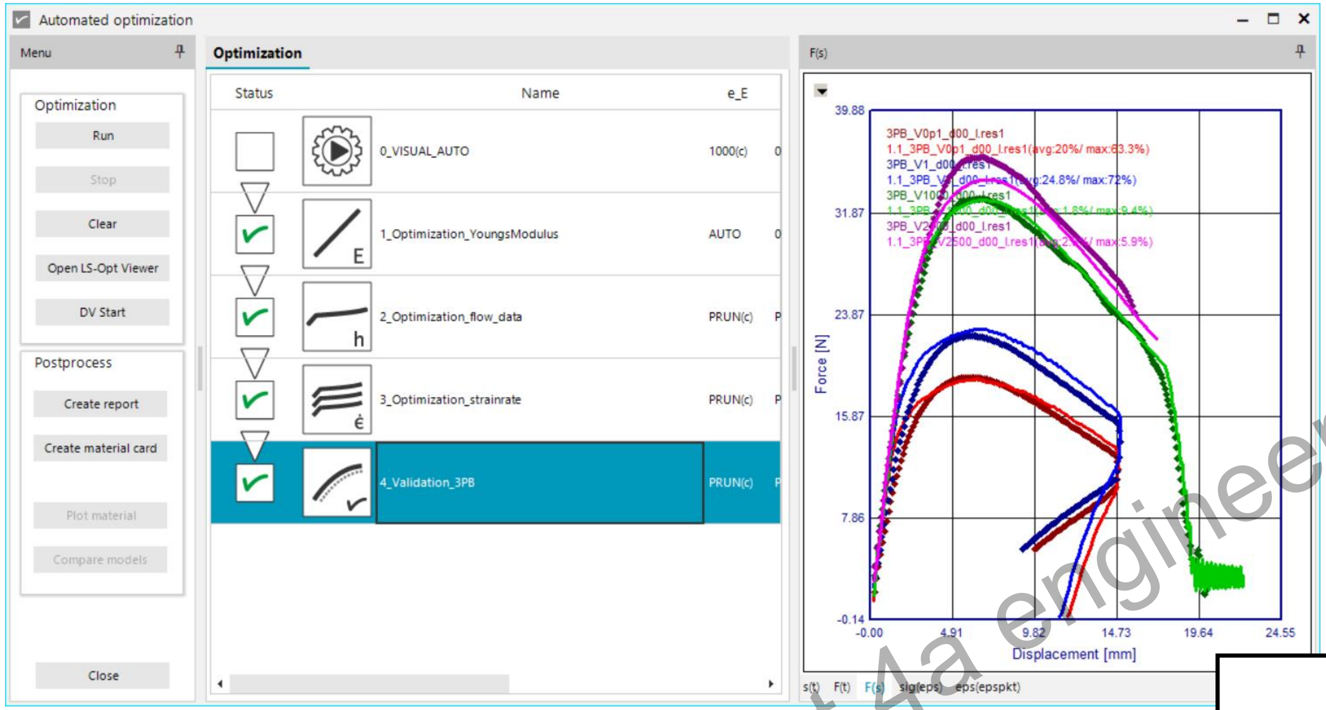


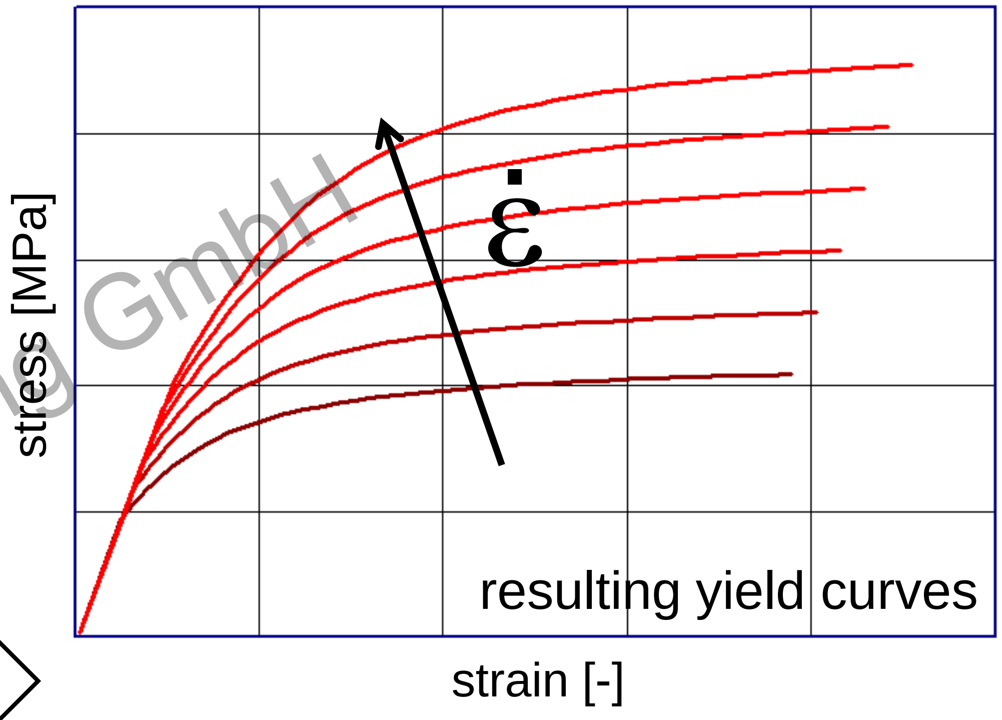
Hardening

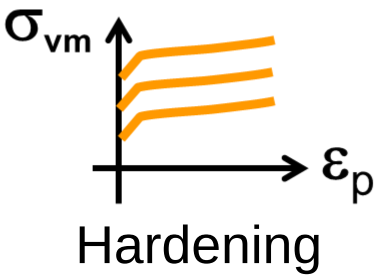


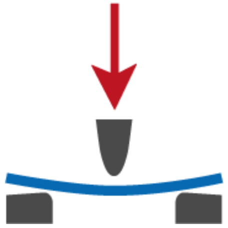
[redacted]

Workflow for Material Card Generation - AUTOFIT



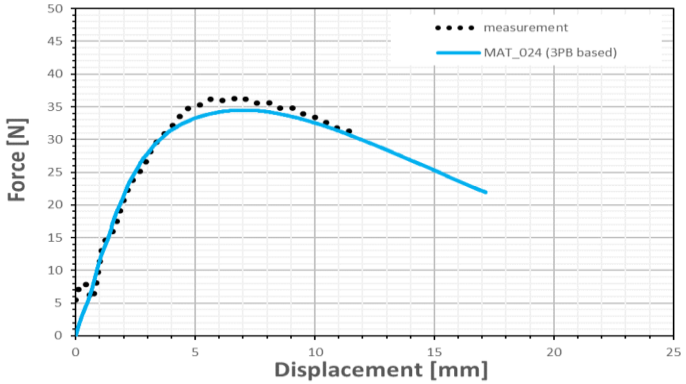




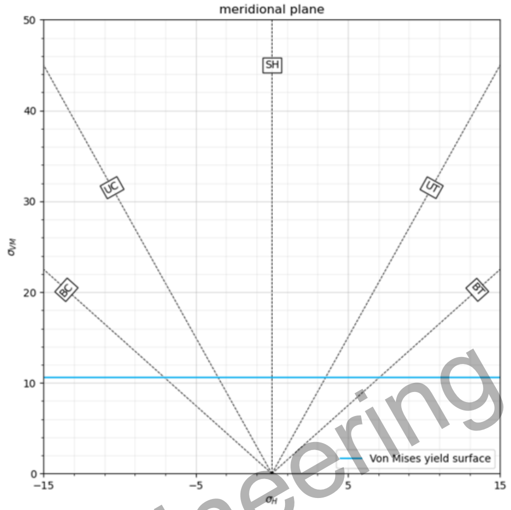


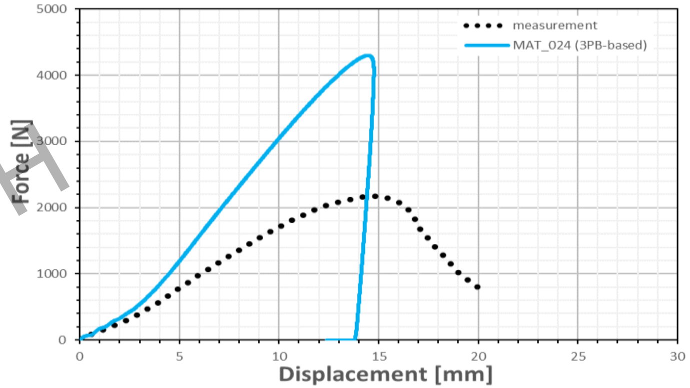
AutoFit Strategy *MAT_024 Bending based

VALIMAT



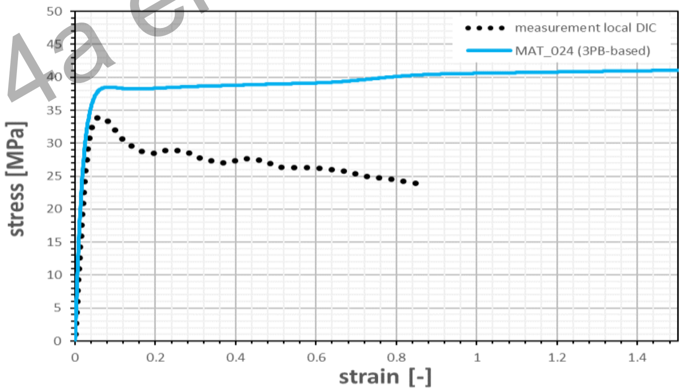
3 POINT BENDING





PUNCTURE TEST

IMPETUS® ~ 3 m/s



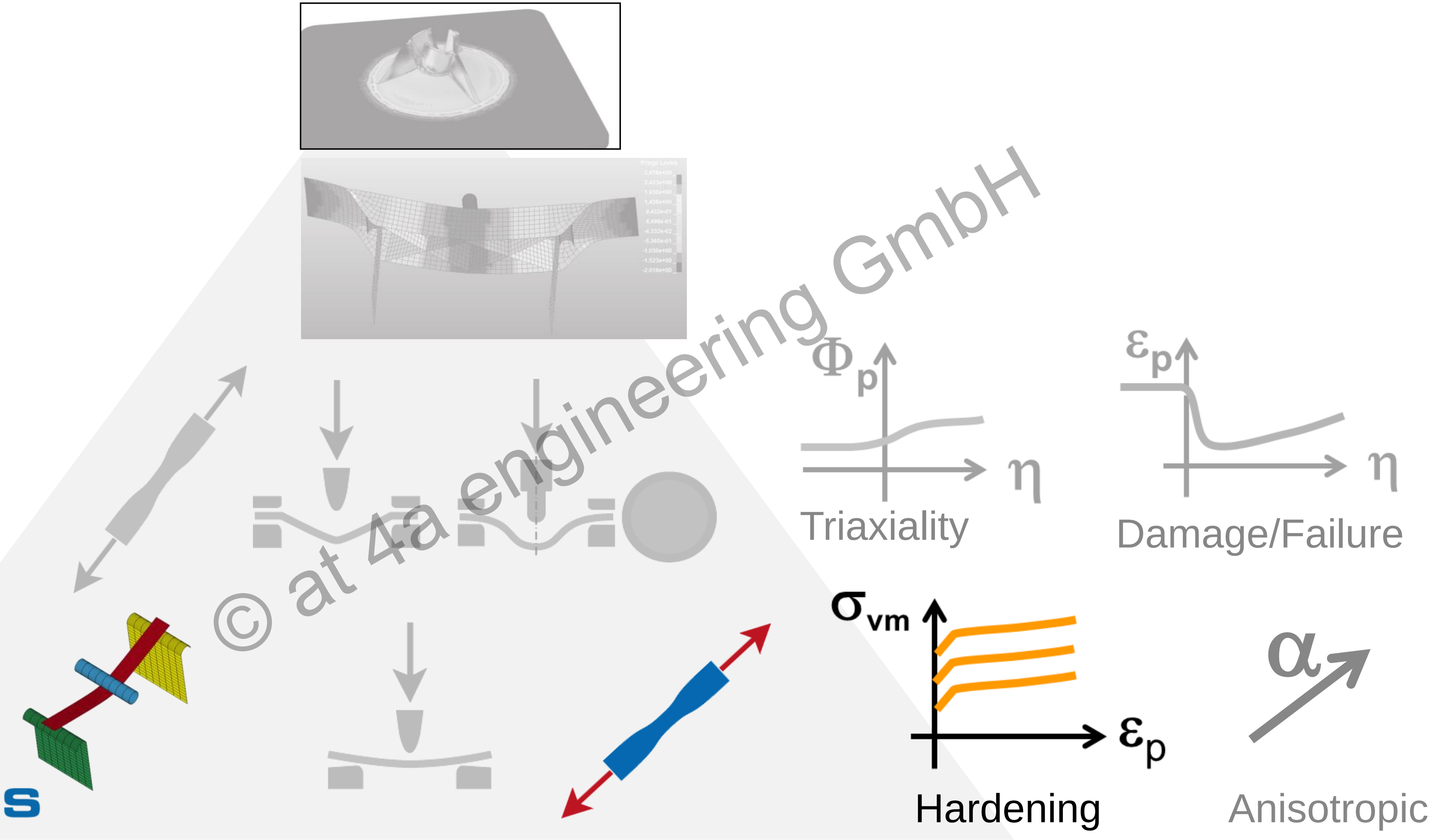
TENSION TEST

···· averaged test curves

— result of simulation

source: Benjamin Hirschmann, master thesis

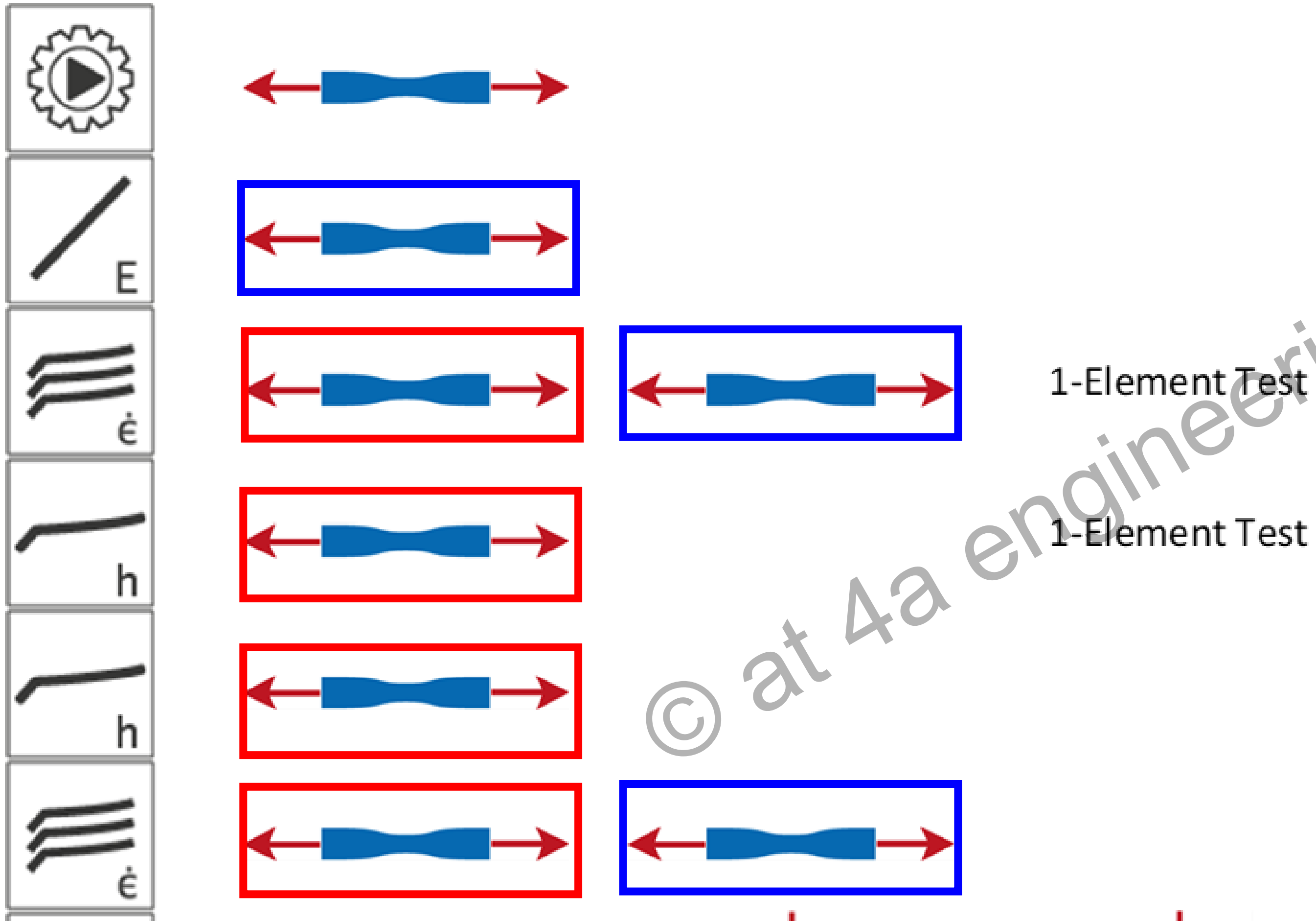
from test to material card

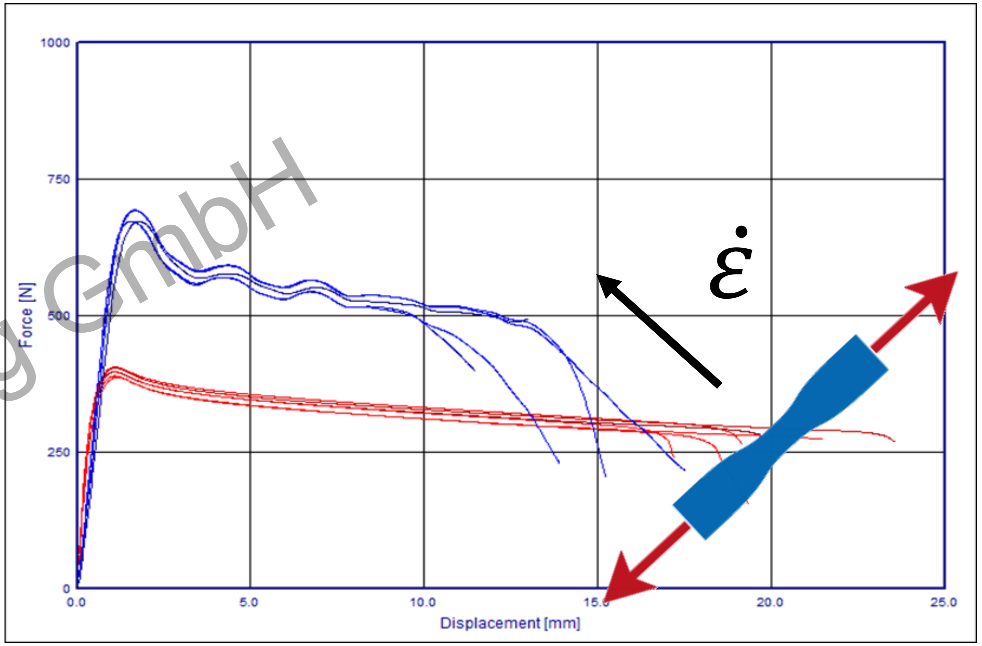


AutoFit Strategy *MAT_024 tensile based

without border all velocities
quasistatic
dynamic

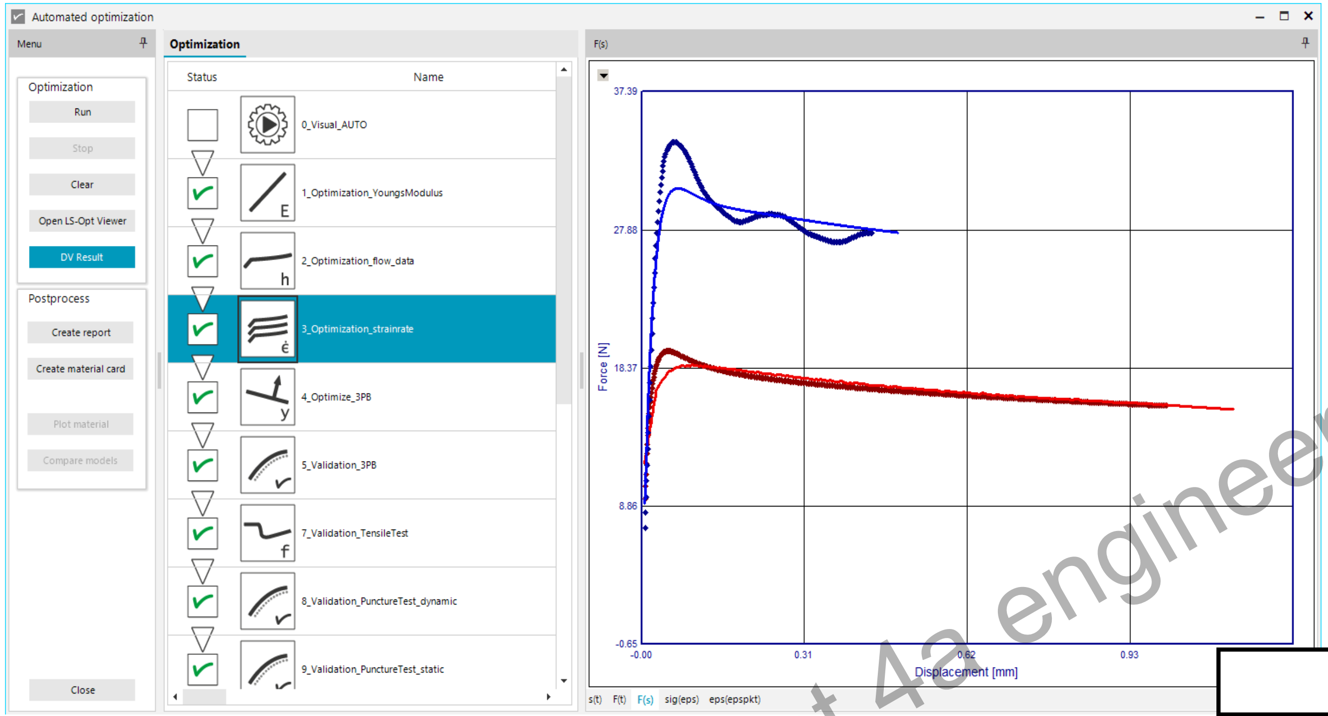
MAT_024



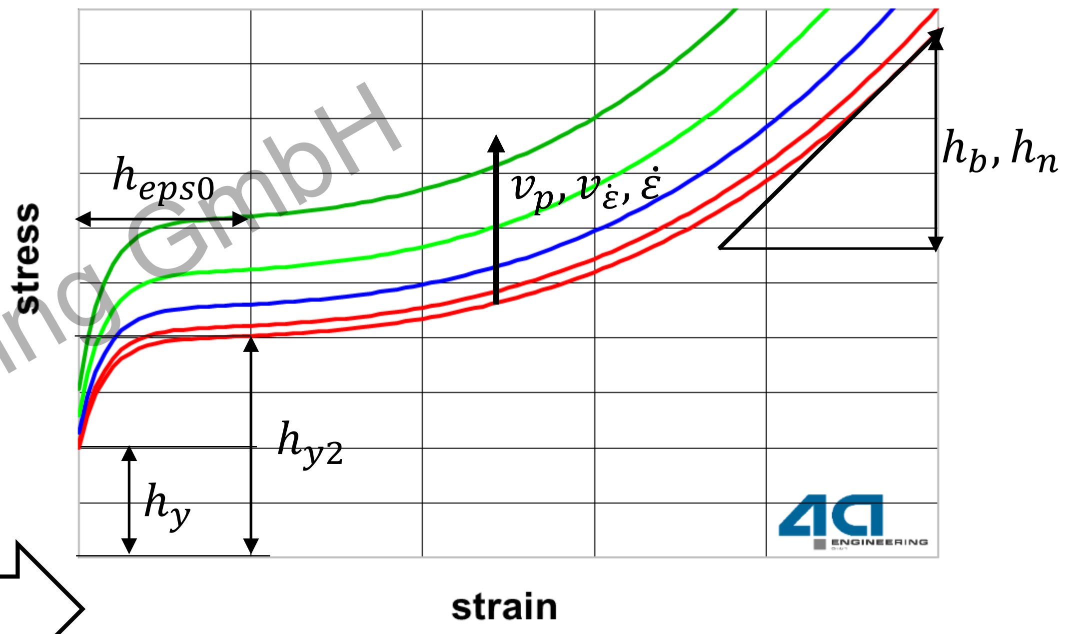


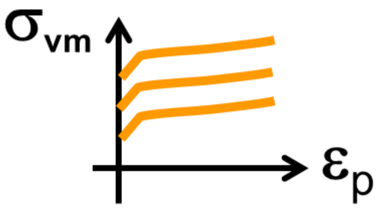
source: Benjamin Hirschmann, master thesis

AutoFit Strategy *MAT_024 tensile based

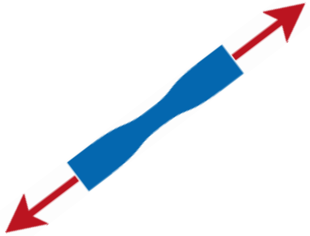


parametrized material card





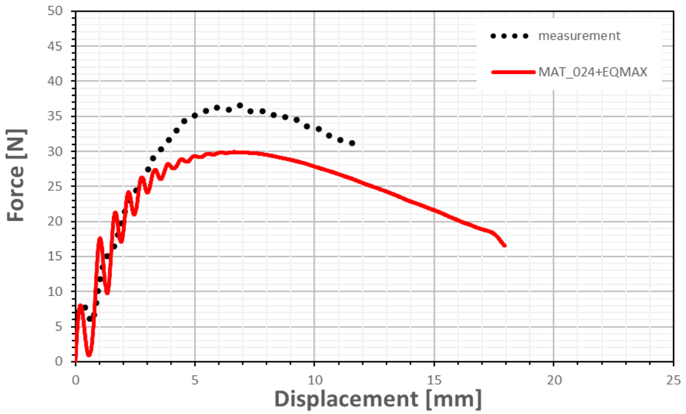
Hardening



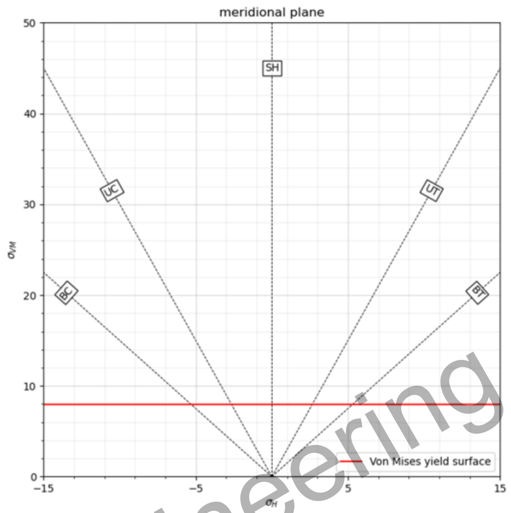
source: Benjamin Hirschmann, master thesis

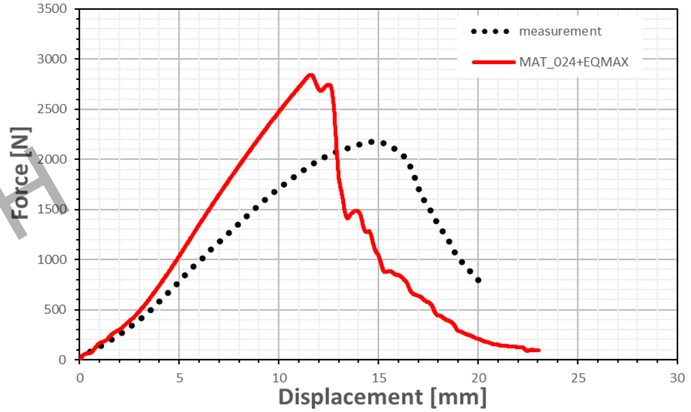
AutoFit Strategy *MAT_024 tensile based

VALIMAT

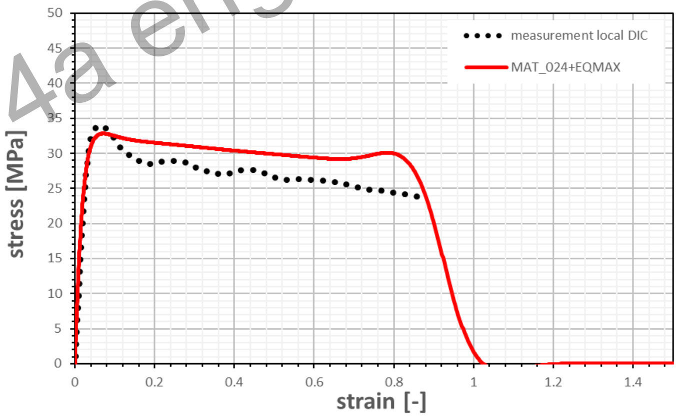


3 POINT BENDING





PUNCTURE TEST



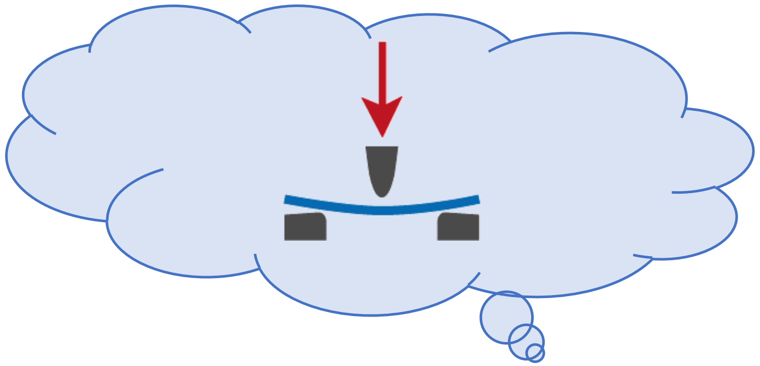
TENSION TEST

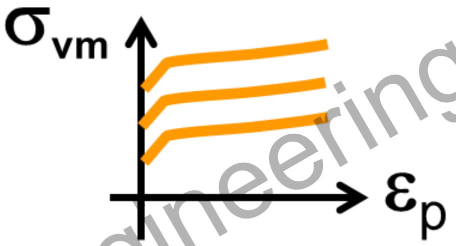
IMPETUS® ~ 3 m/s

···· averaged test curves
— result of simulation

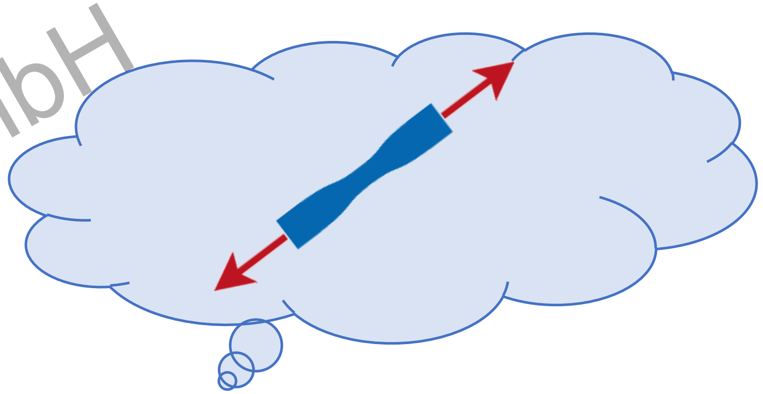
source: Benjamin Hirschmann, master thesis

From test to material card – ?





Hardening

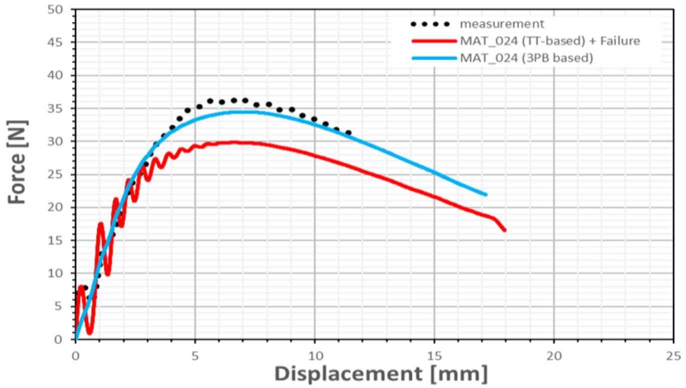


Peter ♡ Bending

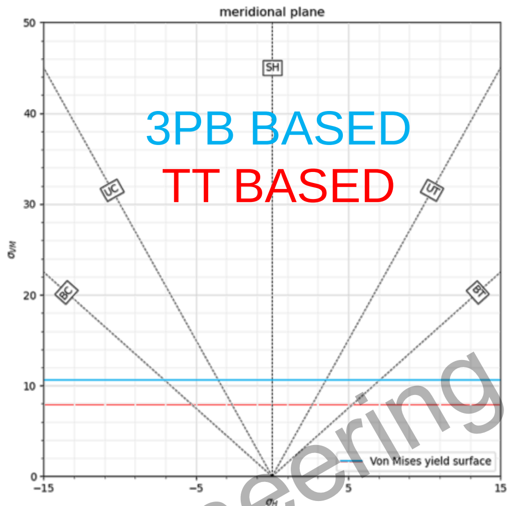
Benjamin ♡ Tension

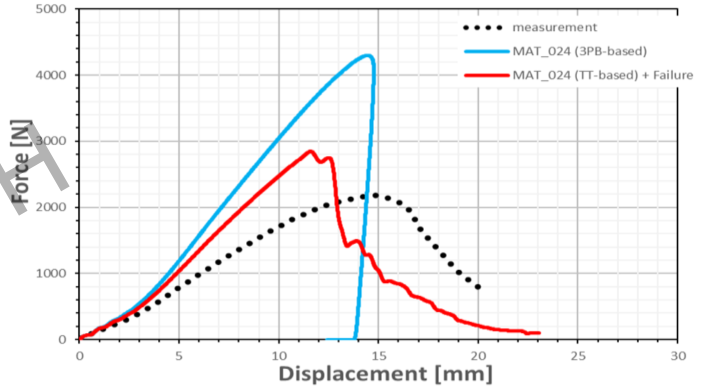
AutoFit Comparison – MAT_024 (3PB/TT - based)

VALIMAT



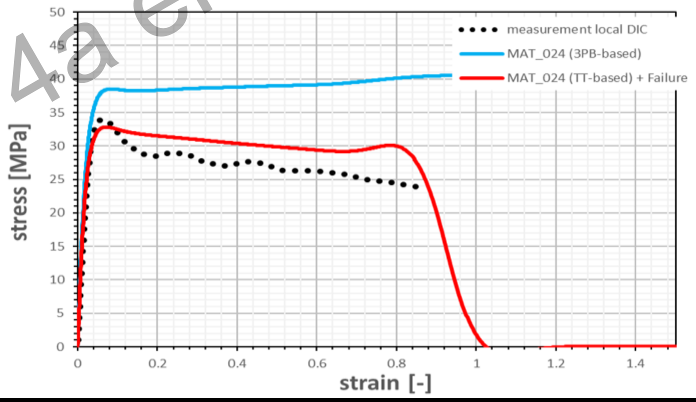
3 POINT BENDING





PUNCTURE TEST

IMPETUS® ~ 3 m/s



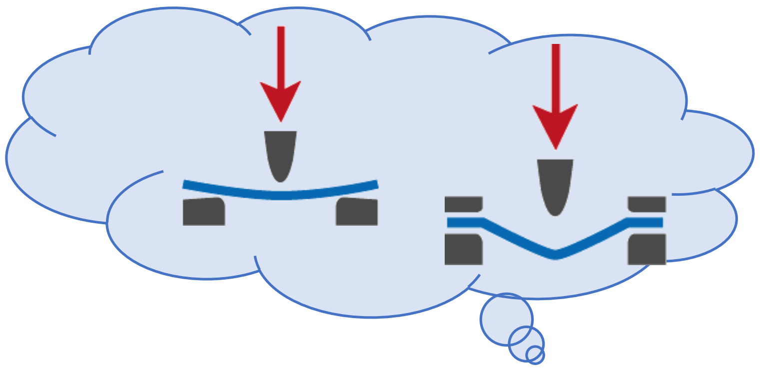
TENSION TEST

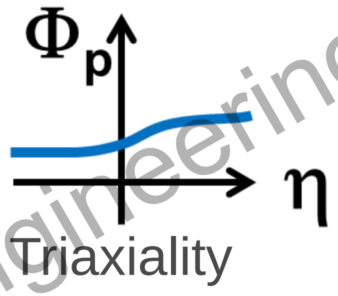
···· averaged test curves

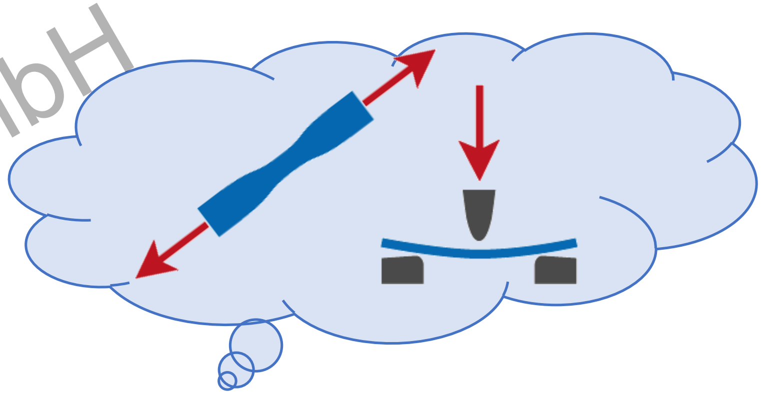
— result of simulation

source: Benjamin Hirschmann, master thesis

From test to material card – yield surface



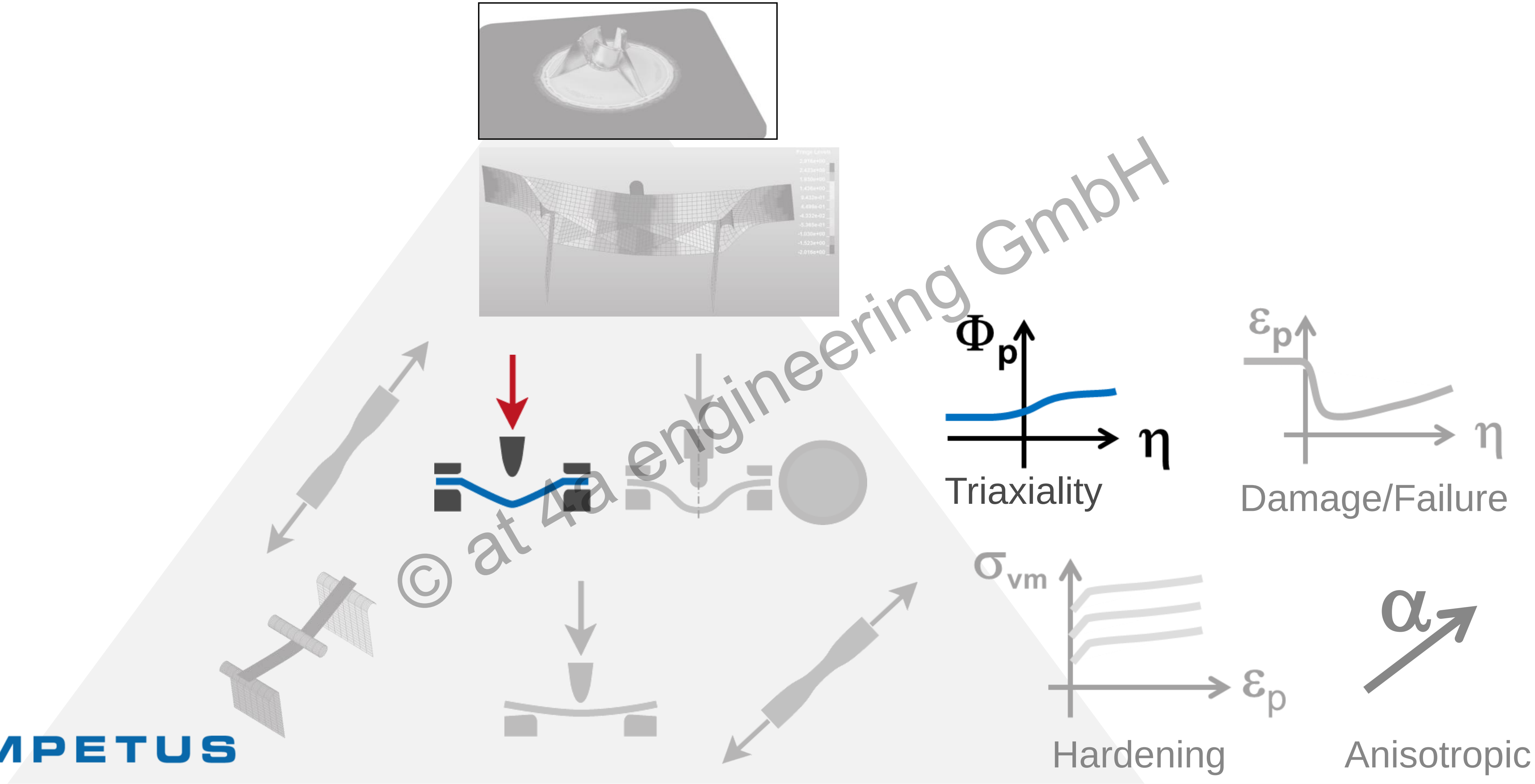




Peter ♡ Bending

Benjamin ♡ Tension

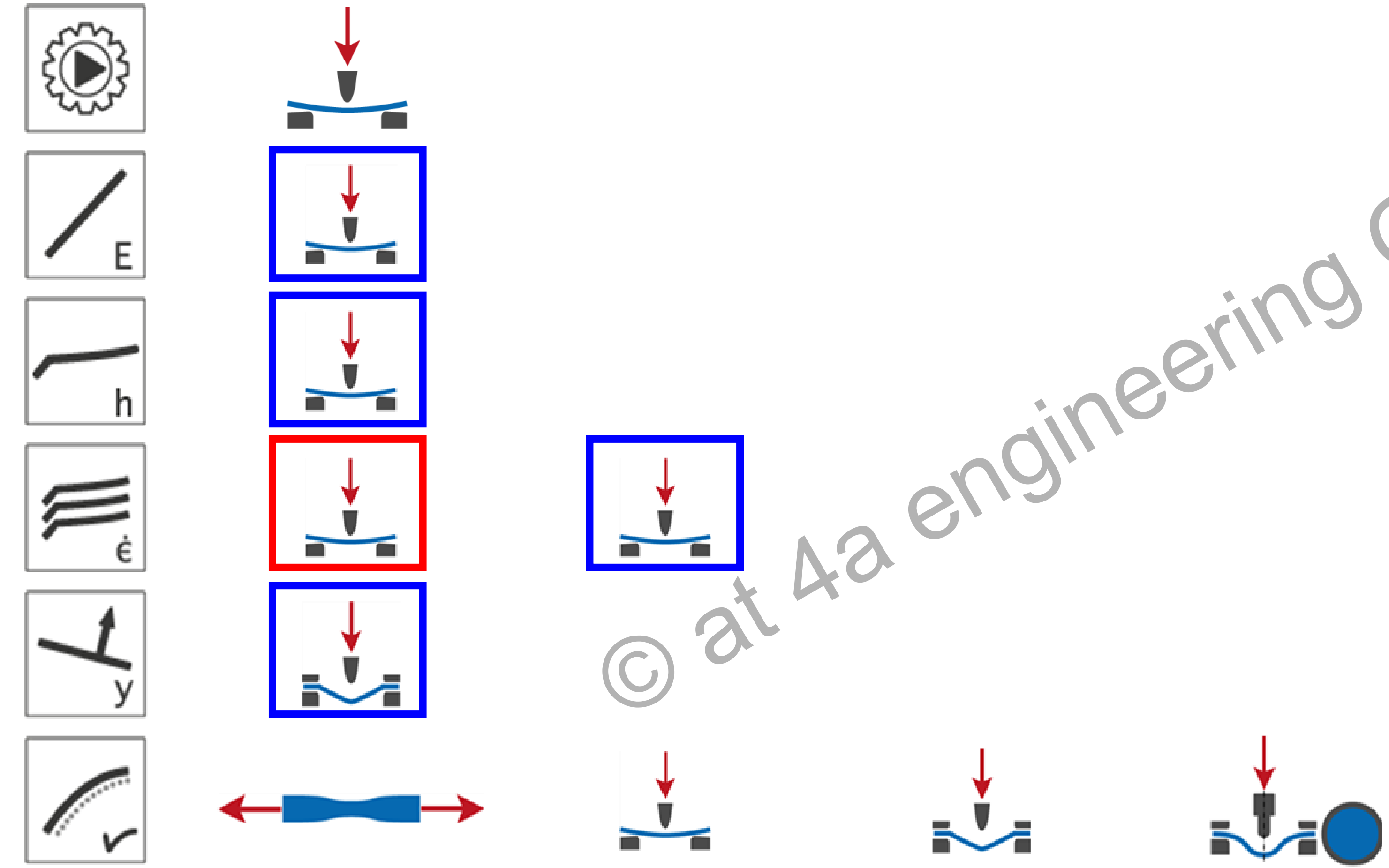
from test to material card

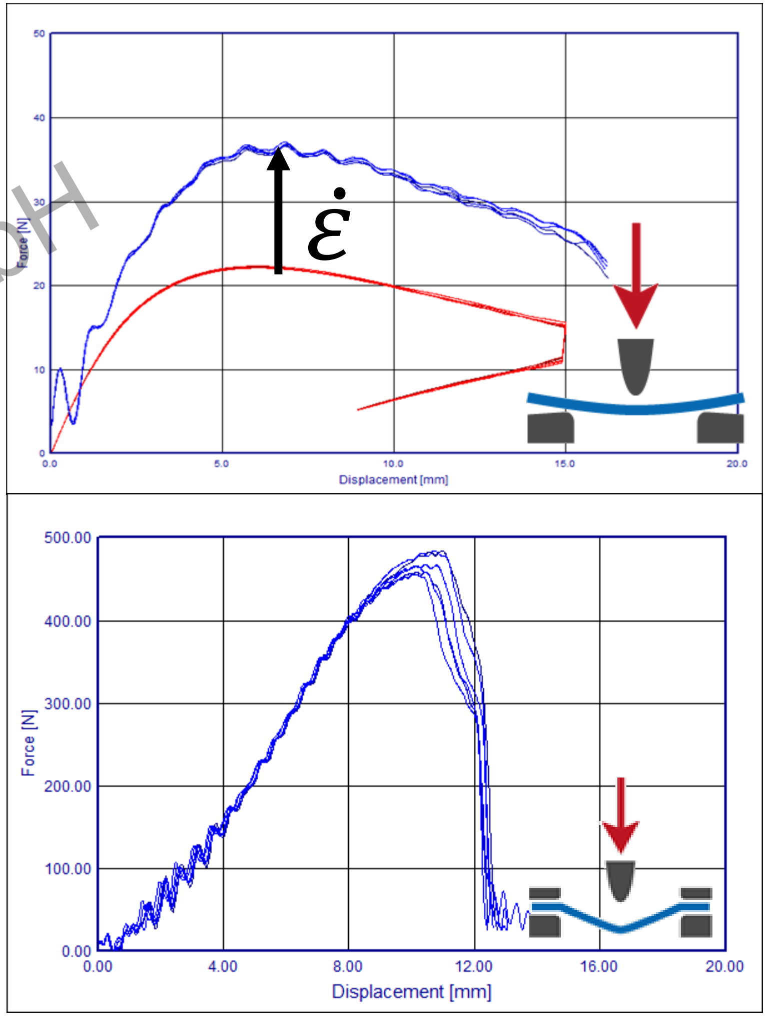


AutoFit
Strategy

without border all velocities
quasistatic
dynamic

MAT_SAMP





VALIMAT

AutoFit

Optimization yield surface – Drucker Prager

Workflow for Material Card Generation - AUTOFIT

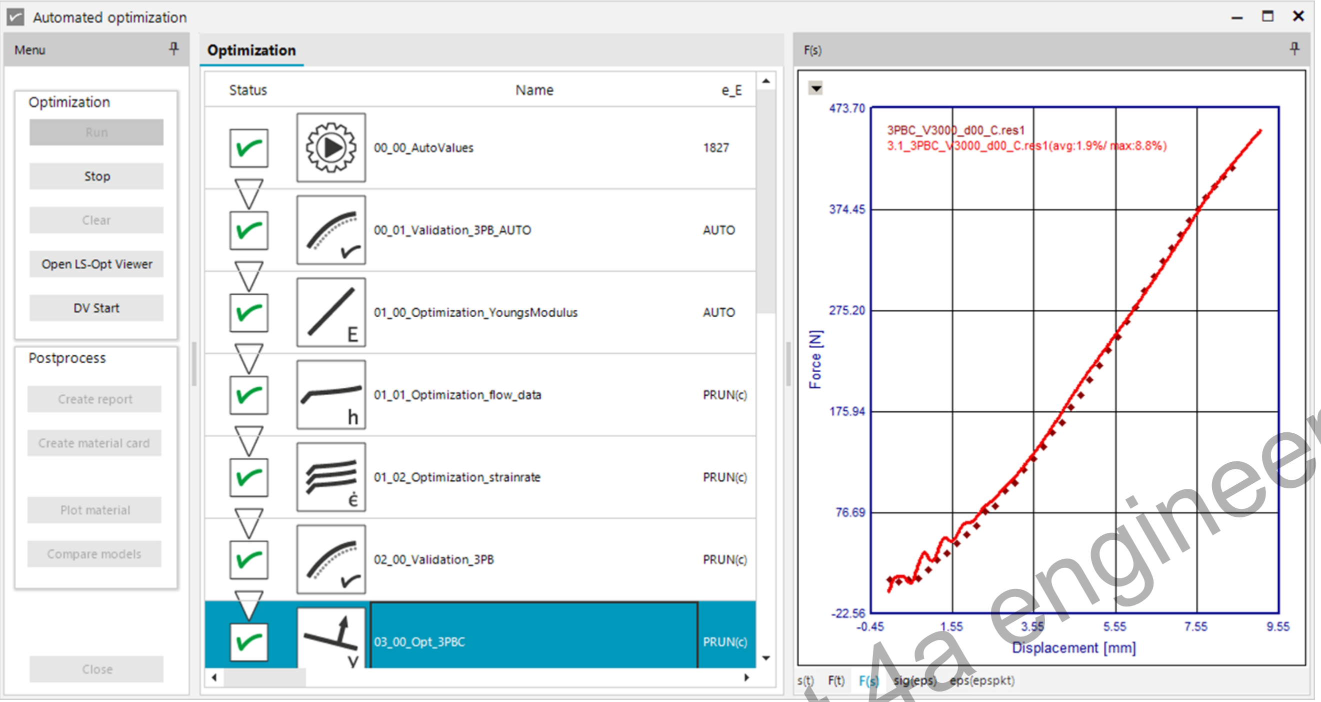
Optimization yield surface – Drucker Prager

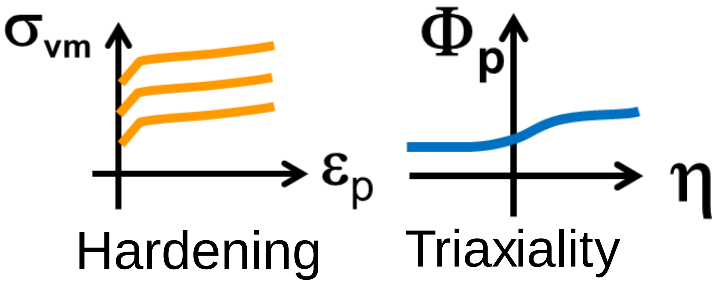
Validation/Optimization: **Optimization Yieldsurface**

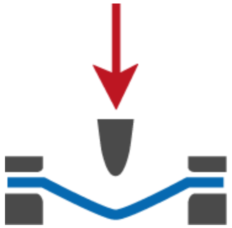
- Drucker/Prager parameters introduced
- Optimized Parameters are set to PRUN
- New Parameters
  - h_scale0: from 3PB ➔ TT
  - h2_scale: from TT ➔ CT

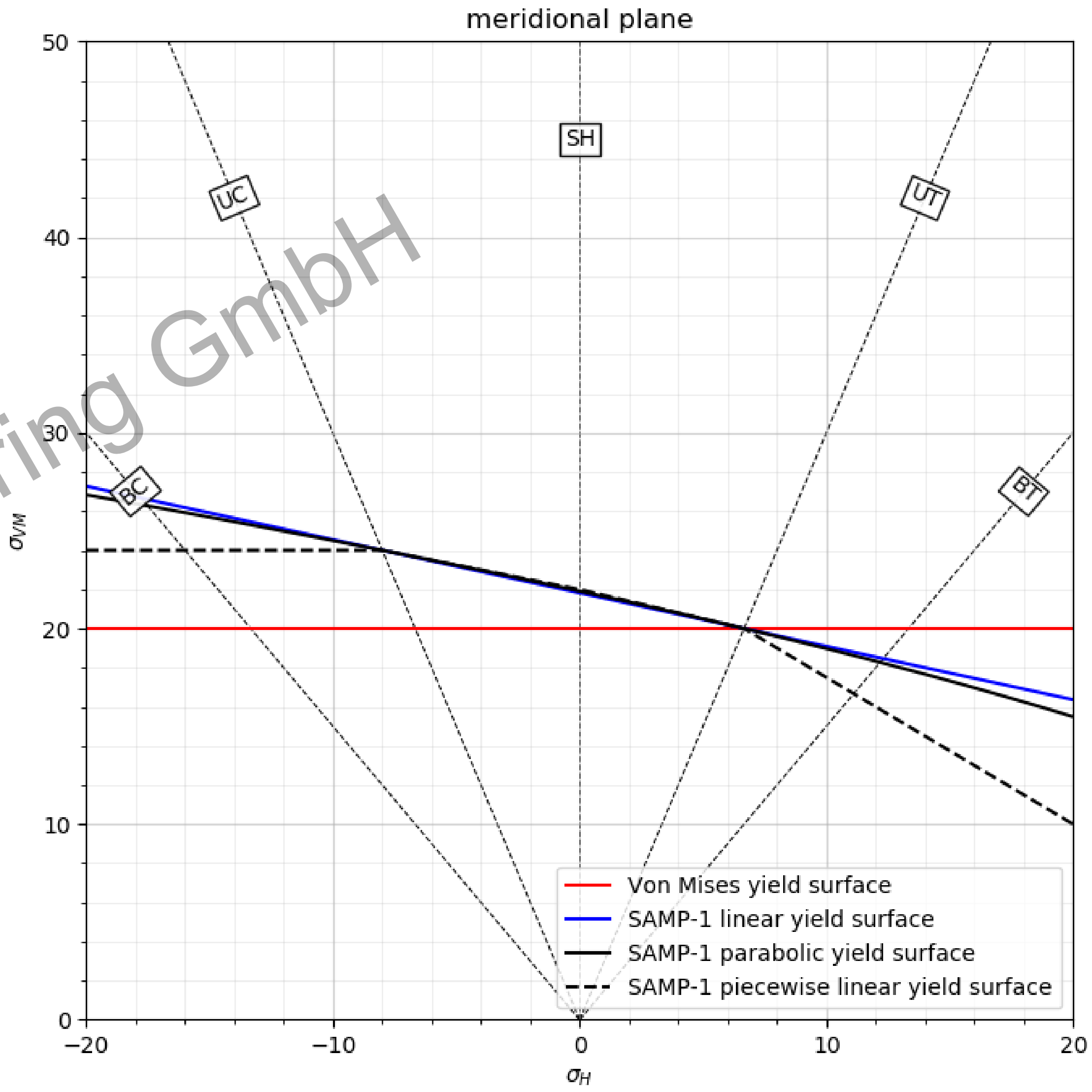
Name	Start	const...	from	to	Variance	Condition	Description
GroupName: 10_elasticity							
GroupName: 20_yield							
y_0	PRUN	✓	20%	50%	50		yield stress
y_nuep	NaN		0.01	0.5	(NULL)	=xm_nuep_plat	plastic poisson ratio
y_C	90		5	150	50	=y_T*h2_scale	yield stress compression
y_T	NaN		5	150	50	=y_0*h_scale0	yield stress tension
GroupName: 21_hardening							
h_nuep	NaN	✓	0	0.5	(NULL)	=xm_nuep_plat	hardening plastic poison ratio
h_scale0	0.7		0.5	1.0	(NULL)		scalefactor for scaling the yieldcurve, e.g. tension/bending
h_y	AUTO	✓	5	150	50	=y_0	hardening yield stress
h_ET	PRUN	✓	0	100	(NULL)	<e_E	tangent modulus
h2_scale	1.8571		1	3	(NULL)	=2/h_scale0-1	scale factor for curve 1
h_h	PRUN	✓	5	200	(NULL)		hardening stress plateau
GroupName: 22_hardening							
xm_nuep_eps	AUTO	✓	(NULL)	(NULL)	(NULL)		plastic strain to almost reach nuep_plat
xm_nuep_plat	AUTO	✓	(NULL)	(NULL)	(NULL)		plastic Poissons ratio at infinite tension strain
xm_nuep_meps	AUTO	✓	(NULL)	(NULL)	(NULL)		last point for LCID-P
xm_nuep_pres	AUTO	✓	(NULL)	(NULL)	(NULL)		plastic Poissons ratio in compression domain
GroupName: 31_strainrate							

Workflow for Material Card Generation - AUTOFIT









Workflow for Material Card Generation - AUTOFIT

Optimization yield surface – Drucker Prager

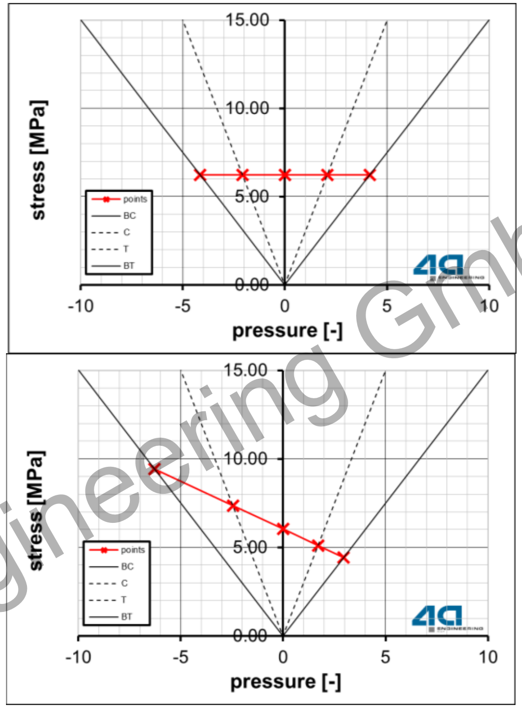
*MAT_024:

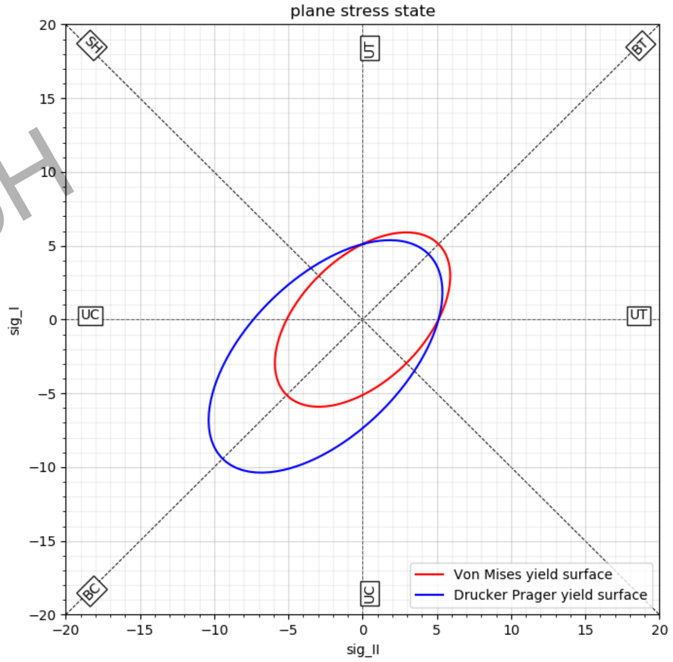
- Von Mises: $f(\boldsymbol{\sigma}) = q - \sigma_0$

*MAT_187:

- Drucker Prager: $f(\boldsymbol{\sigma}) = q - b \cdot p - a$

Material behaviour	
Material source	Implemented
Material card	*MAT_SAMP-1 (*MAT_187) log Table R9.3+
Deformation	Pressure dependent (Drucker-Prager)





- Designvariables:

Name	Start	constant	from	to	Variance	Condition
h_scale0	0.7	False	0.5	1.0	(NULL)	
y_T	NaN	False	5	150	50	=y_0*h_scale0
y_C	90	False	5	150	50	=y_T*h2_scale
y_0	PRUN	True	20%	50%	50	
h2_scale	1.8571	False	1	3	(NULL)	=2/h_scale0-1

BT: Biaxial Tension
UT: Uniaxial Tension
SH: Shear
UC: Uniaxial Compression
BC: Biaxial Compression

Workflow for Material Card Generation - AUTOFIT

Optimization yield surface – Drucker Prager

The change of the flow rule must be considered in the hardening law

MAT_024

⊟ Function (Hardening, Elastic curv	
Curve 1	4a model (nue 0.5)
Strain range upto	1.5
Sampling points	50
Bias factor	10
⊞ Strain rate dependency	Table
Fracture	None
Postfracture	None
⊟ **Loadcases**	
⊞ Casename	3PB_stat_low_velo

$$\left[hy + e_E \cdot \varepsilon_{pl} \cdot \frac{1+\frac{h_{ST}\cdot\varepsilon_{pl}}{e_S}}{1+\frac{e_S\cdot\varepsilon_{pl}}{h_s}} \right] \cdot e^{\varepsilon_{pl}\cdot 2\cdot h_{nuep}} \cdot h_{scale0}$$

0.5 (→ h_{nuep})

MAT_187

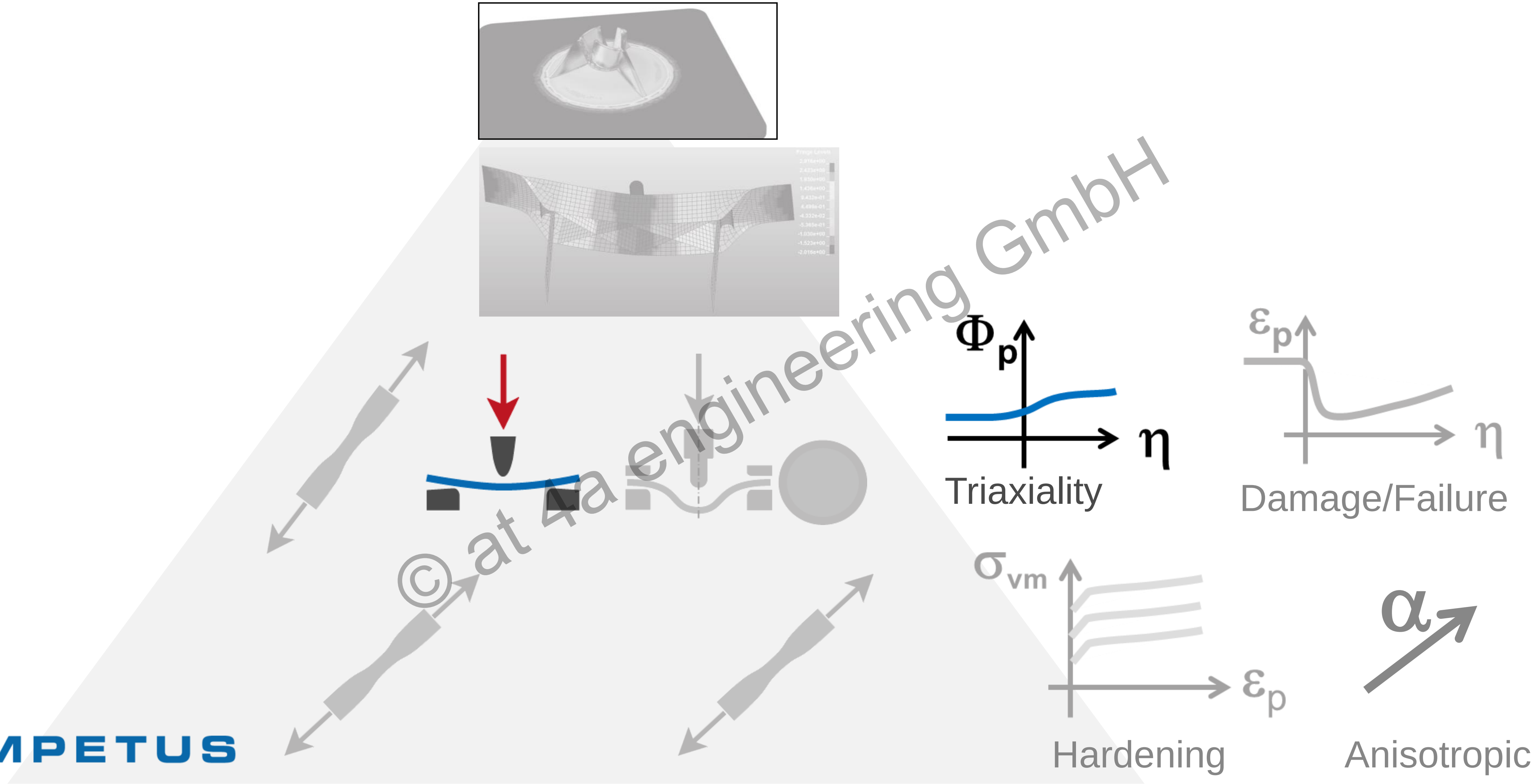
⊟ Function (Hardening, Elastic curv	
Curve 1	4a model (nue)
Strain range upto	1.5
Sampling points	50
Bias factor	10
⊞ Strain rate dependency	Table
Fracture	None
Postfracture	None
⊟ **Loadcases**	
⊞ Casename	3PB_stat_low_velo

$$\left[hy + e_E \cdot \varepsilon_{pl} \cdot \frac{1+\frac{h_{ST}\cdot\varepsilon_{pl}}{e_S}}{1+\frac{e_S\cdot\varepsilon_{pl}}{h_s}} \right] \cdot e^{\varepsilon_{pl}\cdot 2\cdot h_{nuep}} \cdot h_{scale0}$$

xm_nuep_plat (→ h_{nuep})

Somewhat taken into account
Should use law and a compression curve

from test to material card

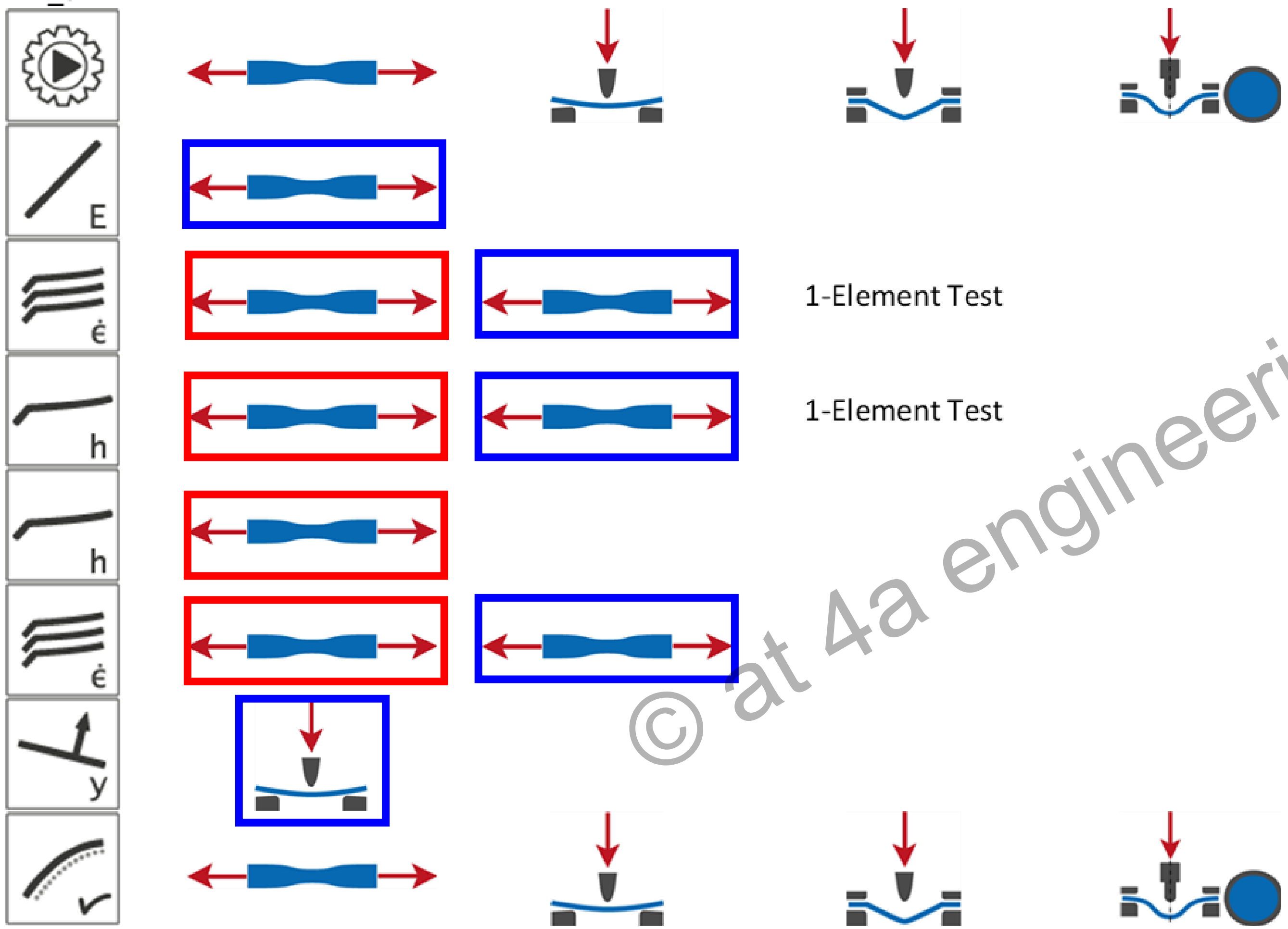


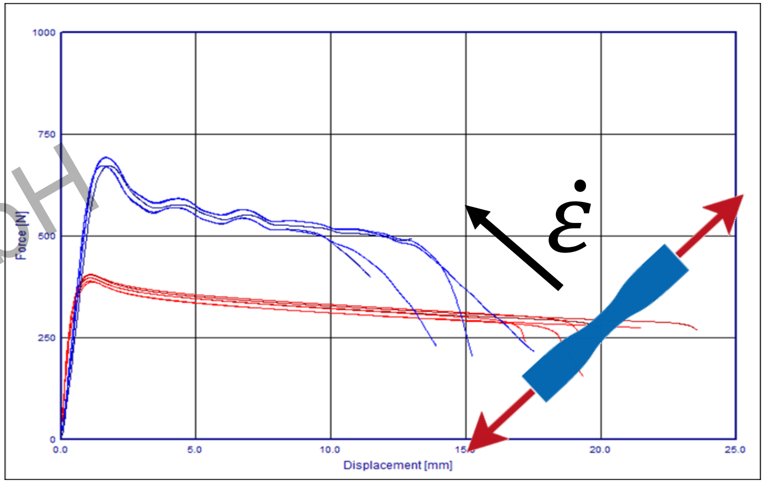
AutoFit

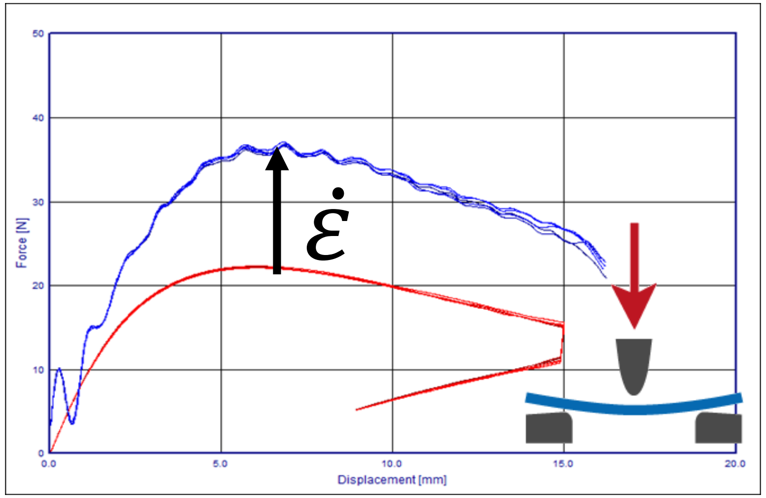
Strategy

without border all velocities
quasistatic
dynamic

MAT_SAMP

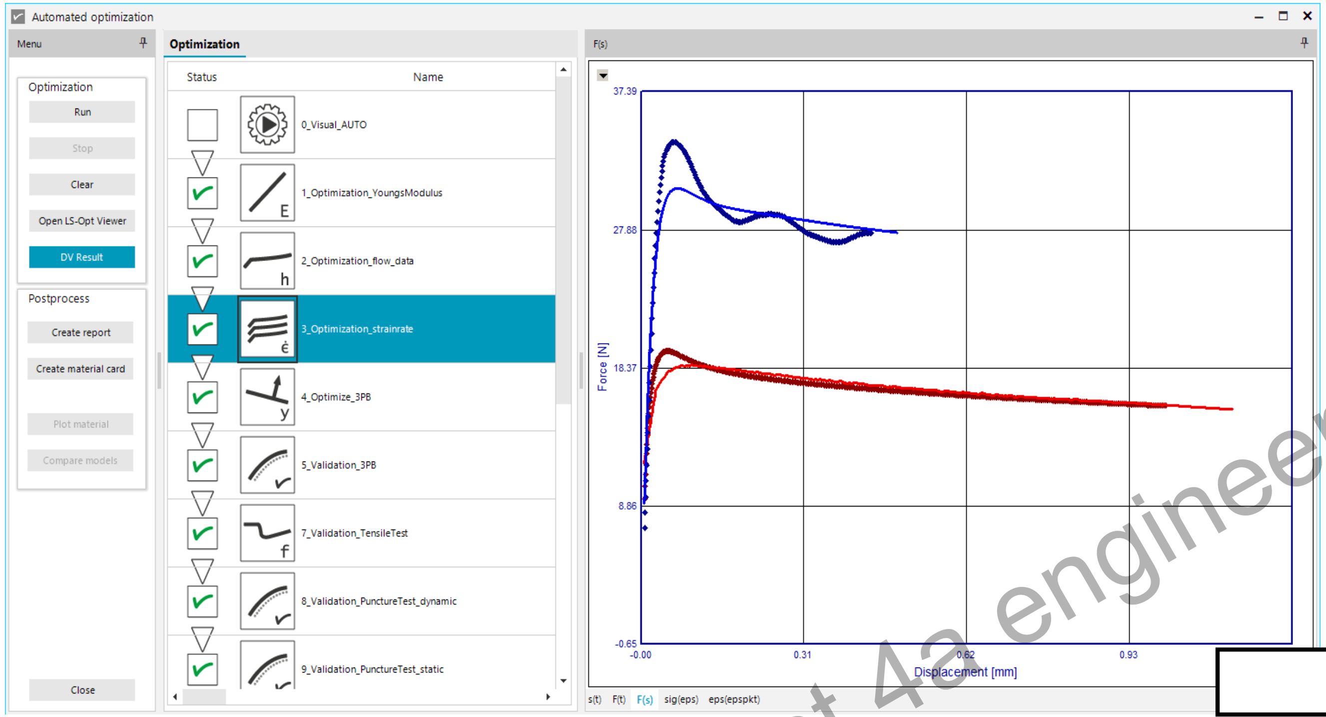


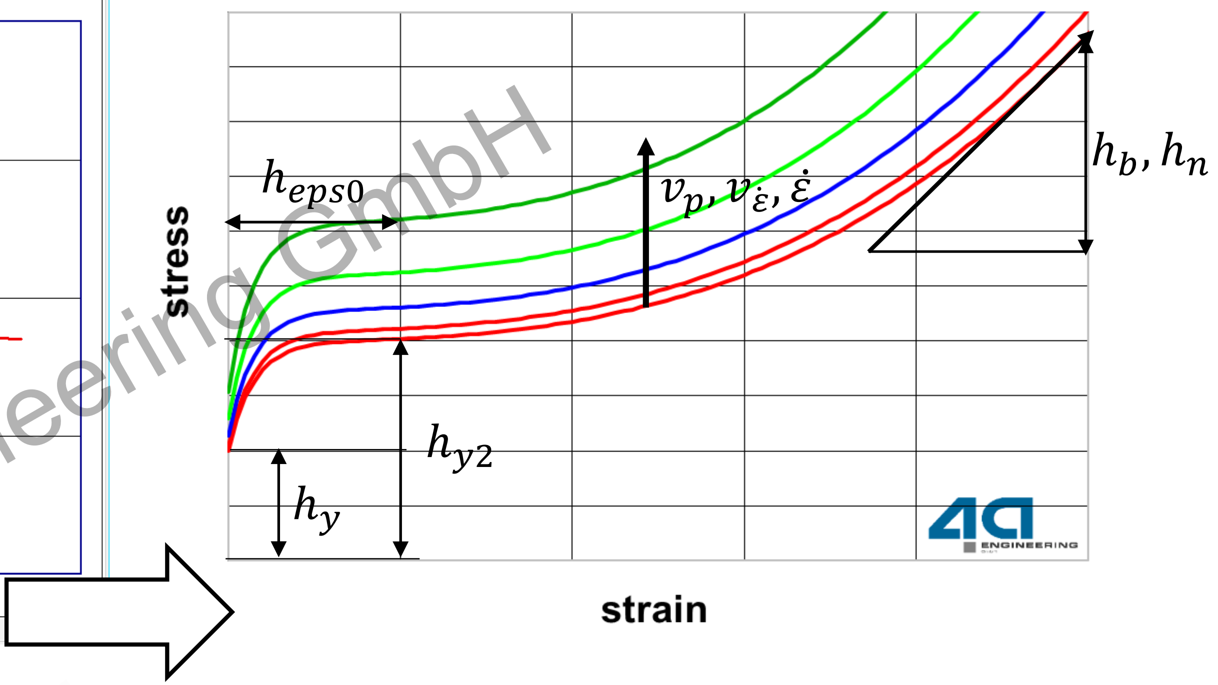


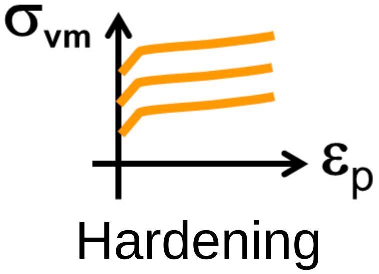


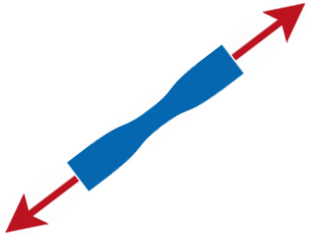
source: Benjamin Hirschmann, master thesis

Workflow for Material Card Generation - AUTOFIT







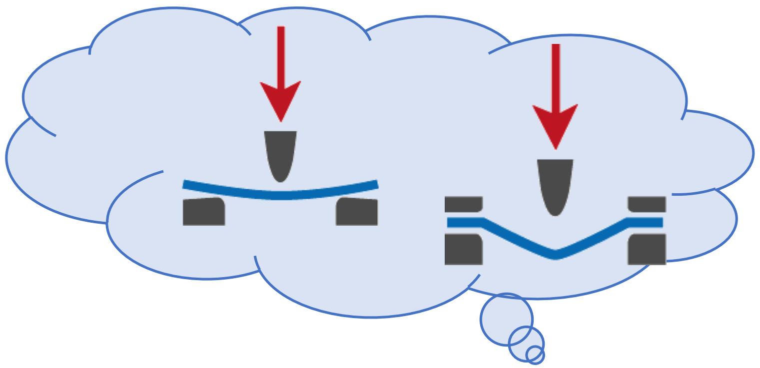


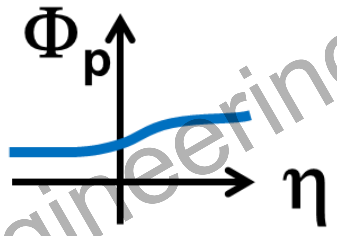
VALIMAT

AutoFit

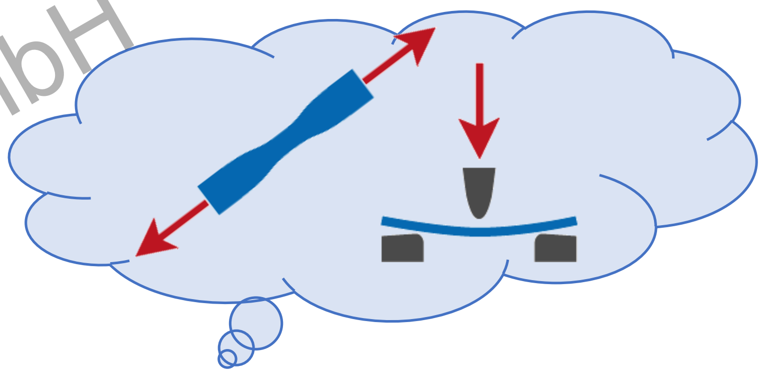
Optimization yield surface – Drucker Prager

From test to material card – ?





Triaxiality

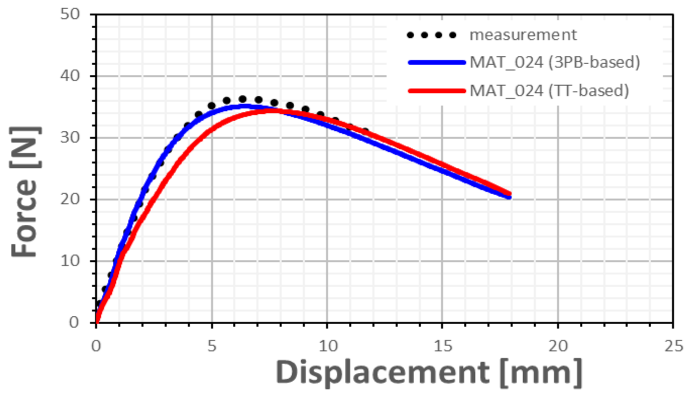


Peter ♡ Bending

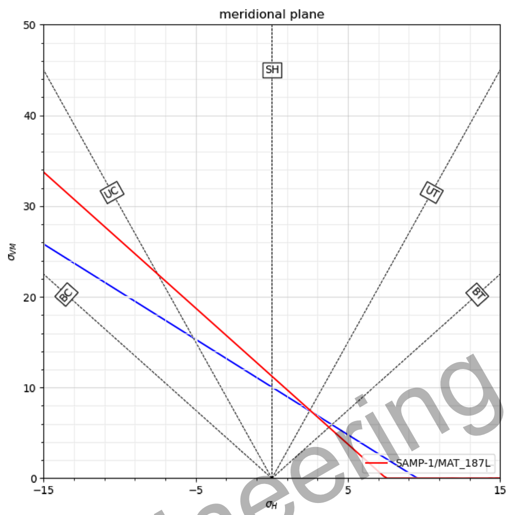
Benjamin ♡ Tension

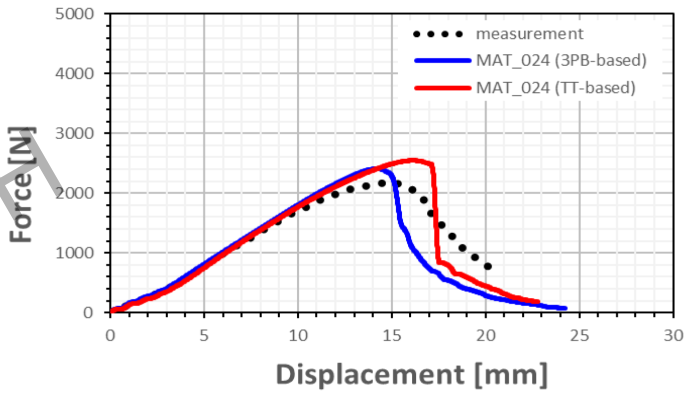
Comparison Fitting Strategies – *MAT_187

VALIMAT



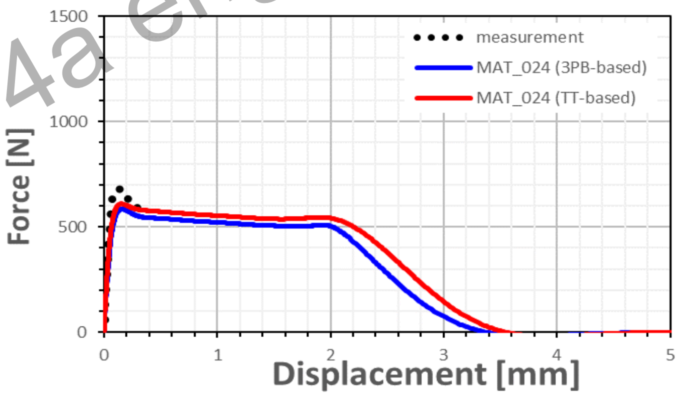
3 POINT BENDING





PUNCTURE TEST

IMPETUS® ~ 3 m/s

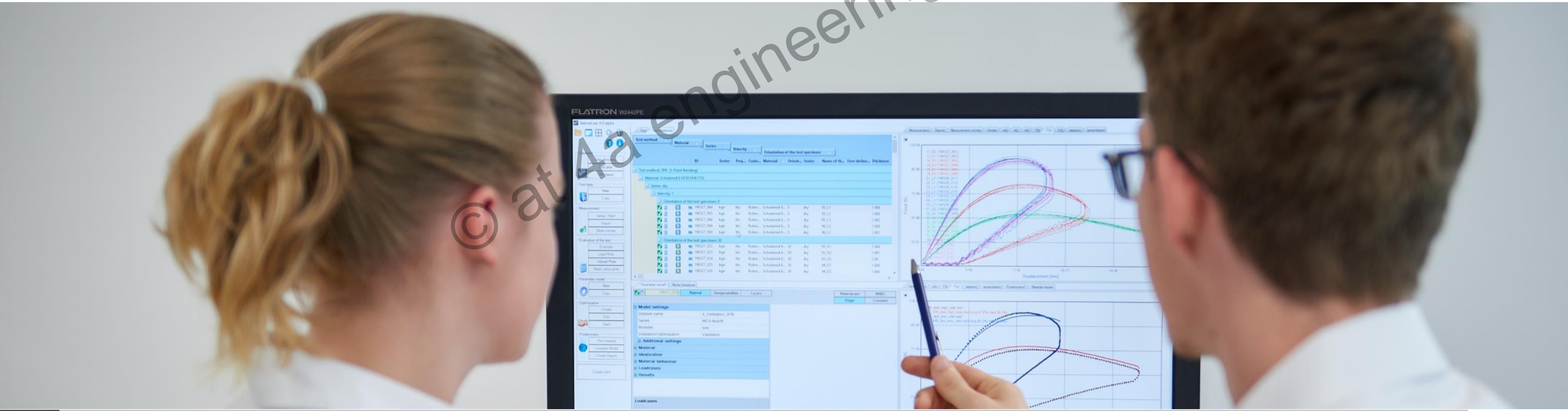


TENSION TEST

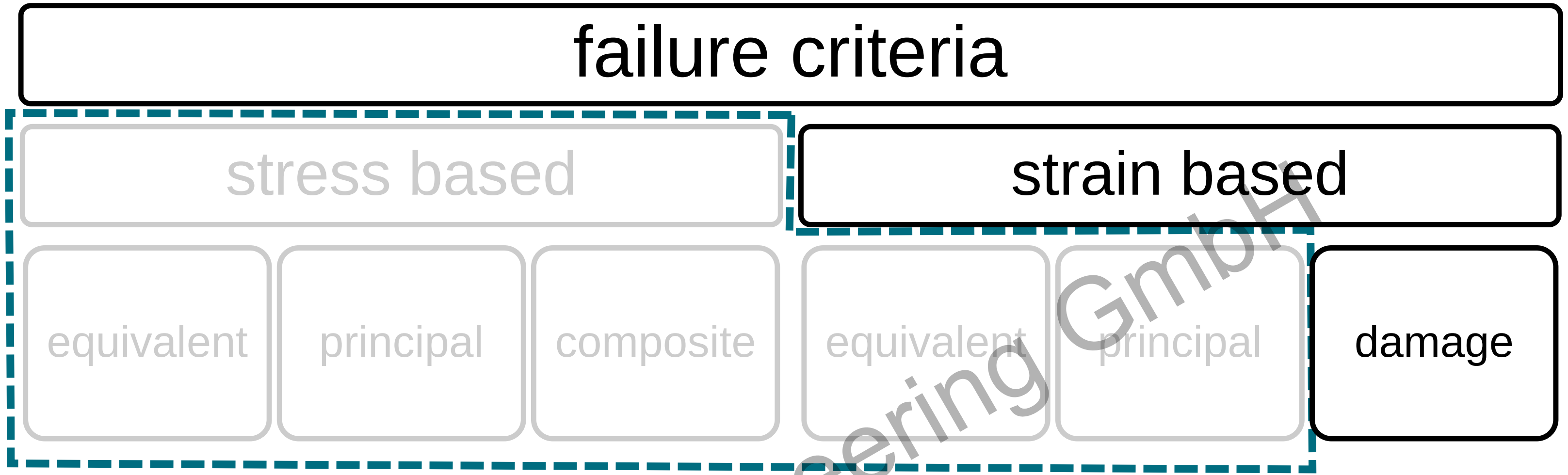
···· averaged test curves
— result of simulation

source: Benjamin Hirschmann, master thesis

Short Recap available failure/damage models in LS-DYNA®



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***

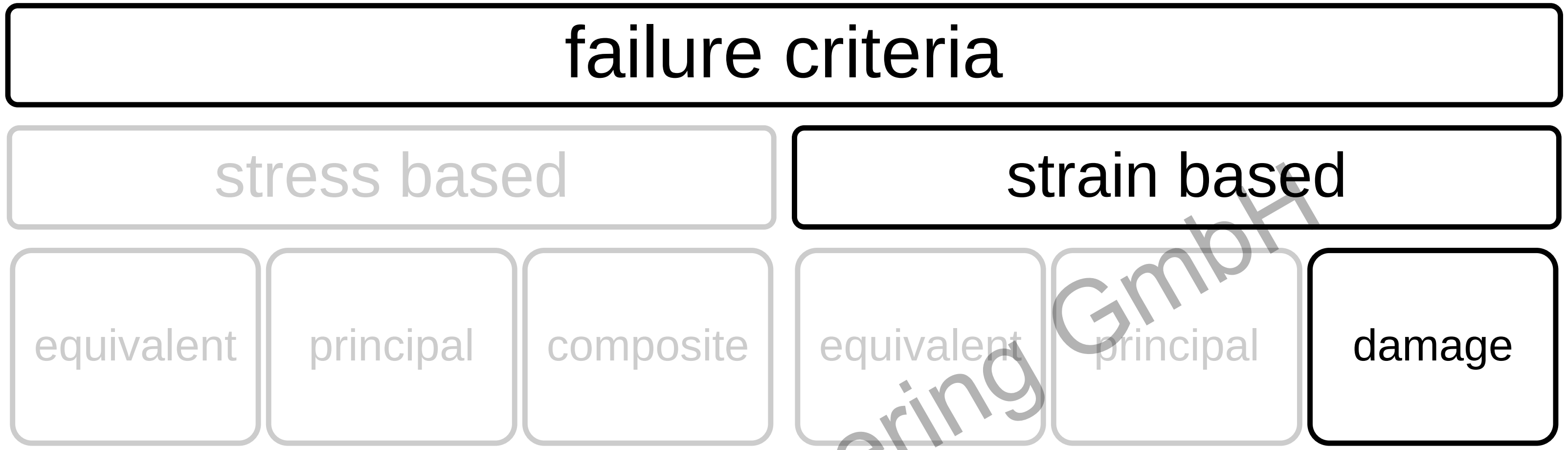
Included eq. pl. strain

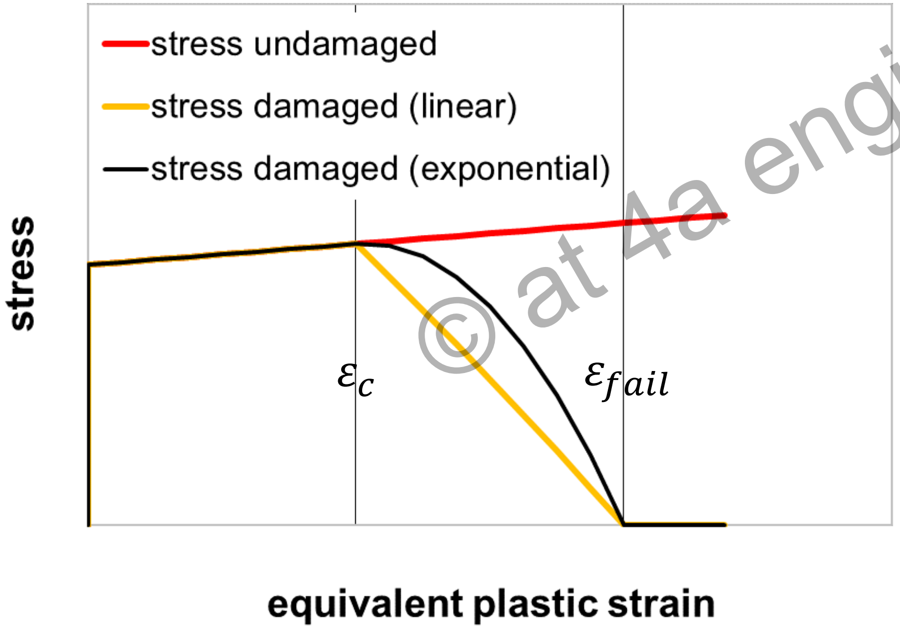
****MAT_024***

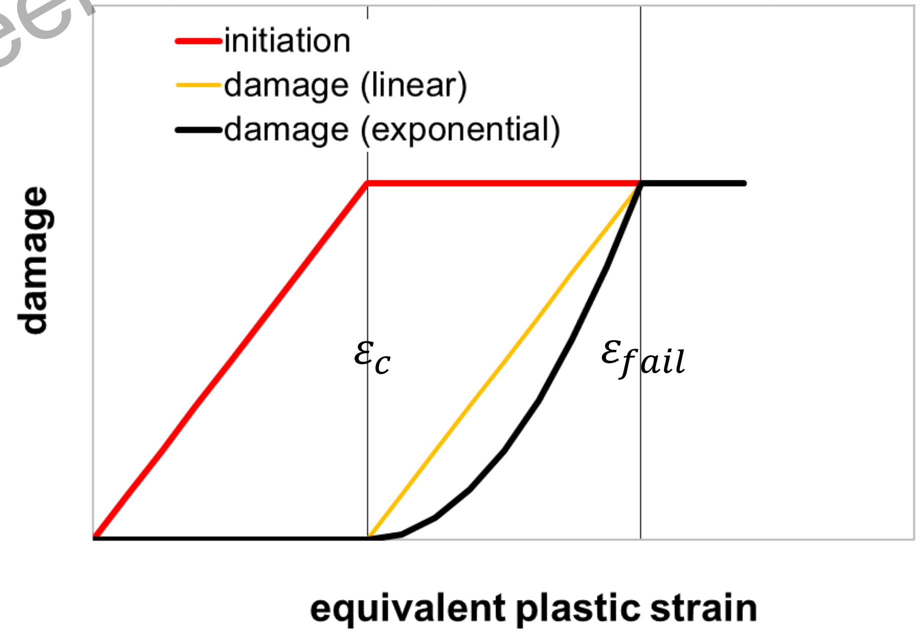
included damage model in

****MAT_SAMP-1(GISSMO like)***

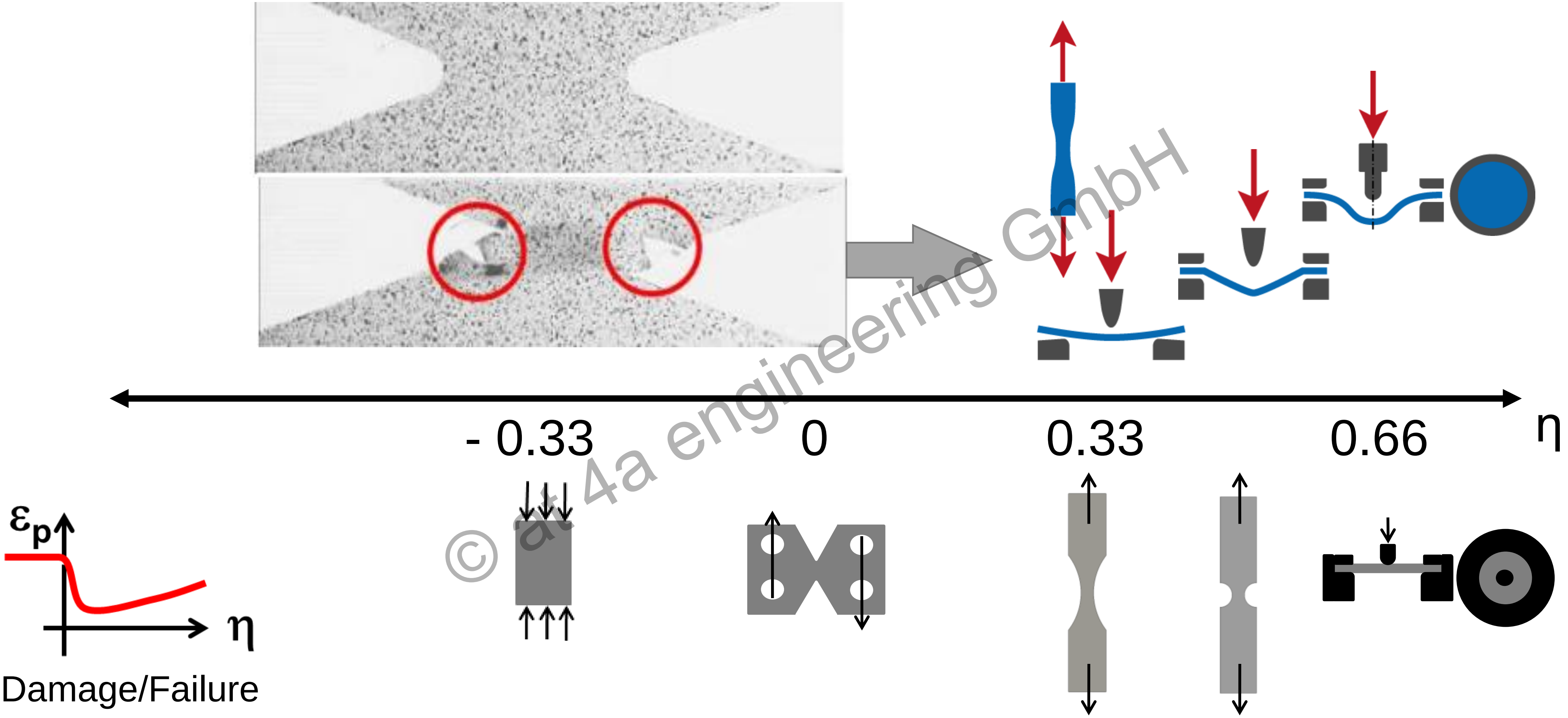
Available failure models – incremental damage formulation



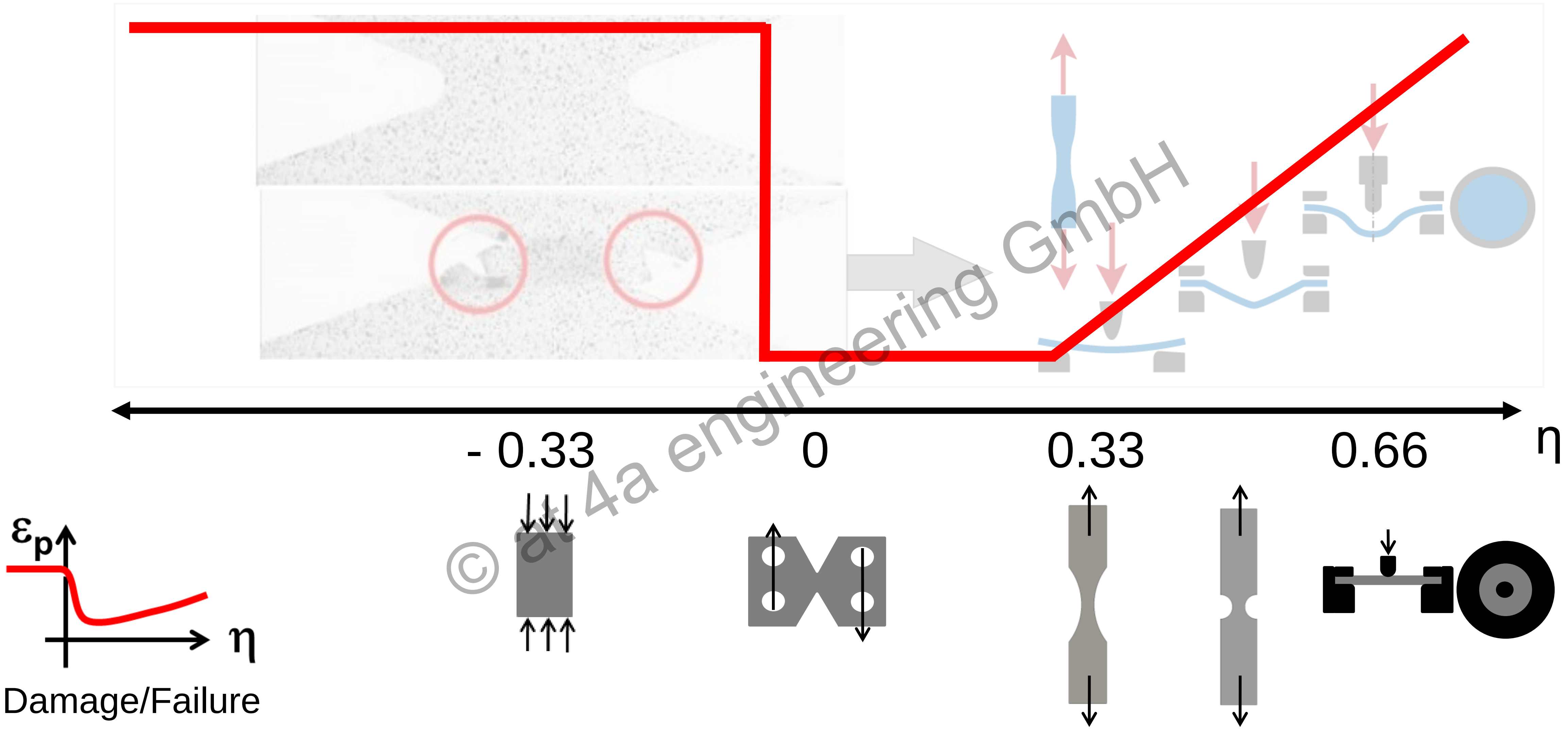




from test to material card

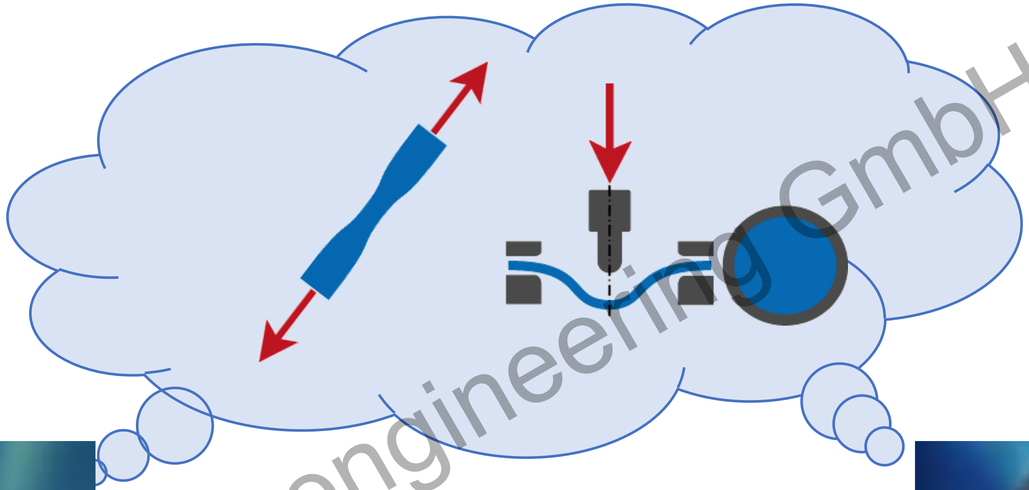


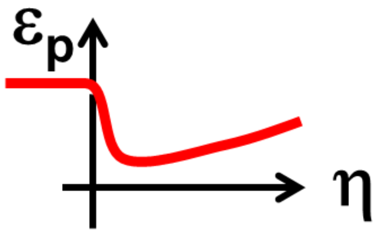
from test to material card



VALIMAT

From test to material card – failure



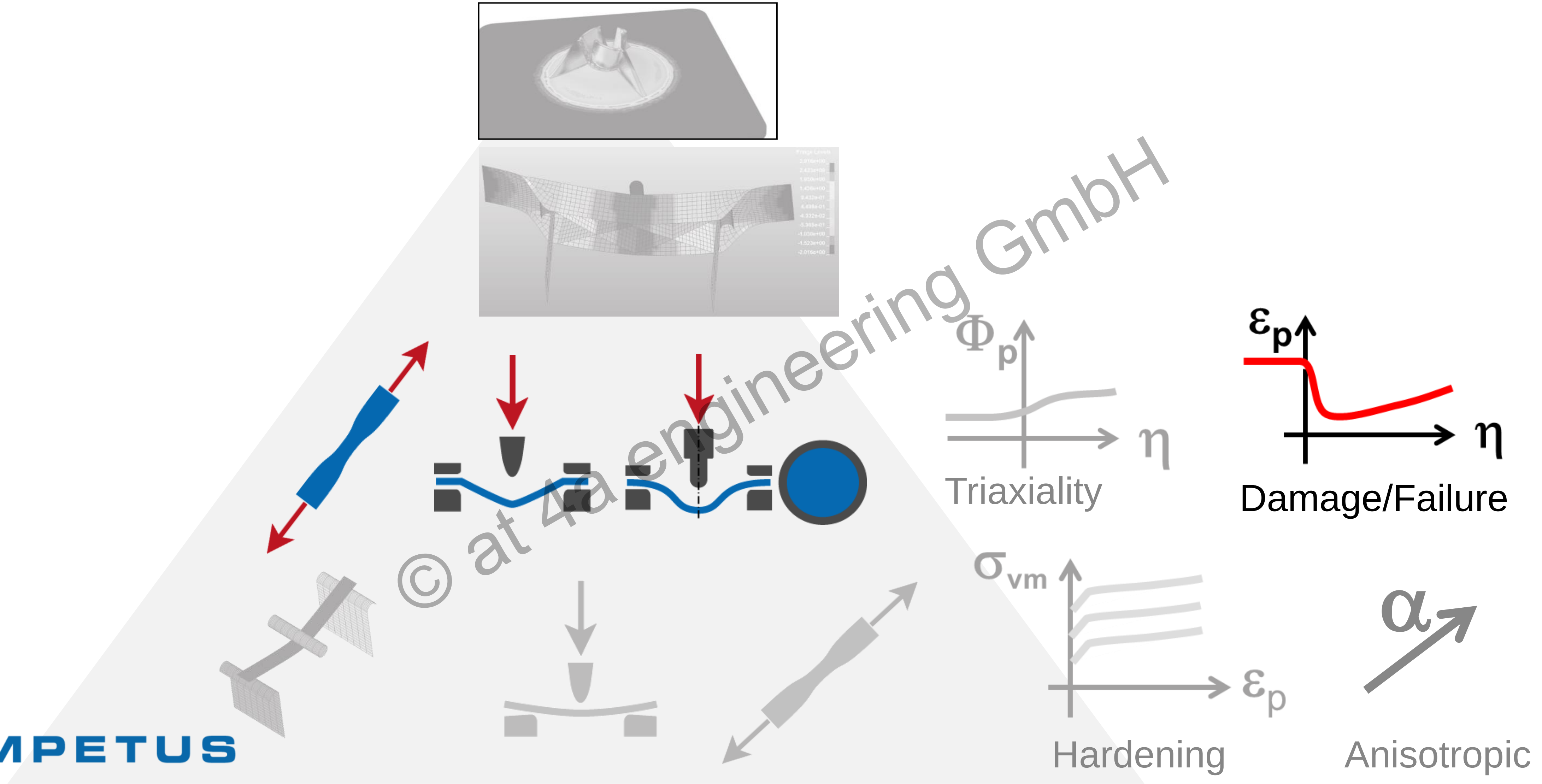


Damage/Failure

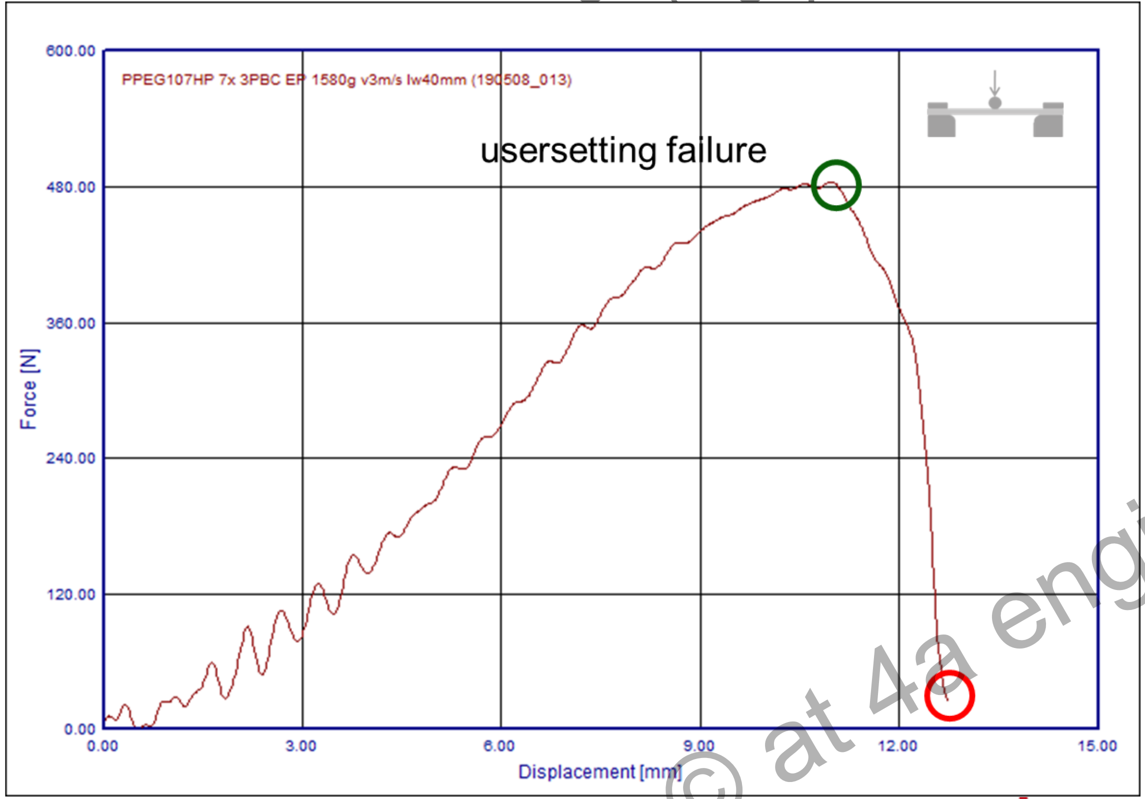
Peter

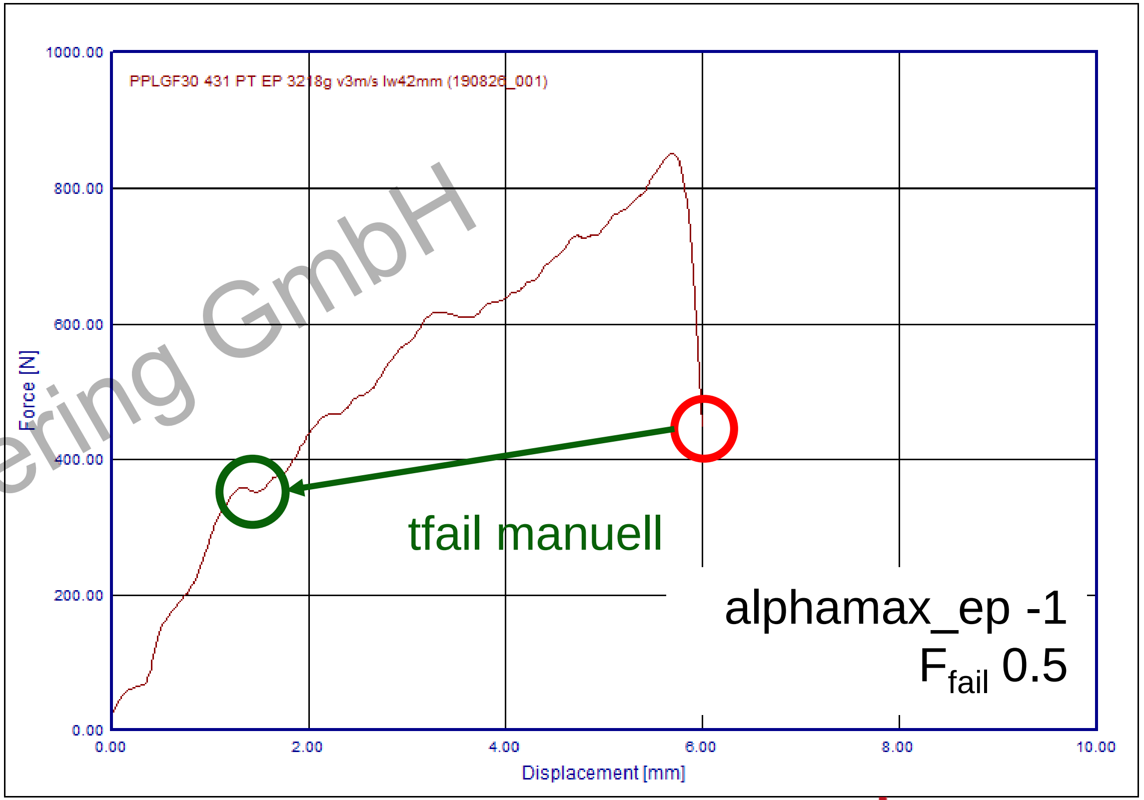
Benjamin

from test to material card

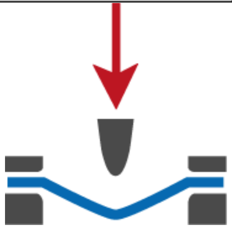


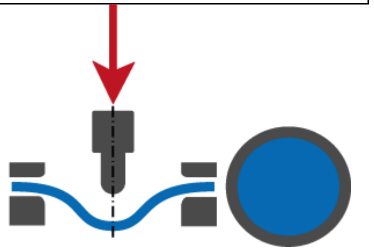
VALIMAT® - Identification of failure
manual failure settings (e.g. puncture test)



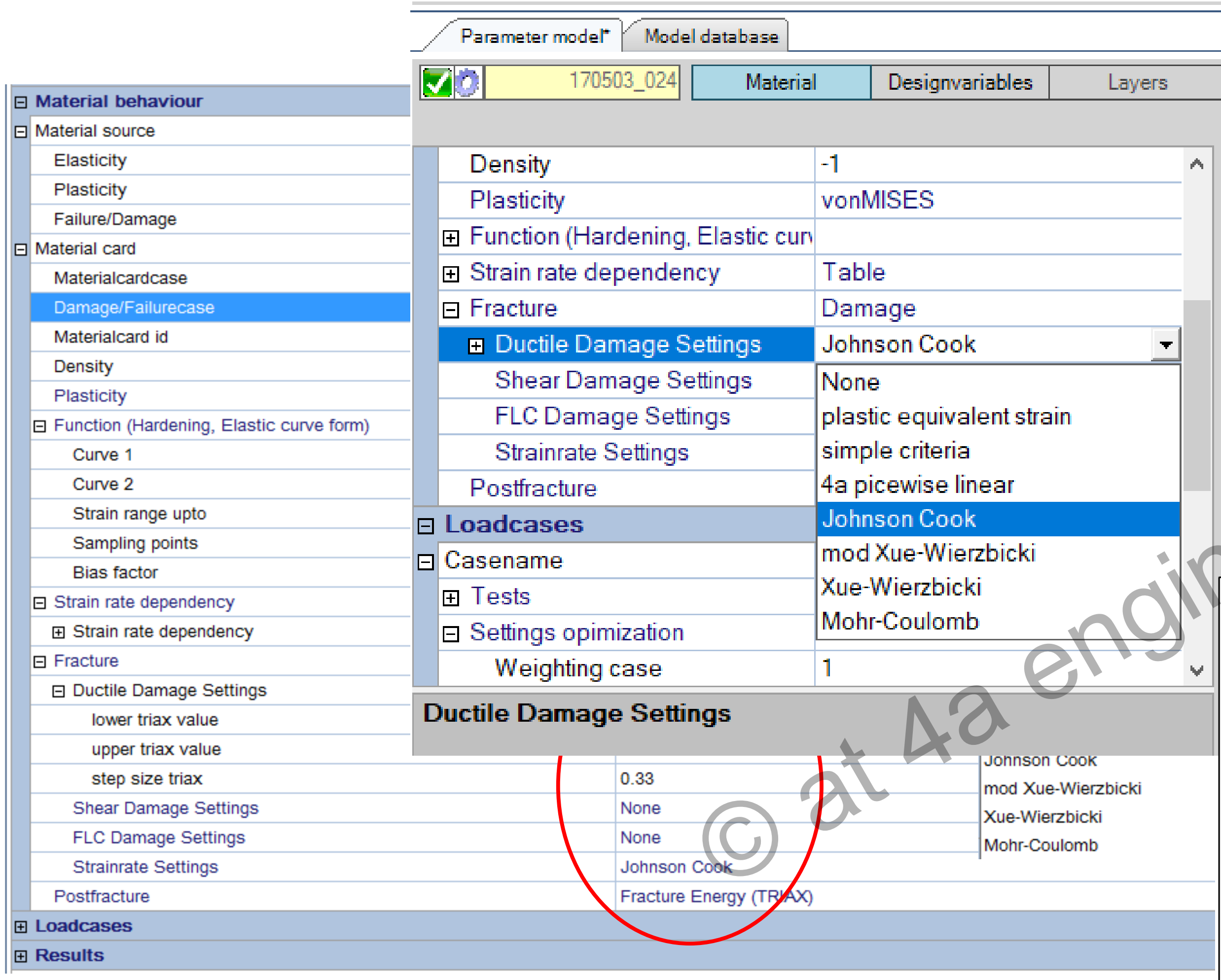


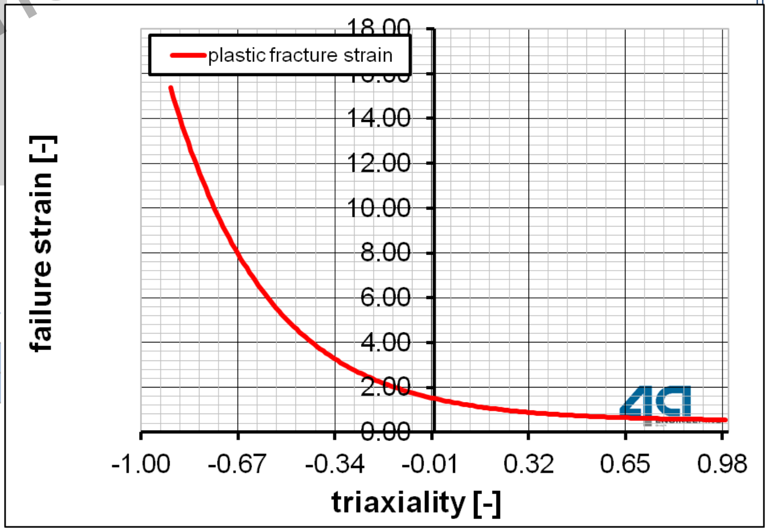
VALIMAT LIVE

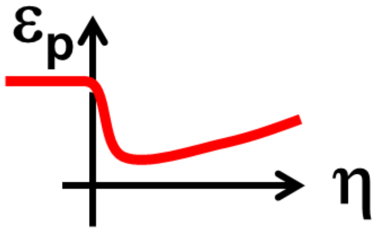




fracture models → *MAT_ADD_EROSION



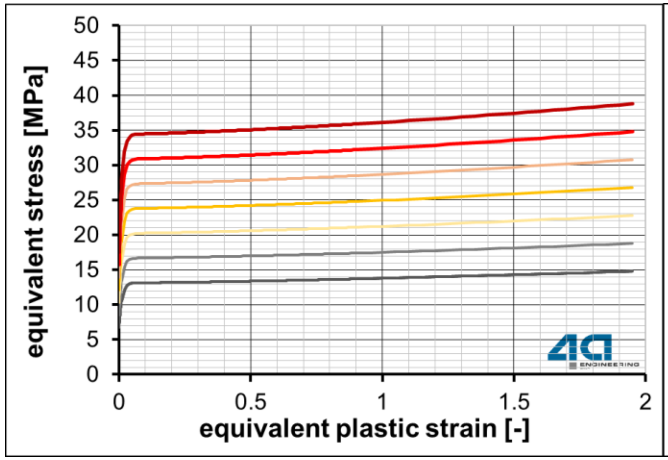


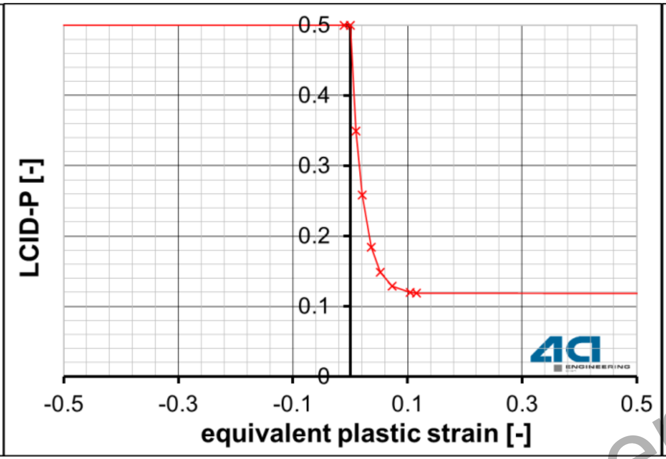


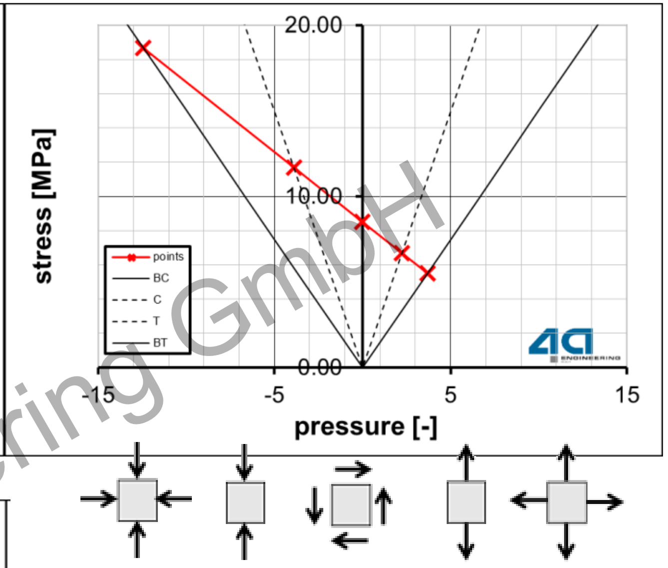
Damage/Failure

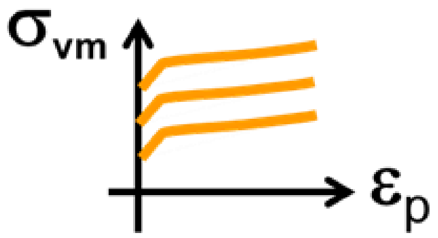
typical result - *MAT_SAMP-1 with failure

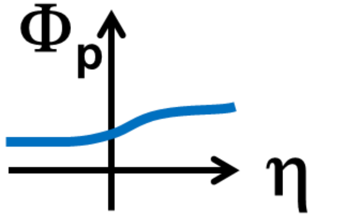
VALIMAT

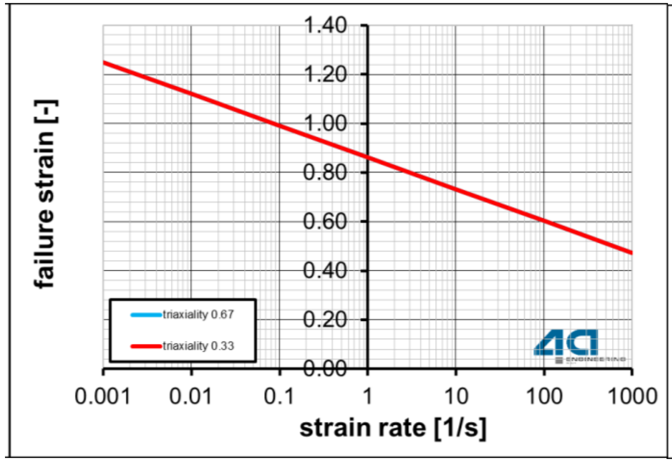


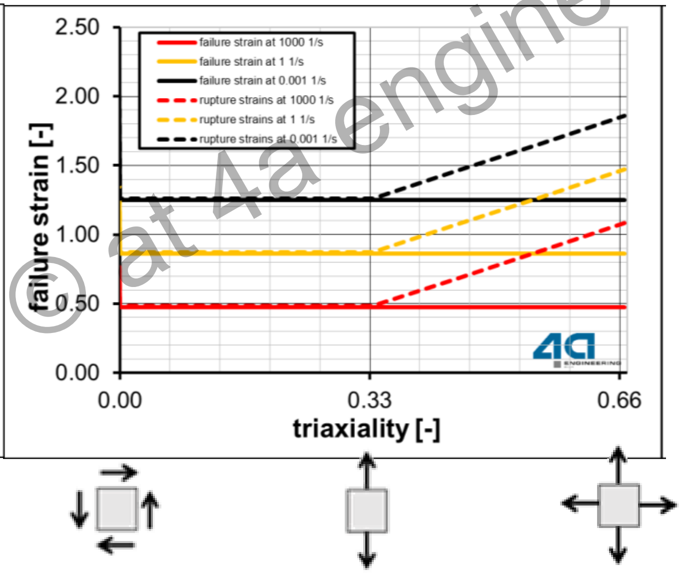


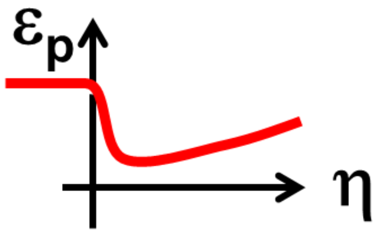






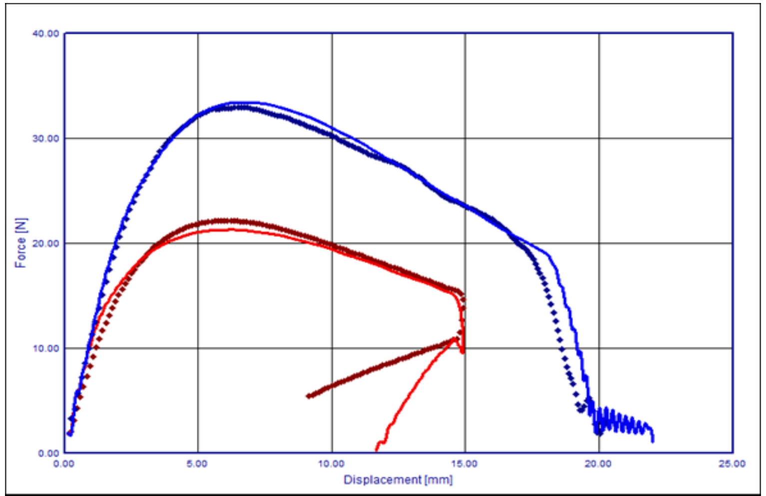




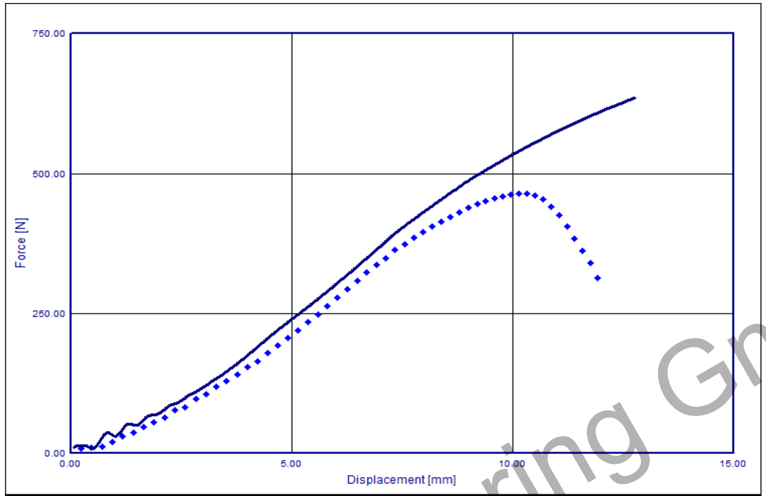


source: Benjamin Hirschmann, master thesis

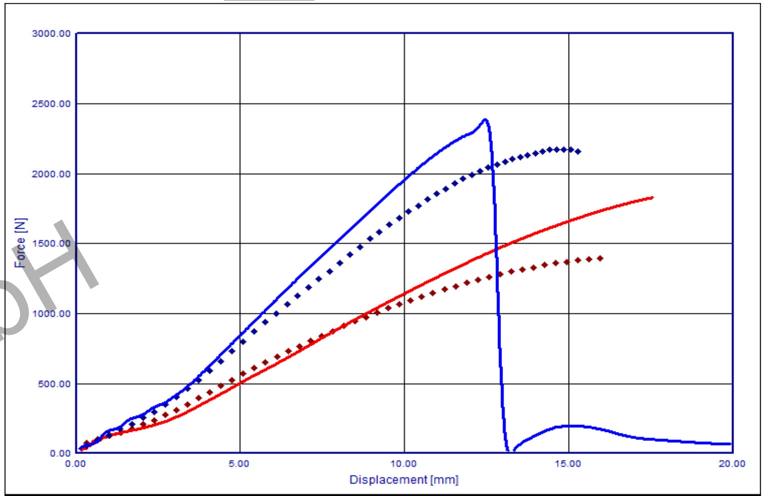
typical result - *MAT_SAMP-1 with failure



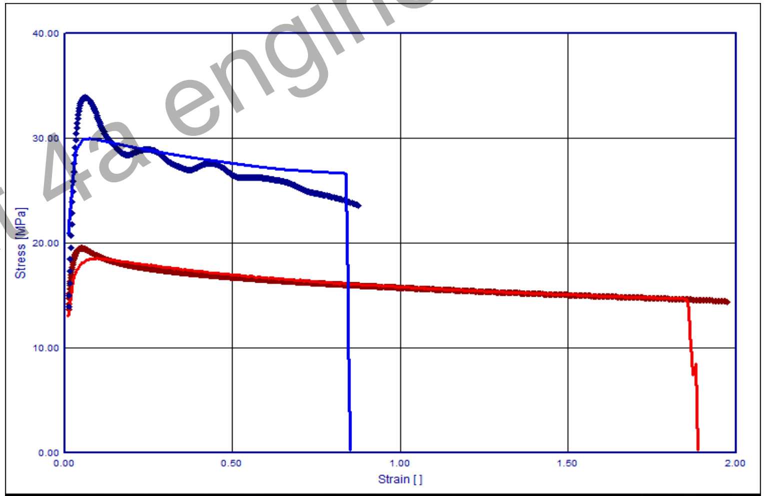
3 POINT BENDING



TENSION BENDING



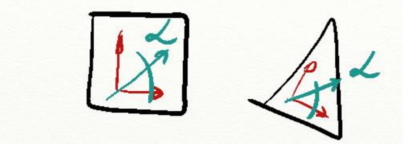
PUNCTURE TEST



TENSION TEST

IMPETUS® ~ 3 m/s

static ~ 1mm/s

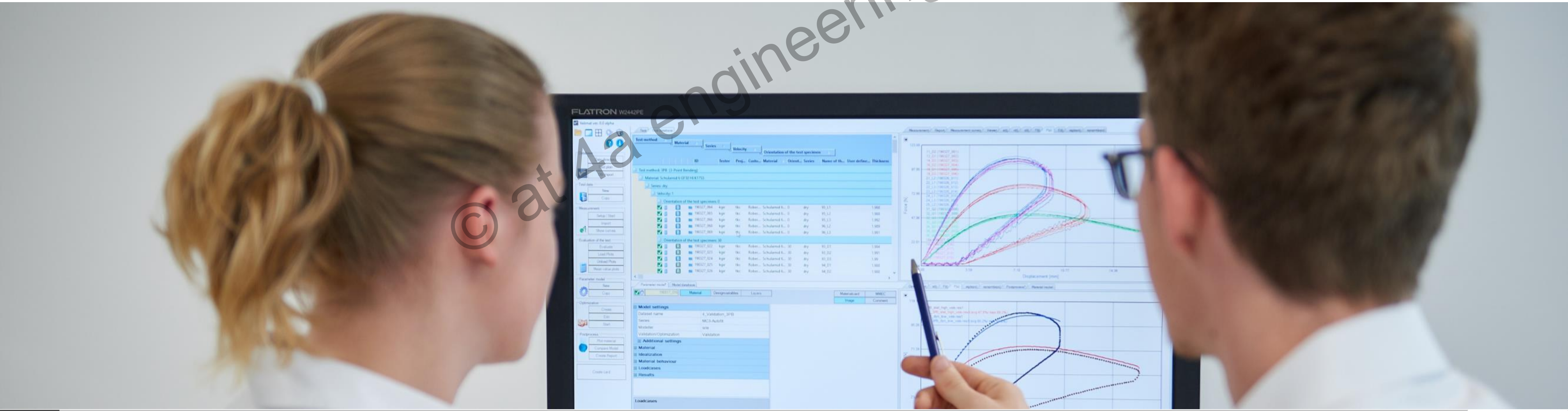


···· averaged test curves

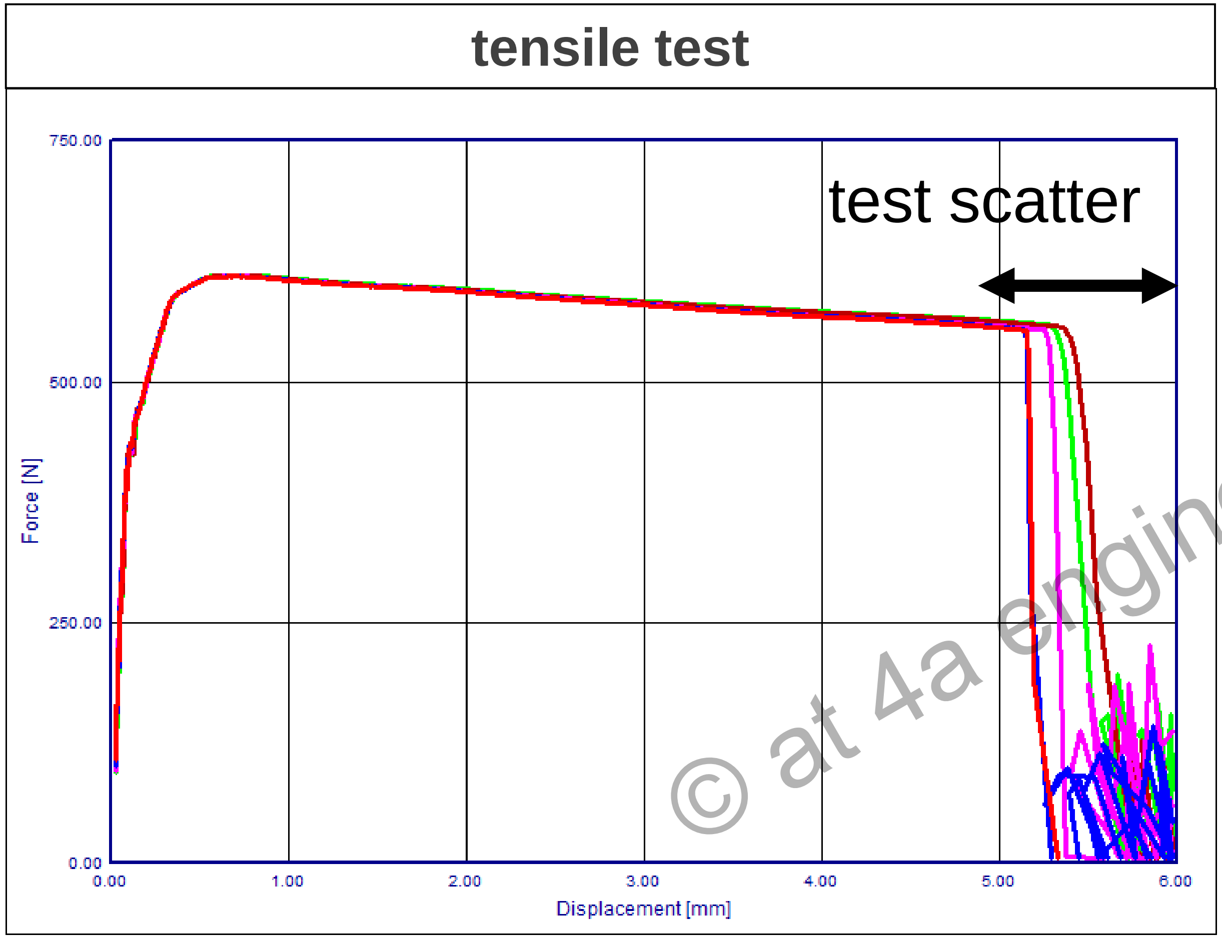
— result of simulation

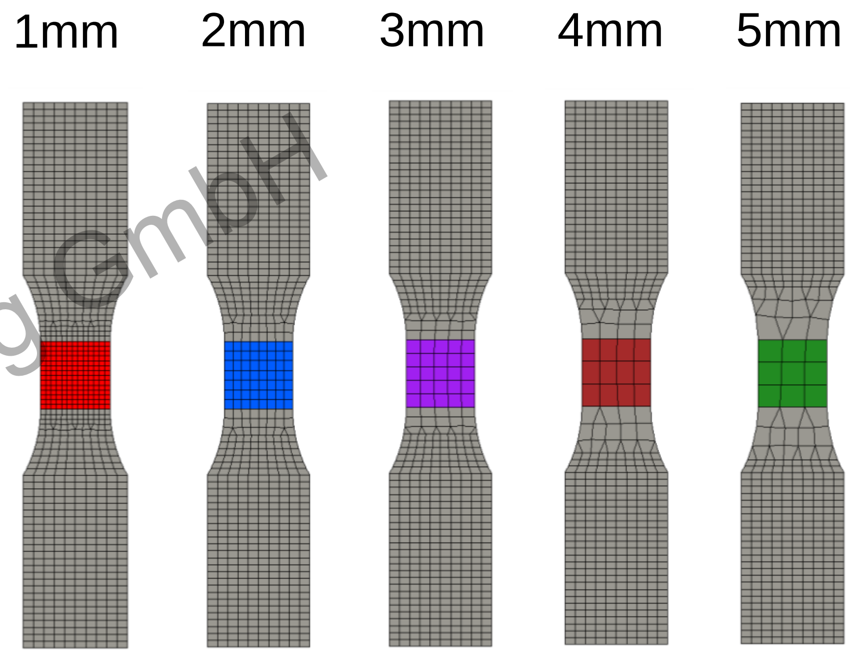
source: Benjamin Hirschmann, master thesis

From test to material card – Element Regularisation



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

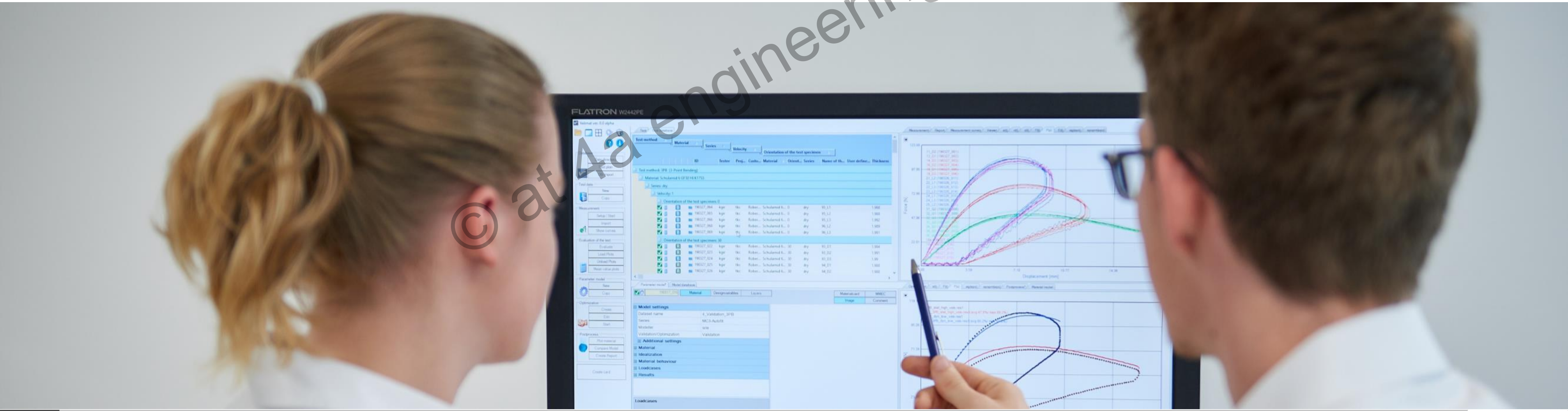




VALIMAT

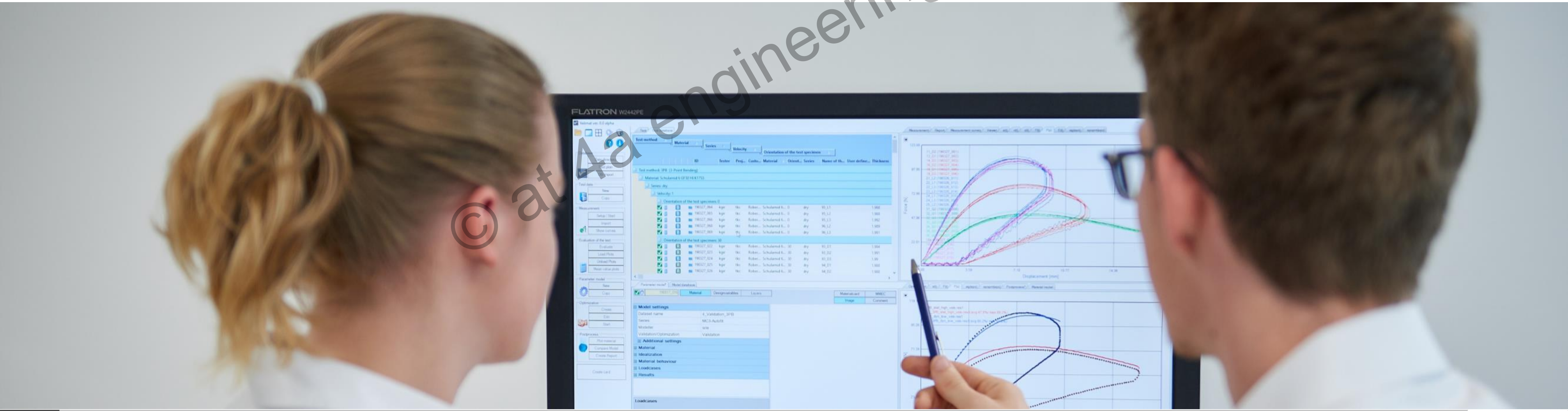
source: Benjamin Hirschmann, master thesis

From test to material card – Comparison different material models



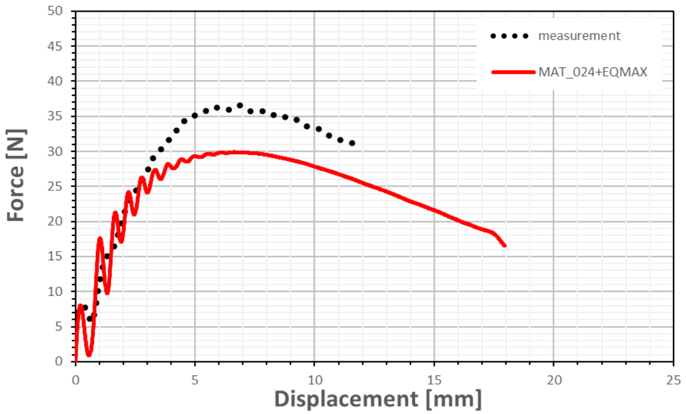
Comparison different material models

- stability
- numerical cost
  - number of operations in material model ➔ Translation into simulation model (localization, load path,…)
  - relative numerical cost of the material model (measurement model comparison)
- accuracy

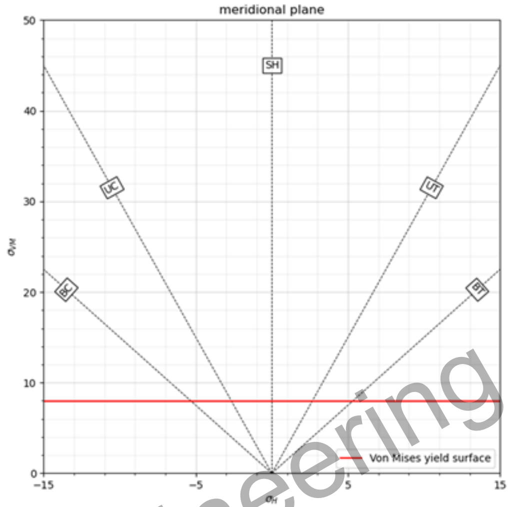


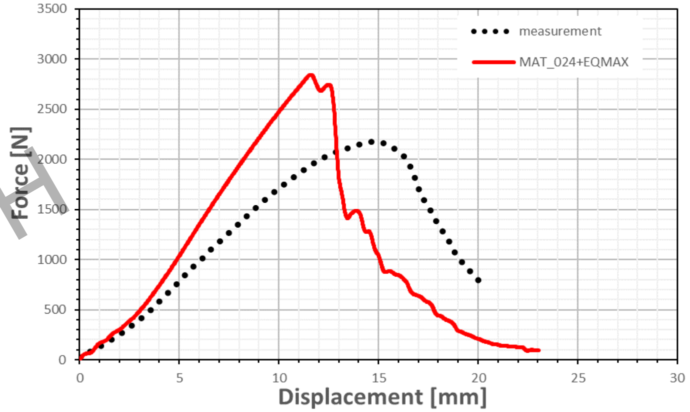
Relative Numerical Cost of the Material Model – *MAT_024

VALIMAT



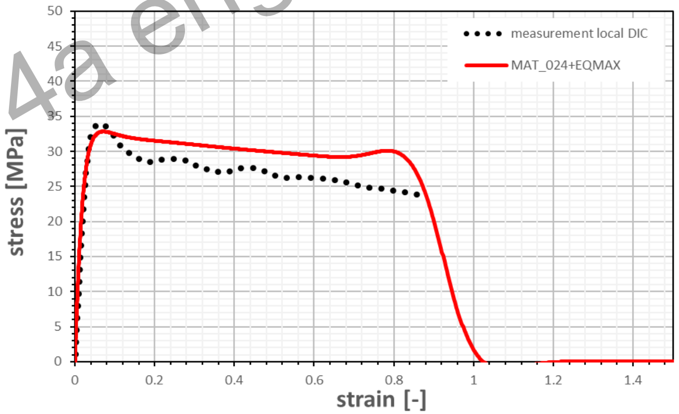
3 POINT BENDING





PUNCTURE TEST

IMPETUS® ~ 3 m/s



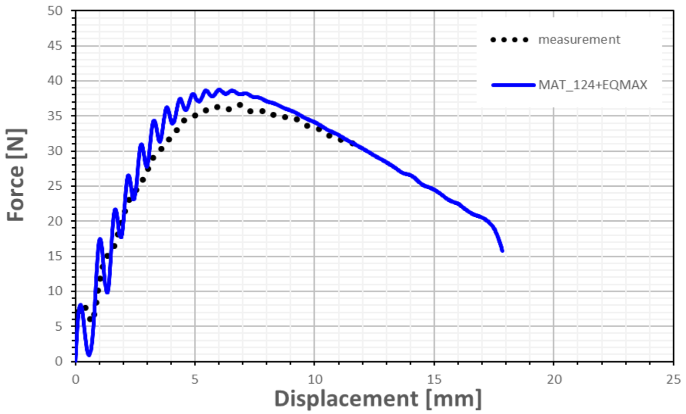
TENSION TEST

···· averaged test curves
— result of simulation

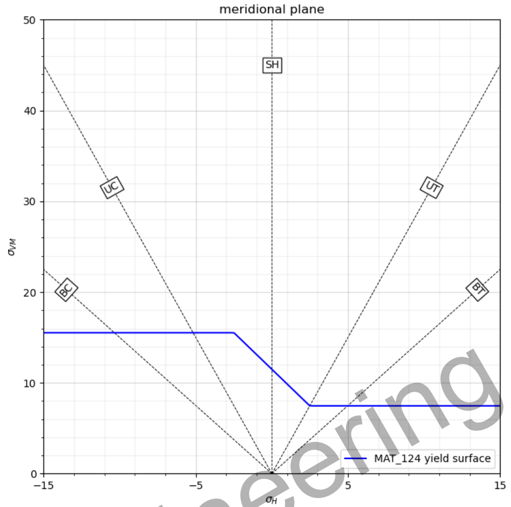
source: Benjamin Hirschmann, master thesis

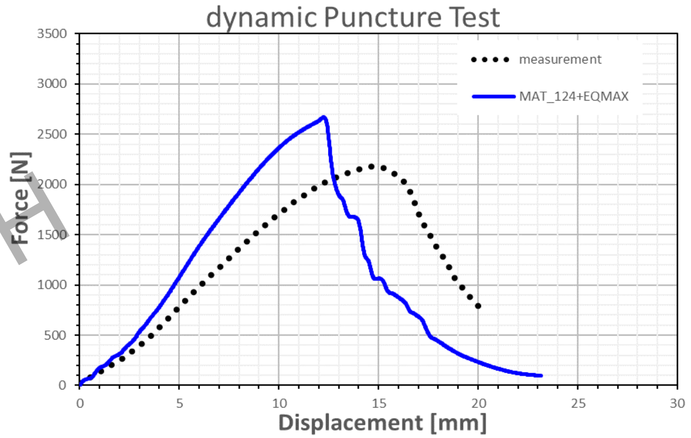
Relative Numerical Cost of the Material Model – *MAT_124

VALIMAT



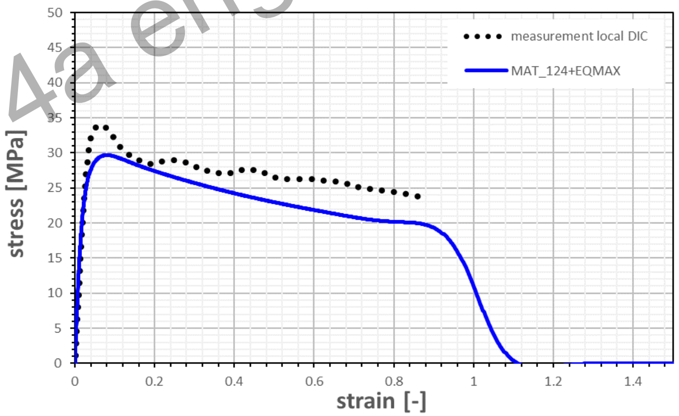
3 POINT BENDING





PUNCTURE TEST

IMPETUS® ~ 3 m/s



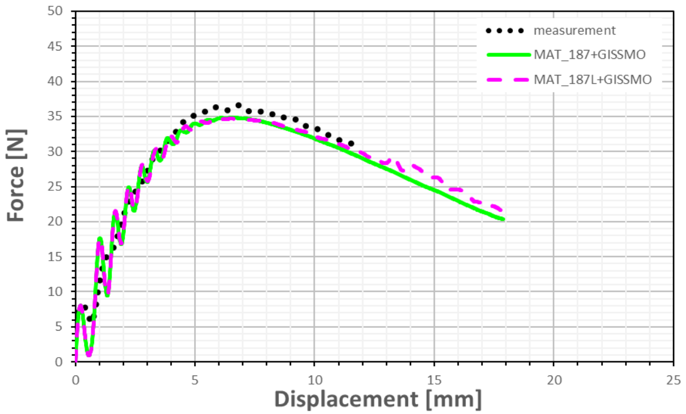
TENSION TEST

···· averaged test curves
— result of simulation

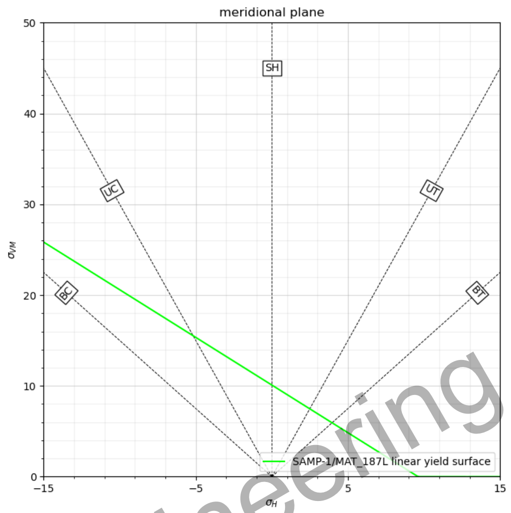
source: Benjamin Hirschmann, master thesis

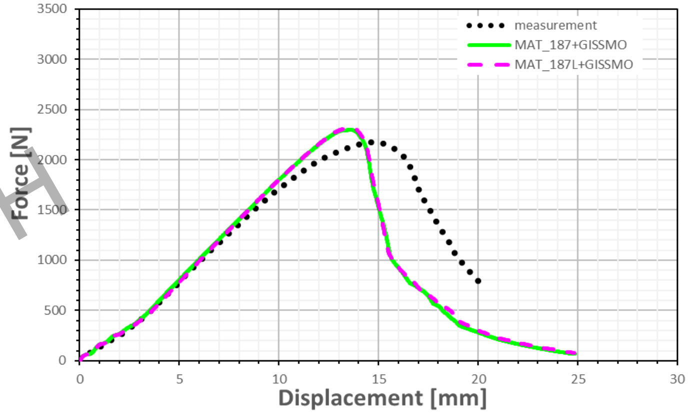
Relative Numerical Cost of the Material Model – *MAT_187

VALIMAT



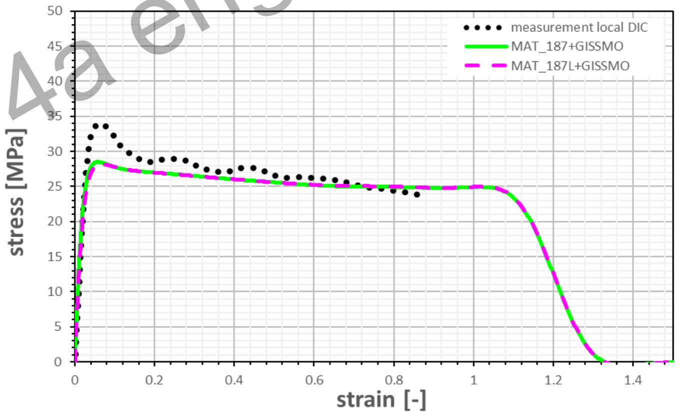
3 POINT BENDING





PUNCTURE TEST

IMPETUS® ~ 3 m/s



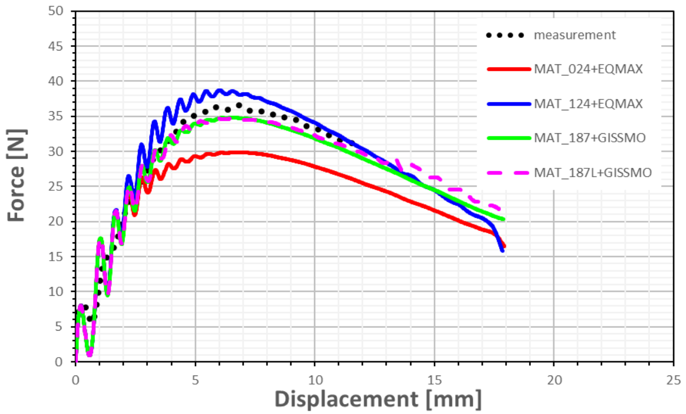
TENSION TEST

···· averaged test curves
— result of simulation

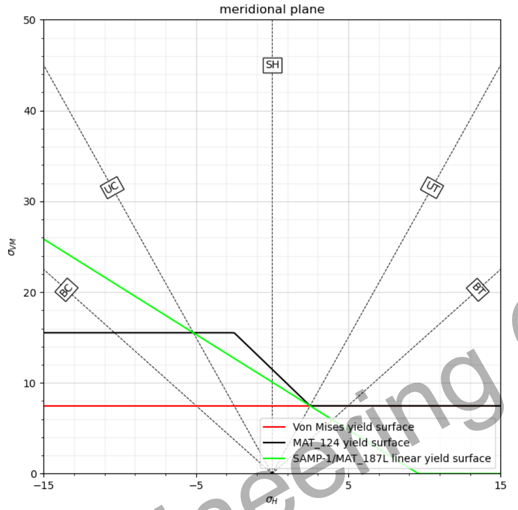
source: Benjamin Hirschmann, master thesis

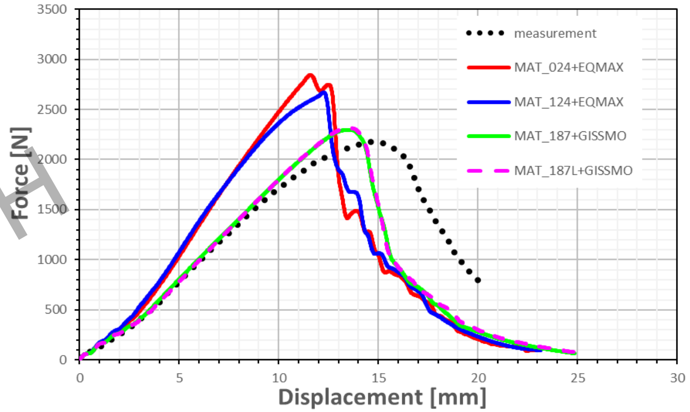
Relative Numerical Cost of the Material Model

VALIMAT



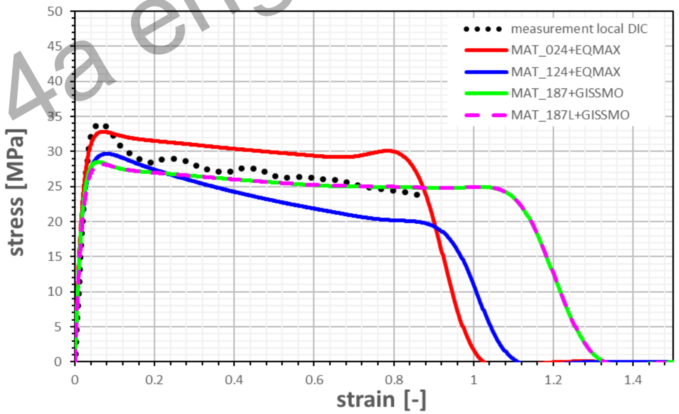
3 POINT BENDING





PUNCTURE TEST

IMPETUS® ~ 3 m/s



TENSION TEST

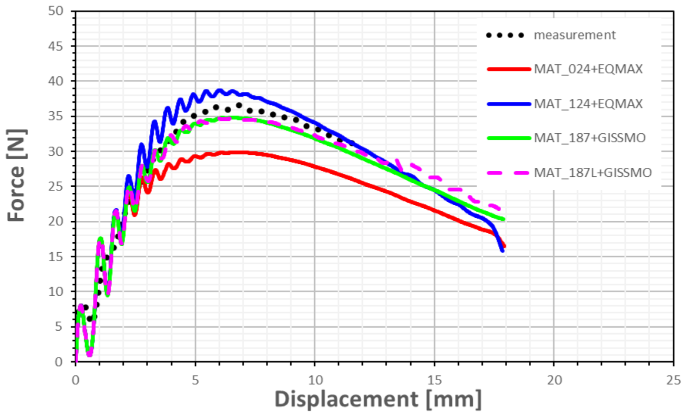
···· averaged test curves

— result of simulation

source: Benjamin Hirschmann, master thesis

Relative Numerical Cost of the Material Model

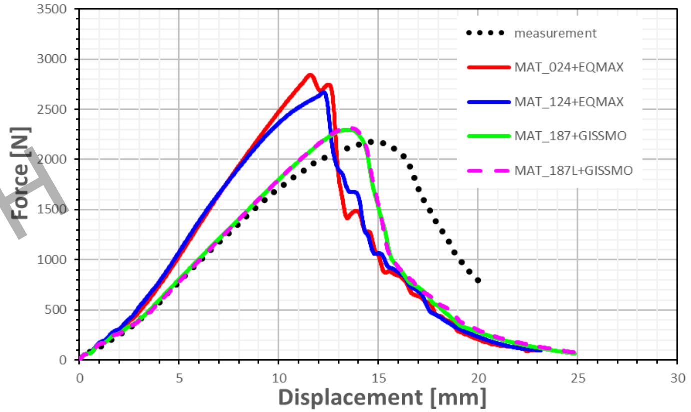
VALIMAT



3 POINT BENDING

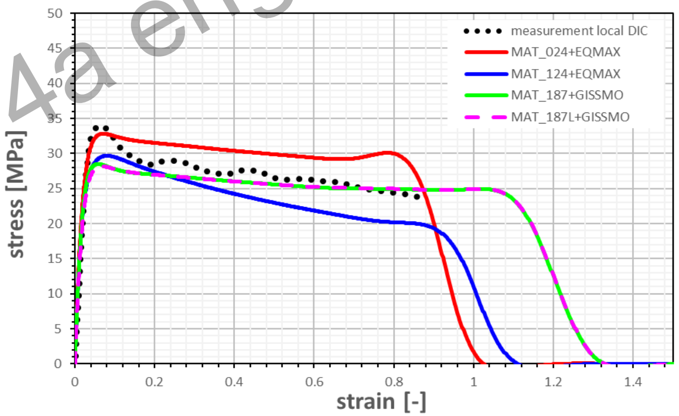
Material model	CPU Time
*MAT_024	1
*MAT_124	1.6
*MAT_187	2.5
*MAT_187L	1.2

CPU Time comparisons



PUNCTURE TEST

IMPETUS® ~ 3 m/s

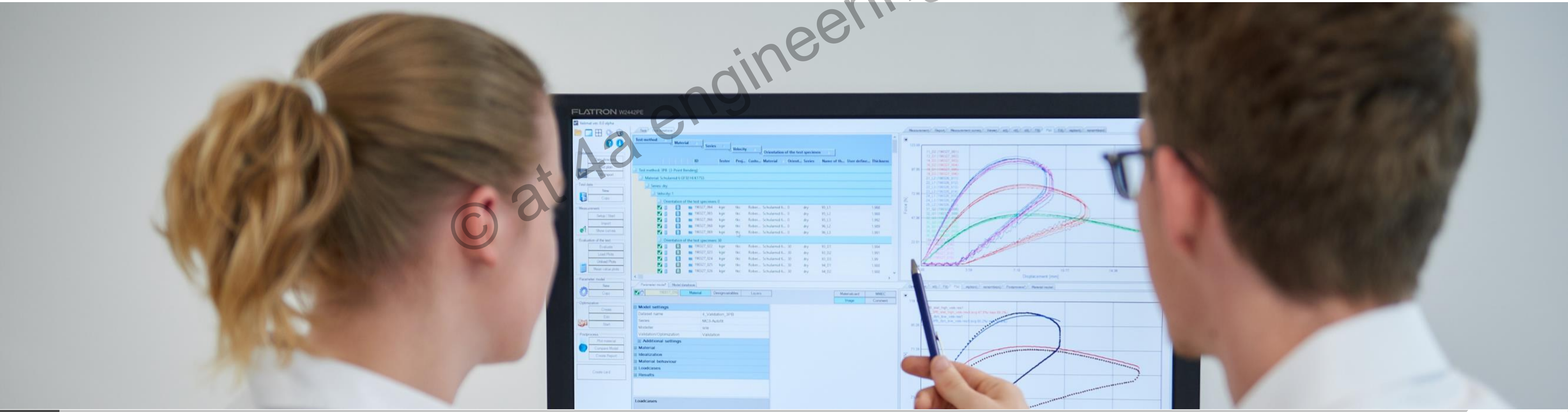


TENSION TEST

···· averaged test curves
— result of simulation

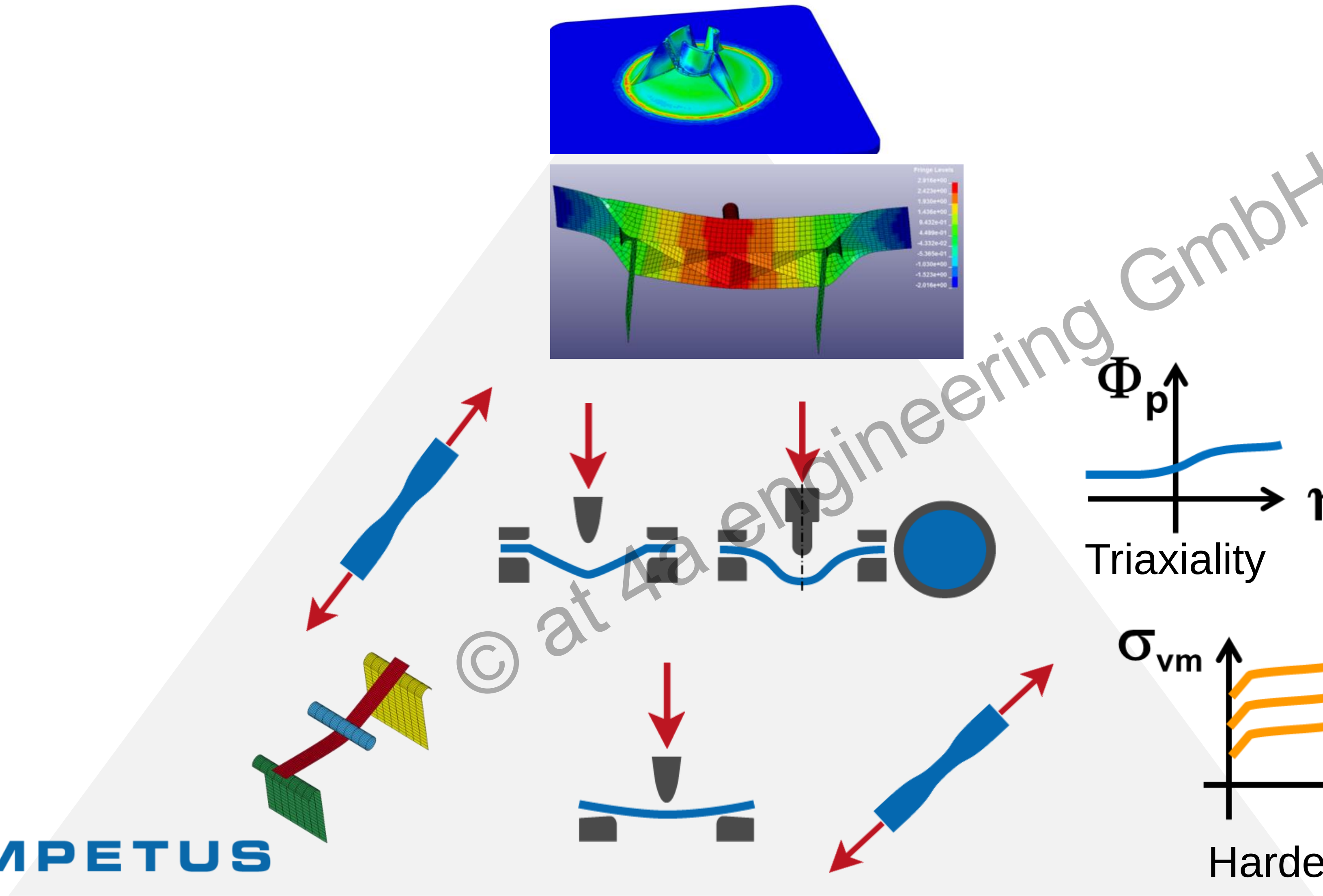
source: Benjamin Hirschmann, master thesis

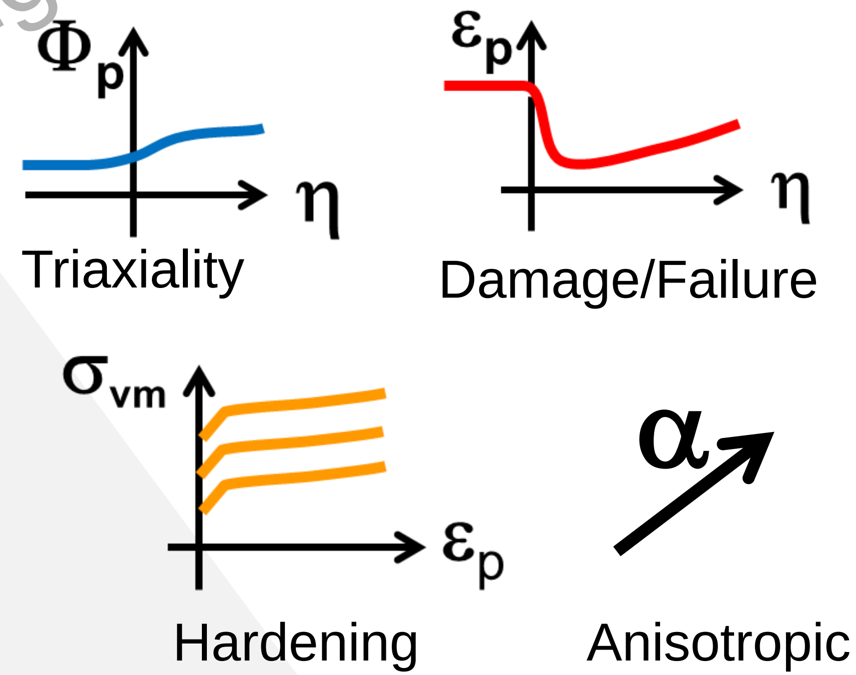
From test to material card – Summary & Outlook



from test to material card

VALIMAT





IMPETUS

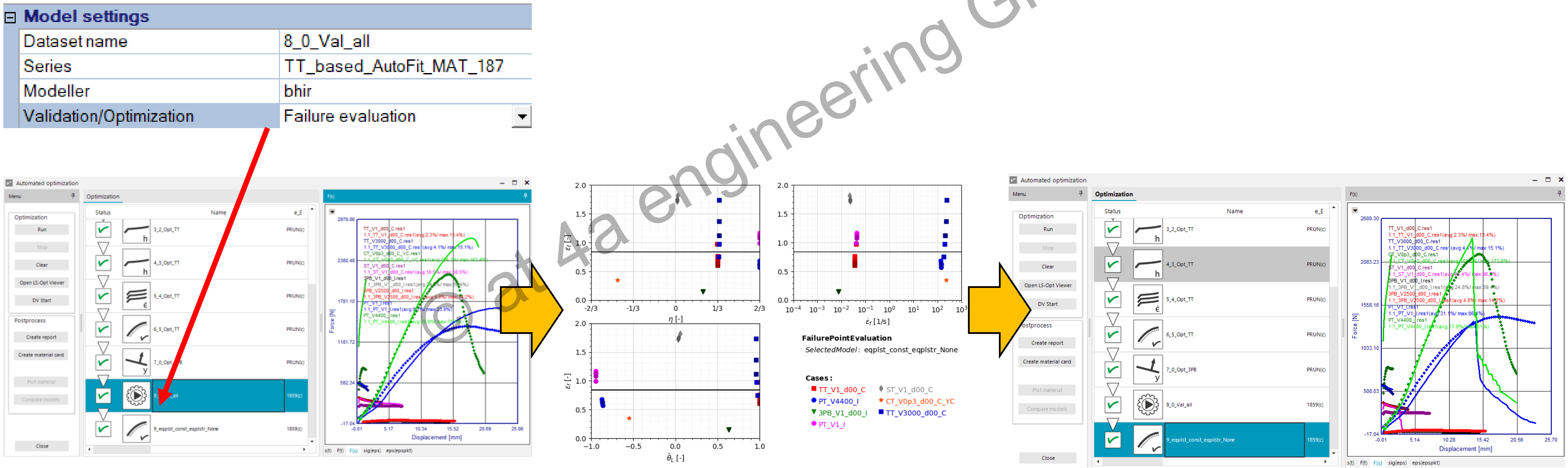
Summary

- Different complexity of material models
  - Hardening – Yield Surface – Failure
  - → different strategies
- material characterization
  - Universal dynamic testing by IMPETUS
  - failure in the triaxiality range of 0.33 to 0.66
- **Simple as Possible, as Complex as Necessary**
- tools needed to handle data and to fit complex failure models VALIMAT

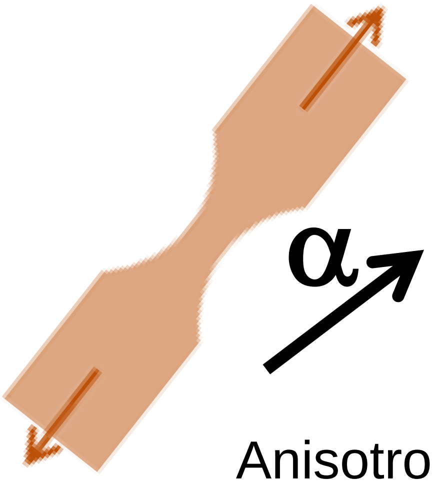
Outlook VALIMAT® 3.8 –AutoFit Failure Parameter Evaluation

VALIMAT

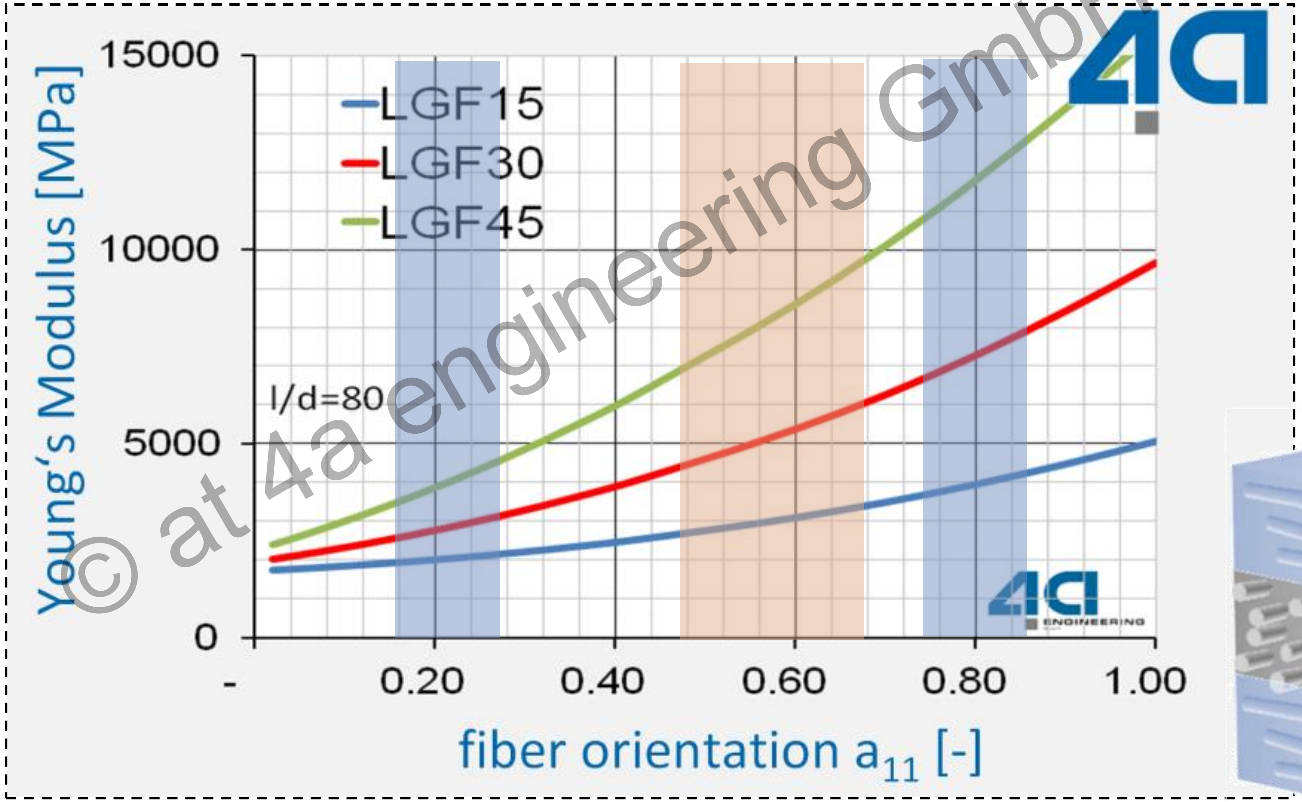
- Added a Model setting for the AutoFit which evaluates failure model parameters on the model results
- The evaluated parameters are available for all following models in the AutoFit

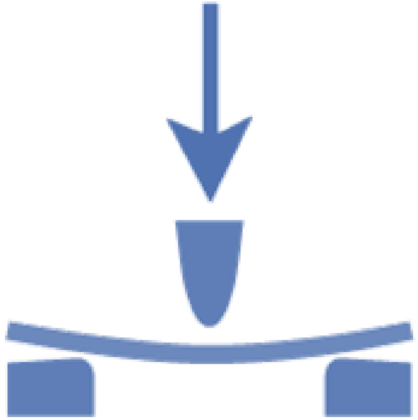


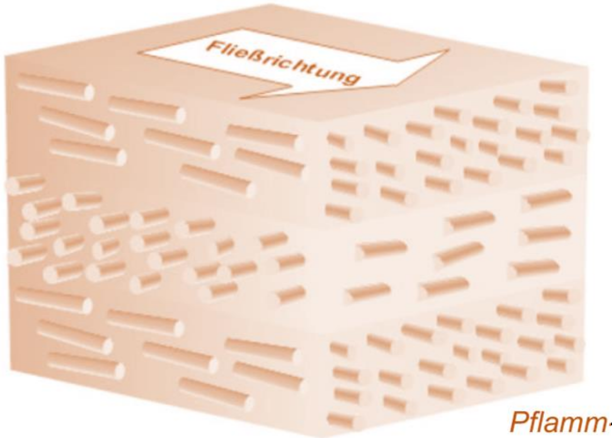
Why not tension (only)?

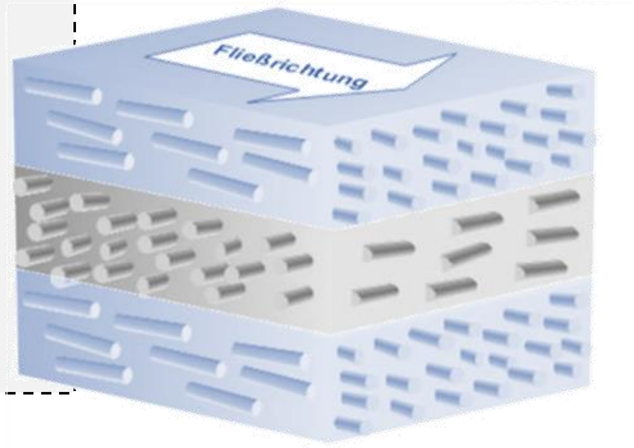


Anisotropic



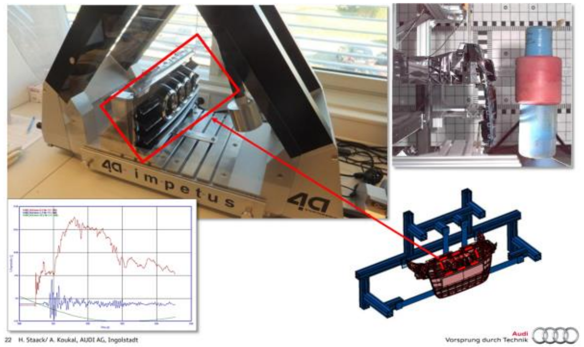




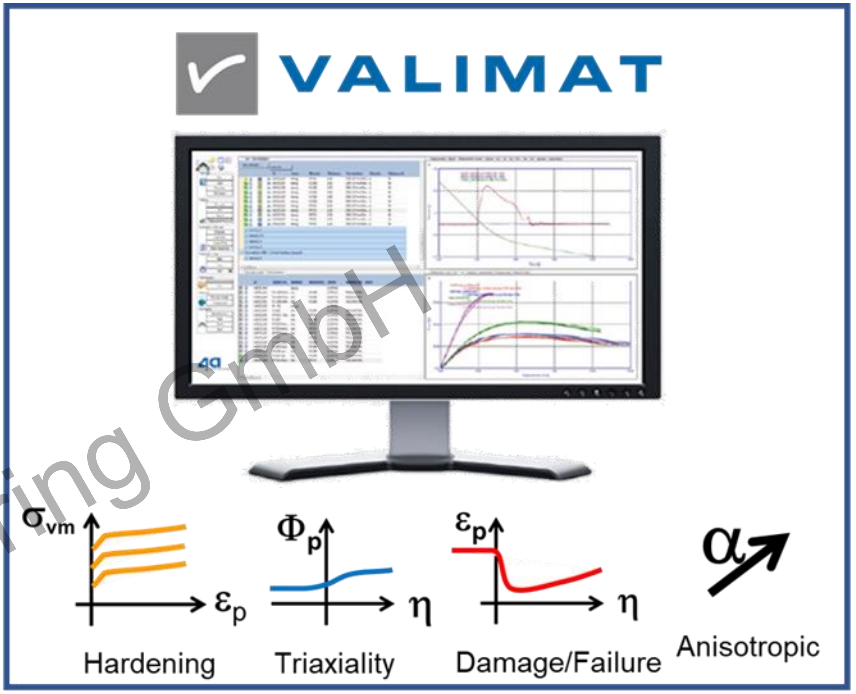


Pflamm-Jonas 2001

DAY 8 – 17th July 2020



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



Possibilities in VALIMAT® with Python

Thank you for your Attention!

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

SAVE THE DATE

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

VALIMAT

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