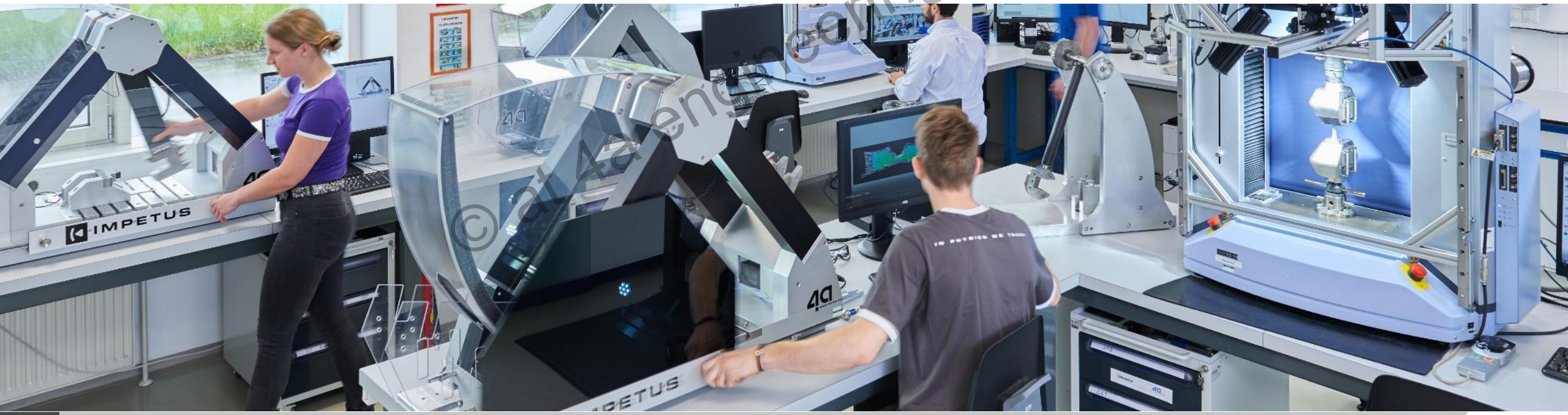
4a Summer School

Material card generation: vonMises plasticity (**MAT_024*), simple failure and how to set up our Autofit

H. Pothukuchi, C. Schober
Traboch, 09.07.2020



4a Summer School

1st week - Introduction and outlook


07. July - Introduction to VALIMAT® from test to material card


08. July - Efficient dynamic testing with IMPETUS®


09. July - Material card generation: vonMises plasticity (**MAT_024*), simple failure, setting up our Autofit


10. July - Summary: Lessons learned, outlook and upcoming features

4a Summer School

2nd 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

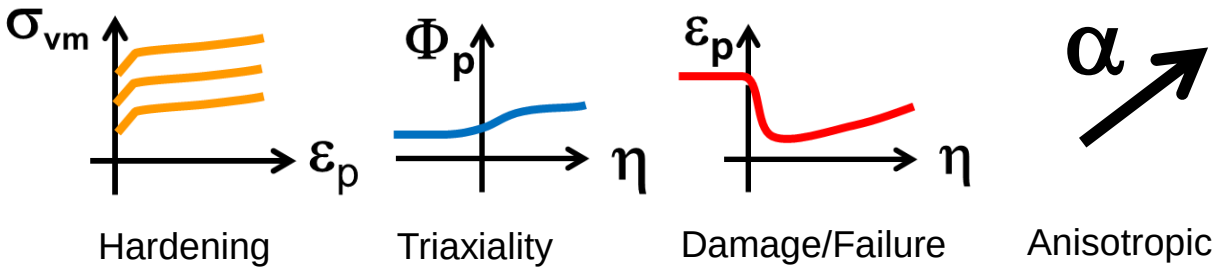
16. July - Fiber reinforced plastics and their modelling approach
an extensive guide

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

from test to material card

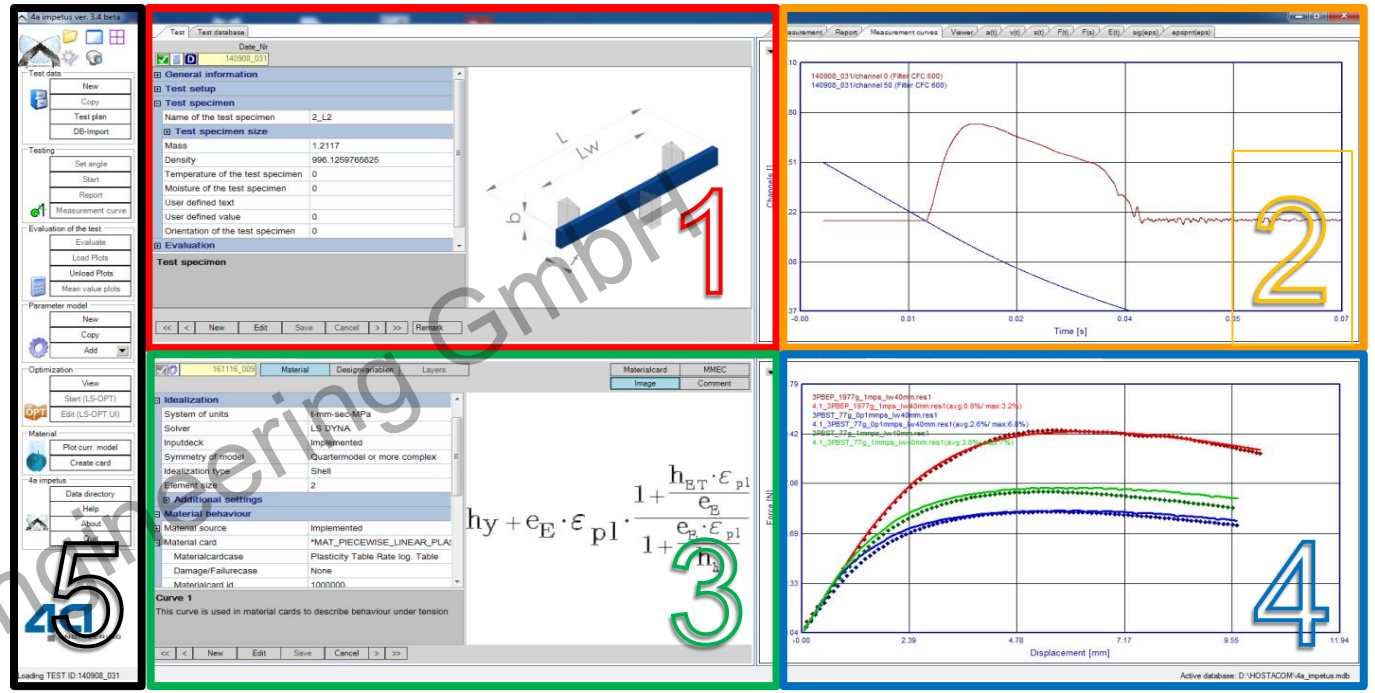
VALIMAT

plastics
engineering
production
excellence in validation
concepts
simulation
lightweight
prototypes



Hardening | Triaxiality | Damage/Failure | Anisotropic

GUI - the graphic user interface

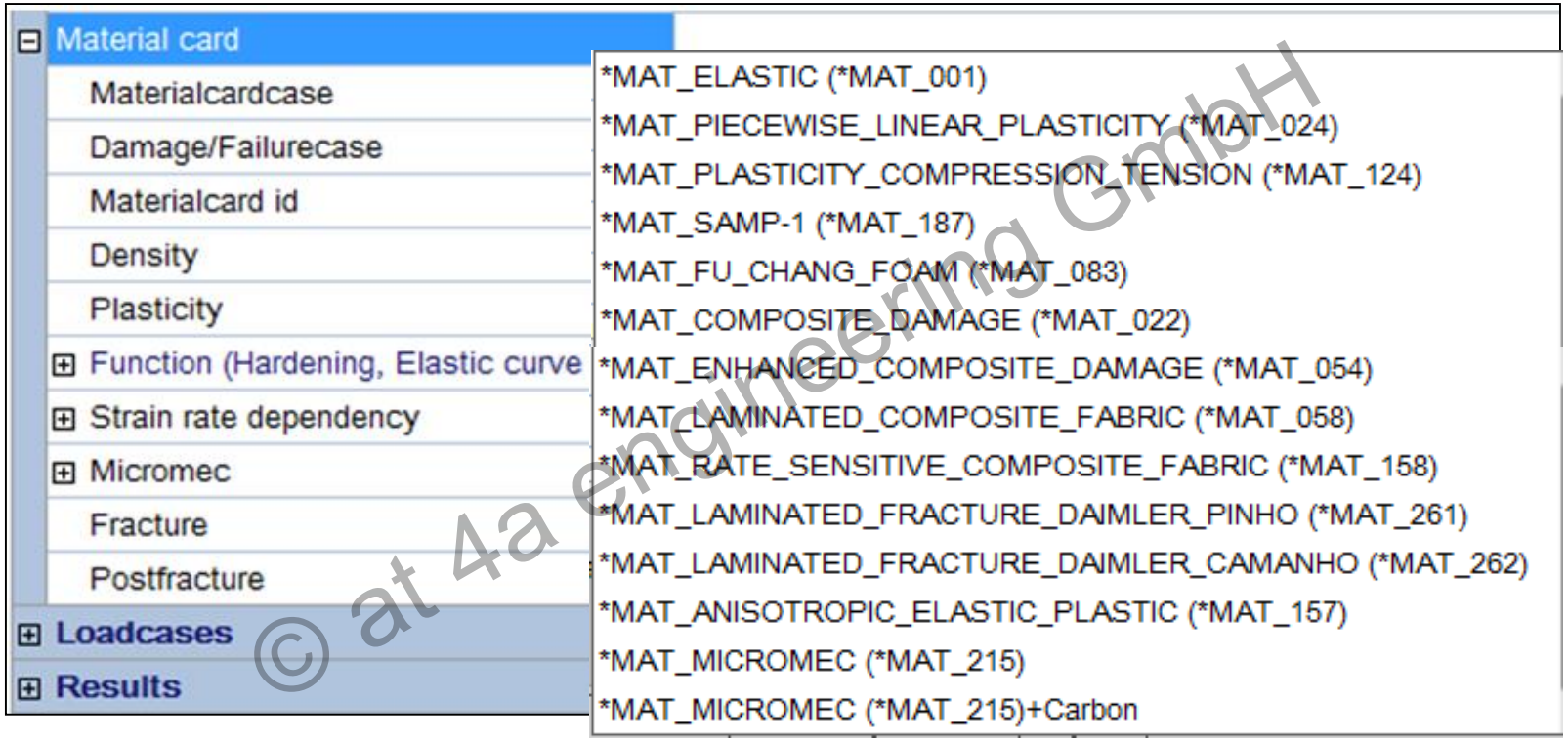


basic menu (left margin, (5))
window top left (1) → test; data base
window top right (2) → measurements; info; measurement results
window bottom left (3) → model parameter; optimization settings
window bottom right (4) → optimization; results of the optimization
the basic menu describes the principal 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)***

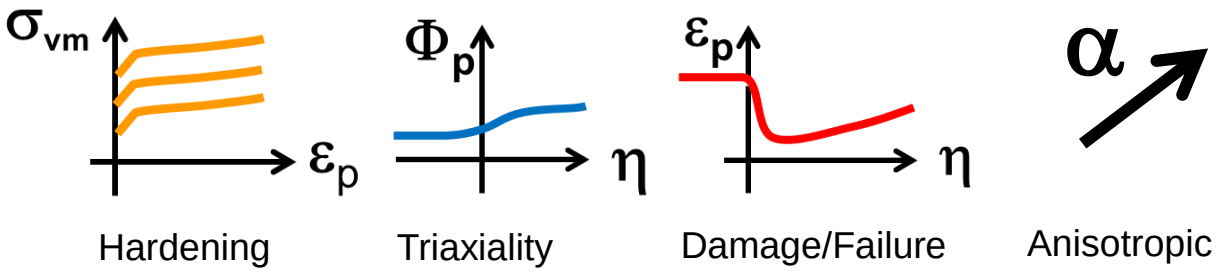


- ***Whole number*** of LS-Dyna material models is available through ***user defined material cards***

HANDS ON SOFTWARE
*MAT_024 Autofit

VALIMAT

plastics
engineering
production
excellence in validation
concepts
simulation
lightweight
prototypes



Hardening | Triaxiality | Damage/Failure | Anisotropic

Objective/requirements

Fit an elastic viscoplastic material model (*MAT_024) for SHELL's on 3-point bending measurements conducted by 4a IMPETUS®. Create an Auto-Report for the found material model.

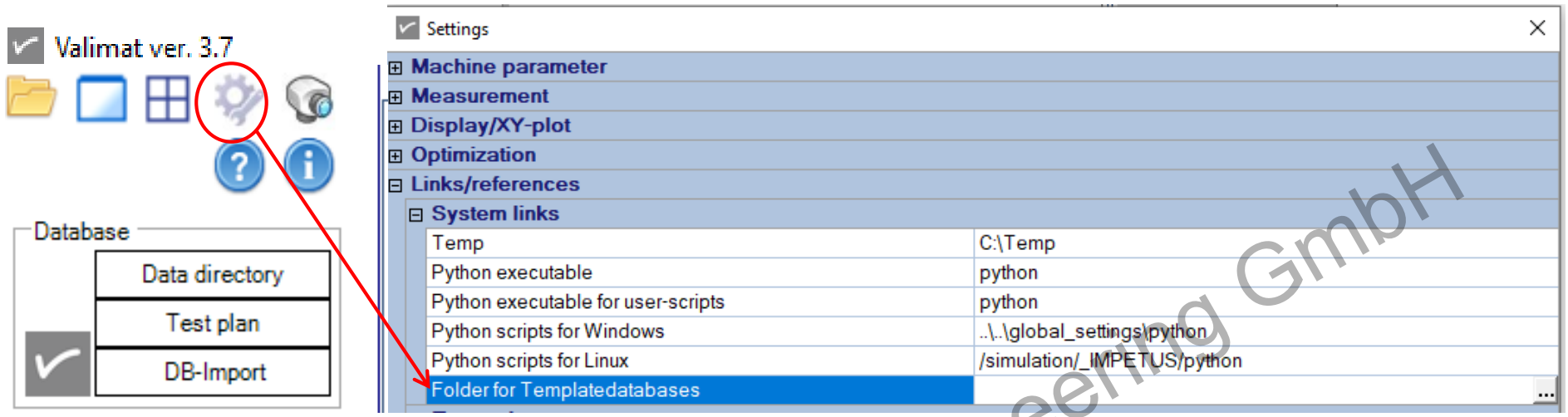
What one should know:

- VALIMAT® GUI overview & key functioning

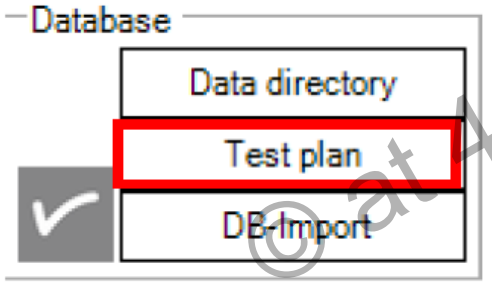
Requirements:

- Installed VALIMAT® and Python
- VALIMAT® Training Database
- LS-DYNA license

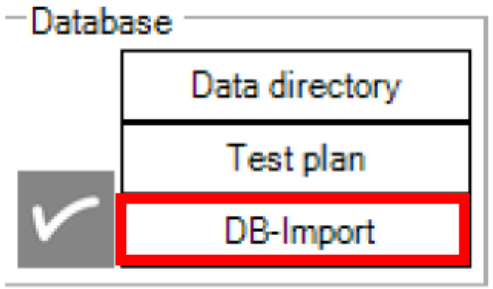
VALIMAT® - Template database



Setup the folder containing the template database under the settings tab



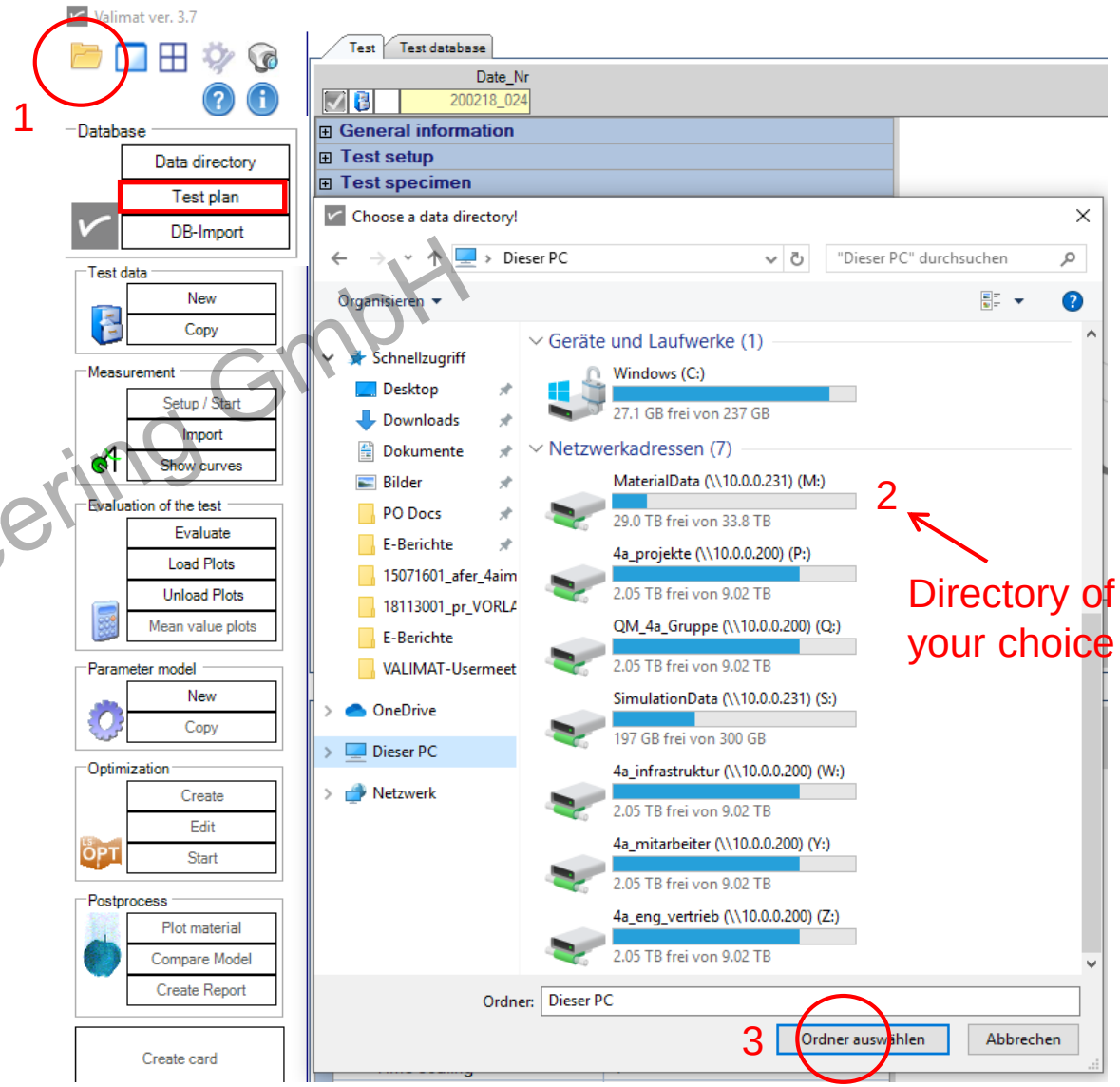
A template database can be imported using the `Test plan` button



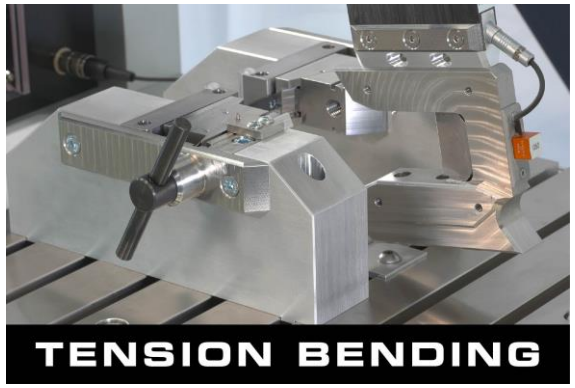
An additional VALIMAT® can be imported in the already opened database

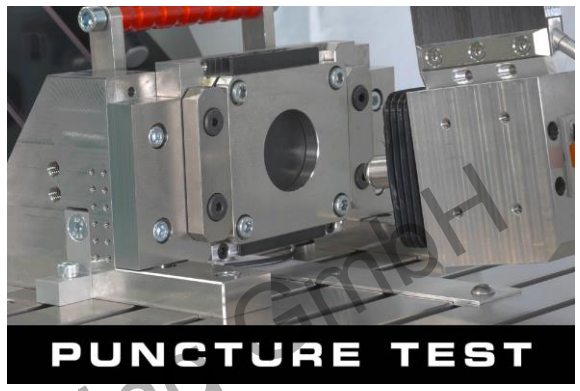
VALIMAT® - Template database

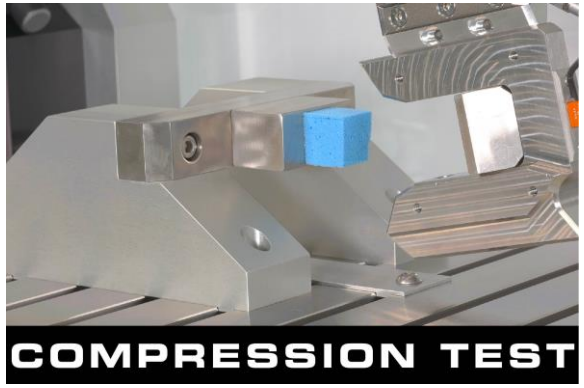
- To use the template database, you have to create it once → 4a provides you with an example template database
- Important steps need to be performed
  - Create a directory where you store tests and models
  - Create a new (empty) database in this directory

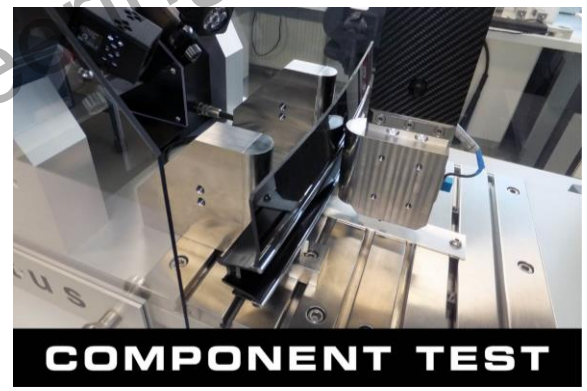


IMPETUS® - configurations









BASIC

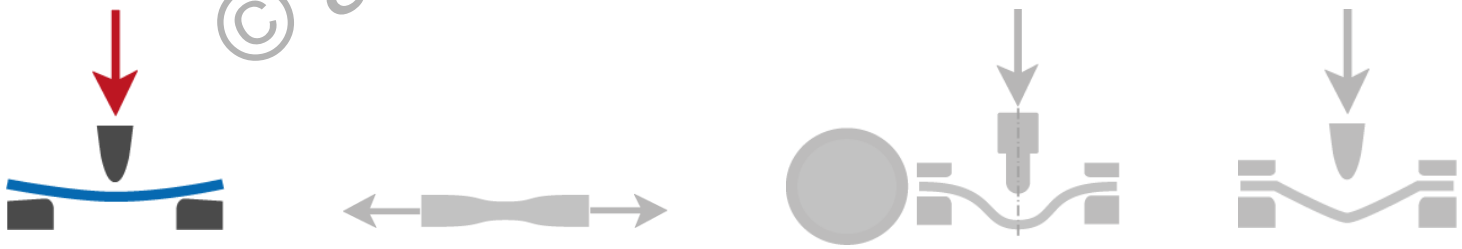
STANDARD

PROFESSIONAL

YouTube

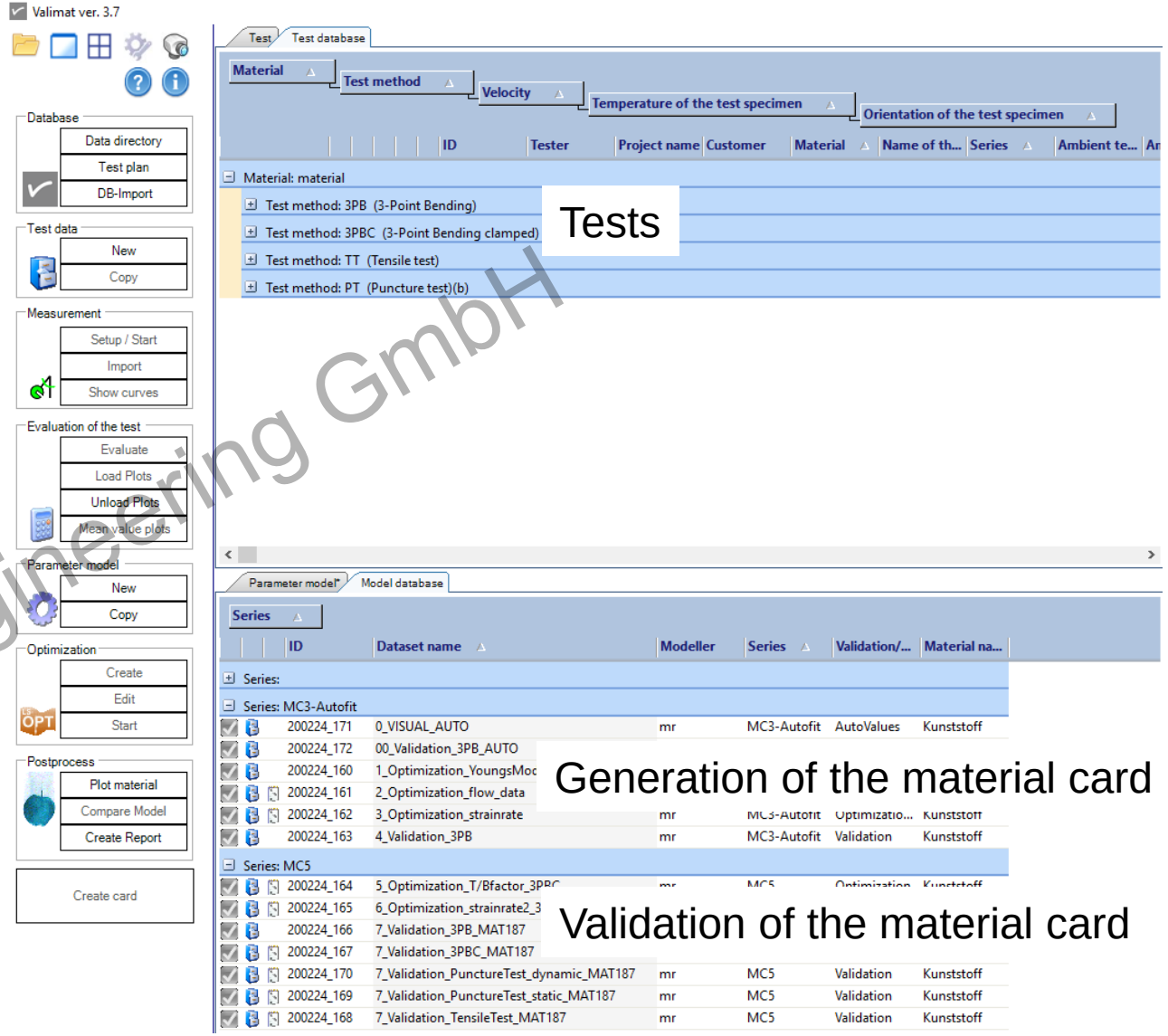
VALIMAT® - Template database

- Using template database streamlines the workflow of generating material cards from the tests conducted under the different loading conditions
- It is especially useful, when the test setups for the optimization or validation of the material cards are the same, as shown in the test package overview in the previous slide
- As a demo, we will go through the template database for the material package **isoP standard**
  - The material package uses static and dynamic bending tests to generate the material card.
  - Dynamic puncture, clamped 3-point-bending and tensile tests to validate the material card.



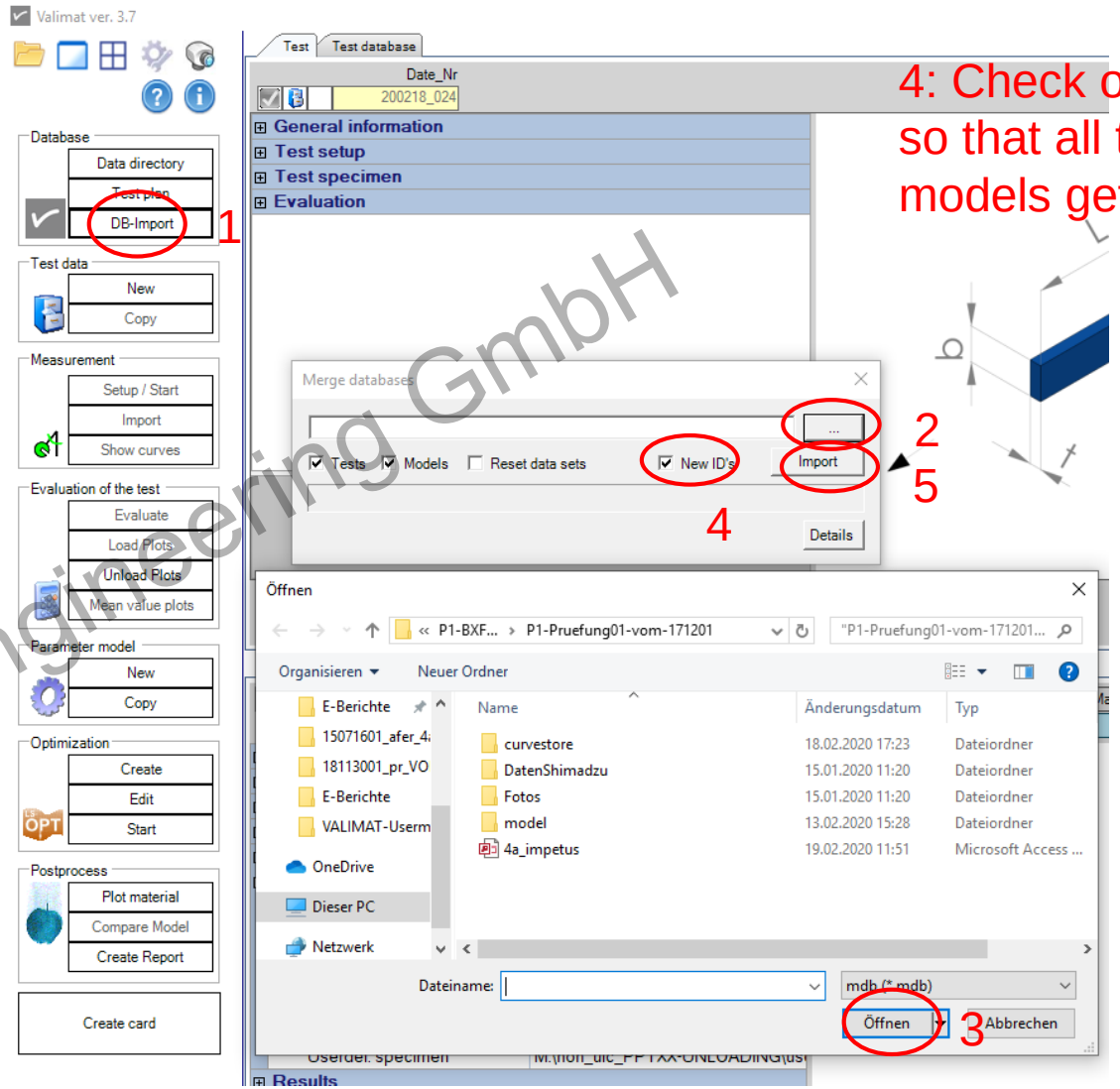
VALIMAT® - Template database

- Template database is available for all packages: basic, standard, professional



VALIMAT® - Template database

- As an alternative, you can also import the template database in an already existing database by following these steps

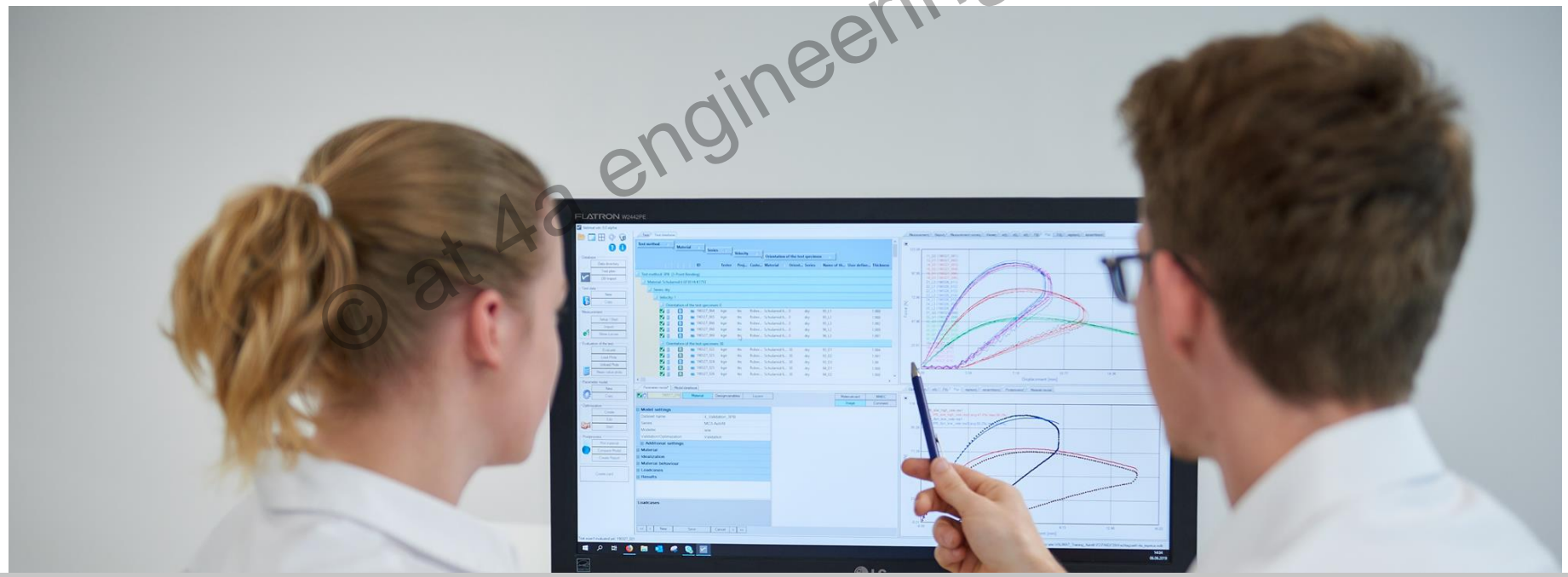


VALIMAT® - Template database

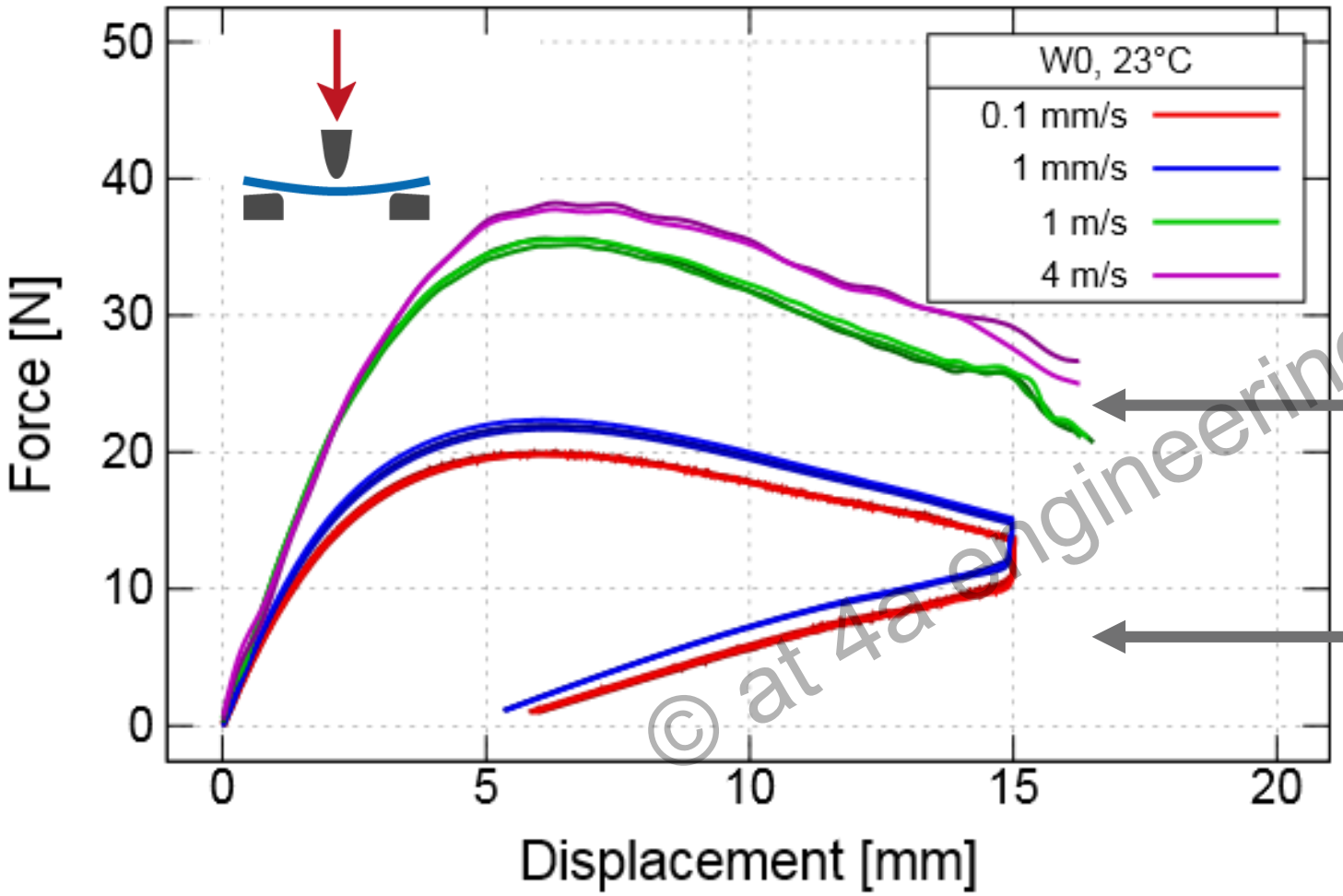
- Advantages of the template database
  - Test setup already pre-created
  - Parameter models for creating workflow already stored
  - Test IDs are linked in models
- Checks that need to be carried out:
  - Update test specimen **names** and **geometry** (e.g. pendulum mass, gauge length)
  - Check **length** of test curves
  - Optimization of Youngs modulus → **trim test curve** to obtain a suitable length for optimization
  - Optimization of plastic data and strain rate dependency → **optimization** curve should be a little **over the force maximum**
  - Check the **starting values** and **limits of design variables**
  - Check if the test IDs are **linked correctly** to the models

Introduction MAT_024 AutoFit

Basis 3-Point-Bending



Efficient dynamic testing

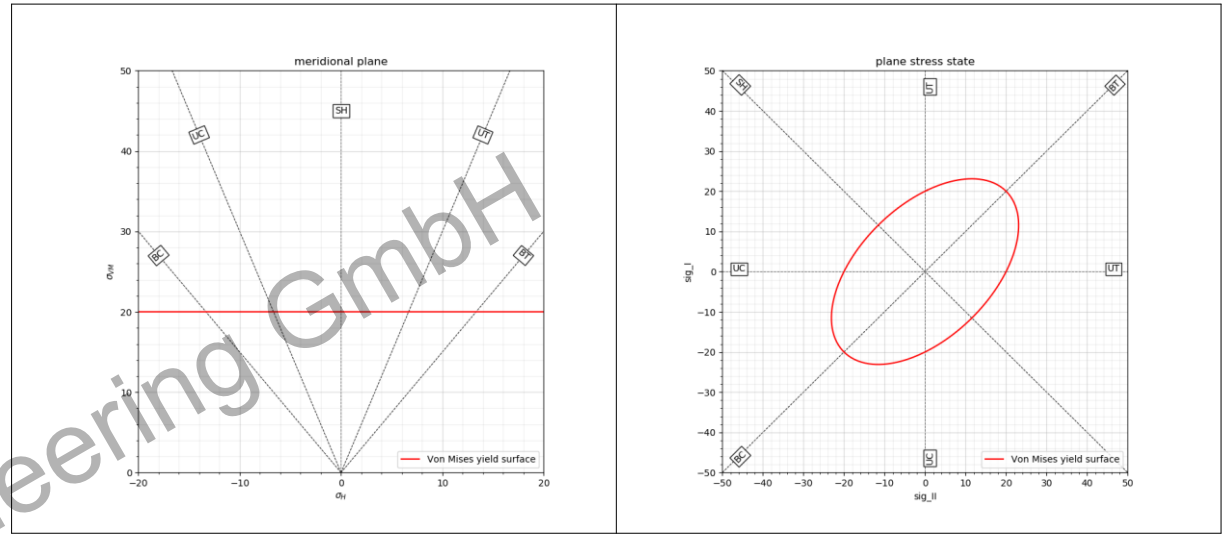


IMPETUS

Universal static testing

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

MAT_024 introduction

***MAT_024** (*MAT_PIECEWISE_LINEAR_PLASTICITY) is the most commonly used material card for crash simulations in LS-DYNA.

- It is an elastic, viscoplastic material model
  - Von Mises yield surface
  - associated flow rule
- hardening curves can be defined arbitrarily for selected strain rates
- interpolation between the hardening curves of different strain rates can be performed either linear or logarithmic

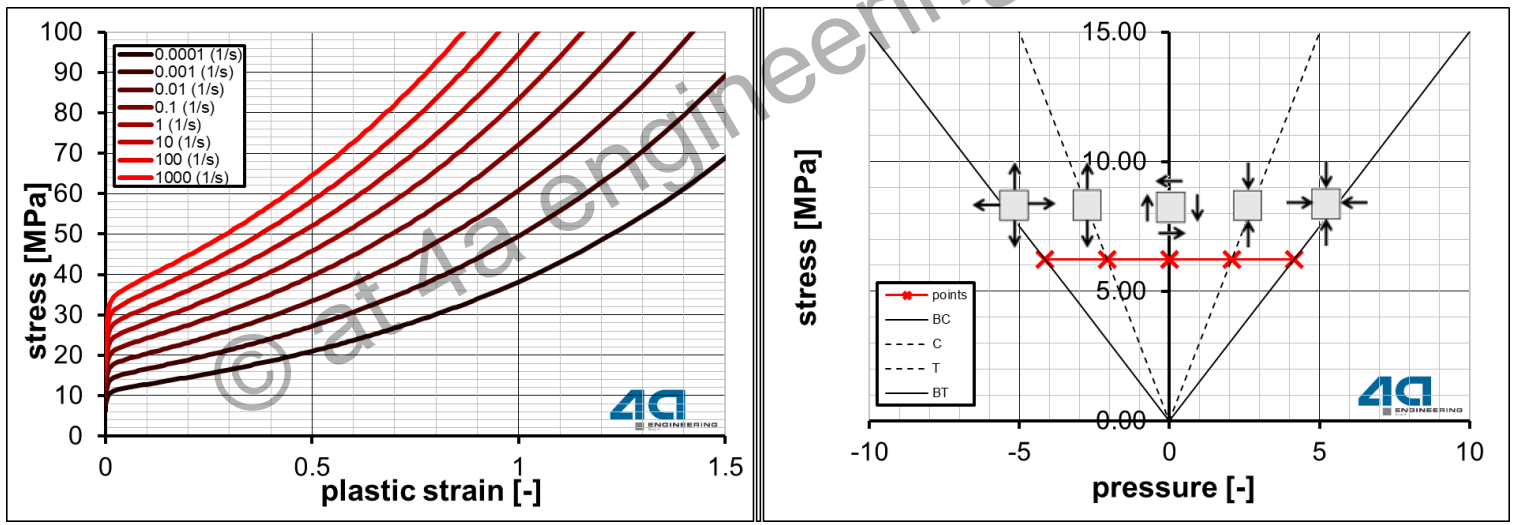
more information:

- "LS-DYNA_Manual_Volume_II_R11.pdf"

MAT_024 introduction

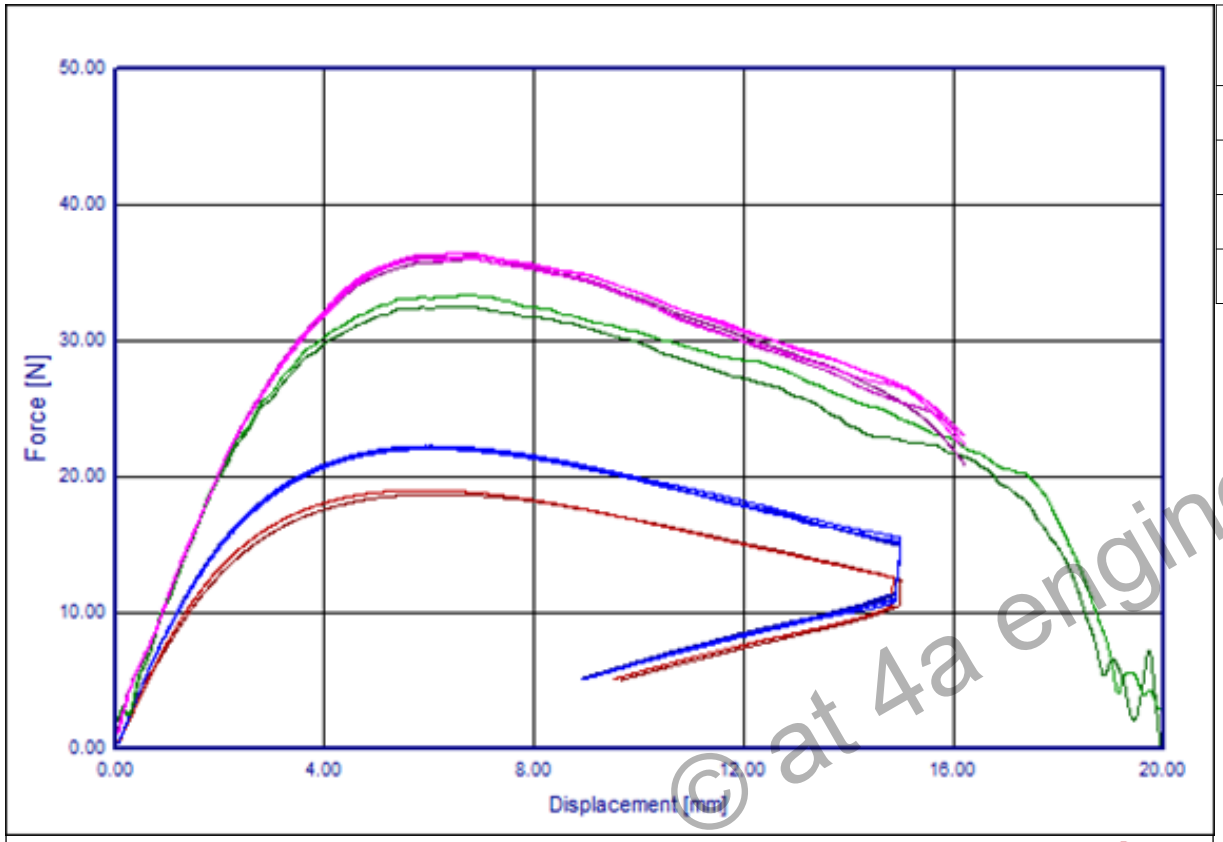
material card overview

- ***Material:*** PPEG107HP
- ****MAT_024*** material card:
  - Deformation: elastic, viscoplastic
  - Von Mises yield surface
  - associated flow rule ➔ plastic deformation at constant volume

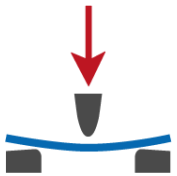


AutoFit

Data



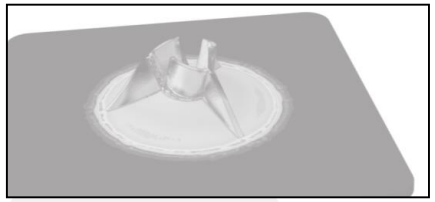
model 190912_019

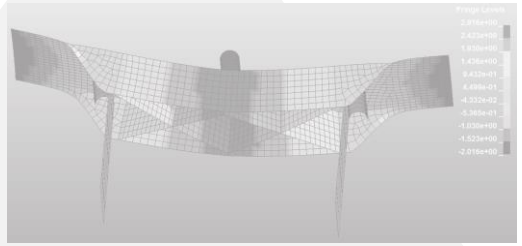


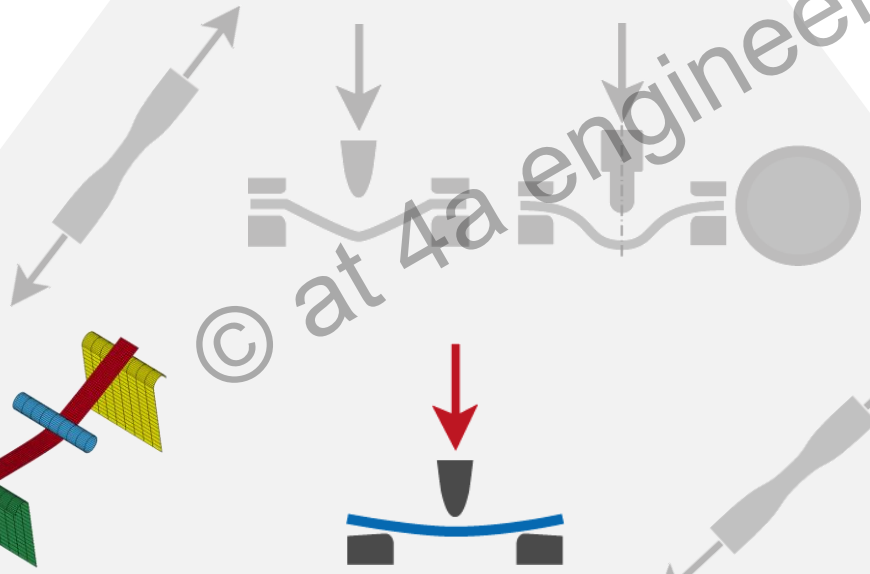
Case	v_0 [m/s]	l_w [mm]	$m_{Pendulum}$ [g]	b [mm]	t [mm]	l [mm]
3PB_V0p1_d00_l	0.0001	40.01	0	9.93	1.99	49.75
3PB_V1_d00_l	0.001	40.01	0	9.91	2.00	50.06
3PB_V1000_d00_l	1	40.01	1580	9.91	1.99	50.10
3PB_V2500_d00_l	2.5	40.01	1580	9.91	1.99	49.94

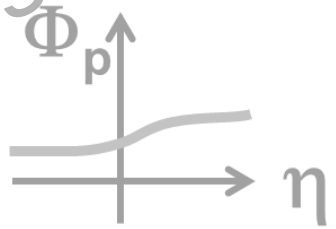
from test to material card

VALIMAT

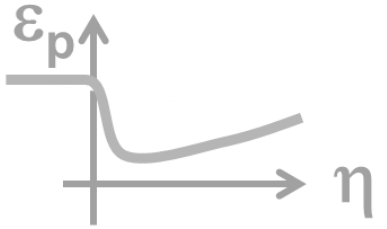




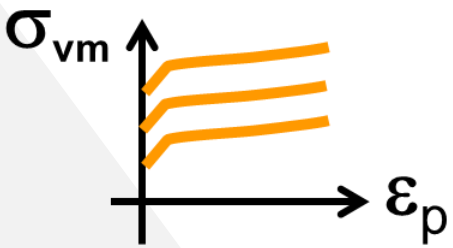




Triaxiality



Damage/Failure

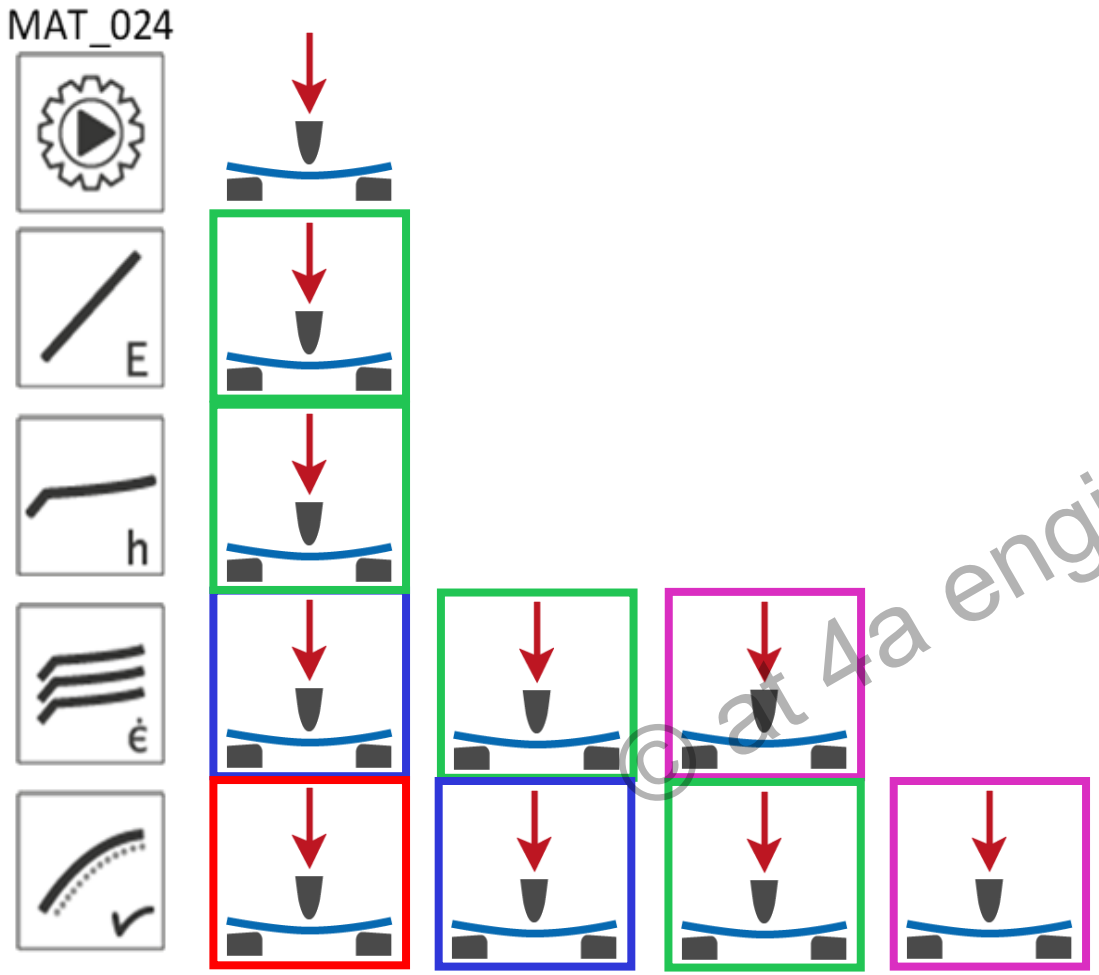


Hardening

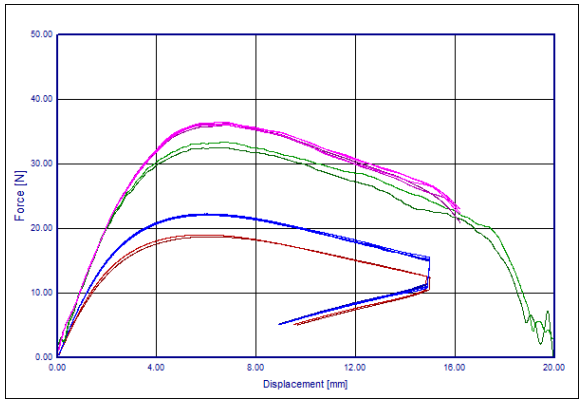
Anisotropic

IMPETUS

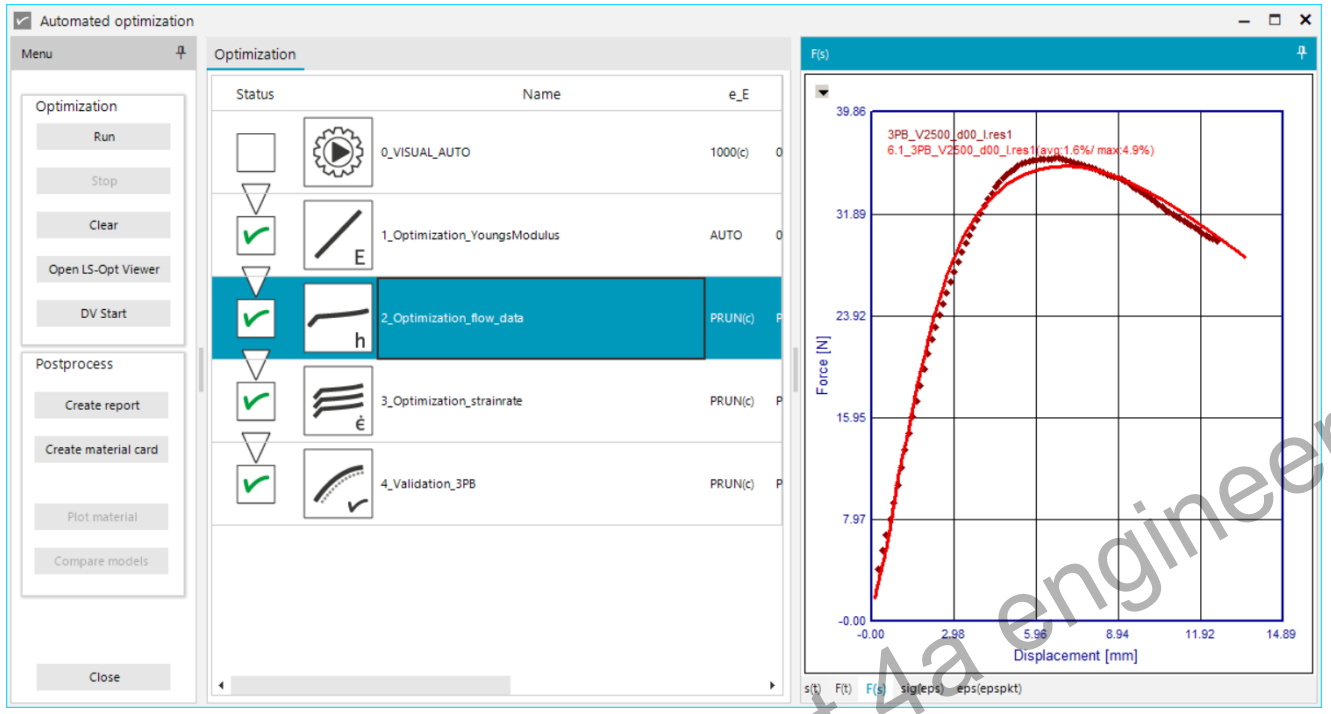
AutoFit
Strategy



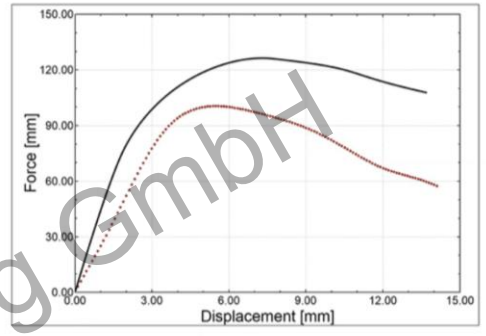
without border all velocities
quasistatic low velocity
quasistatic high velocity
dynamic low velocity
dynamic medium velocity

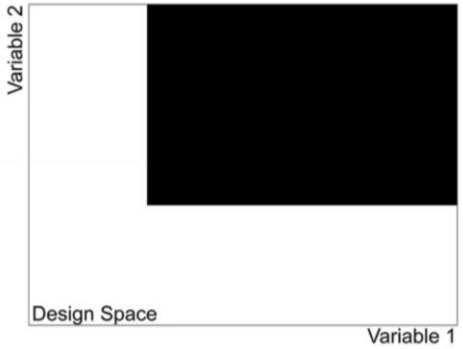


Workflow for Material Card Generation - AUTOFIT

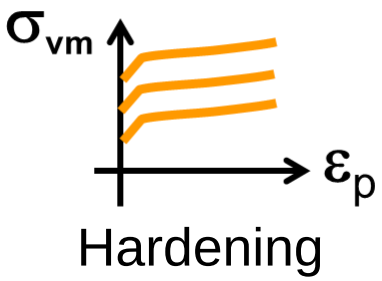


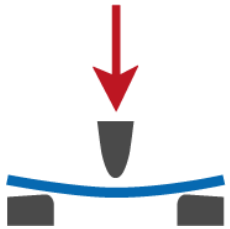
optimization – successive response surface method





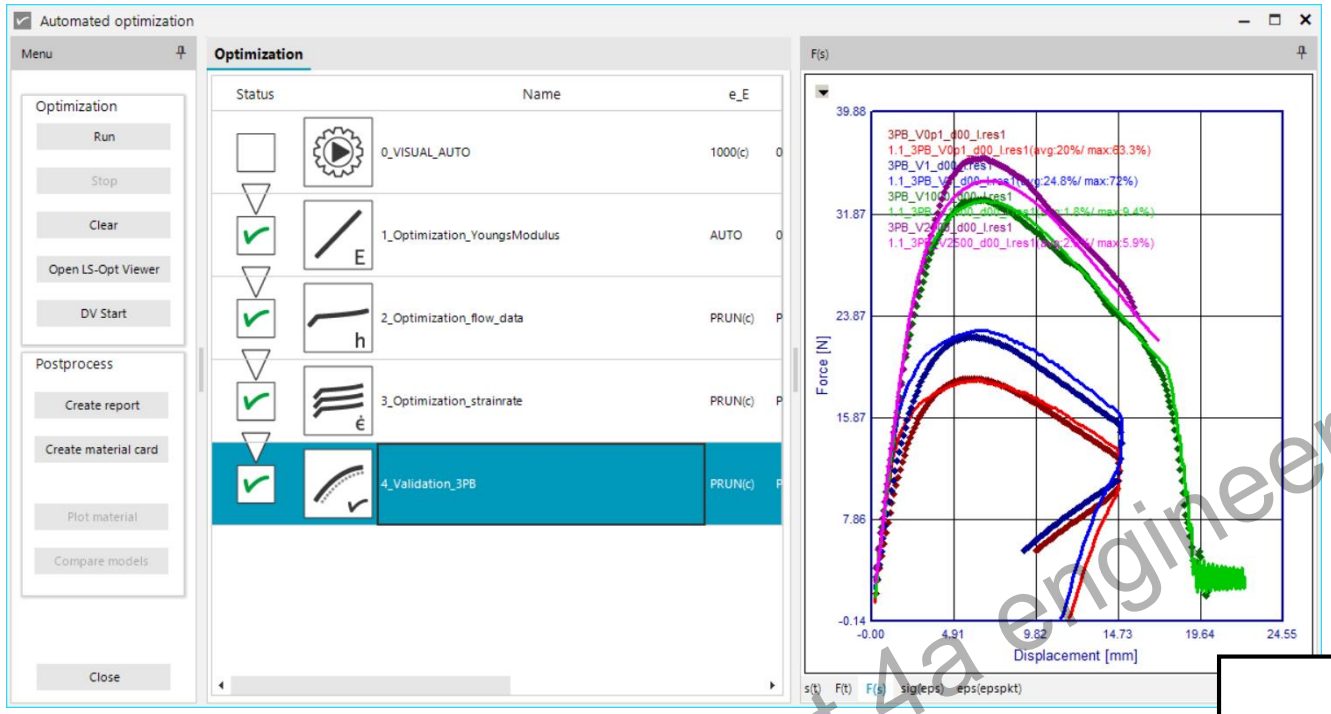
$$hardening\ function = f(Variable\ 1, Variable\ 2)$$

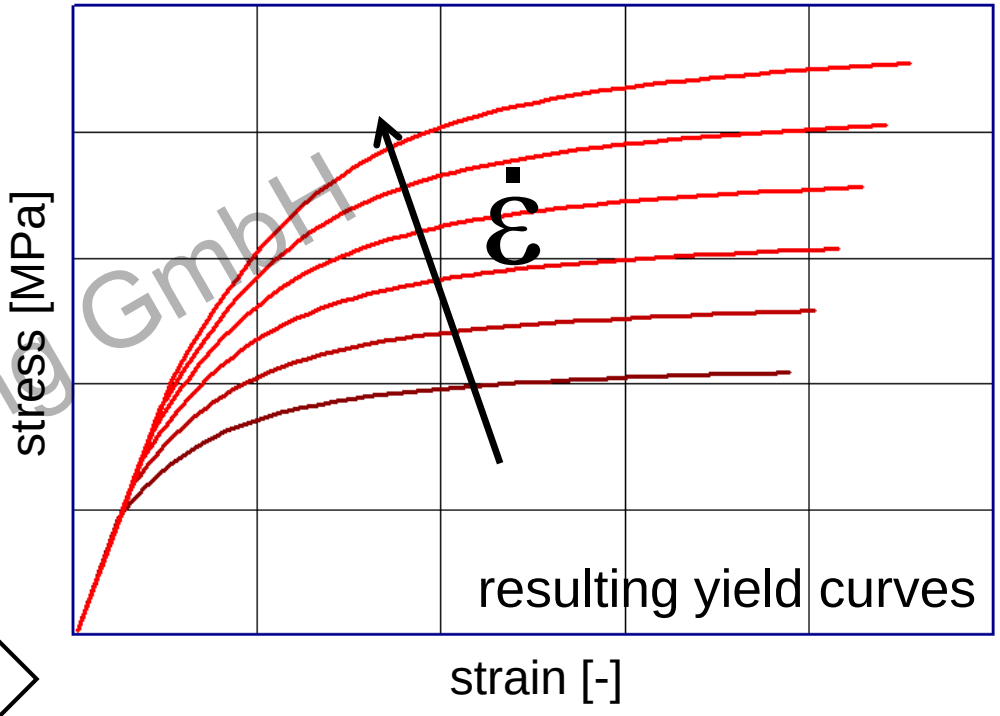


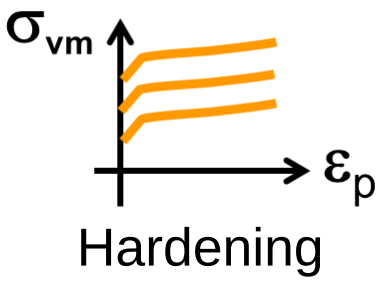


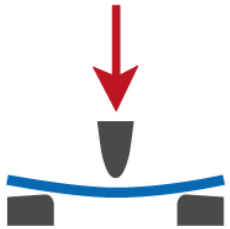
[redacted]

Workflow for Material Card Generation - AUTOFIT







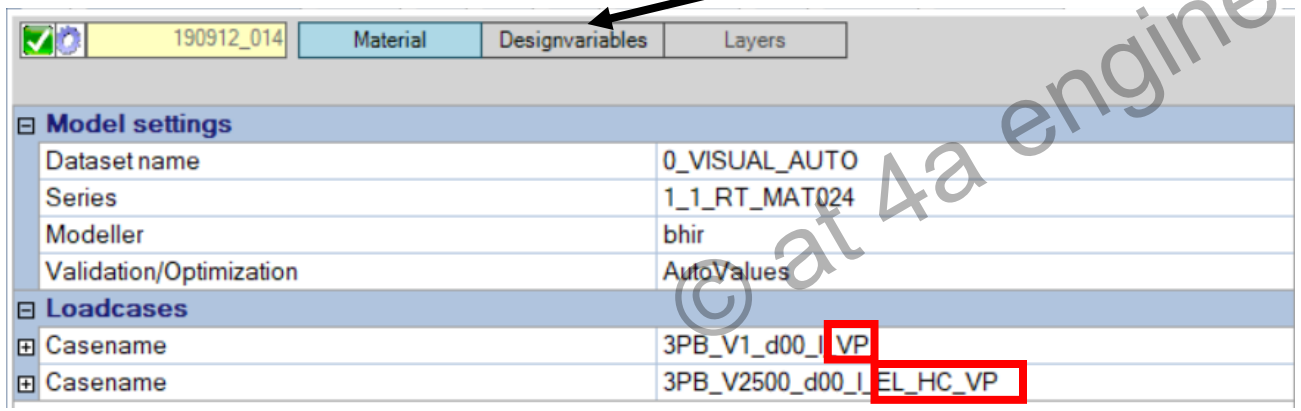


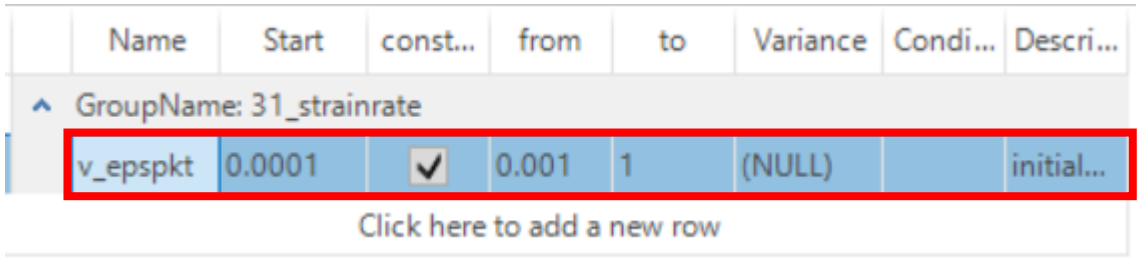
AutoFit

Auto Values

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

- **_EL ➔** Young's Modulus e_E
- **_HC ➔** hardening curve parameter estimation
- **_VP ➔** to evaluate the strain rate dependency v_p
- important **v_epspkt** will be taken from Designvariables

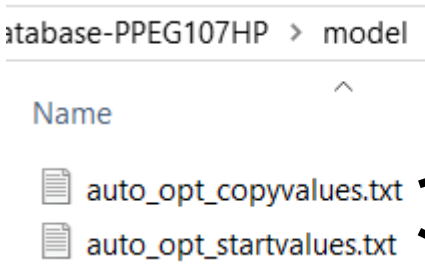




AutoFit

Auto Values

Auto Values Model ➔ script get_auto_opt_startvalues.py




```
Start parameters polymer_law:
Name            Start           constant        from            to              Variance        Condition
e_E             1827.34         True            10%             10%             (NULL)
h_y             7.38390510073361                True            50%             50%             (NULL)
h_y2            14.76781020146722               True            10%             20%             (NULL)          >h_y
h_eps0          0.006771626753819869            True            10%             20%             (NULL)          >h_y
h_n             1.1             True            0               5               (NULL)
h_b             0.01            True            0               1               (NULL)
h_nuep          -1.0            True            10%             20%             (NULL)
v_p             7.893796663800692               True            50%             50                (NULL)
v_epspkt        0.0001          True            0.00001         1               (NULL)
y_nuep=-1000050True             (NULL)          (NULL)          (NULL)
xm_nuep_plat=-1.0               True            (NULL)          (NULL)          (NULL)
```

these values will be used in subsequent models

```
e_E=1827.34CRLF
e_nue=0.35CRLF
y_0=7.38390510073361CRLF
y_T=7.38390510073361CRLF
y_C=7.38390510073361CRLF
y_SH=7.38390510073361CRLF
y_B=22.381144501959284CRLF
h_scale0=1.0CRLF
h2_scale=1CRLF
h3_scale=1CRLF
h_y=7.38390510073361CRLF
h_y2=14.76781020146722CRLF
h_eps0=0.006771626753819869CRLF
h_n=1.1CRLF
h_b=0.1CRLF
h_h=5.907124080586889CRLF
h_ET=365.468CRLF
y_nuep=-1000050CRLF
xm_nuep_eps=0.2CRLF
xm_nuep_plat=0.05CRLF
xm_nuep_meps=0.3CRLF
xm_nuep_pres=0.5CRLF
h_nuep=0.5CRLF
v_p=7.893796663800692CRLF
v_epspkt=0.0001CRLF
```

AutoFit

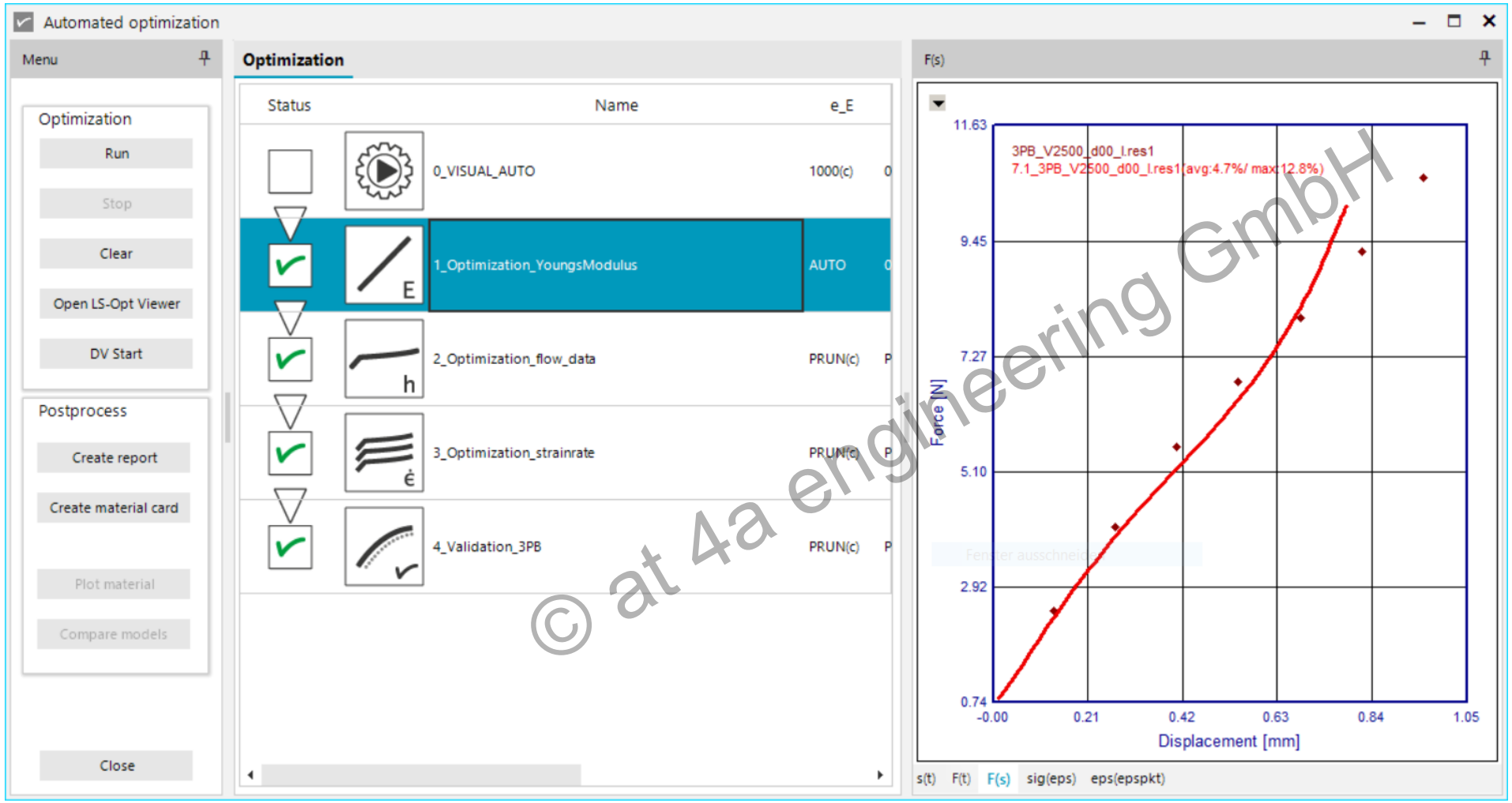
Optimization Young's modulus

Validation/Optimization: **Optimization Young's modulus**

- MAT_ELASTIC ➔ to Fit Young's modulus
- In design variables e_E ➔ AUTO which will be replaced by script result of the Young's modulus

AutoFit

Optimization Young's modulus



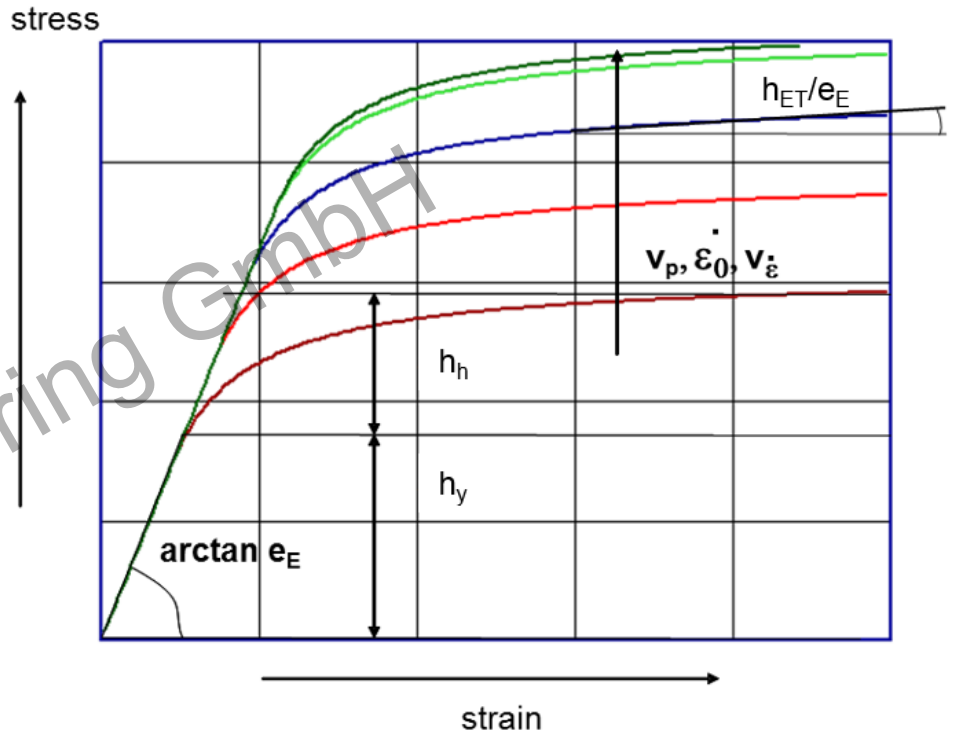
Checks:
are oscillations too high?
curve long enough?
curve still linear elastic?

AutoFit

Optimization hardening – 4a model

- LS Dyna - ***MAT_024**
- 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.

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

AutoFit

Optimization hardening

Validation/Optimization: **Optimization hardening**

- a parametrized model is used for the hardening curve and the strain rate dependency
- Optimized Parameters are set to PRUN
- New Parameters are set to AUTO

hardening model

strain rate dependency model

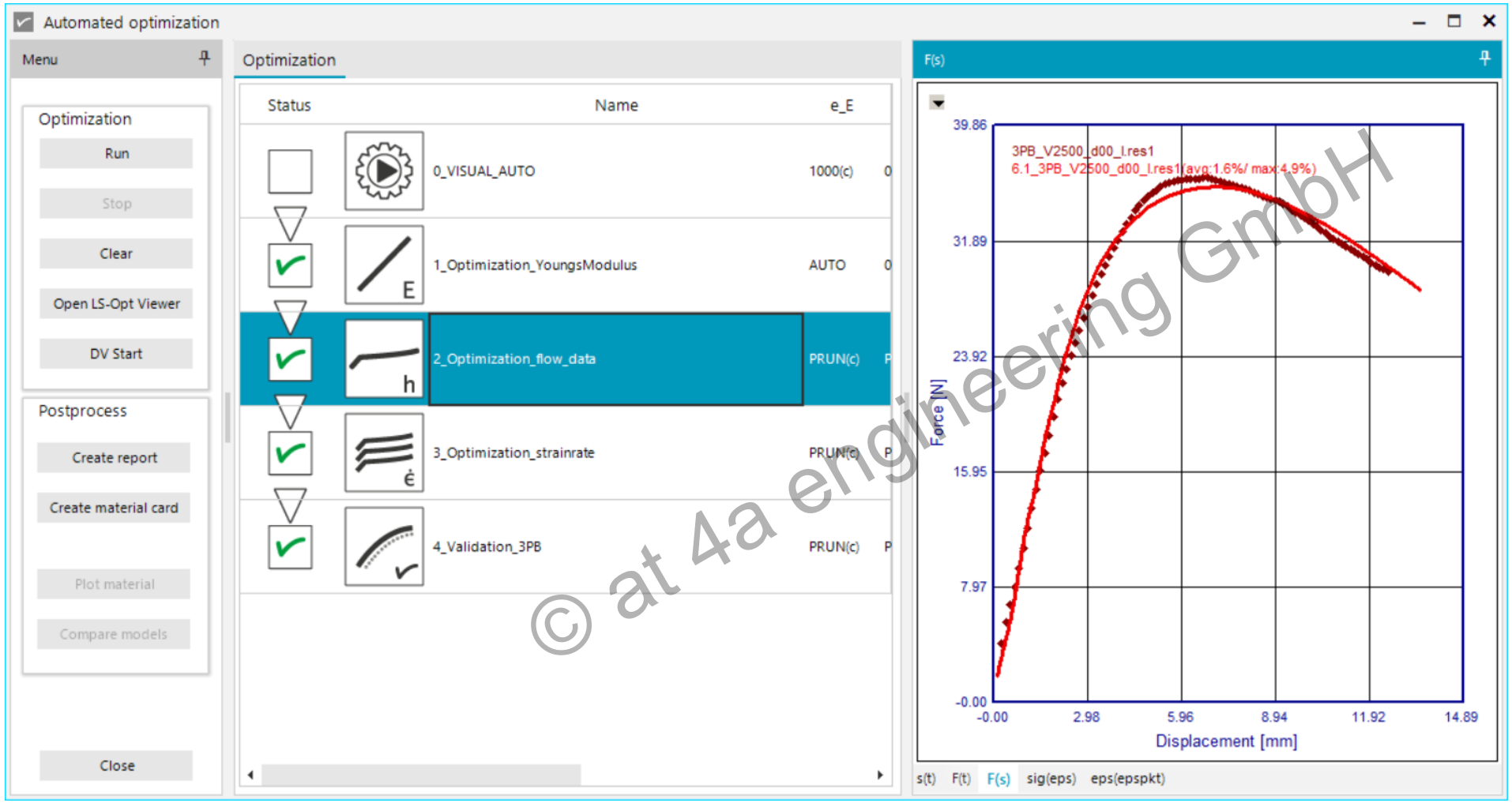
strain rates for strain rate dependency used in the material card

Material behaviour	
Material source	Implemented
Elasticity	Linear isotropic elastic
Plasticity	Yes
Failure/Damage	Damage
Material card	*MAT_PIECEWISE_LINEAR_PLASTICITY (*MAT_024)
Deformation	Plasticity Table Rate log. Table
Damage/Failure	None
Materialcard ID	1000000
Density	-1
Yield behavior	vonMISES
Function (Hardening, Elastic curve form)	
Curve 1	4a model (nue 0.5)
Strain range upto	2.5
Sampling points	100
Bias factor	1
Strain rate dependency	Table
Strain rate dependency curve	Johnson Cook
VP	Plastic strain
1st strain rate	0.0001
2nd strain rate	0.001
3rd strain rate	0.01
4th strain rate	0.1
5th strain rate	1
6th strain rate	10
7th strain rate	100
8th strain rate	1000

Name	Start	const...	from	to	Variance	Condi...	Descri...
GroupName: 10_elasticity							
e_E	PRUN	☑	100	10000	500		young...
e_nue	PRUN	☑	(NULL)	(NULL)	(NULL)		poiss...
GroupName: 20_yield							
y_0	AUTO	☐	50%	50%	(NULL)		yield s...
GroupName: 21_hardening							
h_scale0	1.0	☑	0.5	1.0	(NULL)		scalef...
h_y	90	☑	5	150	50	=y_0	harde...
h_ET	NaN	☑	0	100	(NULL)	=e_E/2	tange...
h_h	AUTO	☐	90%	50%	(NULL)		harde...
GroupName: 31_strainrate							
v_p	AUTO	☑	5	50	(NULL)		strain...
v_epspkt	AUTO	☑	0.0001	1	(NULL)		initial...

AutoFit

Optimization hardening



Checks:
curve long enough?
good fit?

AutoFit

Optimization strain rate dependency

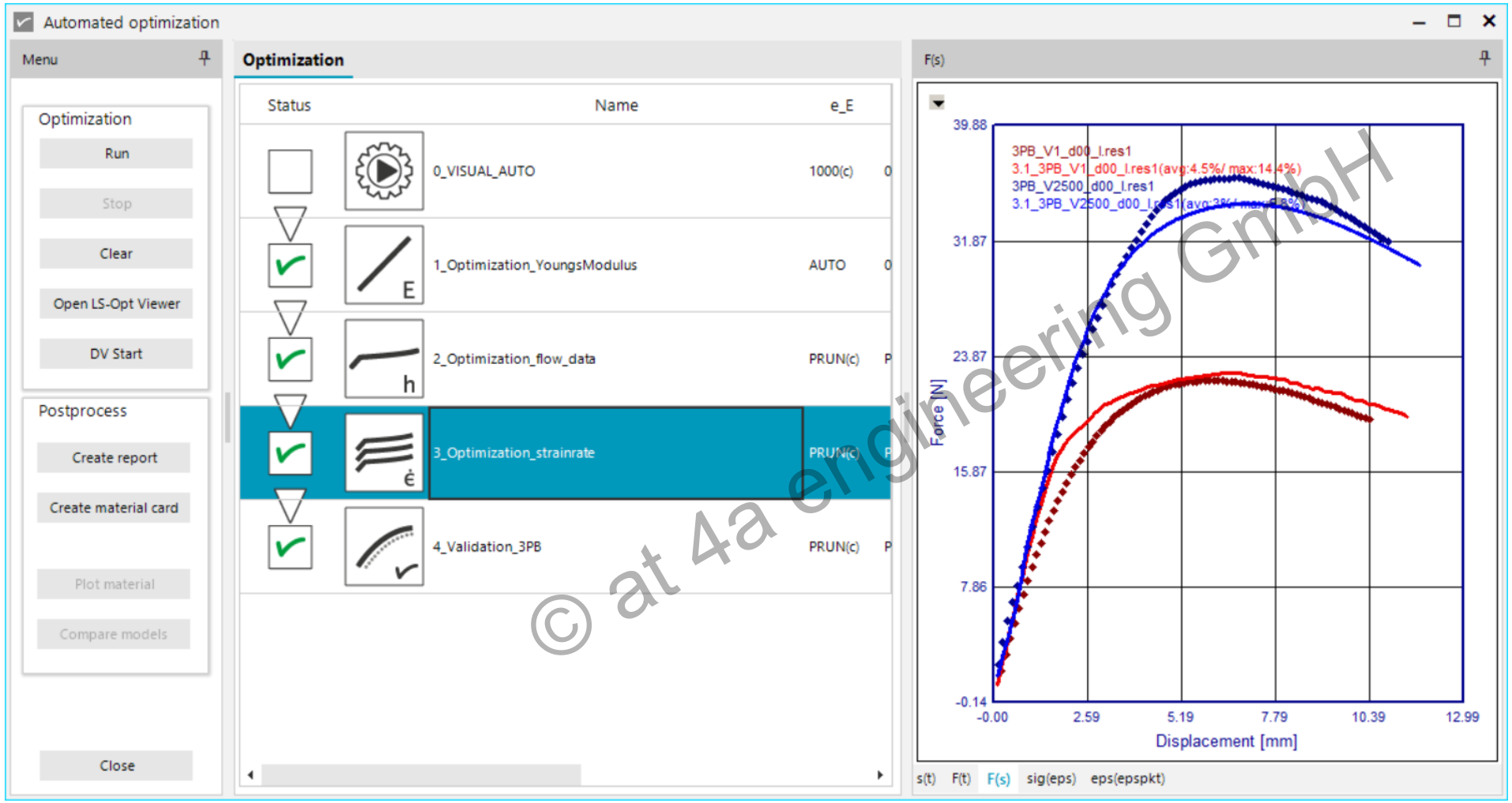
Validation/Optimization: **Optimization strainrate**

- a parametrized model is used for the hardening curve and the strain rate dependency
- Optimized Parameters are set to PRUN
- New Parameters are set to AUTO

Name	Start	const...	from	to	Variance	Condi...
GroupName: 10_elasticity						
e_E	PRUN	☑	100	10000	500	
e_nue	PRUN	☑	(NULL)	(NULL)	(NULL)	
GroupName: 20_yield						
y_0	PRUN	☑	5	150	50	
GroupName: 21_hardening						
h_scale0	PRUN	☑	0.5	1.0	(NULL)	
h_y	90	☑	5	150	50	=y_0
h_ET	PRUN	☑	0	100	(NULL)	<e_E
h_h	PRUN	☑	5	200	(NULL)	
GroupName: 31_strainrate						
v_p	AUTO	☐	20%	20%	(NULL)	
v_epspkt	PRUN	☑	0.0001	1	(NULL)	

AutoFit

Optimization strain rate dependency



AutoFit

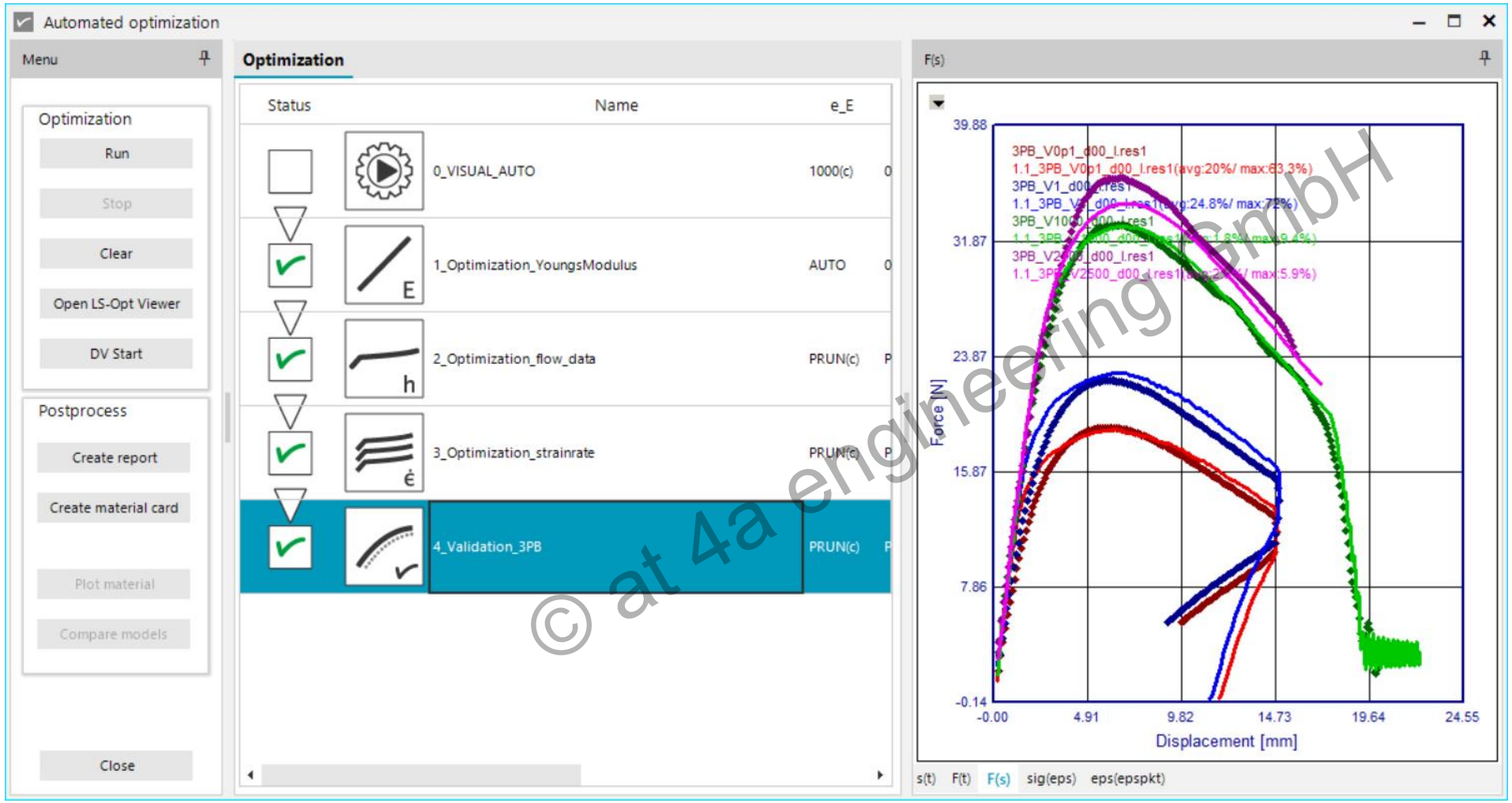
Validation

Validation/Optimization: **Validation**

- All optimized Parameters are set to PRUN

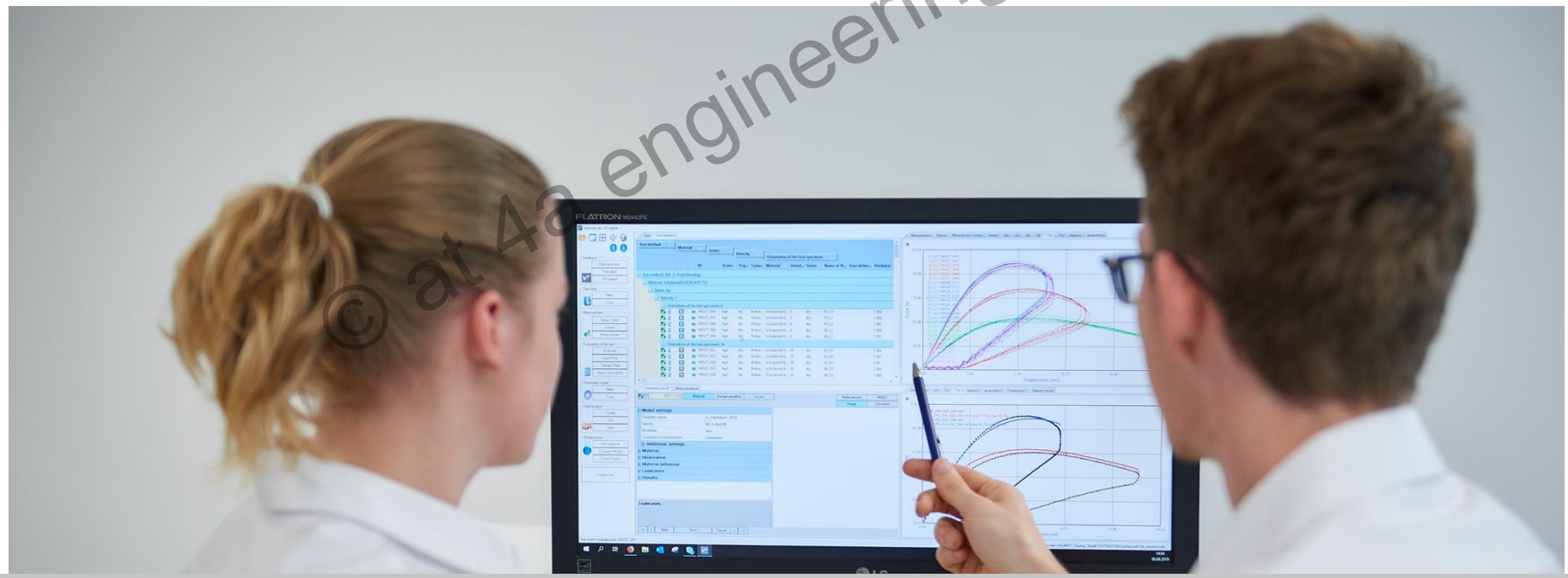
Name	Start	const...	from	to	Variance	Condi...
GroupName: 10_elasticity						
e_E	PRUN	☑	100	10000	500	
e_nue	PRUN	☑	(NULL)	(NULL)	(NULL)	
GroupName: 20_yield						
y_0	PRUN	☑	5	150	50	
GroupName: 21_hardening						
h_scale0	PRUN	☑	0.5	1.0	(NULL)	
h_y	NaN	☑	5	150	50	=y_0
h_ET	PRUN	☑	0	100	(NULL)	<e_E
h_h	PRUN	☑	5	200	(NULL)	
GroupName: 31_strainrate						
v_p	PRUN	☐	20%	20%	(NULL)	
v_epspkt	PRUN	☑	0.0001	1	(NULL)	

AutoFit
Validation

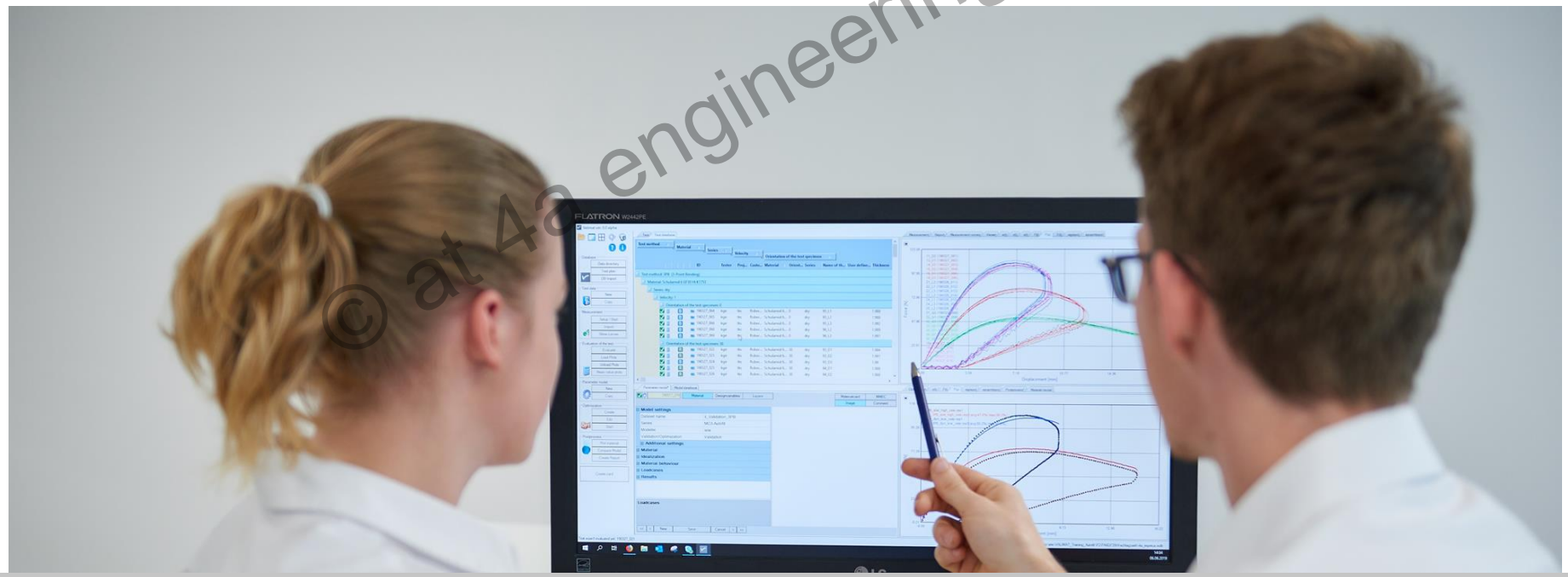


MAT_024 AutoFit - Live

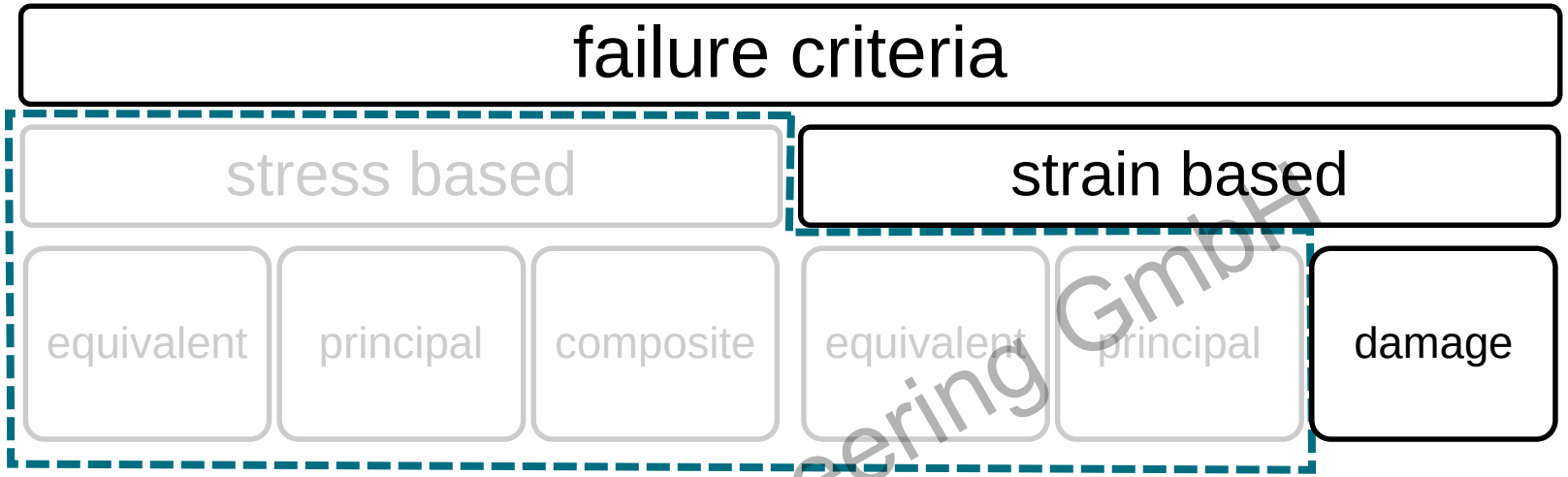
Basis 3-Point-Bending



Simple Failure



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***

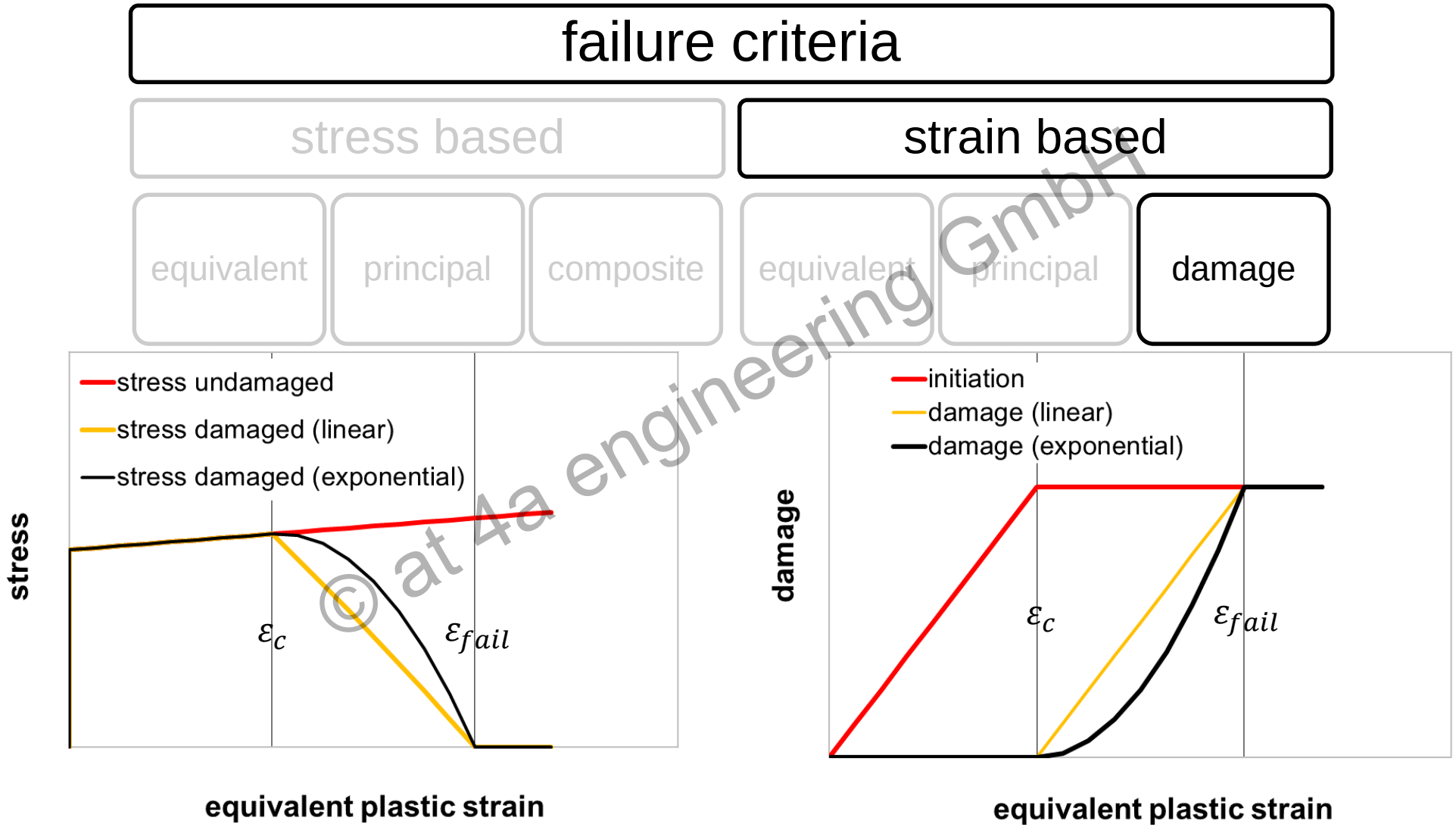
Included eq. pl. strain

****MAT_024***

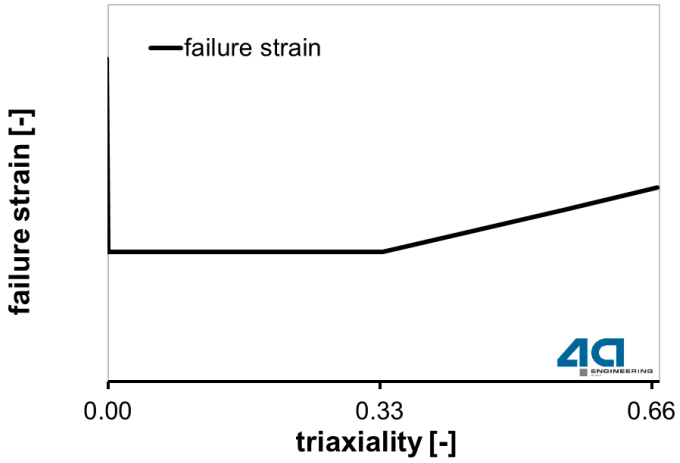
included damage model in

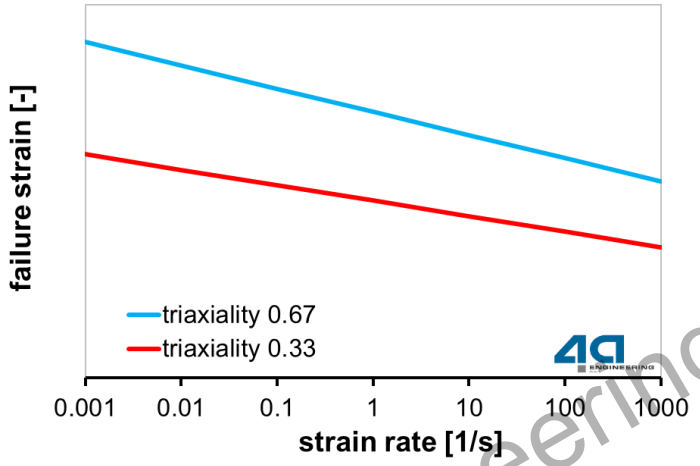
****MAT_SAMP-1(GISSMO like)***

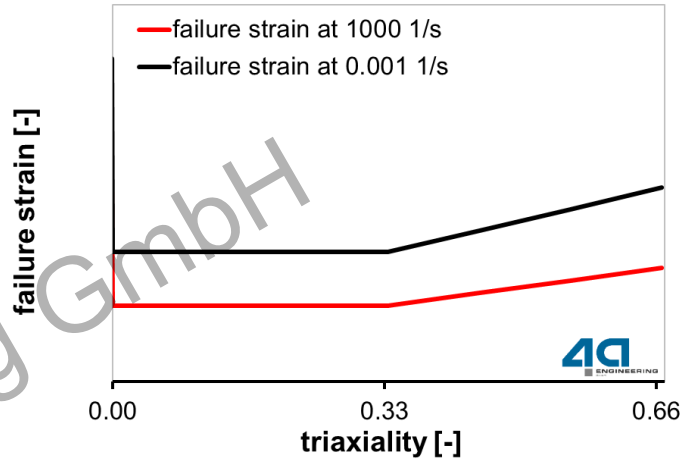
Available failure models – incremental damage formulation



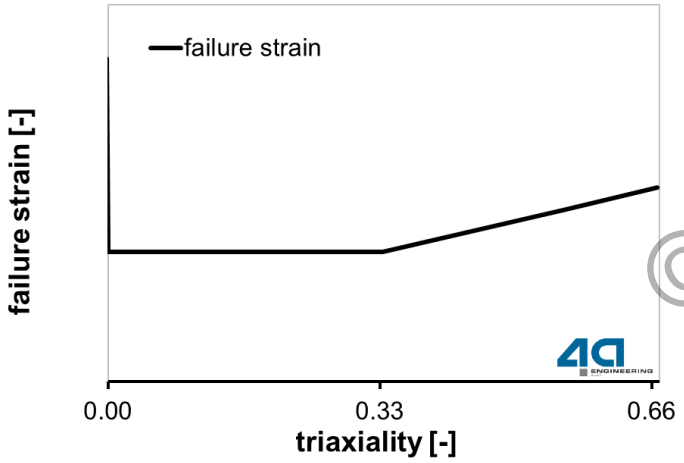
Comparison DIEM-GISSMO visualized

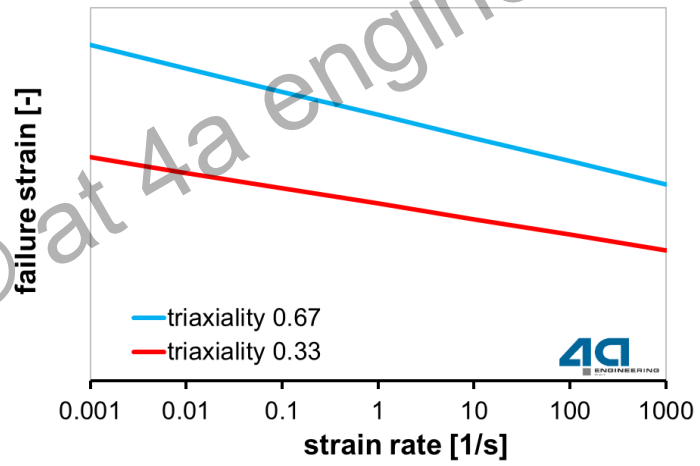


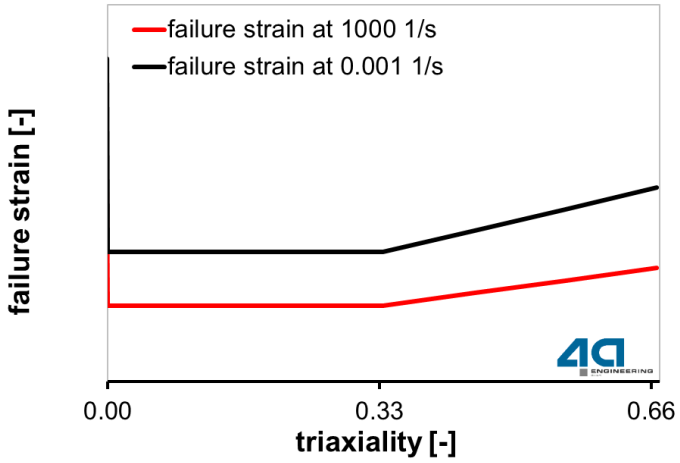




GISSMO

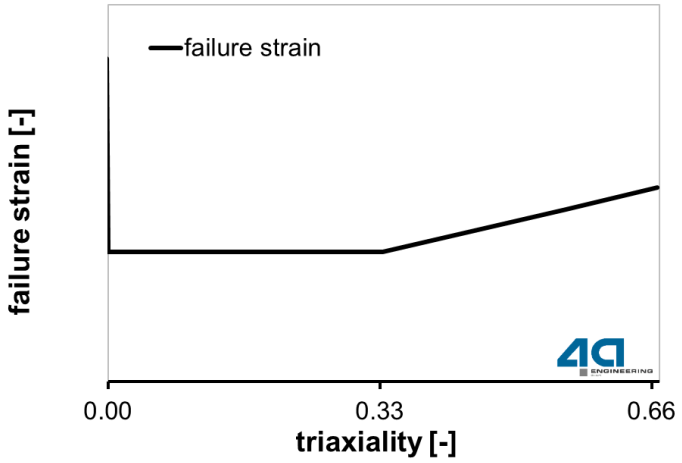


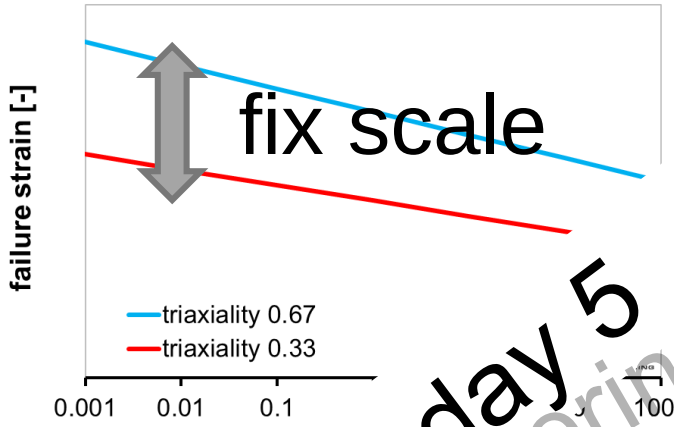


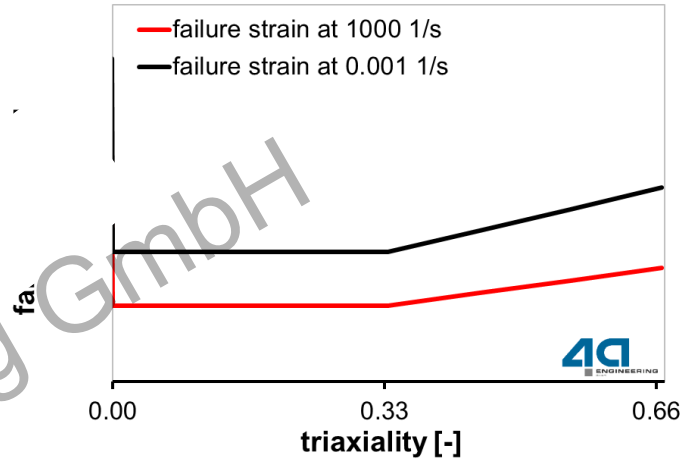


DIEM

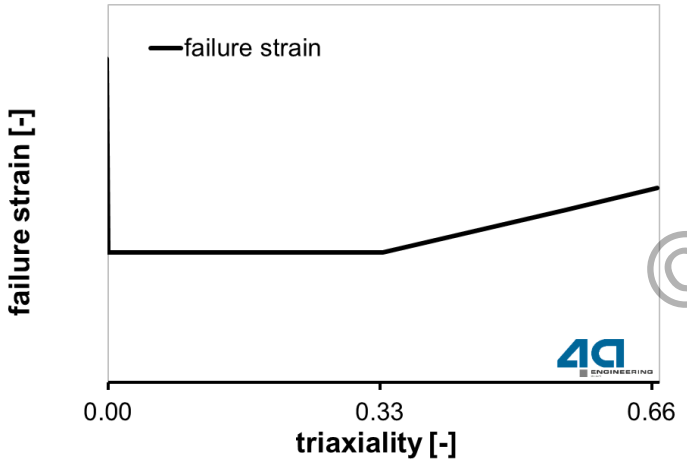
Comparison DIEM-GISSMO visualized

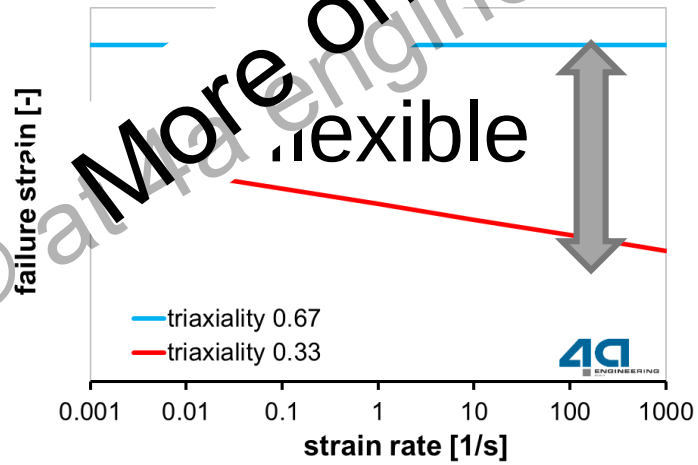


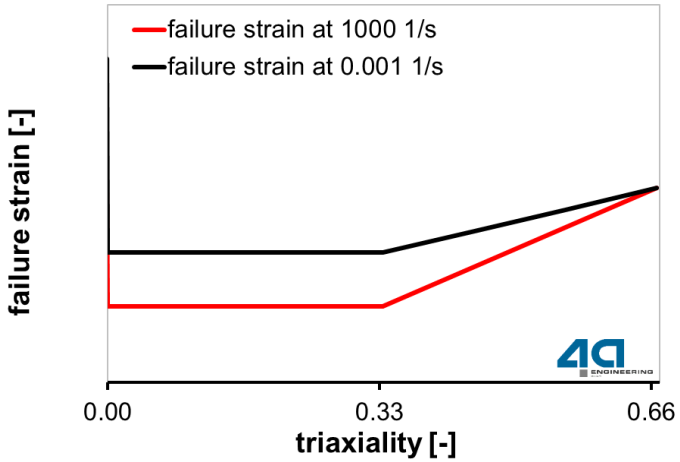




GISSMO







DIEM

More on day 5

Available failure models – typical curves

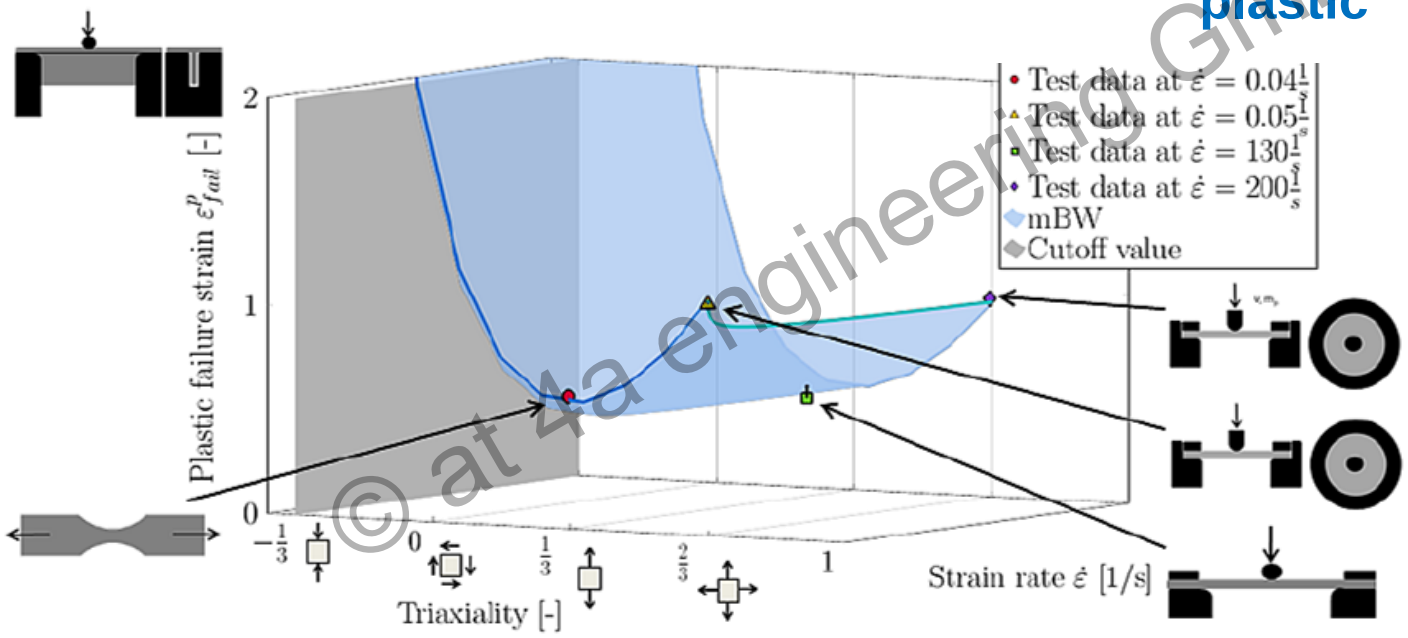
failure criteria

stress based

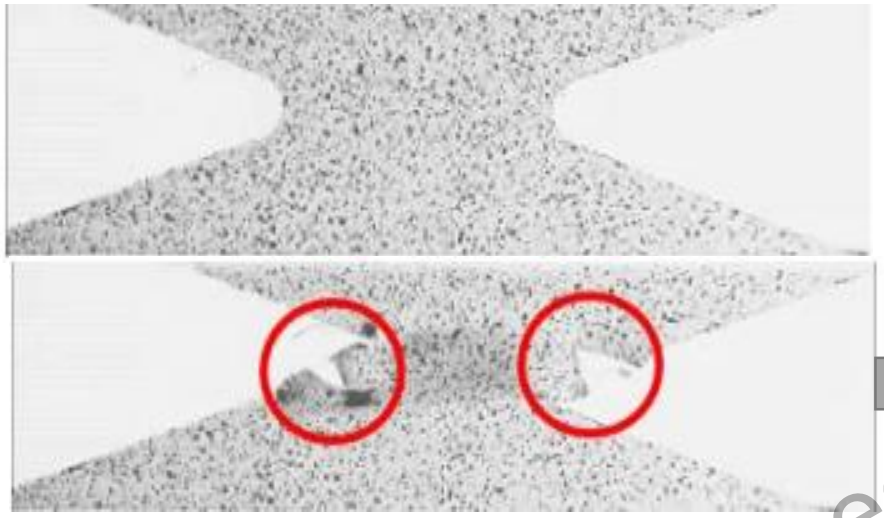
strain based

plastic

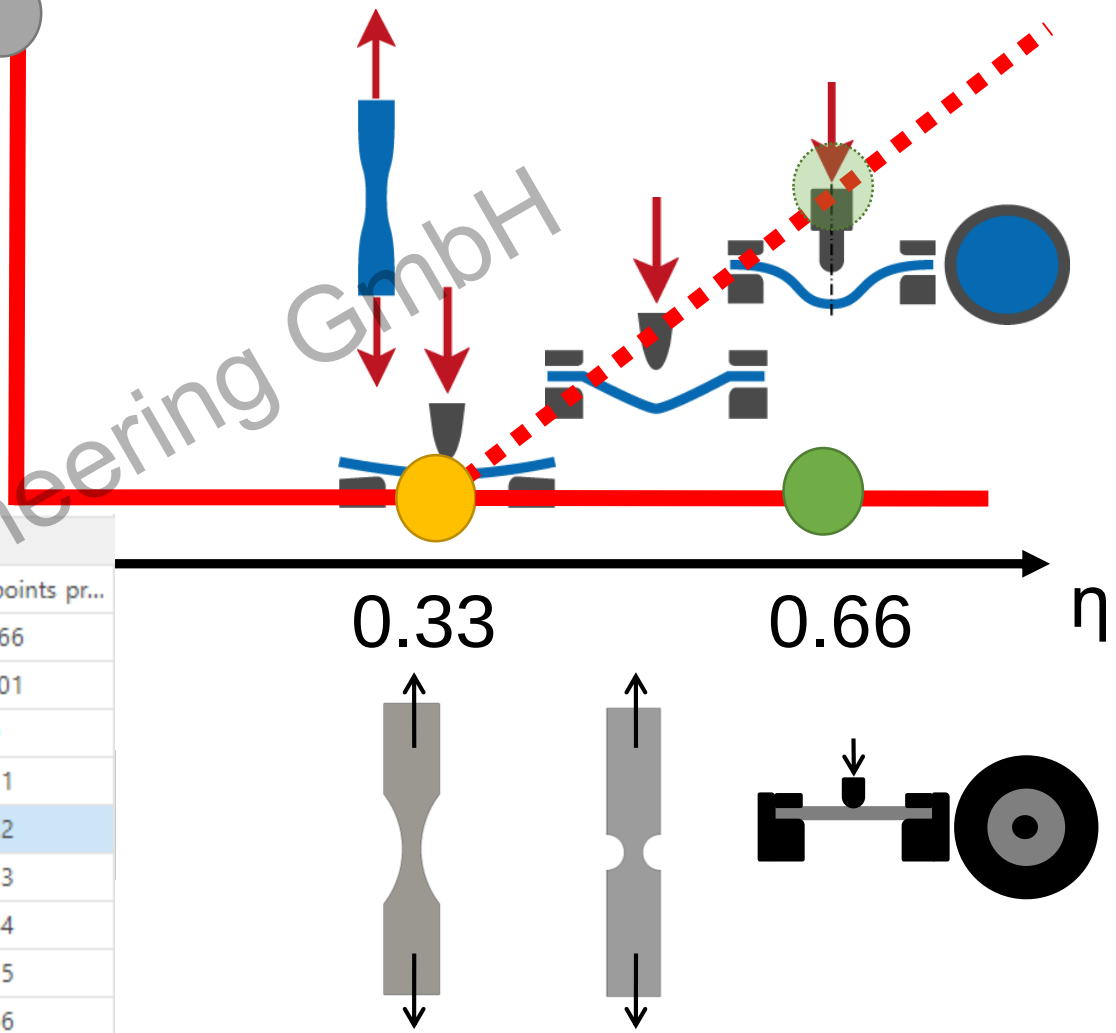
damage



From test to material card



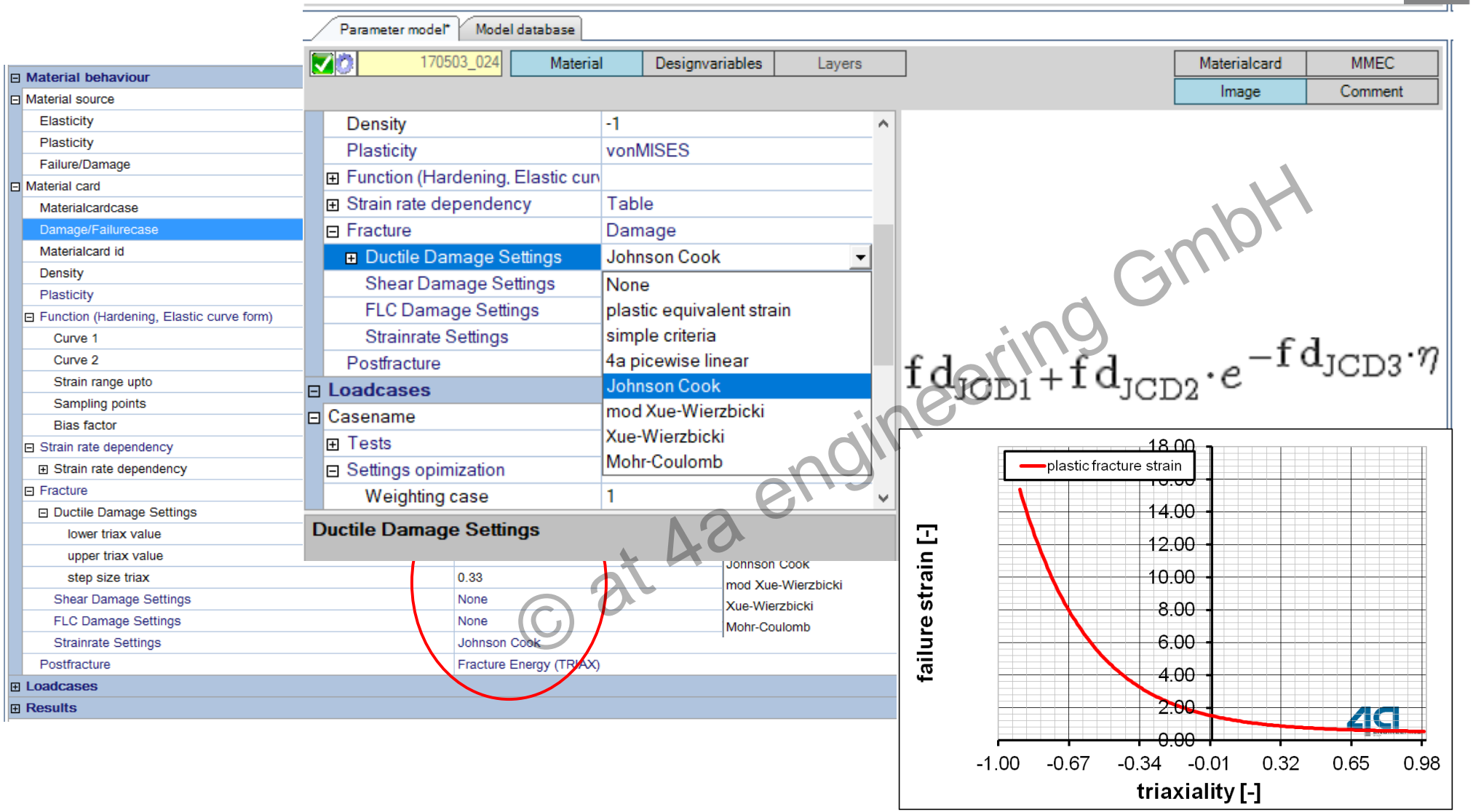
From test to material card

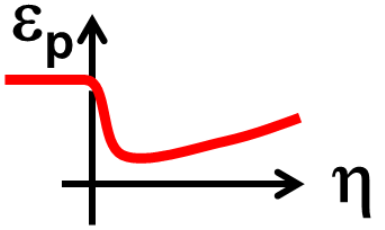


GroupName: 51_failure							
xf_NUMFIP	-75	☑	(NULL)	(NULL)	(NULL)		Number of failed integration points pr...
fd_FC_m0p66	2	☑	0.1	1	(NULL)		Failure curve point at TRIAX -0.66
fd_FC_m0p01	2	☑	0.1	1	(NULL)		Failure curve point at TRIAX -0.01
fd_FC_0p0	0.4	☑	0.8	1.3	(NULL)	=fd_F...	Failure curve point at TRIAX 0.0
fd_FC_0p11	0.4	☑	0.8	1.3	(NULL)	=fd_F...	Failure curve point at TRIAX 0.11
fd_FC_0p22	0.4	☑	0.8	1.3	(NULL)	=fd_F...	Failure curve point at TRIAX 0.22
fd_FC_0p33	0.4	☐	10%	10%	(NULL)		Failure curve point at TRIAX 0.33
fd_FC_0p44	0.4	☑	0.8	1.3	(NULL)	=(fd_F...	Failure curve point at TRIAX 0.44
fd_FC_0p55	0.4	☑	0.1	1	(NULL)	=(fd_F...	Failure curve point at TRIAX 0.55
fd_FC_0p66	0.4	☑	0.1	1	(NULL)		Failure curve point at TRIAX 0.66
GroupName: 52_failurestrainrate							

Fracture models → *MAT_ADD_EROSION

VALIMAT





Damage/Failure

Automatic report generation

- Requirements
  - A testing database with correct values in the following fields

ID	Project name	Customer	Material	Series	Thickness	Width	Length	Temperatu...	Mass of the pendulum	Velocity	Distance of support...
140313_001	Ringversuch	4a engineering GmbH	PP LGF30	longitudinal	1.8	10	50	23	1466	1	39.89
140313_002	Ringversuch	4a engineering GmbH	PP LGF30	longitudinal	1.81	9.97	50	23	1466	1	39.89
140313_003	Ringversuch	4a engineering GmbH	PP LGF30	longitudinal	1.82	9.99	50	23	1466	1	39.89
140313_004	Ringversuch	4a engineering GmbH	PP LGF30	longitudinal	1.82	9.98	50	23	1466	1	39.89
140313_005	Ringversuch	4a engineering GmbH	PP LGF30	longitudinal	1.8	9.99	50	23	1466	1	39.89
140313_006	Ringversuch	4a engineering GmbH	PP LGF30	longitudinal	1.82	10	50	23	1466	1	39.89
140313_007	Ringversuch	4a engineering GmbH	PP LGF30	perpendicular	1.82	9.97	50	23	1466	1	39.89
140313_008	Ringversuch	4a engineering GmbH	PP LGF30	perpendicular	1.81	9.97	50	23	1466	1	39.89
140313_009	Ringversuch	4a engineering GmbH	PP LGF30	perpendicular	1.83	9.98	50	23	1466	1	39.89
140313_010	Ringversuch	4a engineering GmbH	PP LGF30	perpendicular	1.82	9.99	50	23	1466	1	39.89

  - A model database with correct values in the following fields

Material name | Series

ID	Dataset name	Material name	Series
Material name:			
Material name: PPLGF30			
Series: longitudinal			
140318_002	Young's Modulus	PPLGF30	longitudinal
140318_003	Plastic Data	PPLGF30	longitudinal
140318_004	Strain Rate Dependency	PPLGF30	longitudinal
140318_005	Validation	PPLGF30	longitudinal

  - Powerpoint templates

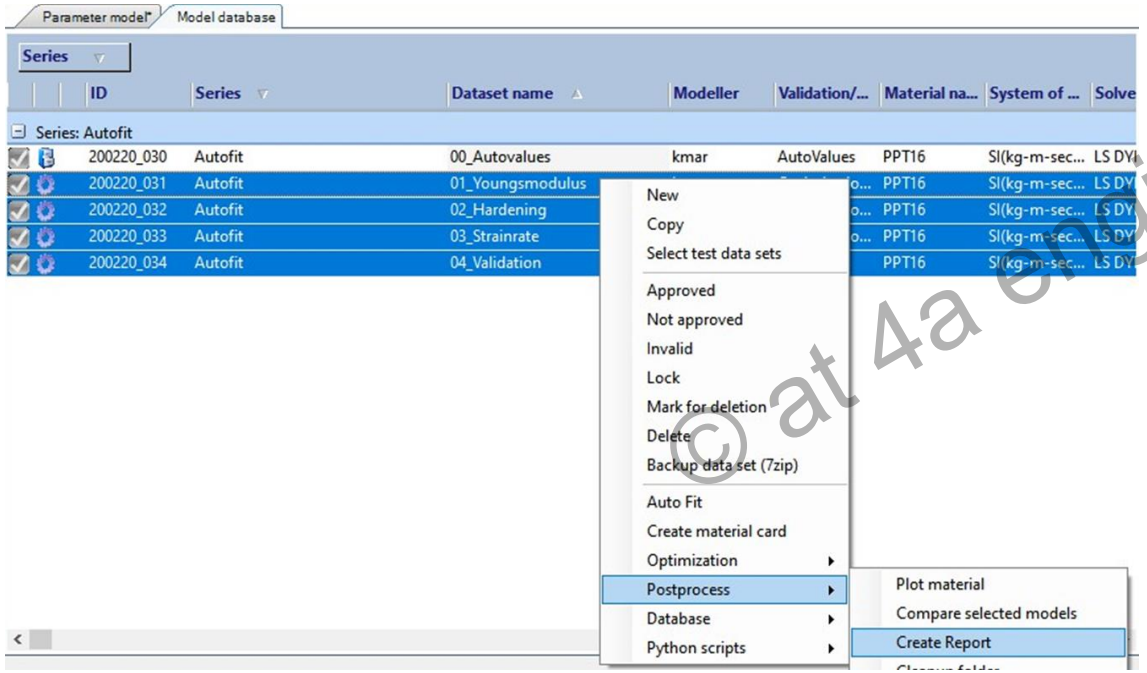
Automatic report generation

- Generation of a template
  - One can generate customized .PPTX template
  - There are several possibilities to choose from
    - <<img_sc_F(s);auto;legend_off>> : image of the simulation curve force vs. displacement with auto scaling and without a legend
    - <<img_sc_F(s);0;0.002;0;1000>> : image of the simulation curve force vs. displacement with scaling from 0 to 0.002 m and from 0 to 1000 N
    - <<img_sc_sig(eps);auto;legend_off;sc_only>> : image of the simulation curve stress vs. strain with auto scaling and without a legend; just the simulation curves are displayed
      <<img_tc_v(t)>> : image of the test curve(s) velocity vs. time with auto scaling
    - <<img_tc_F(t);xmin;xmax;ymin;ymax>> : image of the test curve(s) force vs. time with the scaling xmin to xmax for time and ymin to ymax for force; values have to be replaced

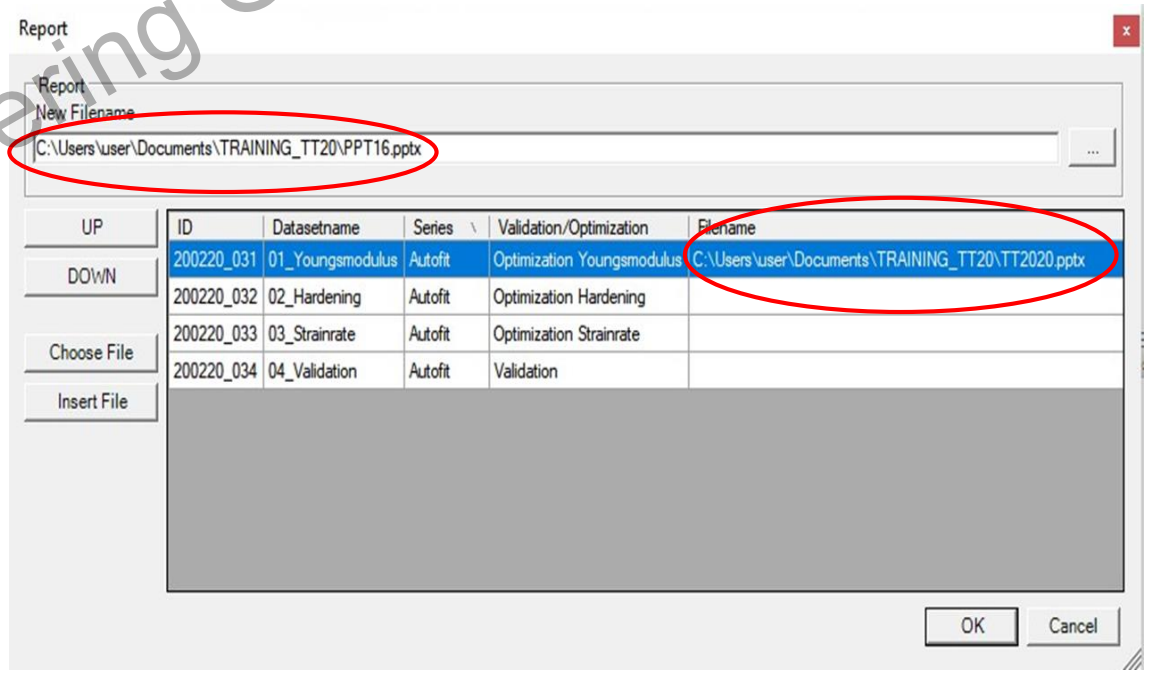
Automatic report generation

- Export using Template

Template



Generated report



Automatic report generation

Template

measurement results, <<db_T_case_1>>°C, <<db_mattyp>>

VALIMAT

overview

E moduli

<<img_sc_F(s);auto;legend_off;index:1>>

Hardening

<<img_sc_F(s);auto;legend_off;index:2>>

3-point bending

Strain rate dependency

<<img_sc_F(s);auto;legend_off;index:3>>

Validation of curves

<<img_sc_F(s);auto;legend_off;index:4>>

1 © Copyright 4a engineering GmbH - 20.02.20 rep_20022001_kmar_PPT16.pptx I N P H Y S I C S W E T R U S T

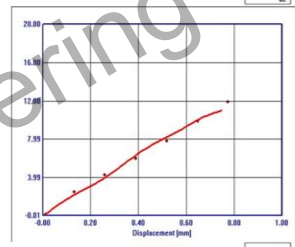
Generated report

measurement results, 23°C, PPT16

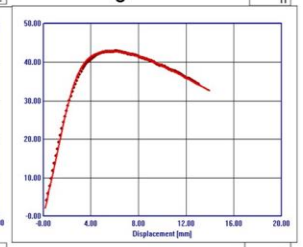
VALIMAT

overview

E moduli

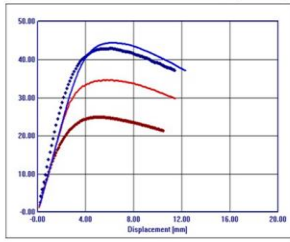


Hardening

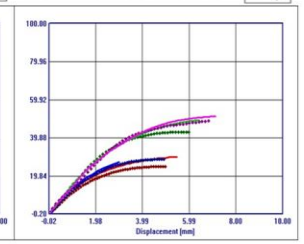


3-point bending

Strain rate dependency



Validation of curves



1 © Copyright 4a engineering GmbH -20.02.20 rep_20022001_kmar_PPT16.pptx I N P H Y S I C S W E T R U S T

Automatic report generation

- Tests are exported to a Powerpoint

Template

Reverse engineering, <<db_mattyp>>, <<db_T_case_1>>°C
3-point-bending tests

VALIMAT

<<img_sc_F(s);auto;legend_off>>

Case	v_0 [m/s]	l_w [mm]	$m_{Pendulum}$ [g]	b [mm]	t [mm]	l [mm]
<<case_1>>	<<db_va>>	<<db_lw>>	<<db_mp>>	<<db_b;f2>>	<<db_h;f2>>	<<db_l;f2>>
<<case_2>>						
<<case_3>>						
<<case_4>>						
<<case_5>>						

♦♦♦ Mean value curves testing
— optimization curves simulation

model <<db_modell_id>>
solver: <<db_solver>>, material card: <<db_mat_file>>, element size: <<db_elsize>>mm,
element type:<<db_elform>>, through thickness integration points: <<db_ellayer>>
assumptions: Poisson's ratio: <<db_nue>>, friction coefficient: <<db_fr>>

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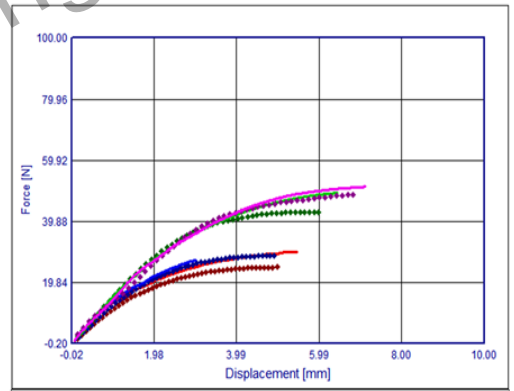
Generated report

Reverse engineering, PPT16, 23°C
3-point-bending tests

VALIMAT



Case	v_0 [m/s]	l_w [mm]	$m_{Pendulum}$ [g]	b [mm]	t [mm]	l [mm]
stat_low_vel_VP	0.0001	40.01	0	10.02	2.42	50.19
stat_high_vel	0.001	40.01	0	10.03	2.42	50.20
dyn_low_vel_EL_HC_VP	1	40.03	1580	10.03	2.42	50.18
dyn_high_vel	4	40.03	1580	10.02	2.42	50.20

model 200220_034
solver: LS DYNA, material card: *MAT_PIECEWISE_LINEAR_PLASTICITY (*MAT_024), element size: 2mm,
element type: 16: Fully integrated shell element (very fast), through thickness integration points: -1
assumptions: Poisson's ratio: 0.3, friction coefficient: 0.1

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Thank you for your Attention!

4a summer-school - webinar and training
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