Automated Material model calibration with failure in VALIMAT®: Failure Fit

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Hanau, Germany

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- Failure Fit
  - Material Calibration Process
  - Material Models For Plastics
  - Failure Models
  - Failure Fit Implementation
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- Outlook Foam Fit
- Conclusion

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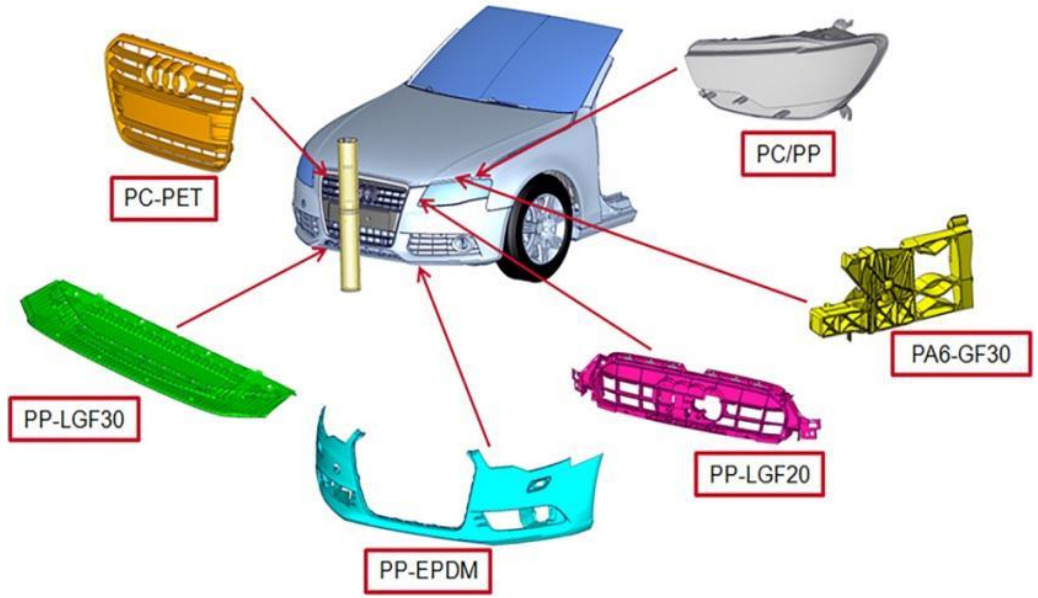
Motivation

- simulation processes more commonly used in product development
- plastics wide variety of behavior and customizable for the application
- ➔demand for calibrated material models
- Automation
  - reduce process times
  - reproducible quality

pedestrian safety



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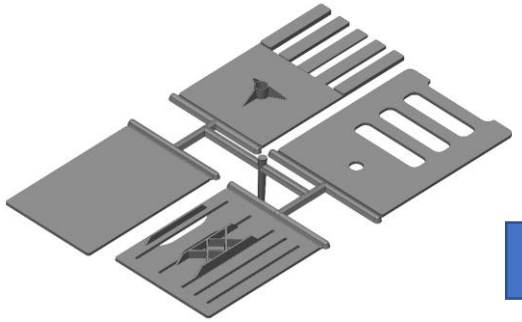
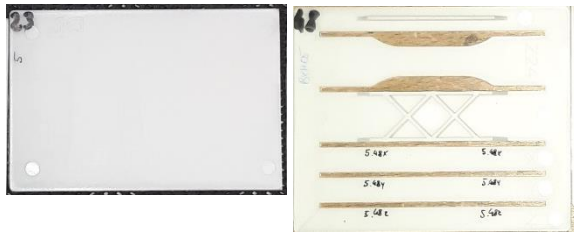
Material Calibration Process

Specimen Preparation



Research injection mold

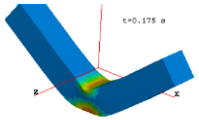


Testing

Shimadzu AG-X

IMPETUS

Modelling



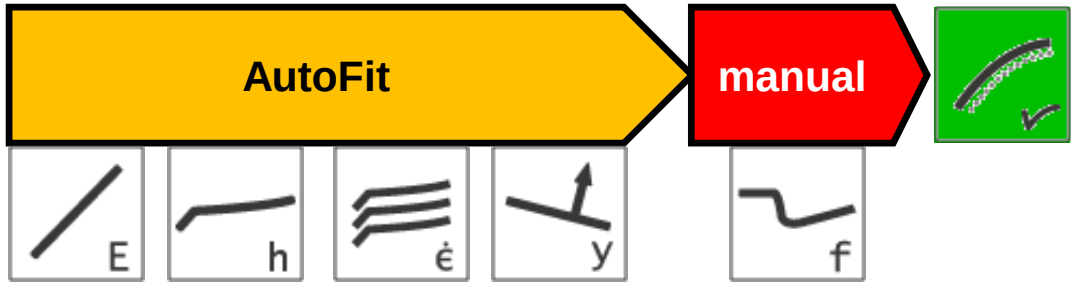
FEM

VALIMAT

Optimization

Data

parameterized Material Model



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Material Calibration Process

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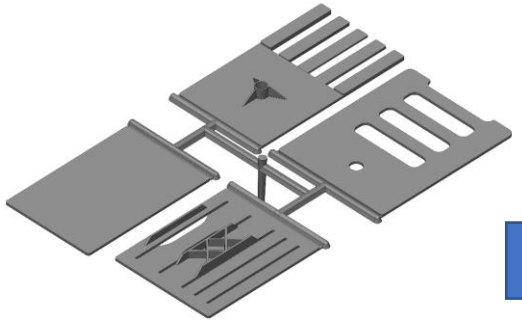

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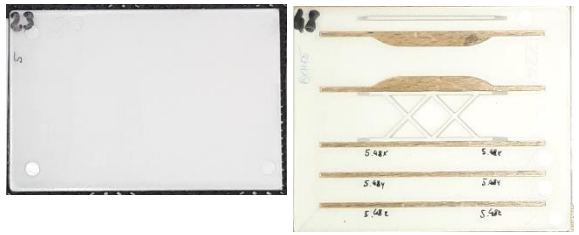
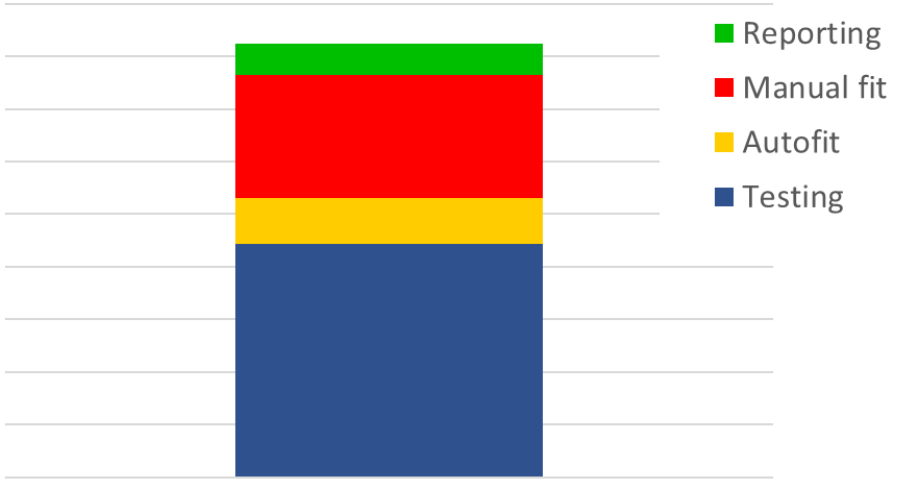


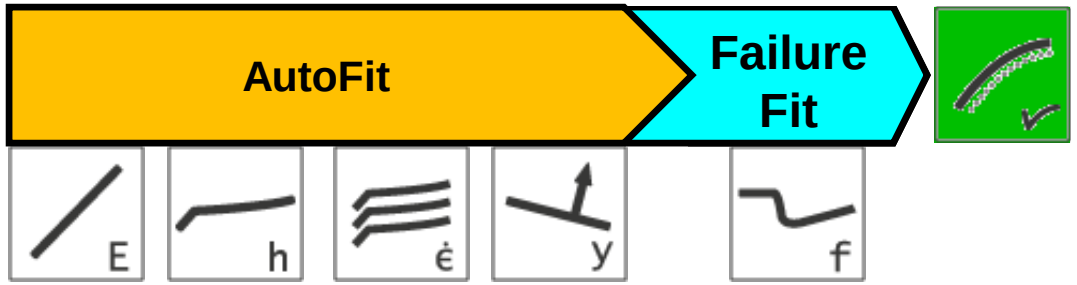
Testing

Shimadzu AG-X

IMPETUS

Process Time Estimation





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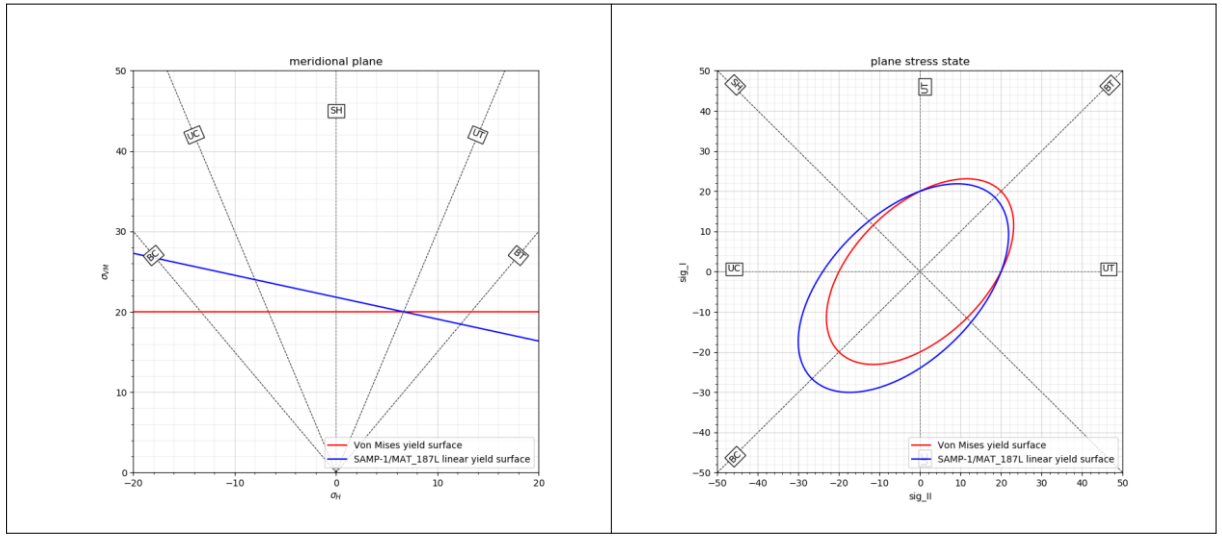
Commonly Used Material Models For Plastics in LS-DYNA®

- ***MAT_024** - The workhorse*
  (***MAT_081**, **MAT_089**, **MAT_123**, …)*
- ***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_187**	linear; parabolic; piecewise linear	✓ $E(\dot{\varepsilon})$	✓	✓	✓ $\nu_p(\varepsilon)$
***MAT_187L**	linear	✓ $E(\dot{\varepsilon})$	✓	✓	✓ $\nu_p(\varepsilon)$

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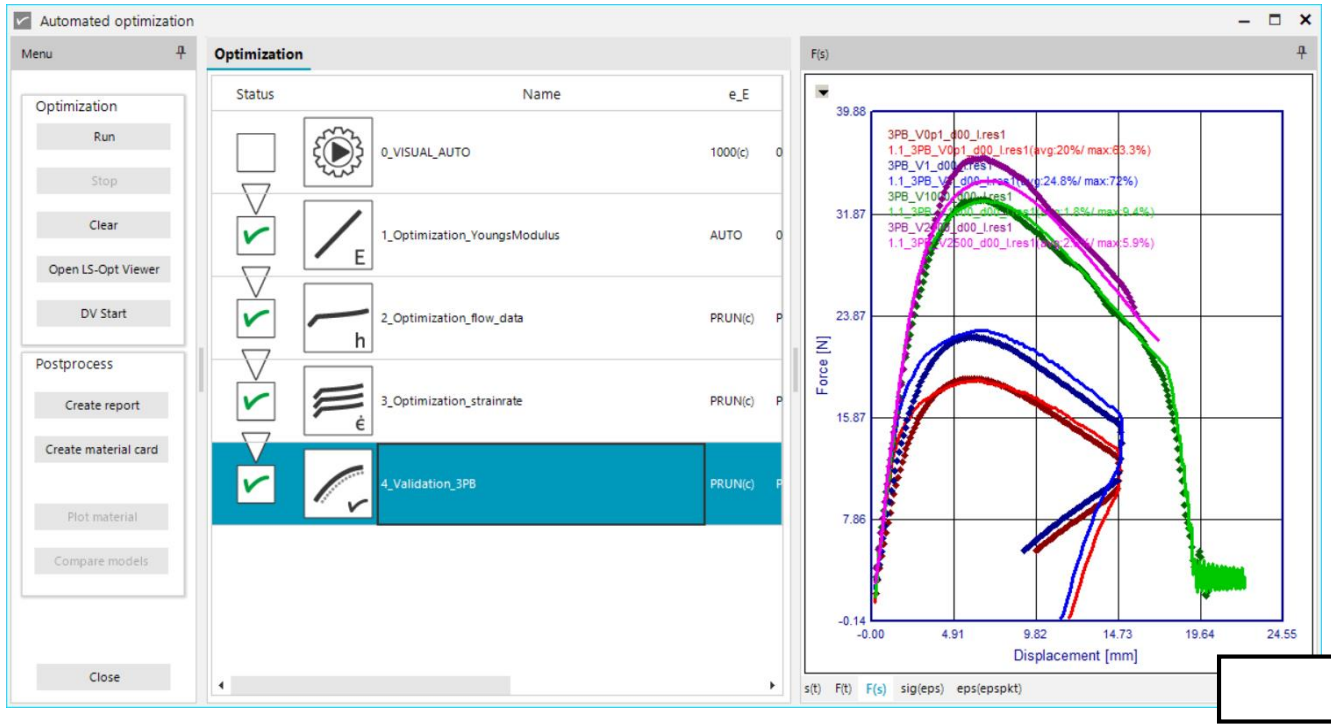
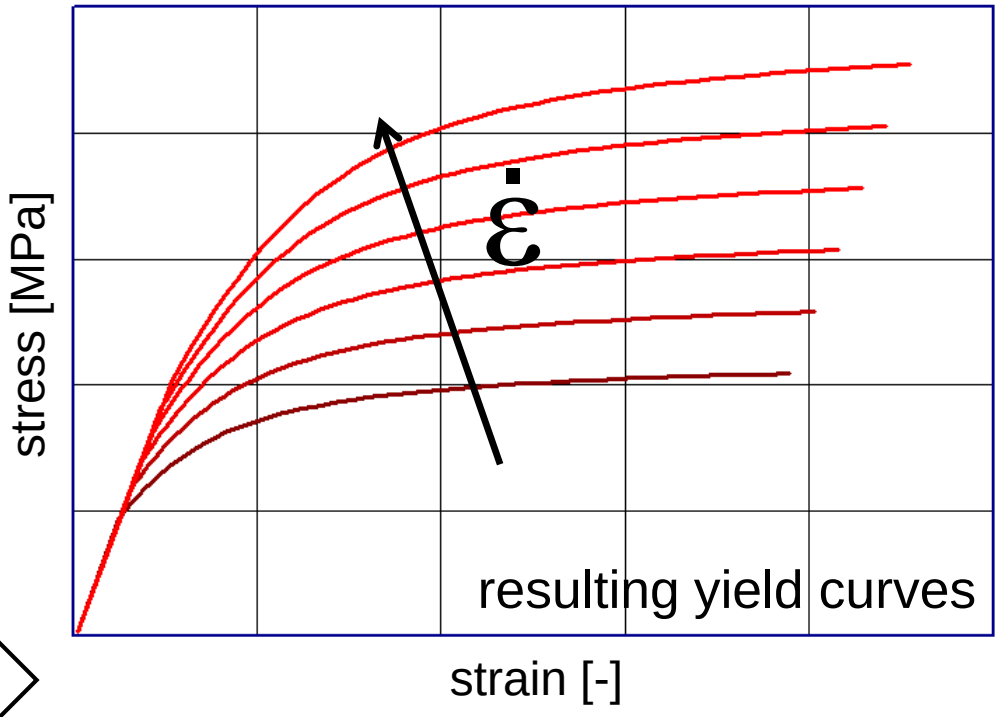
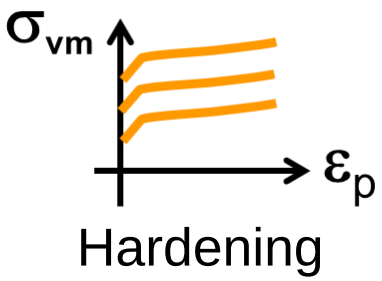
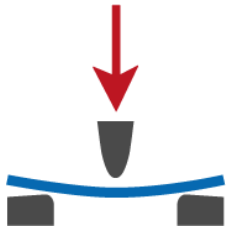
VALIMAT® Workflow for Material Card Generation - AUTOFIT









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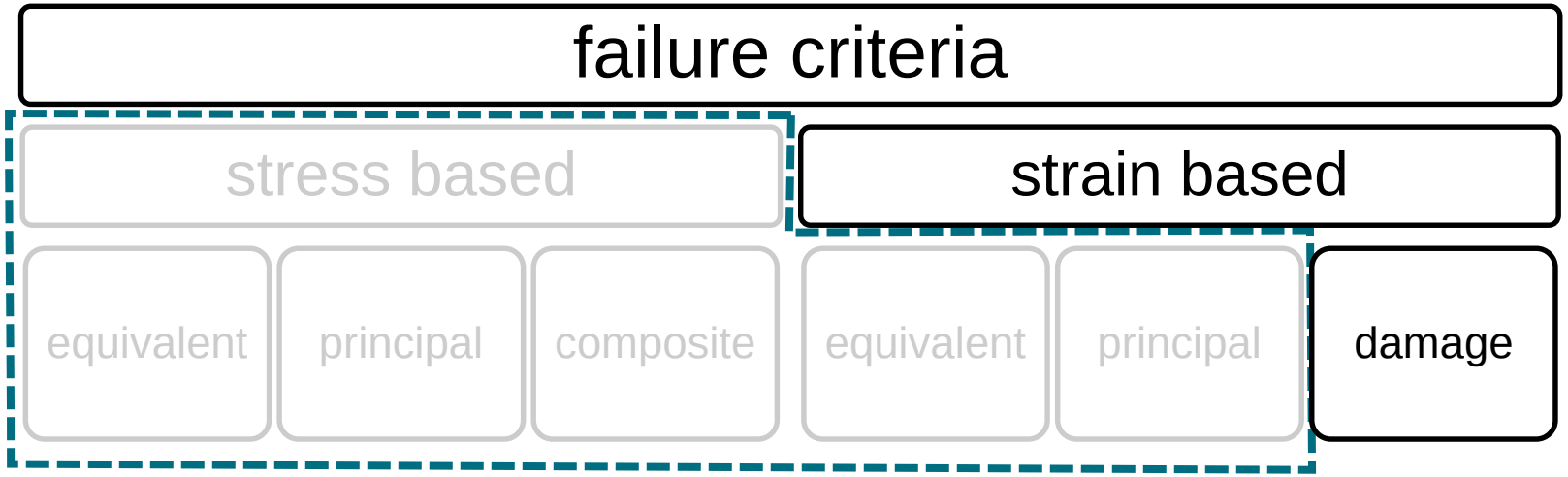
Available failure models in LS-DYNA®



additional failure models

****MAT_ADD_EROSION***

- MXEPS maximum principal strain, …

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)***

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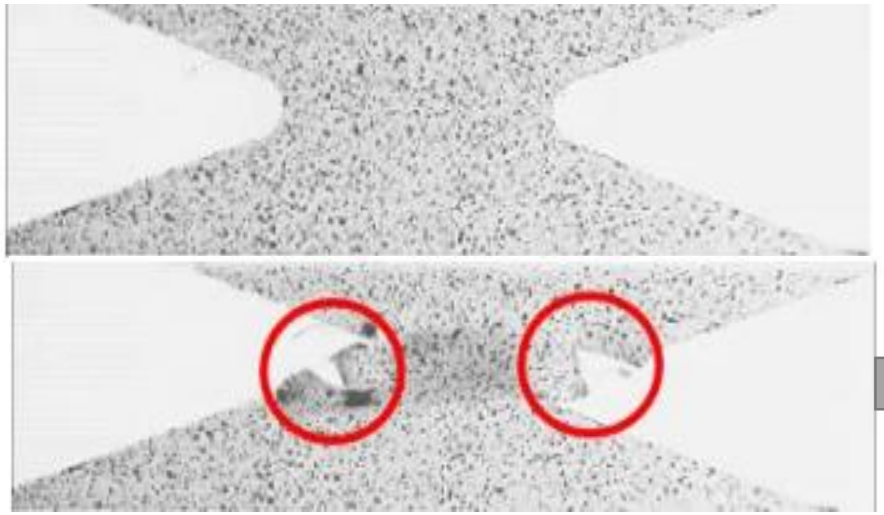
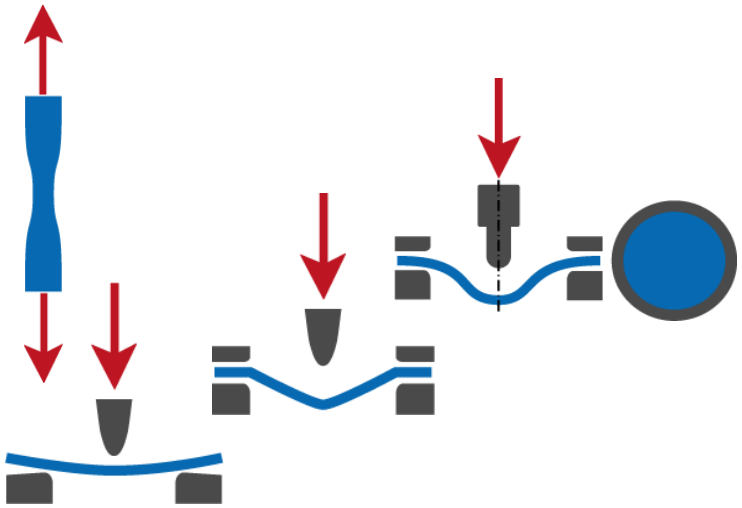
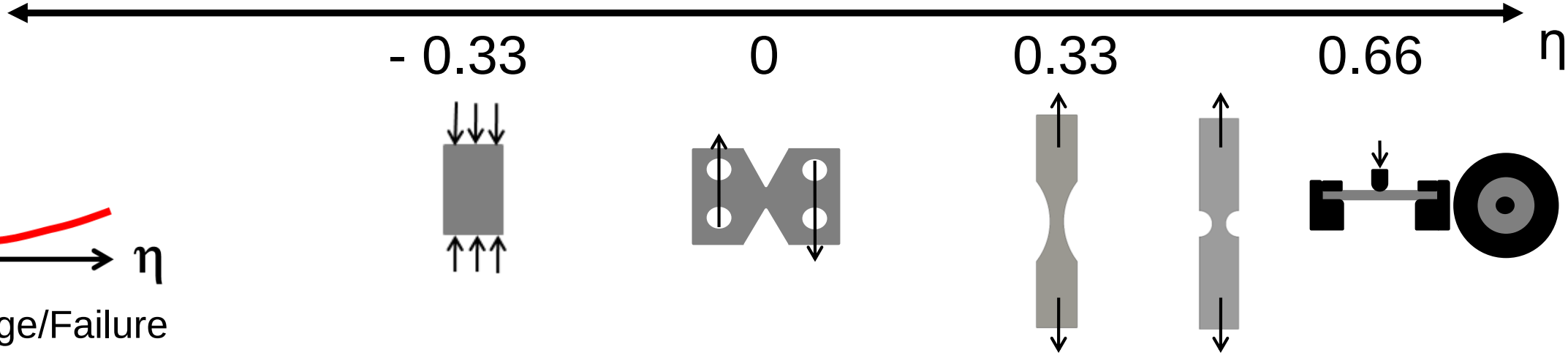
from test to material card







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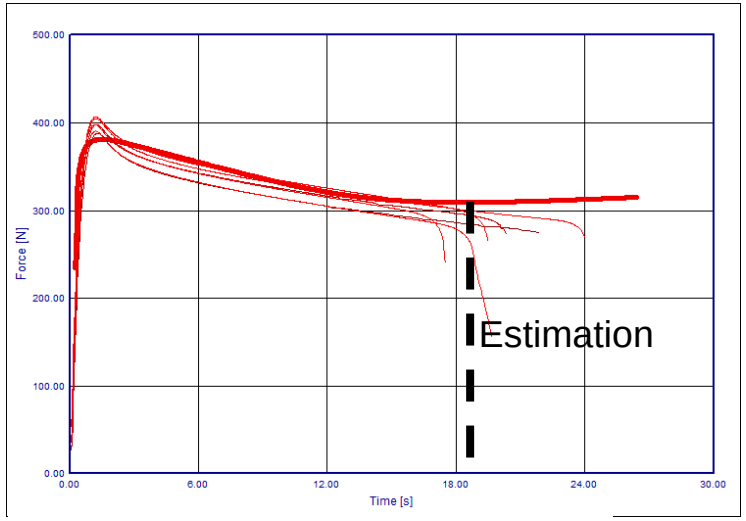
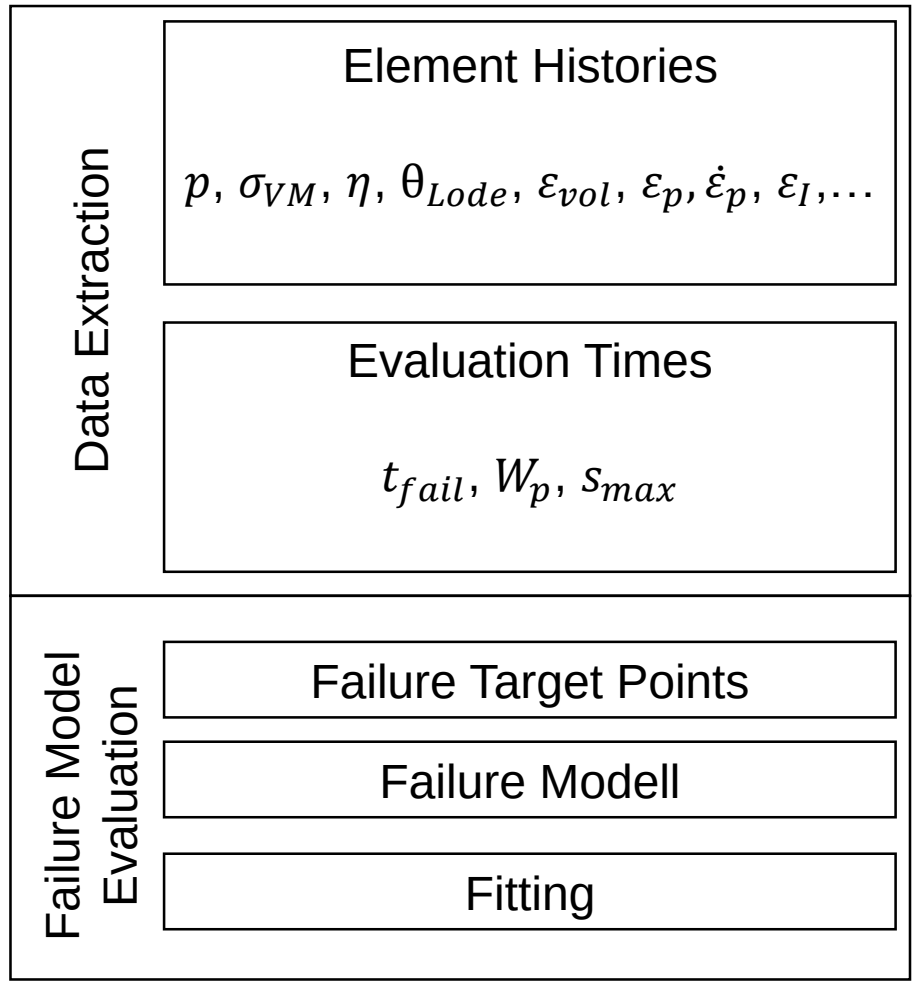
Failure Fit

- Idea: Run a Simulation with of all failure cases where failure occurs ➔ Extract the relevant history variables for the chosen failure model ➔ Estimate failure model parameters
- Consists of 2 parts:
  - Data Extraction from Modell without failure
  - Failure Model Fitting



— simulation results
— single measurement curve



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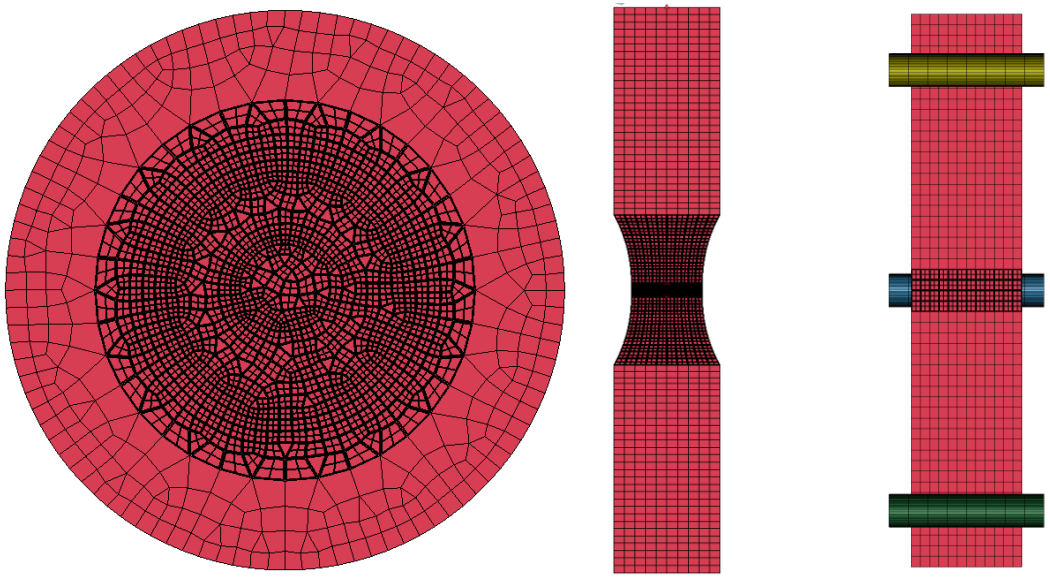
Failure Fit Implementation

Data Extraction – Element Histories

- Define output sets in area of interest
- Data Extraction with VALIMAT python module

puncture test PT *tensile test TT* *3-point bending 3PB*



Additional element history sets for data extraction
For puncture test, tensile test, 3-point bending test

Element Histories

$p, \sigma_{VM}, \eta, \theta_{Lode}, \varepsilon_{vol}, \varepsilon_p, \dot{\varepsilon}_p, \varepsilon_I, \ldots$

p *pressure*
σ_{VM} *Von Mises Stress*
η *stress Triaxiality*
θ_{Lode} *Lode angle*
ε_{vol} *volumetric strain*
ε_p *equivalent plastic strain*
$\dot{\varepsilon}_p$ *equivalent plastic strain rate*
ε_I *maximum principal Strain*

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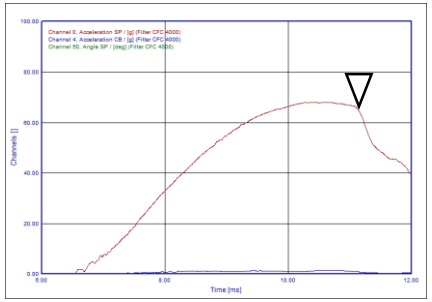
Failure Fit Implementation

Evaluation Times

Decide where failure should occur

- failure time from measurement (force drop, manual)

⊟ Identification of failure	0 - Manual (point in time)
tend	0.013712
tfail	0.01114 get



- Combined value of measurement and simulation results
  - Work equal between Simulation and Test
  - Same displacement in Simulation and Test

Evaluation Times

t_{fail}, W_p, s_{max}

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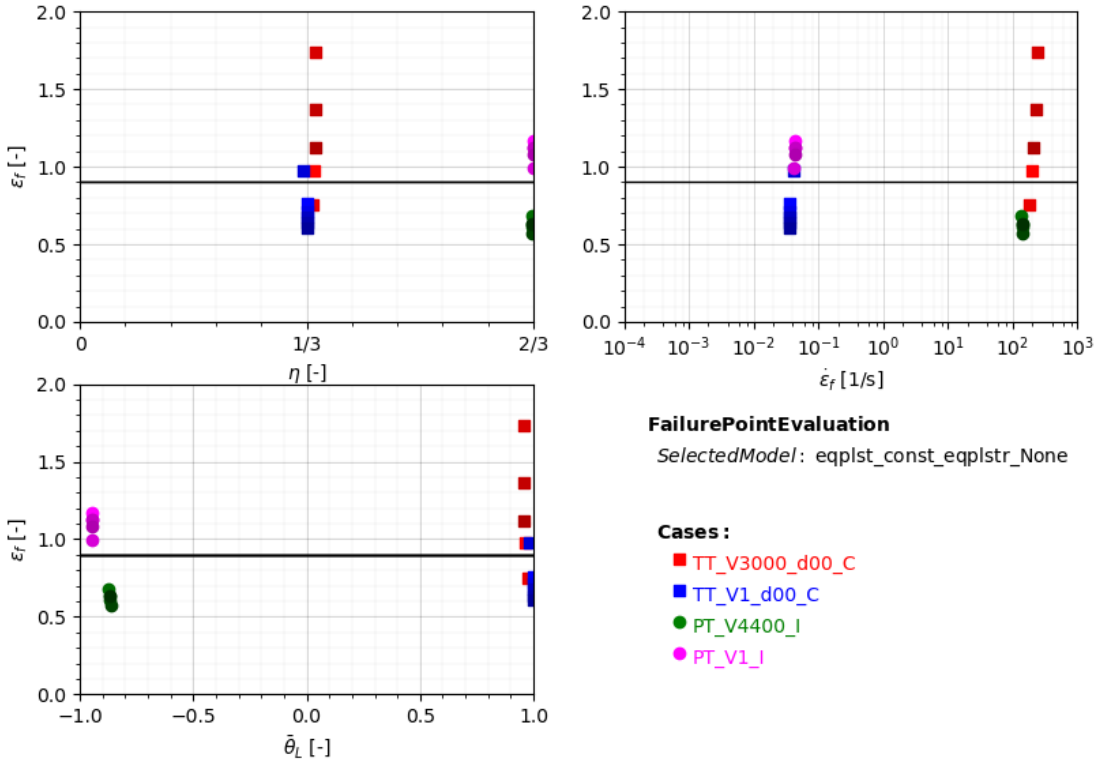
Failure Fit Implementation

Failure Model Evaluation – Simple Evaluation

- Failure Target Points
  - max occurrence of value at failure time from each test in each case
  - ignore not failed tests
- Failure Modell
  - parameter equals history variable
- Fitting
  - weight cases (equally, unequally, …)

Failure Target Points

$\varepsilon_f(\varepsilon_p)$



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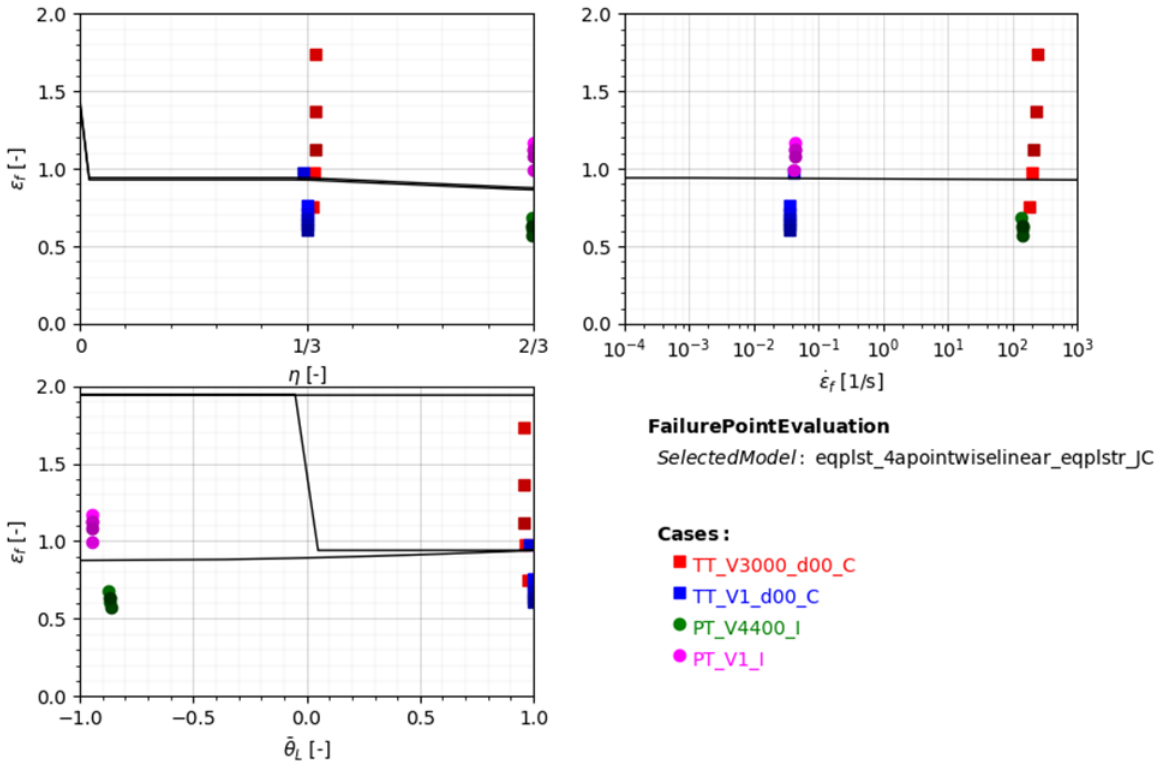
Failure Fit Implementation

Failure Model Evaluation – Max. equivalent plastic strain Evaluation

- Failure Target Points
  - failure dependent on multiple history variables ➔failure target points not obvious
  - simplified approach: use element/integration point with maximum equivalent plastic strain
- Failure Modell
  - function of several history variables
- Fitting
  - weight cases (equally, unequally, …)
  - nonlinear least square fit

Failure Target Points

$$\varepsilon_f\left(\varepsilon_p, \dot{\varepsilon}_p, \eta, \theta_{Lode}\right)$$



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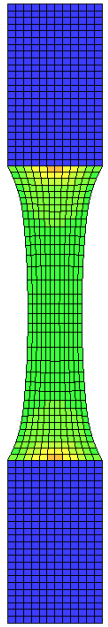
Failure Fit Implementation

Failure Model Evaluation – Max. equivalent plastic strain Evaluation

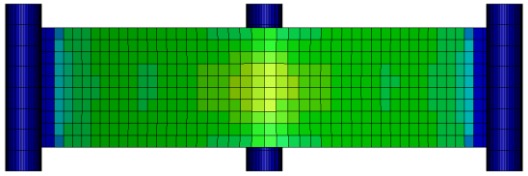
- For the chosen load cases the stress states in the area of interest is similar
- For future developments
  - groupings in triaxiality buckets

tensile test TT

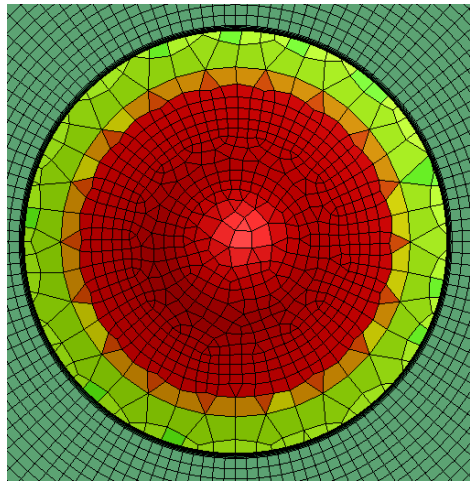


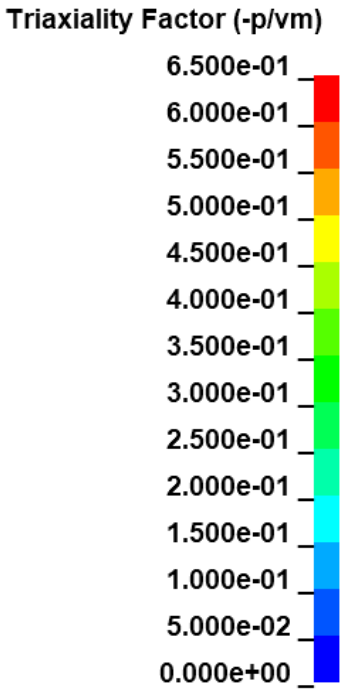
3-point bending 3PB

lower surface ➔ tensile side



puncture test PT





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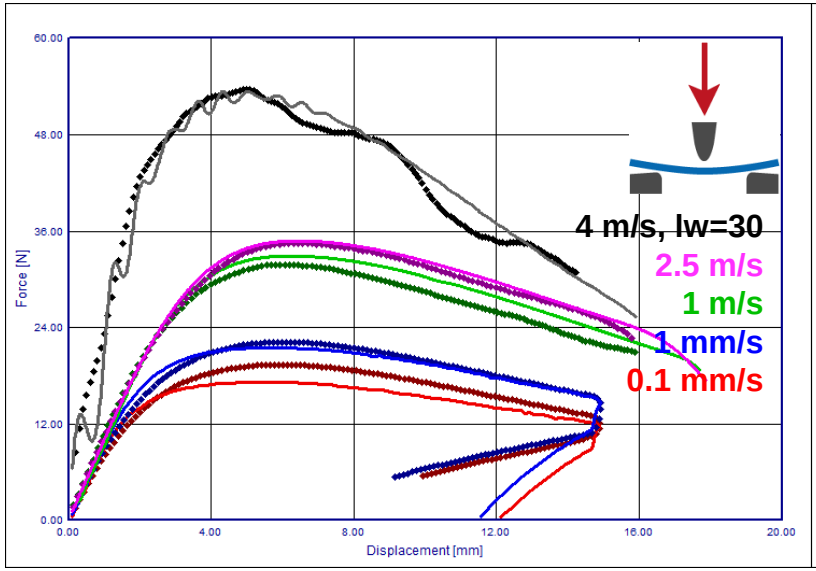
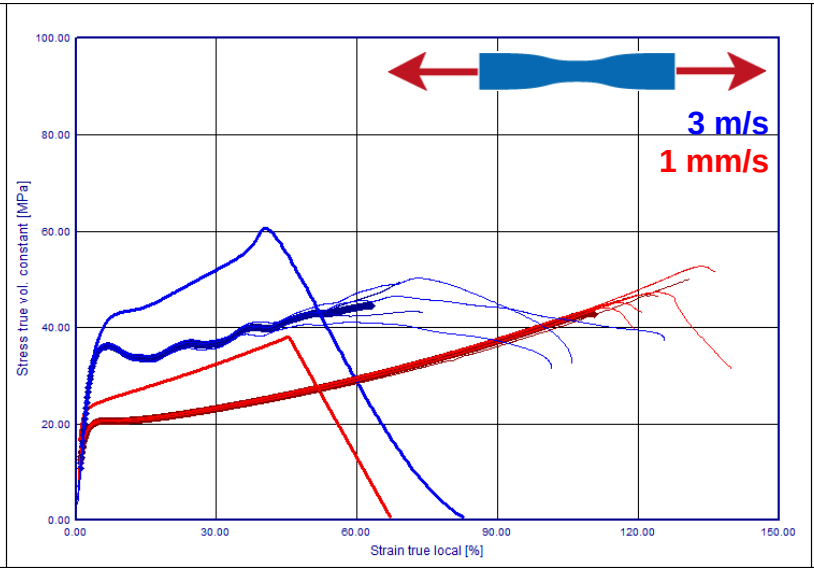
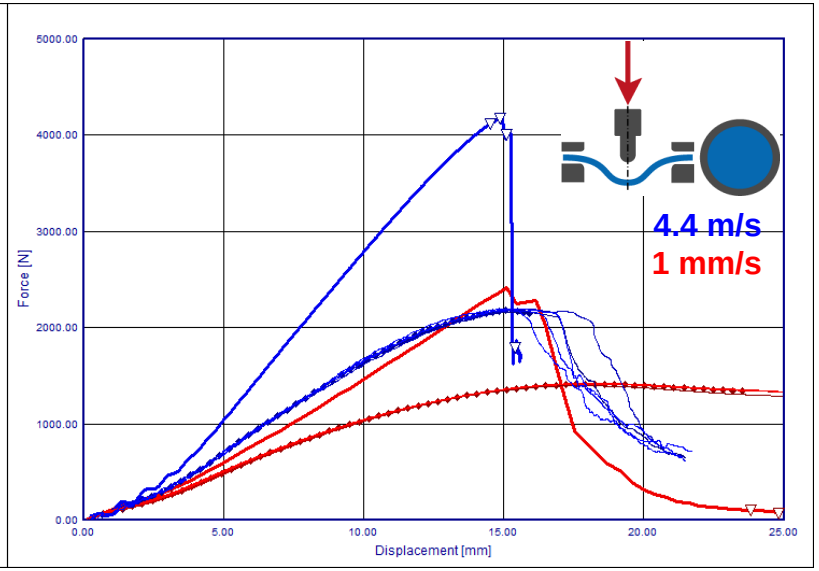
Failure Fit Results

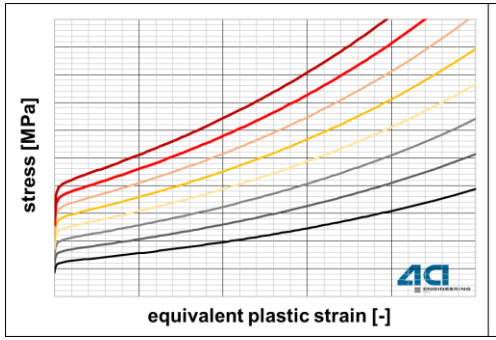
*MAT_024 + MXEPS – Simple Evaluation



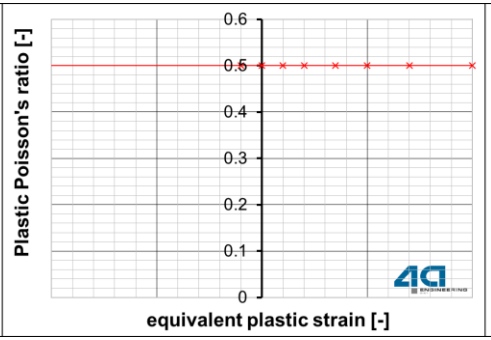




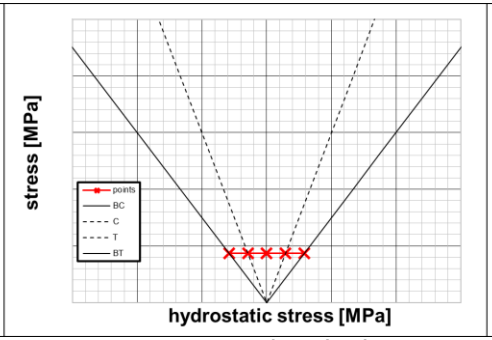
hardening



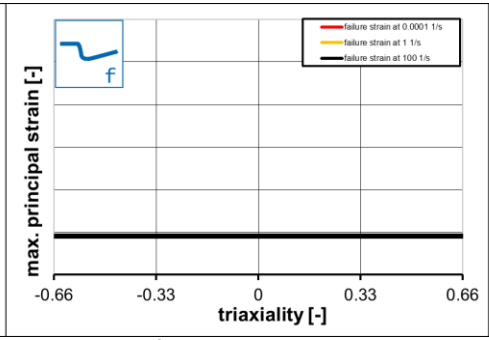
flow rule

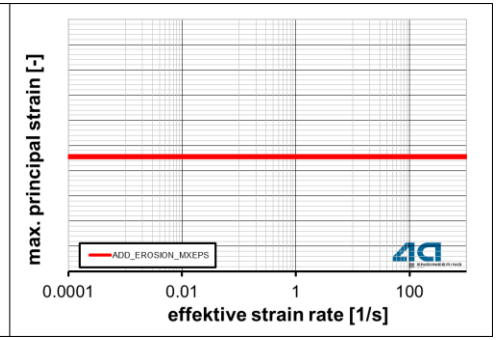


yield surface



failure





♦♦♦ Mean value curve of measurements — simulation results (— single measurement curve) ▽ set failure time

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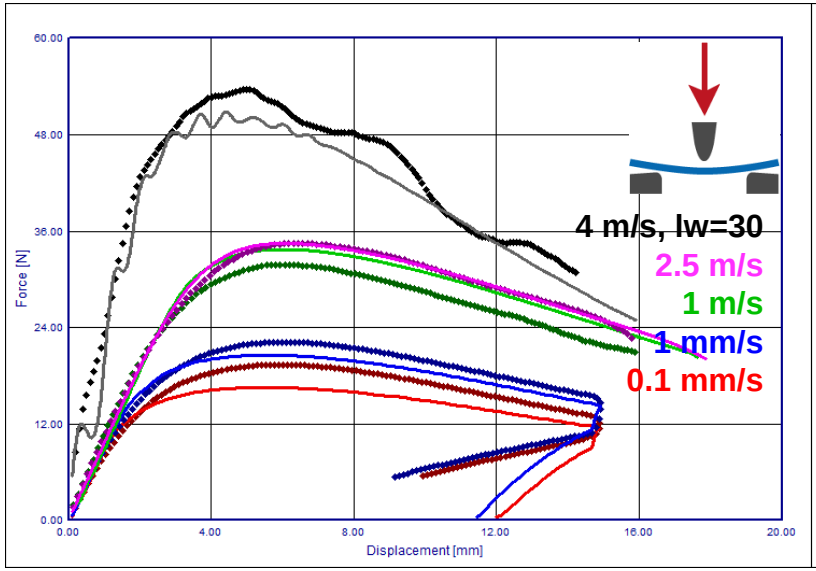
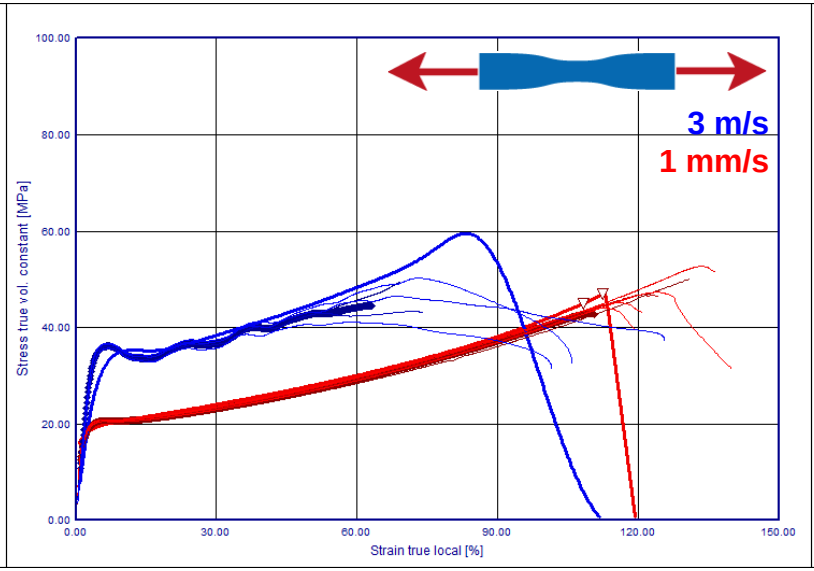
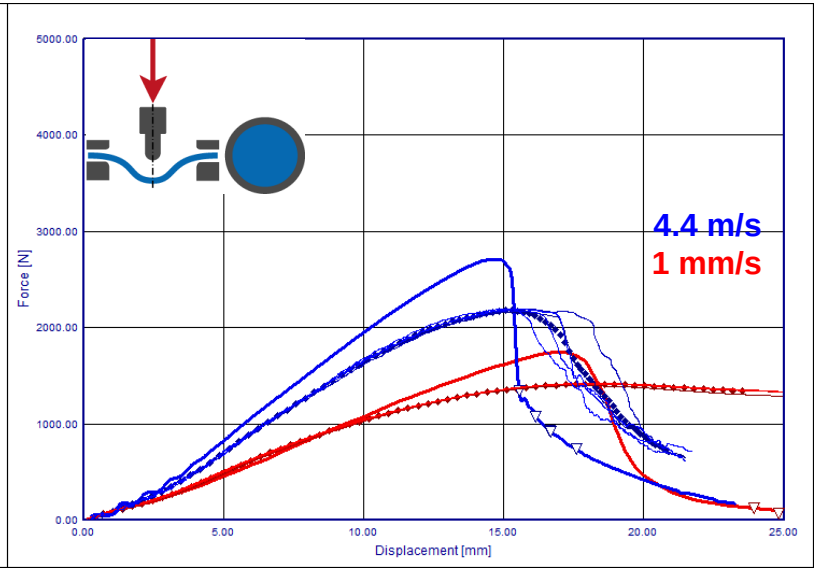
Failure Fit Results

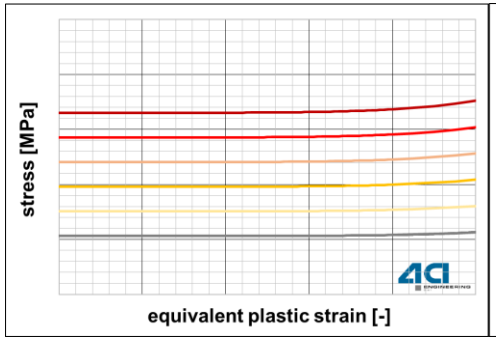
*MAT_187L + DIEM – Max. equivalent plastic strain Evaluation



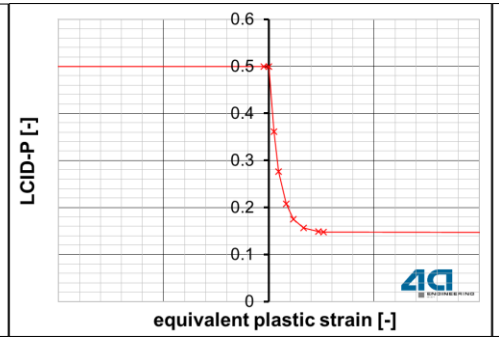




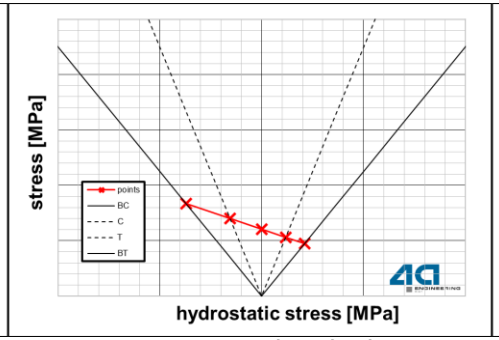
hardening



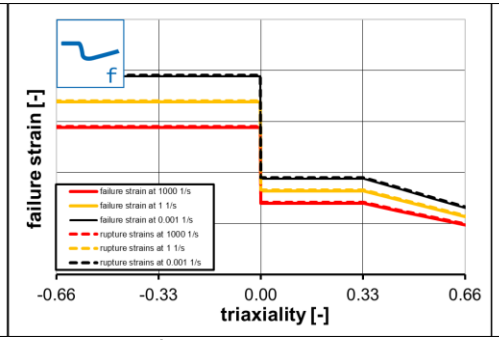
flow rule

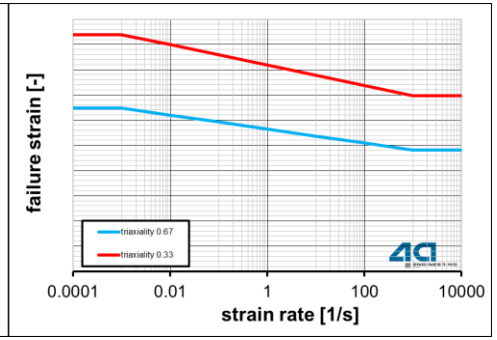


yield surface



failure





♦♦♦ Mean value curve of measurements — simulation results

(— single measurement curve)
▽ set failure time

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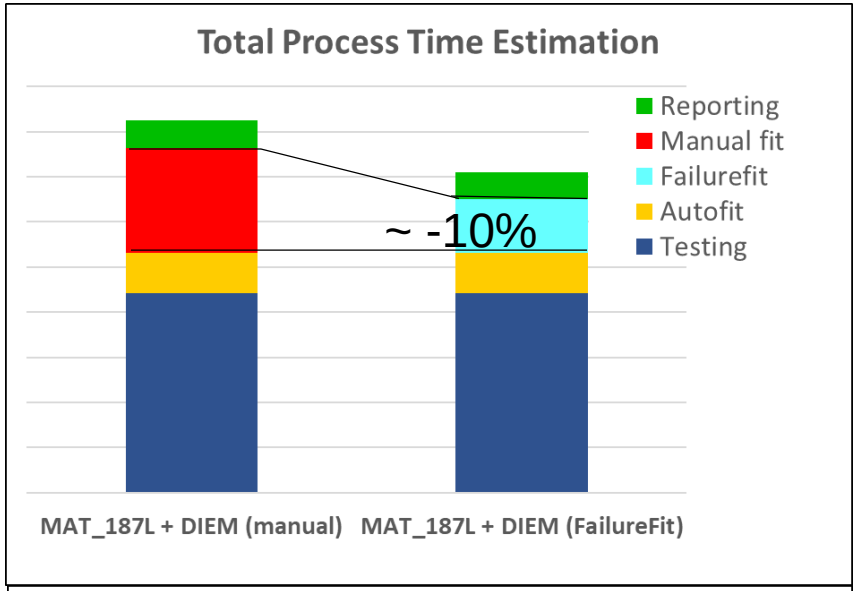
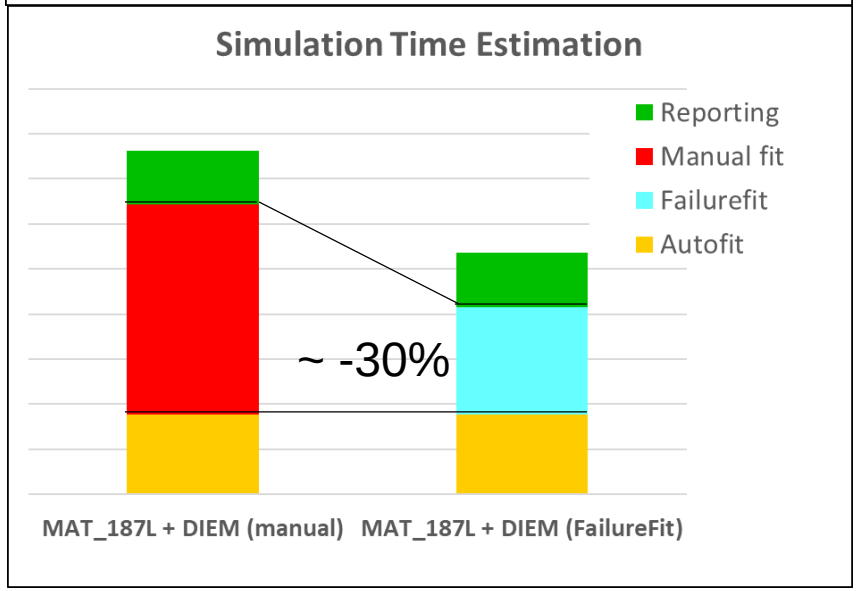
Summary/Conclusion

- Overview of material calibration process with VALIMAT
- Implementation of the Failure Fit in VALIMAT
  - gives reasonable results
  - reduces the total process time
- Provided an outlook for foam materials





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Summary/Conclusion

VALIMAT

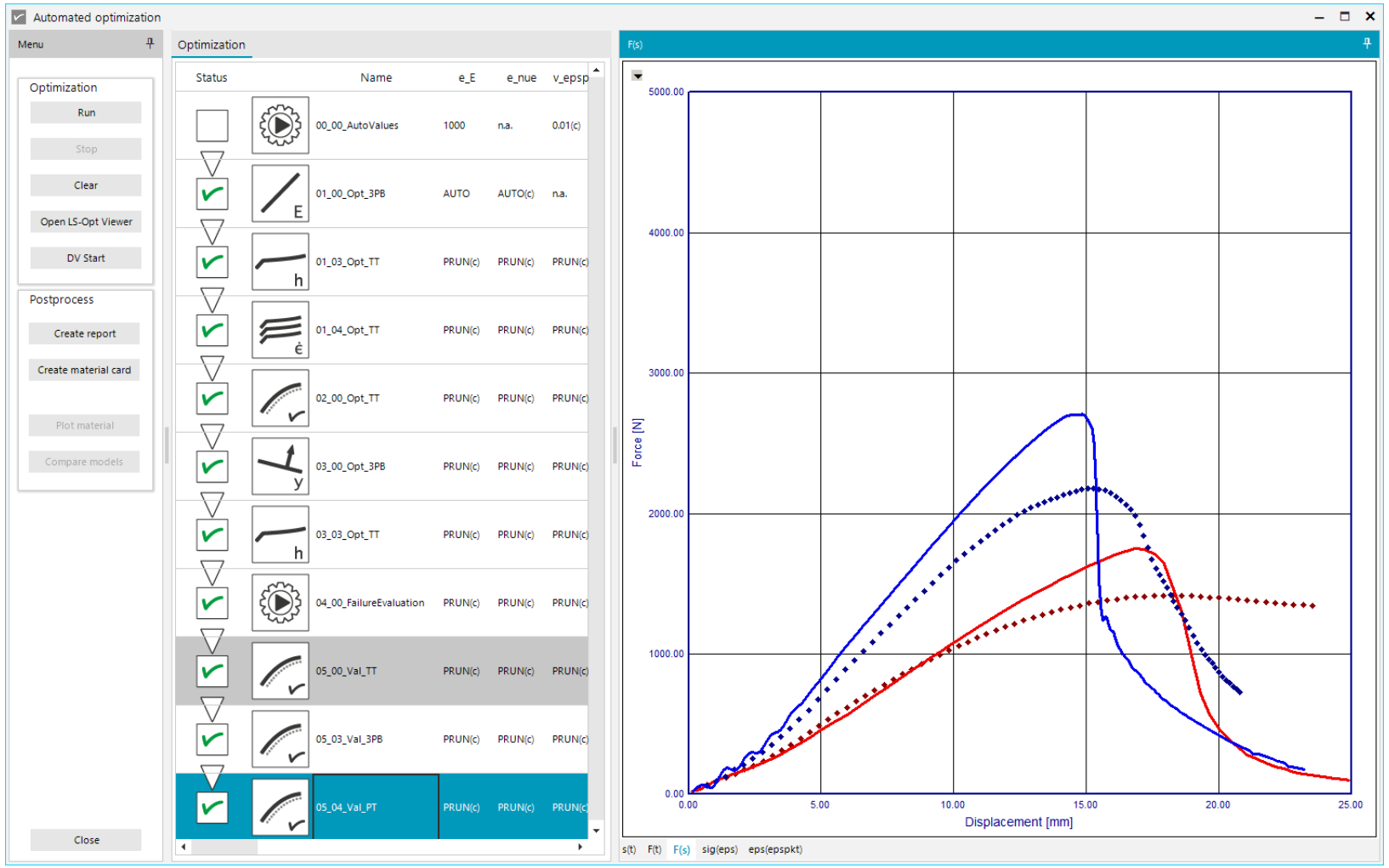
Standardized material characterization packages for your individual material class

isoP frP foam comP

https://www.4a-engineering.at/downloads/matpackages.pdf

Material Calibration increasingly automated with

AutoFit & Failure Fit



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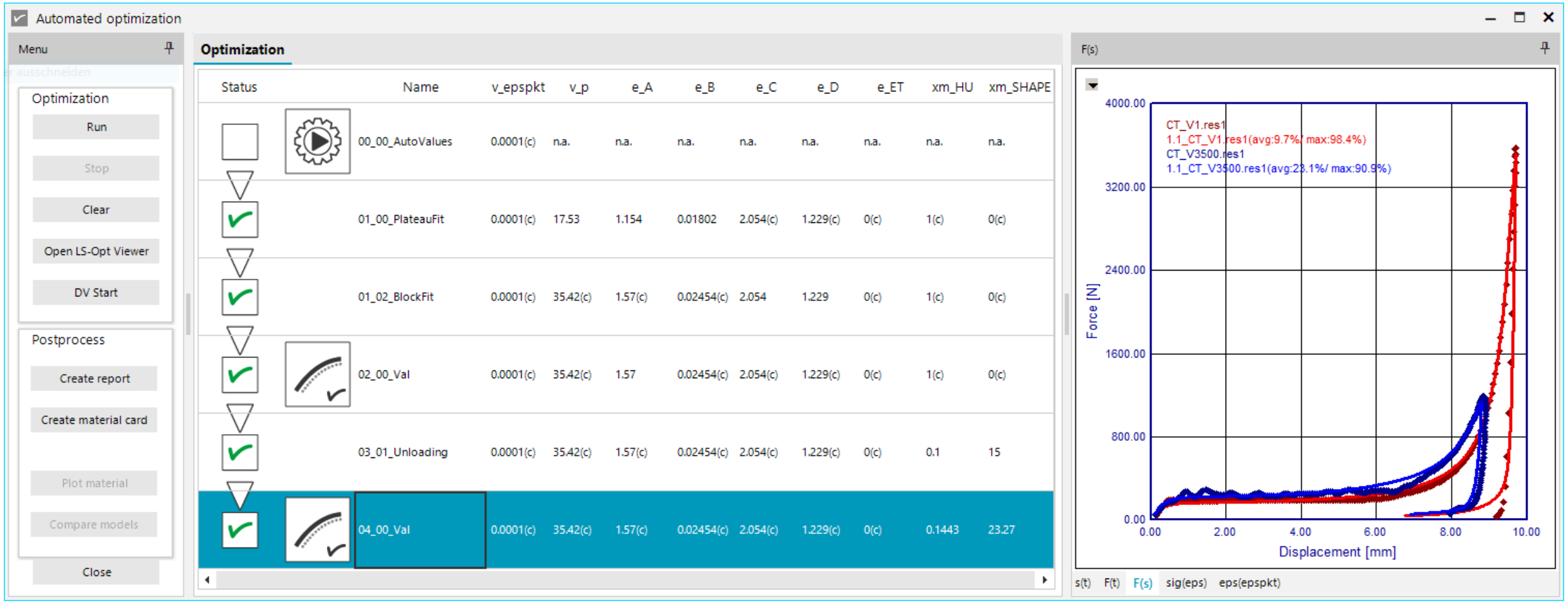
Outlook: AutoFit Foam

foam



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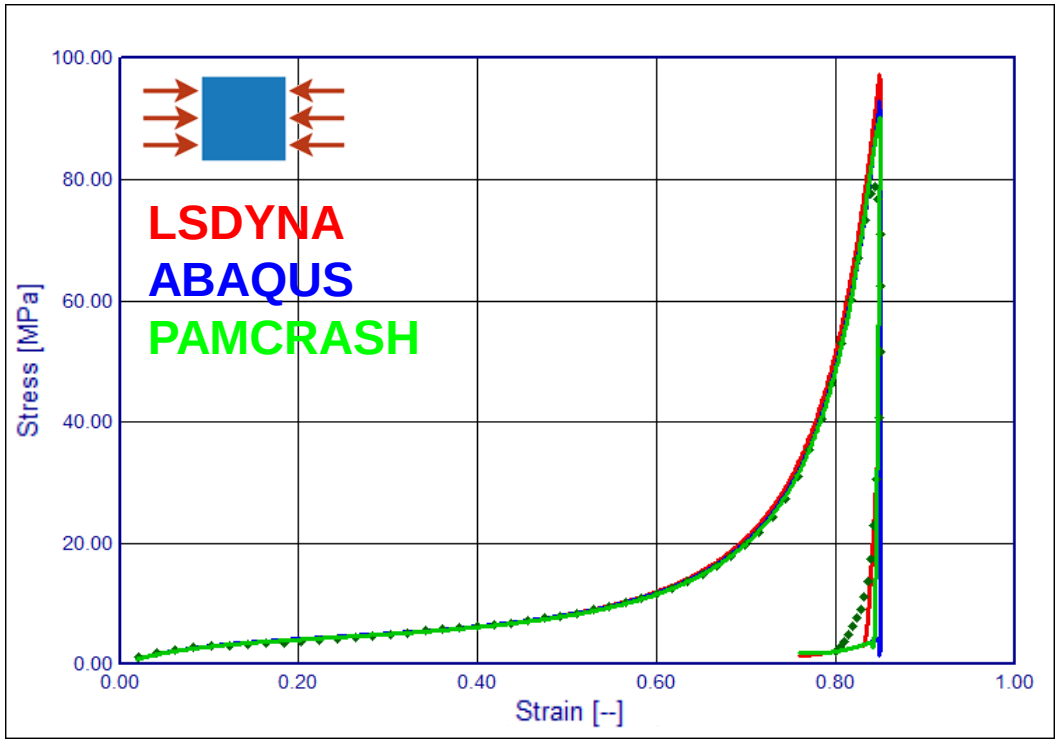
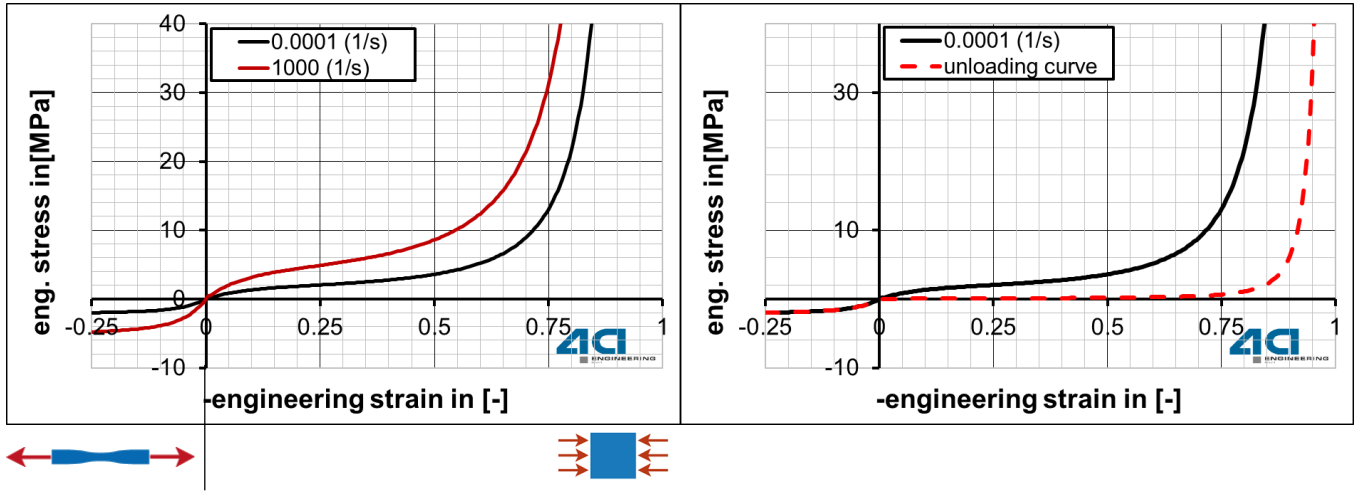
Outlook: Convertible Foam Models

foam

Foam model with compression, tension and unloading in the following solvers:

- LS-DYNA: *MAT_083
- PAMCRASH: MATER45
- ABAQUS: *LOW DENSITY FOAM





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