Automated material model generation in VALIMAT AUTOFIT & AUTOFAILUREFIT

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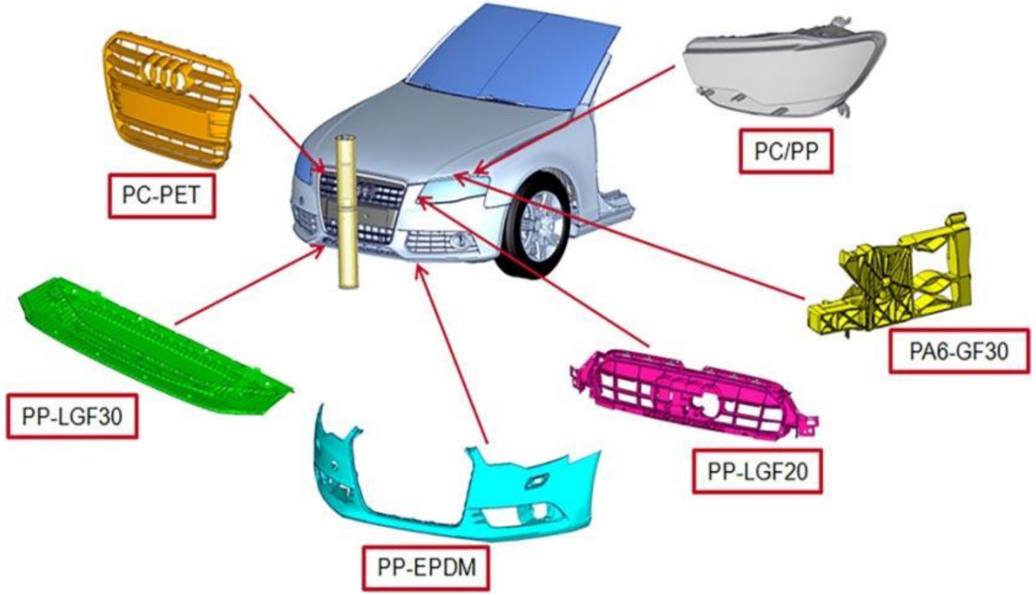
- Introduction / Motivation
- Isotropic Thermoplastics – isoP pro
  - Material Calibration Process
  - Material Models For Plastics
  - Failure Models
  - Failure Fit Implementation
  - Failure Fit Results
- Conclusion

Introduction / 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

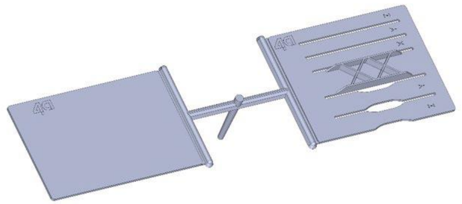
e.g. pedestrian safety



Source: https://technologietag.4a.at/images/tt2016/tt16_t1_v04.pdf

Material Calibration Process

Specimen Preparation



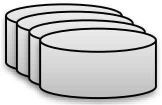
4a injection mold

Testing

Shimadzu AG-X

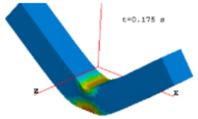
IMPETUS

Modelling



Data

VALIMAT

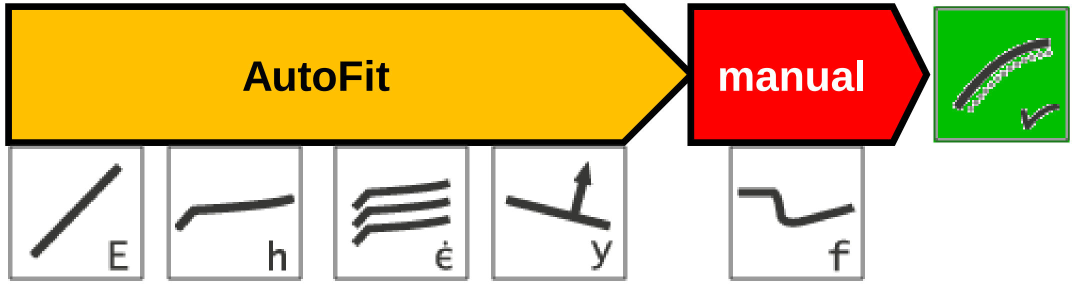


FEM

LS-OPT

Optimization

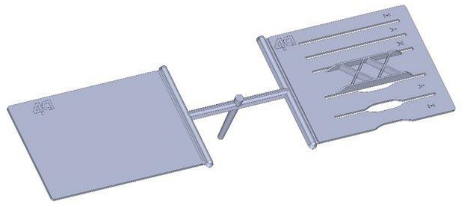
parameterized Material Model



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

Material Calibration Process

Specimen Preparation



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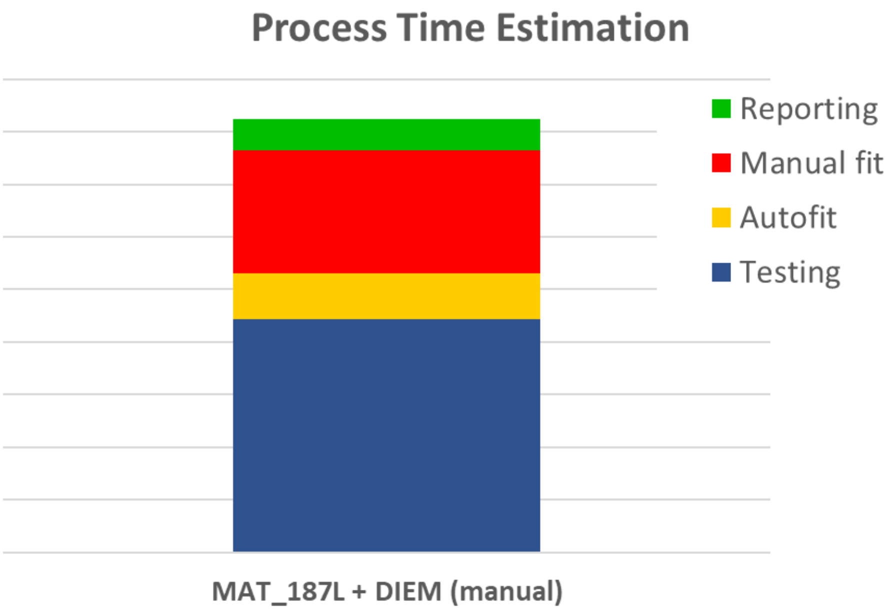
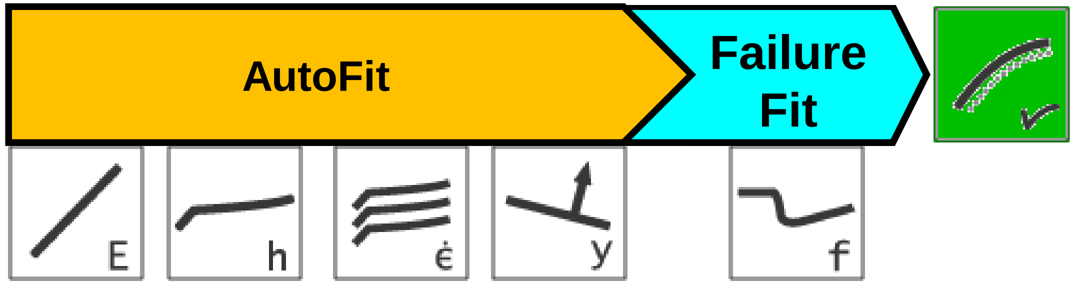
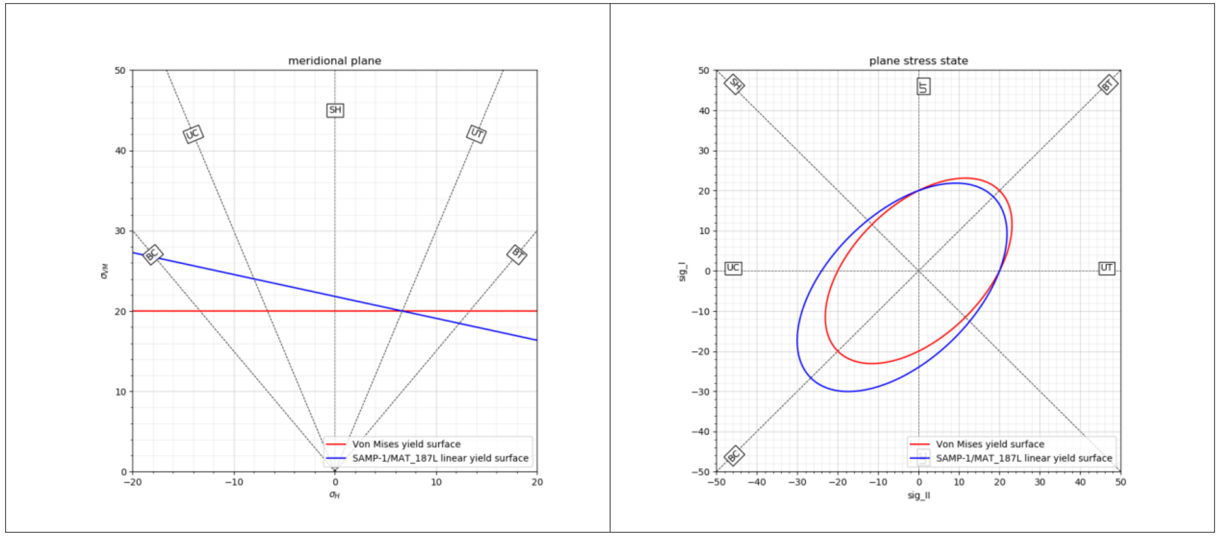




https://www.4a-engineering.at/downloads/testpackages.pdf

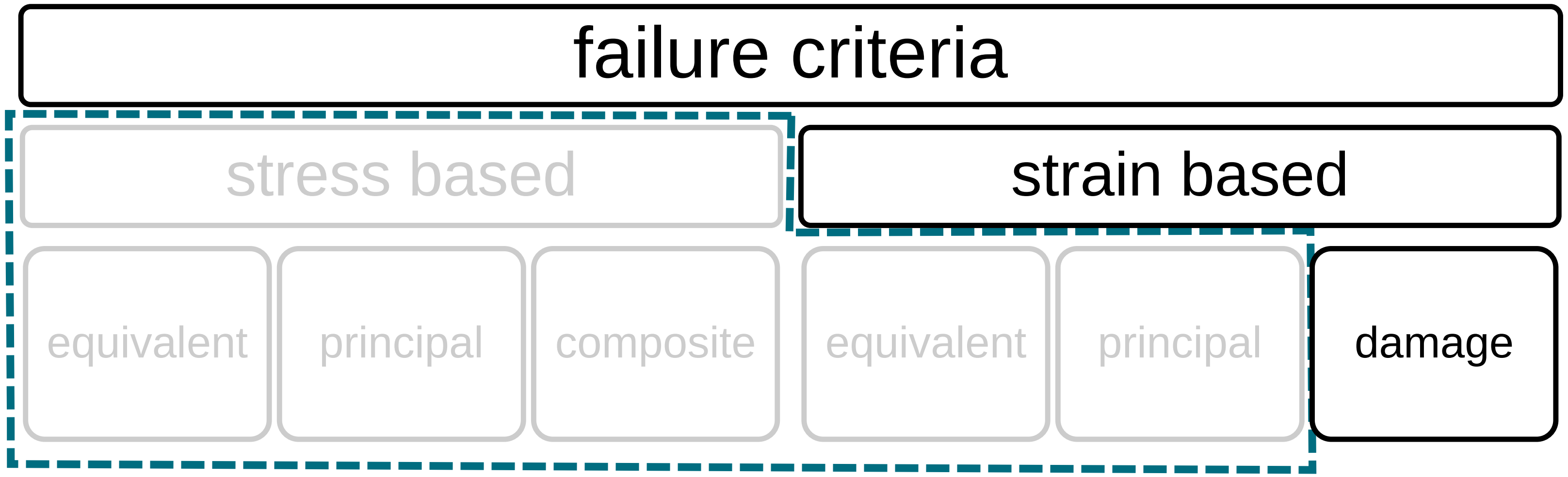
Commonly Used Material Models For Plastics in LS-DYNA®

- ***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	✓ $E(\dot{\varepsilon})$	✓	✓	✓ $\nu_p(\varepsilon)$

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***

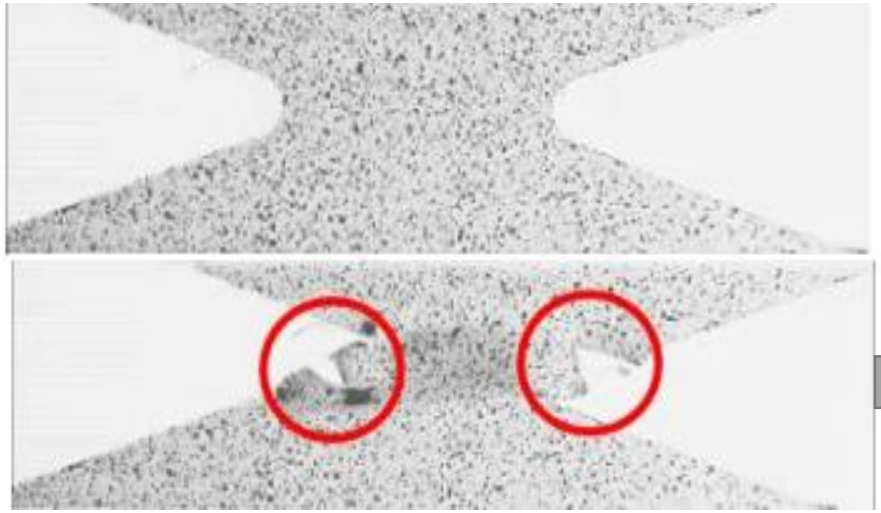
Included eq. pl. strain

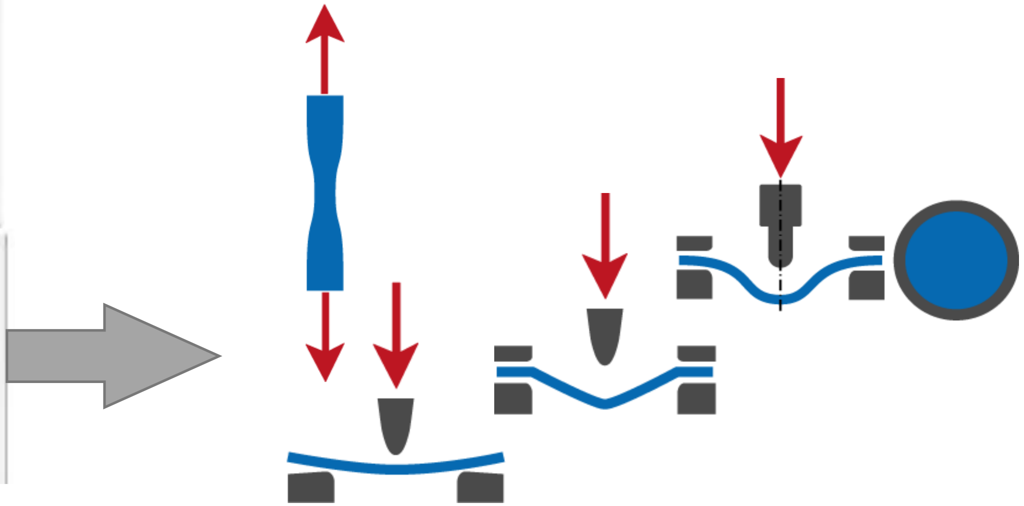
****MAT_024***

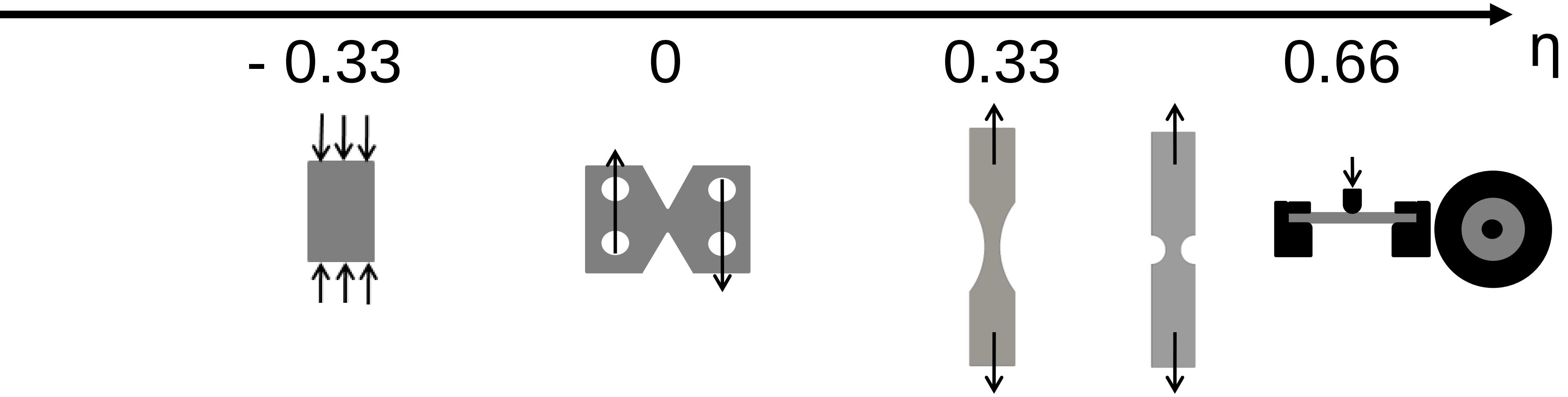
included damage model in

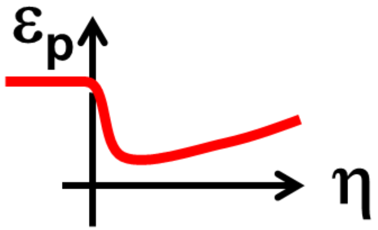
****MAT_SAMP-1(GISSMO like)***

from test to material card





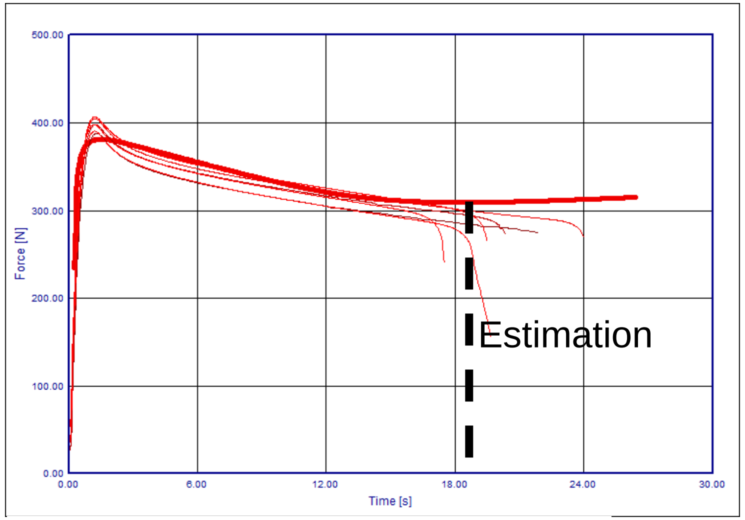




Damage/Failure

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

Data Extraction

Element Histories

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

Evaluation Times

$t_{fail},\ W_p,\ s_{max}$

Failure Model Evaluation

Failure Target Points

Failure Modell

Fitting

Failure Fit Implementation

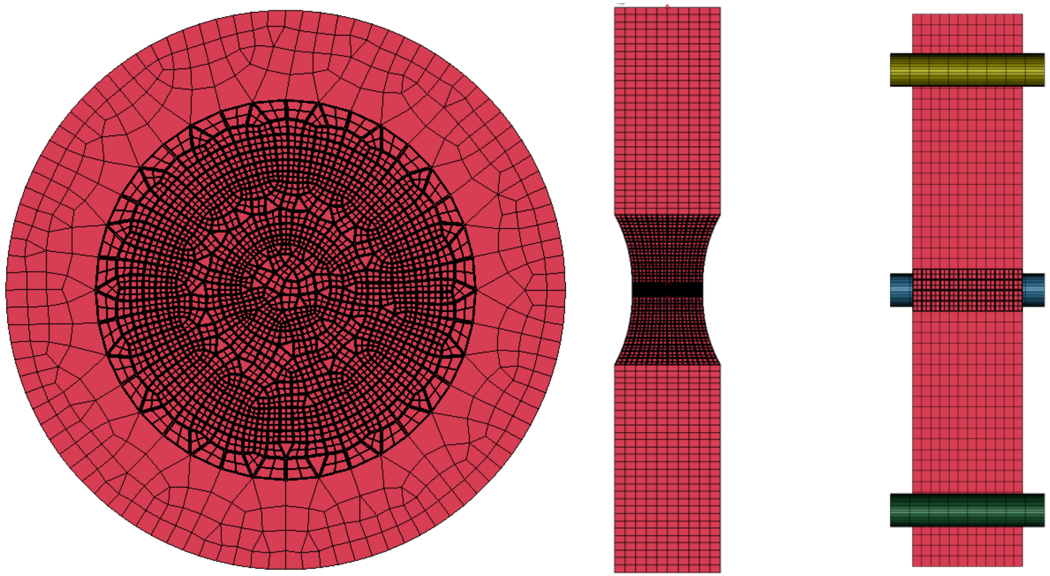
Data Extraction – Element Histories

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

Element Histories

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

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



Additional element history sets for data extraction

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*

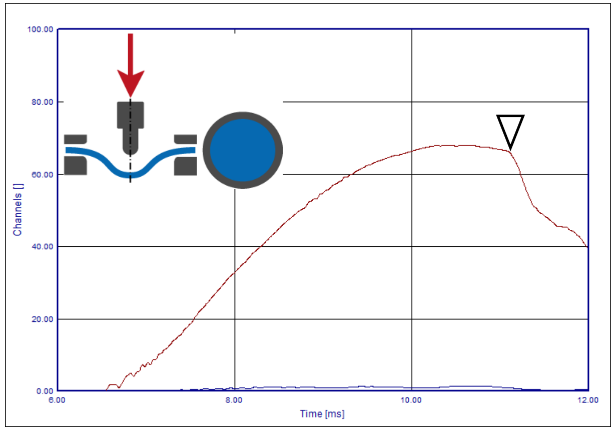
Failure Fit Implementation

Evaluation Times

Decide when 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



Evaluation Times

t_{fail}, W_p, s_{max}

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

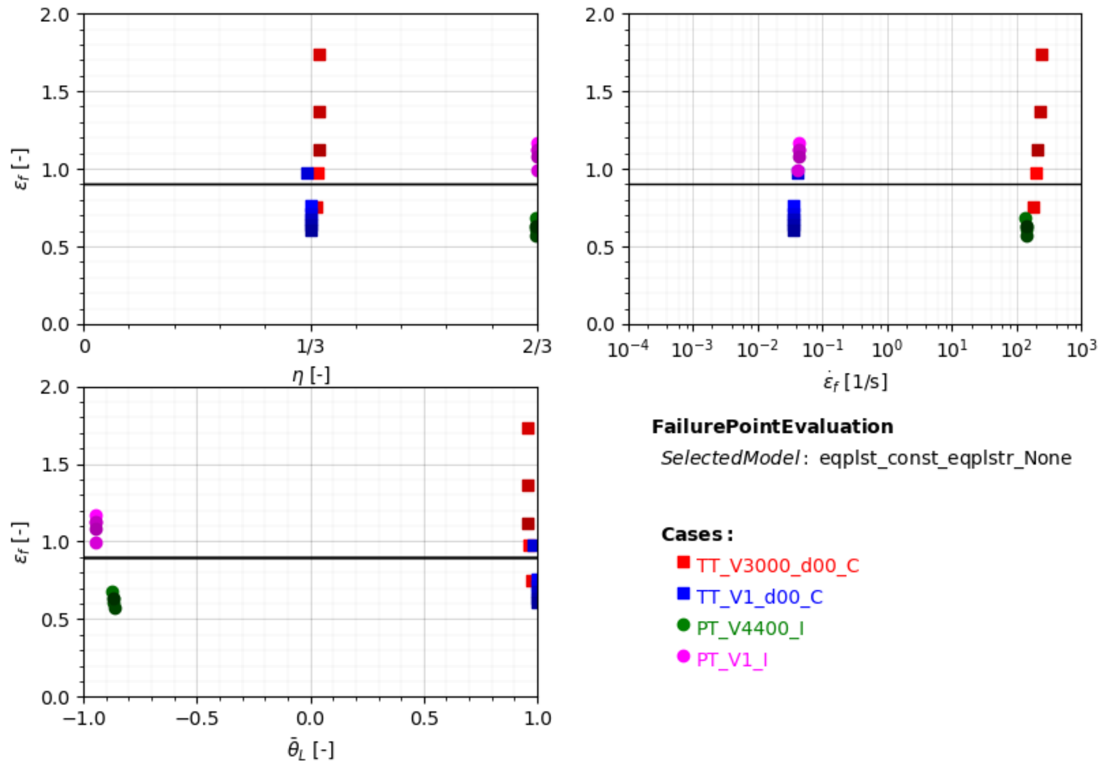
Failure Fit Implementation

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

$\varepsilon_f(\varepsilon_p)$



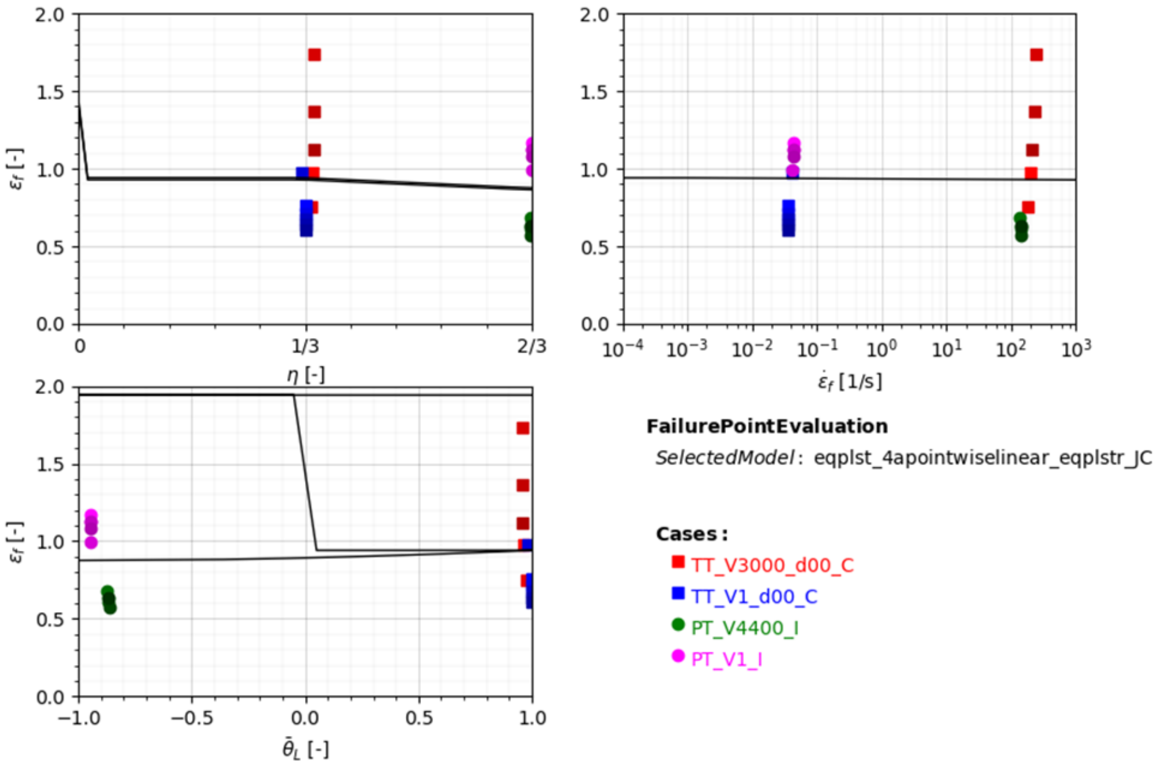
Failure Fit Implementation

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

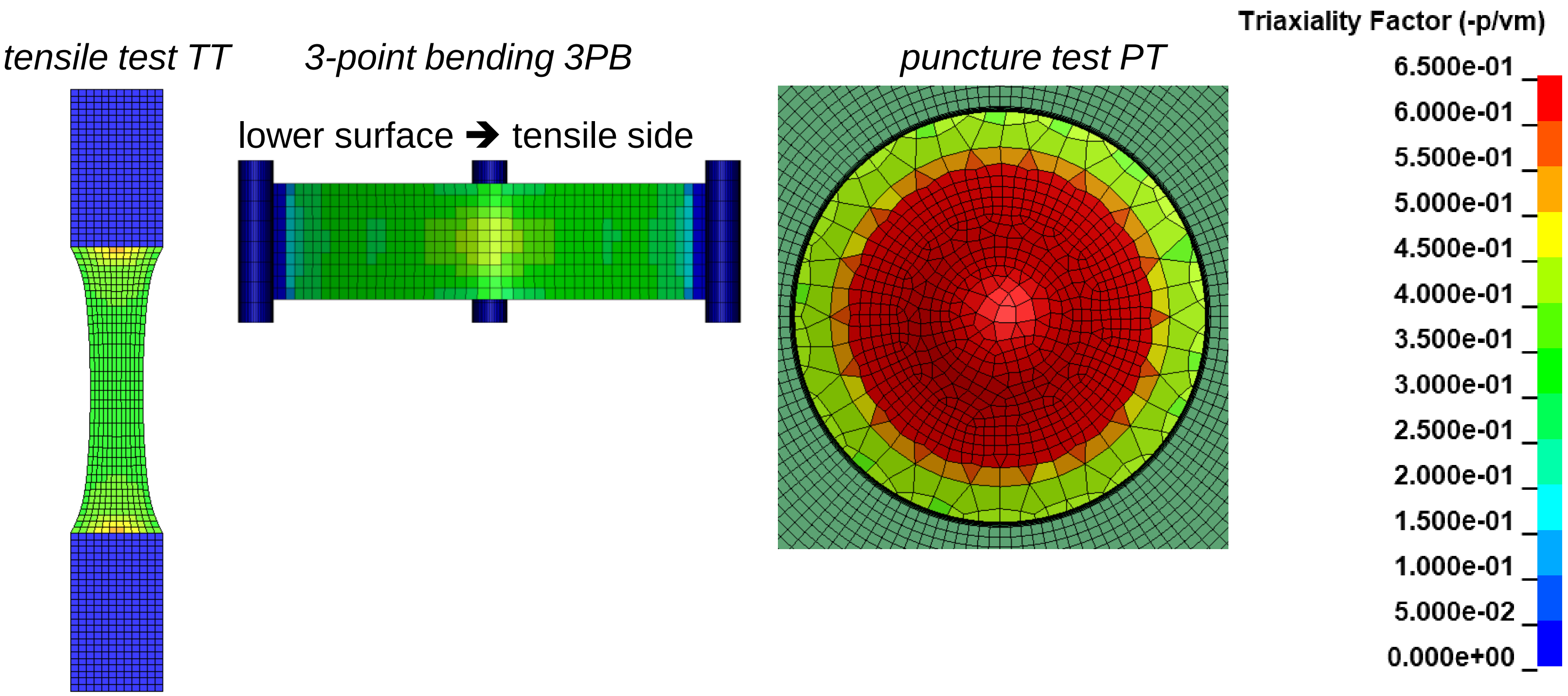
$$\varepsilon_f(\varepsilon_p, \dot{\varepsilon}_p, \eta, \theta_{Lode})$$



Failure Fit Implementation

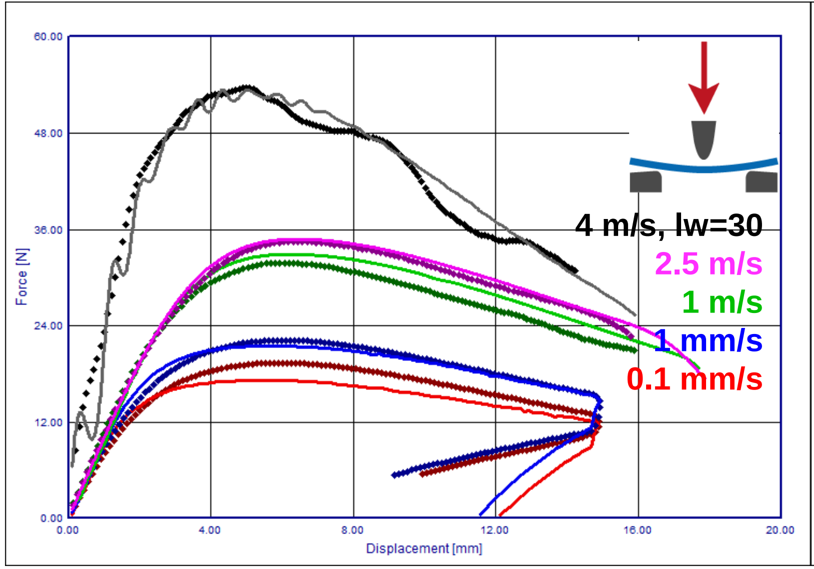
Failure Model Evaluation – Max. equivalent plastic strain Evaluation

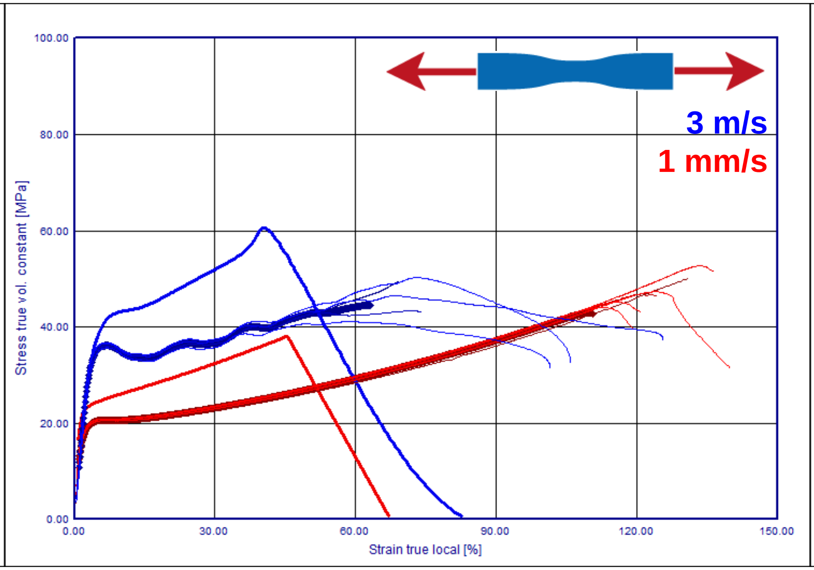
- For the chosen load cases the stress states in the area of interest is similar
- For future developments
  - groupings in triaxiality buckets

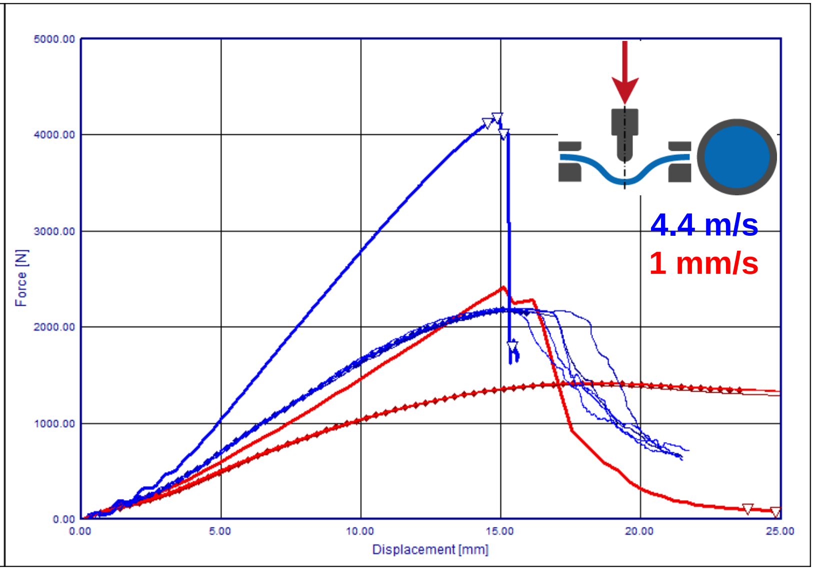


Failure Fit Results

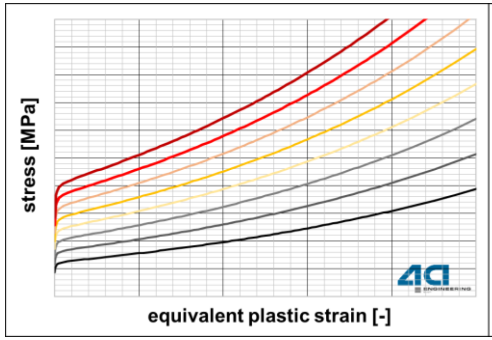
*MAT_024 + MXEPS – Simple Evaluation



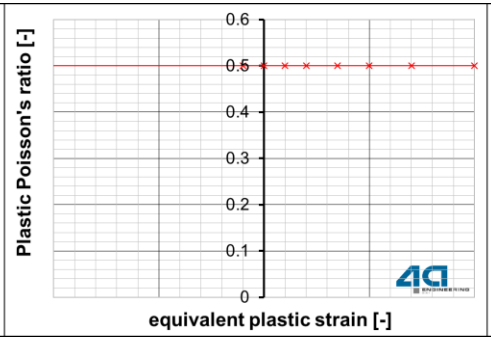




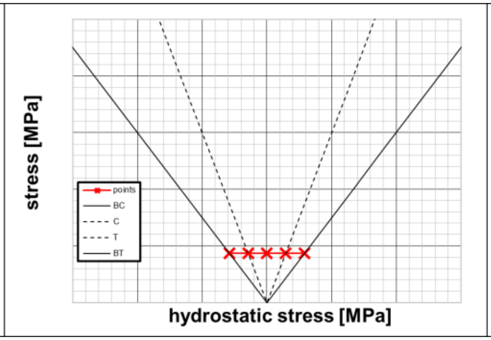
hardening



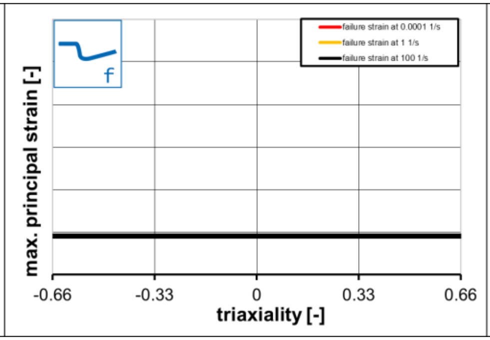
flow rule

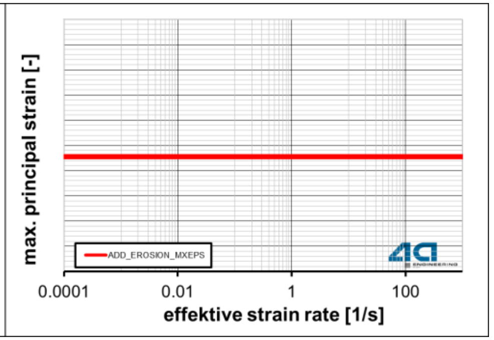


yield surface



failure

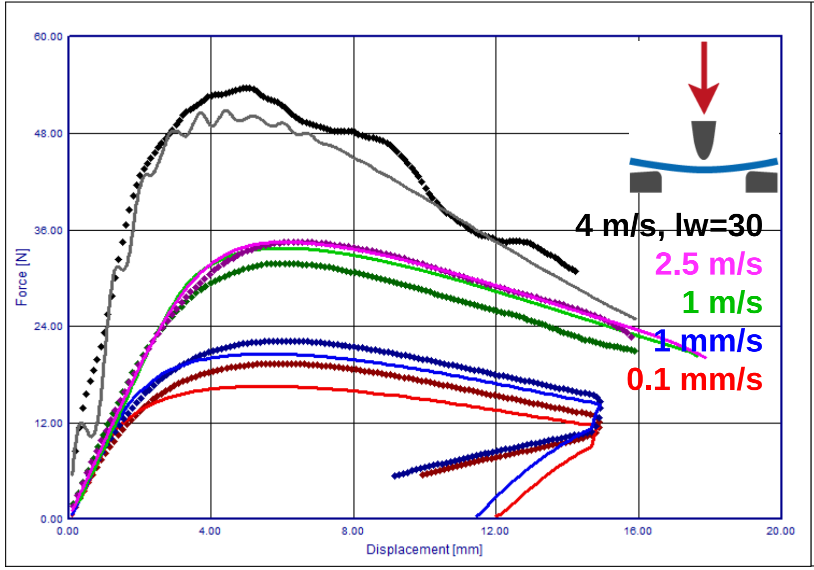


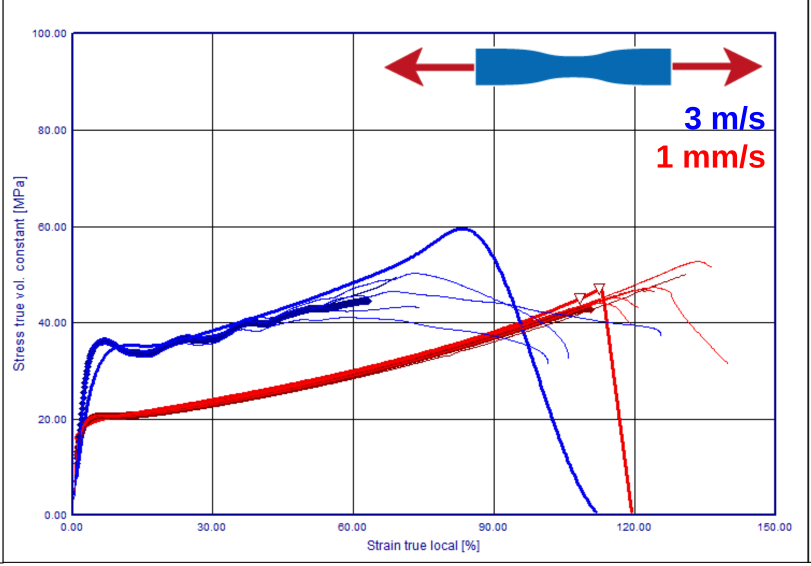


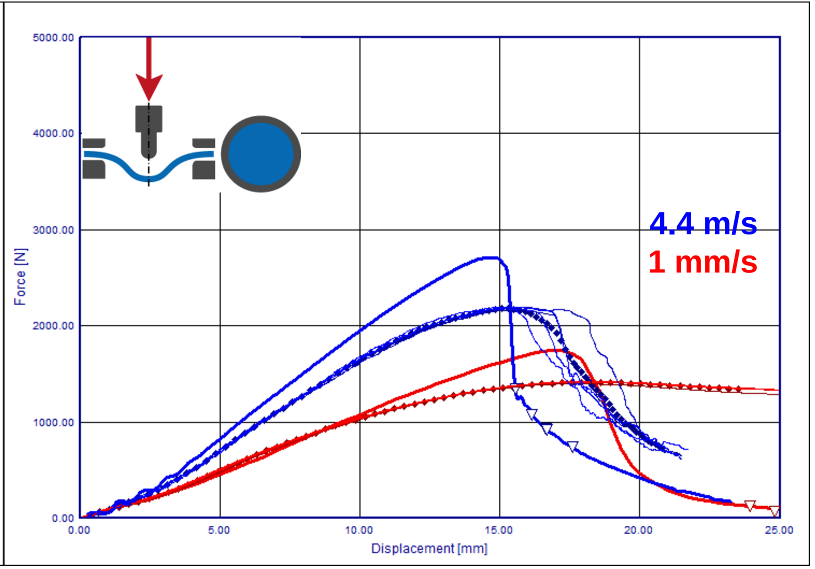
♦♦♦ Mean value curve of measurements — simulation results (— single measurement curve)
▽ set failure time

Failure Fit Results

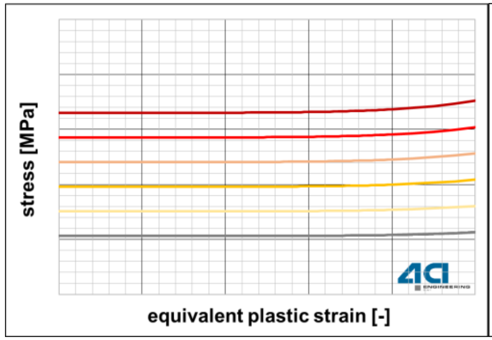
*MAT_187L + DIEM – Max. equivalent plastic strain Evaluation



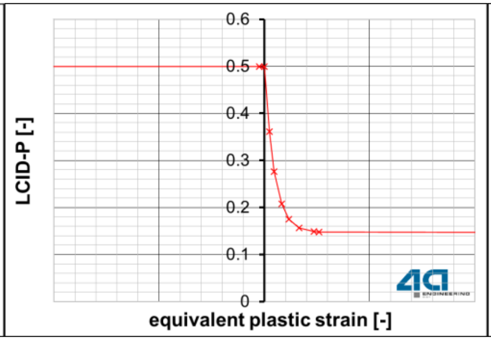




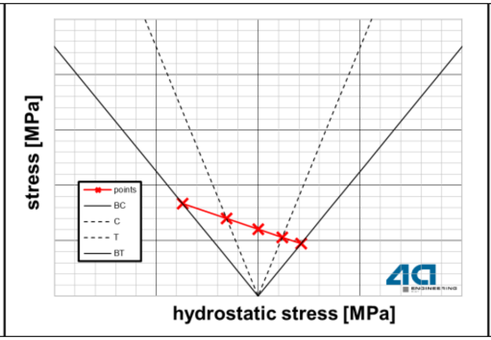
hardening



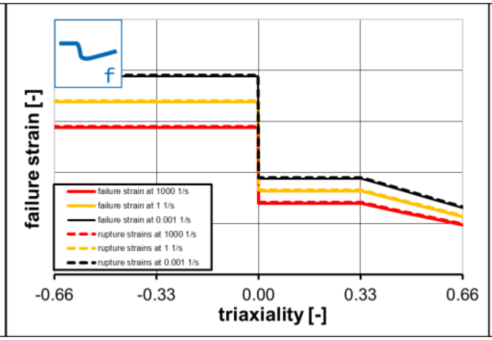
flow rule

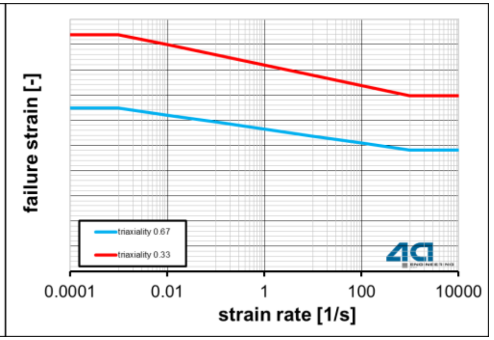


yield surface



failure

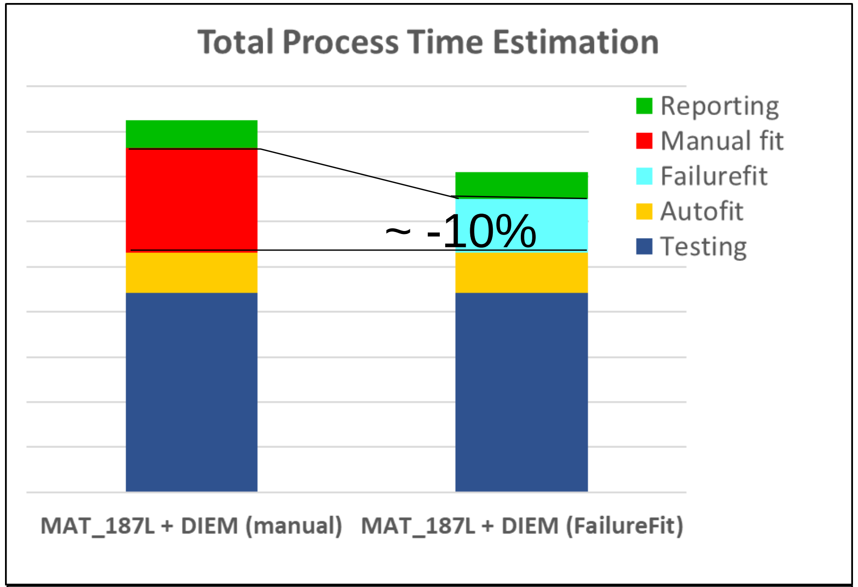


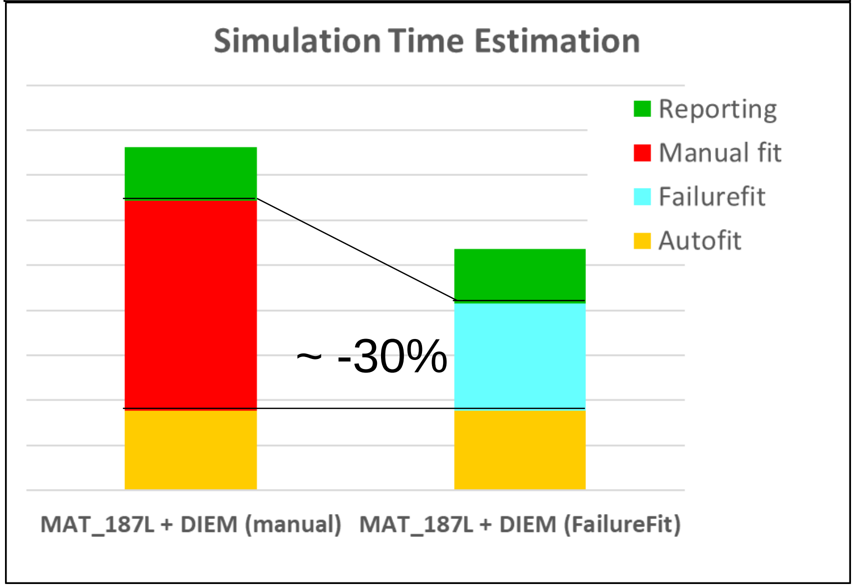


♦♦♦ Mean value curve of measurements — simulation results (— single measurement curve)
▽ set failure time

Summary/Conclusion

- Overview of material calibration process with VALIMAT
- Implementation of the Failure Fit in VALIMAT
  - gives reasonable results
  - reduces the total process time





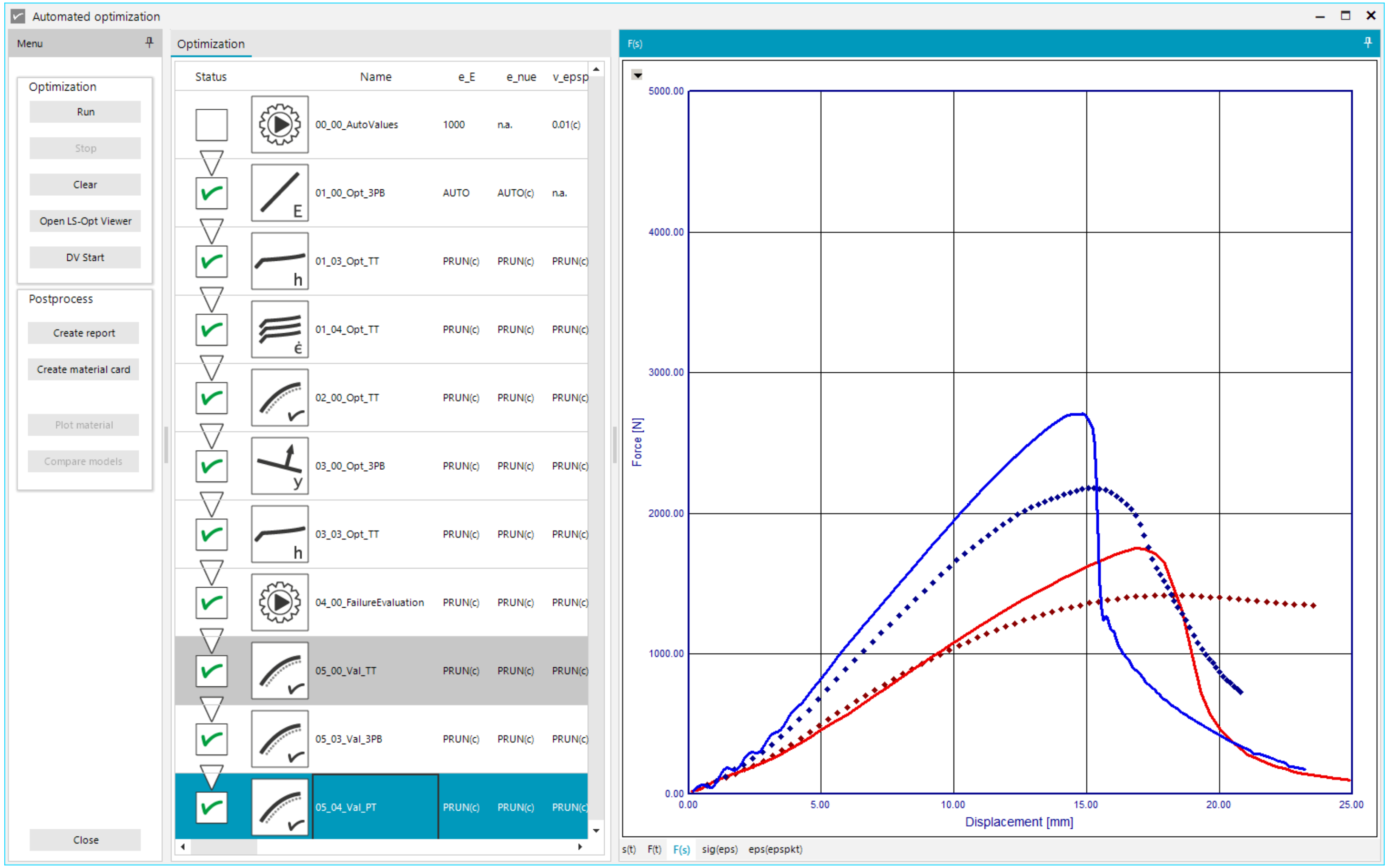
Summary/Conclusion

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

Thank you for your Attention!

VALIMAT

IMPETUS