FFC – Full-field Calibration

Material characterization by consideration of the optically measured strain field

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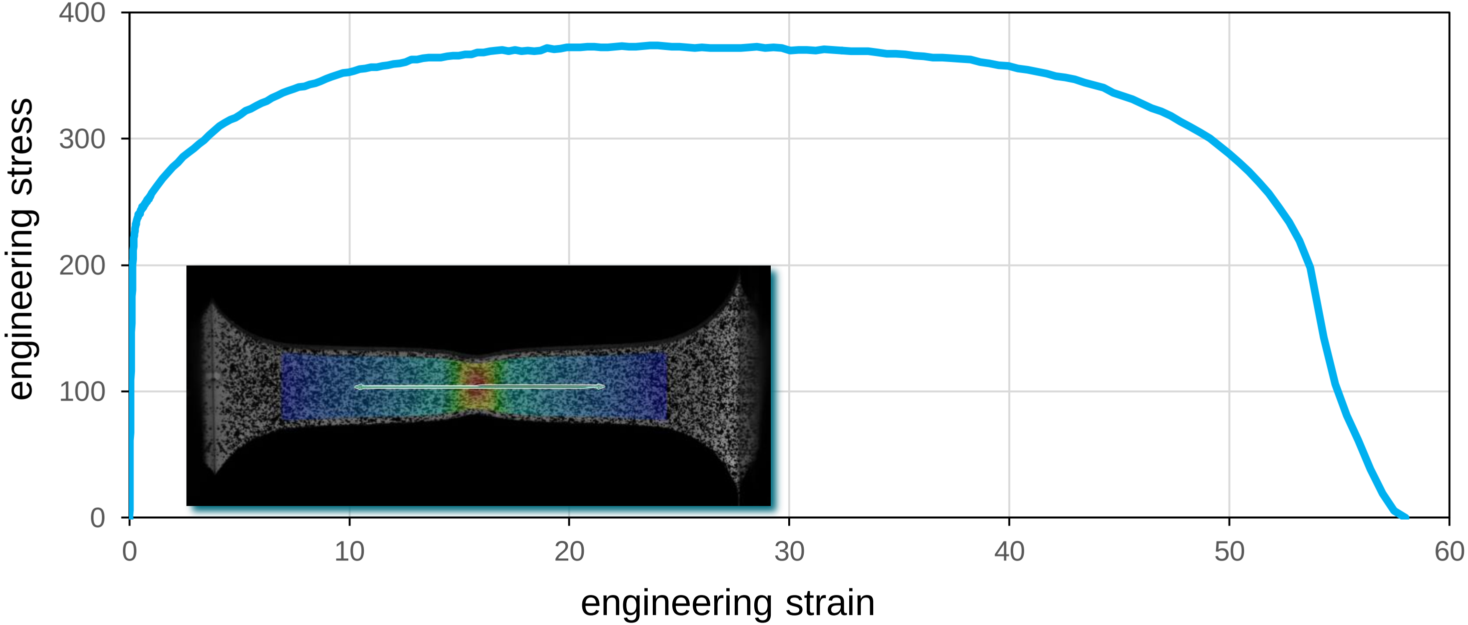
Contents

Motivation

- Classical scheme of characterizing the yield behavior of a material
  - Tensile test – info: engineering stress-strain curve for a specific reference length
  - Adaption of the material parameters via a reverse engineering strategy, where the test is simulated and the resulting stress strain curves were compared to the testing results.
  - Drawbacks:
    - The area with the highest strains, the localization area, is not considered explicitly

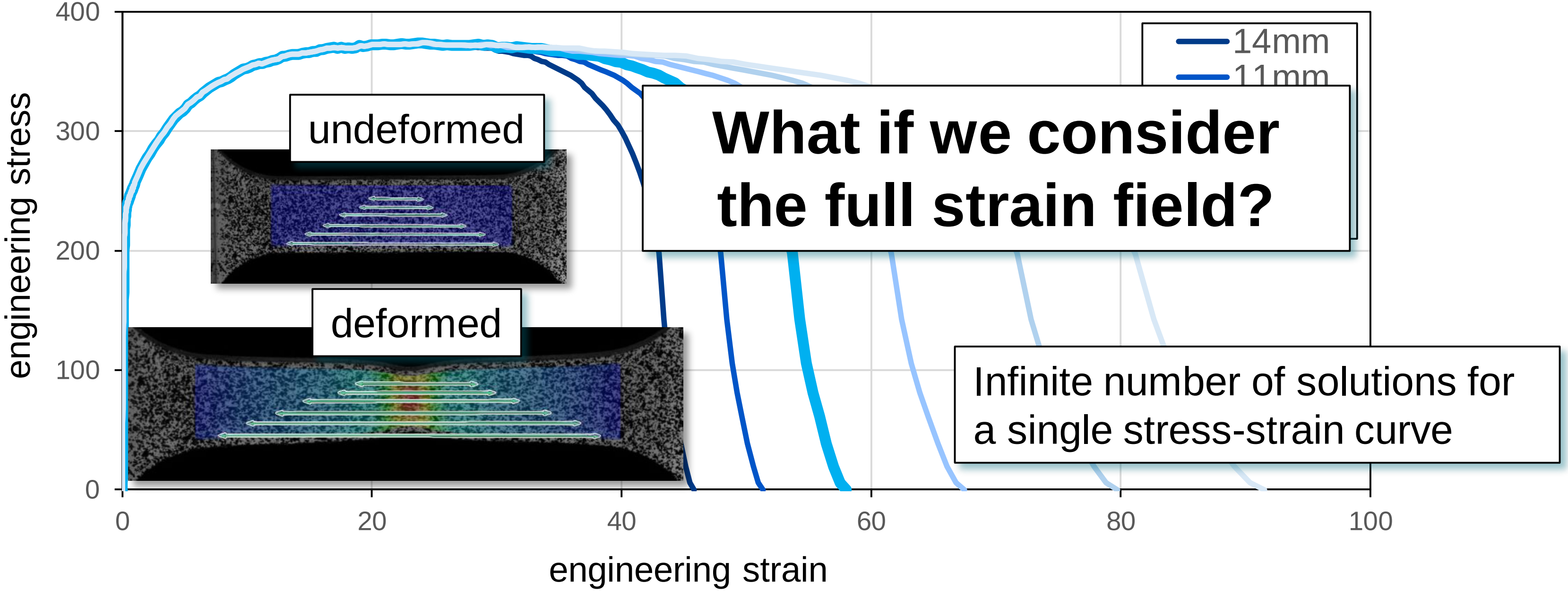
Motivation

- Traditional method for the evaluation of tensile tests
  - Engineering stress-strain curve with a predefined reference length (here: l_0 = 9 mm)



Motivation

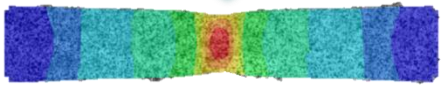
- Traditional method for the evaluation of tensile tests
  - Engineering stress-strain curve for different reference lengths



Motivation

Experiment

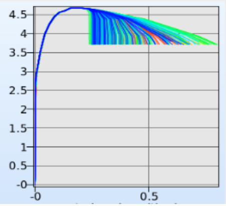
Measurement:
- Force
- Strain field



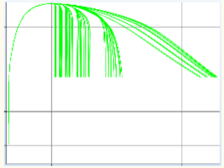
Measured strain field

Optimization

Input from experiment

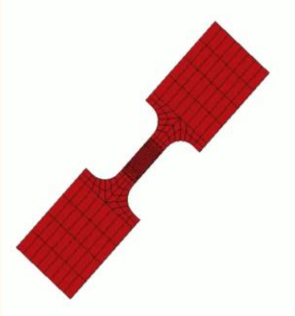


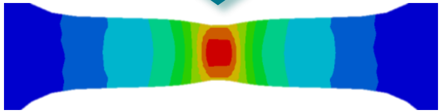
Input from simulation



Objective:
identical strain fields

Simulation

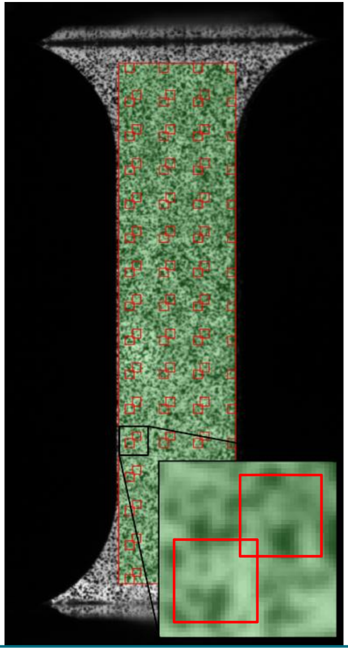




Optimized strain field

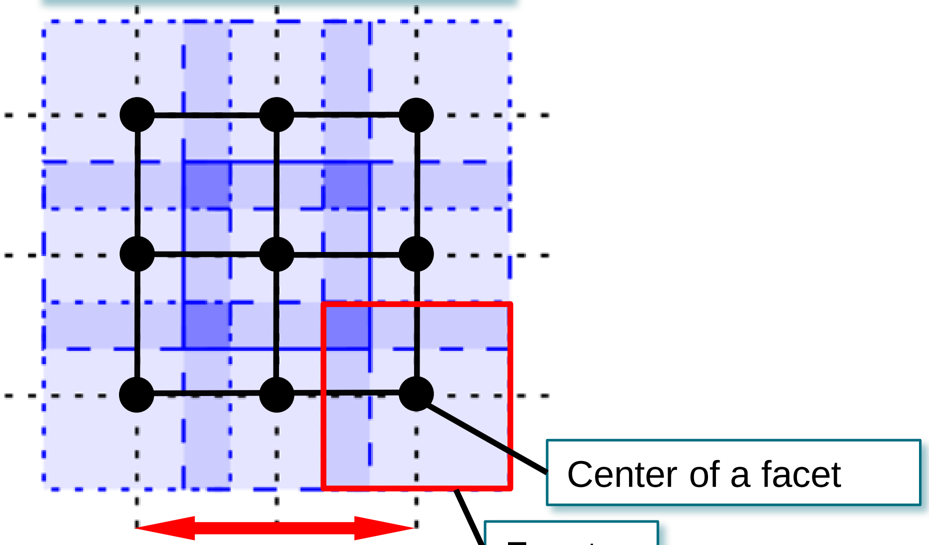
Preparations

- Evaluation of the optical measurement



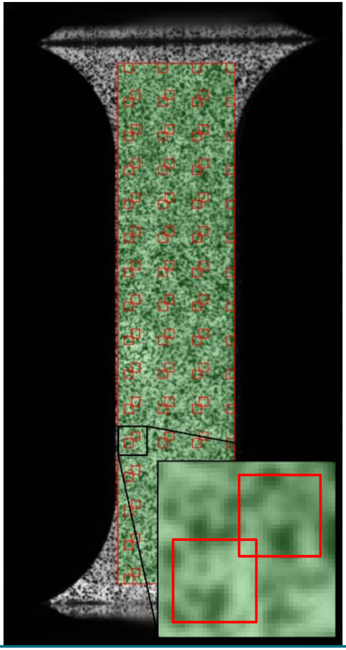
Visualization in ARAMIS

Schematic representation



Preparations

- Evaluation of the optical measurement



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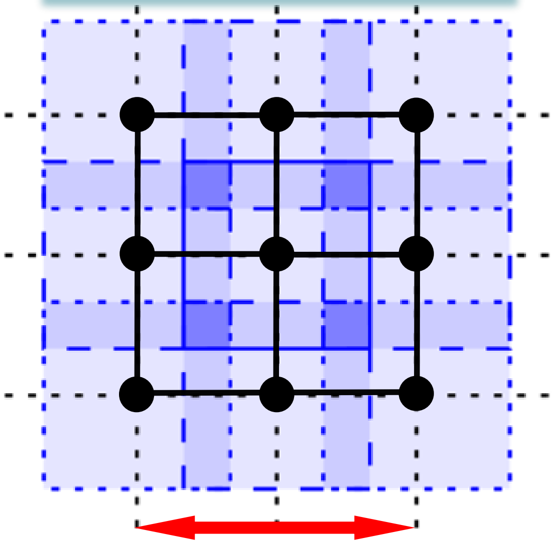
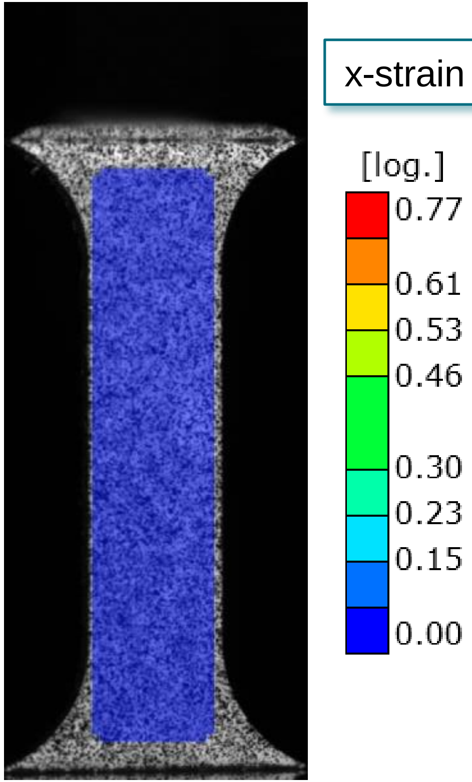


Reference length of
the strain calculation

x-strain

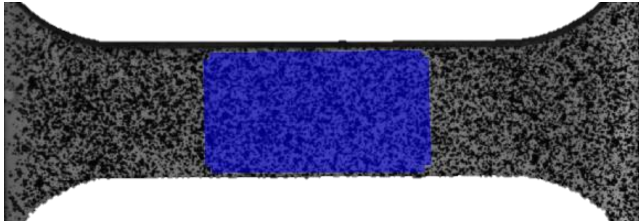


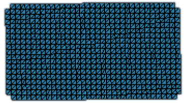
Preparations

- The simulation model

Evaluation area

Export as STL-file

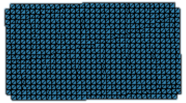




Preparations

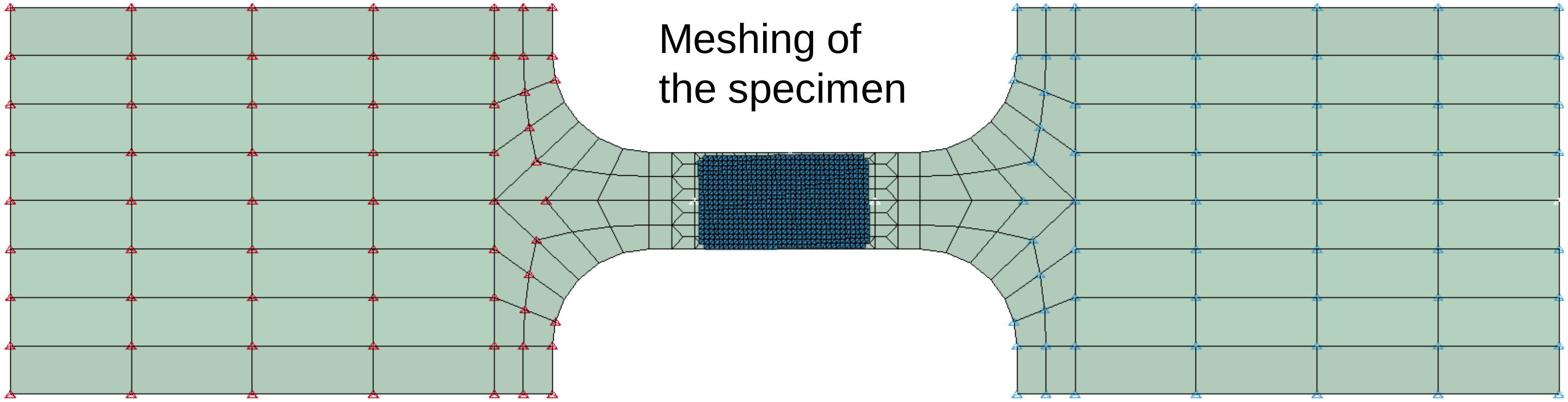
- The simulation model

Import in LS-PrePost



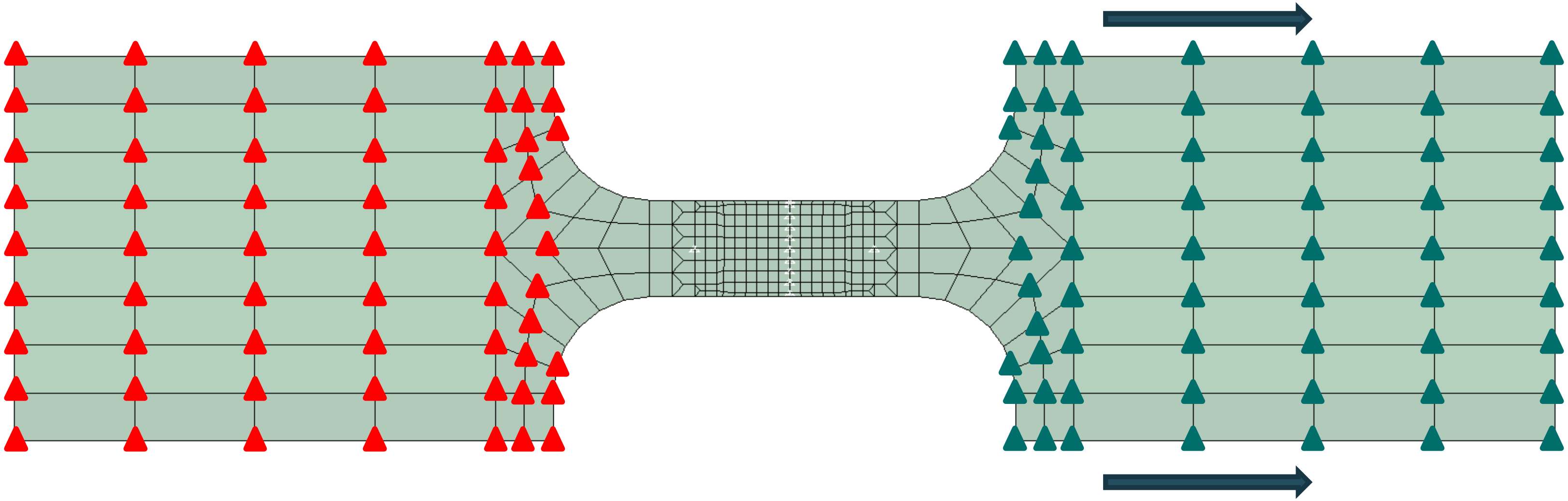
Preparations

- The simulation model



Preparations

- The simulation model



Boundary conditions:

No displacement (x,y,z)

No displacement (y,z) + displacement in x-direction

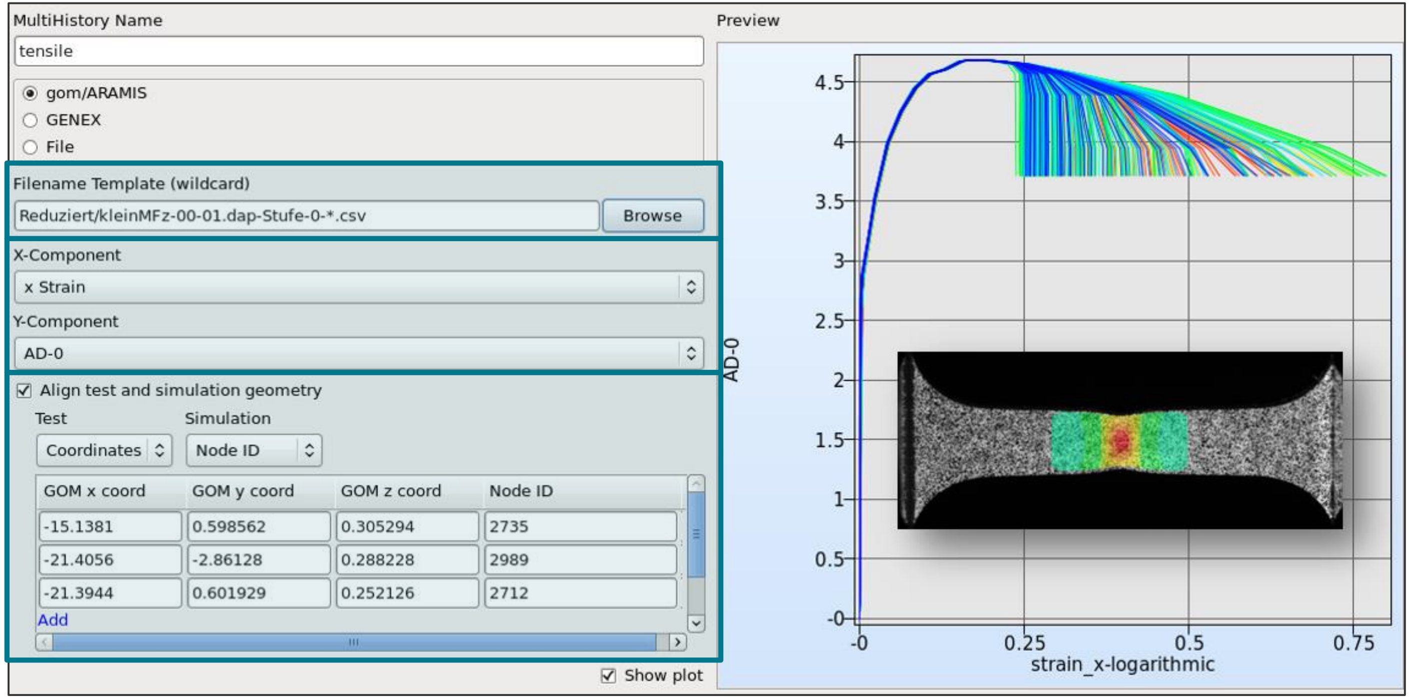
Implementation of FFC with LS-OPT

- New interface in LS-OPT

1. Insert load stages

2. Definition of axes

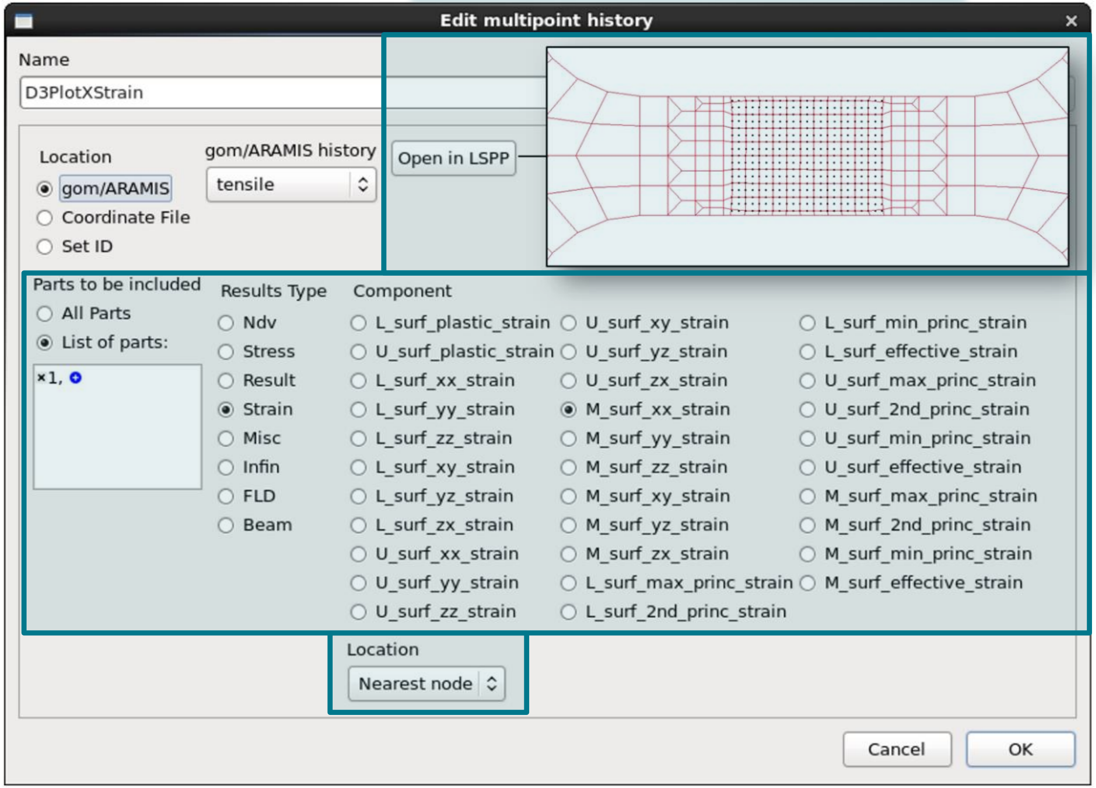
3. Alignment of simulation and experiment



Implementation of FFC with LS-OPT

- New interface in LS-OPT

Possibility to visualize the alignment in LS-PrePost



Selection of the variables from the simulation to be compared

Choose mapping method between test and simulation

Proof of concept

- Material: sheet metal
- Assumptions and choices for the simulation model:
  - Simple and fast material model: *MAT_024 (*MAT_PIECEWISE_LINEAR_PLASTICITY)
  - Reducing the number of free parameters for the yield curve description to two
  - Damage and failure are not considered

Proof of concept

- Parametrization of the yield curve

Direct *calculation* of the yield curve until A_g

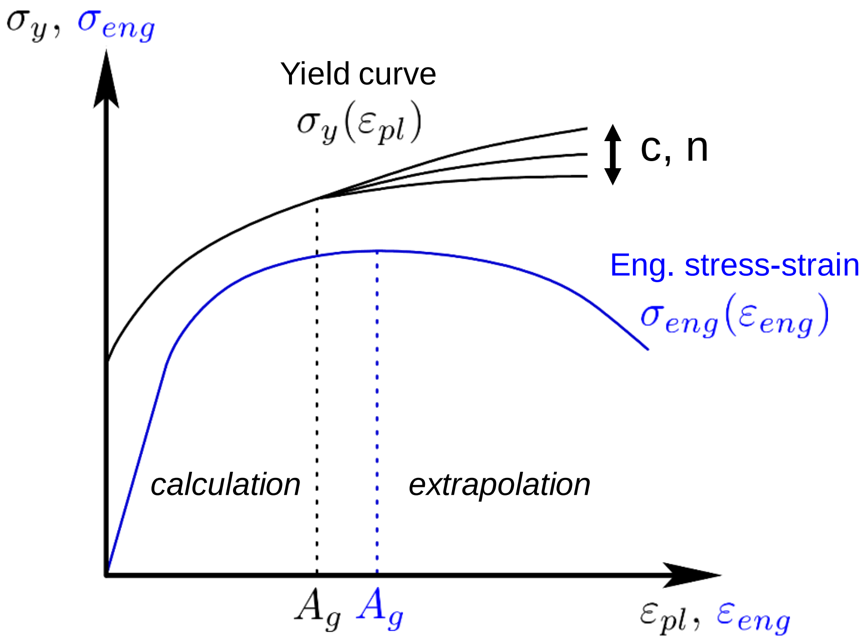
$$\begin{aligned}\sigma_y &= \sigma_{eng}(1+\varepsilon_{eng})\\ \varepsilon_{pl} &= \ln(1+\varepsilon_{eng}) - \frac{\sigma_{eng}}{E}\end{aligned}$$

Extrapolation from A_g with Hockett-Sherby

$$\sigma_y(\varepsilon_{pl}) = A - B\,e^{(-c\,\varepsilon_{pl}^n)}$$

C^1-continuity at A_g:

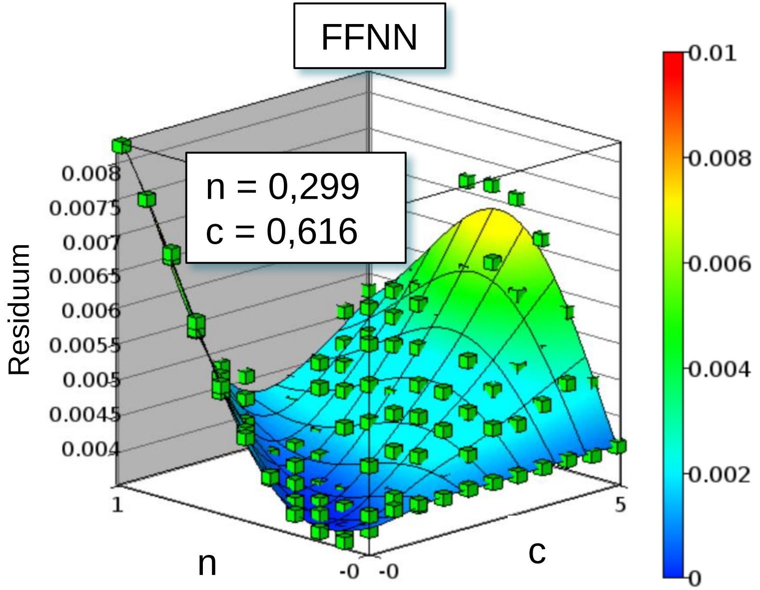
- ➢ Reduction of the function by two variables

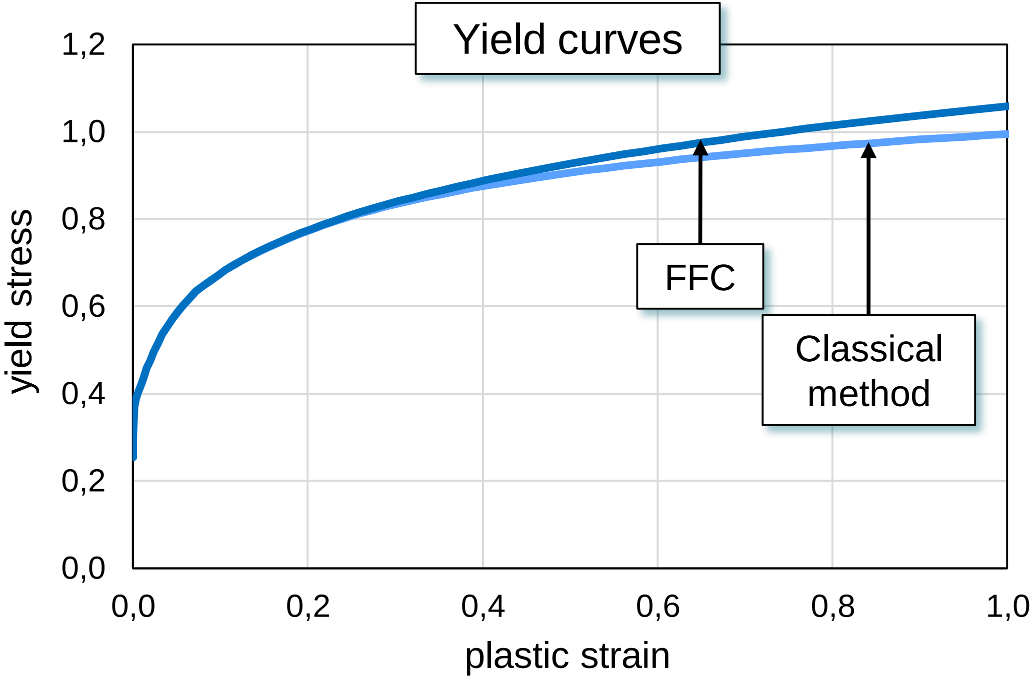


Remaining variables c and n are the optimization parameters

Results

- Optimization with feedforward neuronal network (FFNN)





Results

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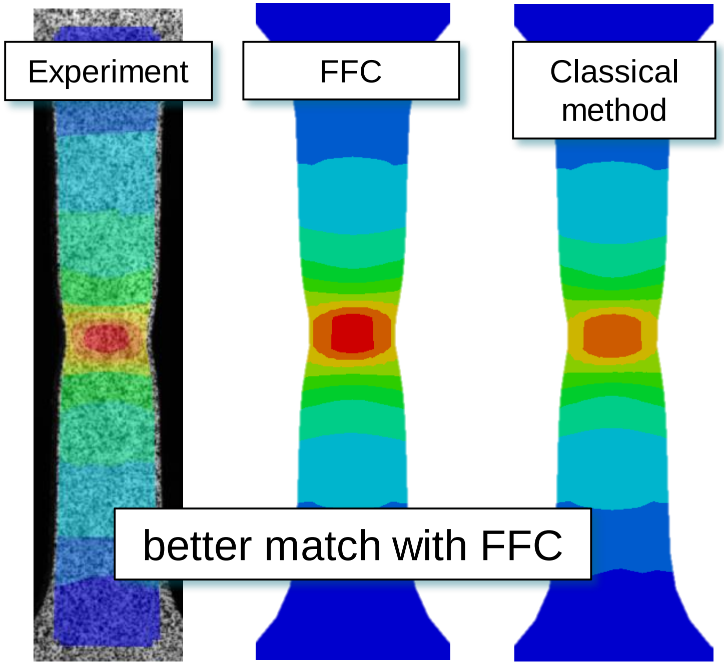

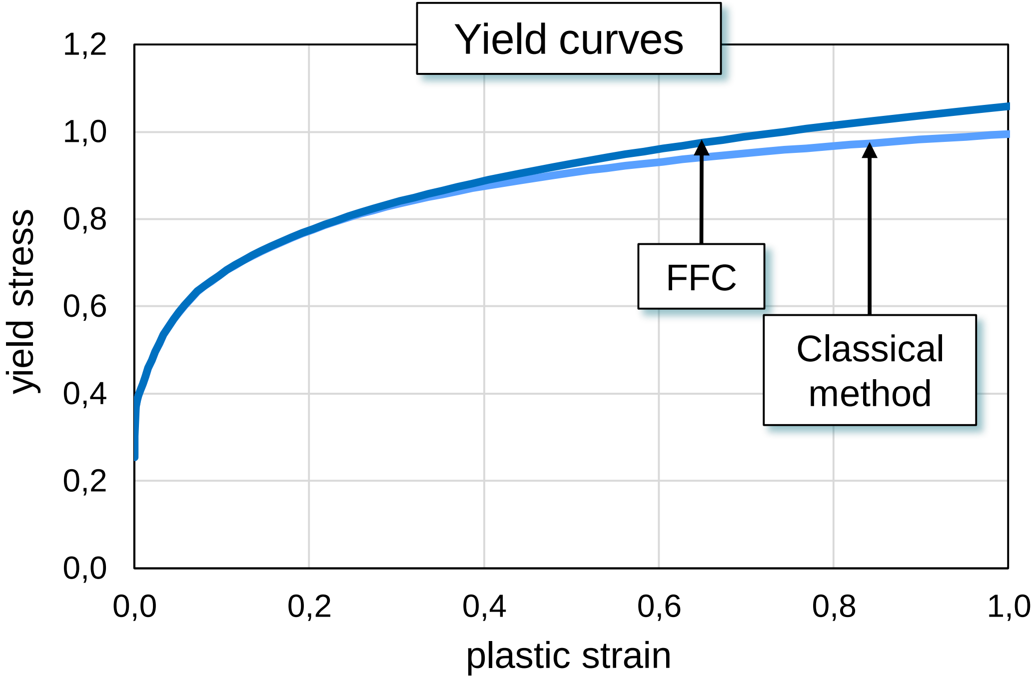

Summary & conclusions

- Description of the disadvantages of classical yield curve adaption
- The FFC-method was compared with the classical method
  - Simple material model (*MAT_024)
  - Anisotropic effects and the influence of the yield locus were ignored
  - Damage and failure were not considered
- Implementation of a new FFC interface in LS-OPT
- The FFC-method is capable of providing at least equivalent results

Outlook

- The multi-histories will be available in LS-OPT from the next release on
- Increasing the number of parameters to be optimized
  - More complex approach for yield curve extrapolation
  - Rolling direction
  - r-values (Lankford coefficients)
  - Yield locus
- Investigation of different, specimen geometries
- Future improvement of the LS-OPT interface
  - Visualizing the deviation between measurement and simulation

Experimental material characterization at DYNAmore Stuttgart

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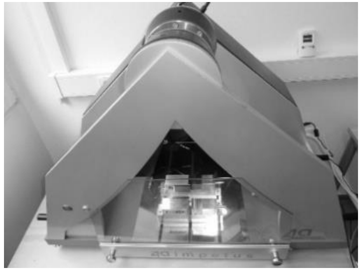
- **Services**
  - Material deformation characterization and LS-DYNA material model calibration for:
    - Polymers
    - Foams
    - Metals
  - Damage and fracture characterization and calibration for GISSMO and MAGD models

- **Experiments**
  - Tensile, bending, compression, punch test
  - Component testing
  - Local strain analysis with DIC



Thank you!