



# GISSMO/DIEM damage model parameter identification using LS-OPT

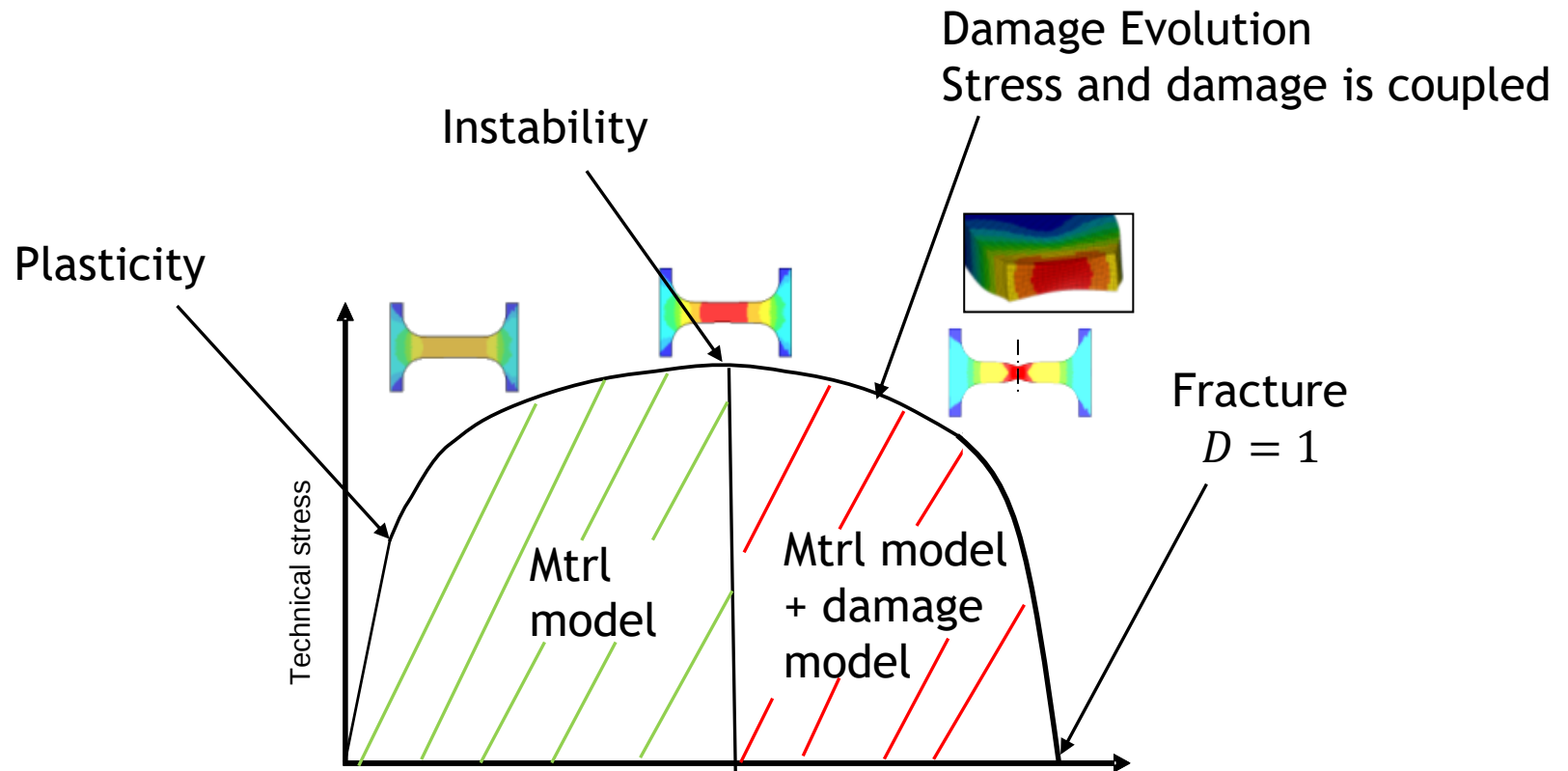
Mikael Schill  
David Aspenberg

# Agenda

- Introduction to ductile failure modelling using add on damage models
- Introduction to LS-OPT
- Material testing
  - Choosing the type of tests
  - DIC/Extensometer
- Identification process
  - Overview
  - Plasticity
    - Yield surface
    - Hardening
  - Damage model parameter identification
    - Tensile test
    - Shear test
    - R1 test
    - Full optimization
  - Regularization
- Discussion
- Related webinars

# Add on damage models in LS-DYNA

- GISSMO
- DIEM
- eGISSMO - Several GISSMO models combined
- Added to “any” material model in LS-DYNA



# GISSMO review

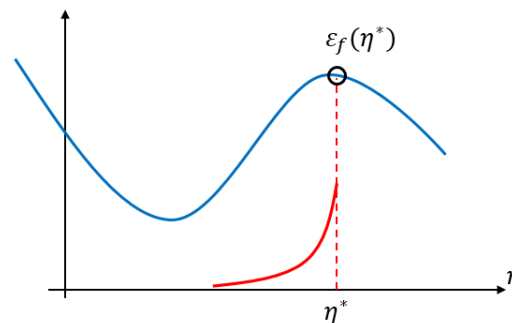
## Input

- Instability curve (when stress is coupled) as a function of triaxiality (and Lode parameter)
- Failure strain as a function of triaxiality (and Lode parameter)
- Damage evolution and coupling exponents

## Instability and Damage evolution

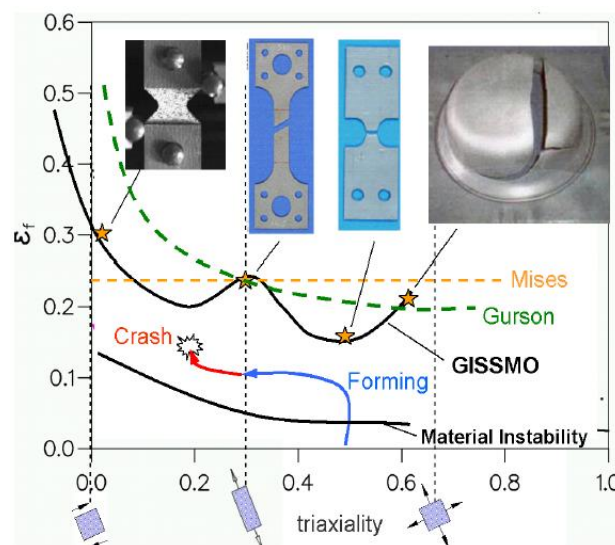
$$\Delta F = \frac{n}{\varepsilon_i(\eta^*)} F^{(1-\frac{1}{n})} \Delta \varepsilon_{eff}^p$$

$$\Delta D = \frac{n}{\varepsilon_f(\eta^*)} D^{(1-\frac{1}{n})} \Delta \varepsilon_{eff}^p$$



## Stress coupling

$$\sigma^* = \sigma \left( 1 - \left( \frac{D - D_{CRIT}}{1 - D_{CRIT}} \right)^{FADEXP} \right)$$

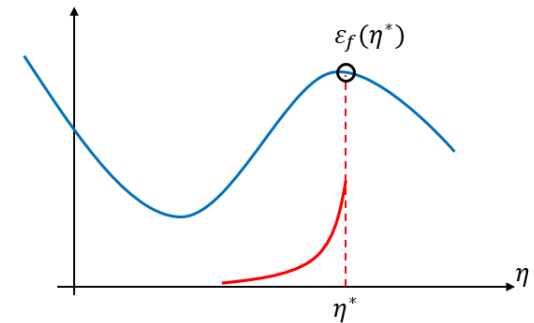


# DIEM Review

- Separates ductile, instability and shear failure, which can be combined
- Input
  - Initiation curve (when stress is coupled) as a function of stress state
  - Failure plastic displacement (optionally as a function of damage and triaxiality)
- Initiation and damage evolution

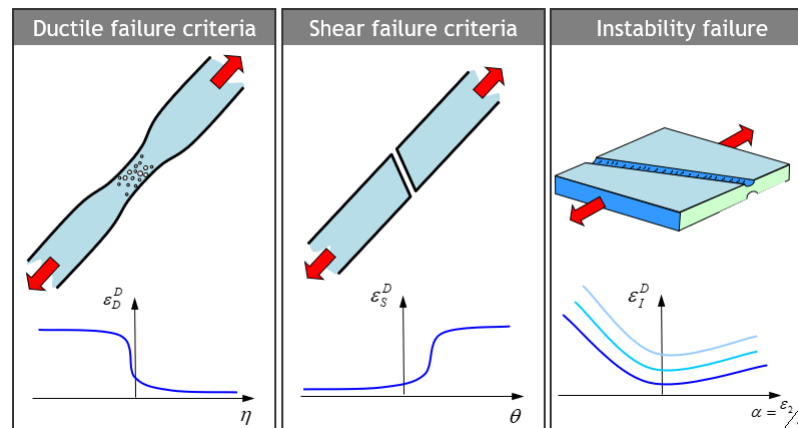
$$\omega_D = \int_0^{\varepsilon^p} \frac{d\varepsilon^p}{\varepsilon_i(\eta^*)}$$

$$D(u^p) = \frac{u^p - u^{p,init}}{u^{p,max} - u^{p,init}}$$



- Stress coupling

$$\boldsymbol{\sigma} = (1 - D) \mathbf{C}^{ep} : \boldsymbol{\varepsilon}$$



# LS-OPT introduction

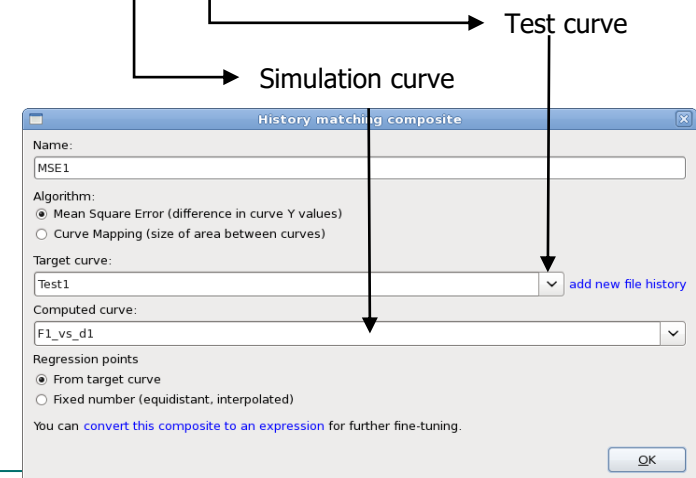
- LS-OPT is the parametric optimization toolbox developed by LST and is therefore tightly integrated with LS-DYNA.
  - Checking of LS-DYNA keyword files (\*DATABASE\_)
  - Importation of design parameters from LS-DYNA keyword files (\*PARAMETER)
  - Support of include files (\*INCLUDE)
  - Monitoring of LS-DYNA progress
  - Result extraction of most LS-DYNA response types
  - D3plot compression
- Windows and Linux versions available.
- Flowchart GUI
- Includes a complete set of optimization toolboxes, but worth mentioning related to material parameter identification is:
  - Curve matching interface
  - Full-field Calibration (FFC) using Digital Image Correlation (DIC) data
  - Sequential Response Surface Method (SRS), a robust iterative metamodel based optimization method for finding an optimal set of parameters
  - Approximate histories for viewing parameter influences on histories



# LS-OPT - Curve matching composite interface

- You give the test curve as a two-column text file
- For the simulation results, cross plots can be defined, e.g. stress vs. strain, force vs. deformation, etc.
- The error measure for the calculation of the mismatch could be either Mean Square Error (MSE) or curve mapping
  - Curve mapping is a good choice when curves have sudden drops, but it requires noise free curves for good results
  - For MSE, it is possible to further fine tune the error calculation, e.g.:
    - number of interpolation points
    - start point
    - end points
    - weighting/scaling
- All error measures have shortcomings, but the general advices are:
  - Filter the curves
  - Use equal density of points on curves
  - Compare the same ranges (i.e. truncation might sometimes help to get good error values)

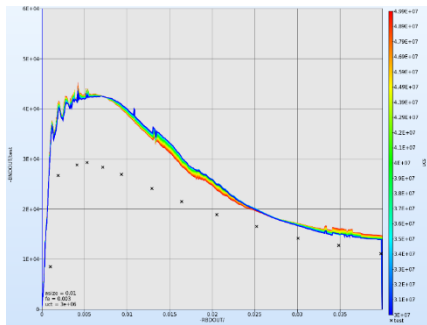
$$MSE(\mathbf{x}) = \frac{1}{P} \sum_{i=1}^P W_i \left( \frac{F_i(\mathbf{x}) - G_i}{s_i} \right)^2 \rightarrow \min$$



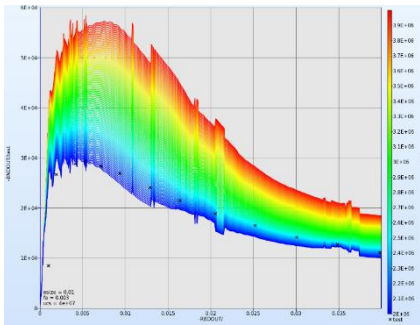
# LS-OPT - Approximate histories

- Based on a few number of simulations, you may visualize how each variable affects a history, e.g. a force-displacement plot.
- This helps you to understand both the effect and the importance of each material parameter for the studied test specimen.
- It is therefore recommended to do a sensitivity study first to see the influence from the parameters, and the choice of start values and variable range
- Can I calibrate this parameter using this test?

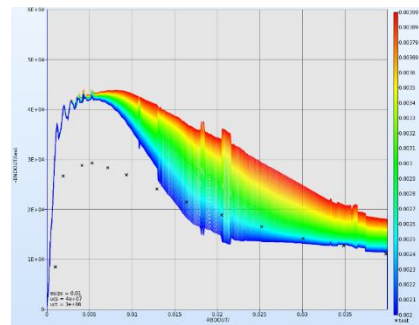
Example:



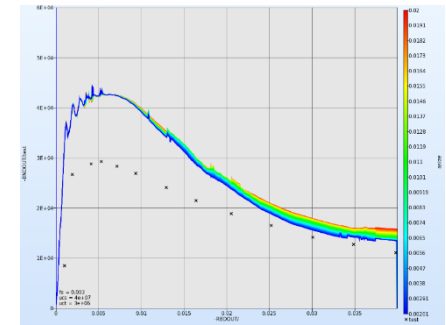
Parameter\_1



Parameter\_2



Parameter\_3

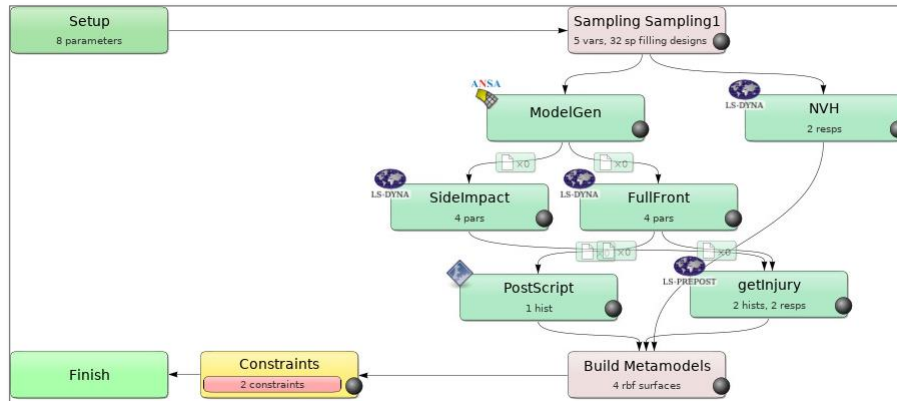


Parameter\_4

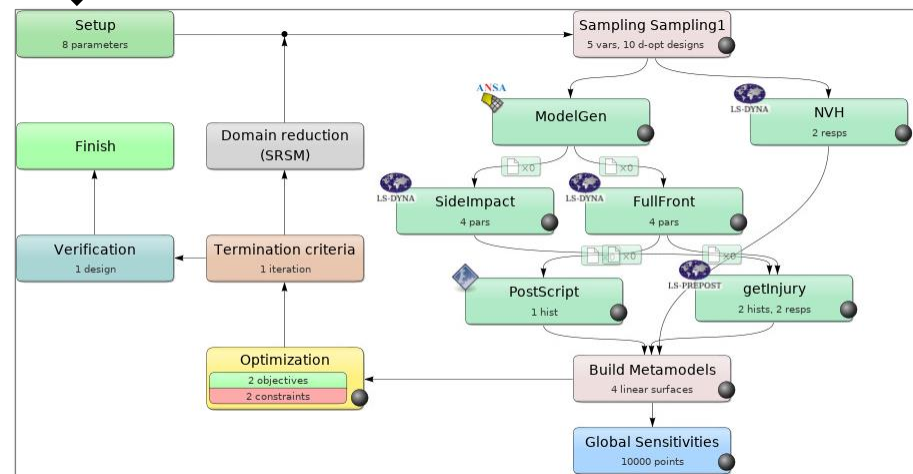
- Only Parameter\_2 and Parameter\_3 are possible to calibrate using this test, the other variables are not active/influencing.

# LS-OPT general - Changing analysis type

- Changing task in LS-OPT does not affect your modelled process, i.e. going from a sensitivity study of your variables to an optimization is easy.

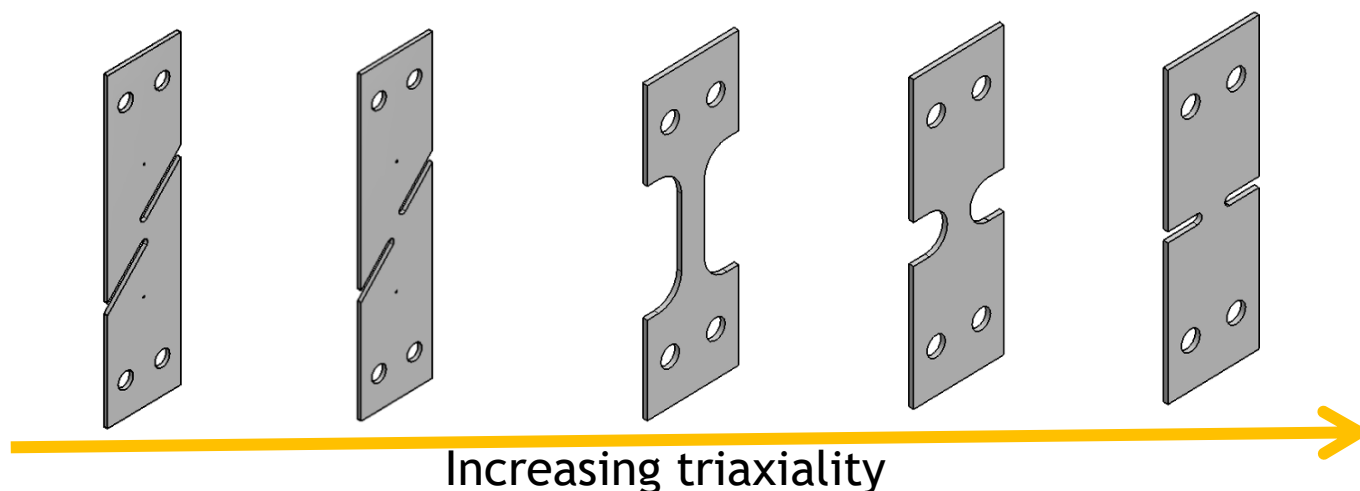


↓ From DOE study to sequential optimization



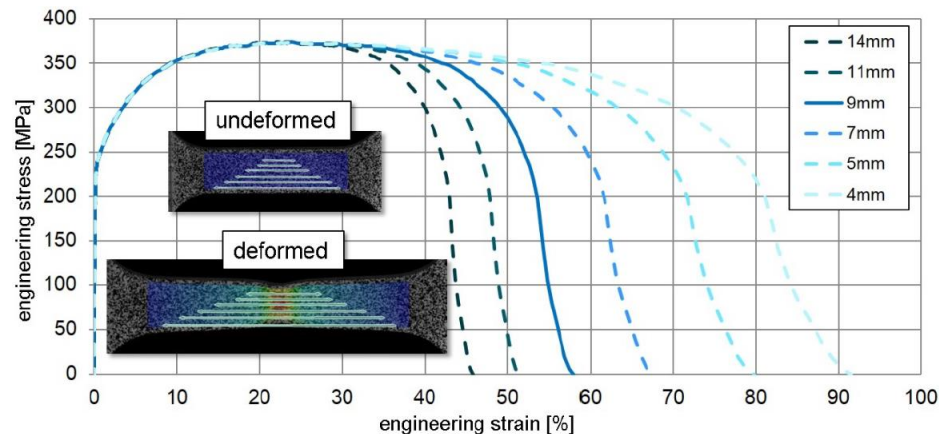
# Choosing the test(s)

- Failure/instability/initiation is to be described for different stress states (triaxiality, principal stress ratio, Lode parameter ..)
- Choose tests that maximizes the stress state range
- Choose tests that matches the application, e.g. bending, and/or typical material characteristics e.g. tension/compression asymmetry.
- Add tensile tests for hardening, anisotropy and possibly viscoplasticity.
- The stress state will not be constant and therefore not possible to be determined analytically. Therefore, identification must be made using inverse modeling.



# Extensometer data

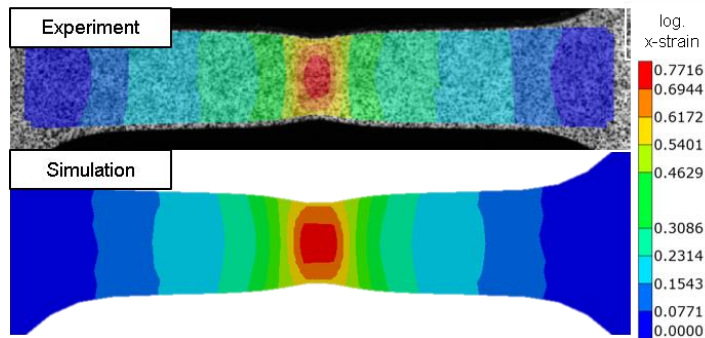
- The test data from tensile specimens are generally the machine force, as well as a strain measurement from an extensometer or in some cases the clamp displacement.
- Extensometer data for a tensile test is homogenous up to the point of diffuse necking. Beyond that point, the results are dependent on the initial length of the extensometer, the shape of the neck, etc.



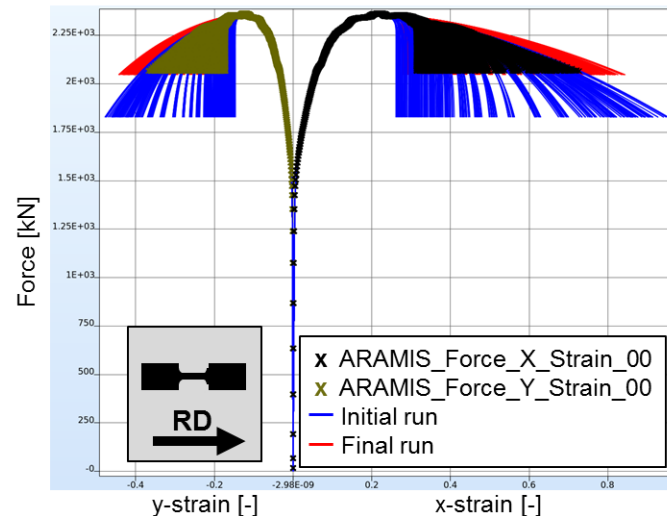
*Application of a Full-Field Calibration Concept for Parameter Identification of HS-Steel with LS-OPT®, Christian Ilg et al., 15<sup>th</sup> International LS-DYNA® Users Conference, 2018.*

# LS-OPT - Full-Field Calibration (FFC)

- Filming your test and using Digital Image Correlation (DIC) enables a Parameter identification using strain field data.
- Matching the force-displacement curve does not necessarily mean that you have the correct deformation.
- The advantage is that you could be able to fit the hardening curve beyond the point of diffuse necking.
- DIC also enables measurements of other quantities that are difficult to evaluate, such as the plastic Poisson's ratio.



Deformation field of tensile test



Multi-point histories for experiment and simulation

# Modeling the tests

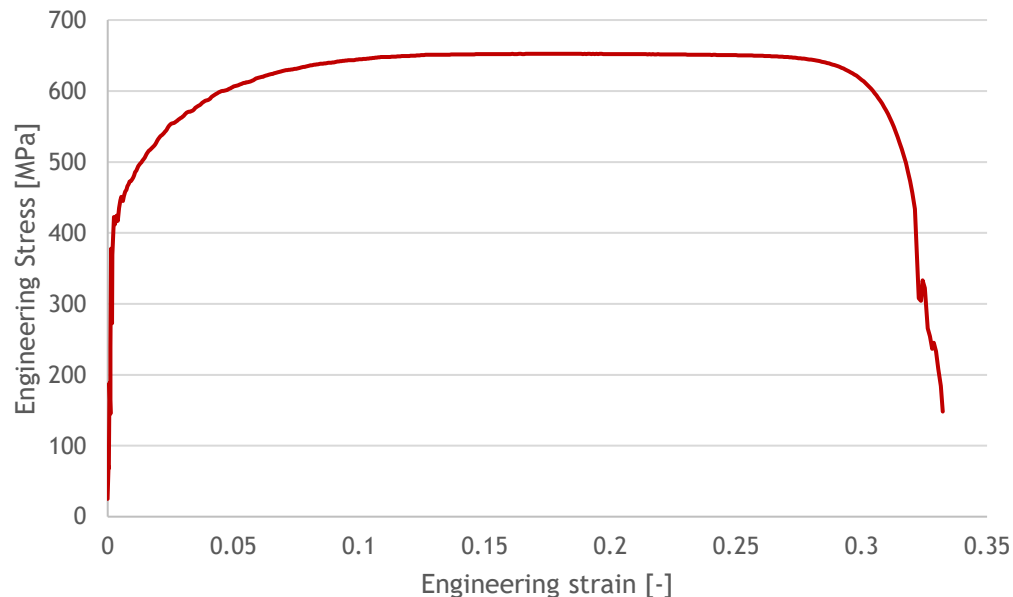
- Damage modeling is element size dependent. Some mesh regularization is possible, but it is recommended to do the identification using the element size that will be used in the simulations.
- Make sure to choose the test geometries cross-section size to match the element size and modeling technique used in your models. For example, number of elements along a shear region and in-plane bending.
- Use the type of element (shell or solid) that is intended for the damage model.
- Force measurements can be done by:
  - \*DATABASE\_CROSS\_SECTION and ASCII file SECFORC
  - Boundary prescribed motion forces through ASCII file BNDOUT (often noisy due to numerical noise)
- Displacement/Extensometer measurements can be done by:
  - Node displacement through ASCII file NODOUT
  - Rigid body displacement through ASCII file RBDOUT
  - Node displacement from D3PLOT file
- Nodes can be “glued” to the test specimen for arbitrary extensometer lengths.

# Identification example

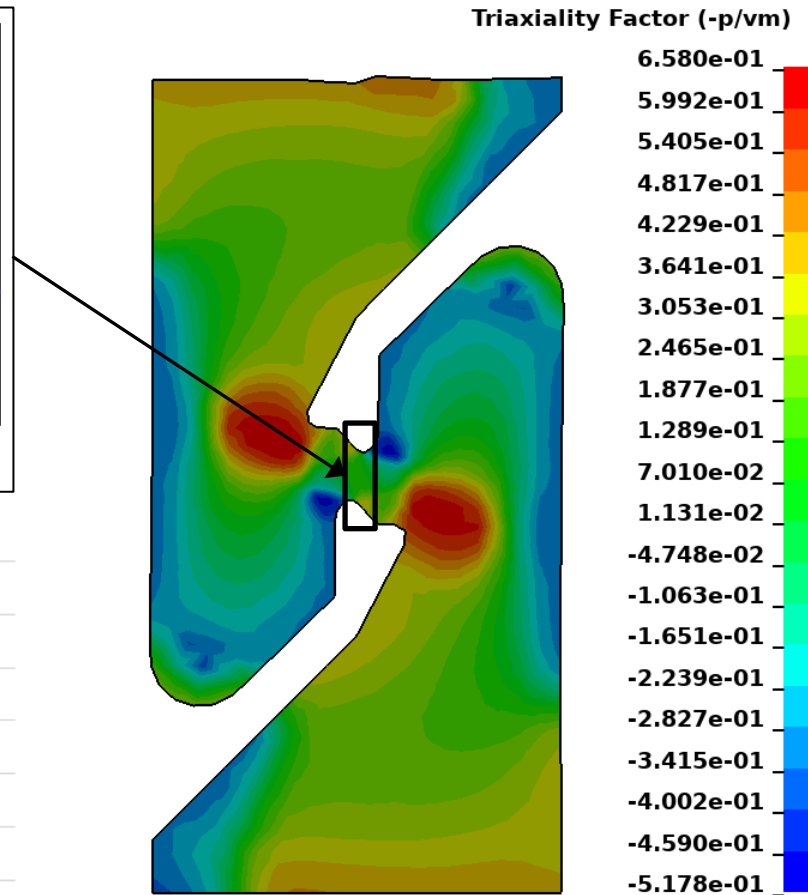
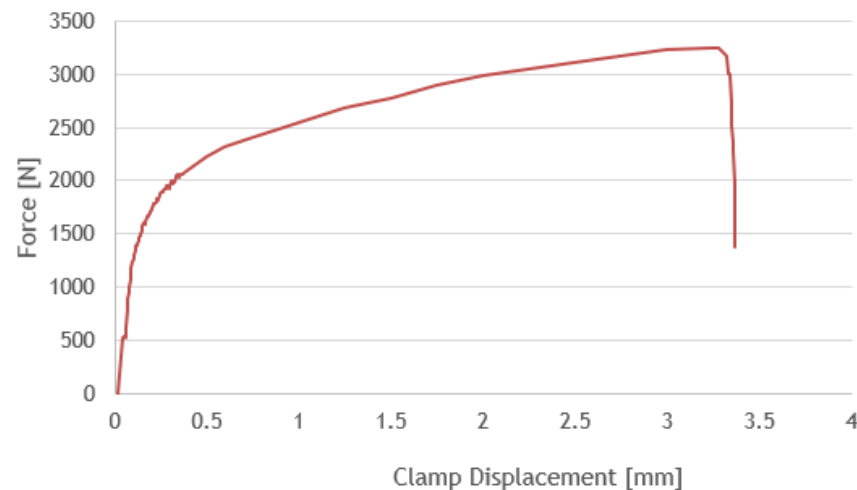
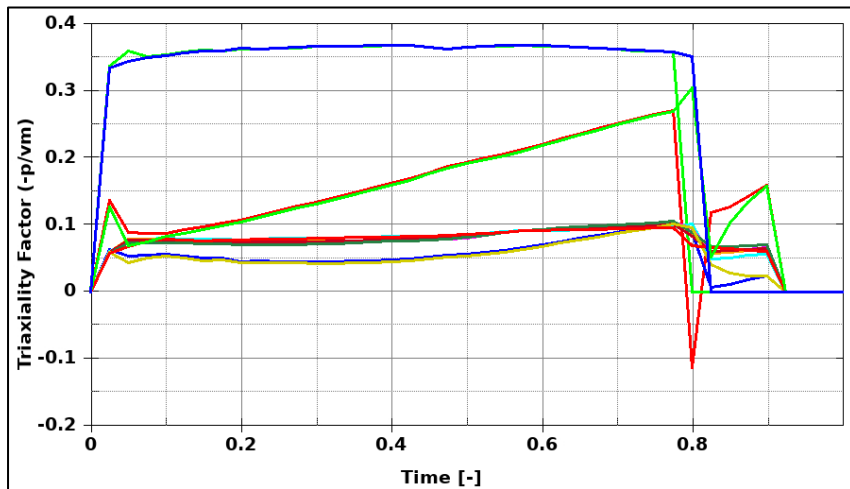
- DP 600 type steel
- Tensile test in 3 directions with Lankford coefficients for anisotropy  $\left(R = \frac{\varepsilon_w^p}{\varepsilon_t^p}\right)$
- 3 tensile tests for damage calibration

- Shear
- Uniaxial
- Plane strain/R1

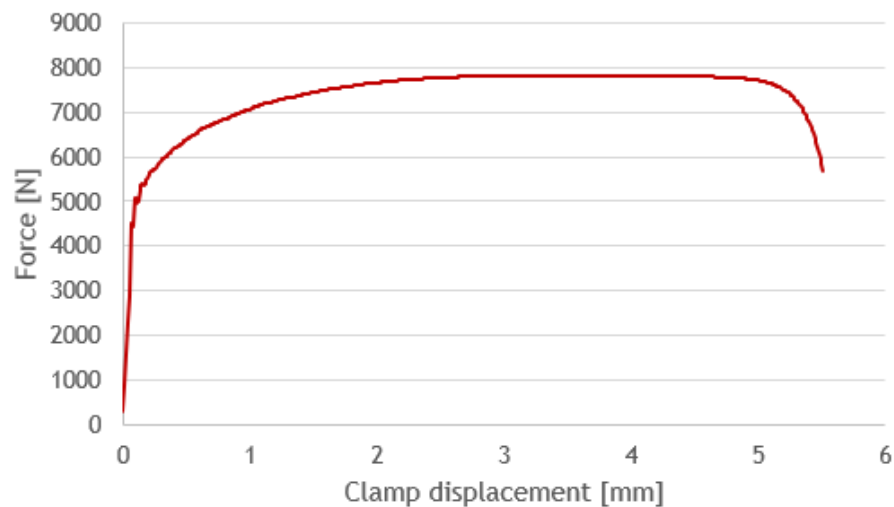
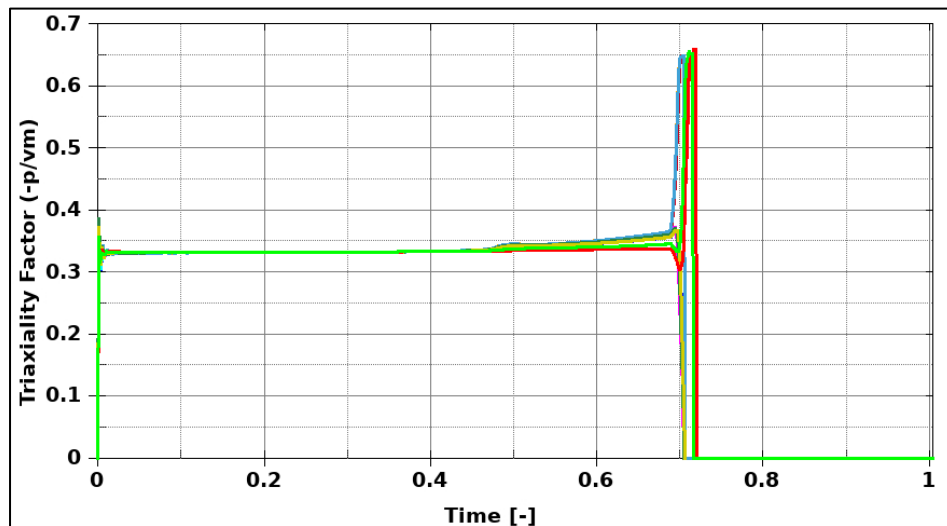
| $\sigma_{00}$ | $\sigma_{45}$ | $\sigma_{90}$ | $R_{00}$ | $R_{45}$ | $R_{90}$ |
|---------------|---------------|---------------|----------|----------|----------|
| 395           | 397           | 407.6         | 0.74     | 0.9      | 0.92     |



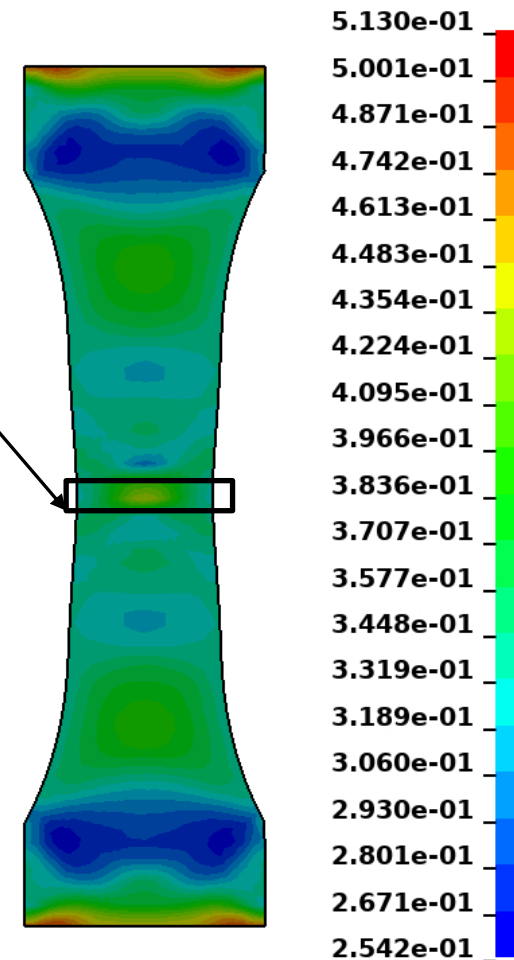
# Shear test



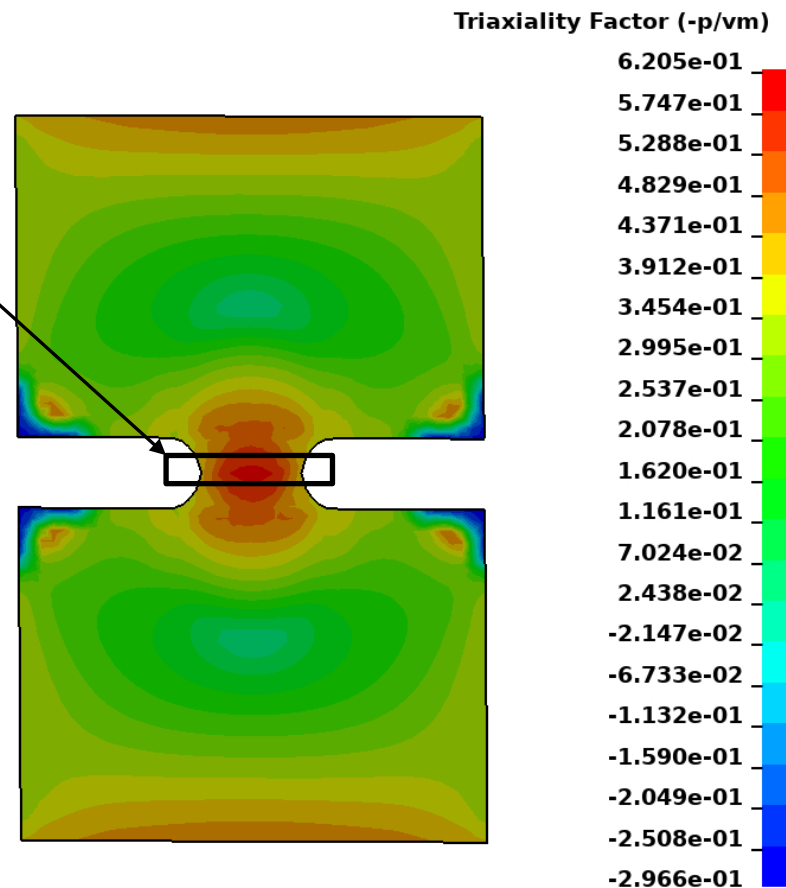
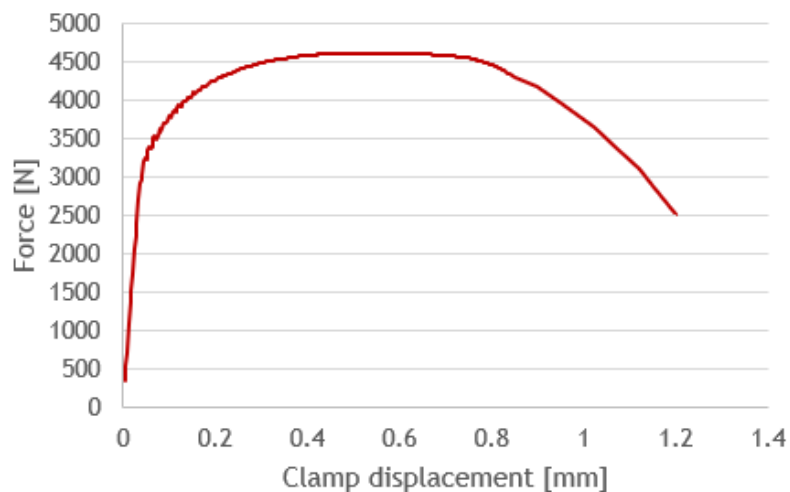
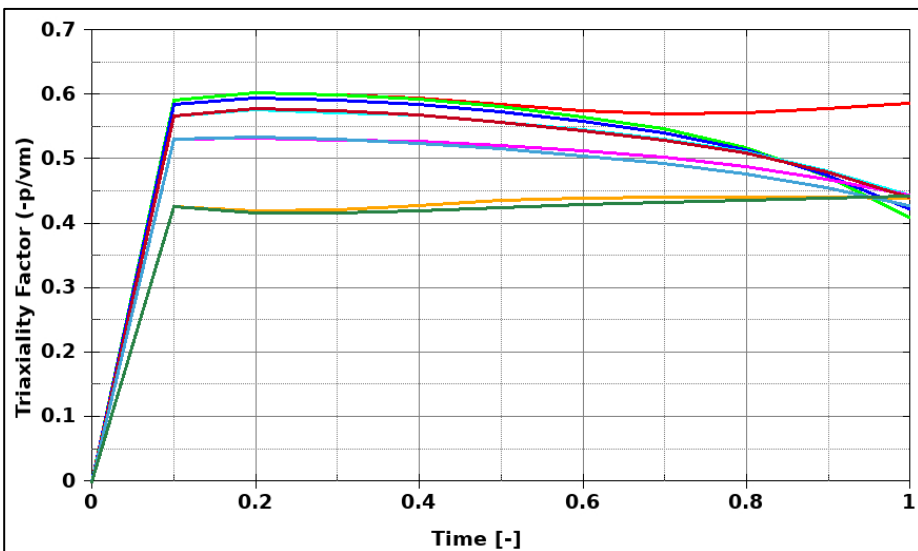
# Uniaxial test



Triaxiality Factor (-p/vm)



# Plane strain test (R1)





# Identification process

## 1. Plasticity model

1. Choose material model and determine hardening
2. Convert hardening to true stress and strain data
3. Extrapolate the hardening

## 2. Responses without damage?

1. Check the responses of the damage coupons
2. Modify the plasticity (if needed)
3. Re-Check the responses of the damage coupons (if needed)

## 3. Determine damage parameters

1. Parameterize the model
2. Determine damage parameters for the uniaxial test
3. Create LS-OPT histories
4. Create LS-OPT Curve matching composite
5. Determine parameters for the remaining tests - Shear
6. Determine parameters for the remaining tests - R1

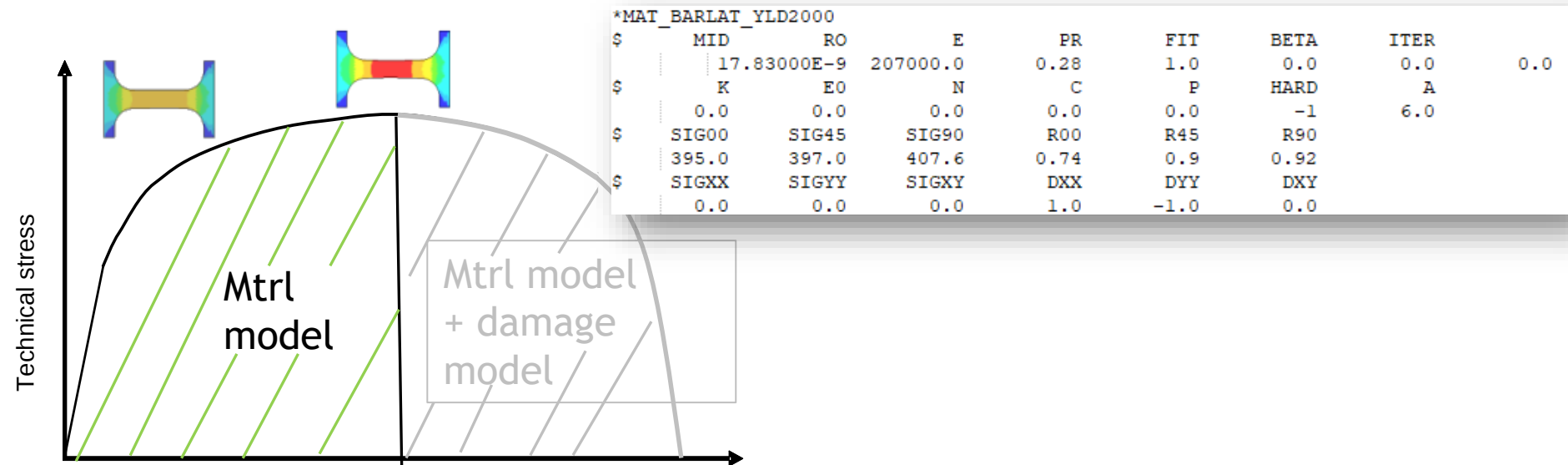
## 4. Do a full parameter identification

1. Look at the results for all coupons

## 5. Regularization

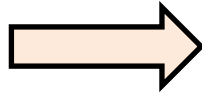
# 1.1 Choose material model and determine hardening

- Depending on material characteristics, choose an appropriate material model in LS-DYNA, e.g:
  - Isotropic hardening (with or without viscoplasticity): \*MAT\_24
  - Polymers: \*MAT\_SAMP\_LIGHT
  - Anisotropic steel: \*MAT\_BARLAT\_YLD2000
- The GISSMO and DIEM damage models are isotropic, but in this example we apply it on an anisotropic yield surface. It will thus only be valid in the direction to which it is fitted. However, if the anisotropy is minor it might be applicable anyway.



## 1.2 Convert hardening to true stress and strain data

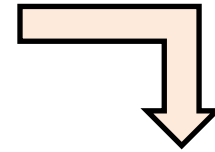
Identify the point of necking in the engineering strain/stress data



Calculate true strain and stress values to the necking point

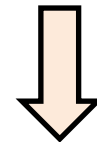
$$\varepsilon = \ln(1 + e)$$

$$\sigma = s(1 + e)$$

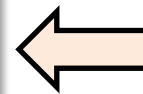


Convert the strain to plastic strain

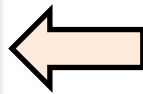
$$\varepsilon^p = \varepsilon - \frac{\sigma}{E}$$



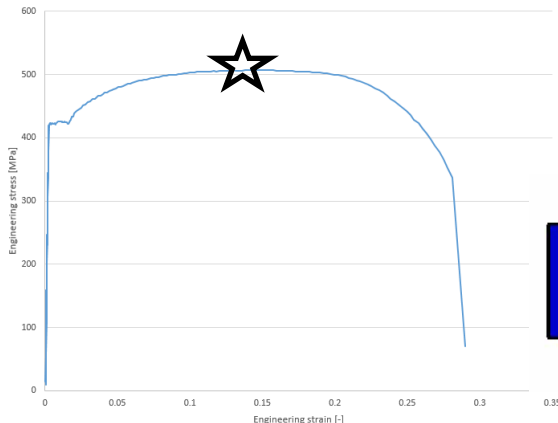
Choose a number of strain/stress point ( $\approx 20$ ) or fit an analytical model to define the hardening



Input the material data in an LS-DYNA model of the tensile test

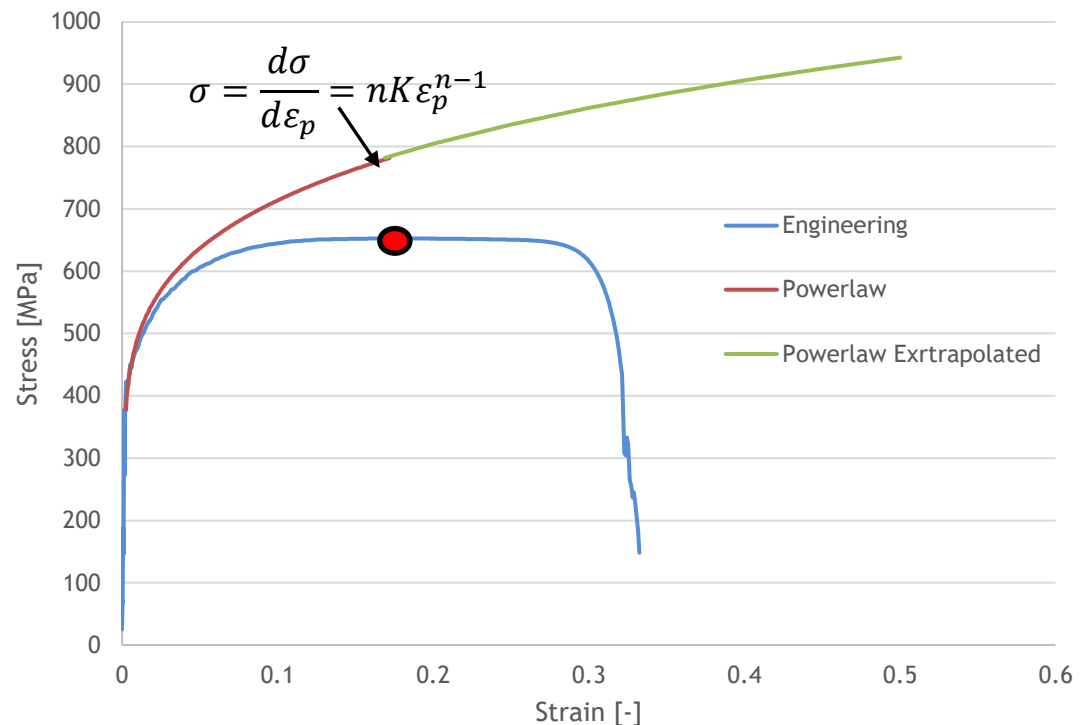


Simulating the tensile test will give the same results to the point of necking



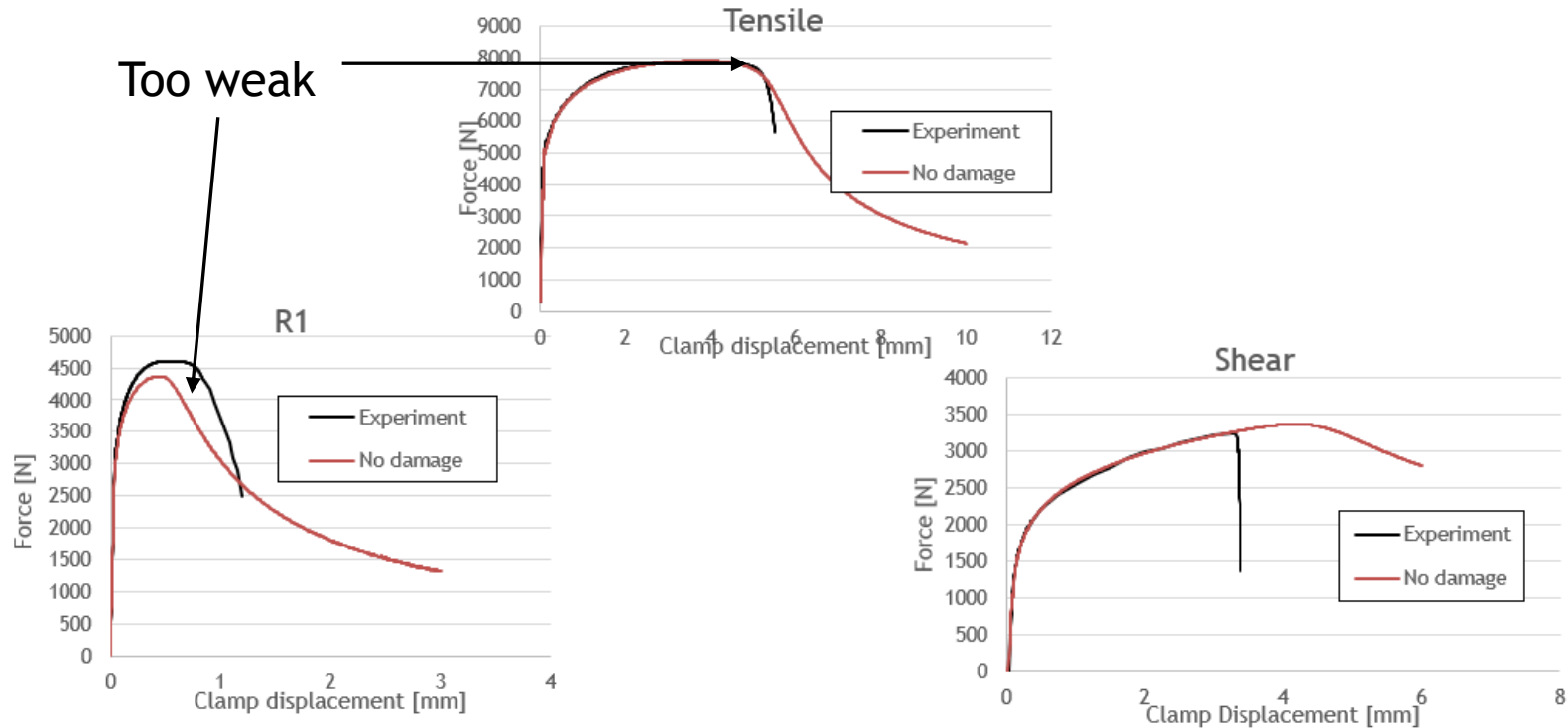
## 1.3 Extrapolate the hardening

- Use e.g. Excel to find Powerlaw parameters ( $\sigma = \sigma_y + K\varepsilon_p^n$ ) to fit the true strain/stress curve.
- At the point of necking, the stress is equal to the slope of the hardening curve. Thus,  $\sigma = \frac{d\sigma}{d\varepsilon_p} = nK\varepsilon_p^{n-1}$ . This can be used to trigger the diffuse necking at the correct point.



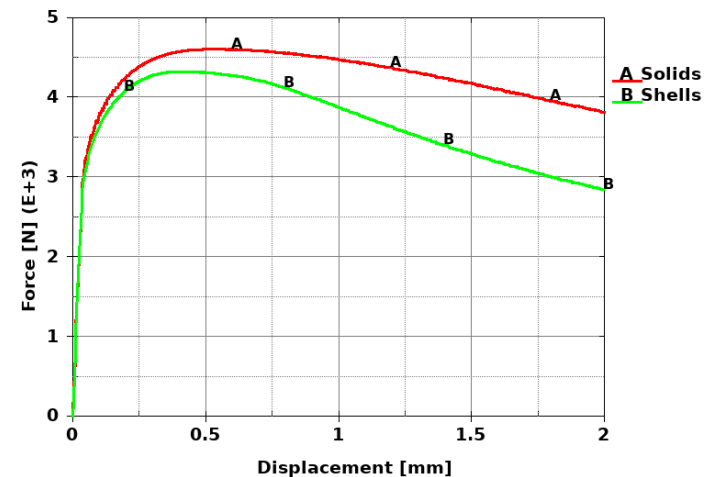
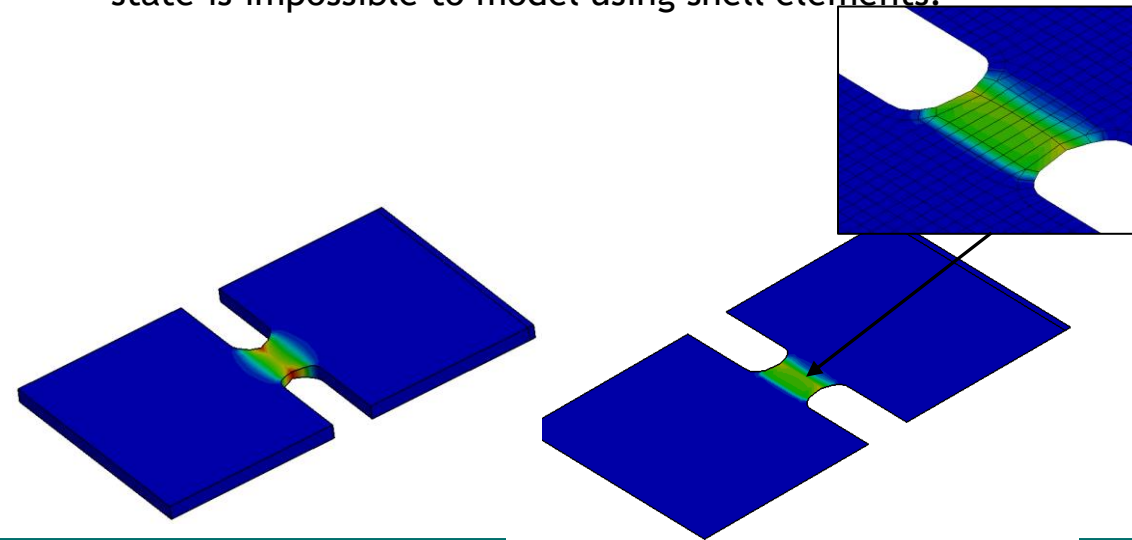
## 2.1 Check the responses of the damage coupons

- Simulate the damage coupons (without damage model) and compare the response to the tests
- If the response of the model is too soft, the hardening or the yield surface need to be modified since adding a damage model will soften the results further.



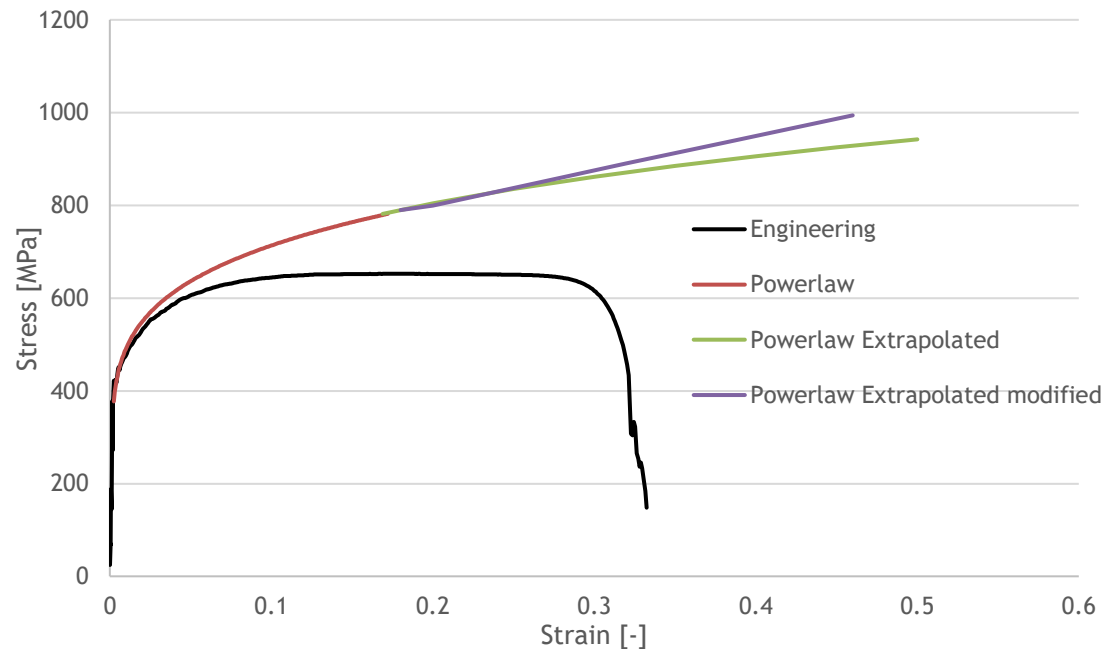
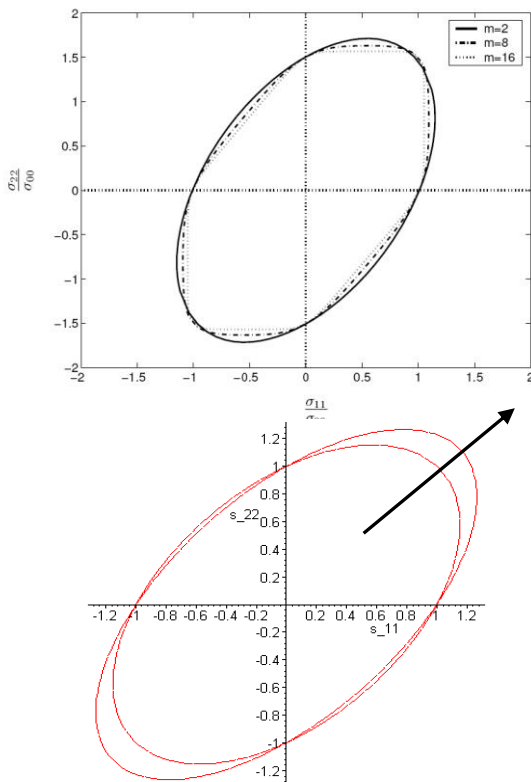
# Plasticity modeling comments

- There might be several reasons that the plasticity part of the response for the damage coupons does not agree with experiments
- **Hardening(1):** The extrapolation of the hardening might be wrong. Try changing the extrapolation but still fit the part before material instability and the diffuse necking point.
- **Hardening(2):** It might be tempting, but try to avoid softening of your hardening curve. Softening will induce a material instability and loss of uniqueness of the solution.
- **Yield surface:** The chosen yield criteria could be an improper choice due to anisotropy or that the yield surface gives a poor estimation for a general stress state. Switch to a yield surface that supports anisotropy or where more stress points can be fitted.
- **Shell element theory limitation:** As the strains localize, the stress will shift to a multi-axial stress state. If shells are used, the plane stress assumption will not allow for this and the actual stress state is impossible to model using shell elements.

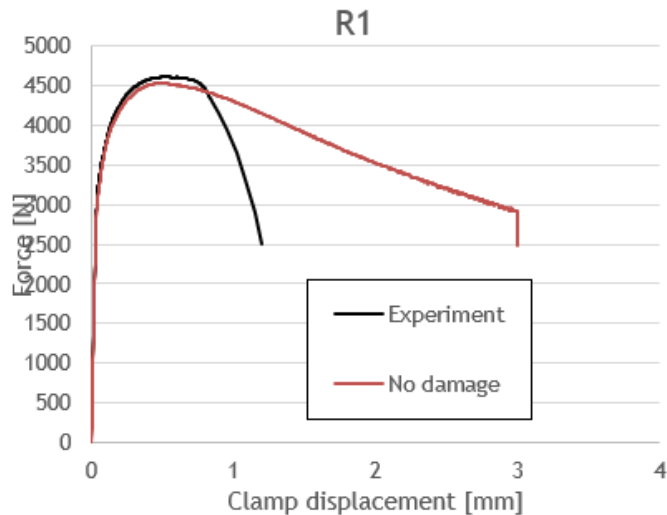
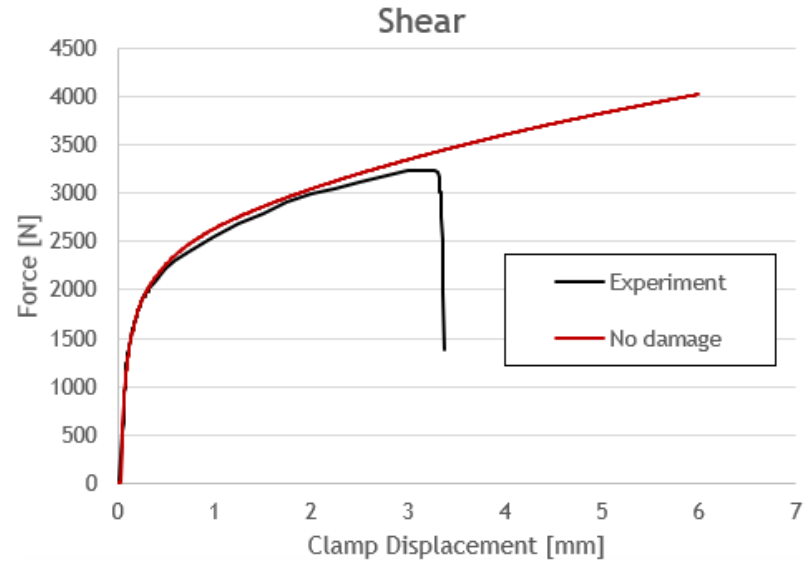
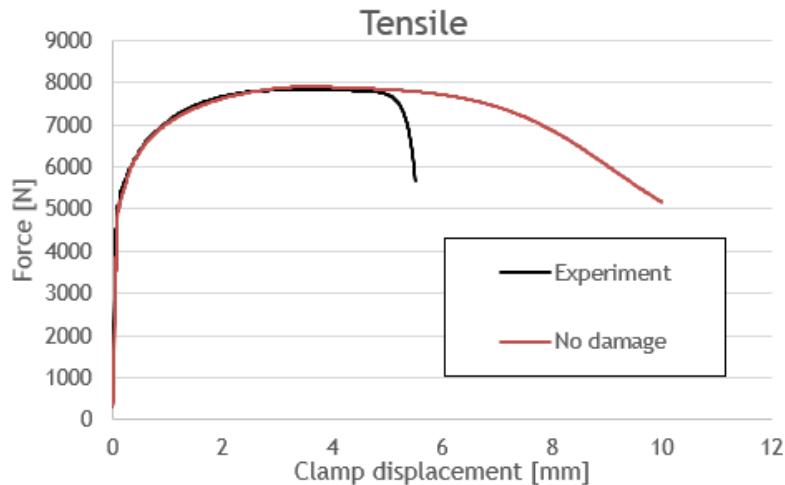


## 2.2 Modifying the plasticity

- The force response can be raised by modifying the extrapolated hardening part.
- The R1 force response can be raised by modifying the biaxial stress point or the yield surface exponent.



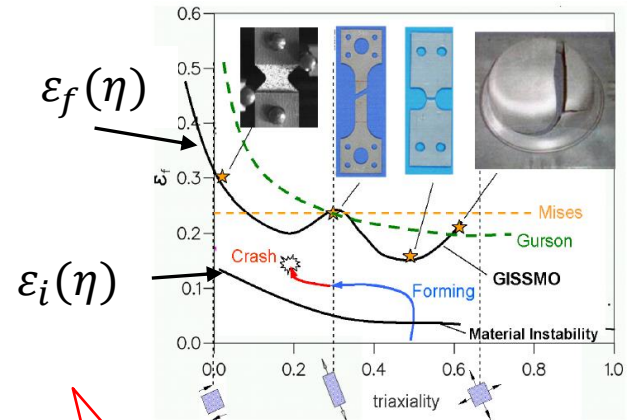
## 2.3 Check the responses of the damage coupons



|                     |             |          |       |      |      |      |      |
|---------------------|-------------|----------|-------|------|------|------|------|
| *MAT_BARLAT_YLD2000 |             |          |       |      |      |      |      |
| \$                  | MID         | RO       | E     | PR   | FIT  | BETA | ITER |
|                     | 17.83000E-9 | 207000.0 | 0.28  | 1.0  | 0.0  | 0.0  | 0.0  |
| \$                  | K           | E0       | N     | C    | P    | HARD | A    |
|                     | 0.0         | 0.0      | 0.0   | 0.0  | 0.0  | -1   | 6.0  |
| \$                  | SIG00       | SIG45    | SIG90 | R00  | R45  | R90  |      |
|                     | 395.0       | 397.0    | 407.6 | 0.74 | 0.9  | 0.92 |      |
| \$                  | SIGXX       | SIGYY    | SIGXY | DXX  | DYY  | DXY  |      |
|                     | 0.0         | 0.0      | 0.0   | 1.0  | -1.0 | 0.0  |      |
|                     |             |          |       |      |      |      |      |
| \$                  | SIG00       | SIG45    | SIG90 | R00  | R45  | R90  |      |
|                     | 395.0       | 397.0    | 407.6 | 0.74 | 0.9  | 0.92 |      |
| \$                  | SIGXX       | SIGYY    | SIGXY | DXX  | DYY  | DXY  |      |
|                     | 440.0       | 440.0    | 0.0   | 1.0  | -1.0 | 0.0  |      |

### 3. Determine damage parameters

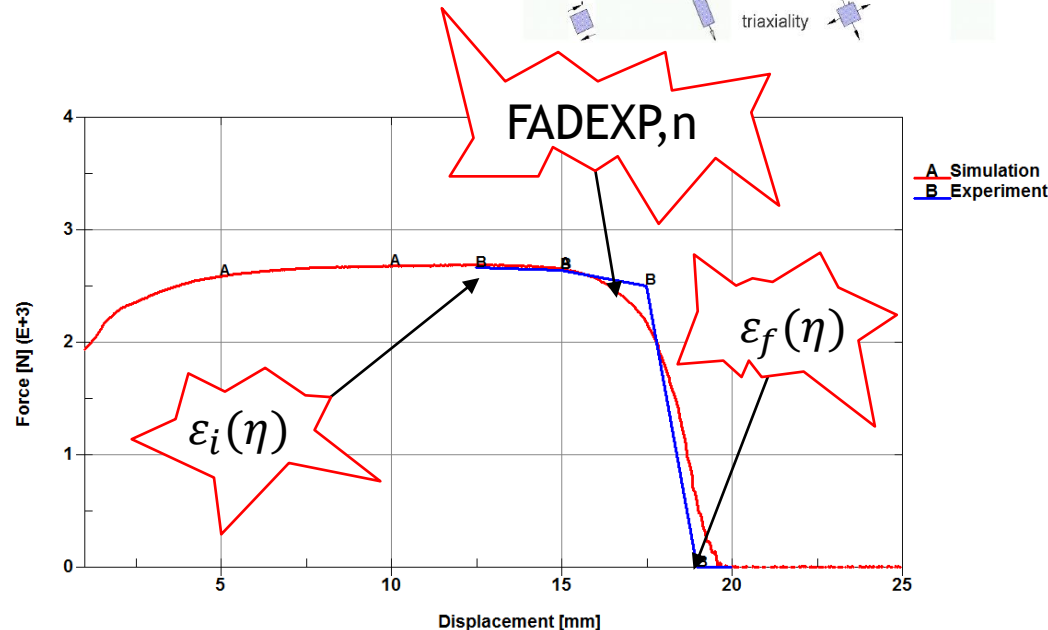
- The example will be done for GISSMO. However, the procedure is similar for the DIEM damage model.
- The parameters that need to be identified is:
  - Instability strains ( $\varepsilon_i(\eta)$ )
  - Failure strains ( $\varepsilon_f(\eta)$ )
  - Stress coupling exponent (FADEXP)
  - Damage and instability evolution exponent ( $n$ )



$$\Delta F = \frac{n}{\varepsilon_i(\eta^*)} F^{(1-\frac{1}{n})} \Delta \varepsilon_{eff}^p$$

$$\Delta D = \frac{n}{\varepsilon_f(\eta^*)} D^{(1-\frac{1}{n})} \Delta \varepsilon_{eff}^p$$

$$\sigma^* = \sigma \left( 1 - \left( \frac{D - D_{CRIT}}{1 - D_{CRIT}} \right)^{FADEXP} \right)$$



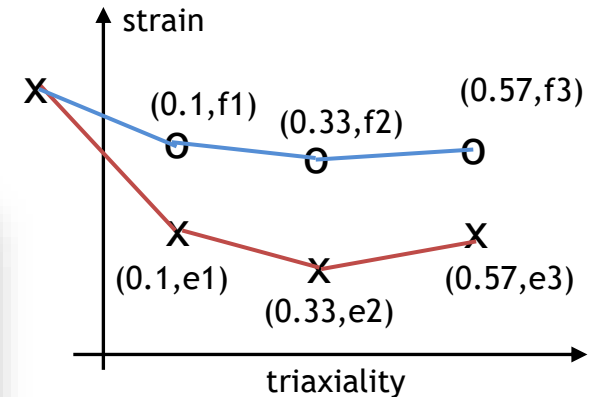
# 3.1 Parameterize the model

- Parameterizing the input files enables LS-OPT to identify the parameters as variables and modifying the variables during optimization.
- The instability and failure curves are discretized using 3 values at stress triaxialities (0.1;0.333 and 0.577). This results in a piecewise linear curve.
- The curves could be inter- and extrapolated using e.g. splines.
- An extra point is added for negative triaxialities to avoid damage during compression.
- The regularization is set to 1.0 for all element sizes. Thus, it is not considered at this instant.

```
*DEFINE_CURVE_TITLE
failure strain
$   LCID      SIDR      SCLA      SCLO
$#   101        0        1.0        1.0
$#           al          ol
$#           -0.1        1.0
$#           0.1&f1
$#           0.3333&f2
$#           0.5777&f3
```

```
*DEFINE_CURVE_TITLE
instability
$   LCID      SIDR      SCLA      SCLO
$#   100        0        1.0        1.0
$#           al          ol
$#           -0.1        1.0
$#           0.1&e1
$#           0.3333&e2
$#           0.5777&e3
```

```
*MAT_ADD_DAMAGE_GISSMO
$#   mid      -      dtyp      refsz      numfip
$#   1         0      1.0      0.0      1.0
$#   lcsdg     ecrit   dmexp     dcrit     fadexp     lcregd
$#   101      -100&dmg  0.0&fad  102
$#   lcsrs     shrf    biaxf     lcdlim    midfail
$#   0         0.0     0.0      0         0.0
```



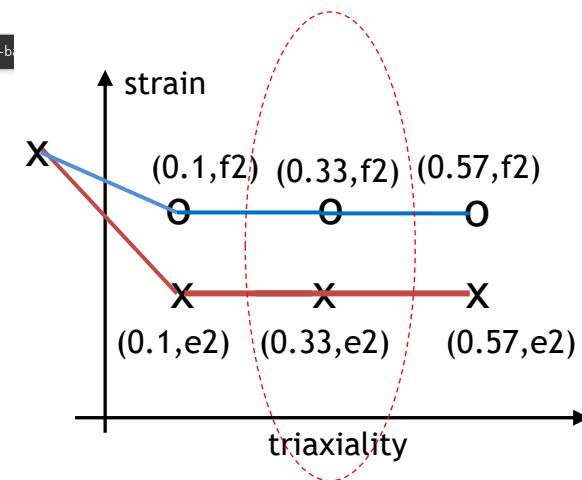
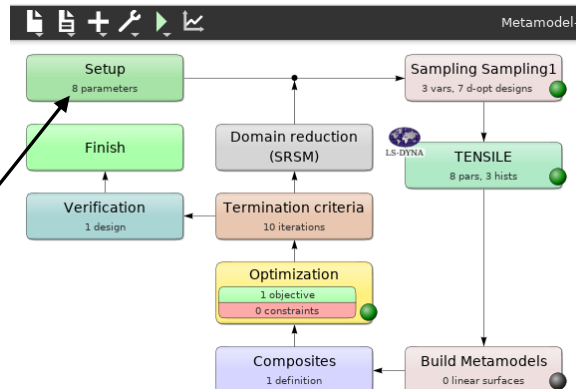
Regularization is disregarded at this point (constant=1.0)

```
*DEFINE_CURVE_TITLE
regularization
$   LCID      SIDR      SCLA      SCLO
$#   102        0        1.0        1.0
$#           al          ol
$#           0.0          1.0
$#           10.0         1.0
```

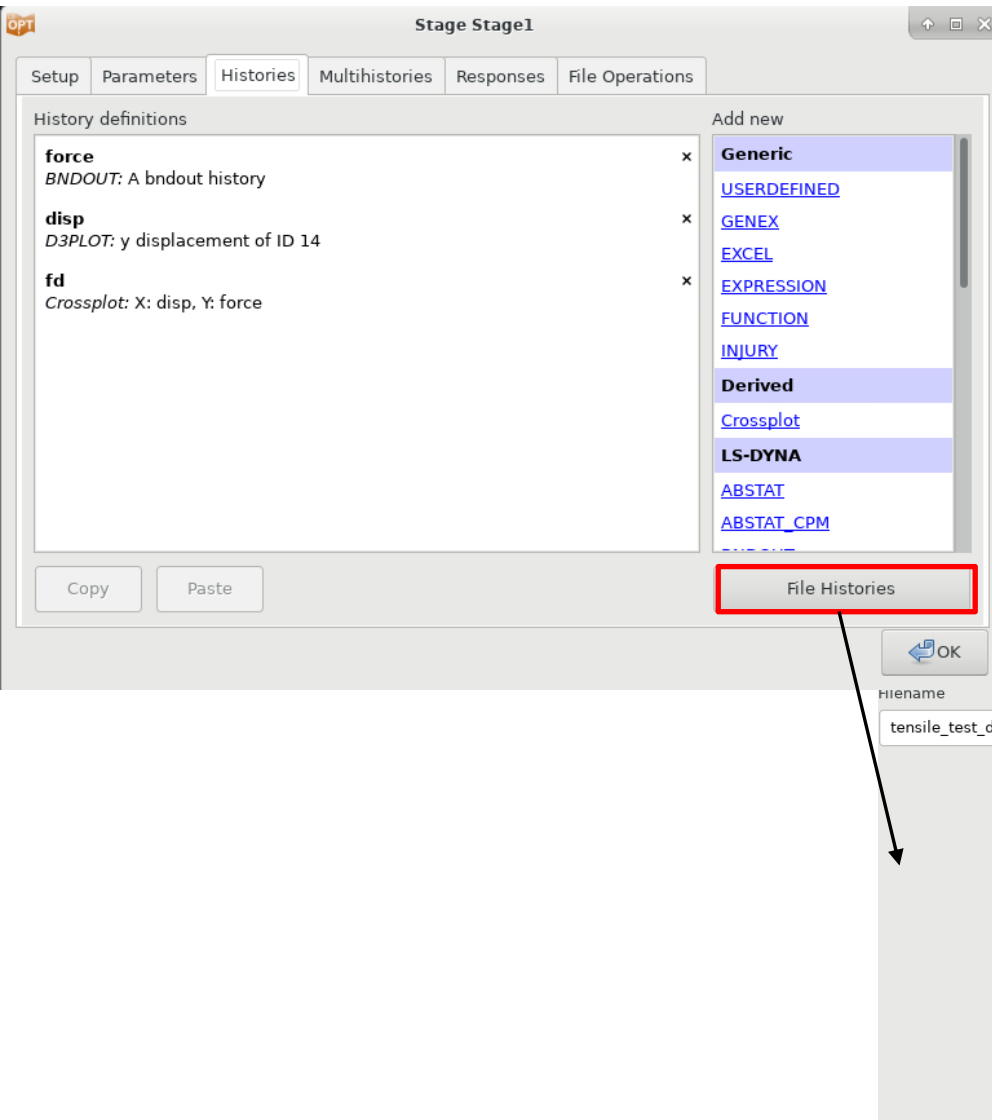
## 3.2 Determine damage parameters for the uniaxial test

- The damage parameter identification is done in two steps:
  - 1. Optimize each test to determine start values for the respective triaxiality values
  - 2. Do a complete optimization with all tests and variables.
- In the initial parameter identifications, the instability strain and failure strain is set to be constant for all stress triaxialities. Thus, the failure is not dependent on the variation in stress triaxiality. The reason for this is to get an initial estimate which is independent on the order of which the tests are fitted. The effect of this procedure is larger the more tests are fitted.
- Start with the tensile test and determine parameters  $dmg$ ,  $fad$  and  $f2$ . The instability strain  $e2$  can be determined directly from test.

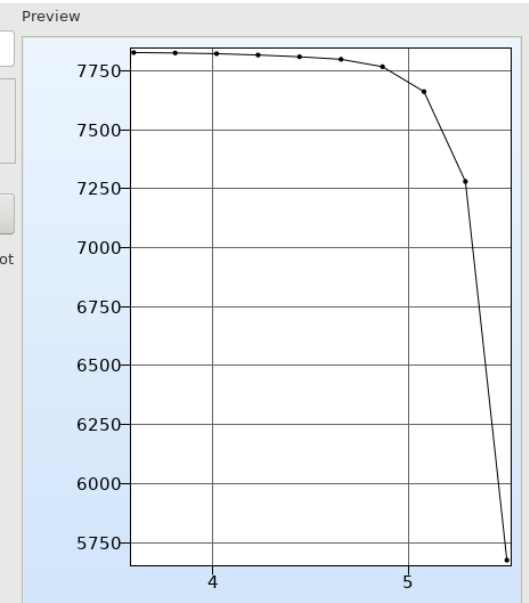
| Parameter Setup                                | Stage Matrix | Sampling Matrix  | Resources | Features |
|------------------------------------------------|--------------|------------------|-----------|----------|
| <input type="checkbox"/> Show advanced options |              |                  |           |          |
| Type                                           | Name         | Starting         | Minimum   | Maximum  |
| Continuous                                     | $dmg$        | 2                | 1         | 4        |
| Dependent                                      | $e1$         | Definition: $e2$ |           |          |
| Constant                                       | $e2$         | 0.17             |           |          |
| Dependent                                      | $e3$         | Definition: $e2$ |           |          |
| Dependent                                      | $f1$         | Definition: $f2$ |           |          |
| Continuous                                     | $f2$         | 0.6              | 0.4       | 1.2      |
| Dependent                                      | $f3$         | Definition: $f2$ |           |          |
| Continuous                                     | $fad$        | 2                | 1         | 4        |



## 3.3 Create LS-OPT histories

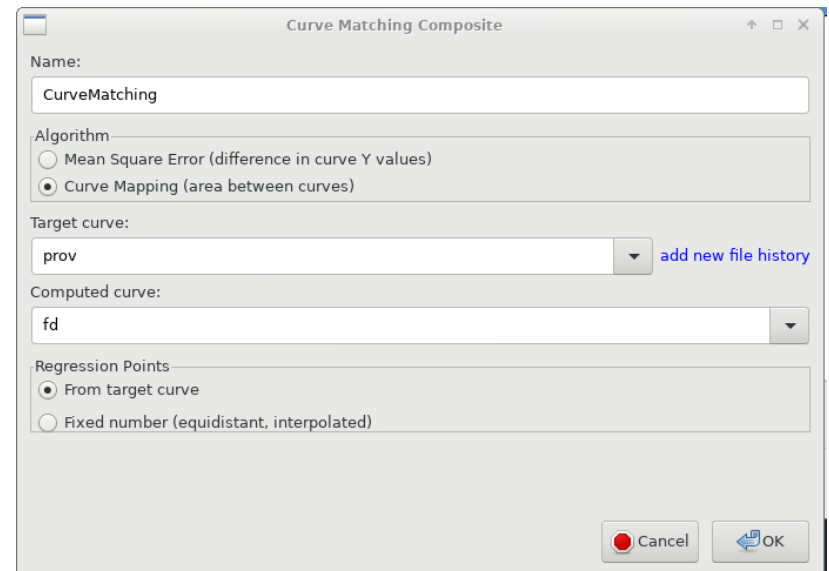
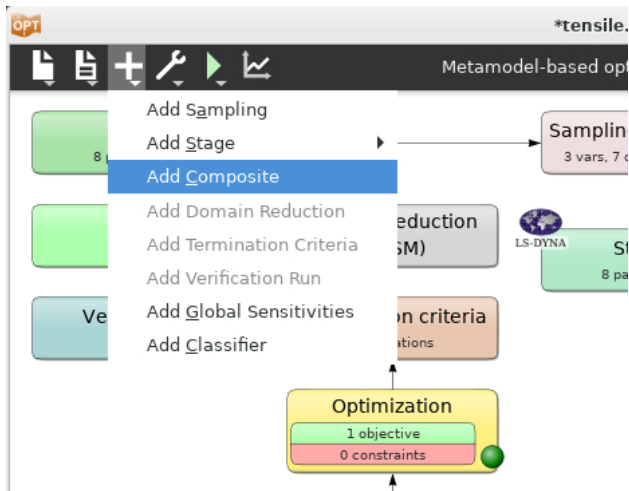


- Histories are typically Force-displacement crossplots.
- File histories from test can be read into LS-OPT
- Only use last part of the test curve for comparison since the first part is determined from the material model.



## 3.4 Create LS-OPT Curve matching composite

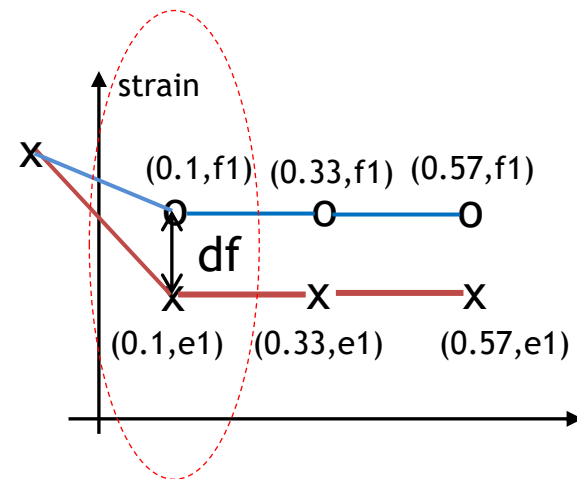
- LS-OPT has several curve matching routines.
- Add a composite and choose to compare the force displacement response from test with simulations.



## 3.5 Determine parameters for the remaining tests - Shear

- In the same manner as for the uniaxial test, identify parameters  $e1$  and  $f1$  for the shear test.
- Use the damage exponent and stress coupling exponent as determined from the uniaxial parameter identification.
- In order to avoid that the failure strain is set lower than the instability strain, introduce a new variable  $df$  and set  $f1 = e1 + df$

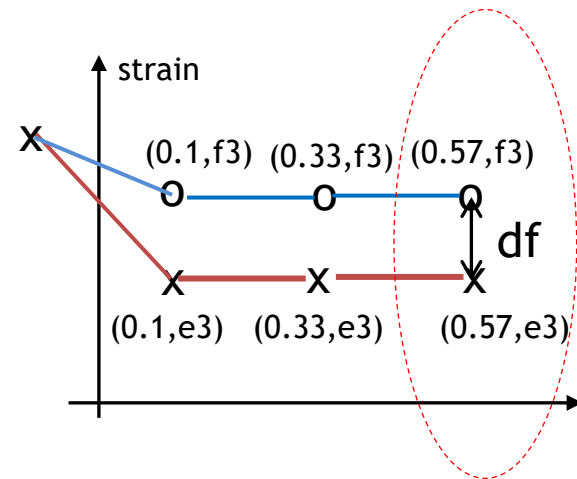
| Parameter Setup                                |      |             |         |         | Stage Matrix | Sampling Matrix | Resources | Features |
|------------------------------------------------|------|-------------|---------|---------|--------------|-----------------|-----------|----------|
| <input type="checkbox"/> Show advanced options |      |             |         |         |              |                 |           |          |
| Type                                           | Name | Starting    | Minimum | Maximum |              |                 |           |          |
| Constant                                       | dmg  | 2           |         |         |              |                 |           |          |
| Continuous                                     | e1   | 0.4         | 0.4     | 1.      |              |                 |           |          |
| Dependent                                      | e2   | Definition: | e1      |         |              |                 |           |          |
| Dependent                                      | e3   | Definition: | e1      |         |              |                 |           |          |
| Dependent                                      | f1   | Definition: | e1+df   |         |              |                 |           |          |
| Dependent                                      | f2   | Definition: | f1      |         |              |                 |           |          |
| Dependent                                      | f3   | Definition: | f1      |         |              |                 |           |          |
| Constant                                       | fad  | 2           |         |         |              |                 |           |          |
| Continuous                                     | df   | 0.1         | 0       | 1.      |              |                 |           |          |



## 3.6 Determine parameters for the remaining tests - R1

- In the same manner as for the uniaxial test, identify parameters  $e_3$  and  $f_3$  for the plane strain/R1 test.
- Use the damage exponent and stress coupling exponent as determined from the uniaxial parameter identification.
- In order to avoid that the failure strain is set lower than the instability strain, introduce a new variable  $df$  and set  $f_3 = e_3 + df$

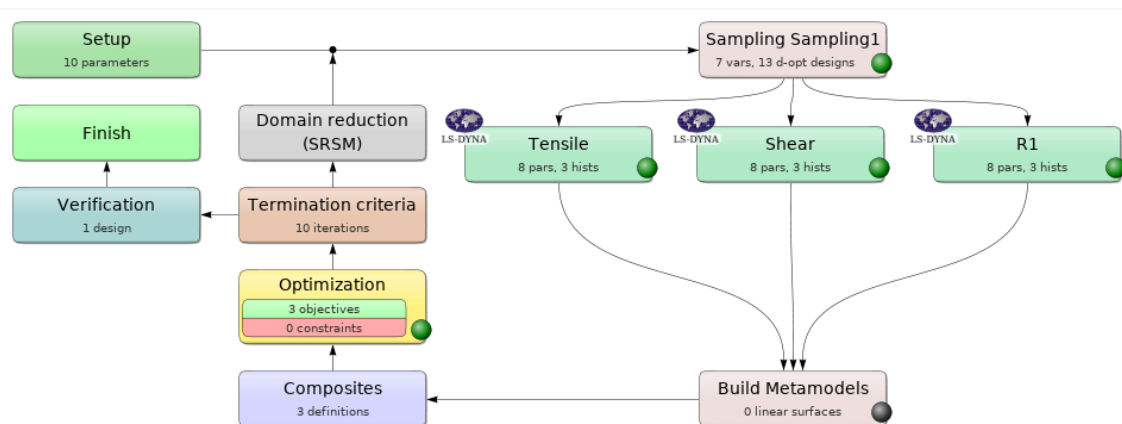
| Parameter Setup                                |      | Stage Matrix | Sampling Matrix | Resources | Features |
|------------------------------------------------|------|--------------|-----------------|-----------|----------|
| <input type="checkbox"/> Show advanced options |      |              |                 |           |          |
| Type                                           | Name | Starting     | Minimum         | Maximum   |          |
| Constant                                       | dmg  | 2            |                 |           |          |
| Dependent                                      | e1   | Definition:  | e3              |           |          |
| Dependent                                      | e2   | Definition:  | e3              |           |          |
| Continuous                                     | e3   | 0.4          | 0.2             | 0.5       |          |
| Dependent                                      | f1   | Definition:  | f3              |           |          |
| Dependent                                      | f2   | Definition:  | f3              |           |          |
| Dependent                                      | f3   | Definition:  | e3+df           |           |          |
| Constant                                       | fad  | 2            |                 |           |          |
| Continuous                                     | df   | 0.1          | 0.              | 1.        |          |



## 4. Do a full parameter identification

- Combine all the start values into a general GISSMO card and check the agreement with experiments.
- If further parameter fit is necessary, include all tests in a full optimization with all variables continuous.
- This optimization problem is substantial, but good start values of the variables will aid in quick convergence.

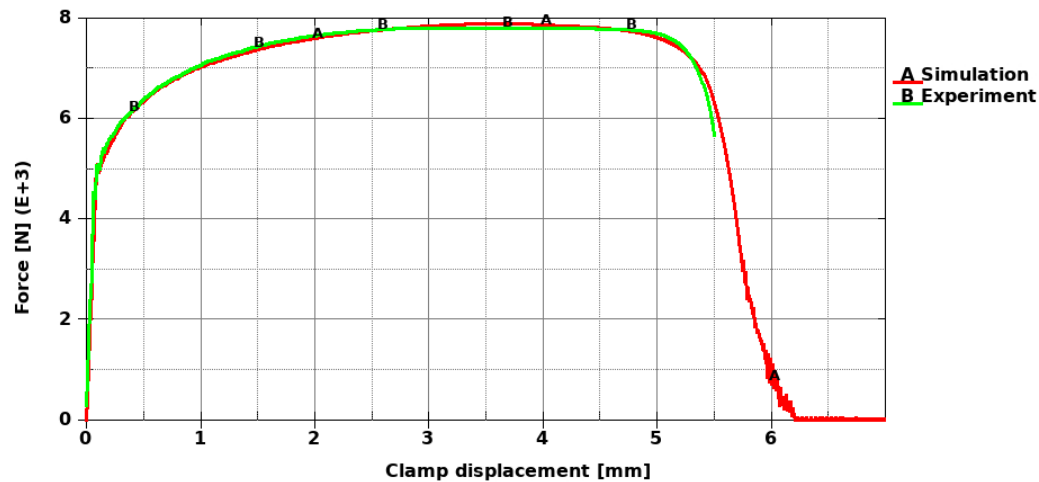
| Parameter Setup                                | Stage Matrix | Sampling Matrix    | Resources | Features |  |
|------------------------------------------------|--------------|--------------------|-----------|----------|--|
| <input type="checkbox"/> Show advanced options |              |                    |           |          |  |
| Type                                           | Name         | Starting           | Minimum   | Maximum  |  |
| Continuous                                     | dmg          | 2                  | 1.5       | 2.5      |  |
| Continuous                                     | e1           | 0.44               | 0.35      | 0.54     |  |
| Constant                                       | e2           | 0.17               |           |          |  |
| Continuous                                     | e3           | 0.25               | 0.2       | 0.3      |  |
| Dependent                                      | f1           | Definition: e1+df1 |           |          |  |
| Continuous                                     | f2           | 0.787              | 0.7       | 0.9      |  |
| Dependent                                      | f3           | Definition: e3+df3 |           |          |  |
| Continuous                                     | fad          | 2                  | 1.5       | 2.5      |  |
| Continuous                                     | df1          | 0.32               | 0.25      | 0.42     |  |
| Continuous                                     | df3          | 0.7                | 0.6       | 0.8      |  |



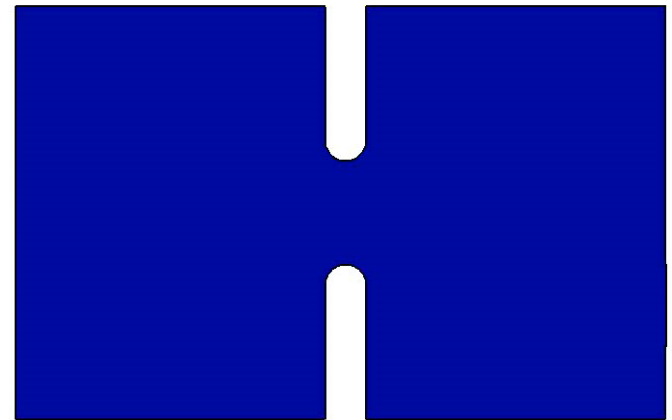
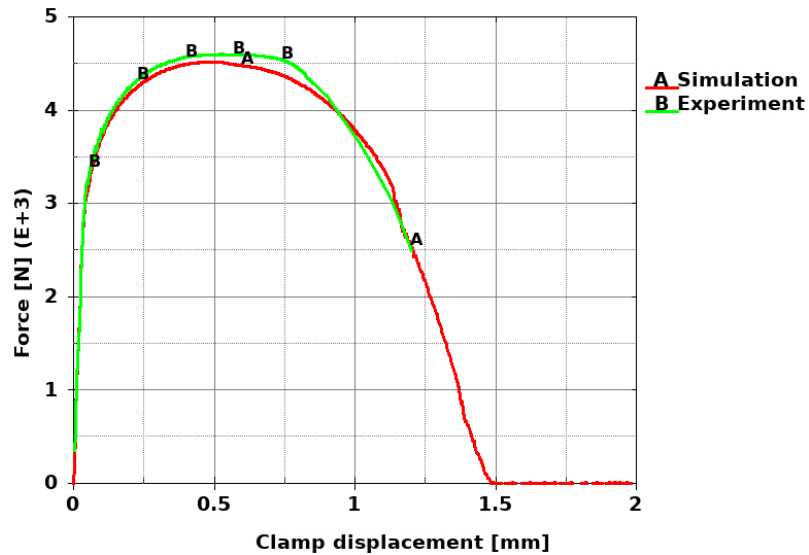
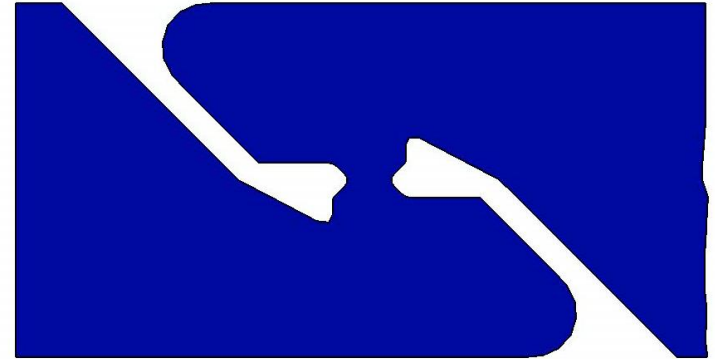
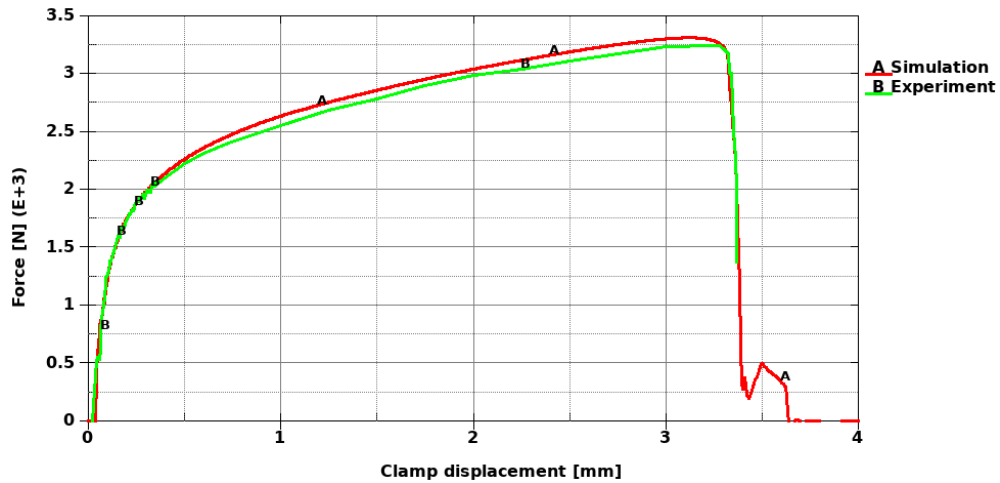
## 4.1 Results

|                 | e1   | e2   | e3   | f1   | f2   | f3   | Dmg  | fad   |
|-----------------|------|------|------|------|------|------|------|-------|
| Before full opt | 0.44 | 0.17 | 0.25 | 0.75 | 0.79 | 0.95 | 2    | 2     |
| After full opt  | 0.45 | 0.17 | 0.25 | 0.77 | 0.81 | 1.04 | 2.07 | 1.734 |

- In this example, the optimum parameters only differed slightly from the initial parameters. Thus, a full optimization might be unnecessary.

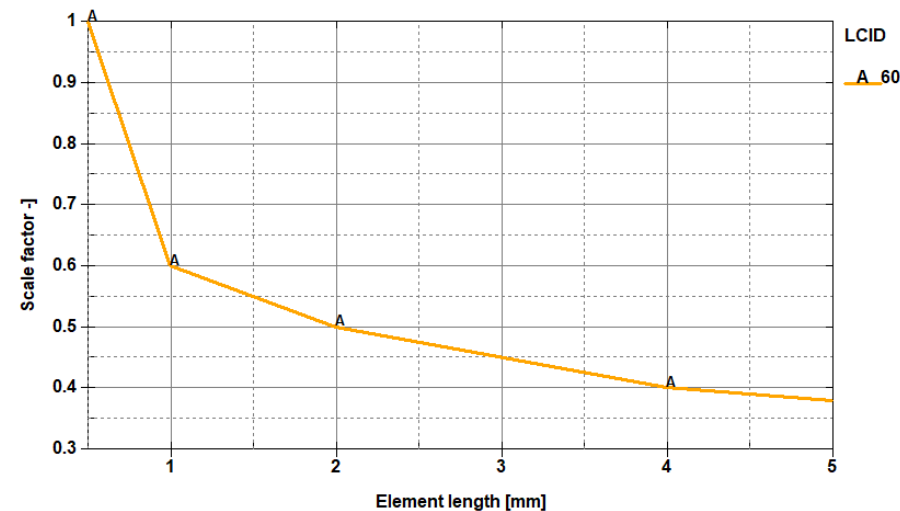
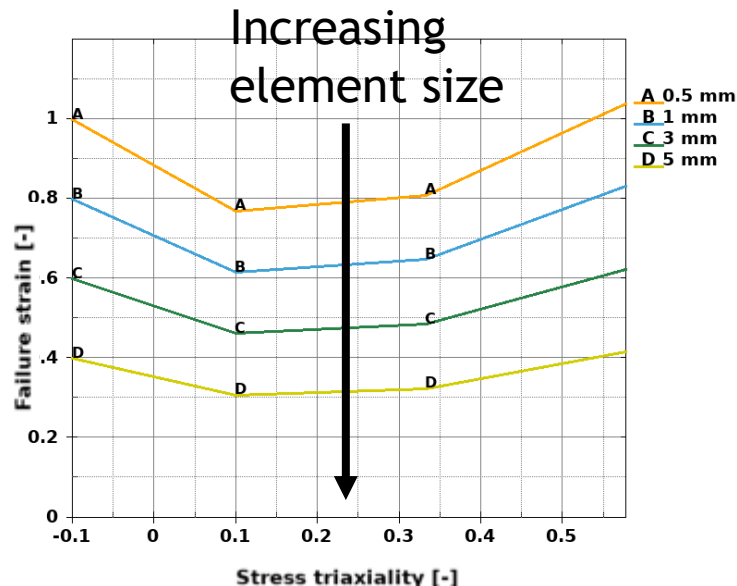


## 4.1 Results



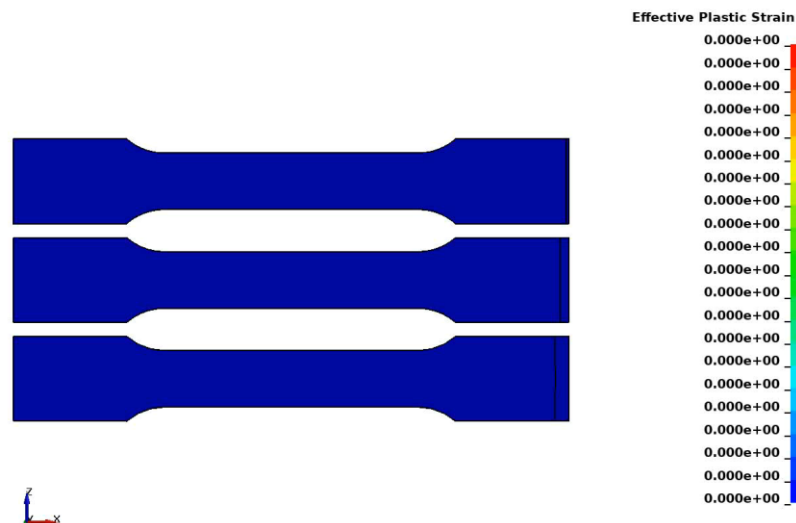
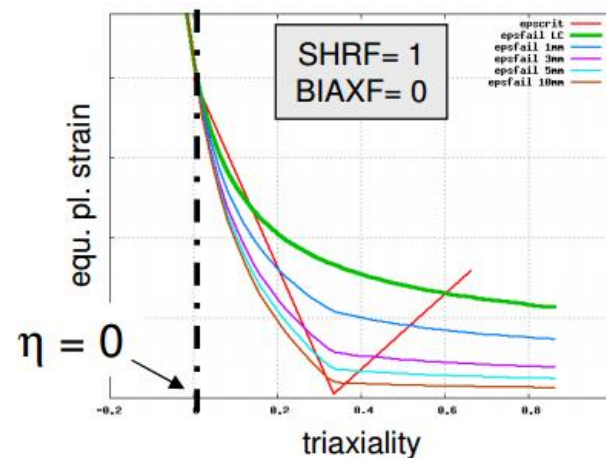
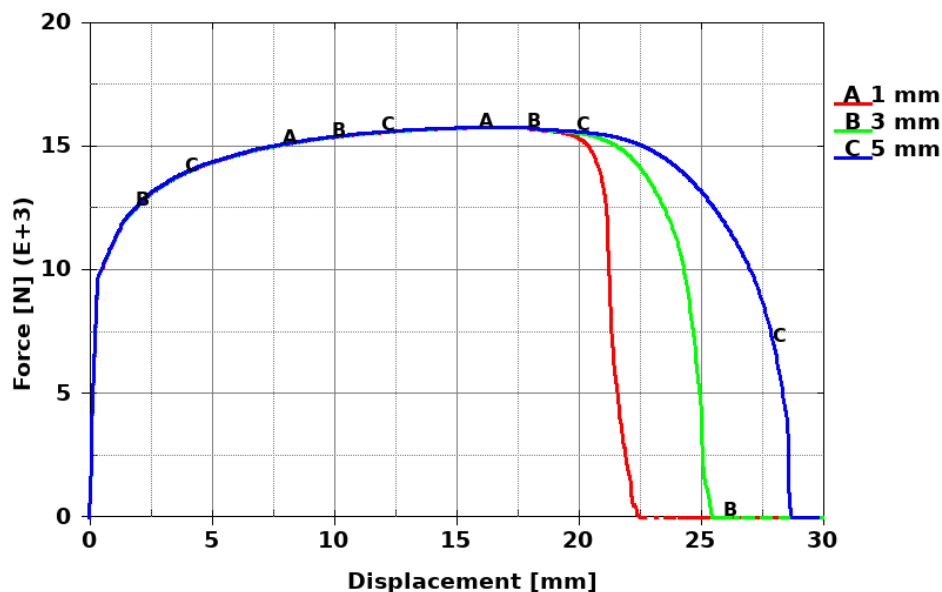
## 5. Regularization

- Beyond the point of instability, the solution becomes non-unique and it is therefore mesh dependent.
- In DIEM, regularization is done “automatically” by the “plastic displacement”,  $du^p = l_{ele} d\varepsilon_p$ , that drives the damage
- In GISSMO, there is a possibility to do mesh regularization, i.e. making the solution take the element size into account. It is done by scaling the failure strain by a load curve.

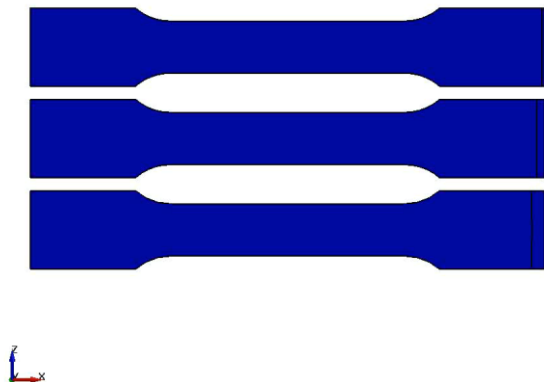
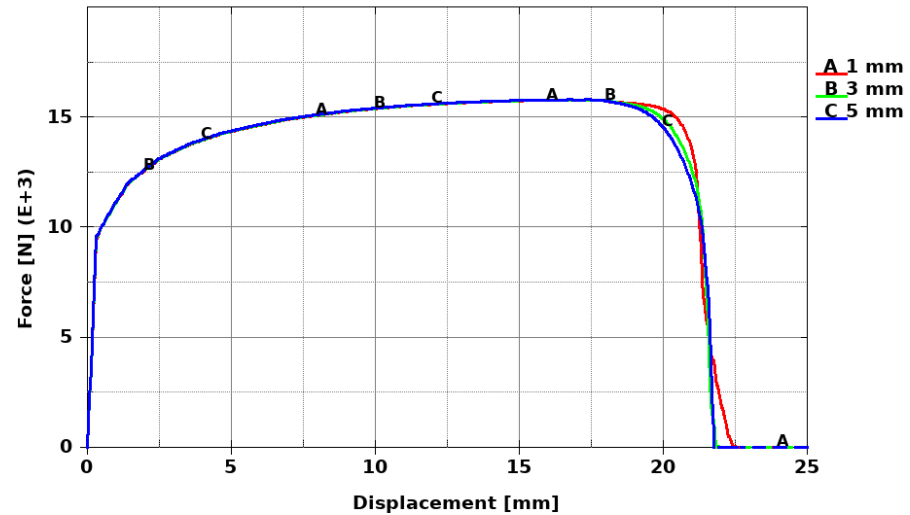
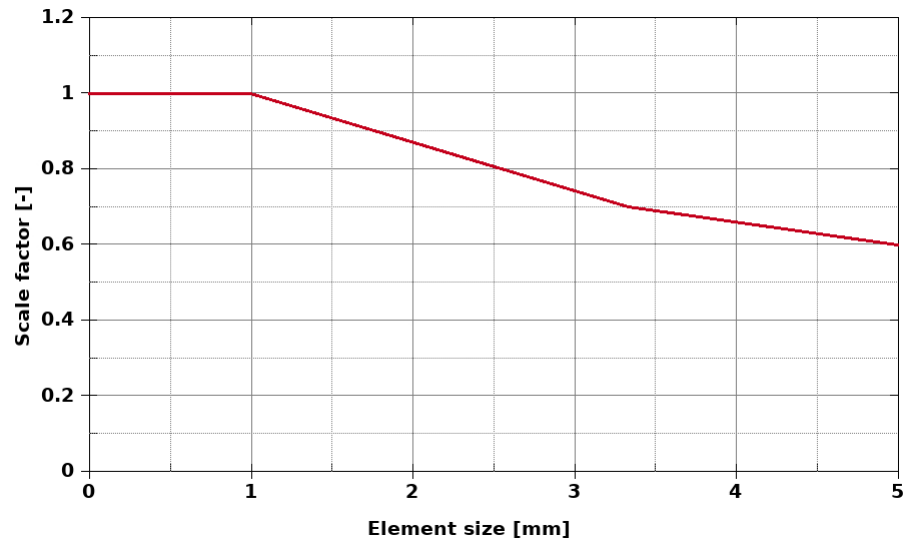


## 5. Regularization cont.

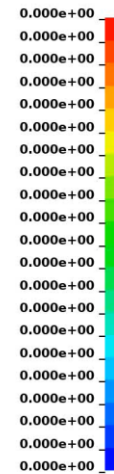
- Furthermore, it is possible to reduce scaling for the shear and biaxial regions by the SHRF and the BIAXF parameters.
- From our experience, it works well to remove the regularization for Shear and keep it for the Biaxial region, SHRF=1 and BIAXF=0.
- The regularization scale factors can be determined by e.g. simulating a large tensile test specimen with different mesh sizes.



## 5. Regularization cont.



Effective Plastic Strain





# Discussion and conclusion

- The methodology presented here is a suggested way of doing parameter identification and is not intended to be a universally prevailing solution
- The material modeling and the damage modeling are highly coupled.
- Plan your testing to be suitable for the material, element size and application and spread the triaxialities as much as possible
- LS-OPT is highly compatible with both pre- and postprocessing of LS-DYNA
- We suggest start fitting the material model (elasticity and plasticity) with no damage.
- Make sure that the damage model has possibility to follow the experimental response.
- Identify the parameters for each test and finish with a large optimization of all tests if necessary.
- Verify the model with a test that is suitable for your application, e.g. 3-point bending, plate with hole, spotweld etc.

# Related webinars and papers

## ■ Material modeling and failure models

- DYNAmore Express: **Introduction to Material Characterization**, DYNAmore GmbH Webinar 2020-05-22, <https://youtu.be/23ascSSRnzQ>
- **Ductile failure modeling in LS-DYNA**, DYNAmore Nordic Webinar 2020-08-20. (slides available for customers on files.dynamore.se)
- DYNAmore Express: **Recent developments in GISSMO**, DYNAmore GmbH Webinar 2020-04-30, <https://youtu.be/r90zTSQJk9U>
- **DIEM and the No-Copy option in LS-DYNA**, DYNAmore Nordic video, 2020-08-11

## ■ Plastics

- DYNAmore Express: **Modeling Plastics in LS DYNA (Part 1)** - Isotropic Modelling of Thermoplastics, DYNAmore GmbH Webinar 2020-06-19, [https://youtu.be/LN\\_FlM-c9As](https://youtu.be/LN_FlM-c9As)
- DYNAmore Express: **Modeling plastics in LS DYNA (Part 2)** - Anisotropic Modelling of Thermoplastics, DYNAmore GmbH Webinar 2020-06-26, <https://youtu.be/WiL4K-5pvRU>

## ■ Calibration

- **Parameter identification using regular curve matching**, DYNAmore Nordic video, <https://www.youtube.com/watch?v=mOWoqcKtTt4&t=12s>
- **Full-Field Calibration**, DYNAmore Nordic video, <https://www.youtube.com/watch?v=hQJ9rM3blXU&t=178s>

## ■ This and previous webinars by Dynamore Nordic on our customer client area <https://files.dynamore.se/index.php/s/information>

## ■ Dynalook.com

- Papers from the 2020 International LS-DYNA conference are now available

Thank you!

