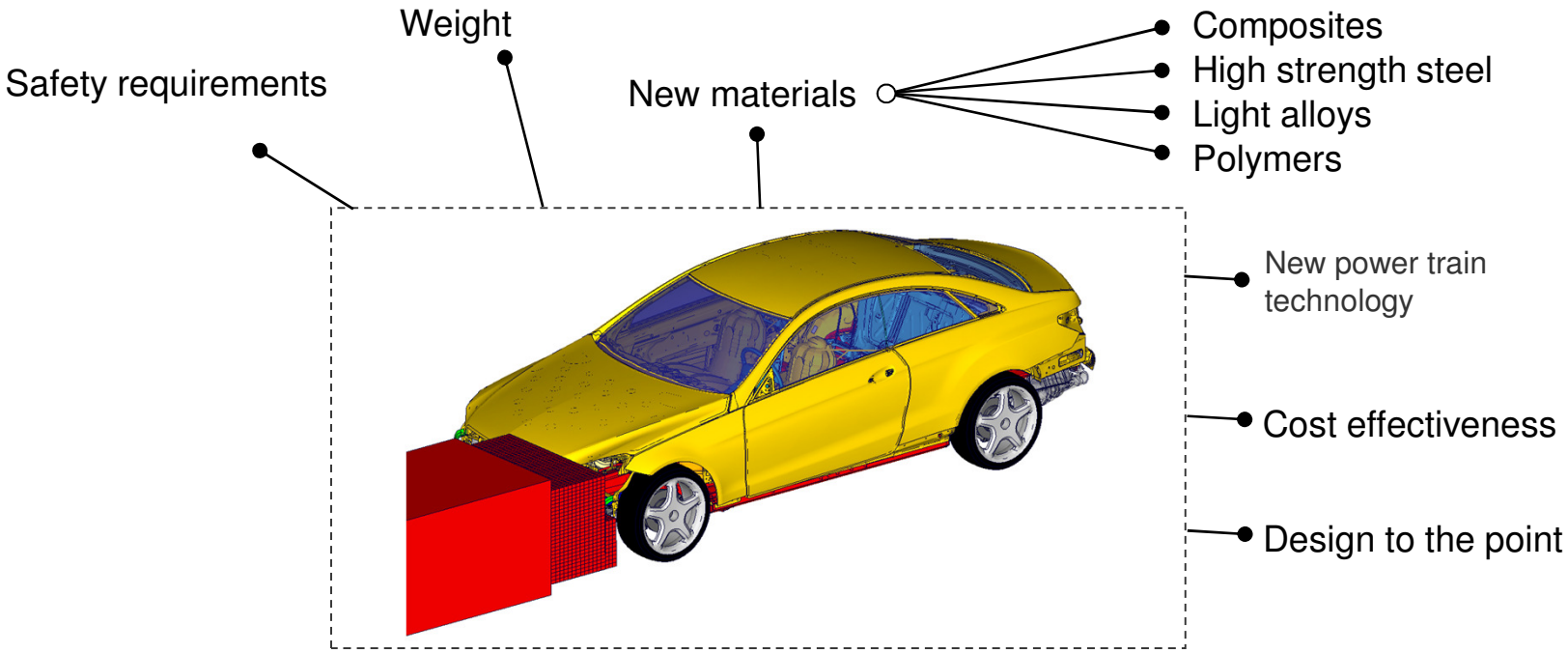
Recent Enhancements to the GISSMO Failure Model in LS-DYNA

André Haufe[1], Markus Feucht[2], Frieder Neukamm[2], Paul DuBois[3]

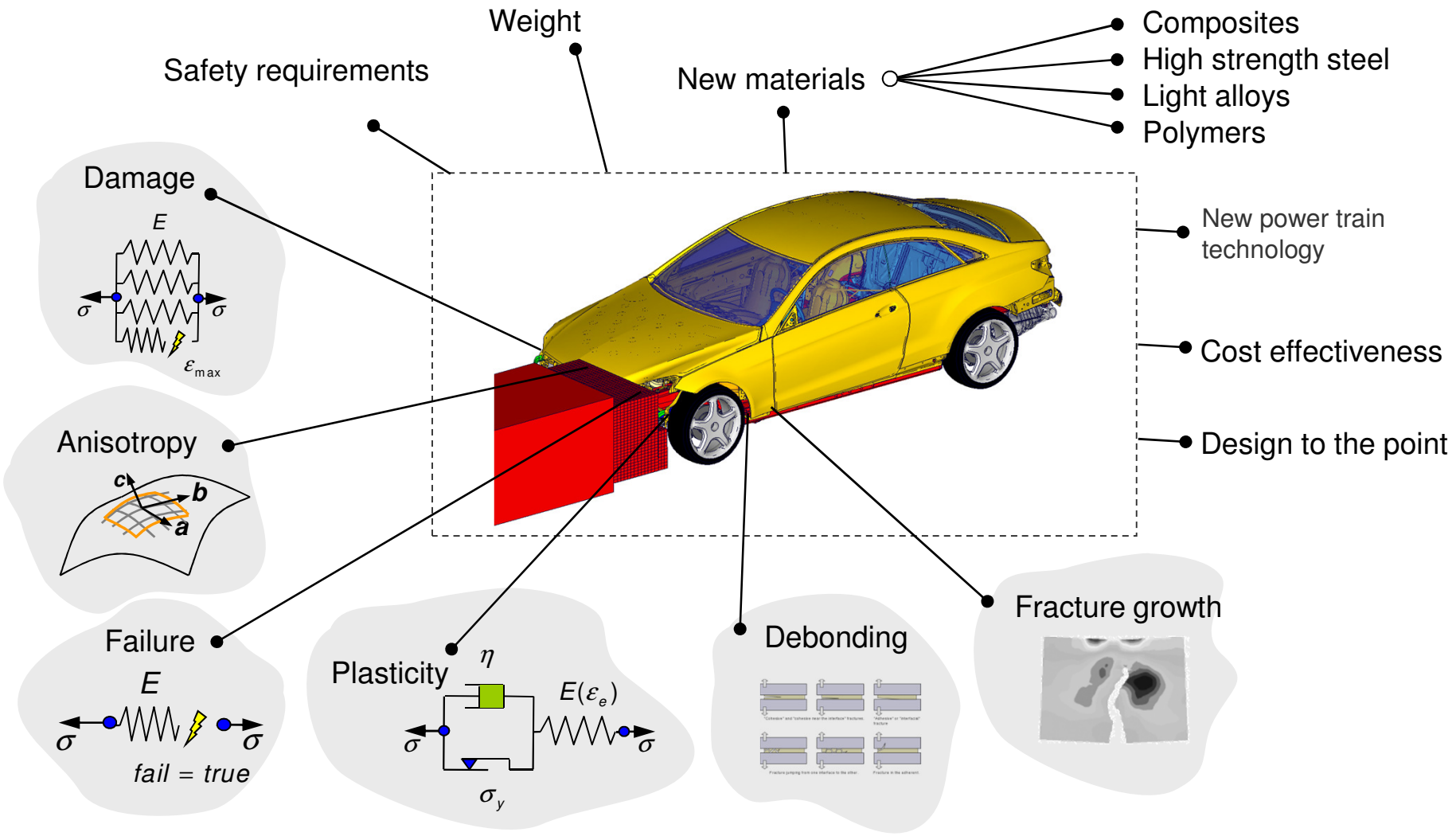
[1] DYNAmore GmbH, 70565 Stuttgart, Germany
[2] Daimler AG, EP/SPB, 71059 Sindelfingen, Germany
[3] Consultant, 63065 Offenbach, Germany

Dynamore GmbH
Industriestraße 2
70565 Stuttgart
http://www.dynamore.de

Technological challenges in the automotive industry

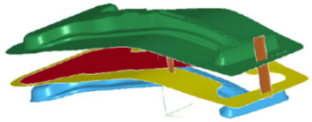


Technological challenges in the automotive industry

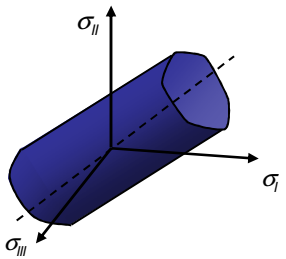


Closing the process chain

Forming simulation



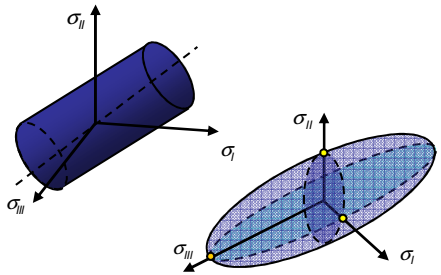
- **Hill based models**
- Anisotropiy of yield surface
- Kinematic/Isotropic hardening
- Failure by FLD (post-processing)
- No computation of damage



???

Crash simulation

- **v. Mises or Gurson model**
- Strain rate dependency
- Isotropic hardening
- Damage evolution
- Failure models (damage variable necessary!!)



Different ways to realize a consistent modeling

One Material Model for Forming and Crash Simulation

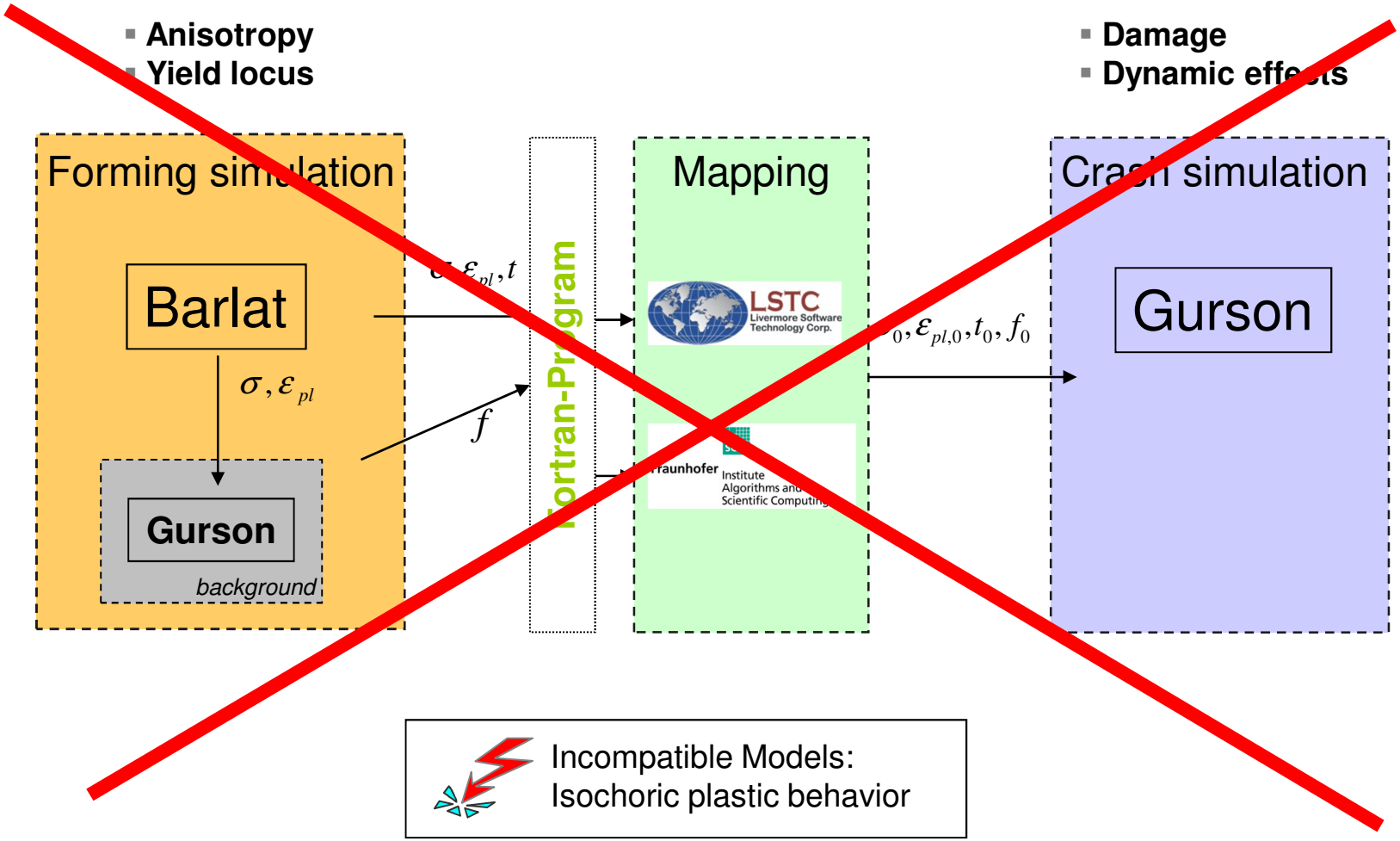
- Requirements for Forming Simulations: Anisotropy, Exact Description of Yield Locus, Kinematic Hardening, etc.
- Requirements for Crash Simulation: Dynamic Material Behavior, Failure Prediction, Energy Absorption, Robust Formulation
- Leads to very complex model

Modular Concept for the Description of Plasticity and Failure

- Plasticity and Failure Model are treated separately
- Existing Material Models are kept unaltered
- Consistent modeling through the use of one damage model for forming and crash simulation

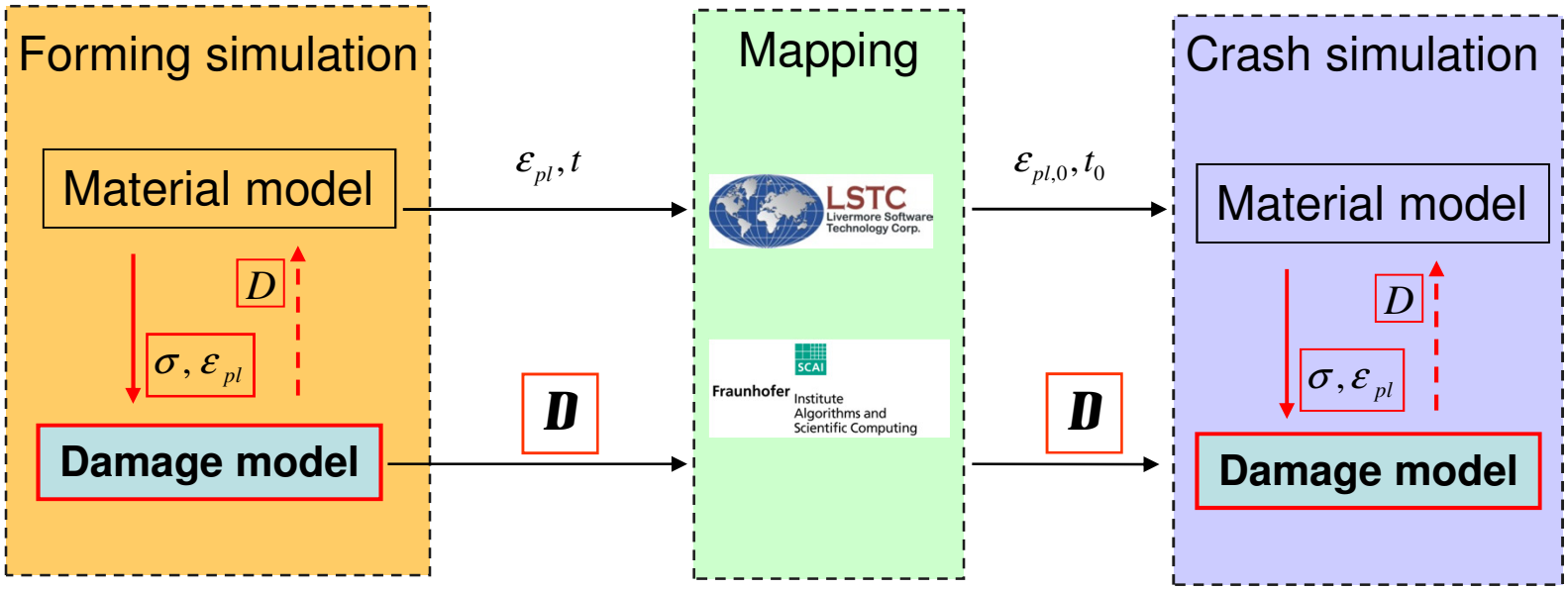
***MAT_ADD….(damage)**

Produceability to Serviceability



Schmeing, Haufe & Feucht [2007]
Neukamm, Feucht & Haufe [2007]

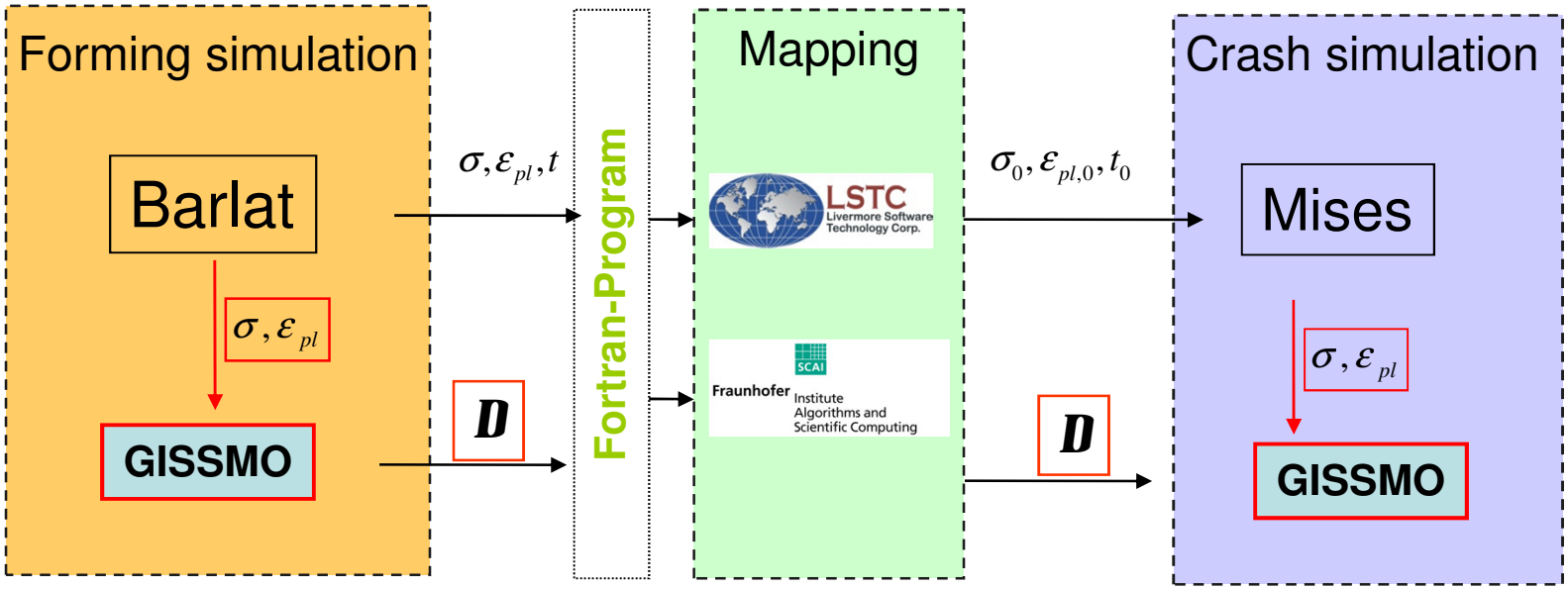
Produceability to Serviceability: Modular Concept



Modular Concept:

- Proven material models for both disciplines are retained
- Use of one continuous damage model for both

Produceability to Serviceability: Modular Concept
Current status in 971R5



Ebelsheiser, Feucht & Neukamm [2008]
Neukamm, Feucht, DuBois & Haufe [2008-2010]

GISSMO – a short description

Effective stress concept (similiar to MAT_81/224 etc.)

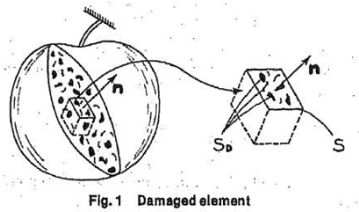
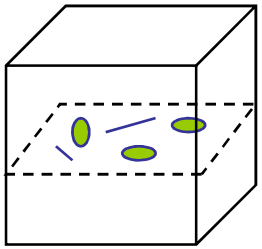


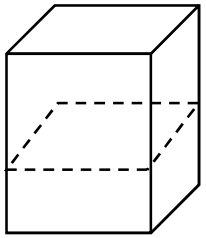
Fig. 1 Damaged element

J. Lemaitre, A Continuous Damage Mechanics Model for Ductile Fracture



Overall Section Area containing micro-defects

$$S$$



Reduced ("effective") Section Area

$$\hat{S} < S$$

Measure of Damage

$$D = \frac{S - \hat{S}}{S}$$

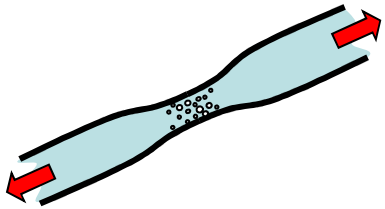
Reduction of effective cross-section leads to reduction of tangential stiffness

→ Phenomenological description

$$\boldsymbol{\sigma}^{*} = \boldsymbol{\sigma}\left(1 - D\right)$$

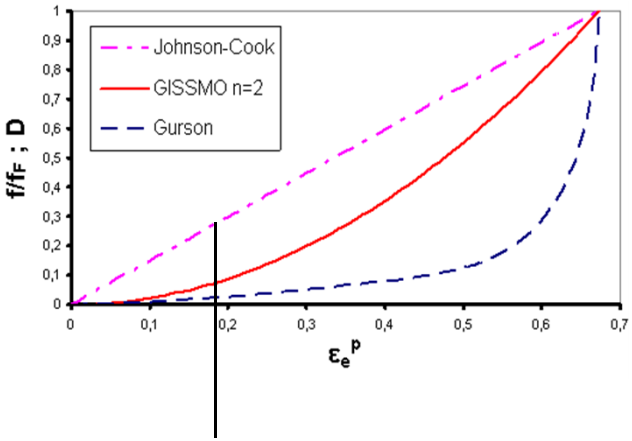
GISSMO - a short description

Ductile damage and failure



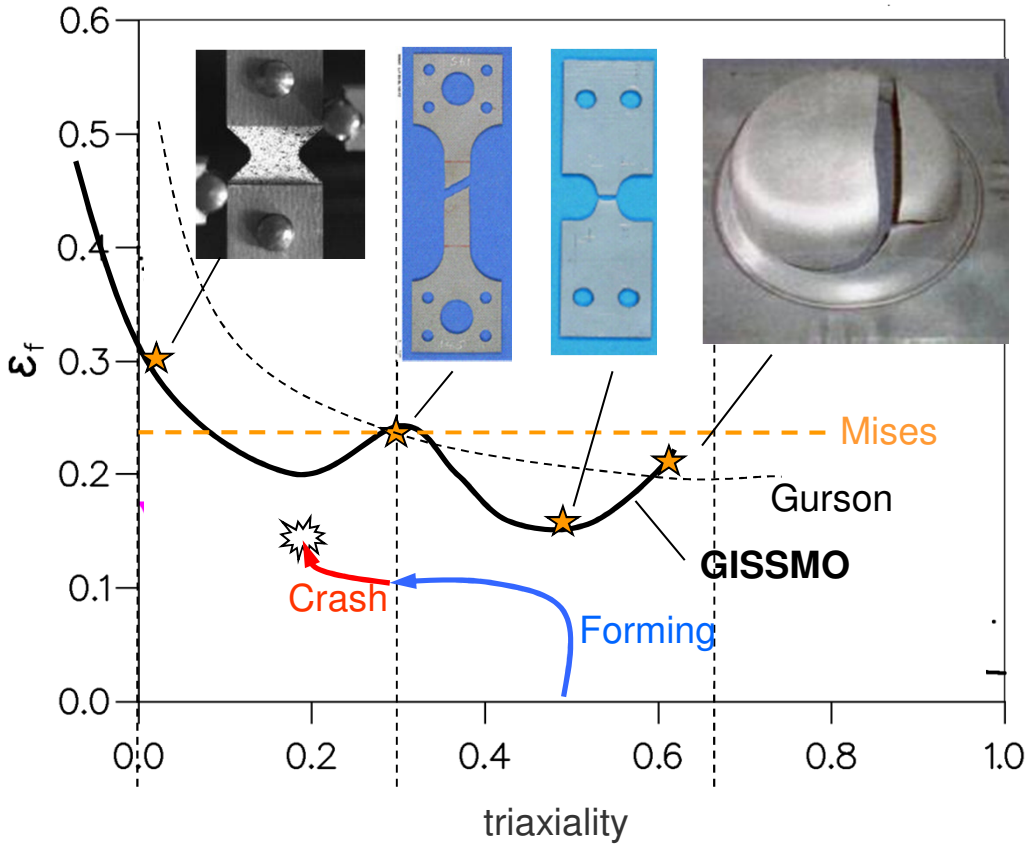
Damage Evolution

$$\dot{D}_f = \frac{n}{\varepsilon_f} D_f^{\left(1-\frac{1}{n}\right)} \dot{\varepsilon}_p$$



Damage overestimated for linear damage accumulation

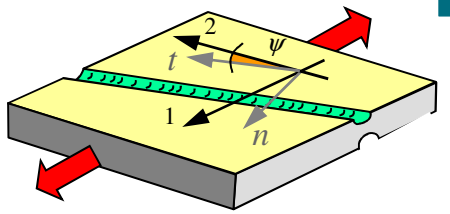
Failure Curve



Neukamm, Feucht, DuBois & Haufe [2008-2010]

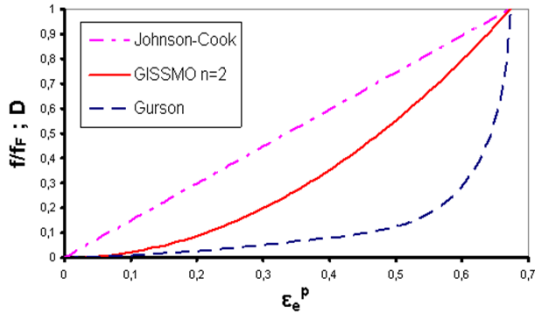
GISSMO – a short description

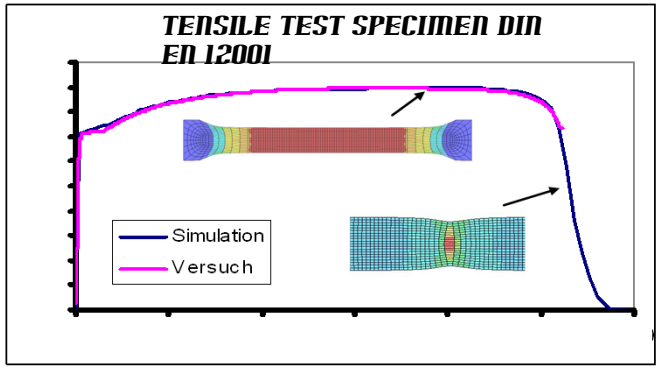
Engineering approach for instability failure



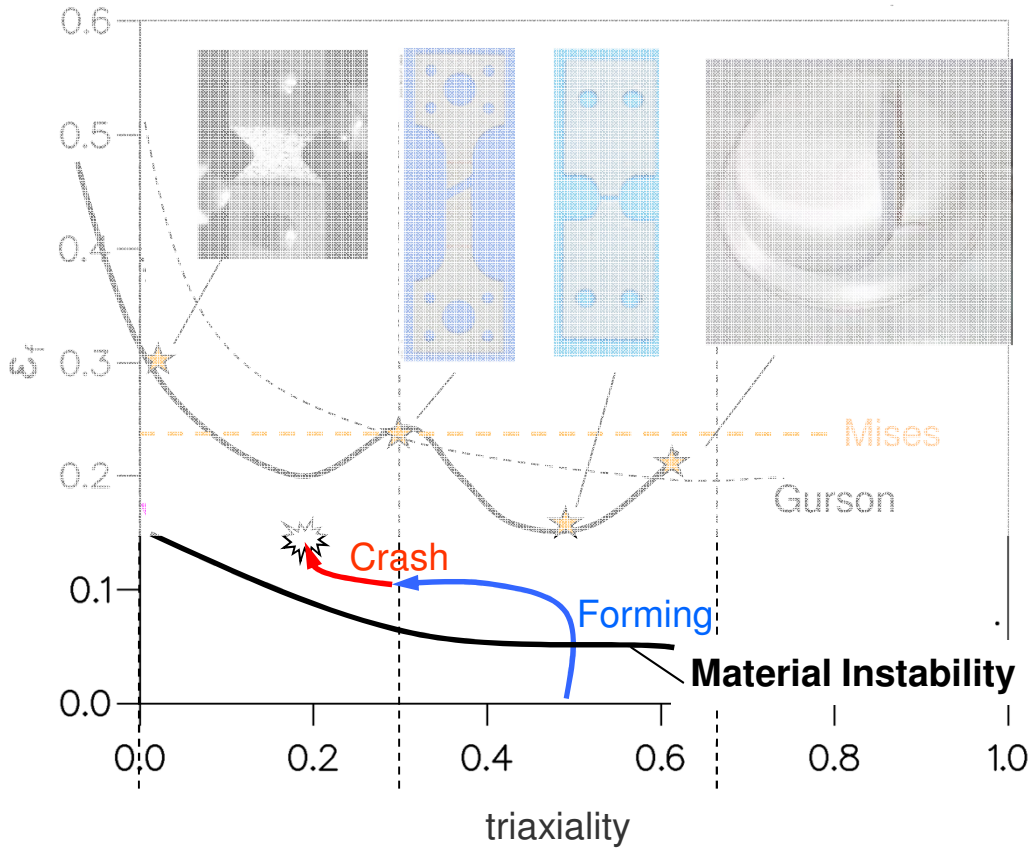
Evolution of Instability

$$\Delta F = \frac{n}{\varepsilon_{v,loc}} F^{\left(1-1/n\right)} \Delta\varepsilon_v$$





Material Instability

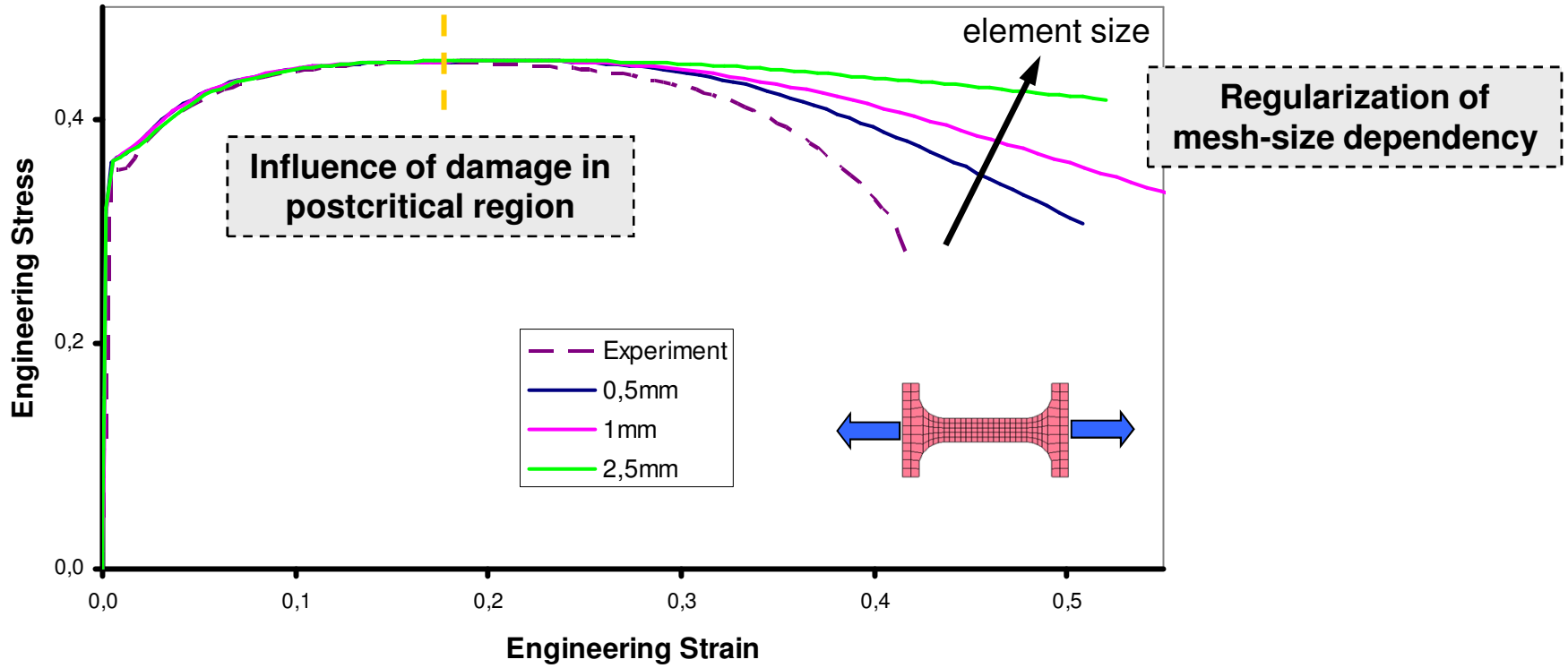


Neukamm, Feucht, DuBois & Haufe [2008-2010]

GISSMO – a short description

Inherent mesh-size dependency of results in the post-critical region

Simulations of tensile test specimen with different mesh sizes

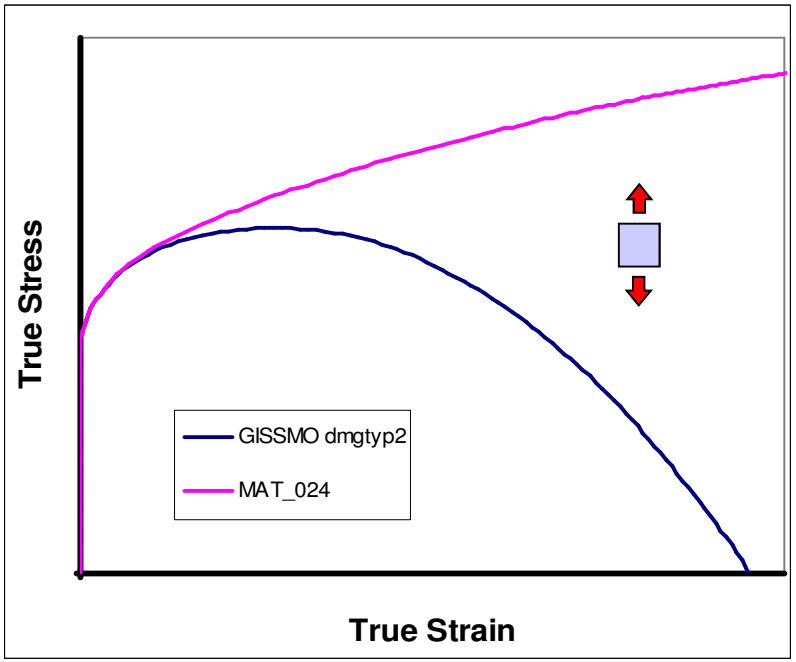


GISSMO – a short description

Generalized Incremental Stress State dependent damage MOdel

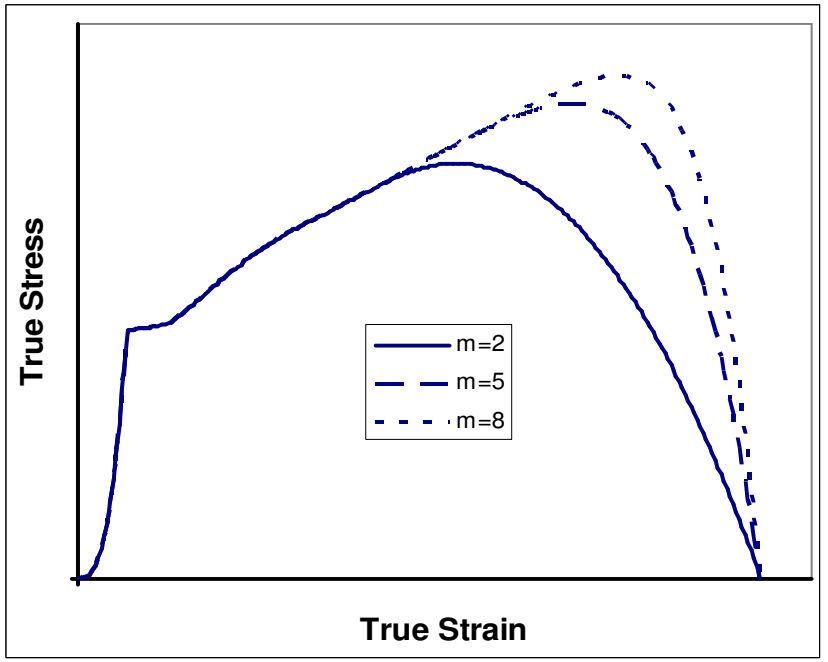
DMGTYP: Flag for coupling (Lemaitre)

$$\sigma^* = \sigma\,(1-D)$$



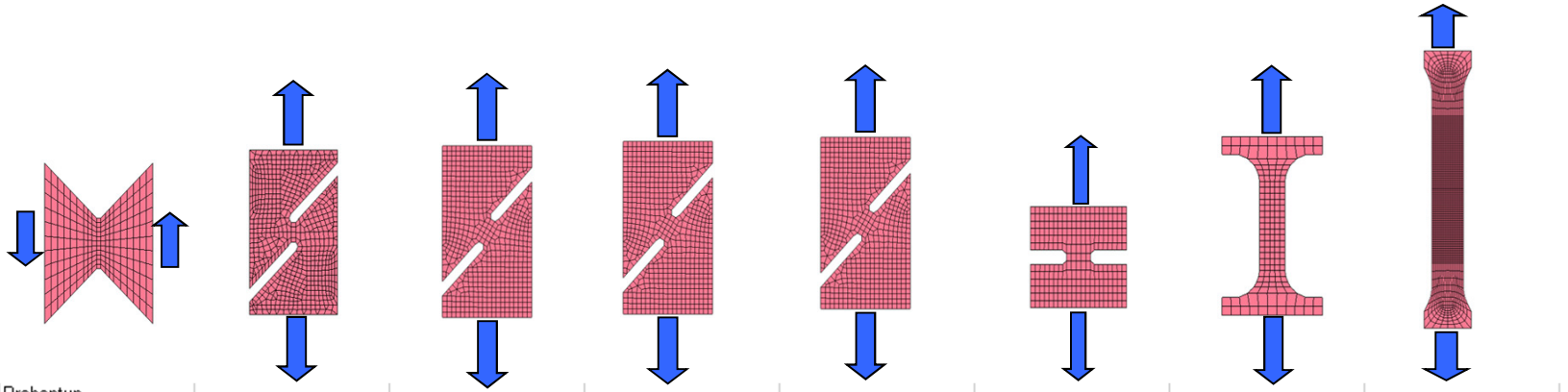
DCRIT, FADEXP: Post-critical behavior

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



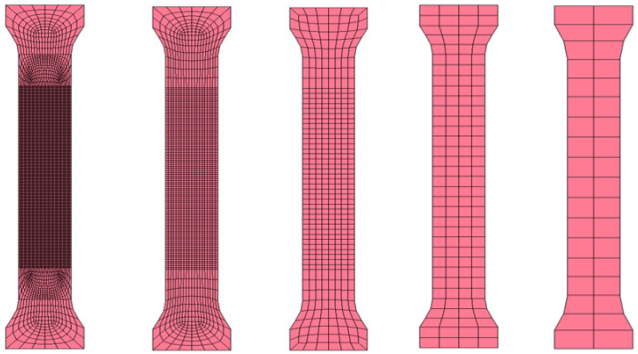
GISSMO

Identification of damage parameters: Range of experiments and simulations



Netzfeinheit	Probentyp: Arcan	Scherzug 0°	Scherzug 15°	Scherzug 30°	Scherzug 45°	Kerbzug R1	Mini-Flachzug	DIN-Flachzug
0,5mm								
1mm								
2,5mm								
5mm								
10mm								

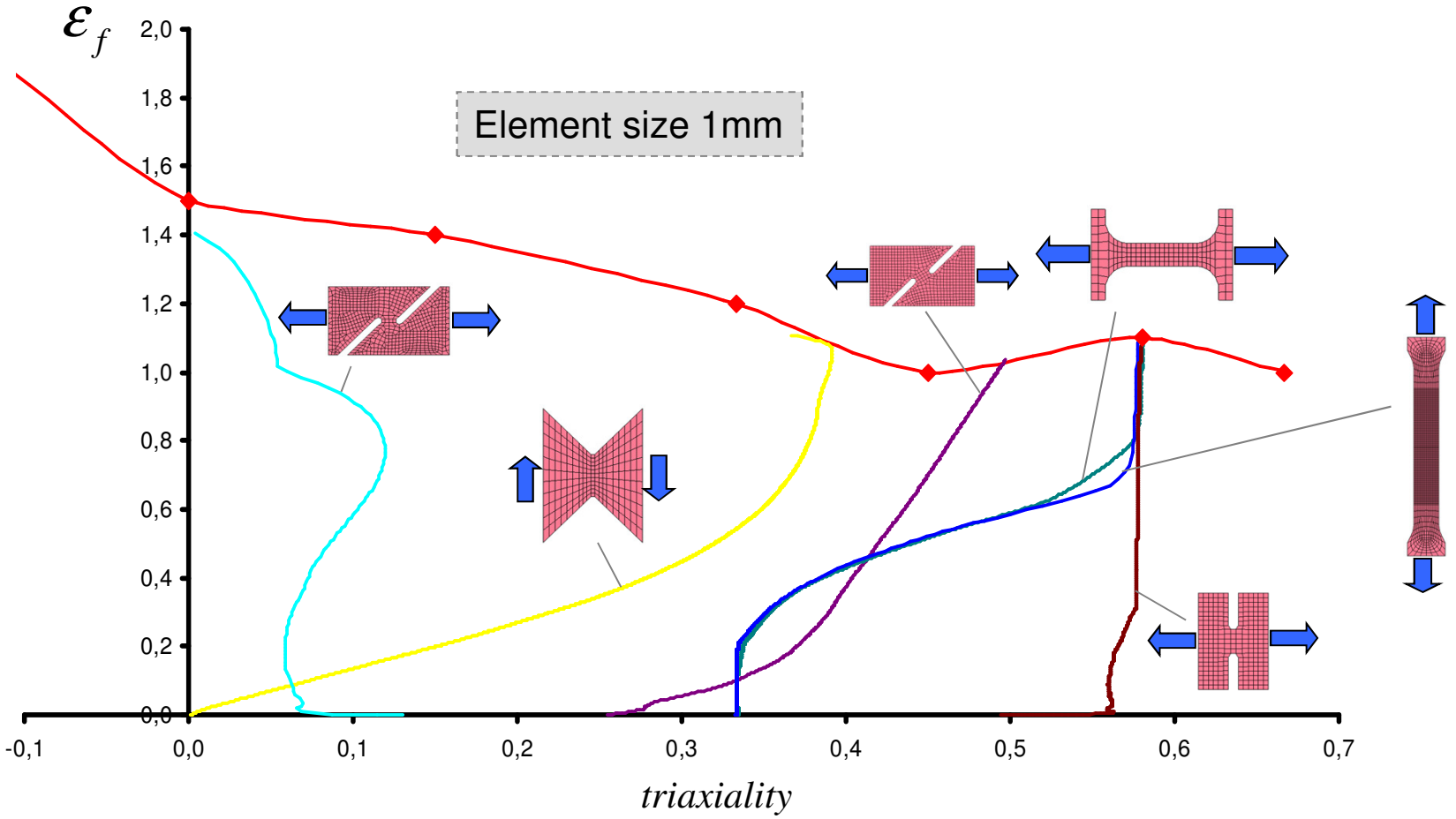
To be considered:
8 Specimen geometries
5 Discretisations



Institut Werkstoffmechanik

GISSMO

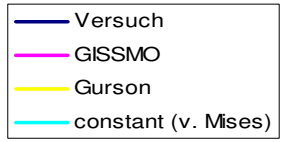
Equivalent plastic strain vs. triaxiality

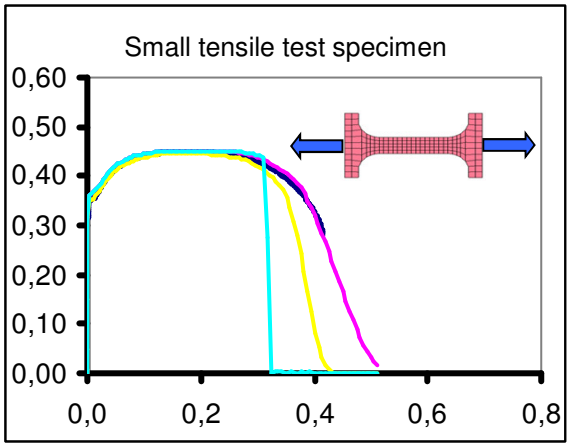


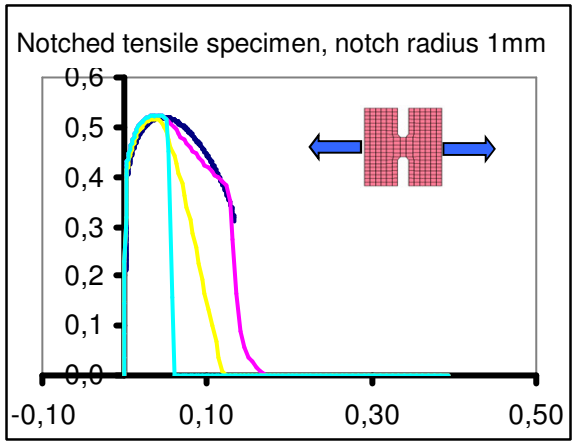
GISSMO vs. Gurson vs. 24/81

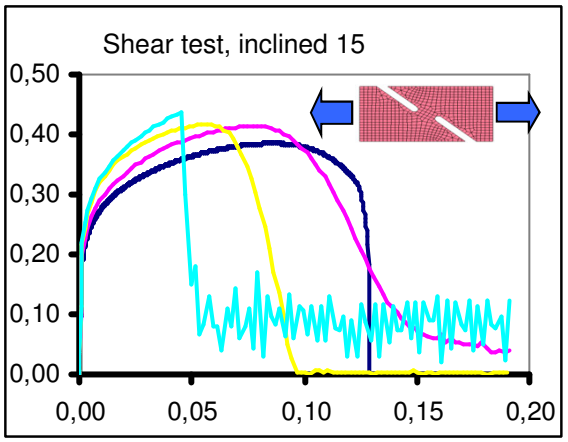
Comparison of experiments and simulations

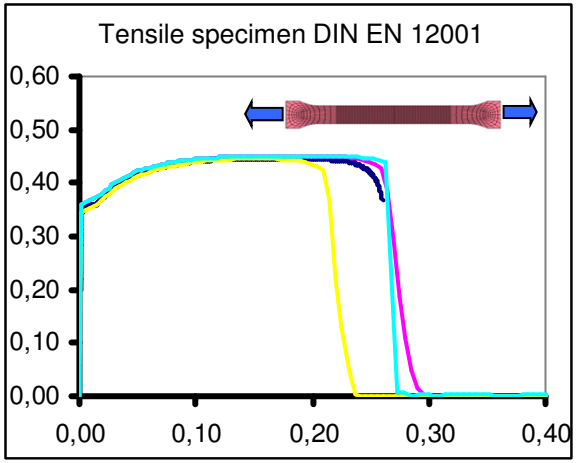
Institut Werkstoffmechanik

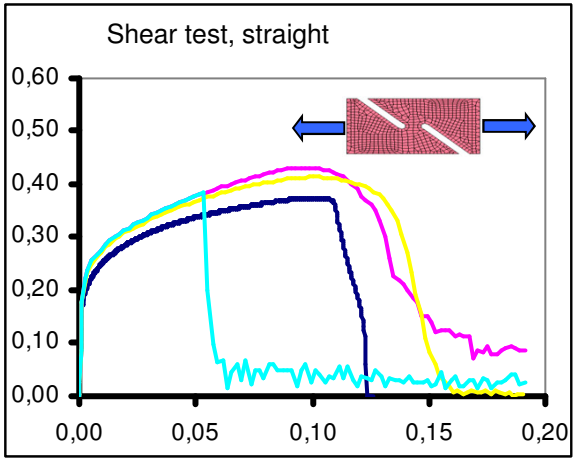


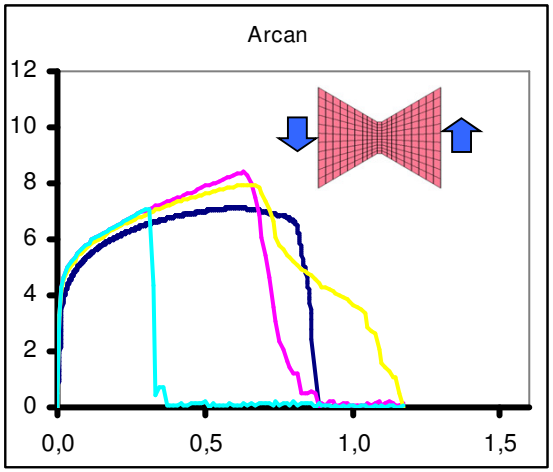






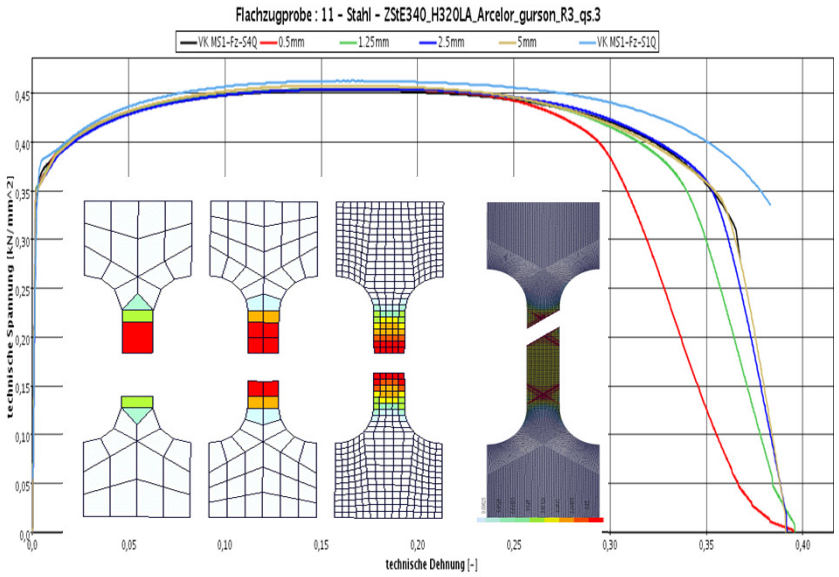


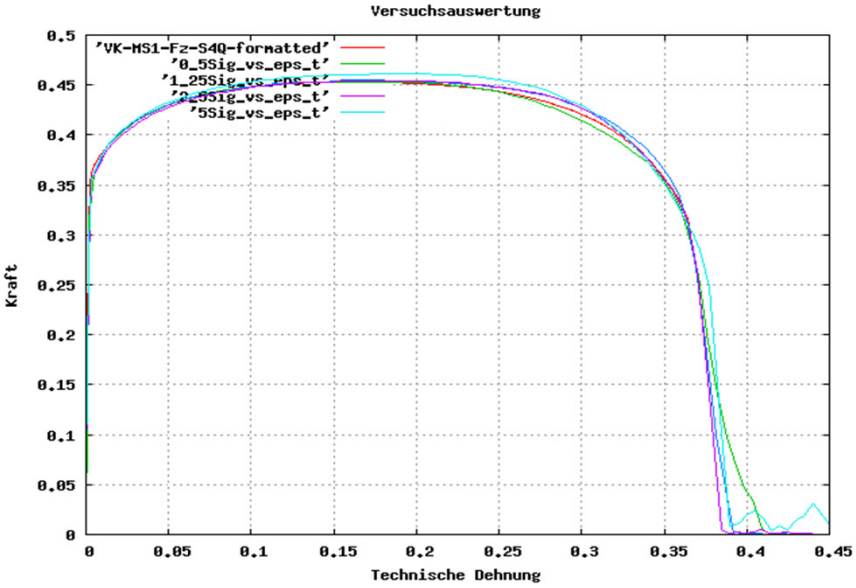




Gurson vs. GISSMO – “regularized”

Regularization of element size dependency





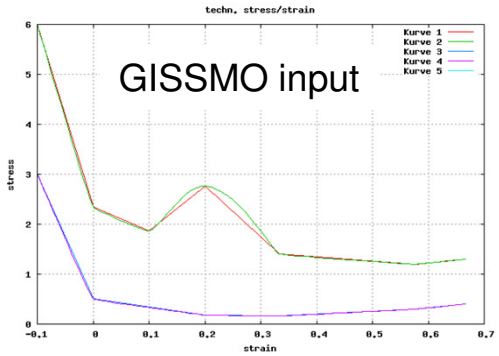
Gurson

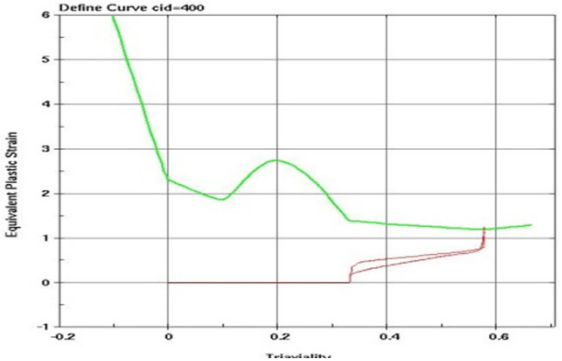
- Resultant Failure Strain constant
- Failure energy depending on el. size
- Identification of damage parameters is difficult

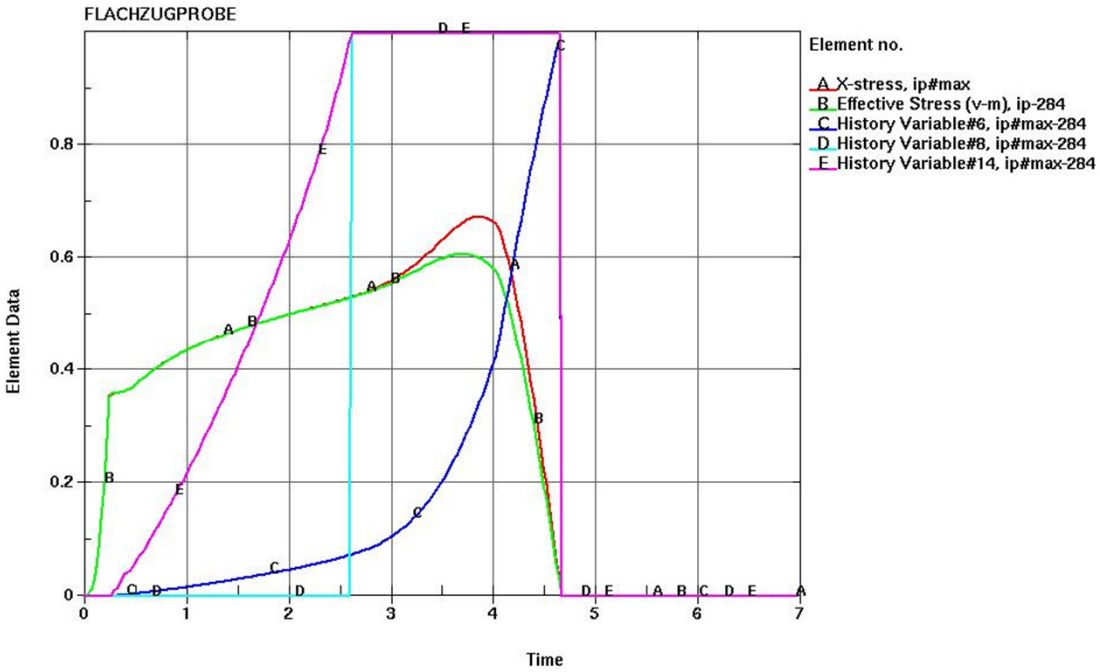
GISSMO

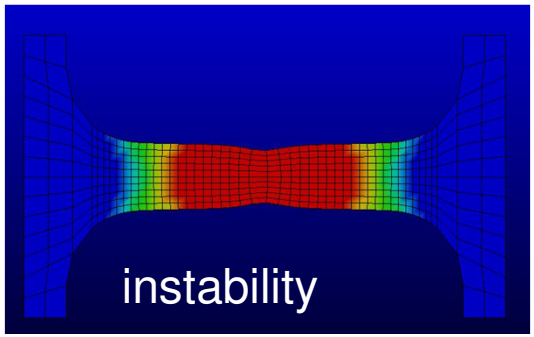
- Failure Strain constant
- Fracture energy constant
- Identification of Damage Parameters is more straight-forward

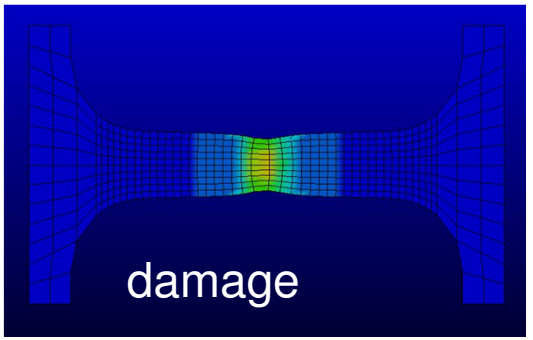
Example: tension rod



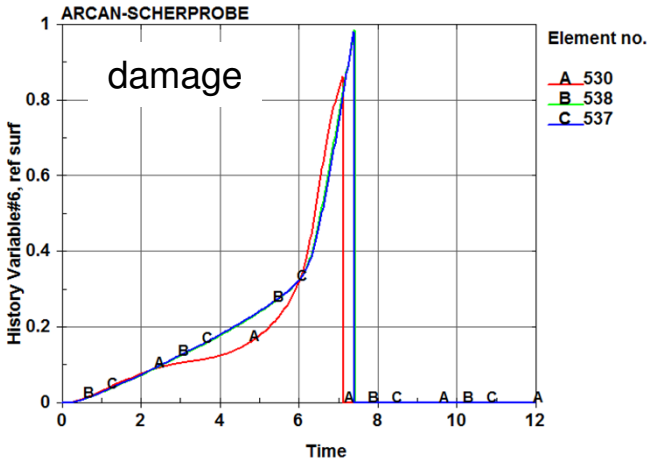


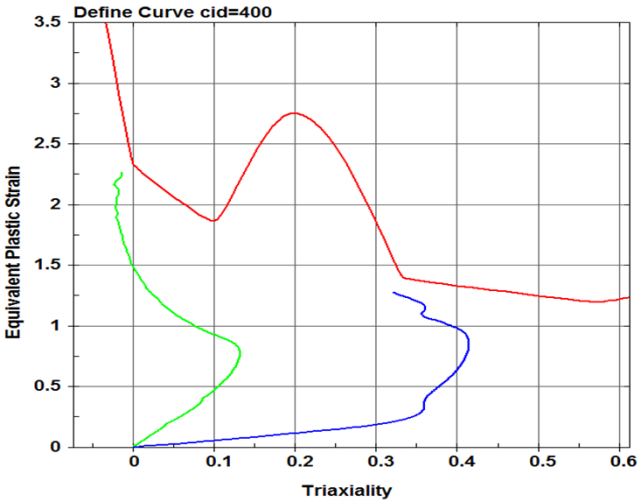


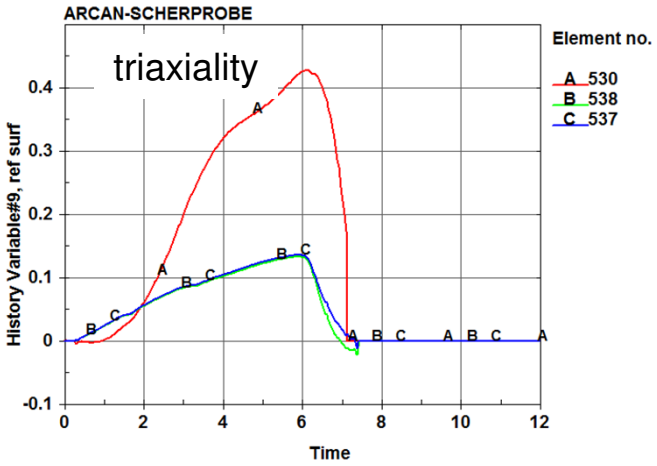


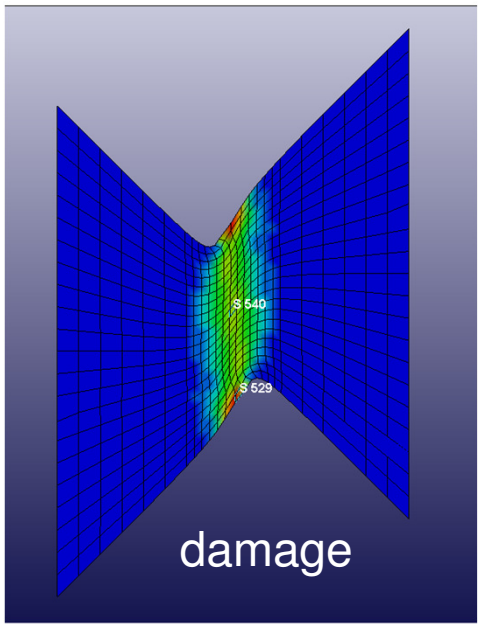


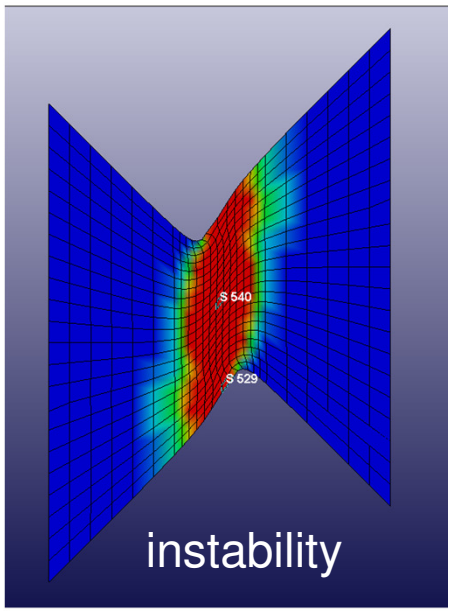
Example: Arcan shear test





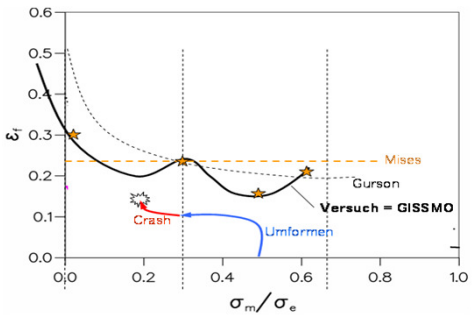


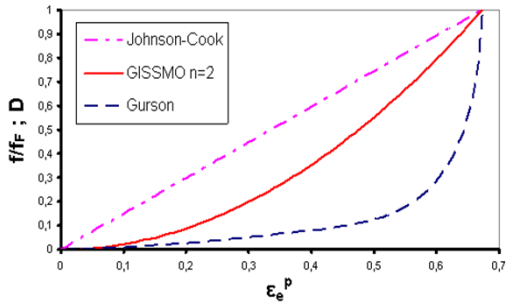




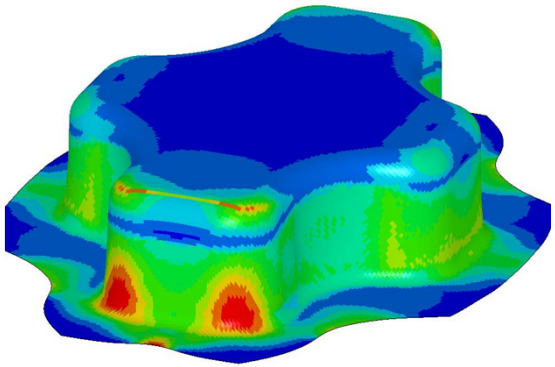
GISSMO

Deep-draw simulation of cross-die using GISSMO

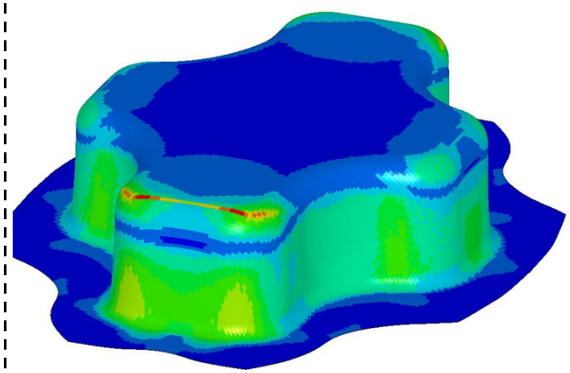




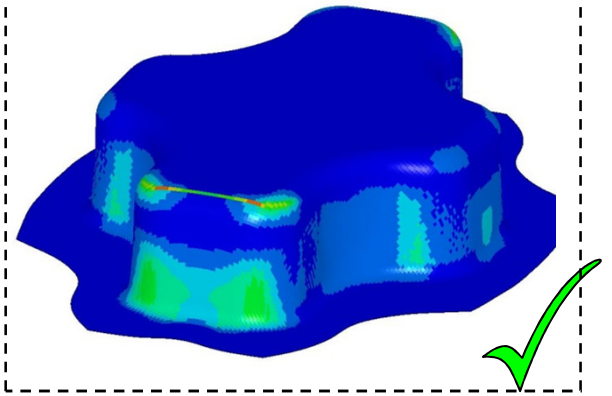
- Constant failure criterion
- Linear damage accumulation
- Failure not predicted correctly



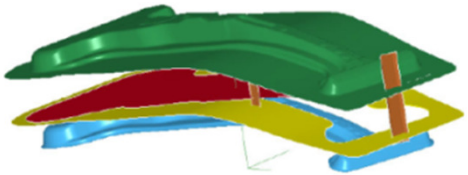
- GISSMO-Criterion
- Linear accumulation of damage
- Possibly overestimated damage



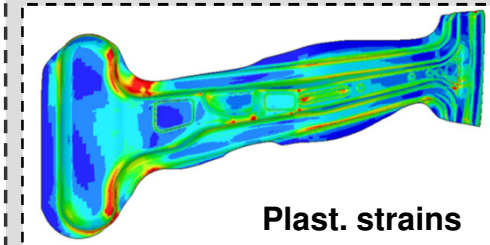
- GISSMO-Criterion
- Nonlinear damage accumulation
- Rupture predicted correctly

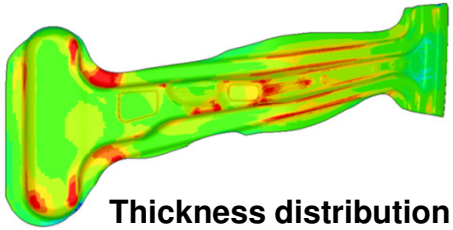


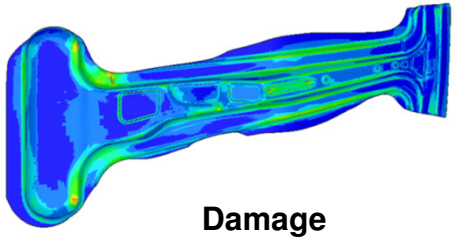
Process chain with GISSMO



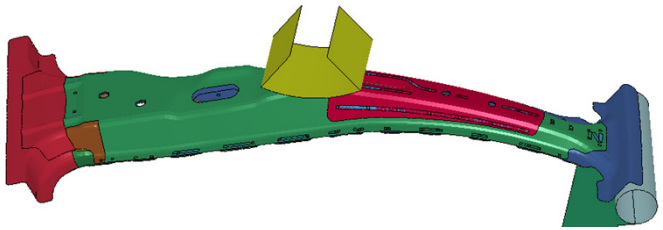
Forming simulation:
***MAT_36 (Barlat 89)**
***MAT_ADD_EROSION (GISSMO)**







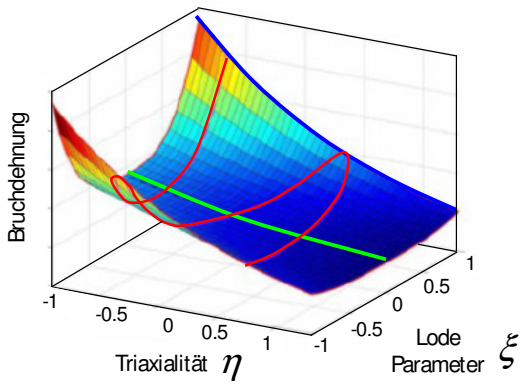
Mapping

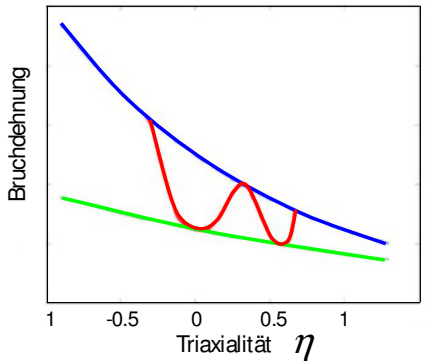


Crash Simulation:
***MAT_24 (Mises)**
***MAT_ADD_EROSION (GISSMO)**

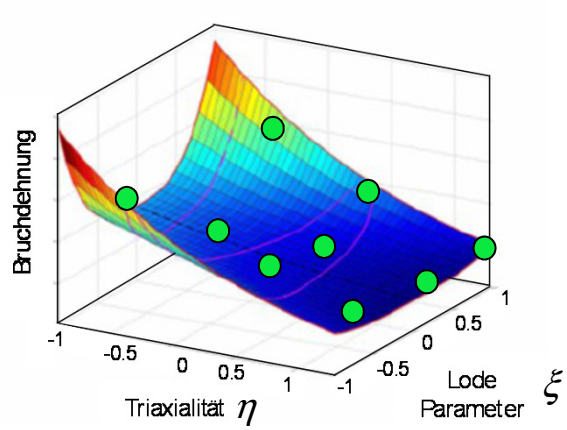
GISSMO
Failure criterion extd. for 3D solids

Shells (2D)





Solids (3D)



- For shells (2D with the assumption of plane stress) triaxility and Lode angle depend on each other.

  → fracture strain is a function of the triaxiality

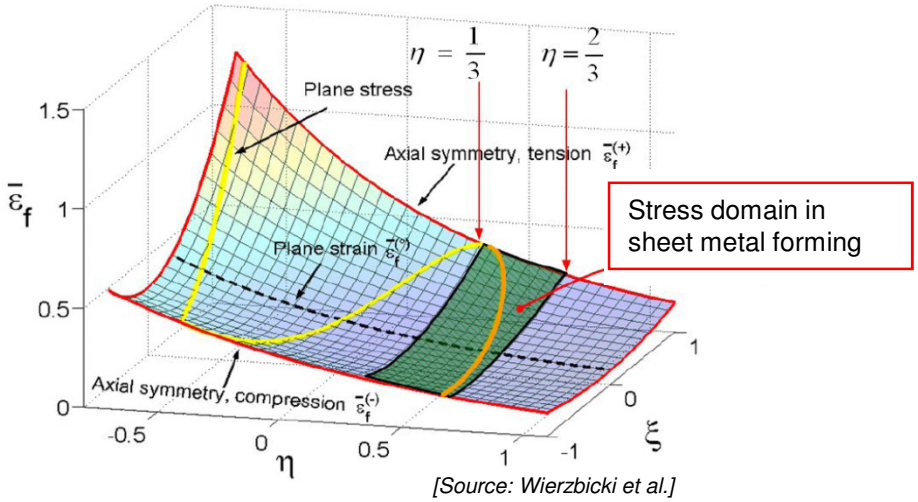
- For Solids (3D) both the Lode angle and triaxiality are independent

  → fracture strain is a function of triaxiality and Lode angle

Baseran [2010]

GISSMO

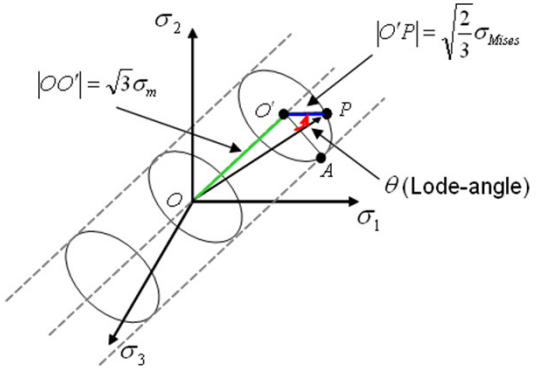
Failure criterion extd. for 3D solids



Stress domain in sheet metal forming

[Source: Wierzbicki et al.]

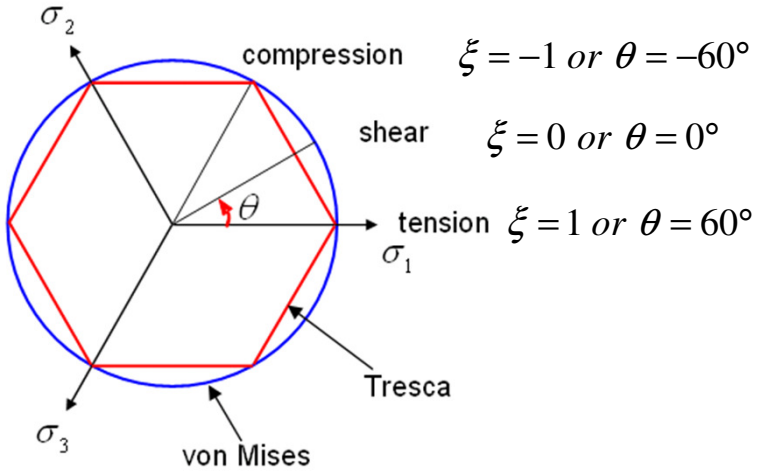
Haigh-Westergaard-coordinates



Parameter definition

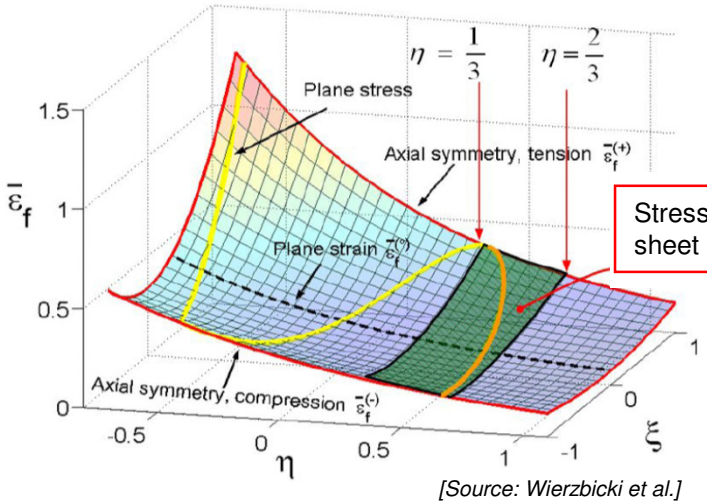
$$\eta = \frac{\sigma_m}{\sigma_{vM}} = \frac{I_1}{3\sigma_{vM}}$$

$$\xi = \frac{27}{2}\frac{J_3}{\sigma_{vM}{}^3} \quad \text{mit} \quad J_3 = s_1 s_2 s_3$$



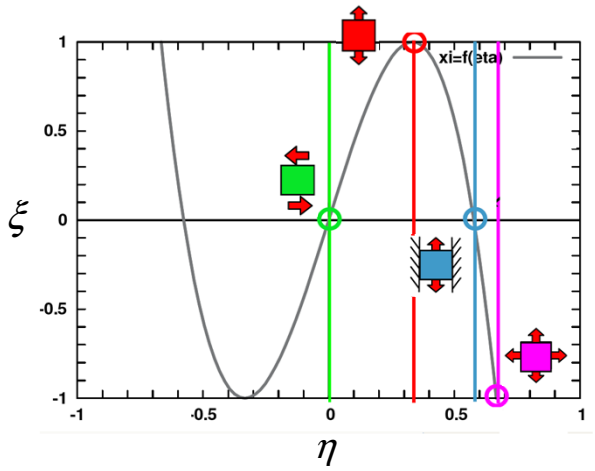
GISSMO

Failure criterion extd. for 3D solids



Stress domain in sheet metal forming

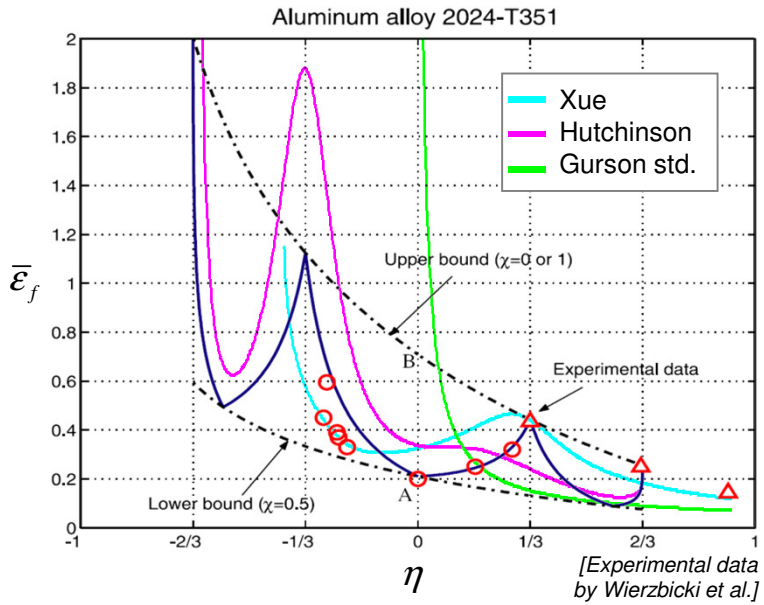
[Source: Wierzbicki et al.]



Parameter definition

$$\eta = \frac{\sigma_m}{\sigma_{vM}} = \frac{I_1}{3\sigma_{vM}}$$

$$\xi = \frac{27}{2}\frac{J_3}{\sigma_{vM}^{\ 3}} \qquad \text{mit} \qquad J_3 = s_1 s_2 s_3$$



[Experimental data by Wierzbicki et al.]

Summary

- Features of GISSMO:
  - The use of existing material models and respective parameters
  - The constitutive model and damage formulation are treated separately
  - Allows for the calculation of pre-damage for forming and crashworthiness simulations

- Characterization of materials requires a variety of tests
- Automatic method for identification of parameters is to be developed
- Offers features for a comprehensive treatment of damage in forming simulations
- Available in LS-DYNA V9.71 R5
- Verification und validation of concepts are under way

END