Validation and Verification of Plastics under Multiaxial Loading

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Validation and Verification of Plastics under Multiaxial Loading

by
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Outline

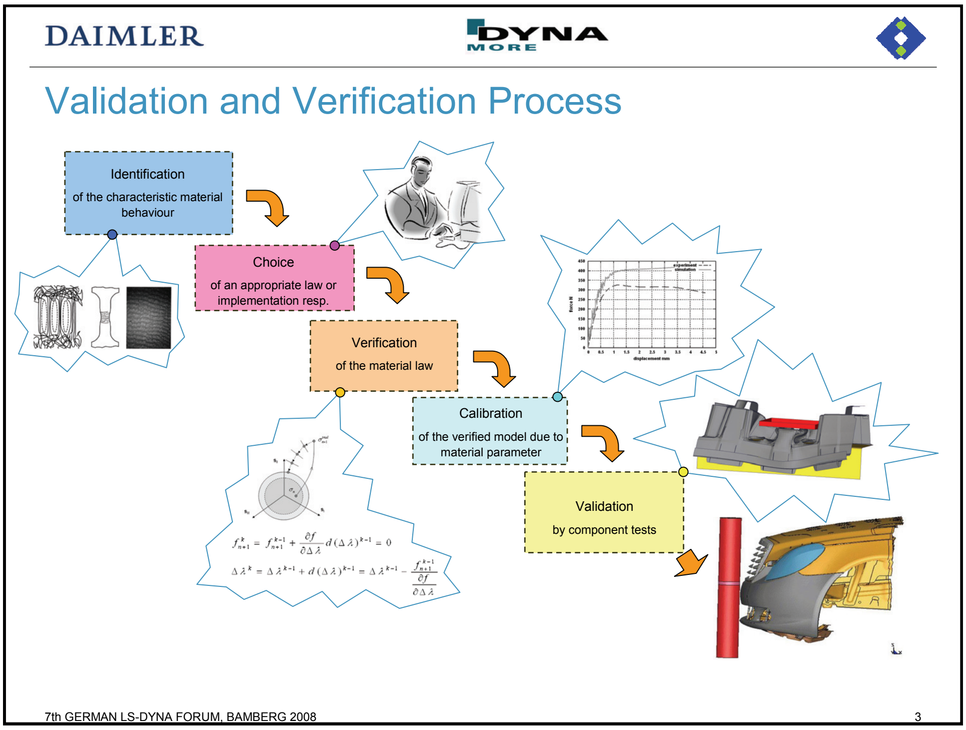
Validation and verification process

Material behavior of plastics - experimental findings

Phenomenological modeling

SAMP-1: MAT_187 in LS-DYNA 9.71 (R3.2)

Examples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Validation and Verification Process
Identification
of the characteristic material behaviour
Choice
of an appropriate law or implementation resp.
Verification
of the material law
Calibration
of the verified model due to material parameter
Validation
by component tests
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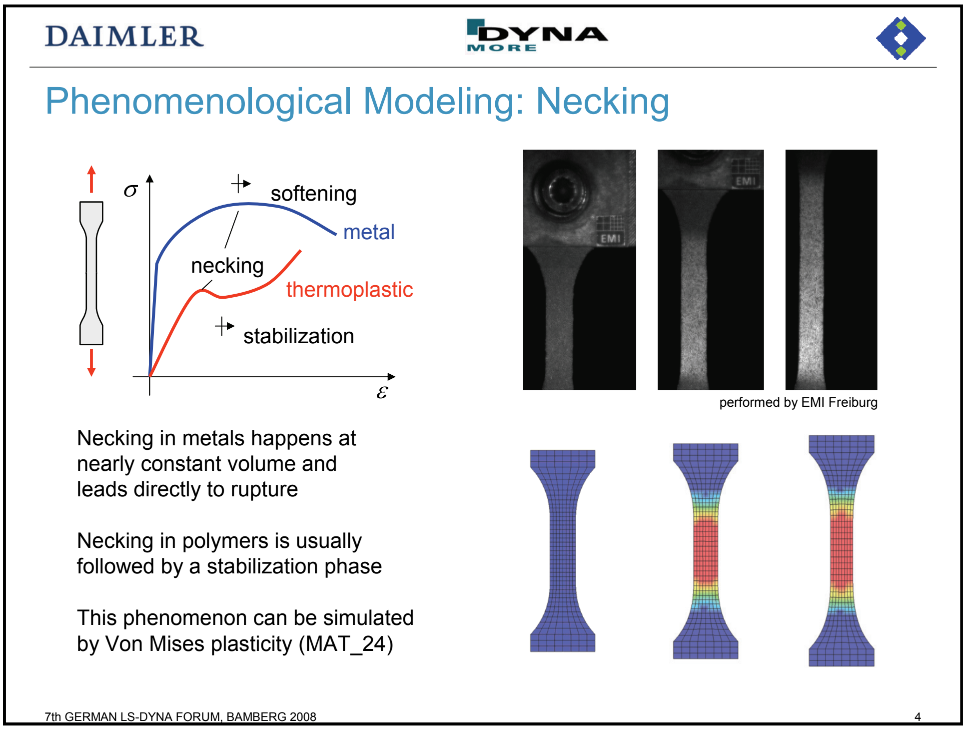
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Phenomenological Modeling: Necking
softening
metal
necking
thermoplastic
stabilization
performed by EMI Freiburg
Necking in metals happens at nearly constant volume and leads directly to rupture
Necking in polymers is usually followed by a stabilization phase
This phenomenon can be simulated by Von Mises plasticity (MAT_24)
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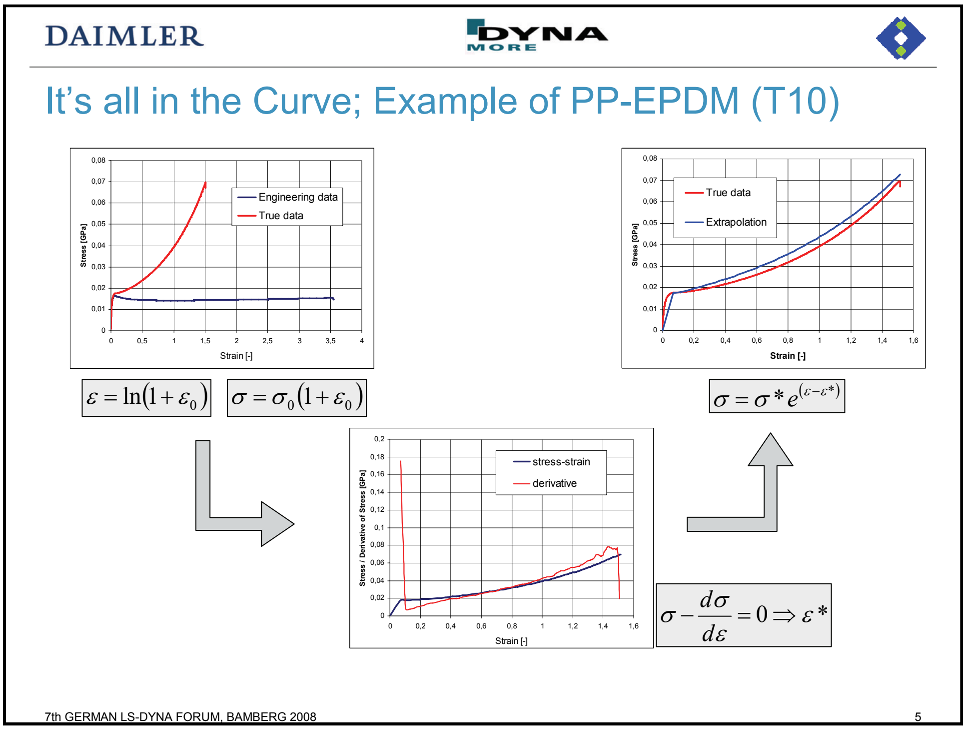
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It's all in the Curve; Example of PP-EPDM (T10)
Engineering data
True data
Stress [GPa]
Strain [-]
$\varepsilon = \ln(1+\varepsilon_0)$
$\sigma = \sigma_0(1+\varepsilon_0)$
True data
Extrapolation
$\sigma = \sigma^* e^{(\varepsilon-\varepsilon^*)}$
stress-strain
derivative
Stress / Derivative of Stress [GPa]
$\sigma - \frac{d\sigma}{d\varepsilon} = 0 \Rightarrow \varepsilon^*$
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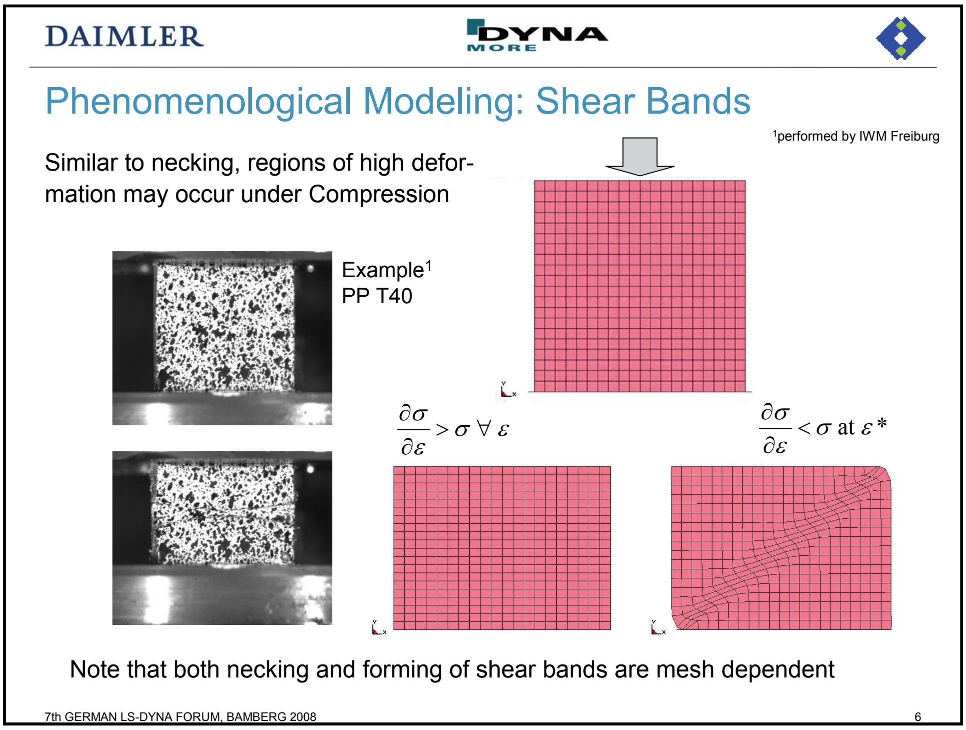
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Phenomenological Modeling: Shear Bands
¹performed by IWM Freiburg
Similar to necking, regions of high defor-
mation may occur under Compression
Example¹
PP T40
$\frac{\partial\sigma}{\partial\varepsilon} > \sigma \; \forall \; \varepsilon$
$\frac{\partial\sigma}{\partial\varepsilon} < \sigma$ at ε^*
Note that both necking and forming of shear bands are mesh dependent
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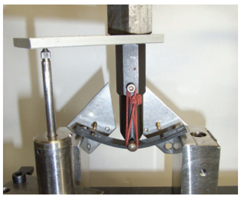
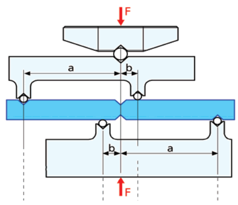
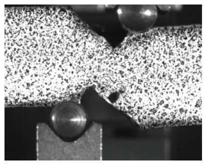
Some Validation Tests (IWM Freiburg)

Three-point bending test

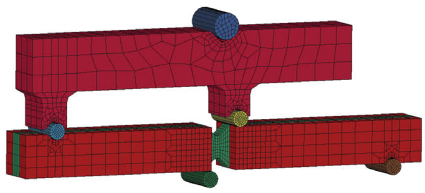


Iosipescu- shear test





compression test



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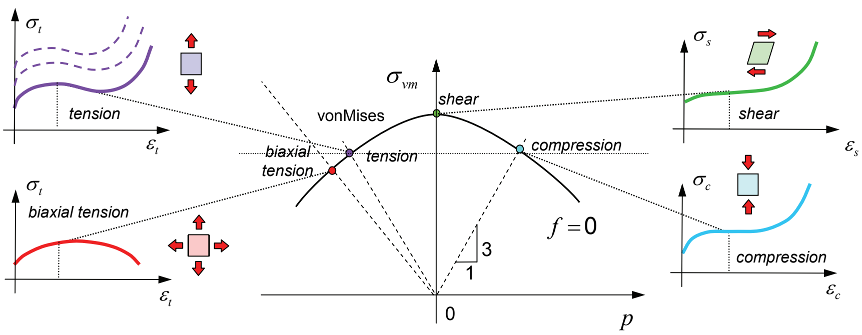
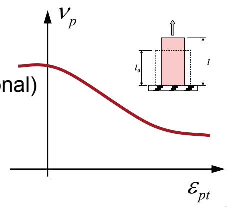
SAMP-1 (MAT_187)
Yield Surface and Plastic Potential



Yield surface $f(p,\sigma_{vm},\bar{\varepsilon}^{pl}) = \sigma_{vm}^2 - A_0 - A_1 p - A_2 p^2 \le 0$

Plastic potential $g = \sqrt{\sigma_{vm}^2 + \frac{9}{2}\frac{1-2\nu_p}{1+\nu_p}p^2}$ (associated flow rule optional)



All hardening curves are tabulated as known from MAT_24

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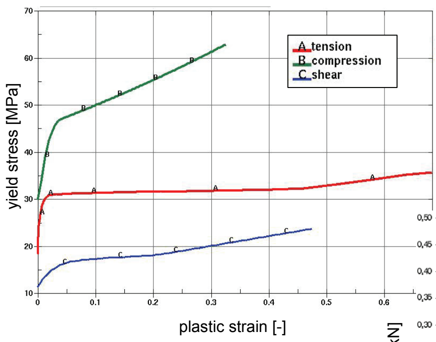
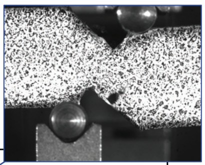
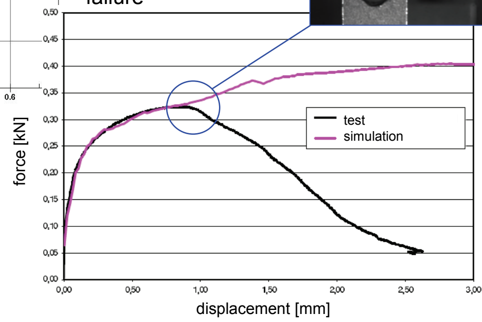
Validation of the Shear Test



yield curve at shear obtained by reverse engineering



good agreement until failure



force-displacement curve: experiment vs. simulation

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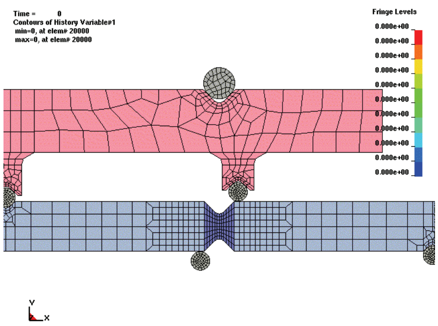
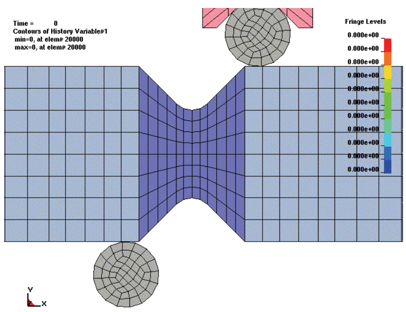
Validation of the Shear Test - Simulations





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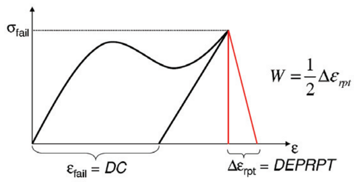
Validation of the Shear Test

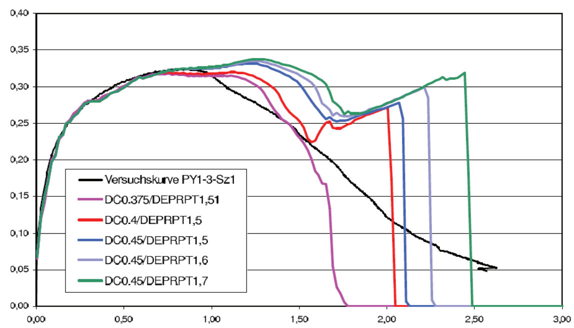


$$W = \frac{1}{2}\Delta\varepsilon_{rpt} \cdot \sigma_{fail}$$

failure criterion in SAMP-1:
element deletion with fadeout
according to a certain
fracture energy *W*

parameter study:
variation of
DC and
DEPRPT

note that different failure
for shear and tension
can be realized
by the use of
a triaxiality curve



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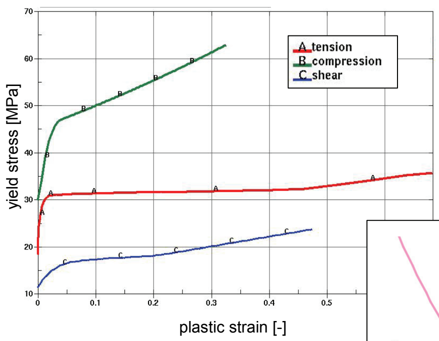
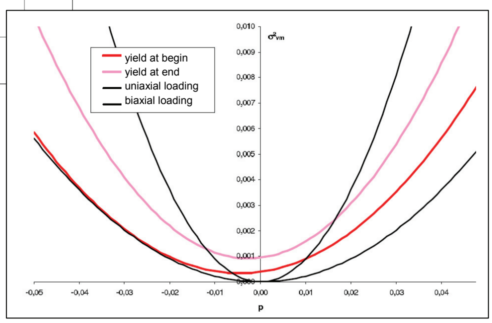
Validation of the Shear Test: iconv=0/1



yield curve for shear implies
a concave yield surface

this may cause some numerical problems

iconv=1 enforces convexity
but what is the influence of
iconv on the accuracy?



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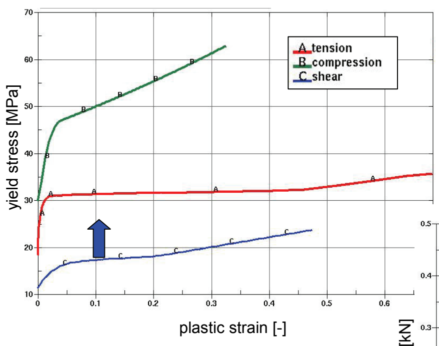
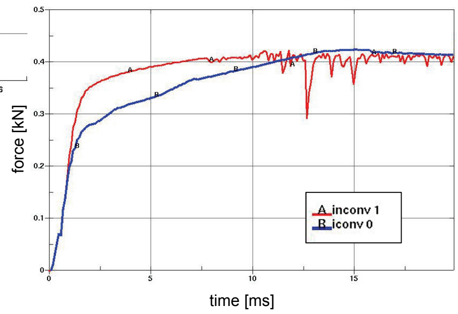
Validation of the Shear Test: iconv=0/1



iconv=1 yields a result that is too stiff because shear stress is increased up to a convex yield surface

However the influence is less components under mixed loading



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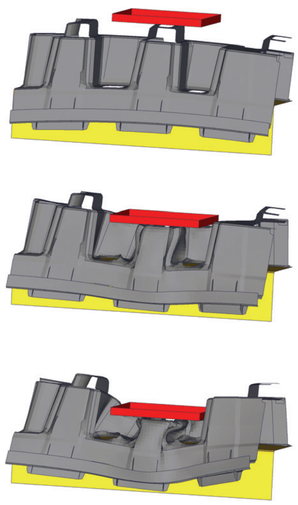
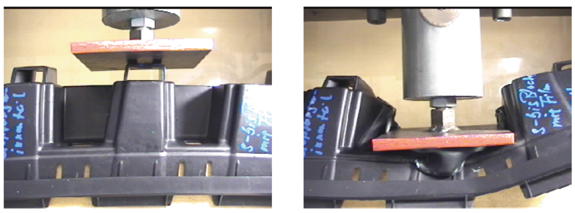
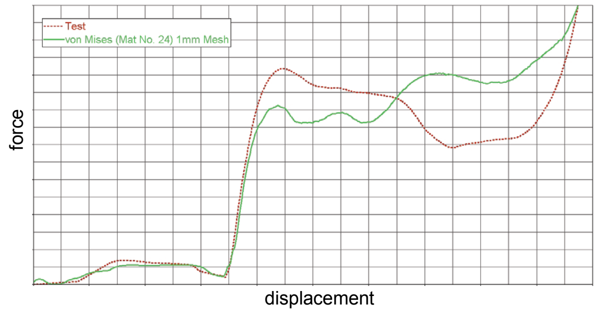
Validation of a Component Test (PP-T10)







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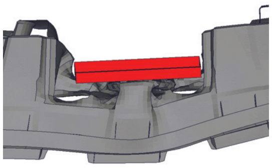
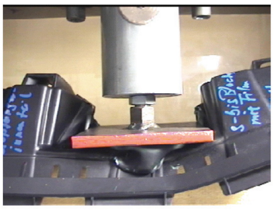
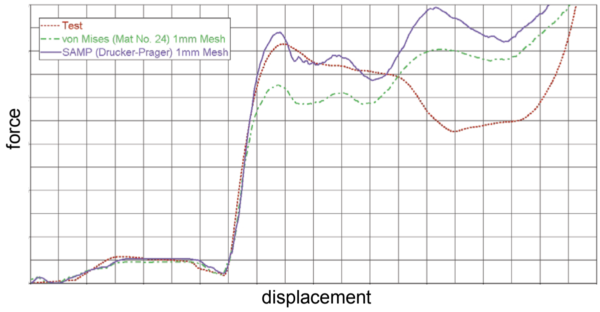
Validation of a Component Test (PP-T10)

Typical behaviour for thermoplastics:
material cards that are fitted for uniaxial tension yield a too soft responds under bending and compression

different yield curves under compression and tension necessary







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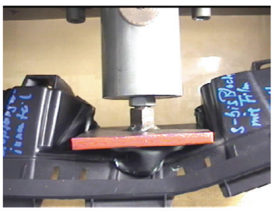
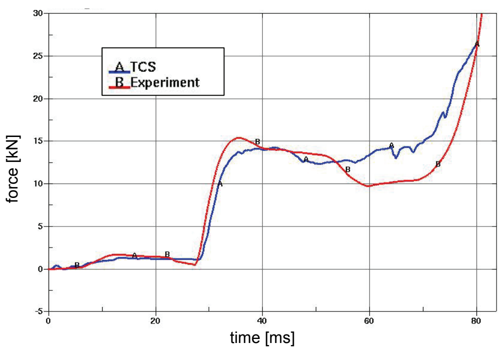
Component Test: TCS-Card + iconv=1

Taking the different behavior of shear into account yields a further improvement

However the computation becomes instable due to non-convexity

The use of iconv=1 may be a practical solution at this point





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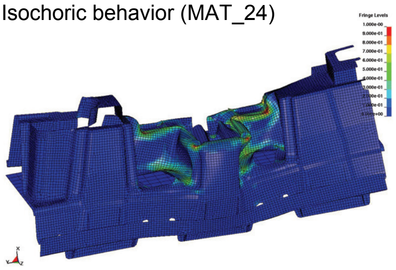
Component Test: Simulation of Crazing

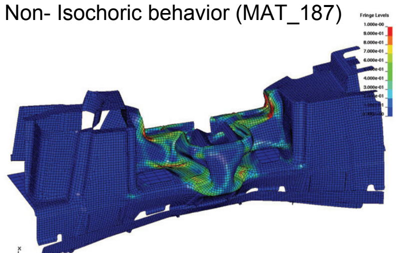
For the simulation of crazing we consider

- plastic Poisson's ratio decreases with increasing plastic strain
- plastic incompressibility under compression

Isochoric behavior (MAT_24)



Non- Isochoric behavior (MAT_187)



Contour-Plot = volumetric plastic strain

This Effect cannot be simulated by any isochoric elasto-plastic material law!
Improvement of the deformation behavior
Influence on the force-displacement-curve is negligible

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Conclusions

The validation and verification process for thermoplastics should consist (at least) of

- (dynamic) tensile tests AND
- a component test for validation (e.g. a three point bending test)
- the use of a material law with different yield under compression and tension

SAMP-1 in LS-DYNA 9.71 R3.2 is now tested successfully for a bunch of examples

The use of non-convex yield surfaces may cause problems in component tests; iconv=1 seems to be a practical solution

Crazing can be investigated by consideration of non-isochoric behavior and is then represented by volumetric plastic strain

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