

Polymers in Crash and Impact Simulation

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More and more structural parts are made from plastics



Percentage of polymeric materials in a middle class car (2003)

- Important application in automotive industry (safety) is subjected to the protection of passengers and pedestrians.
- There are numerous of parts that have to be considered carefully in numerical simulations.



Why Care about Polymers?

- Passenger protection:
 - Cockpit / Internal structures
 - Seatfoams
 - Door and inner trim
 - ...

Door trim*, Opel Corsa



* taken from B. Lauterbach, 5th German LS-DYNA Forum , Ulm 2006









- Pedestrian protection
 - bumper fascia / foam / hood / adhesives
 - different plastic parts / windscreen / ...



Validation and Verification Process







 To characterize a material phenomenologically, we consider a uniaxial tensile/compression test with unloading



- Hereby we use engineering stresses and engineering strains for a rough subdivision where A₀ is the initial cross section and l₀ the initial length.
- There is a number of corresponding material models that are available in commercial codes





- For the dynamic response, strain rate dependent tests are performed subsequently:
 - pendulum test
 - drop test
 - ...



Impetus II in Gießen



Droptower in Friedberg











(Crash-) Numericist: foam is a material with Poisson's ratio close to zero



- For crash and impact simulation, user-friendly material laws are available in commercial FE-codes allowing for a direct input of experimental data from tensile and compression tests
- Improvement of such laws is necessary sometimes

Validation Tests: Compression / Tension







Some Validation Tests - Shear













Unloading has been included by an elastic damage formulation





- Materials with Permanent
 Deformation
 - Metals (Aluminum / Steel)
 - Crushable Foams
 - Plastics









Phenomenological Modeling: Necking





EMI

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

Tensile Test Simulation



- Compare force-displacement-curve for each strain rate:
 - Correlation must be exact before necking!
 - If correlation is sufficiently accurate after necking, stop
 - If not, modify either the extrapolation or the yield curve step by step



Phenomenological Modeling: Shear Bands



¹performed by IWM Freiburg

Similar to necking, regions of high deformation may occur under Compression



Note that both necking and forming of shear bands are mesh dependent

Phenomenological Modeling: Crazing





- change of colour to white detectable
- crazing leads to plastic (permanent)
 deformation with increase of volume
- crazing leads to low yield stress values in uniaxial/biaxial tension
- seems to occur under high values of hydrostatic tension











Experimental Data vs. SAMP





- > Yield surface at initial yielding is fitted quite well using SAMP-1
- Crazing can also be approximated
- Note that the hardening curve has to be treated carefully if compressibility is considered





>

Validation of a Component Test







Validation of a Component Test



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

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



Component Test: Simulation of Crazing

- Simulation of crazing:
 - plastic Poisson's ratio decreases with increasing plastic strain
 - plastic incompressibility under compression



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

Component Test: Simulation of Crazing





Conclusion



- Mechanical properties of thermoplastics are strongly influenced by
 - strain rate (+ temperature, moisture,)
 - triaxiality (tension, compression, shear, ...)
- Consideration of all these effects is expensive !

