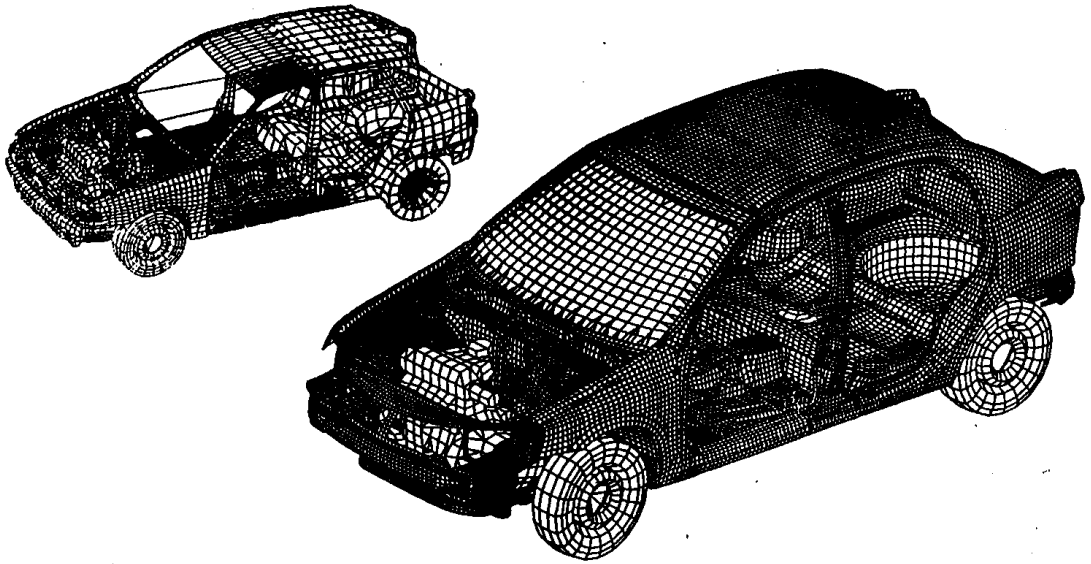
A review of the state-of-the-art in vehicle modeling for crashworthiness analysis using LSDYNA

We have about 15 years of experience and every crashworthiness simulation is a compromise between quality and cost (=speed)

Meshing of Body panels

- Uniform and regular meshing



Meshing of Body panels
Model Size

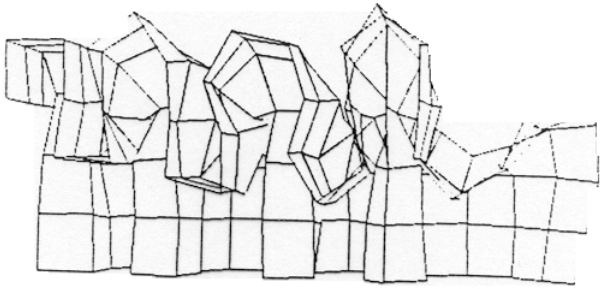
- A car body is about 20-25 m² of steel sheet
- model size evolved from 10k to 500k elements
- relationship meshsize/modelsize :

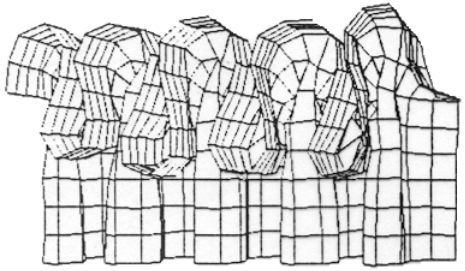
Mesh	10mm	5mm	1mm
model	200k	800k	20M

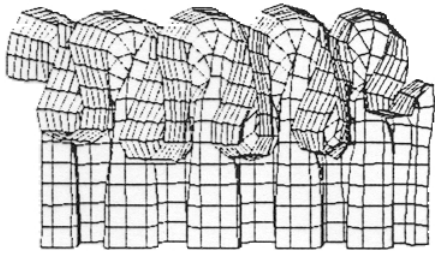
Meshing of Body panels
Mesh density

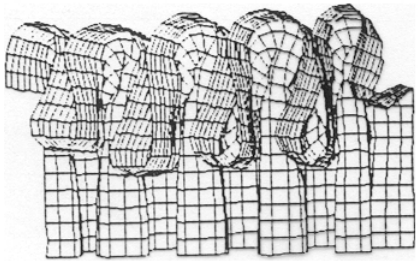
- Minimum of 3 elements per side of any section
- Minimum of 6-12 elements per fold in the energy-absorbing part of the mesh
- Mesh convergence requires smooth representation of deformed geometry

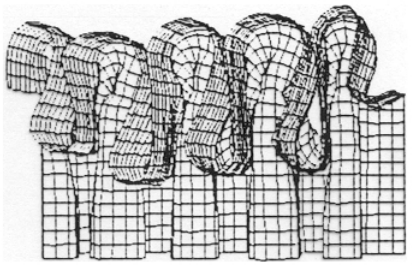
Meshing of Body panels
Mesh convergence











Meshing of Body panels

- Element characteristic lengths should allow for a reasonable initial timestep
- CAD-surfaces must be smoothed before meshing
- Crash analysis in the concept phase can be performed on non-finalized CAD

Stress analysis vs. Crash models

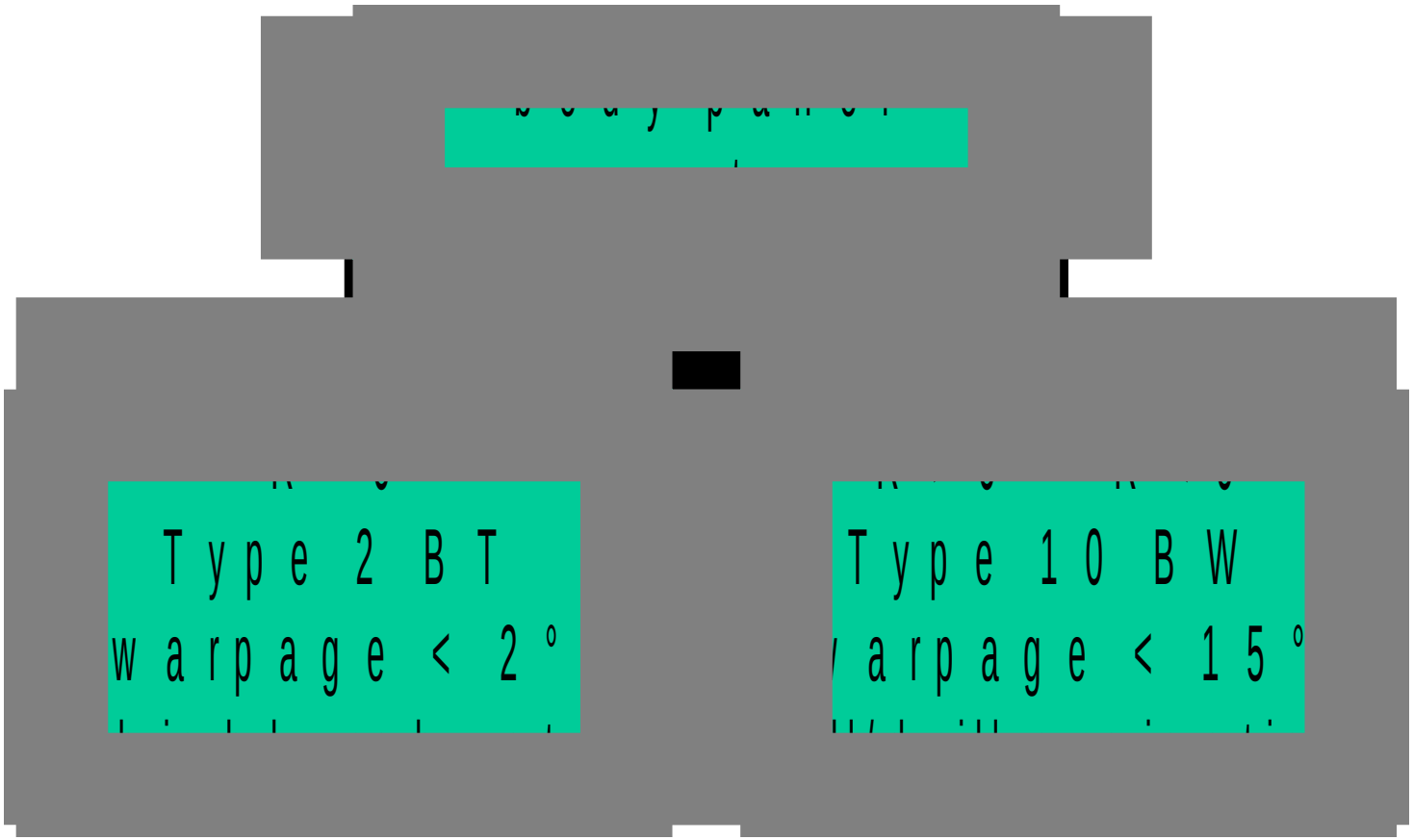
- Stress analysis

- undeformed config.
- geometrical detail
- irregular mesh
- welds = common node
- penetrations
- full integration

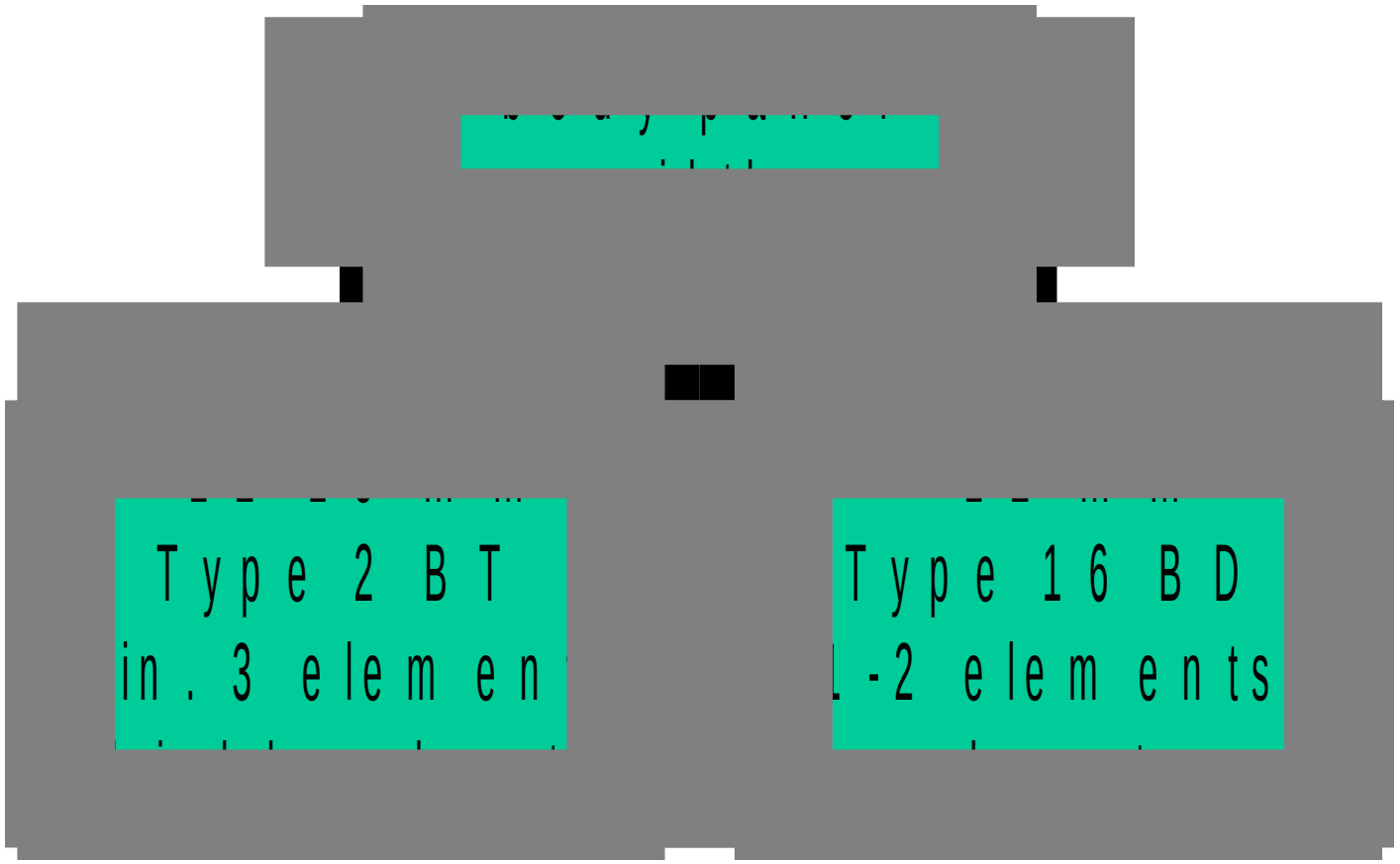
- Crash analysis

- deformed config.
- Smooth CAD
- regular mesh
- spotweld elements
- no penetrations
- reduced integartion

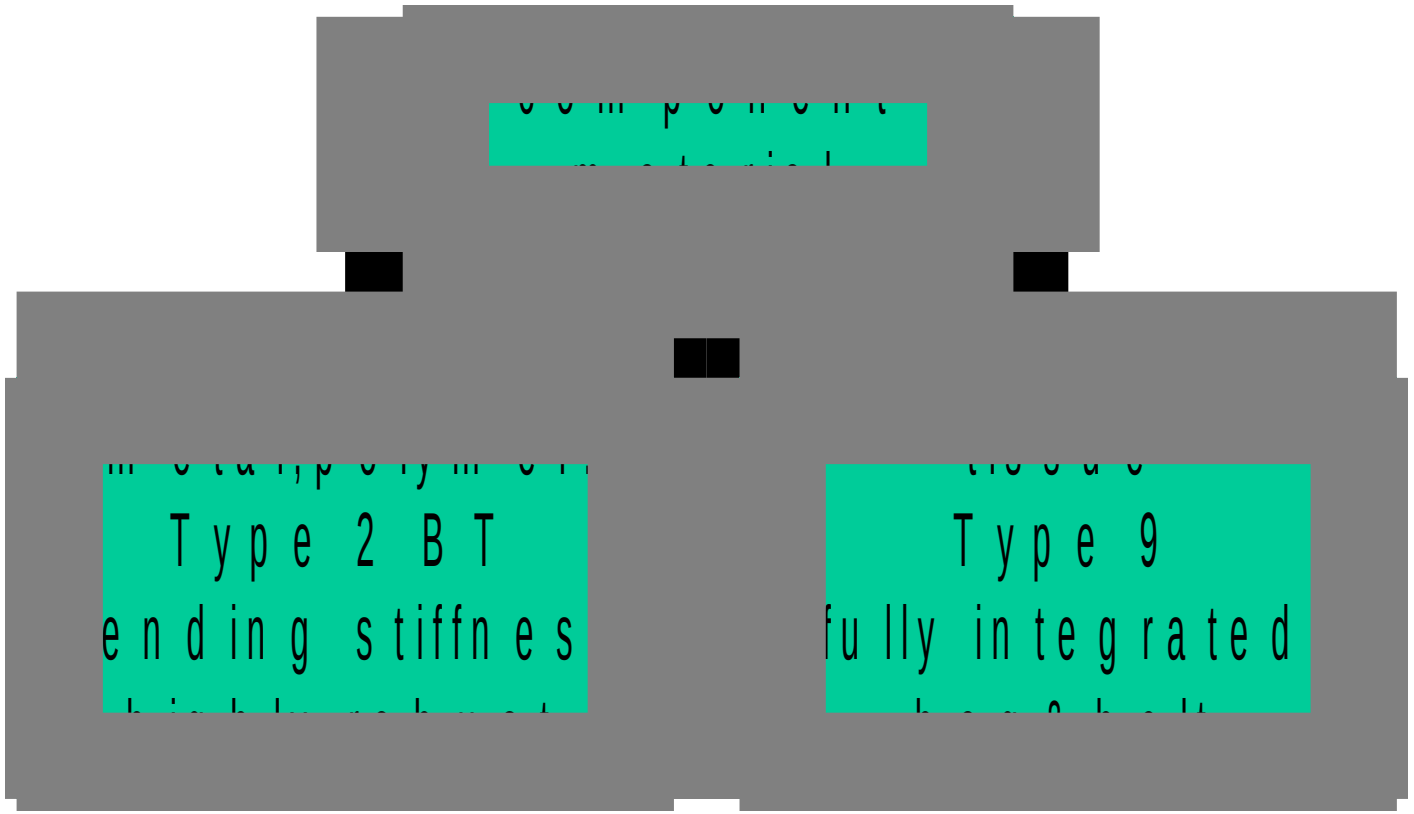
Shell Element Quality



Shell Element Quality



Shell Element Quality



Shell element quality

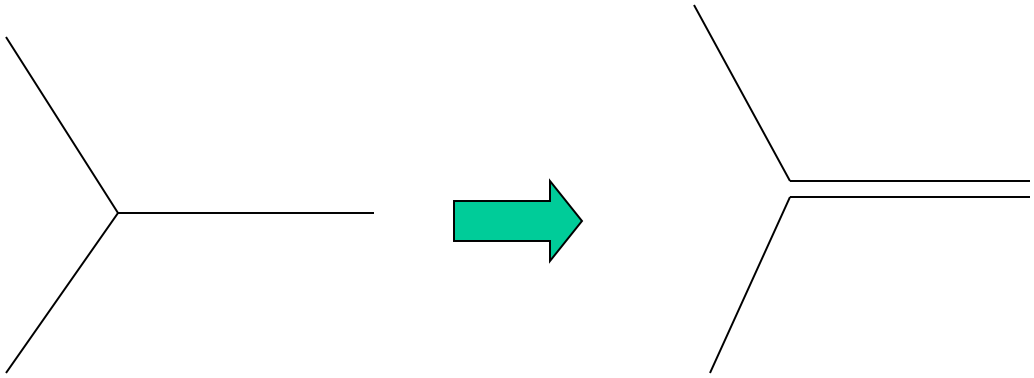
- Limit number of triangles
- 2 Gauss points through the thickness by default
- Increase to 5 for t > 1.5 mm

Connections

- spotwelds
- glue
- bolts and rubber bushings

Modeling of Connections

- Principle : independent modeling of all flanges before connection is known

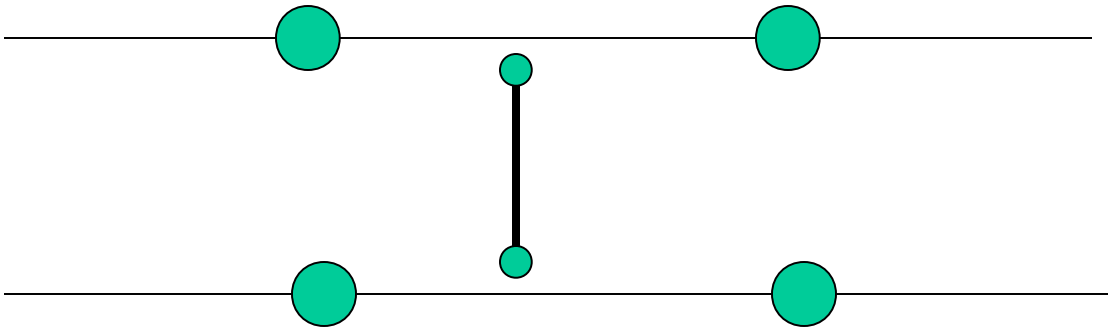


Modeling of Connections

- Easier exchanging of parts
- Faster modeling
- Meshing before connection technique is decided
- allow spreading of the flanges

Modeling of Connections

- Spotwelds :

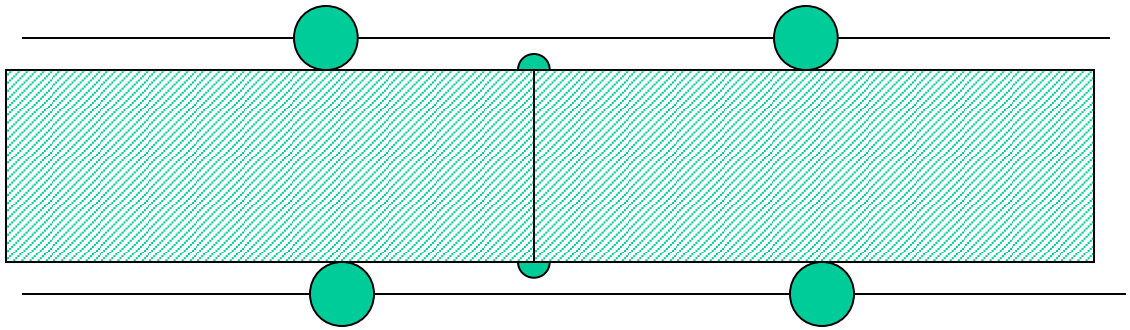


Modeling of Connections

- Tied contacts and type 9 beams
- Torsional stiffness of the weld can be considered using _SPOTWELD option
- Realistic choice of stiffness and mass must be made

Modeling of Connections

- Glue :

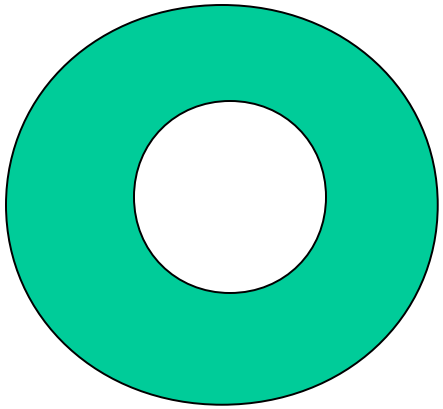


Modeling of Connections

- Tied contacts and single layer of brick elements with thickness (t1+t2)/2
- Glue strength must be validated with respect to testing
- Combining glue and welds poses no problem

Modeling of Connections

- Bolts and Rubber Bushings :

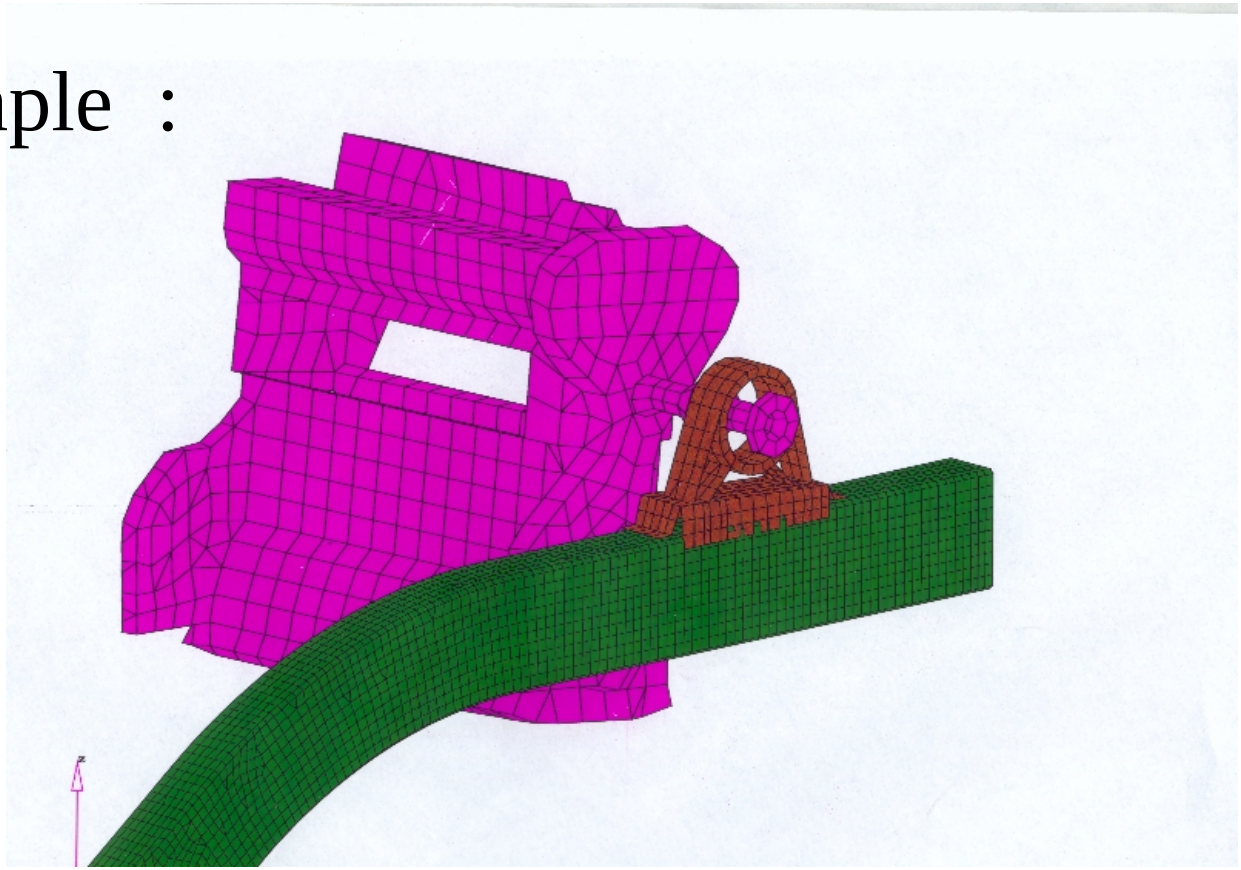


Modeling of Connections

- Simplified modeling leads to non-realistic kinematics and buckling modes
- The AUTOMATIC_ contact handles the contact between 2 concentric cylinders well
- Dynamic behaviour of rubber can be modeled additionally with material law 6/61

Modeling of Connections

- Example ：



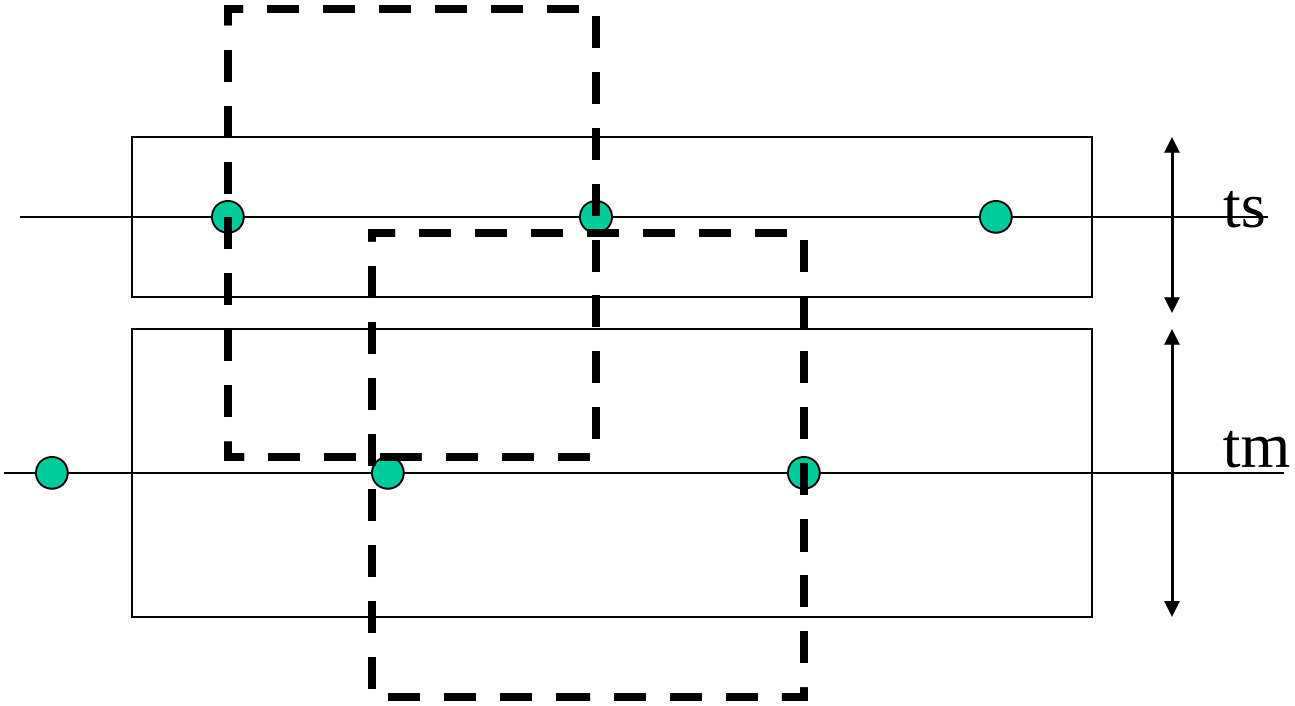
Contact Definitions: Avoid initial penetrations

- Offset of CAD in the midplane
- Carefull thickness definition
- Uniform meshing

Contact Definitions: Realistic gap definition

- LSDYNA uses variable gap definiton in space as (ts+tm)/2 by default
- Simulation results become very realistic since voids between flanges are no longer created
- small initial penetrations become unavoidable, use scale factors

Contact Definitions: Realistic gap definition

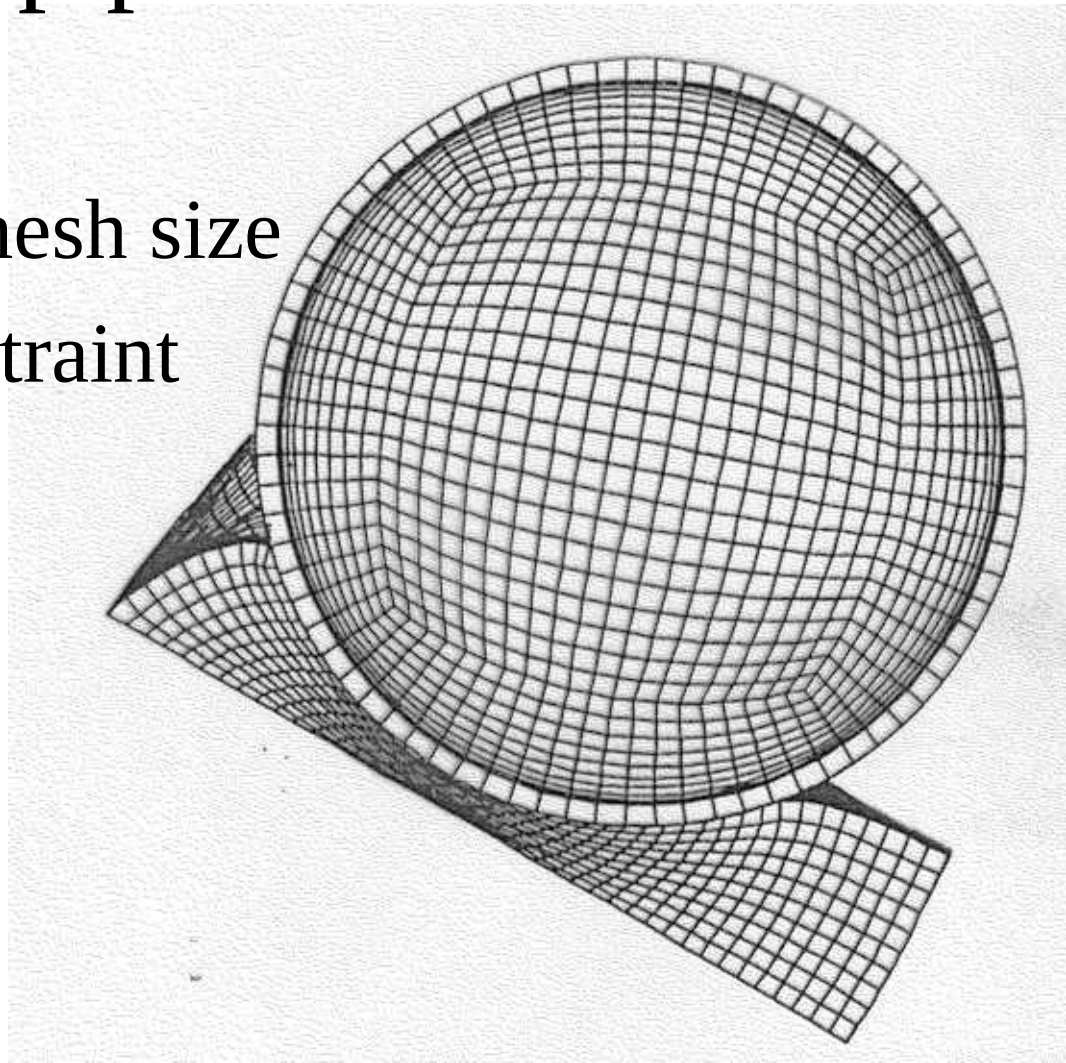


Contact Definitions: Avoid initial penetrations

- SOFT=2 option allows automatic reduction of contact thickness

Contact Definitions: Avoid deep penetrations

- Ensure constant mesh size
- Activate soft constraint



Contact Definitions: Avoid deep penetrations

- AUTOMATIC_GENERAL contact additionally solves edge-to-edge and beam-to-beam contact

Component modeling: Mass distribution

- Mass distribution
- Rotational inertia
- Stiffness of the connection to the car body
- Component stiffness (engine block...)

Component modeling: Mass distribution

- Large component masses (dummy, seat, powertrain...) influence results of frontal and side impact simulations

Component modeling: Mass distribution

- Smaller components (exhaust...) for :
  - Airbag sensor analysis
  - Repairability
  - Pedestrian impact
  - Interior head impact (MVSS201)

Simulation of metal sheet :

- Current Technology :
  - _ von Mises yield criterion
  - _ associated flow
  - _ multilinear hardening curve accurate up to necking, based on virgin material
  - _ rupture for given maximum plastic strain
  - _ viscoplasticity (VP=1)
  - _ mesh size 5.mm

Simulation of metal sheet :

- SIMLAB Technology :
  - _ anisotropic (Barlat) yield criterion
  - _ associated flow
  - _ fitted analytical hardening curve up to rupture
  - _ isotropic damage model (Lemaitre)
  - _ viscoplasticity
  - _ non-localized failure criterion based on thinning
  - _ mesh size < 1.mm

Material modeling

- Influence of forming process
- v960 allows use of DYNAIN file from forming analysis to initialize crash simulation