Considerations on Detailing Dummy Models Adequately

S. Stahlschmidt, A. Gromer, U. Franz (DYNA*more* Gmbh)

A Hirth (DaimlerChrysler AG)

Considerations on detailing dummy models adequately

Considerations on Detailing Dummy Models Adequately

S. Stahlschmidt, U. Franz, A. Gromer
DYNAmore GmbH, Germany

A. Hirth
DaimlerChrysler AG, Germany

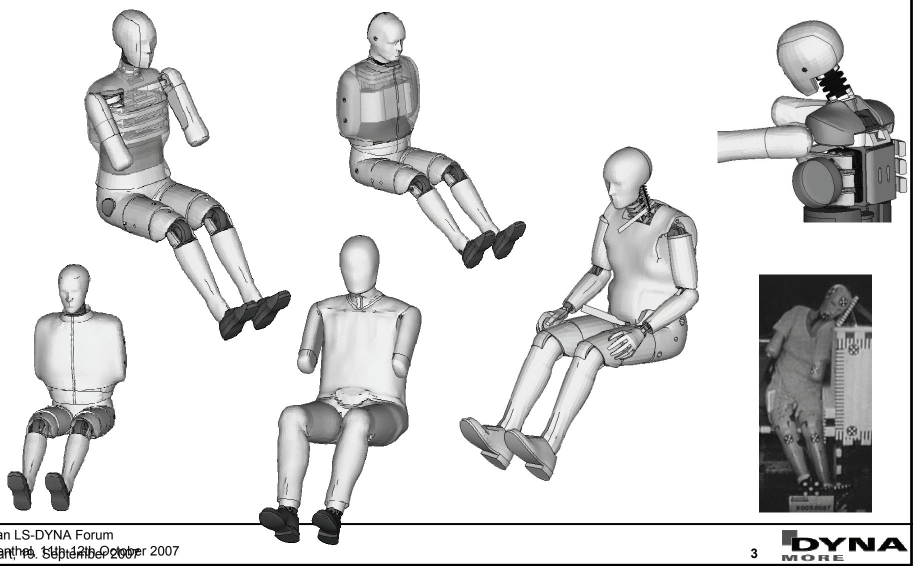
11th - 12th October 2007

Content

- Overview on developed models
- Applied methodology in development
- Aspects on modeling
  - Modeling geometric details
  - Initial geometry
  - Mesh density
  - Material tests
  - Modeling of assemblies
  - Modeling of interacting parts
- Conclusion

DYNAmore introduction

- FAT (German Research Organization of the Automotive Industry)
- Models developed during the past 10 years by staff of DYNAmore GmbH

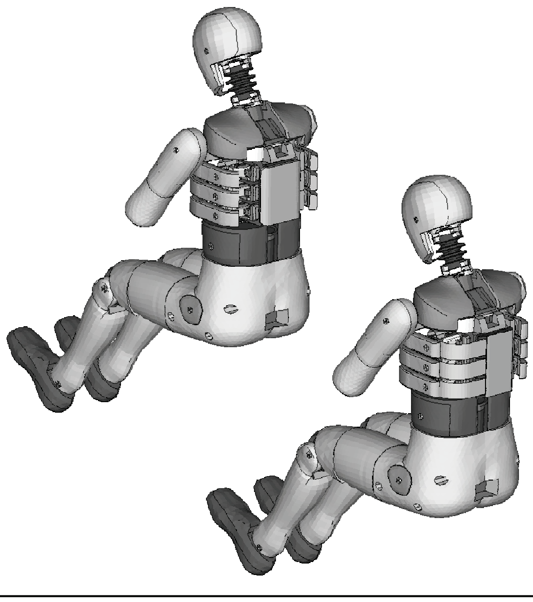


German LS-DYNA Forum
Frankenthal, 11th-12th October 2007
Stuttgart, 19. September 2007
3
DYNA MORE

Developed models

ES-2 / ES-2re v4.0 models

Nodes:	84,060
Beams:	313
Shells	69,185
Solids:	130,631
Material:	109
Parts:	236
Joints	19
Contacts:	8

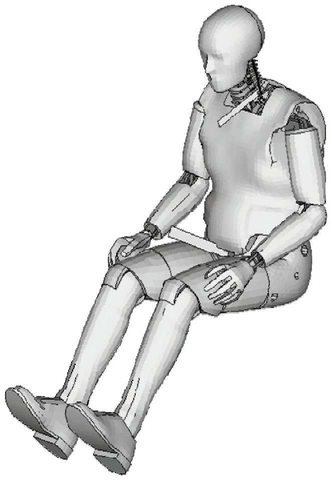


German LS-DYNA Forum
Frankenthal, 11th-12th October 2007
Stuttgart, 19. September 2007
4
DYNA MORE

Developed models

BioRID II v2.0 model

- The models are based on CAD data of BioRID II build level C
- Model details
  - Nodes: 148,000
  - Hexas: 88,000
  - Tetras: 22,000
  - Shells : 72,000
  - Beams : 4,000

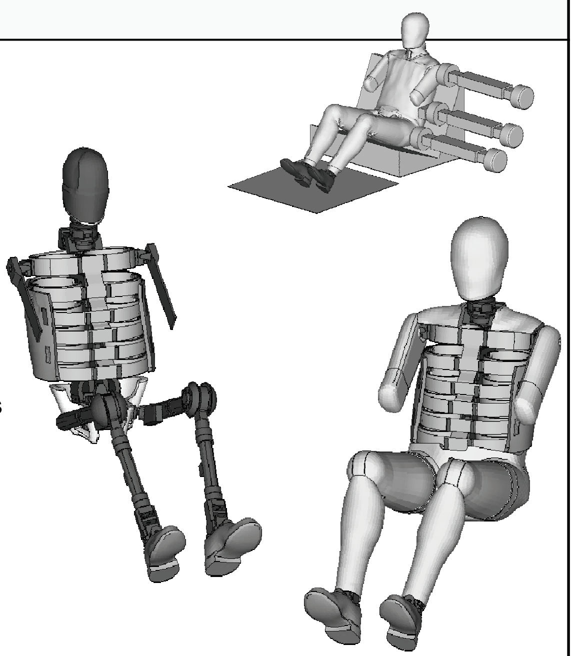


German LS-DYNA Forum
Frankenthal, 11th-12th October 2007
Stuttgart, 19. September 2007
5

Developed models

World SID 50th model

- Model size:
  - Nodes 134000
  - Shell 94000
  - Hexa 54200
  - Tetra 40000
  - Parts 519
- Very few tetrahedron elements

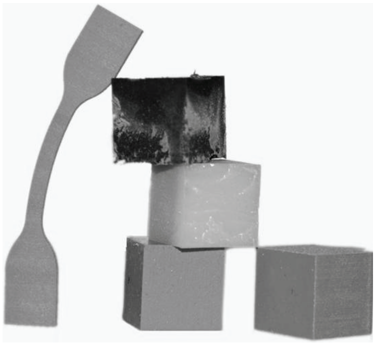


German LS-DYNA Forum
Frankenthal, 11th-12th October 2007
Stuttgart, 19. September 2007
6

Applied methodology in development

Material tests

- A huge material database for static and dynamic material behavior
- Rubber, foams, silicon, urethane, steel, memory alloys, damping materials
- Usually tests that allow to be included directly to LS-DYNA
  (e.g. Mat_Fu_Chang_Foam, Simplified_Rubber,…)

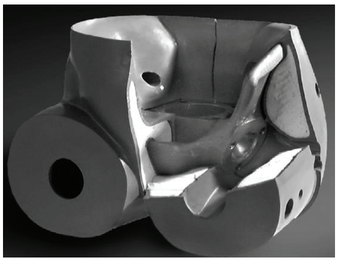


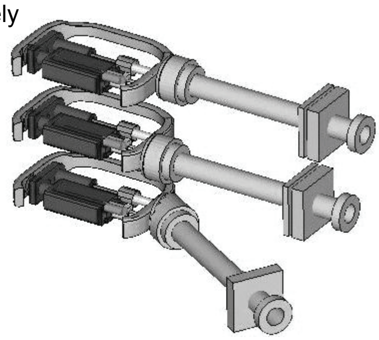
German LS-DYNA Forum
Frankenthal, 11th-12th October 2007 7

Applied methodology in development

Component tests

- Validation of components
- Often difficult to test at appropriate load levels
- Combination of materials can be investigated
  (e.g. rib foam with a rubber hull. Air out-flow influences the result)
- Many phenomena can be investigated effectively
  since component has less complexity



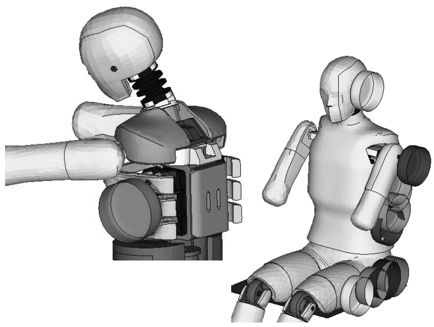


German LS-DYNA Forum
Frankenthal, 11th-12th October 2007 8

Applied methodology in development

Pendulum tests on fully assembled model

- Local loads on specific body regions
- Relatively simple tests
- Difficult to obtain crash relevant load level

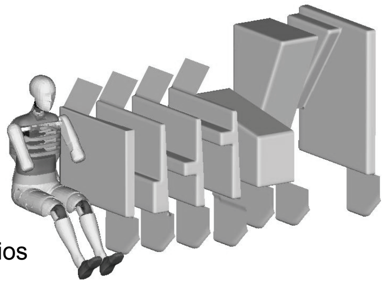


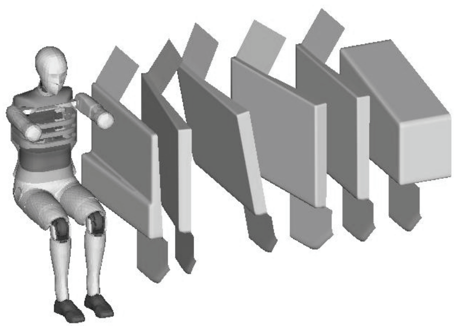
German LS-DYNA Forum
Frankenthal, 11th-12th October 2007
Stuttgart, 19. September 2007
9

Applied methodology in development

Sled test are the major tests

- Allows to understand assembled dummy
- Allows to apply crash relevant loads
- Interaction of parts can be considered
- Different barrier shaped related to crash scenarios

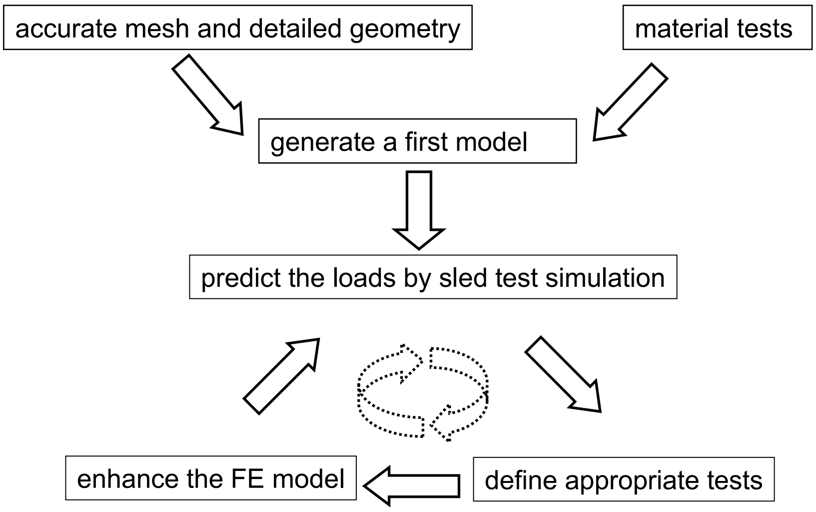




German LS-DYNA Forum
Frankenthal, 11th-12th October 2007
Stuttgart, 19. September 2007
10

Applied methodology in development

Methodology of development



Content

- Overview on developed models
- Applied methodology in development
- Aspects on modeling
  - Modeling geometric details
  - Initial geometry
  - Mesh density
  - Material tests
  - Modeling of assemblies
  - Modeling of interacting parts
- Conclusion

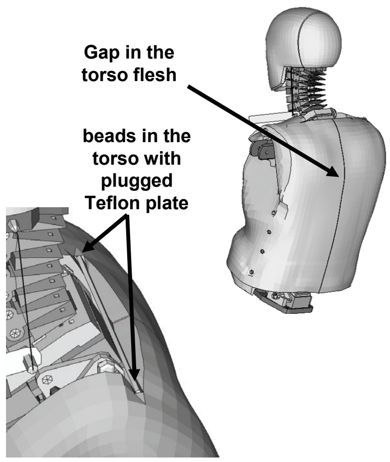
Modeling aspects: Geometric details

Accurate geometry itself

- Fine mesh allows to include all details
  (e.g teflon plate with bonded foam at the back of BioRID II)
- Gaps can be included accurately
  (e.g. gap between two torso parts)

Both geometric details have a

significant influence on the results

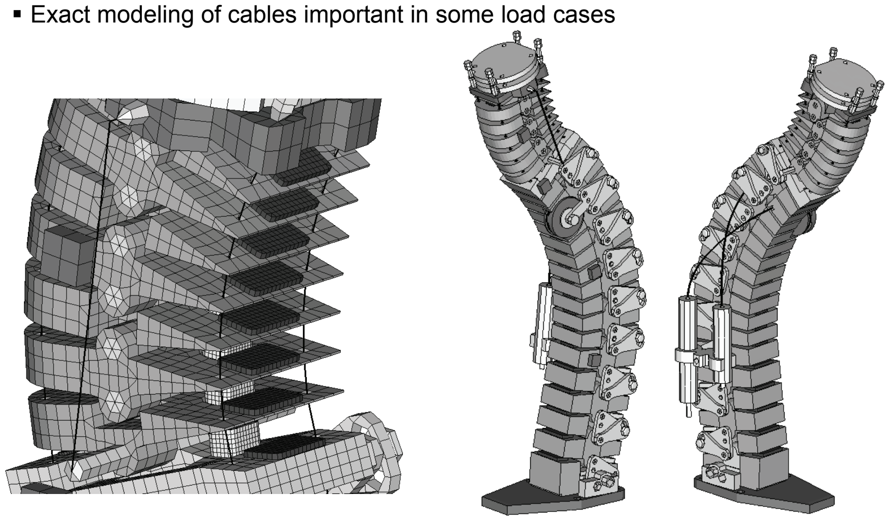


German LS-DYNA Forum
Frankenthal, 11th-12th October 2007 13

Modeling aspects: Geometric details

Accurate geometry itself

- Exact modeling of cables important in some load cases



German LS-DYNA Forum
Frankenthal, 11th-12th October 2007 14

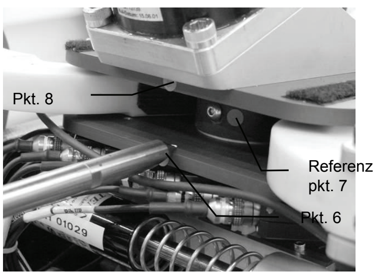
Content

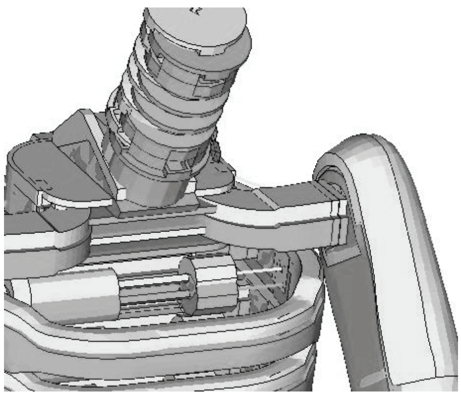
- Overview on developed models
- Applied methodology in development
- Aspects on modeling
  - Modeling geometric details
  - Initial geometry
  - Mesh density
  - Material tests and model details
  - Modeling of assemblies
  - Modeling of interacting parts
- Conclusion

Modeling aspects: Mesh density - exact geometry

From CAD to exact position

- The physical position of the dummies is different to the CAD position
- Differences in arm position
- Ribs differ 20 mm in height
- Angle of clavicle box different

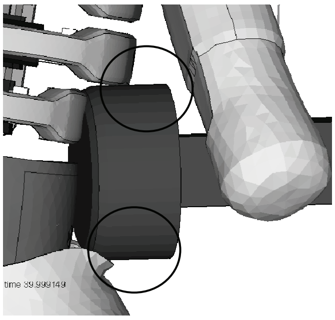


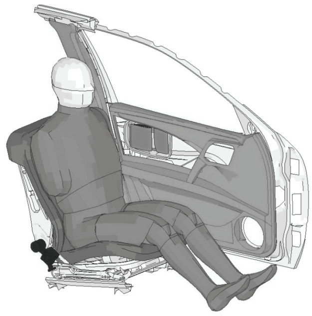


Modeling aspects: Mesh density - exact geometry

Exact initial position

- Examples for accurate geometry and impacting entities
- Pendulum is squeezed between middle rib and pelvis
- Exact initial position essential to see interaction
- Door trims are also equipped with curved contour





German LS-DYNA Forum
Frankenthal, 11th-12th October 2007
Stuttgart, 19. September 2007
17

Content

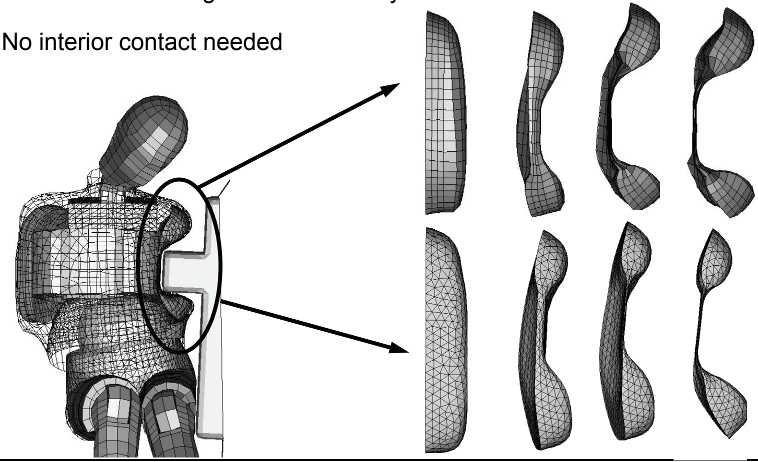
- Overview on developed models
- Applied methodology in development
- Aspects on modeling
    - Modeling geometric details
    - Initial geometry
    - Mesh density
    - Material tests and model details
    - Modeling of assemblies
    - Modeling of interacting parts
- Conclusion

German LS-DYNA Forum
Frankenthal, 11th-12th October 2007
Stuttgart, 19. September 2007
18

Modeling aspects: Mesh density - stability

Fine meshes increase stability

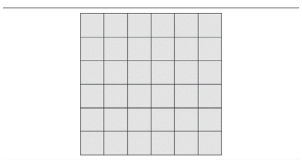
- Further important point in a dummy model is the stability
- Less material changes due to stability reasons
- No interior contact needed

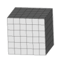
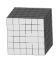
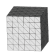
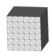


Modeling aspects: Mesh density – computational time

Computational expenses

- Cube with 50 mm edge length
- Mesh methods Hexa and Tetra elements

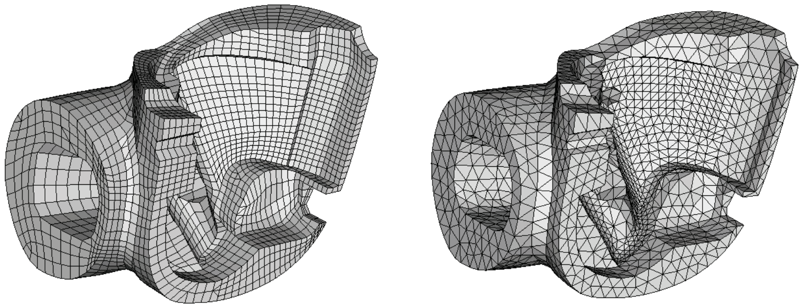


	Hexa Typ1 	Hexa Typ2 	Tetra Typ10 	Tetra Typ13 
Number of elements	216	216	1296	1296
CPU time in [s]	31	134	120	160
Time per element [ms]	143	620	92	123
Relative time per element	1	4.3	0.6	0.9

Modeling aspects: Mesh density – element type

Computational expenses

- Pelvis of WorldSID
- Material: “rubber like” foam



# Element	13 000 Hexa	35 000 Tetra
Normed Time	1	2.4

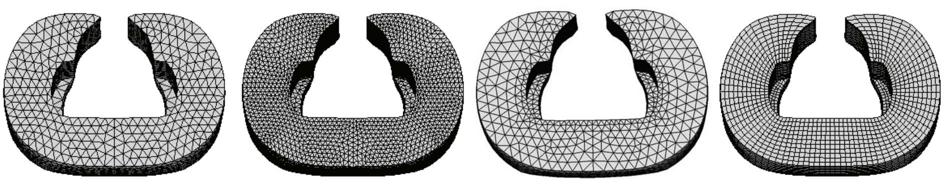
German LS-DYNA Forum
Frankenthal, 11th-12th October 2007 / Stuttgart, 19. September 2007
21

Modeling aspects: Mesh density – element type

Computational expenses and accuracy

- Fine mesh of abdominal insert needed for force measurement

Base mesh of ES-2 v4.0 | Fine tetra mesh | Partially fine mesh ES-2 v4.1 | Fine hexa mesh

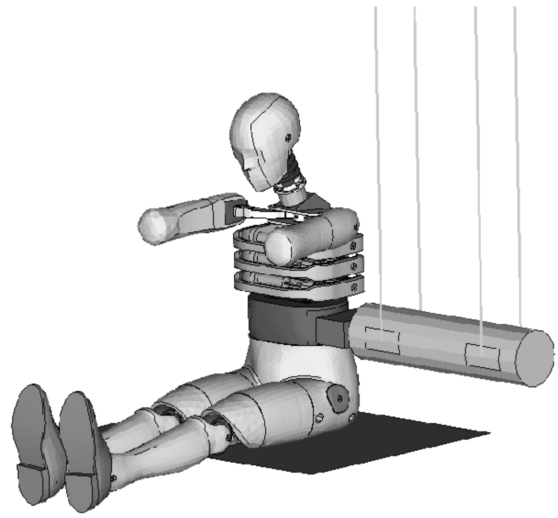


# Element	16 000 Tetra	113 000 Tetra	47 000 Tetra	23 000 Hex
Normed Time	1	6.7	2.8	2.3

German LS-DYNA Forum
Frankenthal, 11th-12th October 2007 / Stuttgart, 19. September 2007
22

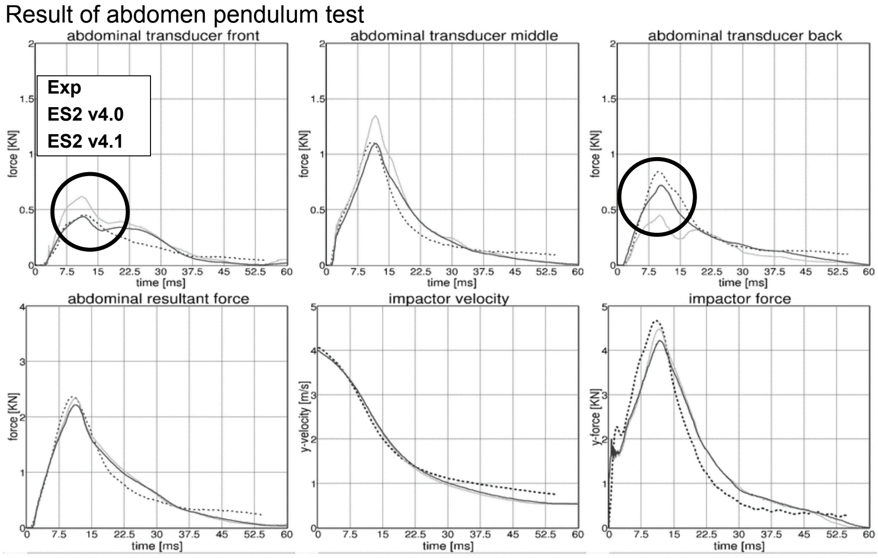
Modeling aspects: Mesh density – element type

Abdomen pendulum calibration test for ES-2



Modeling aspects: Mesh density – element type

Result of abdomen pendulum test



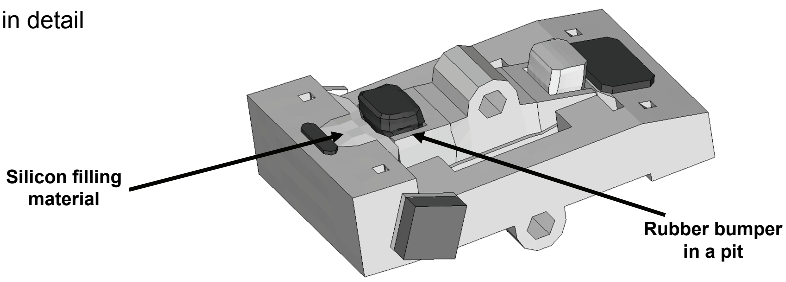
Content

- Overview on developed models
- Applied methodology in development
- Aspects on modeling
    - Modeling geometric details
    - Initial geometry
    - Mesh density
    - Material tests and model details
    - Modeling of assemblies
    - Modeling of interacting parts
- Conclusion

Modeling aspects: Material tests – model details

Influence on material modeling

- Example is the vertebra of BioRID II. It is generated very accurate to the CAD data
- The rubber bumpers are located in a small cavities that inhibit lateral dilatation
- Material test data can be used if cavities and bumpers are modeled in detail

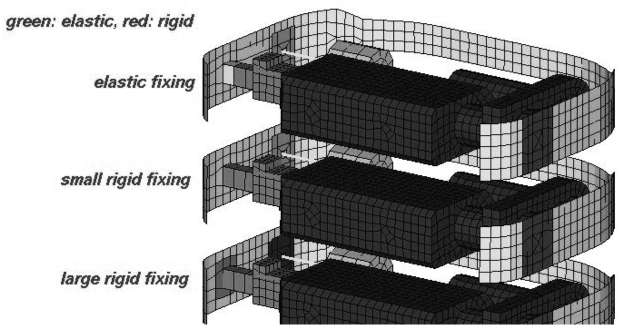


Content

- Overview on developed models
- Applied methodology in development
- Aspects on modeling
  - Modeling geometric details
  - Initial geometry
  - Mesh density
  - Material tests and model details
  - Modeling of assemblies and model details
  - Modeling of interacting parts
- Conclusion

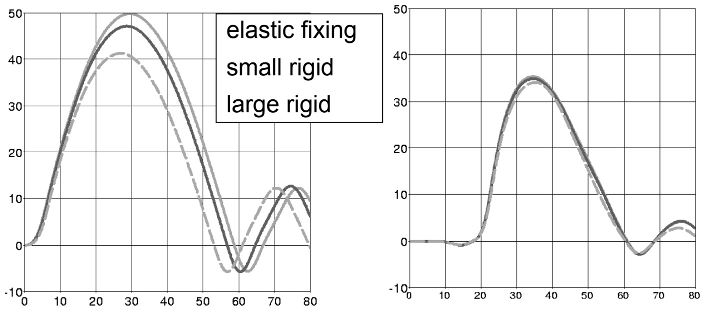
Modeling of assemblies: ES-2 model

- Influence of modeling of connections important
- 3 different types of connections were studied
- Influence only in pendulum tests



Modeling of assemblies: ES-2 model

- The influence was only observed in the component tests and not in the sled tests

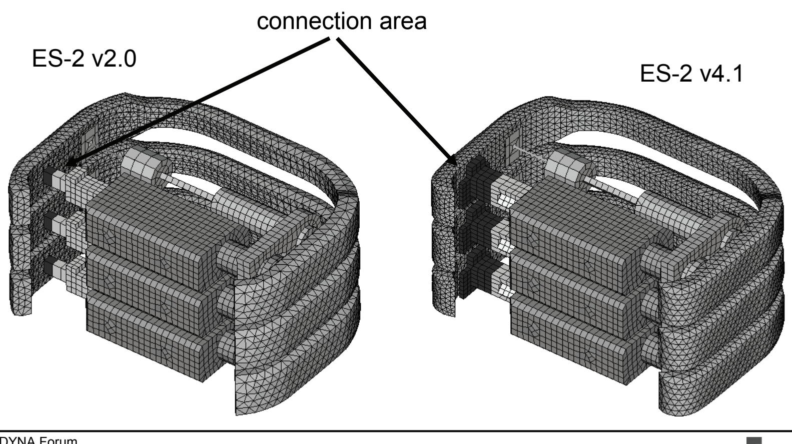


Rib intrusion vs. time, component test left and sled test right

German LS-DYNA Forum
Frankenthal, 11th-12th October 2007
Stuttgart, 19. September 2007
29

Modeling of assemblies: ES-2 model

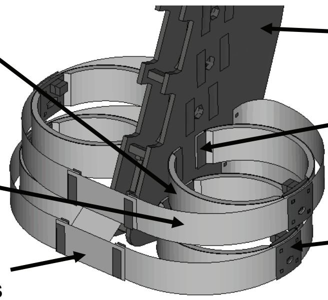
- Influence of modeling of connections is decreased with fine mesh
- Influence often only in a few tests present



German LS-DYNA Forum
Frankenthal, 11th-12th October 2007
Stuttgart, 19. September 2007
30

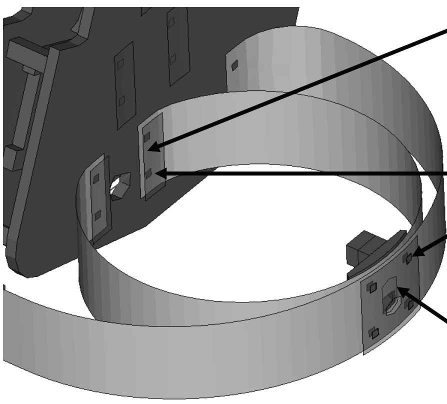
Modeling of assemblies: WorldSID model

- The ribs of the WorldSID 50% consist of two bands. An inner and outer band. The inner band is equipped with a damping material
- In use of clamps the bands are connected on the outside together
- On the inside the bands are connected to the spine box except the front of the outer band. This is connected to a sternum material



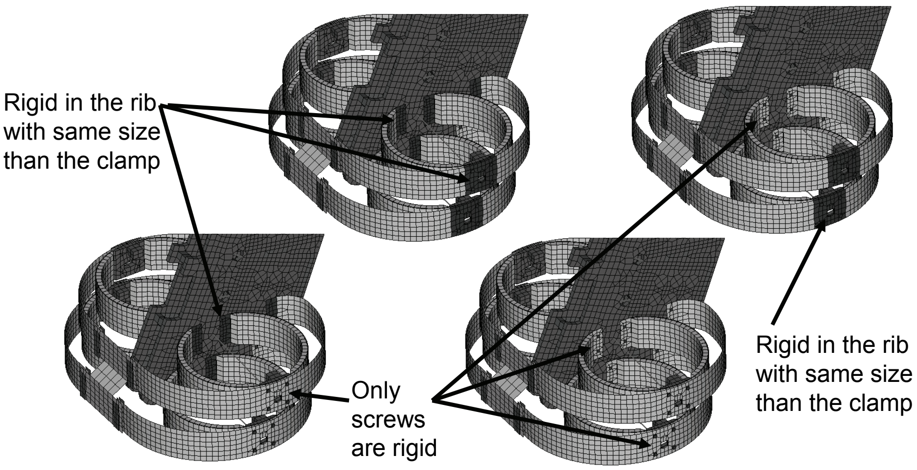
Modeling of assemblies: WorldSID model

- The clamps are all modeled as rigid parts
- Only the dispersion of the rigid parts in the deformable rib bands is varied



Modeling of assemblies: WorldSID model

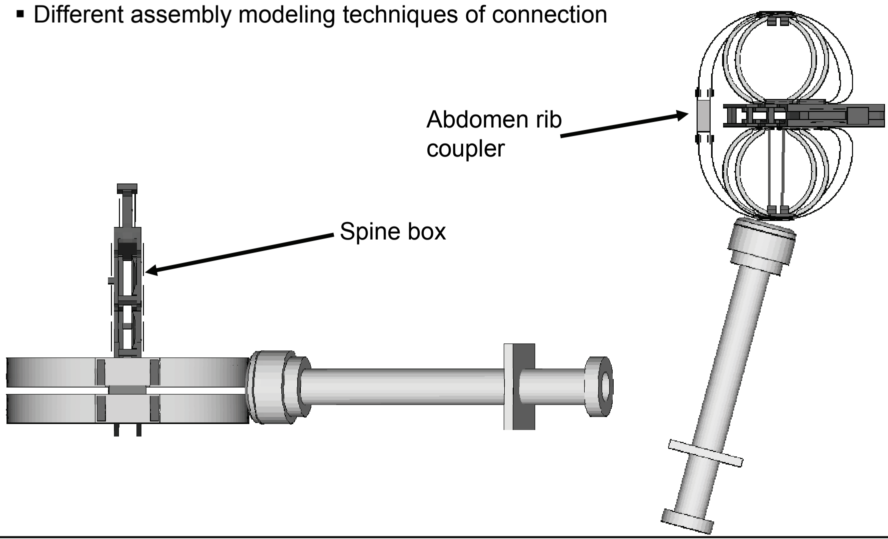
- Two different connection methods are used
- Connection modeling variations



German LS-DYNA Forum
Frankenthal, 11th-12th October 2007
Stuttgart, 19. September 2007
33 DYNA MORE

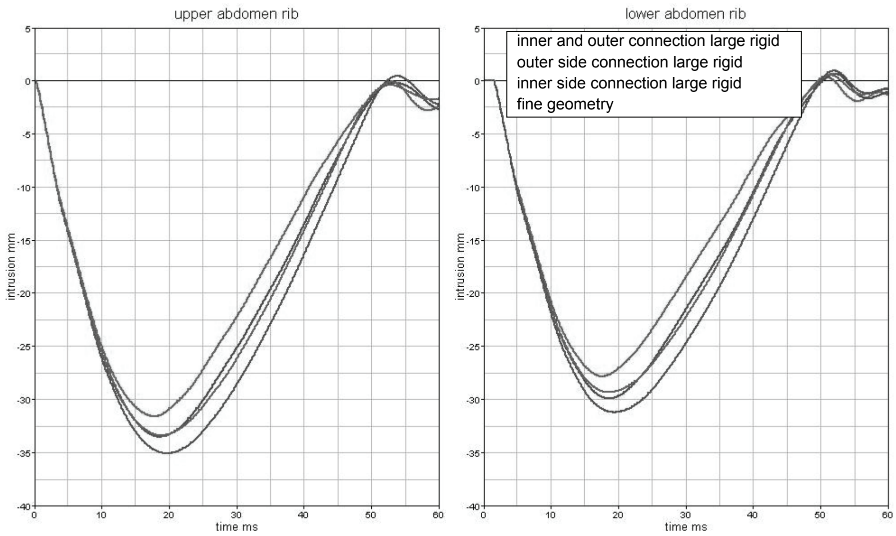
Mesh details example 2

- Component test on a rib assembly
- Different assembly modeling techniques of connection



German LS-DYNA Forum
Frankenthal, 11th-12th October 2007
Stuttgart, 19. September 2007
34 DYNA MORE

Modeling of assemblies: WorldSID model



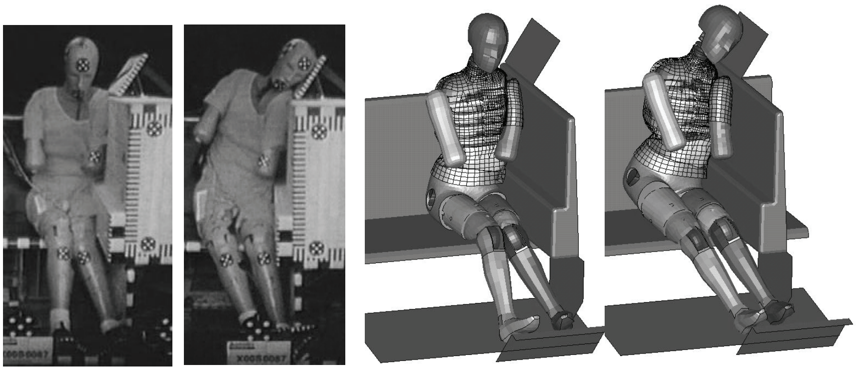
German LS-DYNA Forum
Frankenthal, 11th-12th October 2007
Stuttgart, 19. September 2007
35

Content

- Overview on developed models
- Applied methodology in development
- Aspects on modeling
    - Modeling geometric details
    - Initial geometry
    - Mesh density
    - Material tests
    - Modeling of assemblies
    - Modeling of interacting parts
- Conclusion

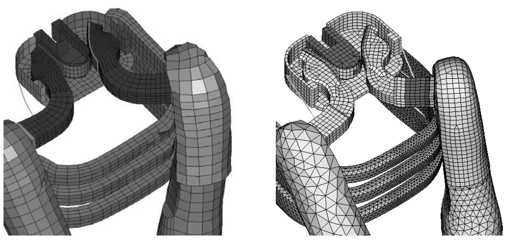
German LS-DYNA Forum
Frankenthal, 11th-12th October 2007
Stuttgart, 19. September 2007
36

Modeling of interacting parts

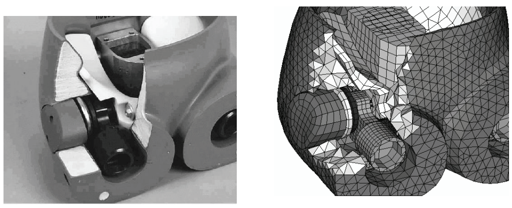


ES-2 in sled test and in simulation

Modeling of interacting parts



ES-2 clavicle and arm during impact, meshes of different releases



ES-2 parts interacting during impact

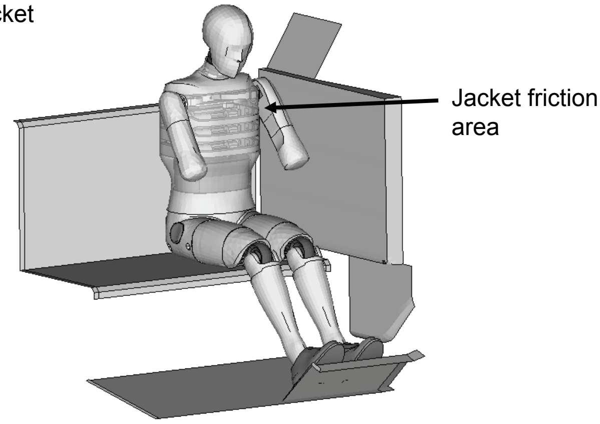
Modeling of interacting parts

Example: friction of ES-2 jacket

- The rotation of the clavicle influences the rib intrusion significantly
- Friction of the arm on the jacket has an minor influence on the results
- Frictional coefficients of jacket

  0.1 (baseline)

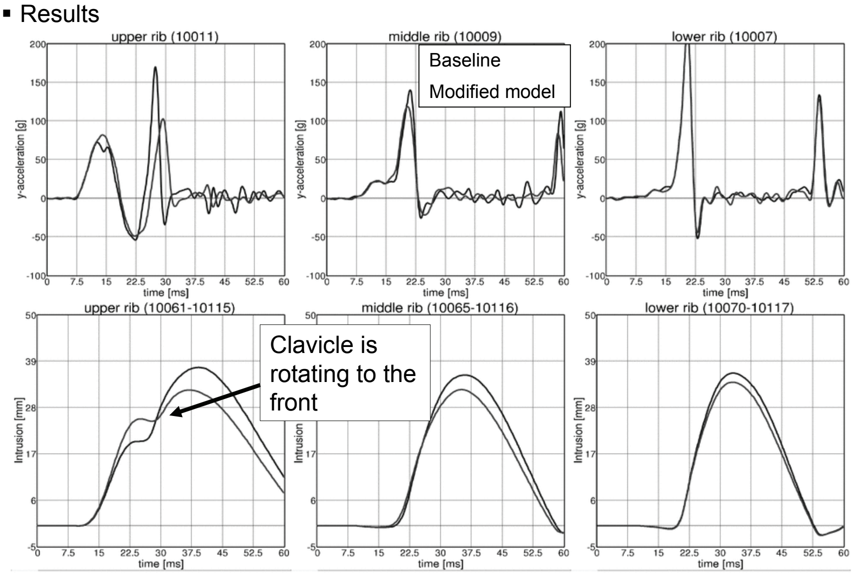
  0.5 (modified model)
- Plane barrier with 6 m/s



German LS-DYNA Forum
Frankenthal, 11th-12th October 2007
Stuttgart, 19. September 2007
39

Modeling of interacting parts

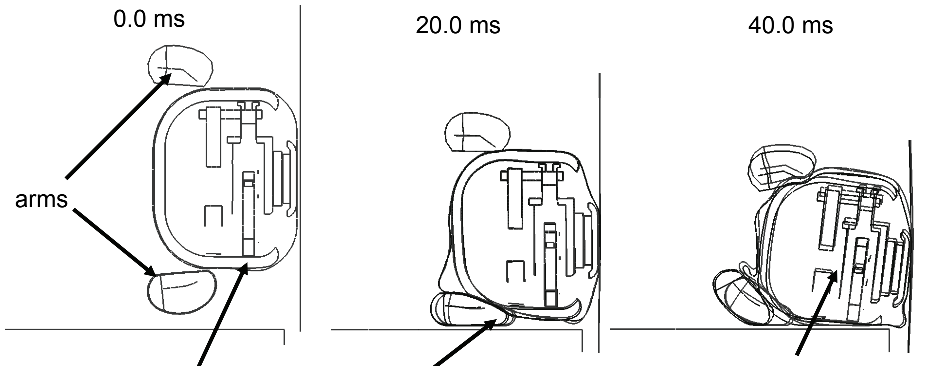
- Results



German LS-DYNA Forum
Frankenthal, 11th-12th October 2007
Stuttgart, 19. September 2007
40

Modeling of interacting parts

- Cut through upper rib.
- Results of baseline and modified model

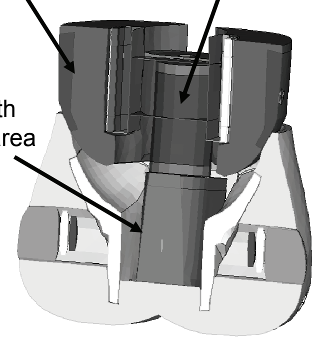


German LS-DYNA Forum
Frankenthal, 11th-12th October 2007
Stuttgart, 19. September 2007
41
DYNA MORE

Modeling of interacting parts

Example 2: ES-2 abdomen

- Interaction between abdominal insert and pelvis
- Friction influences movement of abdominal insert
- Differences only in one test obvious

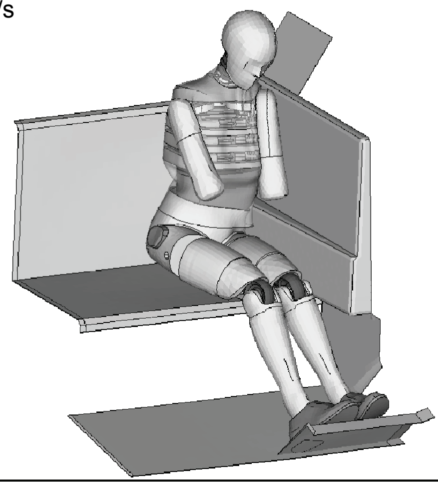


Cut through the abdomen and pelvis

German LS-DYNA Forum
Frankenthal, 11th-12th October 2007
Stuttgart, 19. September 2007
42
DYNA MORE

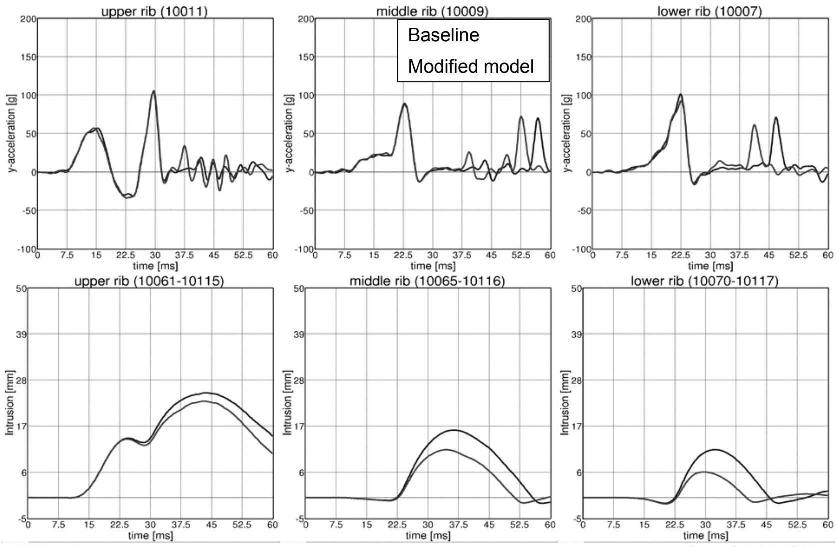
Modeling of interacting parts

- The friction is increased from 0.2 (baseline) to 0.9 (modified model)
- Load case is a plane barrier with a small pelvis impactor
- The barrier has a velocity of 6 m/s



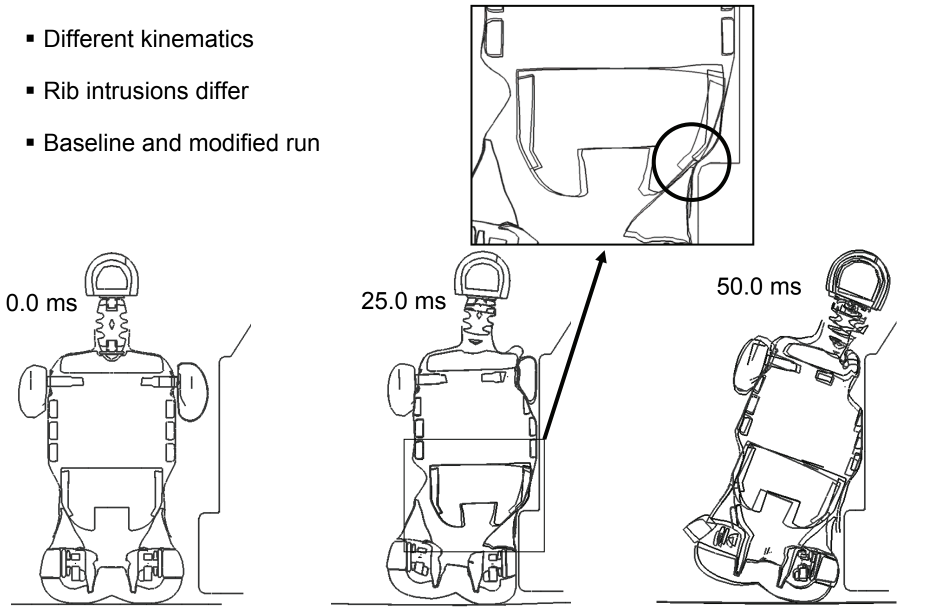
Modeling of interacting parts

- Results



Modeling of interacting parts

- Different kinematics
- Rib intrusions differ
- Baseline and modified run



Conclusion

- Modeling geometry in detail is important to capture many effects
- Element size is often not time step relevant in dummy modeling
- Exact initial geometry is indispensable
- Detailed modeling helps to work with material data from tests
- Fine meshes allow to work with exact frictional values
- Modeling of connections is less important in detailed models
- Often effects can be observed only in very few tests