Ideas on Applying Very Fine Models in Dummy Model Development

A. Gromer, J. Zschieschack, U. Franz (DYNAmore GmbH);

M. Walz (Mercedes Car Group, Daimler AG)

IDEAS ON APPLYING VERY FINE MODELS IN DUMMY MODEL DEVELOPMENT

Jens Zschieschack (DYNAmore GmbH)
Matthias Walz (Mercedes Car Group, Daimler AG)
Uli Franz, Alexander Gromer (DYNAmore GmbH)

30th September - 1th October 2008

Content

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DYNAmore introduction

DYNAmore at a glance

- 38 engineers
- distributor of LS-DYNA in Germany, Austria, Switzerland, Italy, Spain,..
- all engineering work is related to LS-DYNA and LS-OPT
- customers for dummy models world wide
- about 8000 LS-DYNA licenses are supported by DYNA*more*
- main office in Stuttgart
- 4 Offices at Daimler on-site
- one office in Langlingen (close to Volkswagen)
- one office in Ingolstadt (close to Audi)

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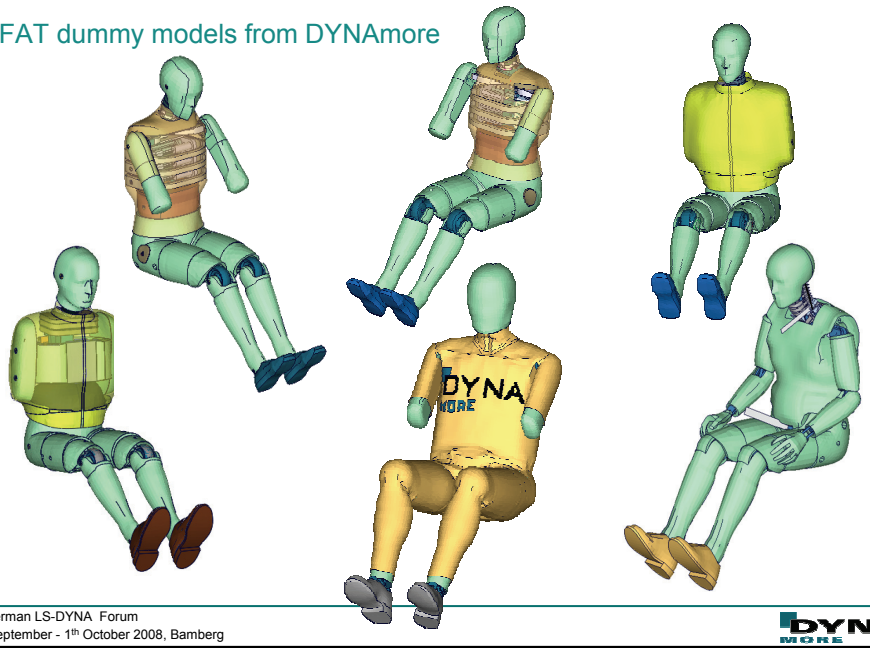
Introduction

FAT dummy models from DYNAmore



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Introduction

Who is the FAT?

- FAT is abbreviation for:
  German Association for Research on Automobile Technology
- FAT performs research related work with the members
- FAT are located in Frankfurt
- dummy modeling activities started in 1992.
- members: Audi, BMW, Ford, Opel, Mercedes, Porsche, Volkswagen,..

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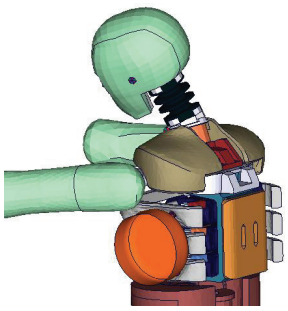
Introduction

ES-2 and ES-2re project

- based on EuroSID 1 development
- first commercial releases available in 2002
- constant enhancements of models
- project is still running
- currently new tests are defined for new FMVSS214 load case



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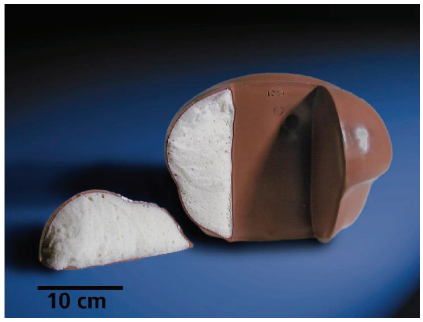
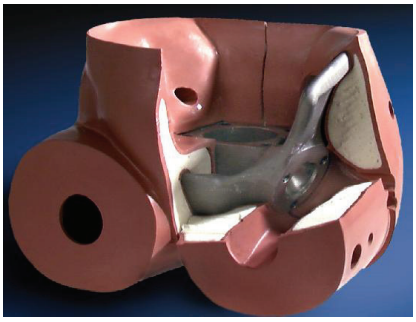
Experimental Data – Material Tests

Material Tests

- all relevant materials were testes
- specimen were taken from new original parts
- some vinyl skins specimen were taken from repair kits.

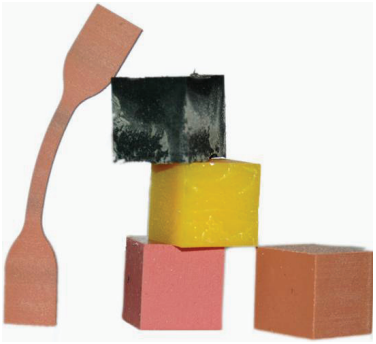




Experimental Data – Material Tests

Material Tests

- static tension tests
- dynamic tension tests
- static compression tests
- dynamic compression tests
- cyclic compression test
- relaxation tests
- hydrostatic triaxial compression tests
- static and dynamic shear tests



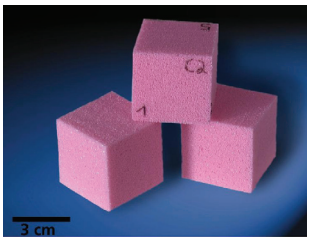
Later tests such data could be used directly in:

- Mat_Fu-Chang_Foam
- Mat_Simplified_Rubber

Experimental Data – Material Tests

Outline of tests for rate dependent foams

- specimen (30x30x30 mm**3)
- static **compression** test
- dynamic compression
- strain rates 10/s, 20/s, 50/s, 100/s and 200/s
- maximum volumetric strain was 90% and 50%
- static **tension** tests
- dynamic tension tests with strain rates: 10 /s, 20/s, 100/s, 200/s



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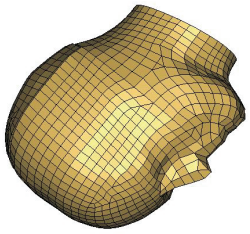
Experimental Data – Component Tests

Performed component tests

The tests were performed with varying speeds, masses and angles:

- Pendulum tests on **rib assembly**
- Pendulum tests for **neck** and **lumbar** spine
- Dynamic shear for the lumbar spine
- Pendulum tests for the **abdominal insert**
- **Head** drop tests
- **Partial thorax** impact tests
- Impact tests for the **pelvis**
- Pendulum tests for the **lumbar spine**
- Impact tests for pelvis with upper legs



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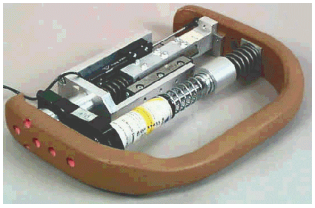
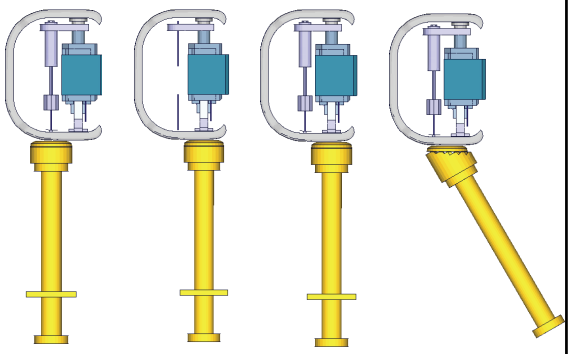
Experimental Data – Component Tests

Outline pendulum test on rib assembly of ES-2

- different impact speeds, such that rib intrusions are: 10, 20, 30, 40, 50 mm
- different masses
- different impact locations
- different angles
- with/without damper unit
- in total 40 different test





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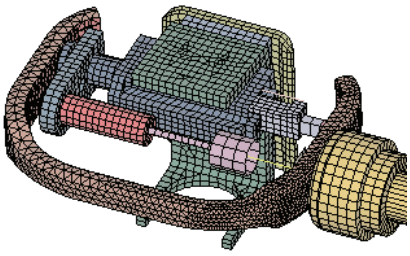
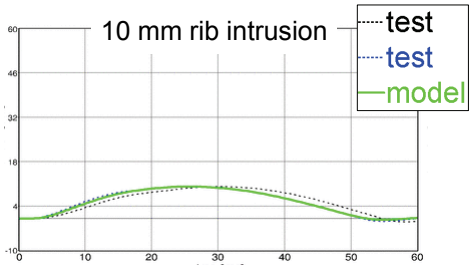
Model Performance – ES-2 Rib Assembly Test

ES-2 rib assembly in component test

- 5 different tests on this impact location
- depicted is rib intrusion vs. time
- green is simulation
- black and blue is experiment





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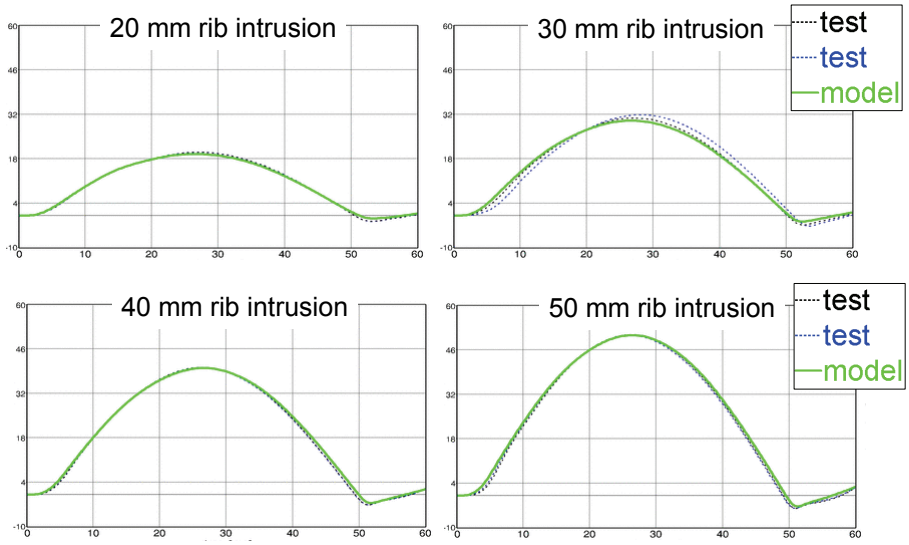
Model Performance – ES-2 Rib Assembly Test

ES-2 rib assembly in component test



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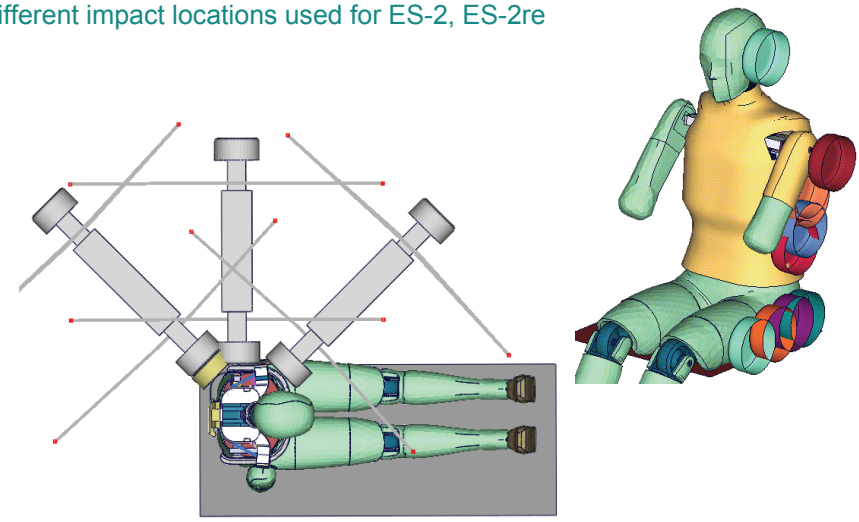
Experimental Data – Fully Assembled Dummy Tests

Different impact locations used for ES-2, ES-2re



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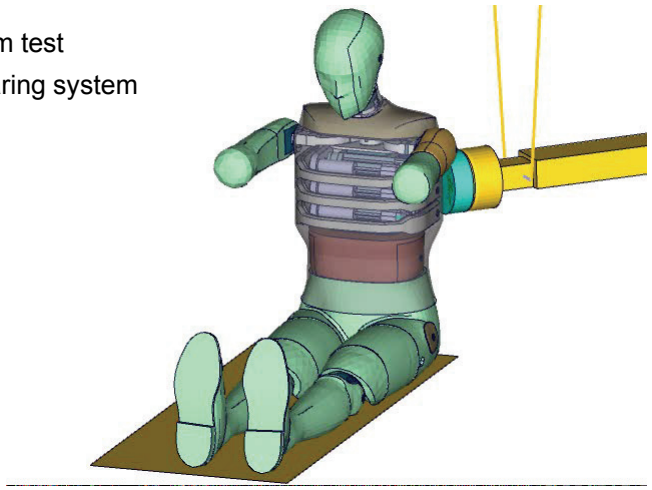
Model Performance ES-2re Pendulum Test

ES-2re model in pendulum test

- ES-2re in pendulum test
- test to validate bearing system



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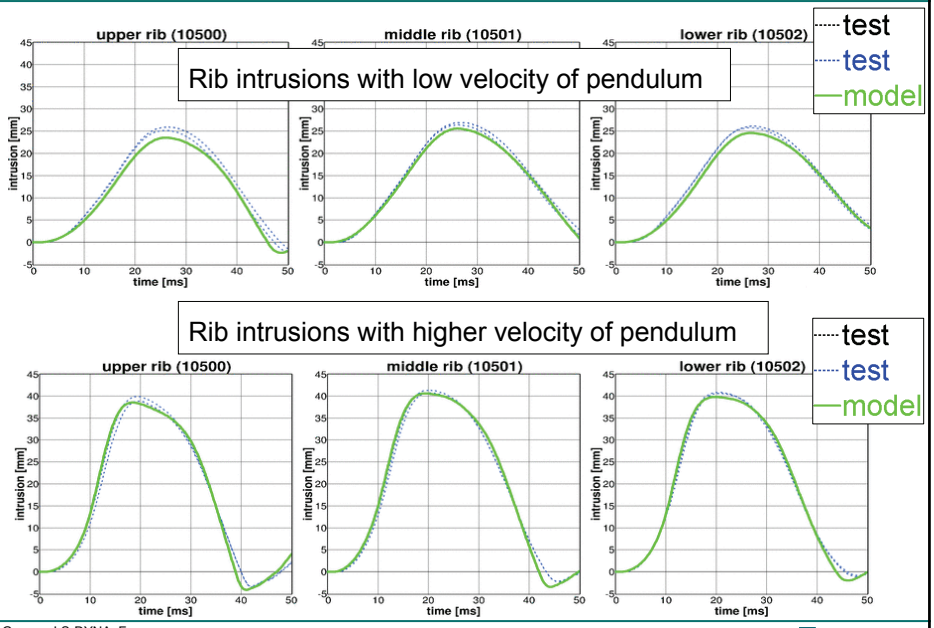
Model Performance – ES2re pendulum test



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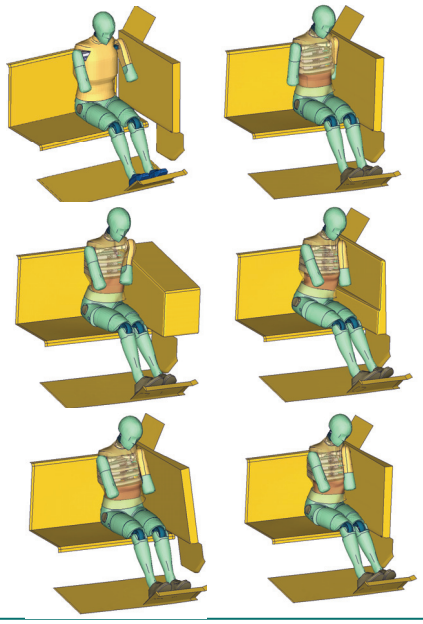
Experimental Data – Fully Assembled Dummy Tests

Outline sled tests data for ES-2 model

- different barrier speed
- different arm positions
- shaped barrier
  - “door” shape
  - small pelvis impactor
- oblique barriers
  - plane barrier
  - x - direction
  - z - direction



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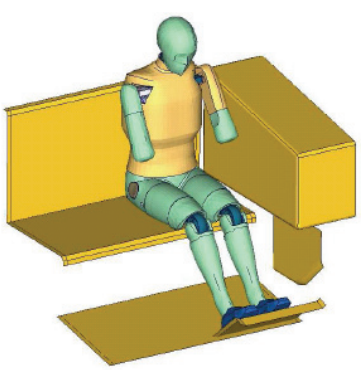
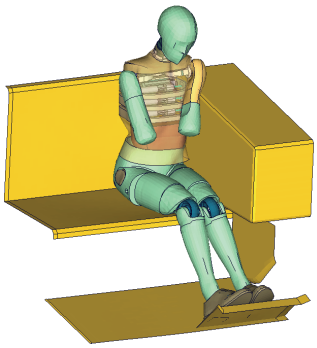
Model Performance

ES-2 model in sled test





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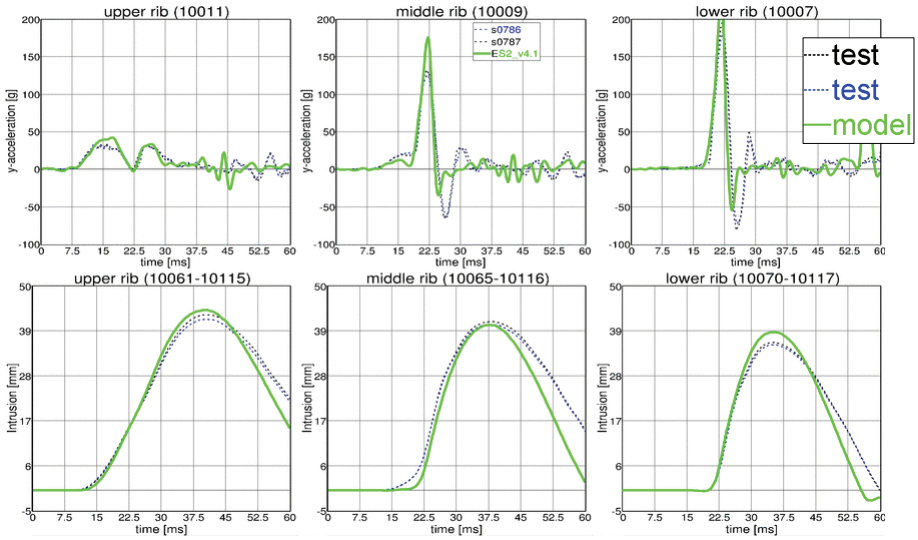
Model Performance – ES-2 Sled Test



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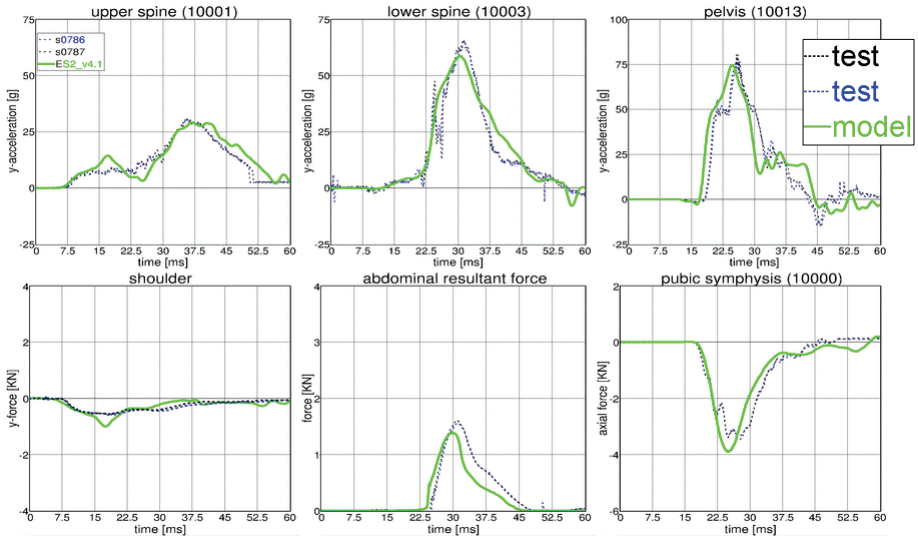
Model Performance – ES-2 Sled Test



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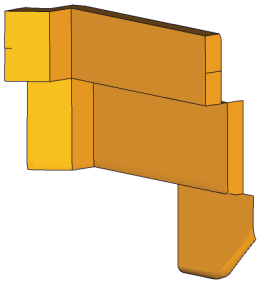
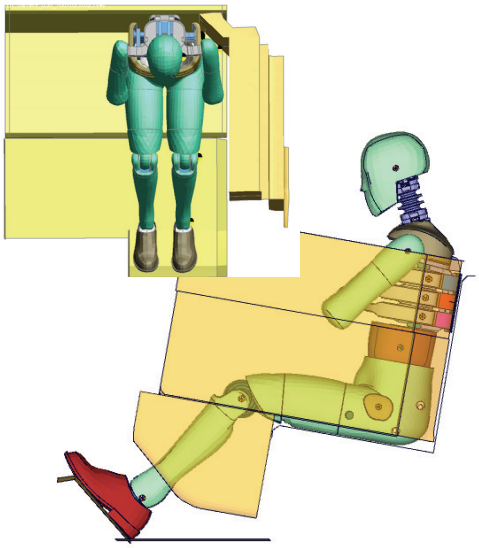
Experimental Data – New Tests

Barrier design for adequate lumbar spine load ES-2

- new barrier designs
- focus on FMVSS 214 new
- one target is to enhance lumbar spine model





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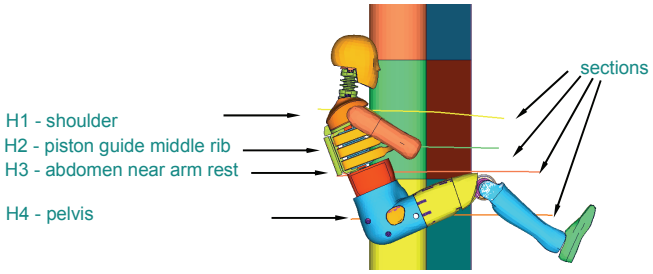
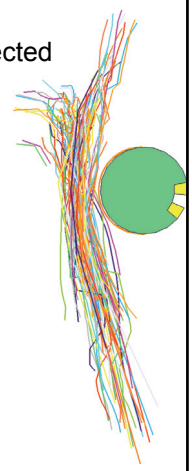
Experimental Data – New Tests

Sled tests – new barrier design

- particularly for FMVSS214 pole test a new barrier shape is considered
- typical intrusion profiles from PDB/FAT members were collected





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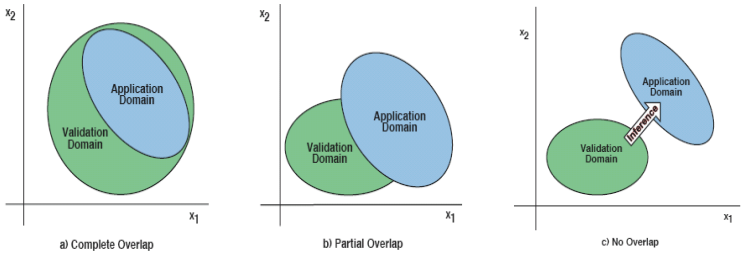
Experimental Data – Aim of Tests

Necessity of the huge amount of tests

- for validated models the application domain is important
- validation domain should contain application domain
- complete overlap is needed



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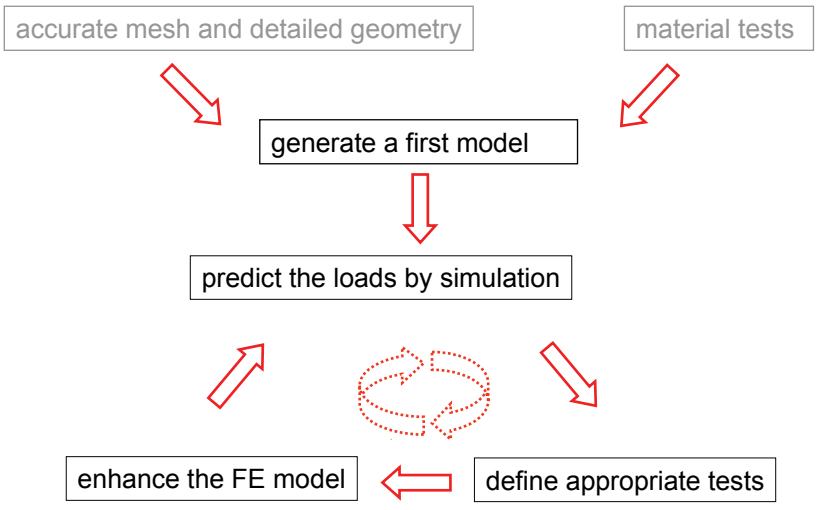
Experimental Data – Aim of Tests

Methodology of development



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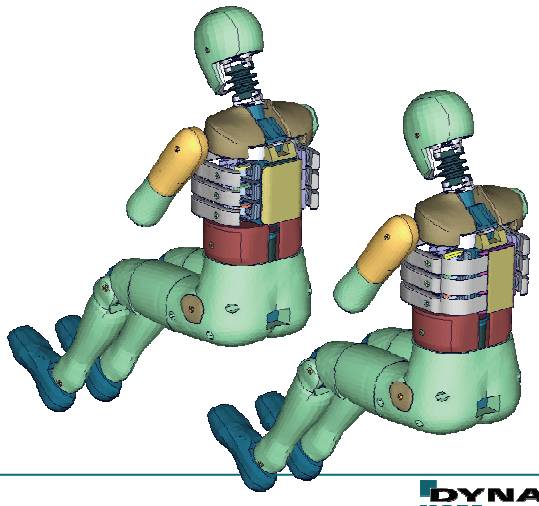
Model Details

Outline details ES-2 and ES-2re Release 4.1

- Nodes: ~ 84,000
- Beams: ~ 300
- Shells: ~ 70,000
- Solids: ~ 130,000
- Materials: ~ 110
- Parts: ~ 240
- Joints: ~ 19
- Contacts: ~ 8



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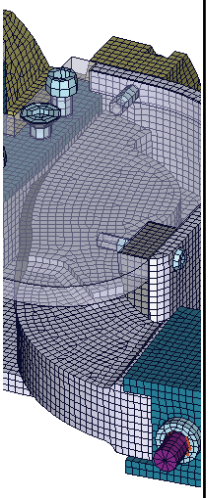
Outline of Fine Model

Outline fine model

- 8-10 times more elements
- number of shells reduced (mainly contact shells)
- no tetrahedron elements (factor 3-4 less solid elements)
- components with different mesh densities can be combined
- time step 0.2 micro seconds (1.5 - 3 mm)
- time step 0.5 micro seconds (2.5 - 4 mm)
- regular model: 1 micro second (7 - 12 mm)
- one contact definition
- mesh such all parts can be pre-stressed, even the bolts
- joint definitions reduced, parts and contact modeled instead
- rigid bodies could be considered as deformable
- very minor initial mass scaling



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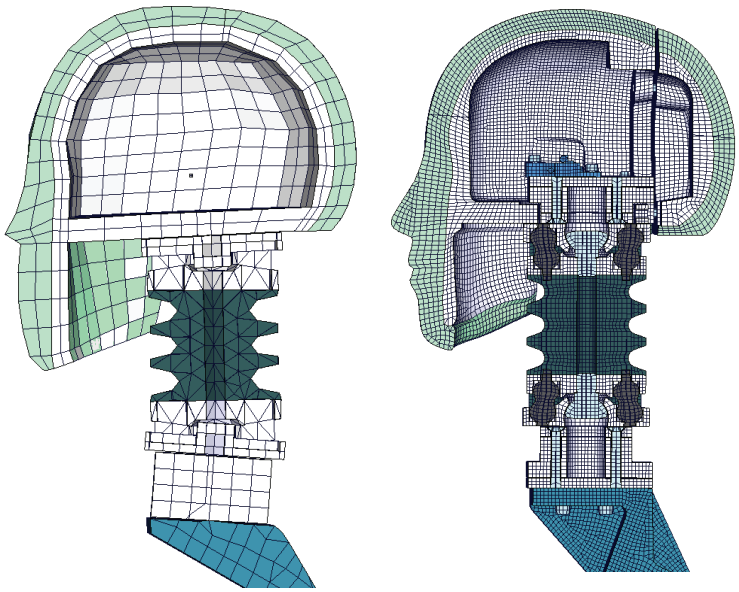

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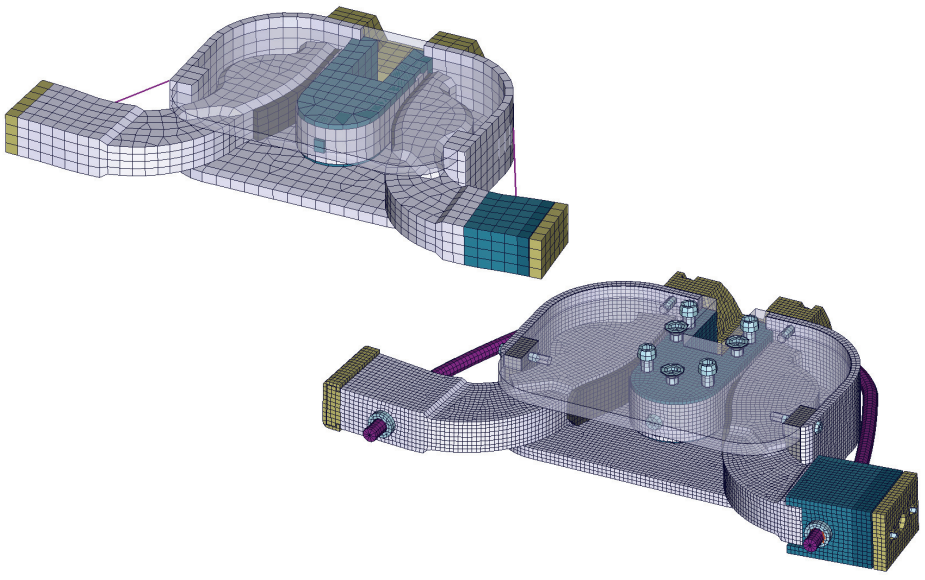
Outline of Fine Model



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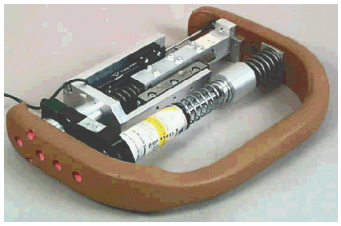

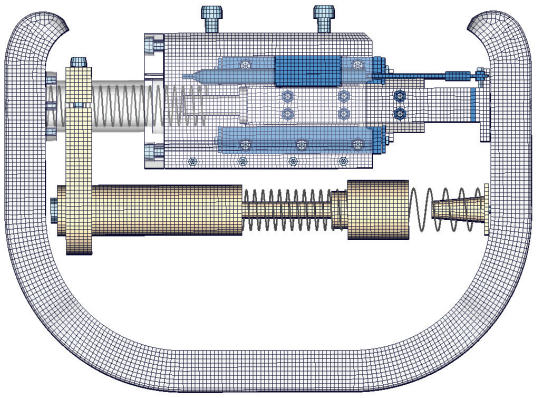

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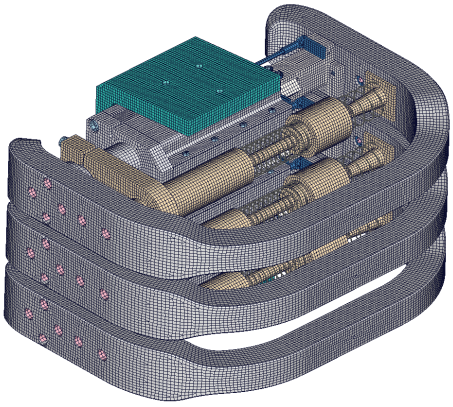
Outline of Fine Model



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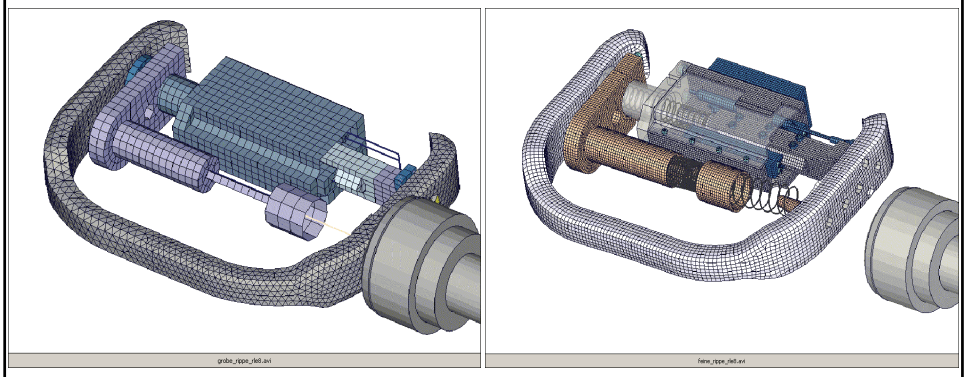

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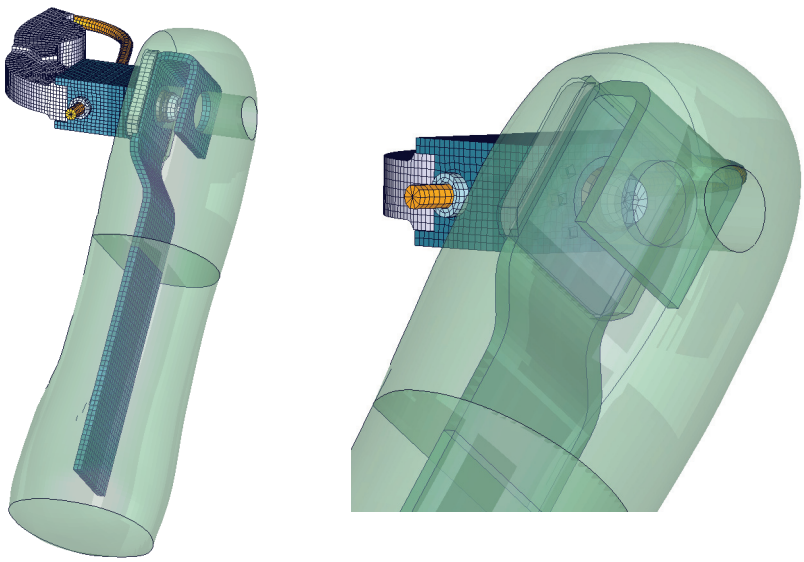
Outline of Fine Model



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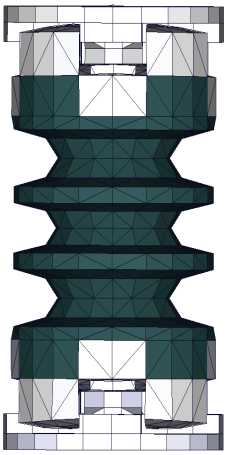
Motivation for Fine Model

Motivation for fine model

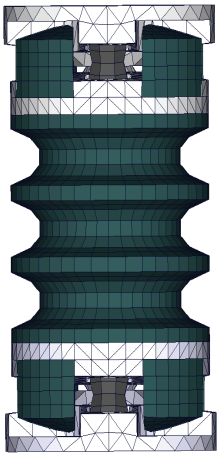
- get better understanding of the physics in the dummy
- get better understanding of the model behavior
- development tool for development of commercial models
- examples:
  - generate validation data
  - mesh convergence studies
  - sensitivity studies
  - investigate connected parts

Applications of Fine Models – Validation Data

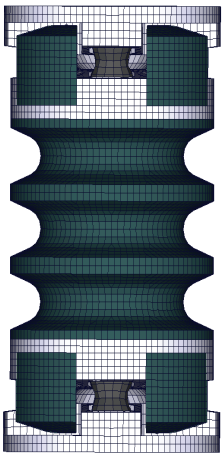
Different neck models



coarse mesh
(current release)



fine mesh

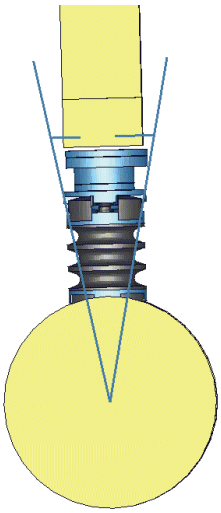


finer mesh

Applications of Fine Models – Validation Data

Pendulum test with neck

- detailed material test available
- coarse model needs parameter fitting
- pre-stress can be included in fine model
- fine model correlates **without** parameter fitting
- fine and coarse model correlate with a set of pendulum tests



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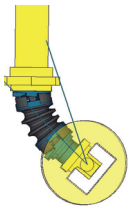
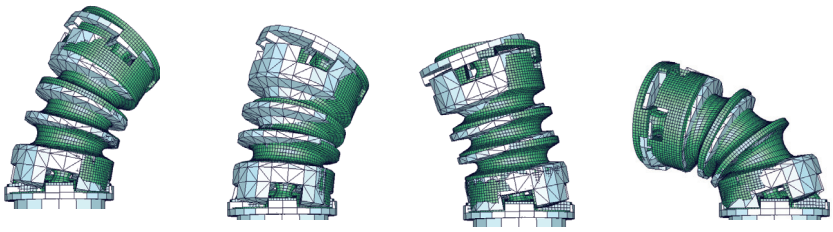
Applications of Fine Models – Validation Data

Fine and coarse neck model during FMVSS 214 pole test

- different results in FMVSS 214
- coarse model in gray, fine model in green
- idea: Fine model can be used to validate coarse model





t= 20 ms t= 40 ms t= 60 ms t= 80 ms

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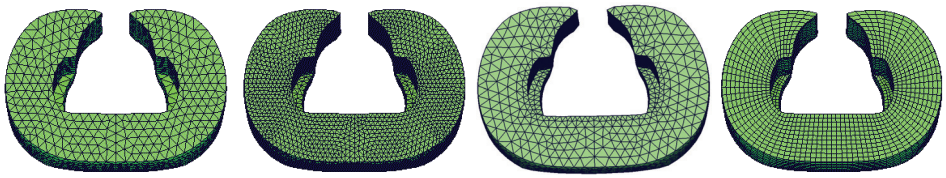
Applications of Fine Models – Mesh Convergence Study

Abdominal insert

- influence of mesh density on force distribution



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

# Element	16 000 Tetra	113 000 Tetra	47 000 Tetra	23 000 Hex
Normed Time	1.0	6.7	2.8	2.3

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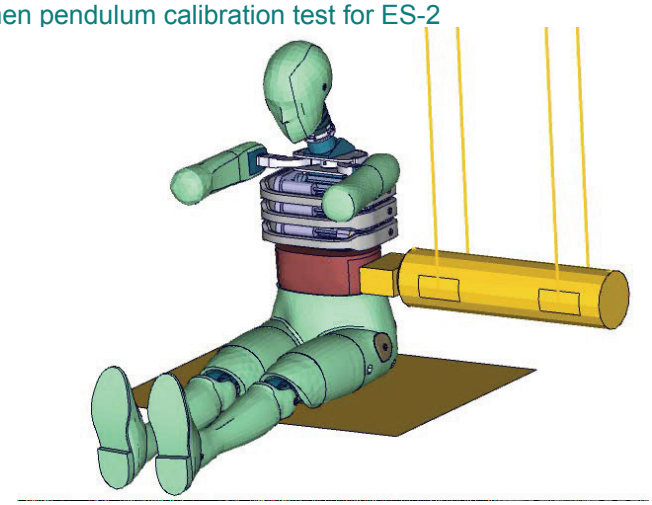
Applications of Fine Models – Mesh Convergence Study

Abdomen pendulum calibration test for ES-2



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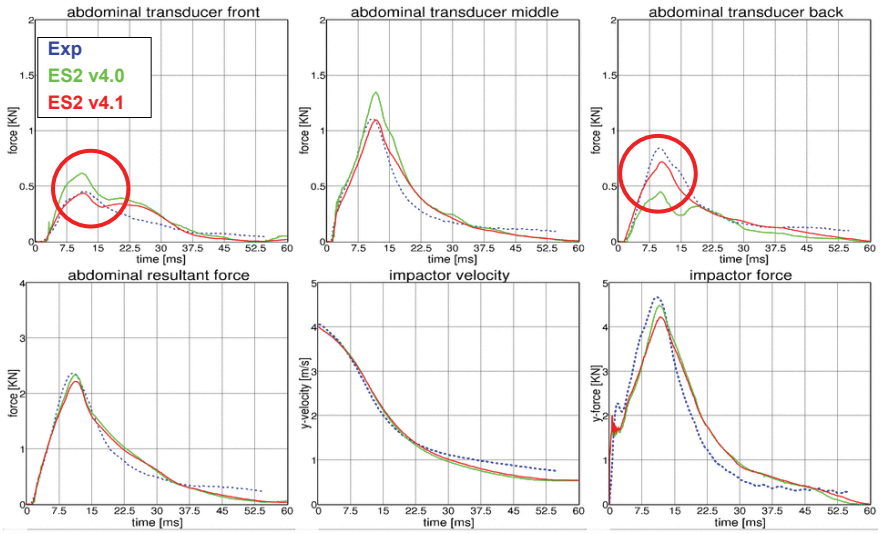
Applications of Fine Models – Mesh Convergence Study

Result of abdomen pendulum test



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Applications of Fine Models – Sensitivities

Influence of jacket modeling

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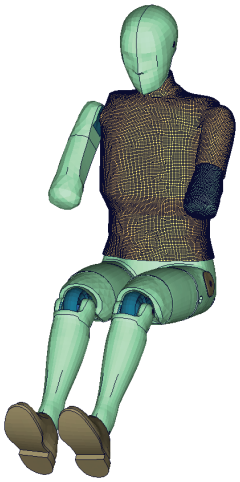
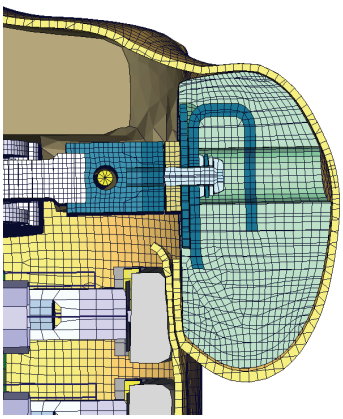
Applications of Fine Models – Sensitivities

Fine shell model and hex model of jacket





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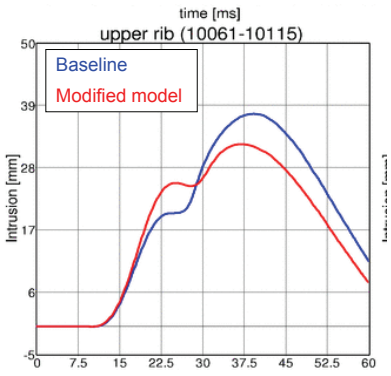
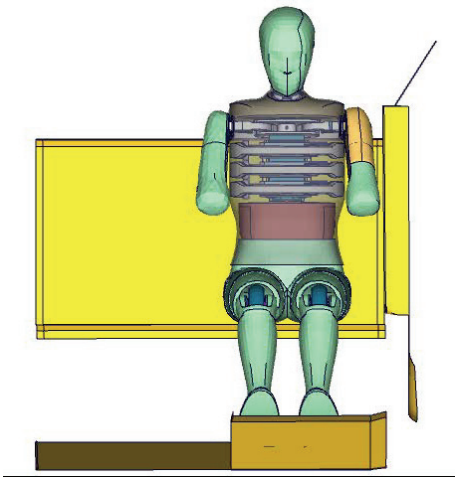
Applications of Fine Models – Sensitivities

Influence of friction on rib intrusion





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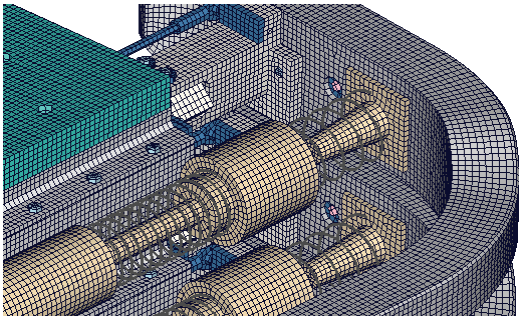
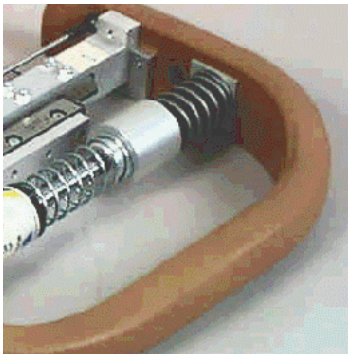
Applications of Fine Models – Connected Parts

Parts connected to rib bow

- connection influences the total stiffness
- rubber is clamped between connected rigid parts





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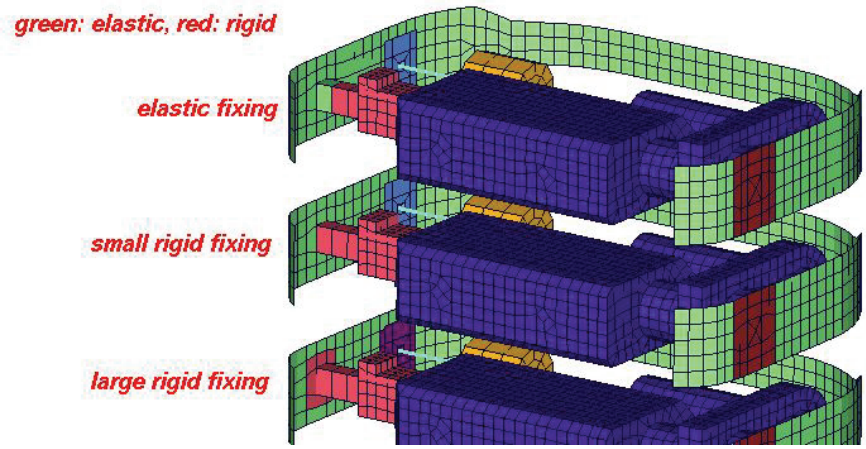
Applications of Fine Models – Connected Parts

Modeling of connections with a very coarse mesh



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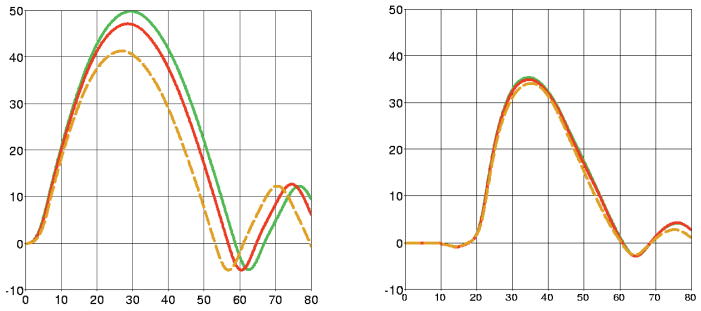
Applications of Fine Models – Connected Parts

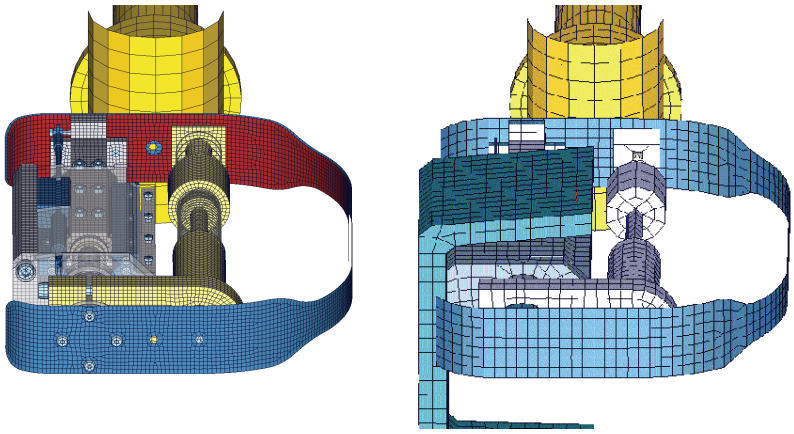
Rib intrusions in barrier test with very coarse mode



- intrusion of upper and lower rib in barrier test
- colors indicate different modeling of connections
- not all tests highlight influence of connection modeling

Applications of Fine Models – Connected Parts

Virtual test to enhance standard model



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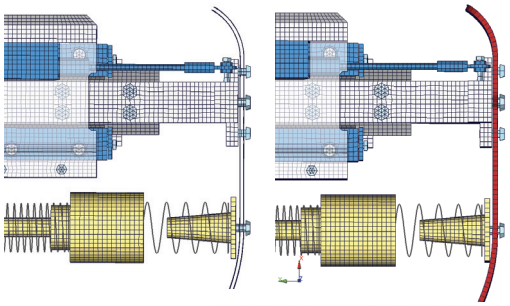
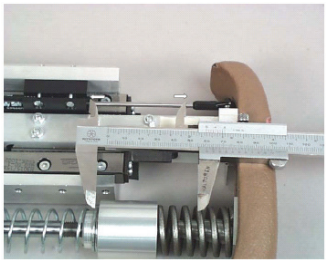
Difficulties

Difficulties in modeling

- time step is very small
- high computational costs
- contact stiffness
- contact thickness
- pre-stress causes oscillations
- huge validation effort
- some times mesh is still to coarse





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Fine Models in Standard Simulations

Usage of very fine models vehicle simulation?

- model would increase CPU time significantly
- higher accuracy only in few cases
- handling difficult
- currently: development tool
- future: ?

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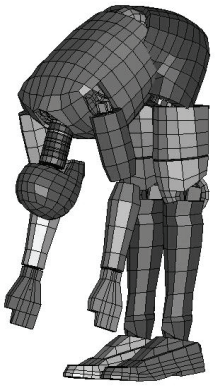
Conclusion

- a very fine model for ES-2 has been developed
- different mesh densities are available
- fine and coarse parts can be combined
- the model can include many physical effects
- the model is used for:
  - generate validation data for coarse model
  - sensitivity studies
  - check mesh convergence
  - investigate interaction of parts
- model is very useful to enhance coarser models
- the coarse models are commercially available and used by many OEMs and suppliers

Conclusion

Thank you very much for your attention!



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