Use of the FTSS Modular Crash Dummy Models in Frontal Occupant Simulation

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Summary:

Legal and consumer vehicle crash tests use crash dummies as the primary measurement device in the assessment of crash severity. The dummies are themselves complex assemblies, and this must be borne in mind during the development of a frontal occupant crash restraint system. The optimisation of these systems has to consider the interaction of many components, including the dummy, for multiple load cases, and is very challenging. Conventionally it has involved a significant amount of prototype sub-system and vehicle testing.

In a world in which vehicle manufacturers are embracing a CAE-led engineering approach, physical prototype testing is reducing, placing demands on simulation tools to be truly predictive. Sophisticated vehicle crash models, with a substantial heritage of test-based validation to refine and confirm model quality, are now standard in the automotive industry. The use of large-scale finite element vehicle models in the development of frontal occupant components and systems is also now well established. Occupant sub-system 'sled' models can typically contain 1M nodes, and full-vehicle models are much larger than this. The significance of the dummies in the system has led to the creation of detailed dummy models that complement the level of refinement in the vehicle system models. These dummy models are typically responsible for 20% of the CPU time, and there is no strong motivation to reduce their size. In fact, the tendency is to make the dummy models more complex, and the latest version of the FTSS 50% H3 dummy has undergone a significant refinement, which has increased its CPU time by a factor of two.

Recent development in the use of DYNA for frontal occupant modelling at Jaguar Land Rover has seen the construction of simple FE crash models. These replace the previous multi-body dynamics technique for target setting, parametric optimisation, and quick comparison tasks, and are complementary to, and compatible with, the full FE representation. The run time for these models has to be significantly lower than for the full-scale models. However, by reducing the run time, the proportion of CPU time taken by the dummy has increased, and can constitute well over half of the total. In order to avoid the dummy setting a limit on the run time, an alternative approach was needed. The standard FTSS 50% and 5% Hybrid 3 dummy models are now offered in a modular format that allows individual dummy parts to be exchanged for simpler representations. The standard parts are retained where maximum fidelity of measurement is necessary, and the simpler representations selected, where this is adequate. The model structure is shown in figure 1.

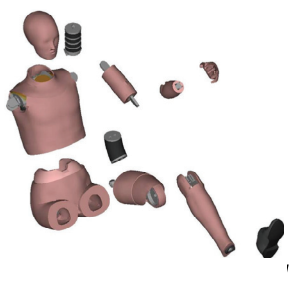

Figure structure

This concept is directed at satisfying the need for a predictive model, whilst maintaining the ability to reduce run time in the new, simple DYNA environment. The model geometry and joint configurations are consistent so that any combination of full and simple parts can be selected in the same model by the user. To make this approach usable in a production environment, simple and standard parts must be interchangeable without excessive user involvement. Dummy model geometry, contact definitions, numbering ranges, the positioning process, and post-processing have to be consistent. Maintaining the same geometry is particularly important, since it allows the model parts to be exchanged without re-aligning seat belts and pre-deforming seat foam; it also makes visual comparison of the behaviour of the standard and simple components easy. In its fully deformable configuration, the modular dummy is identical to the baseline standard model.

A comparison of the simple and complex models has been made for various configurations in a vehicle sled model, and an example is shown in figure 2. In this example, the fully deformable model is compared with a fully rigid, and a part rigid model, and shows acceptable agreement in peak values.

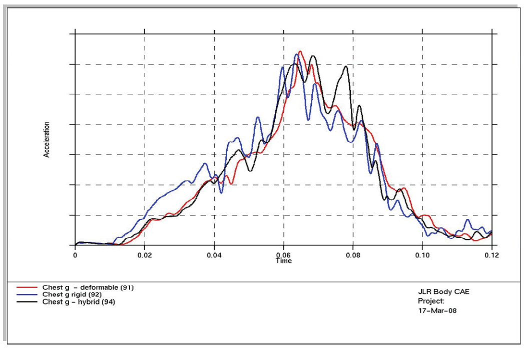

Figure 2. Comparison of fully deformable and part deformable dummy model

The validation process has show that, in many cases, the simple models are an adequate representation of the dummy in areas where the detail of the local behaviour is not required.

The CPU timerequirement can be significantly reduced, and figure 3 shows a progression of reducing CPU time for a sled model as additional parts are replaced by simple models. In this example the run time ranged from over 7 to 3 hours. The figure also shows how the proportion of CPU time spent on the dummy no longer dominates the overall value as the model is simplified.

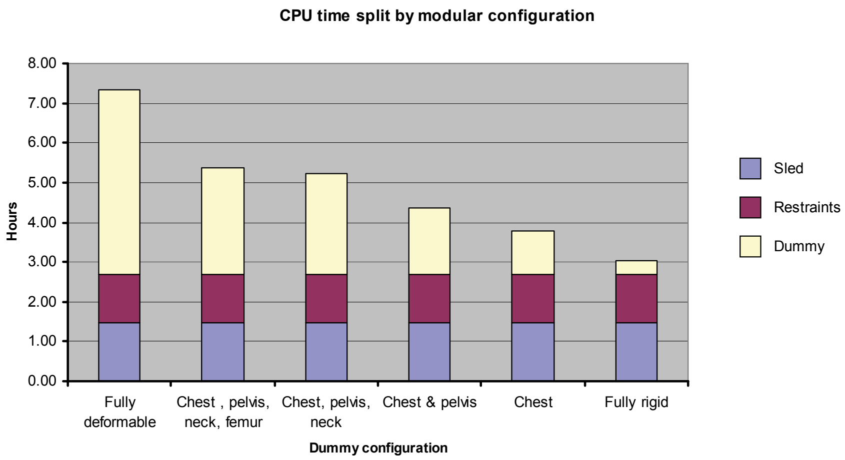

Figure 3. Progressive reduction in CPU time for decreasing dummy complexity

The criteria for efficient usability, including consistency of geometry, identical positioning process, pre and post-processor techniques, and automatic internal contact definition have been achieved, and minimal user intervention is required. The new, modular model approach has proved to be a very useful extension of the standard FTSS 50% and 5% Hybrid 3 dummy models. It represents a flexible, consistent, and usable tool in the simulation of vehicle frontal occupant crash systems.

Keywords
Crash simulation, Dummy models.

Use of the FTSS modular crash dummy models in frontal occupant simulation

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Content

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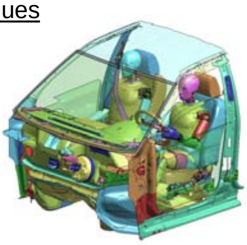
Scope of frontal occupant restraint system

Components that significantly influence dummy injury values

- Airbags
- Seat belts
- Knee bolsters
- Glovebox
- Steering column
- Steering wheel
- Seat
- Carpet
- **Dummy**
- Body structure pulse and intrusion



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Dummy characteristics

Primary measurement device for frontal crash

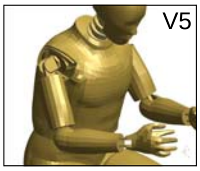
Highly complex assembly

Essential to capture dummy behaviour and interactions in occupant environment

Detailed dummy models are necessary

Size and complexity increasing

Run time factor 2 in latest FTSS V7



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Frontal occupant system development strategy

Current		Future
Madymo Target setting & tuning Parametric Interactive Low run times Validated simple dummy models	→	**DYNA - Parametric** Target setting & tuning Parametric Interactive Low run times **Validated simple dummy models**
Madymo / DYNA Coupling Coupling awkward	→	**DYNA** Coupling inherent in process
DYNA Design development Geometric Batch High run times Validated complex dummy models	→	**DYNA** Design development Geometric Batch High run times Validated complex dummy models

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Benefits of integrated process

Single software and process environment

Intermediate models possible

Reduced costs:

- Software licence
- Restraints and component models
- Process development
- Skill set maintenance and training

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Dummy model requirements for simple, parametric DYNA

- Predictive, where required
- Maintain geometry – for visual overlay and seatbelt fitting
- Use same processes e.g. seat belt fit, contact definition, pre/post processing
- Be interchangeable with detailed model
- Significant run time reduction
- Minimal user intervention

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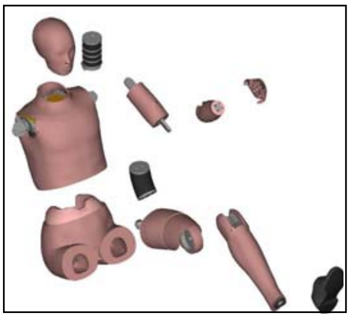
Modular dummy concept

Specification

- Modular functionality (*INCLUDE files)
  - Users choose either deformable or rigid module
  - Maintains existing geometry
  - Positioning file and data extraction capabilities preserved
- Very efficient Spring+Rigid Body neck and lumbar spine models with realistic performance
- Minimum time step controlled by deformable components



By courtesy FTSS

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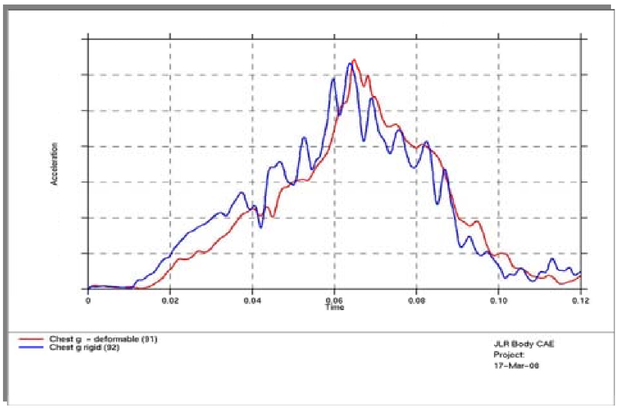
Modular dummy validation - Sled comparison 35mph FFB belted

Chest acceleration - deformable vs. fully rigid.



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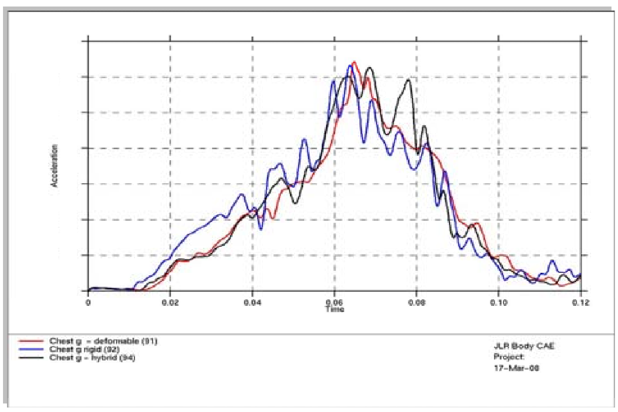
Modular dummy validation - Sled comparison 35mph FFB belted

Chest acceleration - deformable vs. fully rigid vs. part rigid.



* chest, pelvis, femurs, knees deformable.

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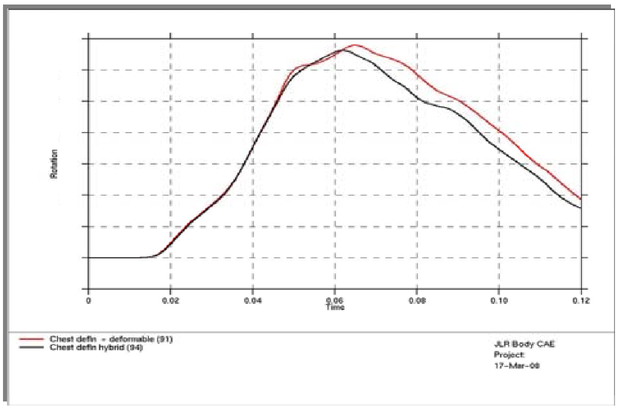
Modular dummy validation - Sled comparison 35mph FFB belted

Chest deflection - deformable vs. part rigid*.



* chest, pelvis, femurs, knees deformable.

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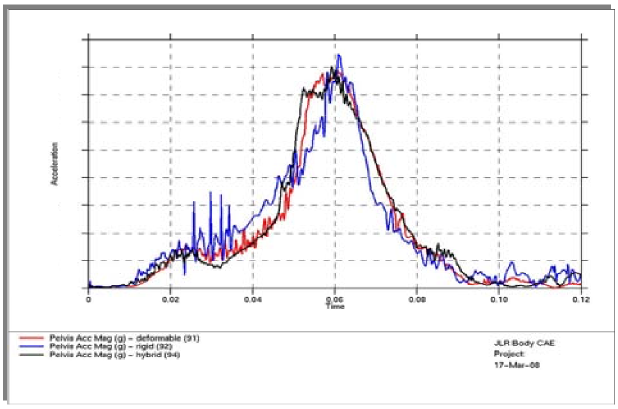
Pelvis acceleration - deformable vs. fully rigid vs. part rigid*.



* chest, pelvis, femurs, knees deformable.

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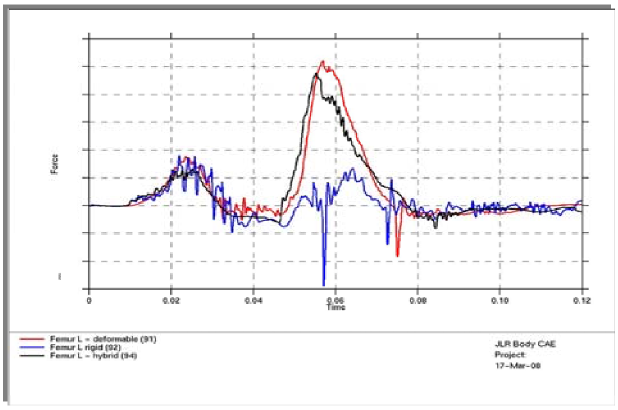
Modular dummy validation - Sled comparison 35mph FFB belted

Femur load (L) - deformable vs. fully rigid vs. part rigid*.



* chest, pelvis, femurs, knees deformable.

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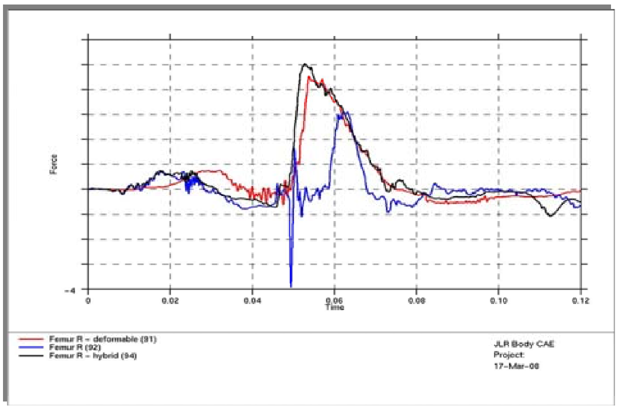
Modular dummy validation - Sled comparison 35mph FFB belted

Femur load (R) - deformable vs. fully rigid vs. part rigid*.



* chest, pelvis, femurs, knees deformable.

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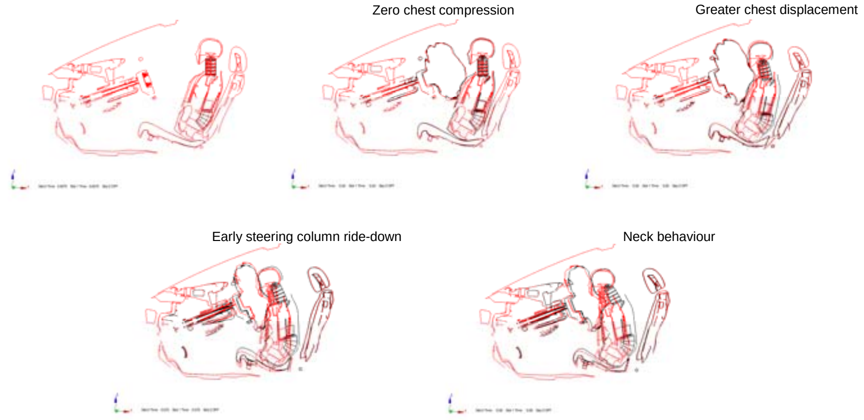
Modular dummy validation - Sled comparison 35mph FFB belted

Centre-line steering column – deformable (red) vs. fully rigid (black)



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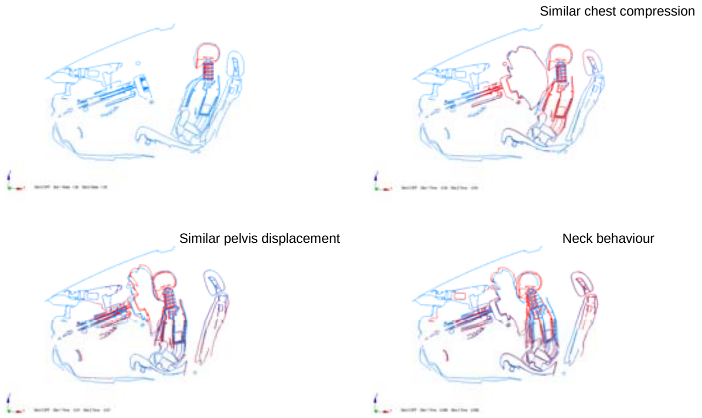
Modular dummy validation - Sled comparison 35mph FFB belted

Centre-line steering column – deformable (red) vs. part rigid* (blue)



* chest, pelvis, femurs, knees deformable.

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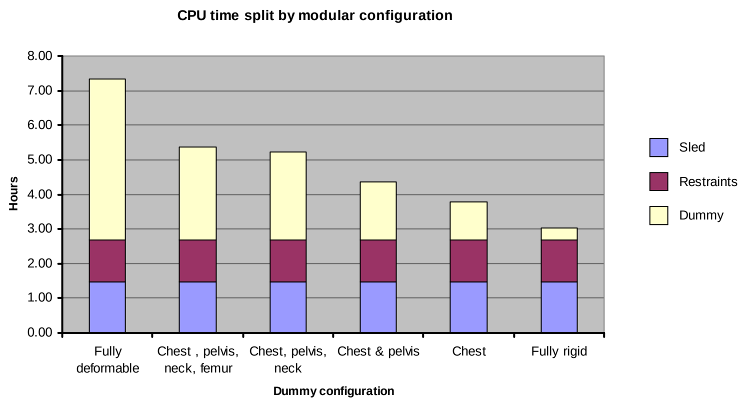
Modular dummy - Sled run times by configuration



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Modular dummy usability

Geometry identical:

- No change to seat belts and seat compressed surface
- Overlays of configurations are easy

Positioning process is identical

Internal contacts are self-selecting

External surfaces have same PIDs

Output nodes / beams etc are the same

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Modular dummy usability

Complexity:

Need to renumber twice

Need to keep track of configurations

Need to do overcheck with fully deformable configuration

Summary

Need for a simple DYNA dummy model for simple vehicle models

Modular is predictive, where necessary

Uses same processes

Low user involvement to exchange parts

Modular deformable is the standard model

Refined dummy model size is increasing

Modular is a useful addition to the tool box