A Full Suite of Hybrid III 50th Dummy Models with the Latest Upgrades

– from Runtime Savor, High Quality Performer, to the More Detailed Model (E)

Z. Zhou, M. Li, J. Rasico, F. Zhu, R. Kant (FTSS, Inc.)
A full suite of Hybrid III 50th dummy models with the latest upgrades

from runtime savor, high quality performer, to the more detailed model

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First Technology Safety Systems, Inc.

Contents

• Current model status
• Future development direction driven by customers
• Modular model
• Detailed model
FTSS H3-50th Dummy Models

- The PDB HIII 50th model has become the standard model per October 1, 2007
  - Significantly higher quality and validation level

For more information on the PDB model see also "Enhancements in Dummy Model Development", LS-DYNA User's Conference Gothenburg 2007

Customer Feedback

- "Models should be more detailed"
  - A group of OEM's (outside Germany)

- "Standard (PDB) model is "almost ready" and runtime is OK even for restraint development"

- "Further enhancements of the standard model should still be given highest priority"
  - German OEM's and German restraint suppliers

- "We need a fast(er) model but with acceptable quality to optimize restraints"
  - Restraint suppliers (outside Germany)
Three Development Directions

- **Research and develop detailed models**
  - Time step < 0.8 µs

- **Continue the standard models**
  - Maintain “1 µs” & order of element count
  - Lessons learned from detailed model are steering the standard model improvement.
  - Refine the mesh when proven to be beneficial

- **Explore “modular models”**
  - Targeting model speed-up and acceptable quality

Presentation Focus

- **This presentation includes**
  - project information of the detailed and the modular models.

- **More info of the standard models can be found in the proceedings of the LS-DYNA User’s Conference Gothenburg 2007**
  - and a status update is available upon request.
Modular FEA Model Concept

- FTSS initiated a pilot project to evaluate the benefits of a modular model
  - Combination of pure rigid and/or deformable modules;
  - A user defined selection.
- Development steps:
  - A deformable full dummy model was split into individual component modules according to joint/positioning functions;
  - CoG location and mass inertia properties were calculated for each module;
  - The counterpart rigid module model was created with rigid shells and calculated mass inertia properties;
  - Two full sets of exchangeable modules were created, sharing the same joint and connection definitions;
- Provides users with the ultimate flexibility in choosing a dummy model assembly and balancing model accuracy and run time.
  - Rigid modules for non-contact, not in the loading path components;
  - Deformable modules for injury induced areas.
Modular Model

Specification

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

Modular Options

Standard vs. Modular H3-50th

Standard H3-50th
- Deformable components
- Positioning function
- Minimum time step: 1 µs
- Deformable element count: 50K

Modular H3-50th
- Rigid and/or deformable components
- Positioning function
- Minimum time step: 1 µs or higher
- Deformable element count: varies
Module Examples

- Deformable
- Rigid with assigned C.O.G and Mass Inertia

C.O.G. with mass inertia

Modular Model: Master File Format

- Main file:
  - *KEYWORDS
  - *CONTROL CARDS
  - *DATABASE CARDS
  - *INCLUDE
    - Include individual module file one by one
  - *CONTACT CARDS
  - *DUMMY POSITION TREE
Modular H3-50th Model

Conclusion

• The modular dummy model can be easily customized by users by selecting the desired combination of rigid and deformable modules;
• The modular model can be highly run-time efficient compared to a fully deformable dummy model.

Further work

• Customer beta testing to explore the benefits.
  – Can the model reduce the run-time significantly and still keep the acceptable predictability?

Detailed
HIII 50th Model
Standard vs. Detailed H3-50th

Standard H3-50th

- Detailed geometry
- Effective material model parameters
- Minimum time step: 1 µs
- Element count: < 100K

Detailed H3-50th

- Most accurate and more detailed geometry
- Vinyl and foam separated, allowing more accurate physical material model parameters to be applied
- Minimum time step: 0.8 µs
- Element count: < 300K

Detailed Geometry

Actual geometry is captured by X-Ray scan and laser scan
- Capture assembled dummy geometry
- Improved accuracy through exact material distribution

Whole dummy scan data + New model → Whole dummy scan data
New Material Tests

Multiple strain rate tests for key materials for better material parameters

<table>
<thead>
<tr>
<th>Material</th>
<th>Test Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vinyl</td>
<td>Compression (4 strain rates)</td>
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<tr>
<td></td>
<td>Volumetric Compression</td>
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<tr>
<td></td>
<td>Stress Relaxation</td>
</tr>
<tr>
<td>Butyl Rubber</td>
<td>Compression (4 strain rates)</td>
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<tr>
<td></td>
<td>Tension</td>
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<td>Stress Relaxation</td>
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<tr>
<td></td>
<td>Volumetric Compression</td>
</tr>
<tr>
<td>Foam</td>
<td>Compression (4 strain rates)</td>
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<tr>
<td></td>
<td>Stress Relaxation</td>
</tr>
<tr>
<td></td>
<td>Poisson's Ratio</td>
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<tr>
<td>Ensolite Foam</td>
<td>Compression (4 strain rates)</td>
</tr>
<tr>
<td>Rib Damping Material</td>
<td>Compression (4 strain rates)</td>
</tr>
<tr>
<td></td>
<td>Stress Relaxation</td>
</tr>
</tbody>
</table>

Total: 148 new tests

New Validation of Material Models

Abdomen foam

Jacket foam

Neck rubber

Knee rubber

Lumber spine rubber

Head skin

Compression
New Validation of Material Models

- Lumber spine rubber
- Neck rubber

New Component Tests

- New component tests were performed in addition to the extensive PDB component test series
  - More realistic loading conditions for the head, neck, thorax, lumbar spine, rib, pelvis, arms and legs
## Component Validation Matrix

<table>
<thead>
<tr>
<th>Component</th>
<th>Test Type</th>
<th>#Tests</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>Drop test - 3 speeds</td>
<td>&gt;100</td>
<td>Partly new tests</td>
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<tr>
<td></td>
<td>PDB Prescribed motion impact to forehead and cheek</td>
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<tr>
<td>Neck</td>
<td>Calibration; flexion and extension 2 speeds</td>
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<tr>
<td></td>
<td>Head replacement direct impact: flexion, extension, straight and oblique</td>
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<td>New tests</td>
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<tr>
<td>Arms (upper, lower)</td>
<td>Multiple speeds dynamic drop - Need bone loadcell, new fixtures</td>
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<td>New tests</td>
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<tr>
<td>Upper leg</td>
<td>Drop test - loadcell</td>
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<td>New tests</td>
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<tr>
<td>Lower leg</td>
<td>Euro-foot impact tests on heel and toe</td>
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<tr>
<td></td>
<td>PDB Multiple impacts - Instrumented tibia</td>
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<tr>
<td>Knee</td>
<td>Knee slider</td>
<td>&gt;100</td>
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<tr>
<td></td>
<td>Knee impact</td>
<td>&gt;100</td>
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<tr>
<td>Lumbar Spine</td>
<td>Pendulum - flexion / Extension</td>
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<tr>
<td></td>
<td>Straight and Oblique torsion loading, multiple speeds - Seatbelt loading/wristing mode</td>
<td>56</td>
<td>New tests</td>
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<tr>
<td>Abdomen insert</td>
<td>Drop test: 2 speeds</td>
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<tr>
<td>Pelvis</td>
<td>Range of motion</td>
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<td>Quasi-static Compression tests</td>
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<td>Thorax single rib</td>
<td>Orthogonal drop, multiple speeds</td>
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<td>Oblique drop, multiple speeds</td>
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<td>Thorax 6-rib sub-assembly</td>
<td>No pocket - round and square drop heads 3 speeds</td>
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<td></td>
<td>PDB Chest impacts – different impactor shapes, locations and pulses</td>
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<tr>
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<td>Multiple speeds, straight and oblique impact</td>
<td>22</td>
<td>New tests</td>
</tr>
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</table>
New Rib Validation

Flat

Oblique

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New Lower Leg Validation

New Upper Arm Validation

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Frankenthal
October 11-12, 2007

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More New Component Validations

### Head

- Sled test serie 1
  - 1996: 15-48 X Rigid 2
  - 1996: 15-48 X Rigid 2

### Upper leg

- Sled test serie 2
  - Planned sept 2007: x-40 X Rigid 10 12
  - FMVSS208/NCAP: x-40 X Rigid 10 12
  - x-56 X X Rigid 4 4
  - x-56 X X Deform 2 2

### Knee

### Lumbar Spine

Full Dummy Validation

<table>
<thead>
<tr>
<th>Test</th>
<th>Pulse (G-km/h)</th>
<th>Belt</th>
<th>AB</th>
<th>Seat</th>
<th># ATD's</th>
<th>Total # tests including repeats</th>
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</table>

Picture courtesy of PDB
Detailed H3-50th Model

Conclusion
• The first correlation improvements on component level have been achieved through more detailed geometry meshing and material modeling;
• Further proof is needed to claim the benefit of detailed model at full dummy level.

Future work
• Complete validations on both component and full dummy level;
• Benchmark the standard and detailed model on full dummy level;
  – In-house and customer beta testing.
• Study dummy hardware reproducibility and explore development of a stochastic model to consider effects of physical dummy variations.
  – FTSS history database.