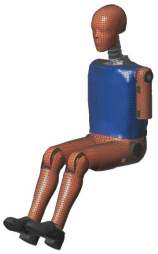
The SID-IIs Dummy Model

– Current Status, Model Improvement and Future Development

Y. Liu, R. Kant, F. Zhu, J. Rasico (FTSS, Inc.)



The SID-IIs dummy model

Current status, model improvement and future development

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Introduction

	SID-IIs hardware	SID-IIs model
1994	Development	
1995	"Alpha prototype"	
1998	"Beta+ prototype"	
2000	"Production level"	
2001		Development started
2002	SBL C specified in IIHS test	SBL C v1.0
2003		SBL C v1.1
2004	FRG NPRM	SBL C v1.2 / FRG v 1.3
2005		SBL C v1.6
2006	SBL D Final Rule issue	SBL D v2.0 (beta)
2007	SBL D to replace SBL C in IIHS?	

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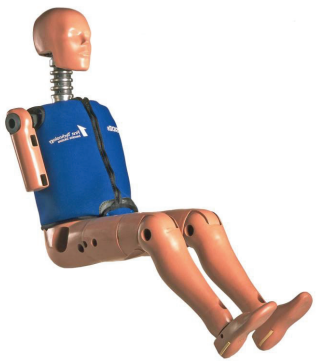
Introduction



SID-IIs SBL C

- IIHS SUV barrier test procedure
  - Movable deformable SUV type barrier test.

SID-IIs SBL D

- Considered for FMVSS 214 final rule
  - NHTSA Oblique Pole Test
    - 75 degree oblique angle.
    - Up to 32 km/h (20 mph) impact speed.
  - Moving Deformable Barrier Test
    - Simulate vehicle-to-vehicle "T-bone" intersection crash.
    - 33.5 mph impact speed.

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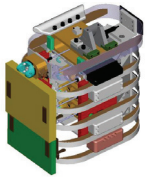
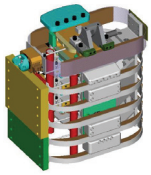
Main differences SID-IIs SBL D and C

- Upper Torso - Standard Build Level D
  - *Address the durability issues related to Level C dummies.*
    - Thinner and taller damping material for shoulder rib.
    - Extended shoulder frontal rib guides.
    - Rounded shoulder rear rib guides.
    - Rigid thorax/abdomen ribs stops.
    - New spine box to ballast weight.
    - Rib pads tied around each rib with plastic tie wrap.
    - ½" diameter linear potentiometers.



SBL C



SBL D

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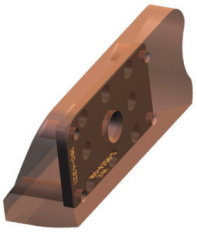
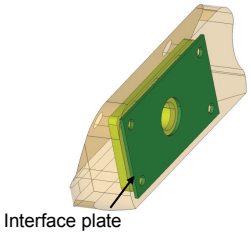
Main differences SID-IIs SBL D and C

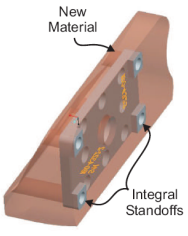
- Iliac wing material and structure change
  - *Address the durability issues related to Level C dummies.*
    - SBL D (NHTSA) – 'Material #2' with interface plate.
    - SBL D (OSRP) – 'Material #3' with stand-off.
    - SBL C (IIHS) – 'Material #3' with stand-off.



Original SBL C
'Material #1'



SBL D (NHTSA)
'Material #2'



SBL D (OSRP)
SBL C (IIHS)
'Material #3'

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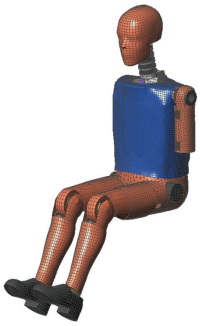
SID-IIs Models

SID-IIs SBL D version 2.0

Item	Total Number
Part, section & material	345
Nodes	68174
Elements	116416
Beam	322
Shell	48383
Solid	67615
Discrete	7
Accelerometer	16
Joint	13
Masses	22
Rigid Links	38
Contact surface	2
Coordinate systems	42
Curves & Table	21



SID-IIs models are available representing the different Standard Build Levels C and D (and FRG).

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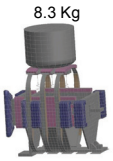
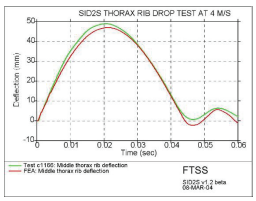
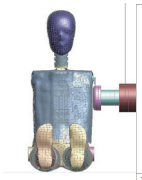
Model performance validation

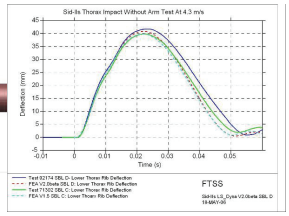
Three levels of model-to-test validations:

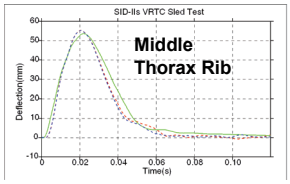
- Material and component (material, ribcage drop and oblique impact).
- Certification (head, neck, shoulder, thorax, abdomen, pelvis impact).
- Sled tests (VRTC, OSRP).











Existing rib validations showed that the model correlated well, however

- the loading phases in these tests usually takes longer than 16 msec.
- mainly pure lateral loading tests.

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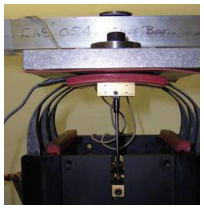
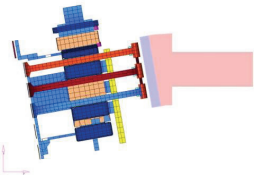
New rib performance validation

New rib validation data has been generated to validate rib performance for faster rib loading and oblique loading.





- Faster rib loading
  - 3 impact velocities (4, 6 and 8m/s).
  - Lower impactor mass 3.5kg.
- Larger rib deflection
  - Rib deflection > 55mm.
- Oblique rib loading
  - vertical and horizontal impact angles.

These tests/validations apply to both SBL D and SBL C.

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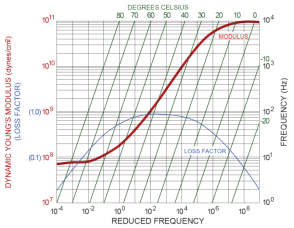
Rib damping material optimization

SID-IIs rib and damping material



- The rib damping material is a viscous elastic-plastic material with fast stress relaxation.
- FTSS has carried out high strain rate tests on the material but yet to find a working FE material model to use the data.
- A visco-elastic model was used to describe the rib damping with parameter extracted by optimization.
- Bulk modulus, short and long time shear modulus, decay constant were optimized for new drop tests shown on the next slide.
- The results compare to the current model:
  - Bulk modulus is reduced (by 50%).
  - G0 is reduced (by 38%).
  - Decay constant is reduced (by 40%).

Sample Hyperstudy/Ls-dyna input card for rib damping:

```
*MAT_VISCOELASTIC
   12207  1.552E-9     {bulk, %5.1f}{g0, %5.1f}{gi, %5.1f}{beta, %5.1f}
```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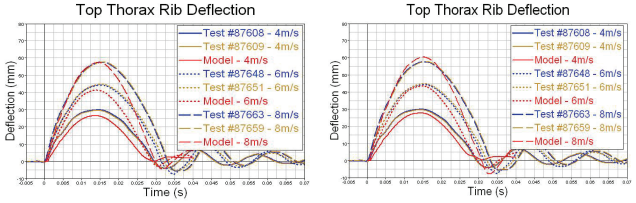
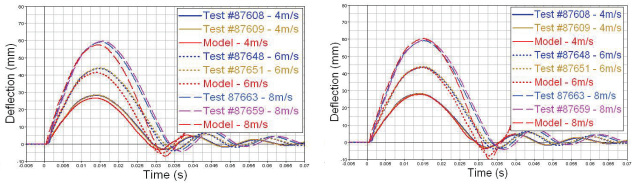
New rib performance validation

Currently released model | **Rib damping optimized**

Top Thorax Rib Deflection



Bottom Thorax Rib Deflection



- 3 ribs loaded
- impact speed: 4, 6 and 8m/s
- Impactor mass: 3.5 kg

Pure lateral rib loading

- The current model shows an under prediction for the lower severity tests.
- The new model shows improved correlation.

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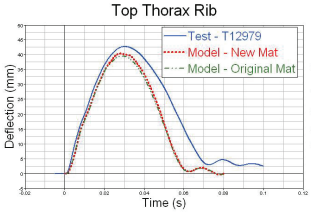
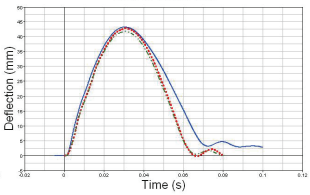
New rib performance validation

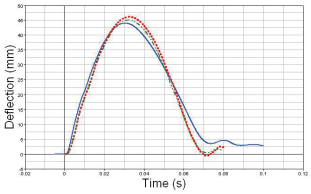
Top Thorax Rib

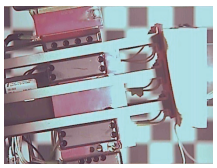


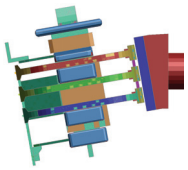
Mid Thorax Rib



Bottom Thorax Rib







Impact speed: 3.0 m/s
X rotation: 10 degree
Z rotation: 0 degree
Impactor mass: 16.3 kg

Loading from below

- The simulation results are similar.

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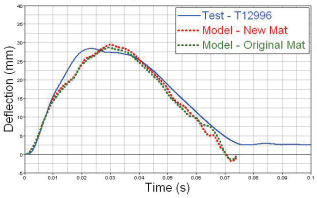
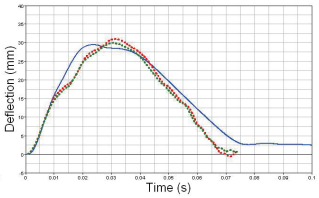
New rib performance validation

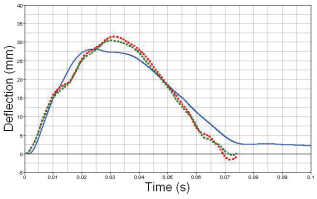
Top Thorax Rib

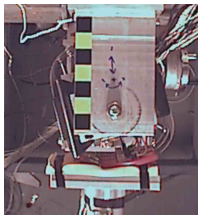


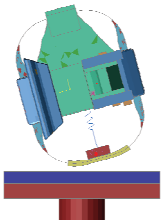
Mid Thorax Rib



Bottom Thorax Rib







Impact speed: 3.0 m/s
X rotation: 0 degree
Z rotation: -15 degree
Impactor mass: 16.3 kg

Loading from front

- The simulation results are similar.

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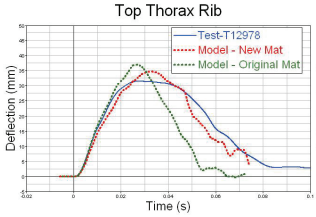
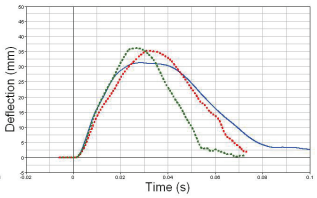
New rib performance validation

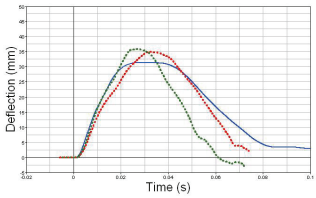
Top Thorax Rib

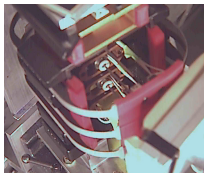


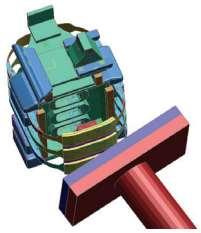
Mid Thorax Rib



Bottom Thorax Rib







Impact speed: 3.0 m/s
X rotation: 10 degree
Z rotation: -15 degree
Impactor mass: 16.3 kg

Loading from back and below

- A significant signal shape improvement is reached.

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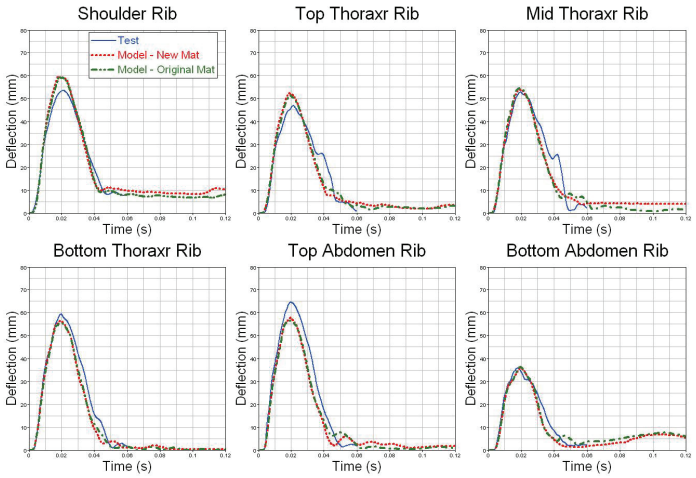
New rib performance validation



VRTC sled test

Test type: rigid barrier
Impact speed: 6.5 m/s

The new rib damping parameters have negligible effect.

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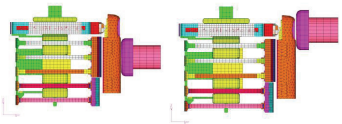
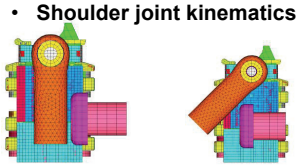
Further model development

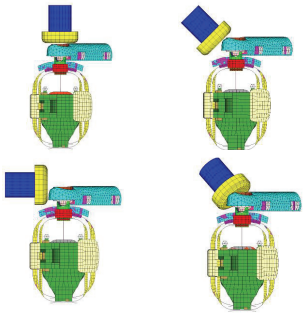
- **Arm-Rib Interactions**



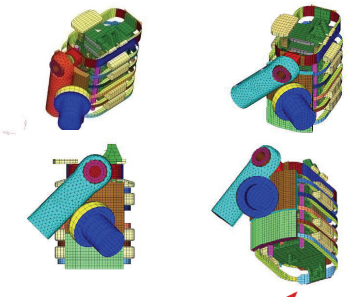
- **Shoulder joint kinematics**



- **Shoulder joint oblique impact**



- **Thorax oblique impact**



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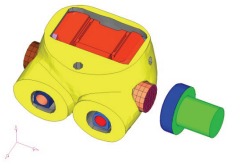
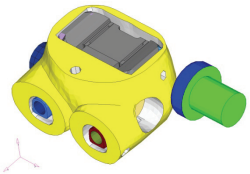
Further model development

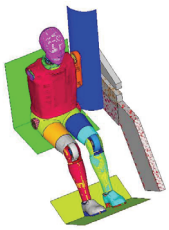
Pelvis impact: SBL D with NHTSA and OSRP iliac wing





Rigid barrier sled tests (SBL D)

- Different impact shapes to vary loading on: shoulder, thorax, abdomen and pelvis.
- 3 load cases.



Further model development

Material model and Geometry updates

Geometry updates

- Arm and pelvis: Vinyl/foam separation.
- Arm/shoulder/joint.
- Symmetric pelvis foam.
- Torso and leg geometry.
- Whole dummy geometry confirmation by laser scanning.

Material model updates

- Arm skin Vinyl.
- Arm foam.
- Rib damping material.
- Thorax/Abdomen pad Ensolite foam.
- Shoulder rubber plug.
- Iliac wing materials (NHTSA & OSRP).
- Pelvis plug.

Conclusions and further work

Conclusions

- Current SID-IIs models are being upgraded
  - Geometry, rib and arm performance, iliac wing and acetabulum performance.
- The rib damping material model parameters have been optimized.
  - Oblique loading from backward and below direction – improved significantly.
  - Pure lateral and fast rib loading tests – under prediction has been improved.
  - Full dummy VRTC sled test – correlation level has been maintained.

  The optimized rib damping generally improves the model performances at both component and full dummy levels.

Further work

- New arm-rib, pelvis and full dummy sled tests will be performed.
- The models will be further validated and optimized to receive the best overall correlation.

