HI-STAR 100 Impact Limiter Benchmarking

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Presentation to NRC
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Overview

- Purpose of Meeting
- History
- Proposed Approach
- Preliminary results of updated calculations

Purpose of Meeting

- Presentation of Improvements to the Impact Limiter Benchmarking Calculations based on NRC Comments
- Technical Discussions
- Goal is a common understanding on what the acceptable approach is

History

- 1997: HI-STAR 1/4 scale drop tests
- 1998: Analytical 1-D/2-D approach to simulate drop conditions, used for HI-STAR 100 approval
- 2007: 3-D transient FEM calculations to benchmark LS-DYNA for Impact Limiter Qualification based on 1/4 scale drop tests
- 2008: RAIs/OTIs on HI-STAR HB, HI-STAR 60 and HI-STAR 180

HI-STAR 180 OTIs related to HI-STAR 100 Benchmarking

- 2-1 Extent of LS-DYNA Benchmarking
- 2-2 Acceleration vs Differentiated Velocities (resolved)
- 2-3 Hexahedron vs. Tetrahedron Elements
- 2-4, 2-5 Material Properties
- 2-6 Mesh Sensitivity
- 2-7 Material Coordinate Systems
- 2-8 Pre-crush (resolved)
- 2-9 Robust Model
- 2-10 Overpack Connection
- 2-11 through 2-14 Bolts

2-1: Extent of LS-DYNA Benchmarking

- We agree with SFST's statement in OTI 2-1 that HI-STAR 100 Scale Model Data is sufficient for Benchmarking the computational capabilities of LS-DYNA with respect to Rigid Body Decelerations of the package and for Impact Limiter Crush Characteristics.
- We propose to limit Benchmarking to
  - Rigid Body Decelerations
  - Extent of Impact Limiter Crush
- Additional Information extracted from LS-DYNA
  - Attachment Forces

2-10 through 2-14: Bolts

- A reliable Benchmarking of Bolt Stresses and Bolt Failures from the scale model is not possible due to inadequate material property data on the bolts.

2-7: Material Coordinate Systems

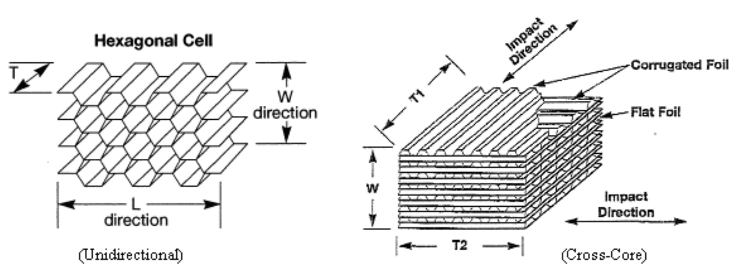
- All new runs will have appropriately oriented material coordinate system
- Studies show an effect of about 5% on peak deceleration if material coordinate systems are not oriented appropriately

2-3, 2-6: Hex vs. Tet, Mesh Sensitivity

- We are currently in the process of converting all sections of the crush material that were modeled as tets to hex
- Some areas need (justifiable) approximations
- Parametric studies show variations of maximum decelerations within +- 20%
- Previously used tet elements appear to overstate the softness of the material
- Mesh Sensitivity Evaluations will include parametric studies on simplified representative geometries

2-4, 2-5: Material Properties

- Some secondary material properties of the crush material are not well known



2-4, 2-5: Material Properties

Input Properties for MAT_026	Uni-Directional	Cross Core
LCA- Compressive strength vs. volumetric strain in a-direction	YES	YES
LCB- Compressive strength vs. volumetric strain in b-direction	NO	YES
LCC- Compressive strength vs. volumetric strain in c-direction	NO	YES
LCAB- Shear strength vs. volumetric strain in ab-direction	YES	NO
LCBC- Shear strength vs. volumetric strain in bc-direction	YES	NO
LCCD- Shear strength vs. volumetric strain in ca-direction	NO	NO
Note: For compression, a-, b-, and c-directions are equal to T-(or T1-), L-(or T2-), and W-directions of the honeycomb, respectively. For shear, ab-, bc-, and ca-directions are equal to L-(or T2-), W-, and T-(or T1-) directions of the honeycomb, respectively.		

2-4, 2-5: Material Properties

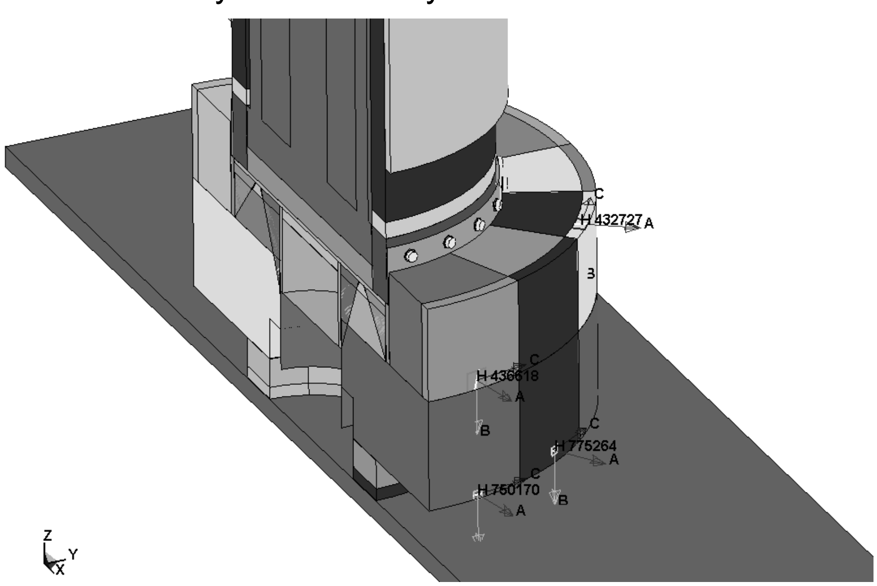
- Obtaining exact values for those properties not feasible, and not considered necessary
- Perform sensitivity studies, with property variations within a reasonable range
  - Determine the sensitivity of those parameters
  - Determine best estimate values, expressed as a percentage of the known properties
  - Determine a reasonable range of those parameters that need to be evaluated in production runs (i.e. HI-STAR 180)

Preliminary Results, End Drop

- 1/4 scale test: 216 g
- Initial benchmark calculations (Phase 3): 228 g
- Updated benchmark calculations:
  - Rigid Body: 216 g
  - Three accelerometers, averaged: 212 g

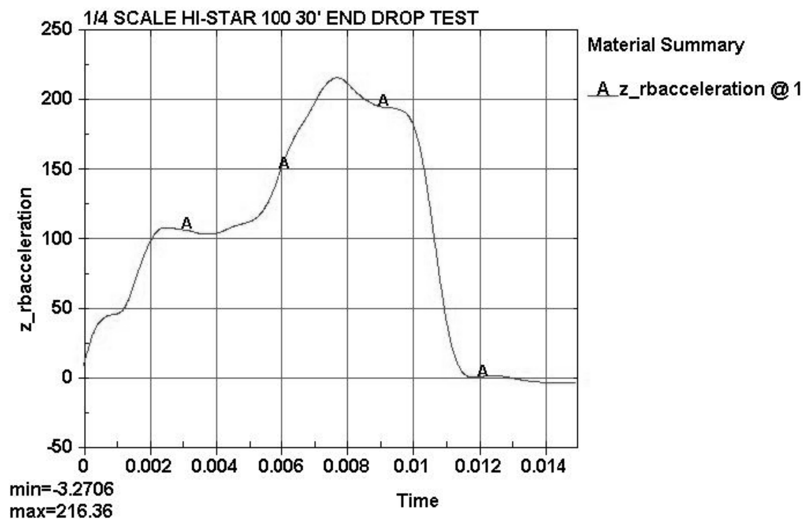
Preliminary Results, End Drop

- Material coordinate system of honeycomb blocks



Preliminary Results, End Drop

- Rigid Body Deceleration of the Overpack



Discussions / Summary

- ***LS-DYNA Benchmark calculations are being updated based on NRC comments***
- ***Benchmarks qualify LS-DYNA for determination of Rigid Body Acceleration and Impact Limiter Deformation.***