HI-STAR 180 Structural Qualification under Drop Accident Conditions

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Overview

- Purpose of Meeting
- History
- Proposed Approach
- Impact Limiters
- Impact Limiter Bolts
- Lid Bolts
- Cask Body
- Basket

Purpose of Meeting

- Present proposed approach for revised structural qualification
- Technical discussion on relevant aspects
- Goal is to reach a common understanding on the acceptability of the approach

History

- Initial application, January 2007
  - Integral three-dimensional transient FEM model (LS-DYNA) to evaluate the response of the entire cask system under the various drop accident conditions.
  - Model contained the impact limiters, impact limiter attachment bolts, lids, lid attachment bolts, cask body, basket, and fuel assemblies.
- NRC Letter with OTIs (Open Technical Issues), June 2008, questions the following areas:
  - Benchmarking of Impact Limiter Simulations
  - Benchmarking of Bolt Modeling
  - Gaps between components
  - Basket deformation
  - LS-DYNA Meshing
  - MetamicHT Properties

HI-STAR 180 OTIs

- 2-16 Hexahedron Elements
- 2-17 Impact Limiter Bolts
- 2-18, 2-19 Basket
- 2-20, 21, 22 Gaps
- 2-29 Slapdown 7 Degrees (resolved)
- 2-30, 31, 32 Shell Elements (resolved)
- 2-33 Failure Strain (resolved)
- 2-34 Welds (resolved)
- 2-35 71.43 (resolved)
- 2-56 Lid Bolt Material (resolved)
- 2-57 Charpy Energy for SA 352-LCC

Proposed Approach

- From the transient analyses of the Impact Limiters, determine appropriate static loads, and apply them to individual components. This is consistent with the HI-STAR 100 approach, with extra conservatism added
  - Impact Limiter Bolts
  - Lids and Lid Bolts
  - Cask Body
  - Basket
- Re-cast solution consistent with the HI-STAR 100, use existing models and analysis approaches as far as possible
  - Methodologies used and developed for the HI-STAR 100
  - FEM models developed for the HI-STAR 180, enhanced based on NRC comments

Impact Limiters

- 3-D transient analyses with benchmarked LS-DYNA
- Model Refinements (material axes, mesh studies) per NRC comments
- Element types (hex) now same as in Benchmarking Calculations
- Interfaces
  - Maximum Rigid-Body Accelerations
  - Bolt Attachment Forces
- Model contains cask and basket including gaps, so the effect of those are captured in acceleration and forces. No stresses determined for cask and basket in LS-DYNA

Impact Limiter Bolts

- Unlike the HI-STAR 100, the HI-STAR 180 bolt connections between Impact Limiters and Casks are all axial bolts, and the design details are chosen in such a way that those bolts do not experience shear loads.
- Bolts will be qualified using classical strength of material approach, using the peak (filtered) interface forces from the Impact Limiter models

Lid and Lid Bolts

- Principal Approach:
  - Static FEM Analysis (similar to HI-STAR 100)
  - Confirm by comparison with LS-DYNA results
- Details
  - Step 1 (Static) : (fuel + basket + lid mass) * rigid-body-deceleration (HI-STAR 100 approach). Apply as static loads.
  - Step 2 (LS-DYNA) : Extract the lid stresses, seal compression loads, lid bolt stresses from LS-DYNA analyses
    - Axial bolt stresses restricted to less than yield strength

Lid and Lid Bolts

- Gaps
  - Gaps need to be based on the physics of the 30 ft drop required by regulation
  - Large gap sizes inconsistent with the physical problem will require shock absorbers on each fuel assembly
- Sealing
  - Seal modeled as preloaded spring in FEM analysis. Not to be unloaded under static load.

Cask Body

- Principal Approach: Same as for HI-STAR 100
  - Static FEM Analyses
  - Load from Rigid Body Acceleration
- Effect of Charpy Energy
  - Model charpy coupon and experiment in LS-DYNA
  - Determine material properties that reproduce the charpy test results
  - Use those material properties, and an initial flaw, in the cask FEM model in the location where the peak stresses occur. Flaw size will be selected based on detectability by ultrasonic test.
  - This approach has been developed and used by Holtec in the qualification of heavy load pins

Basket

- Deformation-based acceptance criteria
- Deformation calculations
  - Step 1: 3-D Static FEM Model, loaded by rigid-body acceleration; fuel modeled as solid rectangular prism with appropriate stiffness
  - Step 2: Determine deformation from transient analyses
  - Step 3: Use the higher of the two (Step 1 or Step 2)
- Improvements at the basket top and bottom to reduce local deformation in those areas.
- Qualification of shims will include creep evaluations, based on shim stresses and temperatures, and creep data from standard aluminum handbooks.

Discussions / Summary

- ***Static loads for the individual components derived from transient analyses***
- ***Consistent with HI-STAR 100***
- ***Not entirely based on LS-DYNA***
- ***Sensible and conservative evolution of HI-STAR 100 approach***