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Hyride Reorientation Model and Experiments

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1444 Multiphysics Simulation Technologies

Sandia National Laboratories

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2007 EPRI Synthesis Report*

- **Synthesis report covering eight EPRI reports on dry storage and transport, concludes**
  - "*radial hydride concentration and the change in the fuel-cladding gap constitute the most important effects of dry storage on transportation*" (pp. 2-9)
- **The report also suggests that (in a 1-foot drop)**
  - "(The) *Cladding failure mode that could lead to fuel assembly reconfiguration is the rod breakage mode (Mode-II) with the transverse tearing mode (Mode-I) as the precursor.*"
  - "*damage initiation can be expected, but progression of the damage to form a pinhole failure can be ruled out…*"
  - "*The guide tubes, …, are predicted to ovalize but not fracture or totally collapse, which preserves the structural integrity of the assemblies in a non-reconfigured state.*" (pp. 6-2)
- **How confident are we in these conclusions (what is the uncertainty)?**

**Spent Fuel Transportation Applications—Assessment of Cladding Performance: A Synthesis Report*. EPRI, Palo Alto, CA: 2007. 1015048.

Possible Model Questions

- **What would be involved in propagating rod internal pressure variability, clad oxide thickness uncertainty, MWTA hydrogen content uncertainty, etc. to uncertainty in the final yield margin?**
- *Reliable failure criteria that capture relevant mechanical behavior regimes of high-burnup cladding with both circumferential and radial hydrides are presently lacking, with limited near-term prospects for developing such criteria experimentally.* (pp. 3-1)
- *Very limited data exist for fracture toughness at high hydrogen concentrations [14], and no fracture toughness data exist for Mode-III failure, which is the only mode affected by radial hydrides. Thus, new criteria and method of application of such criteria needed to be developed for high burnup cladding, as discussed in Reference [9].*
- **Is it possible to directly construct CSED curves from new or existing data?**

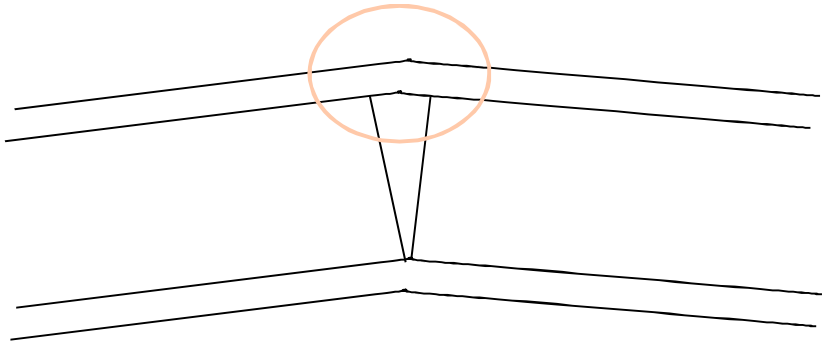
[9] Y. R. Rashid, M. M. Rashid and R. S. Dunham, "Failure Criteria for Zircaloy Cladding using a Damage-Based Metal/Hydride Mixture Model," EPRI Technical Report 1009693, December 2004.
[14] Y. R. Rashid, R. O. Montgomery and W. F. Lyon, "Fracture Toughness Data for Zirconium Alloys; Application to Spent Fuel Cladding in Dry Storage," EPRI Report 1001281, January 2001.

Assembly Response Model in Report

- *The structural modeling and analysis described in the report is intended to represent the dynamic response of all the fuel rods in the cask.*
- *Instead of modeling every fuel rod in detail, which would be an impossible task, a detailed model of the Control Assembly was used as a device to bracket the dynamic response of all the rods in the cask by placing the Control Assembly in various positions in the basket structure where the deceleration is expected to vary over the expected range.*
- *The dynamic forces were calculated at thousands of points and vary over a wide range. This force system constitutes a statistically significant "database" that is appropriately suited for constructing probabilistic evaluation of the drop event consequences.*

Possible Fidelity Questions

- Are there small scale damage features (fretted regions, bowed rods, etc) that might change the peak pinch forces and bending moments?
- What effect might inter-pellet leverage have on the transverse tearing mode (Mode-I) failure probabilities?



Tool for Assessing Cladding Performance during Transport

- **The report findings suggest the following tool requirements**
  - Capability to model multiple assemblies and support structures within the cask
  - Modeling the effects of phenomena inside the cladding may be best accomplished by a stochastic, homogenized model of the fuel that examines the sensitivity of selected parameters on the response of the cladding
  - Accurately assessing the “strength” of the cladding to stress of a transport event requires propagation of uncertainties from the hydride damage model to the structural response calculation
- **Our goal is to demonstrate a capability for high fidelity fuel assembly damage calculations**
  - Use experiments along with sensitivity analysis to improve the confidence in current phenomenological models
  - SA to focus efforts on the aspects of the models that are most impactful

Specific Activities

- **Implement a radial hydride damage model similar to the three-phase mixture model in the report**
  - Build sensitivity analysis into the model as part of its development
- **Use targeted experiments coupled with sensitivity analysis to characterize the uncertainties in the model**
  - Experimentalists and modelers will co-develop the hydride model and the plan for the experiments that need to be conducted
- **Couple the hydride model to AMP to calculate assembly response**
  - Propagate uncertainties from the hydride model through the response calculation
  - Add additional parameters to the model that describe geometric and structural uncertainties