U.S.NRC
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Update on NRC Activities related to Cladding Performance of High Burnup Fuel During Storage and Transportation

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Ongoing work

- Transportation
  - Thermal modeling
  - Stress determination
  - Vibration testing
  - DBTT considerations
- Storage
  - Drying
  - ISG-24

Cladding degradation effects

- Retrievability of the fuel by normal means
- Change of source term for non-leak tight system
- Effect of fuel relocation on criticality, temperature distribution, shielding

Temperature Modeling

- What are realistic maximum temperatures?
  1. Cladding creep
  2. Hydride reorientation
  3. Cladding stress
- What are realistic lower temperatures?
  1. Cladding DBTT
- How does temperature evolve with time?
  1. Low temperature Creep
  2. Delayed Hydride Cracking

Cladding Stress in Spent Fuel During Extended Dry Storage

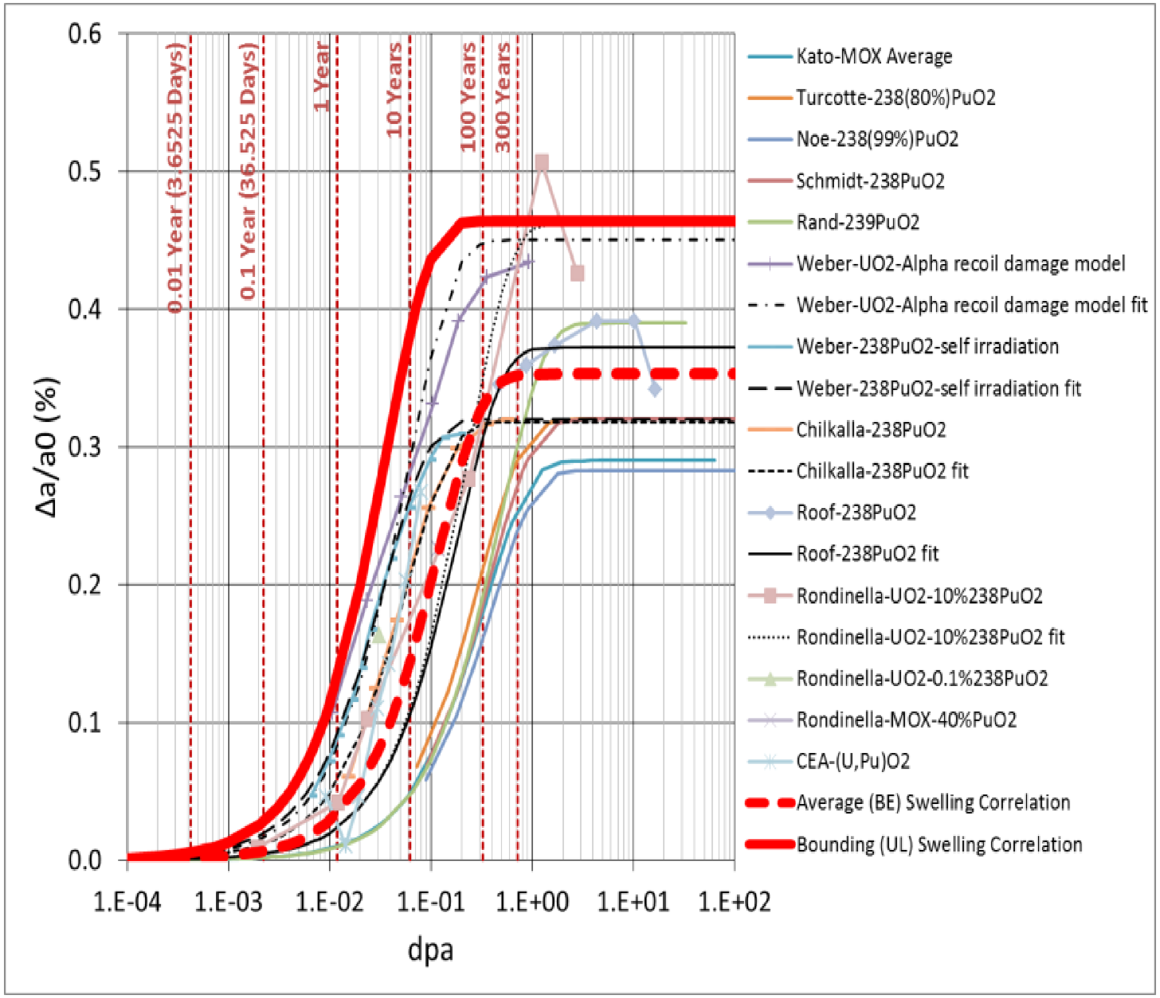
- GOAL: to assess the potential for low temperature creep (LTC) and delayed hydride cracking (DHC) failures Is sufficient cladding stress present to drive LTC and DHC

- TASK - NRC has performed an analytic study to determine if sufficient of cladding stress exists in spent nuclear fuel (SNF) for a 300 year period of dry storage to drive either LTC or DHC

- This work is part of the ongoing research effort for Extended Storage and Transportation (EST)

Fuel Swelling

Fuel swelling driven by helium generation. Simulated by actinide doping and ion implantation.-



Vibration testing Objective

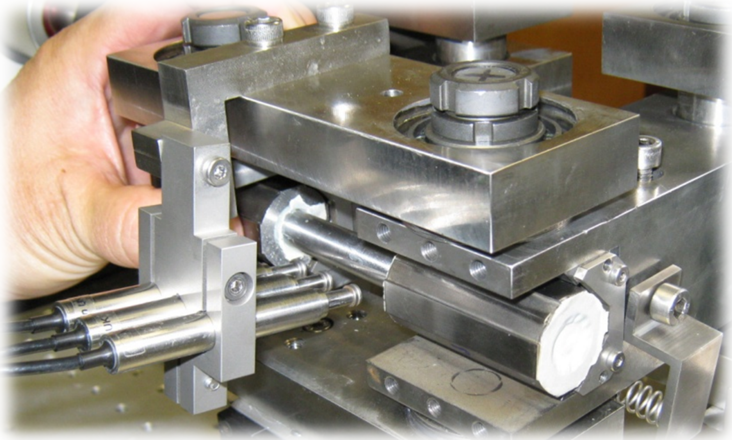
Investigate a number of important attributes of the high burnup, fuel/cladding system including:

- Determining if the presence of fuel increases the flexural rigidity (bending stiffness) of the fuel rod by comparing the moment/curvature relationship from the test to the theoretical results for cladding only. (storage and transport accident)

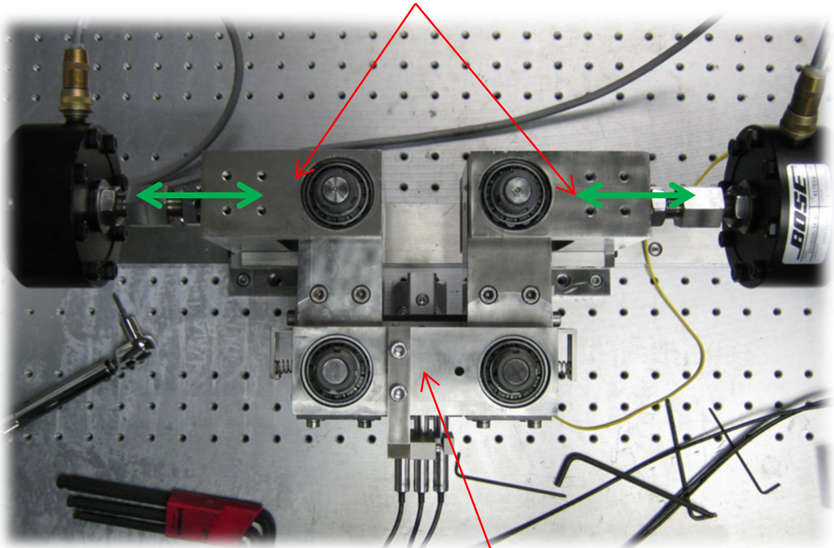
- Determining if the presence of fuel increases the failure strain of the cladding by comparing the failure strain from the bending tests to the failure strain from tension tests. (storage and transport accident)

- Determining the number of cycles to failure for high burnup fuel rods at a range of elastic strain levels. (normal transportation)

Testing Equipment



Push-pull force applied to U-Frame results in bending moment on the test segment



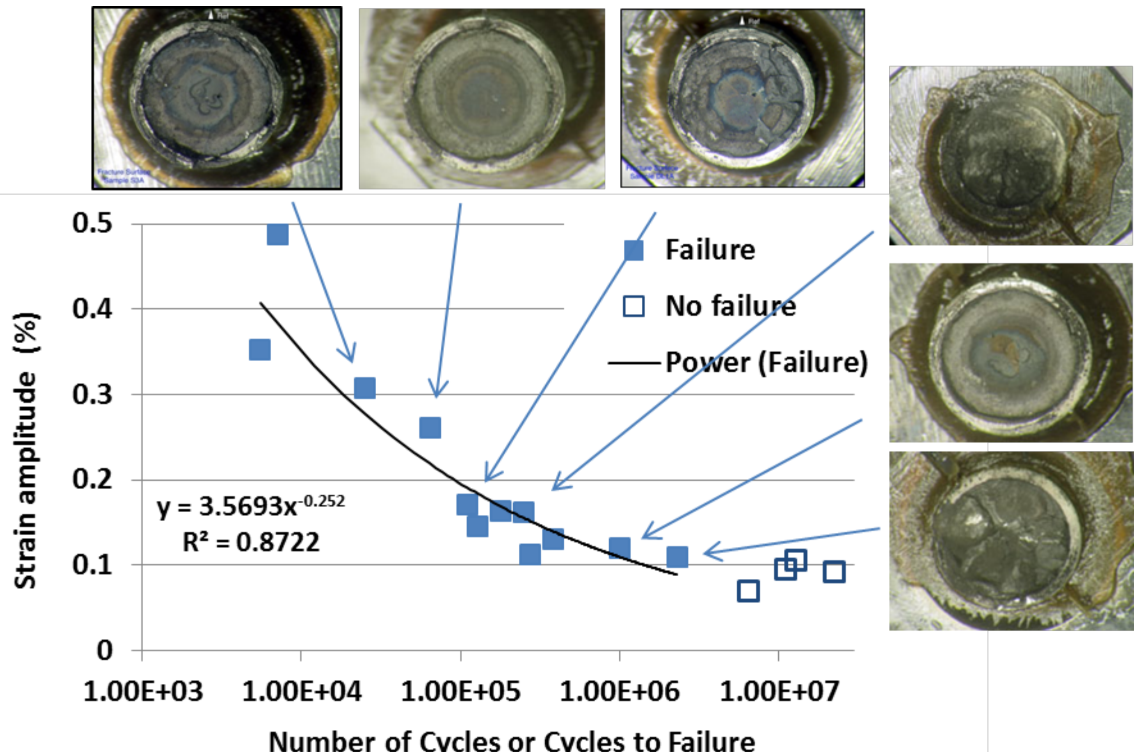
Location of test segment

Top Left: The grip sections have been uniquely designed to induce uniform bending moment (without local pinching loads) across the gauge sections

Bottom Left: The grip design provides for easy loading into the test device and enables frictionless grip in combination with roller bearing design. The deformation of the rod specimen is measured directly using three-point deflection.

Right: Test device seen from above. The reversible bending is conducted utilizing a U-frame setup with the push-pull force applied at the loading point. Final design utilizes two electro-magnetic motors, a U-frame design and a horizontal setup, enabling pure reversible bending with versatility in input functions (frequency, magnitude etc) and frictionless operation.

Results – Cyclic



Important observations:

- The high burnup material fatigue behavior was surprisingly well in-line with a single power-law trend.
- It appears that the tested material may have a “fatigue limit” beyond which continued cycles will not result in failure.
- A large variation of hydrogen content existed in the cladding of the test specimens in the dynamic tests. However, the contribution of hydrogen content to the number of cycles to failure appears to be secondary to the effect of imposed loading amplitudes
- Most fractures occurred at a pellet-pellet interface

Future Vibration Work

- Finalize NUREG/CR report, documenting the results of the Phase 1 testing program (early 2015)
- Finish NRC vibration testing at ORNL on HBF Zry-4 with fuel segments after hydride reorientation - Does it replicate fatigue results with circumferential hydrides?
- Determine Effect of Integrated load
- Integrate DOE replication on other HBF cladding types
- Interact with Sandia, DOE, Railroad Association to determine if vibration is an issue for normal transportation.

ISG-24

- Provides guidance to the staff for reviewing if a demonstration of high burnup fuel (HBF) has the necessary properties to qualify as one method that an applicant might use in license and certificate of compliance (CoC) applications to demonstrate the integrity of HBF for continued storage, and support an AMP

- RE Einziger, “An Aging Management Plan for Spent Fuel Storage and Transportation”, Radwaste Solutions, Vol 20, No. 1, July-August 2013, p 38

Conclusions

- Based on short-term laboratory data there appears to be no cladding issues during storage of HBF for 20 and most likely 40 years of storage
- NRC requires confirmation of cladding performance prior to allowing storage of HBF beyond 20 years
- There are paths forward to ensure integrity of high burnup cladding during normal conditions of transport when test data is unavailable
- NRC work is continuing vibration testing to confirm integrity of HBF cladding during normal conditions of transport
- Issues exist in confirming the integrity of high burnup cladding if the transport temperature drops below the DBTT. Paths forward exist to circumvent this situation