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Development of Technical Basis for In-situ, Passive Surrogate Materials Surveillance for Advanced Non-LWRs

Advanced Non-Light Water Reactors – Materials and Component Integrity Workshop
December 9-11, 2019
U.S. Nuclear Regulatory Commission
Rockville, MD

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Acknowledgment

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Background

- The technology maturity of Molten Salt Reactor (MSR) systems is substantially less than other advanced non-LWRs such as GCRs and SFRs
- Information on materials degradations due to irradiation, corrosion, elevated temperature exposure and stress (creep-fatigue loading) during MSR operations is limited
- The establishment of an in-situ, passive surrogate materials surveillance program that would allow the collection of information on these materials degradations would be an important pathway in support of timely licensing MSRs

Current Practice on Materials Surveillance for Advanced Non-LWRs (1/3)

- ASTM E531 - Standard Practice for Surveillance Testing of High-Temperature Nuclear Component Materials
  - Originally approved in 1975; current edition approved in 2013; there is current effort for re-approval
  - Practice is used when nuclear reactor component materials are monitored by specimen testing
  - Covers procedures for periodic specimen testing performed through the service life of the components to assess changes in selected metallic material properties that are caused by neutron irradiation and thermal effects

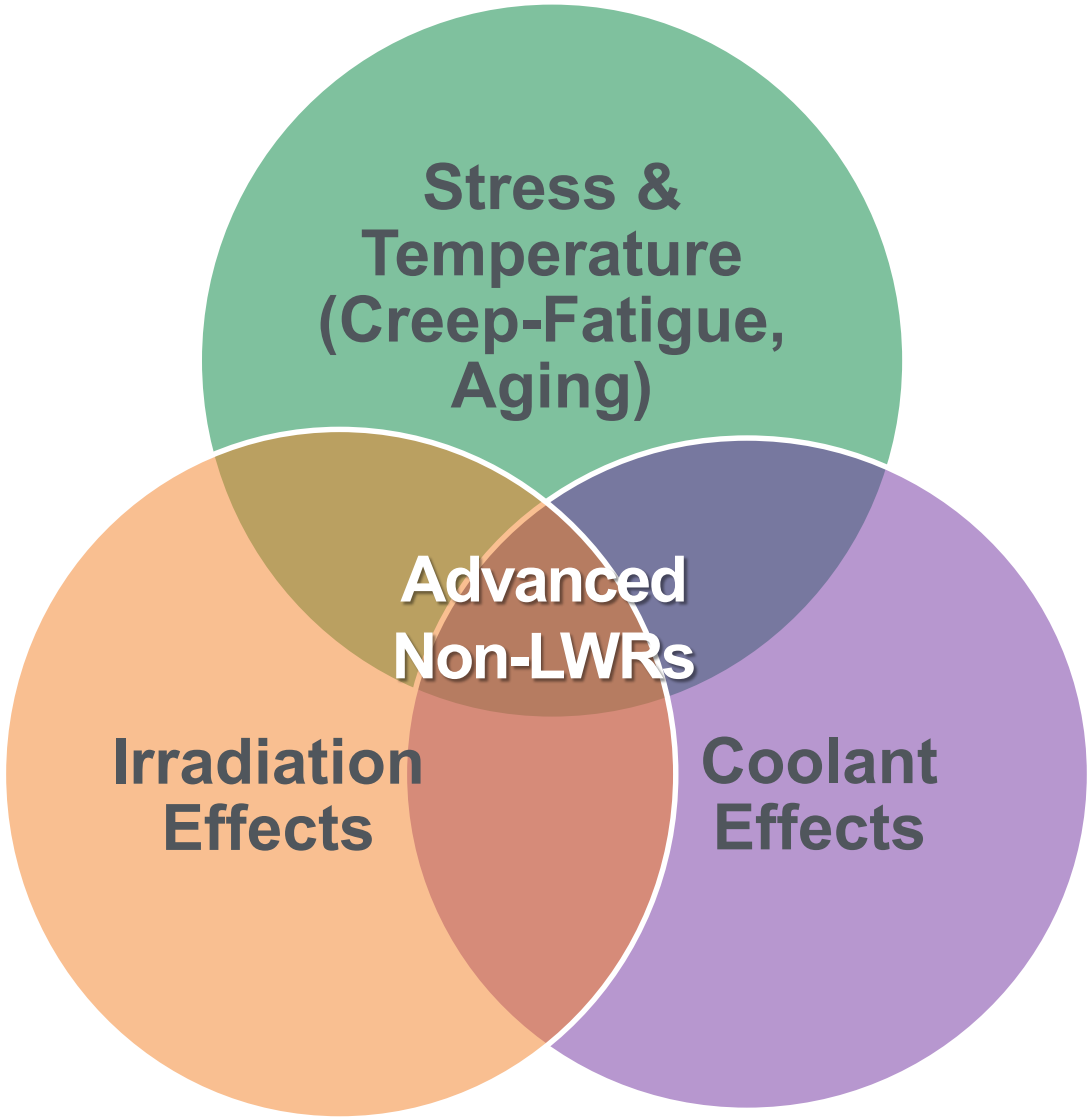
Current Practice on Materials Surveillance for Advanced Non-LWRs (2/3)

- Test specimens covered include
  - Tensile, creep/stress rupture, low-cycle fatigue/creep-fatigue, swelling, and Charpy impact
- Provides guidance on how to place surveillance samples to obtain the desired irradiation conditions
  - Temperature, neutron flux, and neutron spectrum
- Acceptance criteria are not provided in the ASTM E531 Standard Practice

Current Practice on Materials Surveillance for Advanced Non-LWRs (3/3)

- ASTM E531 standard practice is based on the following strategy
  - Know initial structural design properties before reactor operations
  - In-reactor test specimens exposed to neutron and temperature (and coolant) during reactor operations
  - Test specimens removed from reactor per surveillance program schedule for mechanical properties testing
- Testing for time dependent properties of the exposed materials tends to be short

Materials Degradations During Operations of Advanced Non-LWRs



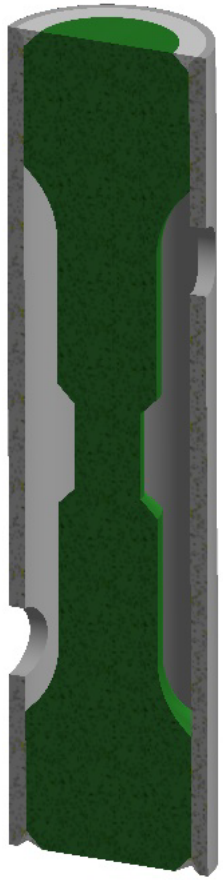
- Effects of materials degradations on structural materials during reactor operations are integral effects
- Would be advantageous to have additional test specimens/articles to capture these integral effects to complement the current test specimens selection in ASTM E531 Standard Practice

In-situ, Passive Test Article to Capture Integral Effects of Materials Degradations

- DOE-NE ART Program has developed a test article, called SMT (Simplified Model Test), that models the key features of structural interaction in prototypical reactor components, the so-called “elastic follow up effects”
- The advancement in the SMT testing methodology allows the generation of “structural data” in air at high temperatures using standard specimen testing setup, without the expensive scaled component testing
- Goal is to develop an in-situ, passive test article based on the SMT concept to capture the integral effects of irradiation, temperature, coolant and stress

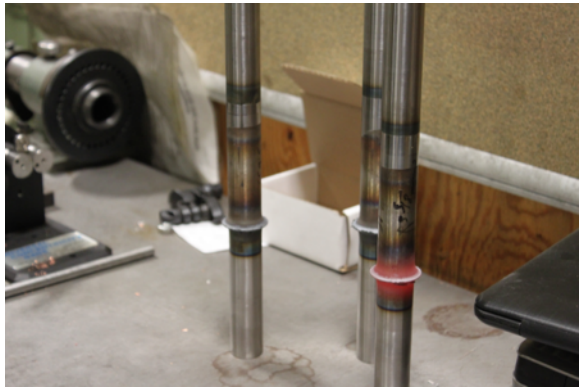
Use Differential Thermal Expansion to Drive Test Article During Reactor Operations

Cross section of axi-symmetric test article

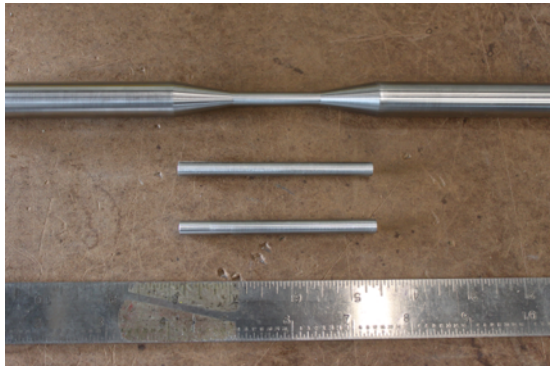


Fabricated a proof-of-concept test article using 316H (test material) and A617 (driver)

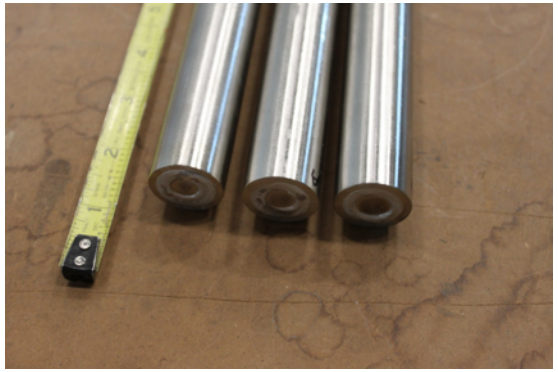
1) Stir-friction weld inner bars together



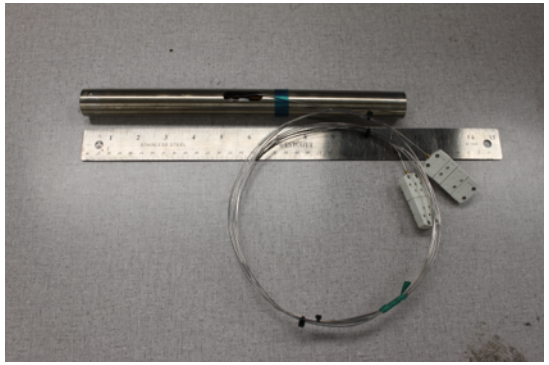
2) Machine inner bars



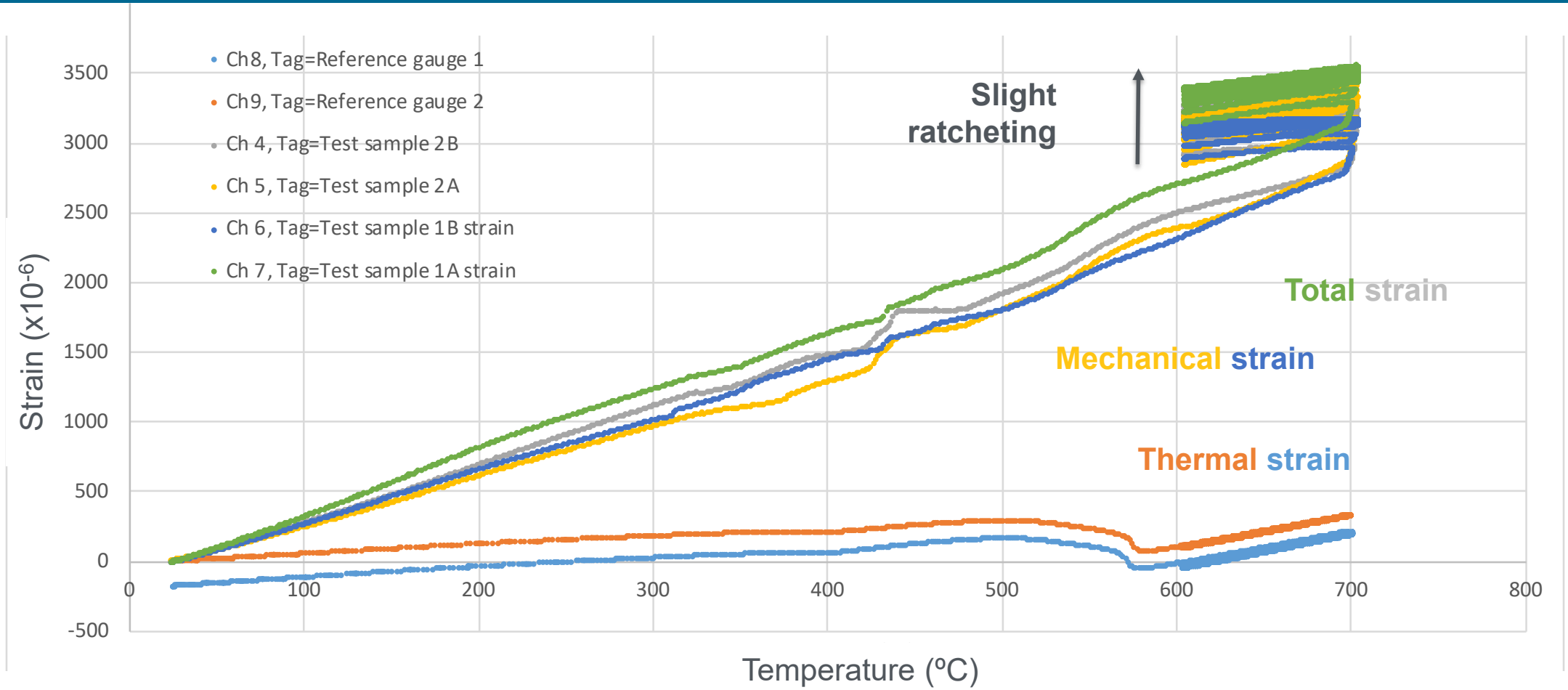
3) E-beam weld outer casing to inner bars



4) Attach strain gauges



Strain-Time Results for Furnace-Tested 316H/A617 Proof-of-Concept Test Article from Temperature cycling



- 100ºC temperature change during steady-cycle
- Test article only has thermocouple and strain gauge – cannot measure stress
- Two measurements of strain (two strain gauges on reference bar, two strain gauges on sample)

Summary of Progress to Date

- Developed and fabricated a proof-of-concept in-situ passively loaded test article
- Trial test by temperature cycling showed that:
  - The fabrication process was adequate
  - Tensile strain could be produced using a driver material with a lower CTE than the test material
  - Strains could be predicted using simple structural models

Near Term Tasks

- Develop prediction tool to select test article geometry and driver material based on
  - Plant temperature transient parameters
  - Desired strain range and elastic follow-up factor
  - Test and driver material thermal and mechanical properties
- Fabricate new test articles based on prediction tool results
- Conduct thermal cycling tests (with hold time)
- Explore if there are issues in fabricating smaller test articles that can conform to the space limitation of an operating reactor

Future Issues to Be Addressed

- What methodologies can be developed to leverage the availability of these test articles that capture plant-specific materials degradations due to irradiation, temperature, corrosion, cyclic loading, and structural interaction effect
  - What types of data can be extracted from these test articles?
  - Can we use these test articles as canaries?
  - How to set acceptance criteria
  - Can we use them to gather material data in a test reactor, e.g., VTR?
    - We don’t have means to measure stress and strain at this time
  - Other questions

Thank you

Contact information

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