Characterization of Irradiation-Assisted Stress Corrosion Cracking in 316 Stainless Steel Baffle-Former Bolts Harvested from a Commercial Pressurized Water Reactor

PI: J. F. Stubbins, University of Illinois at Urbana- Champaign

Program: NSUF-1.1: Core and Structural Materials Behavior and Development

Collaborators:
M. Kasemer, University of Alabama
T.G. Lach, Oak Ridge National Laboratory
M.N. Gussev, Oak Ridge National Laboratory
X. Chen, Oak Ridge National Laboratory
P. Kenesei, Argonne National Laboratory

ABSTRACT:

The objective of this project is to assess the mechanisms for initiation and development of irradiation-assisted stress corrosion cracking (IASCC) in austenitic stainless steel internal components harvested from a commercial pressurized water reactor (PWR). Core internal structural components of PWRs are subjected to multiple environmental extremes such as high radiation doses, high temperatures, corrosive environments, and mechanical stresses. This combination of environmental extremes makes internal alloy components susceptible to IASCC, which may lead to in-service failure and inability to extend the lifetime of existing PWRs. Thus, it is important to understand how the microstructures evolve with irradiation and during service for evaluation of lifetime extension of existing reactors. This work is directed toward resolving the critical need to understand the mechanisms for IASCC initiation and development and determine potential avenues for mitigating this highly detrimental phenomenon.

This project concentrates on the extreme environmental exposure of baffle-former bolts (BFBs) which are an integral component within PWRs. The BFBs join the baffle plates to the former plates. While holding load and subjected to a pressure gradient, the bolts are exposed to a high neutron radiation flux and gamma heating both of which vary along the length of the bolt. On top of this, the transition region between the bolt head and bolt shank is exposed to primary loop water, the location where IASCC cracking and subsequent failure are most likely to occur.

In this work, we will combine a number of post-irradiation examination (PIE) techniques to develop a unified understanding of the service-induced degradation of BFBs retrieved from commercial PWRs. The PIE work includes STEM and SEM/EBSD examination techniques at ORNL as well as characterization using a synchrotron source for high energy x-ray diffraction and near-field techniques to reconstruct 3D microstructural maps of deformation and corrosion processes in these materials. The synchrotron work will be conducted at the new Activated Materials Laboratory at the ANL Advanced Photon Source. The complex microstructures will be modeled using Crystal Plasticity Finite Element (CPFEM) techniques to illuminate the role of the irradiation defect structures, the corrosion zone and the stress states on the IASCC degradation process. This research will enable the ability to validate research reactor and laboratory-based research efforts and provide a detailed analysis of the synergistic and combined effects of multiple extreme environments like radiation, corrosion, and mechanical stresses and exposure temperature.