Modeling and Validation of Irradiation Damage in Ni-based Alloys for Long-Term LWR Applications

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ABSTRACT:

As light water reactor (LWR) plant lives are extended, the need for predictive modeling tools for materials degradation increase in order to ensure safe operation and plan for component replacements. The Grizzly code, which is built on the MOOSE multi-physics simulation environment, is being developed for exactly this purpose. To extend Grizzly to include capabilities for modeling Ni-based alloys, we propose a US/UK integrated program to address thermal and irradiation-induced transformations mechanisms of Alloys 690 and 625. Alloy 690 is widely used in existing LWR plants due to its superior stress corrosion cracking (SCC) resistance compared to Alloy 600. Alloy 625 is used in more limited applications but offers the benefits of both high strength (in the aged condition) and corrosion/SCC resistance [1]. Research has shown that both alloys can undergo phase changes due to thermal or irradiation exposure. In the precipitation-hardened condition, Alloy 625 "softens" during neutron irradiation as the strengthening precipitates decompose and metastable precipitates form [2, 3]. However, the nature and rates of these transformations as a function of exposure conditions are not well understood. Similarly, the effects of these thermal and irradiation-induced microstructural changes on mechanical properties require evaluation. The proposed program combines thermal and irradiation experiments, mechanical testing, microstructural characterization using state-of-the art analytical techniques, atomistic modeling, micro-and macro-scale modeling via Grizzly. This multi-pronged approach yields several benefits: 1) atomistic scale models capture the physics of the mechanisms of phase transformations, which can be generalized to other systems, 2) the modeling results (from atomistic to continuum) will be validated experimentally to ensure the predictive aspect, 3) the microstructure/property relationships captured with mechanical testing provides information at the engineering scale that is needed to validate the integration of the proposed new capability into Grizzly.

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3. Burke, M.G. and R. Bajaj, *Radiation-Induced Precipitation in Direct-Aged Alloy 625*, in *Microscopy & Microanalysis 96*,. 1996, San Francisco Press. p. 994-995.