Project Title

Assessment of Aging Degradation Mechanisms of Alloy 709 for Sodium Fast Reactors

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Program: Reactor Concepts: Creep and Creep-Fatigue Deformation and Grain Boundary Cavitation Mechanisms

ABSTRACT:

The goal of this project is to develop understanding of the mechanisms responsible for behavior of austenitic stainless steel NF 709 under accelerated testing conditions to confidently predict long term creep and creep-fatigue behavior at the times (500,000 hours) and temperatures (550°C) of interest for fast reactor structural applications. Alloy NF 709 has exhibited significantly better creep resistance than Alloy 316H, which is currently specified in design of fast reactor structural components. However, the alloy has not been Code qualified for elevated temperature nuclear design. The elevated temperature microstructure stability, creep damage, and creep-fatigue damage needs to be better understood so service life can be accurately predicted. Alloy 709 was developed for fossil boiler applications, which operate at a higher temperature than the nuclear components. Thus, there is a strong need to characterize its creep and creep-fatigue behavior at lower temperatures and corresponding longer service lifetimes.

The objectives of the project will be accomplished through collaboration between the Colorado School of Mines and Idaho National Laboratory. Specifically, microstructure-property correlations will be developed for creep and creep-fatigue conditions for Alloy 709. Furthermore, the alloy will be subjected to accelerated aging conditions designed to simulate long term exposure to service temperatures. The aging conditions will be designed to utilize higher temperatures to produce similar microstructural changes in significantly less time but also maintain consistency with the types of microstructure that are produced in service conditions at lower temperatures. These aged conditions as well as-received Alloy 709 specimens will be subjected to various mechanical tests to evaluate creep and creep-fatigue behavior. The creep behavior will be assessed to determine stress levels at which the deformation mechanism changes from climb-controlled to diffusion controlled. It is critical to determine these conditions because using creep data from climb-controlled deformation can over predict creep lives governed by diffusion-controlled deformation. In support of this effort, stress relaxation, stress drop, and constant load creep testing will be performed. Additionally, interrupted creep-fatigue experiments will be conducted at two different strain amplitudes with the objective of correlating internal damage developed during the interrupted experiments to the creep studies. High resolution characterization through transmission electron microscopy and atom probe tomography will be a valuable component of the project to track microstructural and damage evolution that can then be correlated to observed mechanical behavior.

Two Ph.D students will be trained and educated in important issues related to nuclear materials through the project. Additionally, a strong research partnership will be established between the Colorado School of Mines and Idaho National Laboratory.