Mechanical Behavior of Alloy 709 for Advanced Fast Reactor Applications

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ABSTRACT: The advent of next-generation nuclear reactor systems brings with it a multitude of material challenges. The structural materials to be used for these reactors will be exposed to more extreme conditions of radiation, stress, and temperature than those of prior generations. The development and characterization of novel materials to withstand such environments is a necessity. Alloy 709, developed by Oak Ridge National Laboratory, is a high strength austenitic stainless steel initially designed for boiler tube applications. In this work, the mechanical performance of Alloy 709 was studied using tensile tests with in-situ X-ray diffraction (XRD) at various temperatures, ranging from room temperature (RT) to 600ºC, and strain rates, from 0.001 to 0.004 mm/s. Using these stress-strain curves, empirical models of Alloy 709's deformation behavior over a range of temperatures and strain rates were developed. From these models, an optimization of terms was carried out to best characterize Alloy 709's thermomechanical properties and sensitivity. To establish an accurate empirical deformation model for Alloy 709, subsequent microstructural analysis was completed using the collected in-situ XRD data, Electron Backscattered Diffraction (EBSD) and associated Transmission Electron Microscopy (TEM) analysis. By applying these techniques on the samples, information such as: load partitioning, preferred orientation, presence of secondary phases and their corresponding phase fraction, active dislocation types and their density evolution, all as a function of temperature, was revealed. These techniques functioned to form a complete picture of the development of the Alloy 709 microstructure during deformation. These results were used to clarify microscopic mechanisms underlying the empirical deformation model.