

***In situ* ion irradiation mechanical testing to inform physics-based modeling of irradiation creep mechanisms in Grade 91**

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ABSTRACT:

A critical need exists to develop a mechanistic understanding of irradiation deformation, to inform the safe design of advanced nuclear reactors. The current understanding is lacking, as it is derived almost exclusively based on data of structural materials irradiated *without mechanical load*, followed by post-irradiation mechanical testing (PIMT) *without irradiation flux*. It is well-known that stress influences the evolution of radiation damage in Fe-based materials. In addition, studies have demonstrated that different deformation mechanisms occur during in-reactor mechanical testing compared to testing specimens without flux. We therefore propose a targeted suite of *in-situ* and *in-operando* irradiation deformation experiments, with comprehensive characterization and supportive modeling, to establish the relationship between radiation, stress, microstructure, and mechanical properties crucial to performance predictions for next generation nuclear reactor components. This project will study the impact of *sequential vs. simultaneous* irradiation and mechanical loading during tensile and creep testing of F/M steels, Grade 91 and HT9, to produce the following outcomes: i) investigation, validation, and publication of subsized specimen geometry effects during elevated temperature tensile testing of F/M steels; ii) a mechanistic understanding of how mechanical loading affects microstructural evolution, including α' precipitation, during irradiation of high-Cr F/M alloys; iii) determination of the deformation mechanisms that are active during sequential and simultaneous irradiation-tensile testing of F/M steels and their impact on the measured mechanical properties; iv) an integrated experimental-modeling investigation into the interplay between irradiation-induced microstructural changes and irradiation creep mechanisms in F/M steels. Our results will inform current and future Department of Energy Office of Nuclear Energy (DOE-NE) programs focused on advanced fuel development (AFC), Advanced Materials and Manufacturing Technologies (AMMT), and advanced modeling and simulation (NEAMS).