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Integrated Computational and Experimental Study of Radiation Damage Effects in Grade 92 Steel and Alloy 709

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**Program**: Reactor Concepts Research R&D

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**ABSTRACT:**

The objective of this project is to develop a mechanistic understanding and models with predictive capabilities for radiation-induced microstructural evolution and resulting mechanical properties in optimized ferritic-martensitic Grade 92 steel and austenitic Alloy 709. These candidate alloys are being developed for the Sodium-cooled Fast Reactor (SFR). To achieve this objective, synergistic experiments and simulations will be employed. Ion irradiations will be used to simulate the effect of neutron irradiations on hardness changes in these materials, because ion irradiation does not result in radioactive samples and inflicts similar levels of damage in significantly smaller time-scales. In particular, proton and Fe ion irradiations will be used to achieve specific types and levels of irradiation damage in the materials, relevant to SFR applications. To develop corresponding models for experimental observations, multiscale simulations and modeling approaches, including molecular dynamics (MD), self-evolving atomistic kinetic Monte Carlo (SEAKMC), and object kinetic Monte Carlo (OKMC) will be employed. The unique aspect of this research is to accurately include more fundamental physics and realistic defect migration and interaction from atomistic simulations, particularly SEAKMC, into the OKMC model, which is capable of spanning the required time and length scales that are comparable with experiments. The project is composed of two central and synergistic tasks. The first task will focus on using surrogate ion irradiation to simulate neutron irradiation in regards to equivalence in radiation damage in the two materials. The second task will determine the mechanical properties in these two materials caused by radiation damage and explore ways of manipulating point defect evolution and interaction to control mechanical property changes. The research is driven by the fact that there is very limited experimental data on fast neutron irradiation effects in Grade 92 steel and austenitic Alloy 709 and a lack of understanding of effects of irradiation on microstructural evolution and mechanical properties. Fundamental insights into the correlation between ion irradiation and fast neutron damage will be established during the course of the project. This will enable pilot ion irradiation investigations to guide future neutron irradiation campaigns for the two alloys under the Advanced Reactor Technologies (ART) program, which without such focus can be very time consuming and expensive. The outcome will also provide invaluable insights and prototype for radiation resistance assessment of other interested alloys.