NEUP Nuclear Energy University Programs
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Novel Dissimilar Joints Between Alloy 800H and 2.25%Cr and 1%Mo Steel

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Program: RC-3.2: Dissimilar Transition Weld Issues for High Temperature Reactors

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ABSTRACT:

Background: Dissimilar metal joints between steel and nickel base alloys are currently fabricated using conventional arc welding processes with selected filler metal combinations and are commonly used in generator to superheater tubes, nozzles in hot vessels, and vessel to piping welds. Long term service has demonstrated that these joints are particularly susceptible to both creep and creep fatigue failures and decreased corrosion resistance. The mechanisms driving these creep failures primarily involve carbon diffusion from the low to the high chromium alloy, which creates a carbon depleted zone that contains very few stable carbides. These dissimilar metal joints contain abrupt variations of composition and a high carbon potential gradient. In contrast, additive manufacturing (AM) technologies, when guided by appropriate thermodynamic, kinetic and heat transfer and fluid flow modeling, offer a highly controllable means for reducing carbon diffusion through theoretically-designed, gradual, nonlinear compositional profiles and the incorporation of carbon diffusion barriers. After the mechanical and creep properties of these joints are rigorously tested and the scale-up issues are addressed, the data on structure and properties can serve as valuable initial inputs for the initiation of an ASME code case.

Task Breakdown and Objectives: Researchers from Penn State, Ohio State, and Oak Ridge National Laboratory (ORNL) will undertake an integrated experimental and theoretical program to develop, fabricate, and test highly engineered dissimilar metal weld joints between 2.25 Cr-1 Mo ferritic steels and an 800-H nickel base alloys. The alleviation of carbon migration in dissimilar metal joints will be addressed. Penn State will be responsible for the overall management of the program and the thermodynamic and heat transfer and fluid flow modeling and the fabrication of test samples. Ohio State will provide additional analysis and characterization for the scale up of the sub-size specimens. ORNL will be responsible for the creep and creep fatigue testing and coordinating the development of the methodology and data collection supporting code qualification. Specific technical objectives include the following:

(a) Minimize carbon diffusion by reduction of carbon potential gradient at typical service temperatures in graded transitional joints and design carbon diffusion barriers by thermodynamic and kinetic modeling.
(b) Fabricate transitional joints with additive manufacturing guided by numerical modeling of heat transfer and fluid flow and the carbon potential/diffusion barrier modeling.
(c) Examine mechanical properties and creep testing results of the fabricated part with a combination of established and unique methodologies.
(d) Perform a series of scaling experiments and modeling to investigate the validity of the graded joints at length scales typical of in-service components.
(e) Generate, evaluate and document data that will be helpful for the initiation of the ASME code case for the eventual code qualification of the AM fabricated dissimilar metal joints.

Extensive and specialized resources of multiple leading organizations, prior success of the senior investigators in highly complex collaborative research projects, and knowledge of senior investigators in the data necessary for eventual code compliance make the proposed research both a promising venture and an appropriate undertaking within a realistic time frame.