
Development of Novel Functionally Graded Transition Joints for Improving the Creep Strength of Dissimilar Metal Welds in Nuclear Applications

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ABSTRACT:

Dissimilar Metal Welds (DMWs) between 2.25Cr-1Mo steel and Alloy 800 are required to fabricate the Very High Temperature Reactor (VHTR) that will be used to generate nuclear power. Experience has demonstrated that failures of such DMWs can occur prematurely well below the expected service life of either base metal. As described in a recent review article written by the PI, premature failure is caused by the sharp change in composition, microstructure, and mechanical properties that occur across the fusion line of the weld. Recent research completed by the PI and co-PIs has demonstrated that these factors can be eliminated with Graded Transition Joints (GTJs) that are made with a gradual change in composition from the 2.25Cr-1Mo steel to Alloy 800. With this approach, the GTJ is placed between the two alloys so that similar welds can be made to each alloy, thus eliminating the DMW that is prone to failure.

Research is now needed to advance these concepts for application to welds required in the VHTR. Thus, the primary objectives of this research are to: 1) Develop design and processing methods for fabricating novel GTJs that eliminate failures that occur due to enhanced carbon diffusion and high thermal stresses, 2) Establish a database of creep life and improved creep life models of GTJs that are supported by new techniques for measuring localized strain in the presence of composition and microstructure gradients, and 3) Apply this information to initiate code acceptance by the American Society of Mechanical Engineers (ASME) for use of GTJs in the VHTR application. This research will benefit both the nuclear and fossil power generation industries by avoiding premature DMW failures that have plagued each industry for more than 40 years. The research will directly address the needs described in Advanced Structural Materials, Dissimilar Transition Weld Issues for High Temperature Reactors.

The collaborative project capitalizes on recent advances made by each organization in the field of dissimilar metal joining. The team will first conduct high temperature tests on candidate GTJs that were recently developed by the PI. The tests will be conducted with new strain measurement techniques (recently developed by the co-PIs) that are critical for understanding the performance of the joints. These results will then be used to develop refined creep models of strain localization for the GTJs. Methods will also be developed for further optimization of the GTJs by minimizing carbon diffusion and thermal stresses that arise due to CTE mismatch. The results from these activities will then be combined and applied to manufacture and test optimized GTJs. The GTJs will be made with the dual wire gas tungsten arc welding (DWGTAW) process that has already been demonstrated for this purpose and is easily scalable to mass fabrication. The results will produce a database of high temperature mechanical properties and a creep constitutive model for GTJs that will pave the way for eventual ASME code acceptance that is required for use of GTJs in the VHTR application.