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Effects of High Damage Dose on Laser Welded, Irradiated AISI 304SS

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ABSTRACT:

The objective of this project is to ***assess the mechanical integrity of laser weld repairs of highly irradiated, He-containing AISI 304 stainless steel under extended LWR service conditions***. Life extension of commercial light water reactors (LWR) raises concerns about possible cracking of critical in-core or near-core components. Cracks, accelerated by and often attributed to, irradiation damage, have already been observed in some near-core or in-core components of commercial LWRs. Attempts have been made to repair such cracks by welding, but weld repairs have been complicated by helium accumulation in the material during reactor operation. Heat input and thermal stresses from welding cause helium to coalesce into bubbles on grain boundaries, resulting in helium-induced cracking near and around the weld-melt boundary. The helium concentration, as well as the irradiated microstructure (e.g. voids, radiation-induced segregation) influencing crack propagation, are highly dependent upon LWR type and operating conditions. Since LWR internals span a range of irradiation damage levels and helium concentrations, weld repair technologies must be adaptable to a variety of conditions. Even if successful weld repairs can be performed on irradiated, He-containing materials, the possibility remains that further irradiation will induce changes at the weld boundary. Thus, there is a critical need to assess the integrity of these welds over extended irradiation service.

To address this knowledge gap, we will utilize AISI 304 stainless steel hexagonal blocks irradiated in the EBR-II reflector. These hex blocks are ideal for this study because they were produced using technology typical of current LWR internals and have appropriate He concentrations and distributions. The hex blocks are stored in the Westinghouse Materials Center of Excellence (MCOE) hot cells, a NSUF partner. We hypothesize that low-energy input laser welding will minimize stresses driving cracking and He coalescence at the weld boundary. Fortuitously, MCOE is one of the only facilities worldwide with in-hot-cell laser welding capabilities. We will make laser welds on the hex blocks over a range of He and swelling conditions; without the need for extensive pre-characterization, the project can progress rapidly. Weld cross-sections will then subjected to additional irradiation at LWR-relevant conditions using self-ions to achieve high damage doses ~200 displacements per atom (dpa). Subsequently, welds will be examined for residual stress, microstructure, mechanical properties, and cracking.

This project will have crosscutting impact across all DOE-NE programs. It will also complement ongoing DOE-NE Light Water Reactor Sustainability (LWRS) long-term operations collaborative research on Advanced Welding Methods for Irradiated Materials. This project will leverage optimization of laser welding techniques for irradiated, He-containing materials being developed by the LWRS effort. Individuals directly involved with laser welding development through LWRS have provided input to the proposed workscope and will serve on a Welding Advisory Board for this project.