Friction Stir Based Repair Welding of Dry Storage Canisters and Mitigation Strategies: Effect of Engineered Barrier Layer on Environmental Degradation

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Program: FC-4.2: Used Nuclear Fuel Disposition: Storage and Transportation

ABSTRACT:

The proposed project aims to develop a friction sir based repair technique to heal cracks of stainless steel dry storage canisters (DSCs), created by the effect of stress corrosion cracking (SCC). In real service conditions, the welded parts of the canisters become prone to SCC under exposure to aggressive chemical environment. The focus of the project is on developing a mitigation strategy that can be implemented for countering SCC in DSCs following a two-pronged approach: (i) apply friction stir processing (FSP) as a crack repair technique while creating compressive residual stresses at the canister material surface, thus improving resistance against SCC; (ii) add molybdenum and/or nitrogen by friction stir based alloying process to create compositions that improve pitting resistance and thus enhance resistance against SCC.

The specific project objectives are listed below:

- Investigate FSW of 304L SS a potential repair welding technique of dry storage canisters;
- Optimize the FSW parameters to introduce surface compressive stress profiles in the weldments;
- Develop a FSP method to surface alloy the 304L with nitrogen and Mo by adding CrN and Mo powders;
- Evaluate the surface compressive residual stress profile during FSW and FSP processes;
- Evaluate the localized corrosion resistance of the FSW and FSP samples as a function of temperature, chloride concentration, and surface alloy composition;
- Evaluate the SCC behavior of the FSW and FSP samples as a function of stress, chloride concentration, and temperature at three different surface chemistries and induced compressive stress profiles.

The FSP activities will be performed at the state-of-the-art friction stir facility available at the Pacific Northwest National Laboratory. Cracks will be machined using electrodischarge machining in the welded and unwelded 304L plates. Then FSP will be carried out on those plates to 'heal' the cracks and also introduce molybdenum and nitrogen into the surface layer. The residual stresses in the repair welds will be measured using X-ray diffraction. Nondestructive evaluation of process defects will be performed using ultrasonics method. These plates will be sent to the University of Idaho where detailed microstructural characterization using TEM and SEM/EBSD will be carried out. Furthermore, detailed corrosion tests (both pitting corrosion and stress corrosion cracking) will be performed to examine the effect of crack repair on the properties. Mechanical testing involving Vickers microhardness and tensile testing will be also performed. The goal of these activities would be to obtain a fundamental understanding of the processing-structure-properties correlations. If successful, this work will lead to the development of a crack repair/mitigation strategy based on friction stir technology that can be efficiently implemented for spent fuel dry storage casks, which will enhance safety and reliability of these systems. Two doctoral students will be trained in this project.