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U.S. Department of Energy

Low-Force Solid-State Technologies for Mitigation of Stress Corrosion Cracking in Dry Storage Canisters

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

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ABSTRACT:
The proposed research will focus on evaluation of two technologies for field mitigation and repair of stress corrosion cracking (SCC) in stainless steel canisters for dry cask storage of used nuclear fuel (UNF): (i) additive friction stir welding and (ii) cold spray deposition. One of the concerns associated with long-term storage of UNF in the on-site dry cask storage system for extended periods is SCC of the stainless steel canister particularly at the fusion welds used in their fabrication. Given this propensity for SCC, mitigation and repair technologies for SCC to ensure safe long-term operation without the need to replace the existing canisters are needed. Crack repair technologies have traditionally relied on high-heat-input fusion weld overlay methods that involve melting, which leads to segregated microstructures and shrinkage stresses in the material and leaves open the possibility of a resurgence of SCC at a later time.

This research focuses on the development of additive friction stir welding and cold spray deposition, as low heat input and low force solid state processes for SCC crack mitigation and repair. A laboratory scale additive friction stir welding capability will be first built at the proposing university in collaboration with the partnering industry, a key developer of this technology. Following this, the process parameters of additive friction stir welding and cold spray deposition processes will be optimized with the goal of applying this technology for dry cask canister applications. Since conventional friction stir welding has already shown promising results at the partnering national laboratory, the team will bench-mark the additive friction stir welding and cold spray deposition processes against friction stir welding, using simulated cracks and stress corrosion cracks on fusion welded stainless steel provided by the second partnering industry. Rigorous parametric studies for both additive friction stir welding and cold spray deposition will be performed to characterize the achievable bonding, microstructure, and residual stresses in the repaired regions. The relation between process parameters and temperatures and forces acting on the workpiece will be used to develop scaling laws for reducing the size of equipment. This knowledge will inform a study on the feasibility of using the two technologies to conduct field repairs within the gap between the canister and the concrete overpack. Finally, a conceptual design of the processes for *in situ* canister repair will be proposed in consultation with industry as a path towards commercialization.

Repair of stress corrosion cracks will be followed by mechanical testing and corrosion testing of the repaired regions of the promising samples. Detailed microstructural characterization to understand the repair mechanisms at a microstructural level and depth of bonding and repair will be performed. All this data can be collectively used in finite element models to determine if the repair is structurally qualified for transportation. Finally, based on experimental data from this project the team will develop documentation for NRC licensing compliance as a path forward to implement these technologies for mitigation and repair of dry cask storage stainless steel canister.