Cold Spray Repair & Mitigation of Stress Corrosion Cracks in Spent Nuclear Fuel Dry Storage Canisters

PI: Janelle P. Wharry, Purdue University

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

Collaborators: Charles R. Bryan (Sandia National Laboratory), Eric J. Schindelholz (Sandia National Laboratory), Kyle W. Johnson (VRC Metal Systems)

ABSTRACT:

The objective of this project is to ***demonstrate cold spray repair and mitigation of chloride-induced stress corrosion cracks and pits in AISI 304 stainless steel dry storage canisters***. Nearly 2000 dry storage canisters at commercial light water reactor (LWR) sites, especially those in coastal environments, are susceptible to chloride-induced stress corrosion cracking (SCC) and pitting. As canisters cool, deliquescence of deposited sea salts is anticipated to create corrosive, chloride-rich brines that may induce SCC at weld seams having high residual tensile stresses. Repair of existing SCC and mitigation of potential SCC is necessary to ensure long-term integrity, security, and regulatory compliance of spent nuclear fuel (SNF) storage. But repair and mitigation approaches must meet several system constraints: the technology must be deployable in-field, must not utilize sparks because of the potential presence of hydrogen gas, must ideally access the canister surface through only the manufacturer-dependent 2”-4” annulus between the canister and its concrete or concrete/steel overpack.

This project will evaluate cold spray as a potential method to resolve this engineering challenge. During cold spray, metallic powder particles travel at a sufficiently high velocity so as to peen the substrate upon incidence, producing corrosion-resistant compressive residual stresses. This negates the need for an additional peening step to mitigate detrimental tensile stresses that would arise from other repair techniques such as friction stir welding. Further, cold spray is a non-sparking, non-contact method that can be applied to complex surfaces such as that which might form by excavating a SCC. High deposition rates reduce repair times and minimize radiation exposure. A cold spray nozzle and associated robotics specifically compatible with the canister-overpack gaps are being developed to a high technological readiness level (TRL), through DOE support to our industry partner. That effort optimizes cold spray technology for SNF canisters, enabling funding for this project to be used efficiently to obtain a detailed and rigorous understanding of the cold spray material and its long-term efficacy for repair and prevention of SCC in chloride environments.

The project will optimize the repair process and gain a scientifically informed understanding of SCC mechanisms. Within an integrated feedback loop, we will first excavate SCC from representative AISI 304 stainless steel coupons, then cold spray to fill the excavated volume. We will vary repair parameters and evaluate SCC susceptibility of each repair. We will then conduct microstructure, electrochemistry, and crack propagation studies. The task loop will reveal fundamental relationships between repair parameters, residual stress, and SCC resistance. Optimized repairs identified through this loop will be demonstrated on sections of a full-scale canister mockup, which have been cut to retain in-service residual stresses. Finally, the relationships identified experimentally will validate a finite element based model of the relationships governing SCC in cold sprayed materials, which can be used in the continuum models in the Multi-Physics Object Orientated Simulation Environment (MOOSE). This project will inform the fundamental cold spray-residual stress-SCC relationships that will complement ongoing DOE-supported efforts to deploy in-field cold spray repairs in the near term, together solving a critical industry need.