Surface Peening and Hybrid Surface Engineering Approaches to Mitigate Initiation and Resurgence of Stress Corrosion Cracking in Dry Cask Storage Stainless Steel Canisters

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ABSTRACT:

Long-term safe storage of UNF is one of the key issues for viability and sustainability of the current Light Water Reactor (LWR) fleet. Presently, used fuel is stored in stainless steel canisters in a dry cask storage system (DCSS). The majority of the DCSS in the U.S. consist of fusion welded austenitic stainless-steel canisters containing UNF assemblies placed in a concrete overpack. The UNF storage time in the interim storage systems is projected to be beyond 60 years. One of the limiting factors in the extended storage of UNF in DCSS is susceptibility to chloride-induced stress corrosion cracking (CISCC) in the welded regions of the stainless-steel canisters. The welded regions are more prone to SCC due to a confluence of solidification induced tensile stresses, susceptible microstructure (sensitization of stainless steel in the heat affected zone, HAZ), and the presence of corrosive chloride salt environment. While no CISCC failure in DCSS canisters has been reported, the propensity for its occurrence has warranted the development of mitigation technologies for CISCC to ensure the safe and long-term storage, for both the canisters presently in use and those that will be deployed in the future. Low heat input solid state methods that do not entail melting and solidification are preferred for this application.

The goal of the proposed research is to develop, evaluate, and competitively benchmark various surface peening technologies and associated hybrid surface engineering approaches to mitigate initiation and growth of CISCC in DCSS canisters, with the focus being on the fusion welded regions of the canister. Commercial surface peening processes that have been identified as being promising approaches by the Mitigation committee of the Extended Storage Collaboration Program (ESCP) coordinated by Electric Power Research Institute, national laboratories, and associated industries will be investigated, including: shot peening, cold spray peening, ultrasonic impact/shot peening, ultrasonic nanocrystal surface modification, laser shock peening, and forced pulsed water jet peening. Hybrid approaches consisting of cold spray coating of peened surfaces will be developed to further mitigate CISCC initiation and growth. Microstructural developments such as grain refinement and orientation, deformation-induced martensite formation, deformation-induced compositional redistribution, dislocation entanglements will be investigated. Compressive stresses from the surface peening processes will be measured using a variety of complementary methods including deep-hole drilling, contour, and x-ray diffraction methods, and the more recent focused ion beam (FIB) methods. Fundamental electrochemical corrosion parameters such as corrosion current density and potential, pitting potential, passivation characteristics, and corrosion kinetics will be determined using potentiodynamic corrosion tests. Crack growth will be quantified using *in-situ* and high-resolution (near-nanometric) tests using direct current potential drop (DCPD) method.