Local resonance-based linear and nonlinear NDE techniques for repaired DSC wall structures

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Program: Topic area 6 – Spent fuel, waste science & technology and integrated waste management system

ABSTRACT:

Long-term integrity assurance of storage systems for used fuel dry shielded canisters (DSCs) is a critical need for the nuclear power industry. Multiple reports express concern about chloride-induced stress corrosion cracking (SCC) in DSCs, especially for those located in marine environments, and call for experimental data about degradation of stainless steel canisters owing to SCC and repair and mitigation of cracks in those cannisters. Cold spray (CS) technology shows good potential as a tool for mitigation and repair of SCC, intergranular attack, and flow accelerated corrosion in stainless steel canisters. However, current nondestructive evaluation (NDE) capabilities are insufficient to detect and fully characterize SCC and to monitor the efficacy of repair strategies such as cold spray *in situ*; these represent significant knowledge and capability gaps and further may limit the effectiveness of this important repair technology. The filling of these capability gaps with new inspection technology and know-how will help support the goals of safe, durable and long-term storage of used fuel. The objective of this research is to develop practical NDE methods that deploy linear and nonlinear resonant vibration methods to monitor meso- and micro-structural defects in DSC structures and the overlying CS repair material. Although some resonant vibration methods, such as non-linear resonant ultrasound spectroscopy (NRUS), have been effective in characterizing macro- and micro-structural defects in engineering materials, their application is so far restricted to slender geometric elements. ***The new idea and technological breakthrough in our work is to develop and deploy vibration resonance methods, including non-linear methods, to repaired DSC wall structures by exploiting the unique behavior of local canister wall vibration***. The team will carry out an extensive experimental test series, supported by numerical simulation, to develop and evaluate how linear and nonlinear vibration methods can characterize meso-scale defects, such as porosity of CS layers, and micro-structural defects, such as interfacial strength between CS coatings and the substrate and the presence and extent of SCC in canister structures beneath CS-repaired zones. The proposed work plan comprises three tasks: *1)* study of local resonances, including zero-group velocity modes, cut-off frequency resonances, and edge resonances, in plain and CS-coated surrogate canister wall specimens; *2)* development of local resonance-based linear and non-linear (e.g. NRUS) techniques that exploit both harmonic and impulse excitations; and *3)* evaluation of local resonance-based technique to characterize and quantify coating/substrate adhesion quality, porosity of CS coating, and the presence of CS-repaired SCC-like defects. Major milestone deliverables include *1)* identification of critical local vibration resonances in plain and CS-coated canister wall structures; *2)* design and development of local resonance-based NDE methods considering practical application; and *3)* quantitative evaluation of developed NDE methods for important CS coating and CS-repaired SCC-like defects. The investigating team offers a broad range of expertise relevant to the task at hand and comprises two research universities (University of Illinois and University of Utah) and two National Laboratories (Pacific Northwest National Laboratory and Oak Ridge National Laboratory).