Nuclear Energy University Program
U.S. Department of Energy

Predicting Pitting and Stress Corrosion Cracking of Dry Cask Storage Canisters via High Throughput Testing, Multiscale Characterization, and 3D Computer Vision based Machine Learning

PI: Xiaolei Guo, The Ohio State University

Collaborators: Jenifer Locke, Eric J. Schindelholz, Gerald S. Frankel, The Ohio State University; Tiankai Yao, Idaho National Laboratory; Timothy Burnett, University of Manchester (UK)

Program: Fuel Cycle Technologies

ABSTRACT:

The global mission to attain net-zero greenhouse gas emissions cannot be achieved without significant investment in nuclear energy technology. This means that more nuclear reactors will be constructed and more spent nuclear fuels (SNF) will be generated. The total U.S. SNF inventory is approximately 82,500 metric tons heavy metal as of 2017, and the number is expected to double by 2048. Currently, SNF in the US is stored on-site in dry cask storage (DCS) made from stainless steel (SS). It is known that the ambient air used to cool the SS canisters contains salt aerosols that can deposit on the canister wall and form an aggressive aqueous brine after deliquescence from the reaction with humidity, thereby facilitating localized corrosion. Canisters with high tensile residual stresses near welds may preferentially undergo stress corrosion cracking (SCC), which is the fastest form of corrosion and could potentially lead to the failure of DCS canisters in a typical coastal marine environment. Therefore, research to gain a deeper fundamental and quantitative understanding of nucleation and growth of pitting and SCC is needed, thereby enabling decision-makers to accurately define in-service inspection intervals and make knowledgeable life-extension decisions while maintaining safety.

Here we propose a US-UK collaborative research program focusing on the nucleation and growth of pits and SCC of SS alloy 304, a canister material used for DSC of SNF, by leveraging high throughput testing methods, multi-scale characterization techniques, and 2D/3D computer vision based machine learning (ML) approaches. The proposed study will enable the understanding and prediction of how and when pitting corrosion can nucleate, grow, and transition into SCC. Additionally, the approach developed via this proposal can be applied to a wide range of materials that are susceptible to localized corrosion and SCC while used in a number of other applications, both within and outside of the nuclear energy sector.

The unique approaches proposed in this study include: **1)** High-throughput pitting corrosion experiments, rigorous accelerated laboratory and field atmospheric corrosion exposures, and SCC experiments performed in a wide range of environments that are of relevance to the disposal of SNF. **2)** *In-situ* and *ex-situ* 2D/3D morphological investigations to fully capture the evolution of a large number of pits and cracks, and the transition in between, through a combination of X-ray micro computed tomography, automatic optical profilometry, serial sectioning by focused ion beam, and electron microscopy analyses. **3)** Morphological digital twins to represent the pits and cracks found in 1 and 2 will be created via 2D/3D computer vision. **4)** The resulting large dataset generated via the digital twins will then be used to train a ML model to facilitate the prediction of nucleation and growth of pits/cracks and the pit-to-crack transition in an environment relevant to the disposal of SNF.