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Optical Fiber Sensor Based Acoustic NDE for Nuclear Canister Monitoring

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ABSTRACT

Establishment of a permanent repository for spent nuclear fuel has yet to be accomplished in the US. Consequently, the amount of waste accumulated in temporary storage systems continues to grow, with dry cask storage systems (DCSSs) playing an increasingly important role. Although current industry practice involves periodic manual inspections to ensure security and safety of DCSSs, developing alternatives to assess the integrity of these casks autonomously and in real-time over the storage life, could have several benefits including ability to detect degradation at earlier stages and reducing exposure to workers associated with periodic manual deployment of sensors. In this work we present an overview of our efforts which seek to develop and demonstrate a real-time monitoring technique for stainless-steel canisters containing the spent nuclear fuel, as well as monitoring internal activity indicative of fuel degradation or failures. The size, structural complexity, and limited access to the surface of the canister poses a challenge to conventional nondestructive evaluation techniques. Our work therefore seeks to leverage the capabilities of ultrasonic elastic wave generation with a vibro-acoustic quasi-distributed optical fiber sensor (DOFS) system capable of a broad frequency bandwidth spanning sonic (<20kHz) to ultrasonic (>20kHz) frequencies into the MHz, coupled with artificial intelligence-based data analytics techniques for structural health monitoring. Experiments are conducted on an existing mockup in the laboratory demonstrating the sensor system capabilities and its spatial-temporal characteristic, as numerical simulation is used to investigate the wave propagation in more detail and extend the dataset beyond existing experimental setup for establishing an AI-based interpretation framework. To investigate off-normal activity, effects of a damaged spent fuel rod yielding an internal gas leak, as well as a canister leakage to the exterior, on the vibration signatures of the canister are also investigated through numerical simulation.

Keywords: Fiber optic sensing, acoustic nondestructive evaluation, ultrasonic guided waves, leak detection

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