Advanced High Temperature Inspection Capabilities for Small Modular Reactors

PI: Leonard J. Bond, Iowa State University

Collaborators: John R. Bowler, Iowa State University and Dan Barnard, Iowa State University

Program: RCD&D: Instrumentation, Control, Human, Machine Interface

ABSTRACT:

It is recognized that both under-coolant viewing and in-service nondestructive evaluation (NDE) are key enabling technologies required to facilitate the development of advanced small modular reactors (aSMR) and ensure the safety of their operation. For aSMR significant attention has focused on materials and their expected performance, however much less attention has been directed to providing NDE capabilities for deployment in-service. Molten salt and liquid metal cooled reactors operate at elevated temperatures (250^{o}C and higher) and the conducting fluids form harsh environments. It is necessary to have NDE sensors capable of in-coolant deployment, that can perform inspections and reliably detect and size cracks.

The objective of this project is to develop NDE techniques for aSMR's employing novel ultrasound and eddy currents approaches which enable in-coolant deployment of probes, whilst providing the modeling and experimental capabilities needed to analyze and understand the phenomena that limit sensor performance and to enable optimization of in-service inspection capabilities.

The fundamental questions for ultrasonics relate to piezoelectric materials properties and for both inspection technologies, the electromagnetic fields, all at elevated temperature in the coolants. The study is structured to understand the limitations on high temperature performance of piezoelectric and eddy-current sensors in liquid metals and lower conductivity fluids, with analysis of sensitivity and S:N. The insights will be used to guide novel sensor design. The study will determine the causes of the fundamental limits to performance (S:N), crack reflectivity and detectability for the two NDE modalities in coolants. A test cell will be designed, built and be used at room temperature with a liquid metal and a surrogate for a molten salt. Limited testing in an oil for a range of temperatures (~20-300^{o}C) will be used to provide confirmation for temperature dependent properties. The project will separate conductivity and electromagnetic interference (EMI) effects from those due to temperature. The performance of inspection methods will be investigated using NDE computer simulations and these will assess both conventional and novel inspection configurations. Performance will be given in the form of probability of detection (POD) and take account of the electro-mechanical effects of coolant filled cracks.

The project will provide key enabling NDE inspection technologies needed to support the design and the reactor component performance validation process for advanced small modular reactors (aSMR) and ensure the safety of operating reactors. The modeling and laboratory testing can significantly reduce the costs associated with developing sensors, test samples and reduce the experimentation needed to evaluate performance of NDE tools for characterization of cracks, which would otherwise consume large volumes of coolants, such as sodium or molten salt, operating at high temperatures (250^{o}C and higher).