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# High Temperature Transducers for Online Monitoring of Microstructure Evolution

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## Abstract

A critical technology gap exists relative to online condition monitoring (CM) of advanced nuclear plant components for damage accumulation; there are not capable sensors and infrastructure available for the high temperature environment. The sensory system, monitoring methodology, data acquisition, and damage characterization algorithm that comprise a CM system are proposed. Thus the proposal supports the DOE mission to develop a fundamental understanding of advanced sensors to improve physical measurement accuracy and reduce uncertainty. The project aims to: (1) demonstrate ultrasonic transducer capabilities, including temperature resistance, thermomechanical fatigue resistance, and signal/noise ratio for tubular structures, (2) detect and characterize macroscale defects in tubular structures, (3) demonstrate proof of concept for online CM system to detect cracks in a reactor vessel nozzle, (4) prove that ultrasonic transducers can generate and receive higher harmonics under operating conditions, (5) link higher harmonics to incipient damage, and (6) show feasibility of the online CM system for a compact intermediate heat exchanger. The research plan involves a concept viability assessment, a detailed technology gap analysis, and a comprehensive technology development roadmap.

Condition monitoring with ultrasound will be enabled by development and processing of piezoelectric materials that have the unique capability to function at high temperatures. Bismuth titanate lithium niobate composites have been shown to generate and receive ultrasound signals at temperatures up to 1000°C. The capabilities of this and other high temperature piezoelectrics will be assessed for CM applications in the NGNP. Light water reactor applications at more moderate temperatures will also be explored. Of course there is more to a CM system than just the sensor material; instrumentation, data acquisition, and monitoring methodology all play key roles and will be investigated. Innovative transducer designs will be employed that are based on the generation of ultrasonic guided waves to monitor significant volumes of material, rather than simply at the transducer location. Furthermore, detection of macroscale damage often occurs too late in the life of the component to enable effective operations management. Thus, it is very beneficial to track microstructure evolution and the development of precursors to macroscale damage, which is possible through detection of higher harmonics. A CM system would be incomplete without prognostic modeling to guide decision making. In this project prognostics will focus on microstructure evolution leading to initiation and growth of a macroscale crack.

Three test cases will be investigated to concretely demonstrate the online CM capabilities. A comb transducer for tubular heat exchanger structures will be tested at high temperature. Second, a hybrid annular array – strip transducer will be tested for damage to reactor vessel nozzles. Lastly, the feasibility of a distributed 3D transducer array that relies heavily on interface waves will be tested for a compact intermediate heat exchanger design.