Ultrasonic Sensors for TREAT Fuel Condition Measurement and Monitoring

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Program: NEET 2.3

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ABSTRACT:

We propose to design and fabricate an ultrasonic sensor for measurement of fuel dimensional changes during transient testing of fresh and pre-irradiated nuclear fuel samples at the Transient Reactor Test Facility (TREAT). The TREAT facility was specifically designed to conduct transient reactor tests and to simulate conditions ranging from mild upsets to severe reactor accidents. Instrumentation that is deployed in transient irradiation tests typically focuses on time-resolved monitoring of fuel pins, with a specific need for monitoring thermal conditions and deformation of fuel pins. Of particular interest for TREAT transient test instrumentation is the need for high-fidelity measurements of axial and radial fuel deformation, while avoiding disturbing operating conditions of the fuel.

The proposed research addresses the limitations of current dimensional measurements in transient tests through the design of an ultrasonic sensor that is capable of *rapid, non-contact, in-situ* measurements of dimensional changes of pre-irradiated fuel during irradiation.

Specifically, the proposed sensor design will target:

- Reliable operation at elevated temperatures (between ~300^{o}C and 600^{o}C)
- Design compatibility with proposed near-term TREAT irradiation capsule concept designs
- Direct measurement of dimensional changes, including direct measurement of fuel rodlet diameter
- High-speed measurements to enable rapid characterization of changes during a transient test.

To achieve these design targets, specific technical gaps will be addressed including: (1) selection of appropriate materials for sensor design and fabrication; (2) determination of compensation techniques for factors (e.g. temperature) that may influence in-pile ultrasonic measurements, and; (3) design of the sensor package for easy application to pre-irradiated fuel rods. The proposed research will leverage prior studies in piezoelectric sensor material selection for in-pile instrumentation, and ultrasonic characterization of irradiated fuel specimens.

The expected outcomes of this research are prototypic ultrasonic sensors, in support of the TREAT transient studies of pre-irradiated fuel, for characterizing the deformation of each component of the fuel pin. Data on the fidelity of the measurements from these sensors in high-temperature environments (but without irradiation) will provide baseline sensor performance data (including measurement uncertainties). The resulting prototypes will be capable of integration into planned test capsules at TREAT and a plan for qualifying the sensors for use in future TREAT experiments will be developed.