Contribution ID: **118**

Type: **Poster**

#5-118 Improvement of the high-temperature performance of multi-element ultrasonic transducers

Tuesday, June 10, 2025 4:30 PM (5 minutes)

As one of the world's pioneers in nuclear energy, France has long relied on nuclear power to meet its growing energy needs. In response to the aging of the reactors, fourth-generation sodium-cooled reactor projects have been initiated, requiring advanced instrumentation such as high-temperature ultrasonic transducers developed by the CEA to monitor submerged structures. The High-Temperature Ultrasonic Transducer, developed by the CEA for sodium-cooled fast reactors, is a piezoelectric sensor designed to withstand extreme conditions. In addition to the challenges related to high temperatures and irradiation in sodium-cooled fast reactors, these transducers must support various applications, including event detection, telemetry, and visualization in liquid sodium. The CEA is currently developing several models tailored to these specific applications and more. One of these models is the High-Temperature Multi-Element Ultrasonic Transducer. A doctoral thesis is currently underway in partnership between the FEMTO-ST Institute and the CEA, focused on the development of this transducer. Multi-element transducers are considered the most suitable tools for continuous inspection or periodic inspections of reactors during shutdowns. These transducers offer greater sensitivity compared to single-element piezoelectric transducers. Unlike single-element transducers, multi-element transducers can generate images without the need to scan the target, resulting in time savings and a reduced equipment footprint. Furthermore, they enhance spatial resolution, providing more precise obstacle localization through parallel control of the individual piezoelectric elements. The High-Temperature Multi-Element Ultrasonic Transducer consists of a stack of a matrix of piezoelectric elements and metals.

This transducer must meet various technical and environmental constraints. For instance, the spatial resolution directly affects the size of the piezoelectric elements; to achieve a resolution of 0.5mm, the element size must be smaller than 0.25mm. However, manufacturing elements of this size currently seems difficult, with a target element size of 2.5mm being more feasible. Additionally, for continuous monitoring, the transducer must operate at the nominal temperature of liquid sodium, around 550°C. Since it is located inside the reactor, the transducer must also withstand corrosion from sodium and irradiation caused by nuclear fission reactions. To meet these constraints, lithium niobate was selected as the piezoelectric material. This material has a high melting of approximately 1250°C, enabling it to resist the nominal temperature of liquid sodium. Additionally, lithium niobate exhibits a good coupling coefficient (0.15 to 0.49), depending on the crystal orientation. The Y36° cut of lithium niobate is preferred for its sensitivity to vibrations and high coupling coefficient of 0.49. However, the Z-cut of lithium niobate can be used due to its thermal expansion coefficient, which offers better mechanical stability, despite its lower coupling coefficient of 0.17. Furthermore, ultrasonic transducers made from lithium niobate crystals maintain their integrity and performance even at high temperatures. Regarding metals, 304L and 316L stainless steels were selected for their melting points of approximately 1400°C, which allow them to tolerate the nominal temperature of liquid sodium in the reactor. Due to their low carbon content, 304L and 316L stainless steels provide good corrosion resistance.

The objective of this study is to develop a fabrication method for the piezoelectric element matrix as well as an assembly method between this matrix and the metallic components. Cleanroom fabrication techniques are employed to ensure the best possible performance of the transducer. The first phase of the study involves material characterization, specifically analyzing surface conditions and thermomechanical stresses applied to lithium niobate and stainless steel. The second phase focuses on developing an assembly method using cleanroom manufacturing processes. Finally, the last phase will involve high-temperature tests, acoustic tests, and resistance evaluations. Ultimately, this research aims to contribute significantly to the advancement of monitoring technologies in the nuclear industry, enhancing safety and operational efficiency.

Primary author: Mrs MOISSON, Hauriann (CEA)

Co-authors: Mr GALERON, Gaëtan (CEA); Mr BONZOM, Paul-Vincent (CEA); Dr MARGUERON, Samuel (FEMTO-ST)

Presenter: Mrs MOISSON, Hauriann (CEA)

Session Classification: #05 - Nuclear Power Reactors and Nuclear Fuel Cycle

Track Classification: 05 Nuclear Power Reactors and Nuclear Fuel Cycle