A Novel and Comprehensive Approach to the Thermophysical Characterization of a SiC-Based ATF Cladding

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Post-Fukushima, the development of Accident Tolerant Fuels for safer nuclear energy has led to promising new nuclear materials, such as SiC-fiber-reinforced SiC (SiC_f/SiC). This material demonstrates promising nuclear, mechanical, and chemical attributes. However, its thermal properties require more exploration. This work aims to comprehensively assess the thermal conductivity of SiC_f/SiC using a three-pronged approach: tomographic analysis, FEM heat transfer modeling, and experimental evaluation using a novel, contact-free technique.

Synchrotron tomography was used to reconstruct the microsctructure of SiC_f/SiC, revealing the features that could affect heat transfer through the material. This data was used to develop various FEM models to understand the theoretical behavior of the material for different size scales. Microscopic models indicated a decrease in thermal conductivity by approximately 20% compared to the matrix, with slight anisotropy. Larger models showed much greater anisotropy, with radial thermal conductivity at only about 9.5% of the axial, suggesting a significant insulating effect from the larger pores. Finally, the primary experimental setup helped deduce both radial and axial thermal conductivities by observing temperature profiles under laser-induced internal heat and infrared spectroscopy for temperature analysis. Findings show a stark contrast between lower radial (below 3.5 W/m/K) and higher axial (around 20 W/m/K) thermal conductivities, confirming the theoretical understanding of this material's behavior. A secondary steady-state experiment confirms the results on the axial thermal conductivity.

This work confirms the efficacy of steady-state methods in evaluating thermal properties of potential nuclear fuel materials. However, the results indicate lower thermal conductivity for SiC_f/SiC compared to the reported dynamic measurements, a factor to be considered in future material characterizations.