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ABSTRACT:

Molten Salt Transport through Graphite Pores

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Among the several advanced reactors being developed in the United States, the molten salt reactor (MSR) offers unique characteristics that can be tailored for applications such as generating electric power and process heat, burning actinides, and nuclear fuel breeding. Nuclear graphite is the neutron moderator of choice for several thermal-spectrum MSR designs. One of the chief distinguishing features of nuclear graphite is the presence of pores or cracks with a wide distribution of size, shape, and morphology characteristics. In our previous work [1], we had used X-ray Computed Tomography (XCT) and machine learning (ML) techniques to identify the various pore regions. Extensive three-dimensional analyses of several grades of nuclear graphite (AXF-5Q, IG-110, and NBG-18) quantified the distributions of pore size, coordination number, link distance, and throat diameter.

In this work, we develop a continuum model of the pore network using the statistical distributions derived from our previous machine learning investigation [1]. The various distributions employed in our work include pore size, link distance between the pores, pore coordination number, and pore connection (throat) diameter. First, we use finite elements (FE) to determine heat transport across the pores. Since the thermal conductivity of the molten salt is lower than that of graphite, we observe regions of 'hot spots' where the local temperature is higher than the average value. Such regions can potentially influence the neutronic properties. Next, we perform several hydrodynamic simulations to evaluate the effective permeability of each graphite grade. We show that POCO grade AXF-5Q, with the lowest permeability, is more suitable for molten salt reactors than NBG-18, which has a noticeably higher permeability.

[1] D. Elgewaily and J. Eapen, Characterizing porosity in nuclear graphite using machine learning, ASME – PVP Conference, Montreal (2025).