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CERAMIC FOAMS FOR NUCLEAR FUEL ELEMENTS: AN INVESTIGATION OF NEUTRONIC PROPERTIES

Abstract

Utilization of high-performance propulsion systems, such as nuclear rockets, will allow quicker travel time for human exploration missions in space. Solid-core nuclear rockets could provide a specific impulse more than double that of conventional chemical rockets. Open-cell ceramic foams have potential for use as fuel elements in nuclear reactors for both propulsion and energy applications due to their high melting points and large surface areas. A fuel element could be formed by creating a multi-layered ligament structure throughout the foam. One or more of the ligament layers would consist of a nuclear fuel, such as a tri-carbide that incorporates uranium. Tantalum carbide (m.p. 3880 C) has one of the highest melting points of all known materials, and has potential to be incorporated within the ligament structure of a foam fuel element. This study examines reticulated vitreous carbon (RVC) foams coated with TaC. One set of foams had a coating of pyrolytic carbon between the RVC and TaC, while the other had a TaC coating directly on the RVC. Three foam pore densities were utilized in this study: 45 pores per inch (ppi), 65 ppi, and 100 ppi. The purpose of this study was to evaluate neutron transmission through tantalum carbide foams of different compositions, ligament sizes, and densities. Low neutron absorption by non-fissile foam components is necessary to utilize foam as a nuclear fuel element. Pycnometry was performed on foam rounds in order to measure their volume. Optical microscopy and SEM were utilized to examine the foam microstructure. Imaging software was utilized in conjunction with micrographs to determine the average pore and ligament size of the foams. Monte Carlo N-Particle transport code software was used to model neutron transport through tantalum carbide foams. Neutron transmission experiments were conducted using an Americium-Beryllium neutron source. Foam samples were placed between the neutron source and a piece of indium foil. Neutrons that passed through the foam and were absorbed by the indium foil induced radioactive decay within indium atoms. A Geiger-Müller counter was utilized to count radioactive decays of the indium foil. Neutron transport modeling data will be analyzed with respect to data obtained from neutron transmission experiments and the results will be discussed. Data obtained from foam characterization using microscopy and pycnometry will also be presented. Prior studies in the area of nuclear propulsion technology and materials will be discussed briefly, along with potential areas for future research.