A New Light Weight Structural Material for Nuclear Structures

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ABSTRACT: Light- weight structural materials with excellent mechanical strength are important in nuclear structures, especially when designed to incorporate radiation attenuation of gamma rays and neutrons. Metal foams are new class of materials offering an- order of magnitude higher energy absorption under compression compared to the bulk materials that they are made of at an order of magnitude lower density. Composite metal foam (CMF) has up to 7-8 times higher energy absorption compared to any other metal foam made from similar materials and over 70-80 times higher energy absorption under loading compared to the bulk materials that they have been made of. Although the mechanical properties of metal foams have been studied extensively, their properties in nuclear environments has never been studied and there is no database to show the effectiveness of metal foams in such environment. This study is necessary before we can implement these novel low-density materials into the next generation nuclear structures. In this study, we plan to evaluate the properties of open and closed cell metal foams with and without a filling agent in the open porosities of open cell foam in gamma and neutron environment and establish a database for the first time that correlate those properties to the known properties of bulk material that the foam are made of (e.g. aluminum or steel).

We will then utilize the advantages of metal foams into design, manufacture and test a new multi-layered structure in order to maximize the shielding effectiveness and mechanical strength while maintaining a characteristically low weight, all necessary components for an effective shielding of nuclear reactor's structural material or storage cask materials. A study of the properties of metal foams (in general) and composite metal foams (in particular) in various nuclear environments will be conducted, focusing on processing of various samples with variety of different cell sizes and morphologies and thicknesses of different layers of open and closed cell foams separated from each other with solid layers of metal. These samples will be tested under various mechanical loading and thermal conditions to simulate the nuclear, mechanical loading or thermal environment that the material is going to be exposed to. Radiation shielding effectiveness will be evaluated using standard gamma ray sources and radiation detection experiments, and neutron attenuation will be conducted in an on campus reactor, as well as experiments with neutron emitters. The research benefits from combined experimentation, and high-performance modeling and simulation efforts towards the optimization of such structural material.