Effects of Microstructural Composition on the Elastic Moduli of Nuclear Graphites

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Abstract

Nuclear graphite is an important structural material for future designs of advanced high-temperature, gas-cooled nuclear reactors as well as various molten salt reactor designs. Nuclear graphite has favorable material properties that recommend its use in these environments including high thermal conductivity, high strength and low anisotropy. These properties depend not only on the graphitic content itself but are largely dictated by the microstructural constitution of the material. The types of raw materials combined with the manufacturing processes used to produce the graphite yield the microstructural content which primarily includes graphite filler, graphitized pitch binder, and voids/defects that typically occupy approximately 20% of the volume. Among these microstructural components, porosity and microcracking (considered to be part of voids/defects) heavily influence the overall properties of the material including the elastic moduli. Most measurements of elastic modulus in nuclear graphites yield results that tend towards the Reuss limits – the theoretical, lower bounds for the moduli – but no attempts have been made to explain these results within the broad context of elasticity in porous materials containing microcracks. In this work, we examine elastic modulus measurements of nuclear graphites under various conditions and place them in this context to provide a rational, physical interpretation of the measurements. In particular, we show how the majority of results can be understood using relatively simple models that describe the effects of porosity on modulus and how these models must be modified to account for microstructure-related effects that are unique to polycrystalline, bulk graphites.