Advanced Characterisation of Pore Structure in Next-Generation Reactor Graphites

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Abstract

Nuclear energy accounted for 17% of total electricity supply in advanced economies in 2023, avoiding the release of 72 gigatons of CO_2 since 1971 by replacing fossil fuel generation [1]. Maximising the operational lifespan of current and proposed nuclear reactors therefore reduces present and future CO_2 emissions.

Nuclear grade graphite is a critical component of the UK fleet of Advanced Gas Reactors (AGRs) and those Generation IV reactors, which are graphite-moderated. Reliable characterisation of its microporous network is therefore indispensable for safe and optimal performance. This microstructure, in particular porosity, dictates material properties and the evolution of those properties under operational conditions (i.e. oxidation rates, gas diffusion, and thermal degradation). This project develops and initially validates a methodology for characterising the surface porosity of IG-110 and IG-430 nuclear graphites via computational analysis of composite Scanning Electron Microscopy (SEM) micrographs, covering an FOV (Field of View) comparable with previous Optical Microscopy (OM) -based works (mm^2 scale). A semi-automated workflow involving composite assembly, intensity thresholding, and pore diameter thresholding within ImageJ/Fiji was developed to quantify surface porosity and generate void size distributions. Preliminary findings indicate that this SEM-based approach yields statistically robust surface porosity data, capturing features down to the micron scale. This represents a significant advancement upon previous OM analyses of surface porosity, operating at a comparable field of view (FOV) but now with sufficient resolution to enable reliable classification of pores as small as 1.12 µm in diameter. The new approach allowed for the construction of surface porosity void size distribution that encompasses nearly the entire range of physically relevant pore sizes. The construction of surface porosity pore size distributions over a measured size interval down to a diameter which aligns with the steepest section of the Hg intrusion porosimetry datasets enables validation of SEM-derived surface porosity against experimental data. New insights are gained into the representativeness and credibility of both this and previous OM-based works. Initial integration of this more representative surface porosity data into a new version of the PoreXpert void network and pore fluid simulation framework, integrated with Hg porosimetry and N_2 adsorption, produced physically plausible preliminary models of the pore network and simulated pore-fluid flow properties such as tortuosity, diffusivity and permeability. This enhanced characterisation method forms a further useful methodology in refining models of graphite behaviour, ultimately contributing to the safe and optimal operation of current and proposed graphite-moderated nuclear reactors.

Keywords: keyword, keyword, keyword

1. Introduction

This is a citation.[2]

Now testing if integration between branching on VSCode and GitHub is effective.

References

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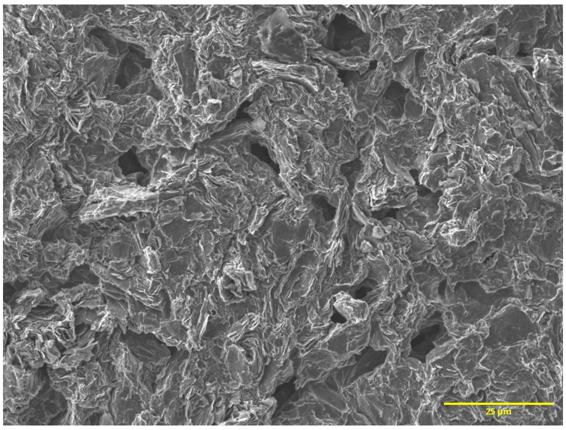

Figure 1: Your caption here

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