Postprint: Advances in Fracture Mechanics of Nuclear Engineering Graphite

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Abstract

As the main candidate reactor types for Generation IV nuclear reactors, high-temperature gas-cooled reactors and molten salt reactors both utilize nuclear graphite as neutron moderator and core structural material. During nuclear reactor operation, nuclear graphite, serving as the primary core structural material, will endure conventional mechanical loads, thermal stresses under various operating conditions, irradiation deformation, and seismic effects, subjecting graphite components to complex stress states. Microscopic damage continuously accumulates within the material, and local stress concentration at keys, slots, and discontinuities can even lead to the initiation of macroscopic cracks, thereby compromising the dimensional integrity of the entire core structure and jeopardizing reactor safety. Consequently, investigating the damage and fracture mechanics characteristics of nuclear graphite materials is essential for improving the reliability of core structural integrity assessments. This study first reviews the research progress in nuclear graphite fracture mechanics from the perspectives of material failure criteria, fracture criteria, R-curves, nonlinear fracture mechanics models, and multiscale analysis methods; subsequently, it summarizes the standard test methods adopted for determining nuclear graphite fracture parameters and reviews the current research status in conjunction with commonly employed experimental techniques; finally, it outlines future development trends in nuclear graphite fracture mechanics research from three aspects: service environment effects, fracture process zone characterization, and size effects. This study can provide references for the development and refinement of nuclear graphite fracture mechanics models, offer a basis for selecting test methods to obtain nuclear graphite fracture parameters, and furnish insights for nuclear graphite fracture mechanics research.

Full Text

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