Failure Predictions for VHTR Core Components Using a Probabilistic Continuum Damage Mechanics Model

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ABSTRACT

The proposed work addresses the key research need for the development of constitutive models and overall failure models for graphite and high temperature structural materials, with the long-term goal being to maximize the design life of the Next Generation Nuclear Plant (NGNP). To this end, the capability of a Continuum Damage Mechanics (CDM) model, which has been used successfully for modeling fracture of virgin graphite, will be extended as a predictive and design tool for the core components of the very high-temperature reactor (VHTR). Specifically, irradiation and environmental effects pertinent to the VHTR will be incorporated into the model to allow fracture of graphite and ceramic components under in-reactor conditions to be modeled explicitly using the finite element method. The model uses a combined stress-based and fracture mechanics-based failure criterion, so it can simulate both the initiation and propagation of cracks. Modern imaging techniques, such as x-ray computed tomography and digital image correlation, will be used during material testing to help define the baseline material damage parameters. Monte Carlo analysis will be performed to address inherent variations in material properties, the aim being to reduce the arbitrariness and uncertainties associated with the current statistical approach. The results can potentially contribute to the current development of American Society of Mechanical Engineers (ASME) codes for the design and construction of VHTR core components.