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A Coupled Peridynamics Model for the Ablation and Plastic Fracture Simulation of Reactor Pressure Vessels

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ABSTRACT

The reactor pressure vessels (RPV), a typical kind of axisymmetric structures, usually serve under high temperature and pressure conditions. The numerical analysis of the mechanical behaviors of these structures plays a dominant role for their structural design, advanced manufacture and safety assessment in practical engineering applications[1-2]. However, the extremely conditions bring great challenges for the numerical analysis of structures undergo ablation, plastic, damage and even fracture during an accident[3]. Based on the superior performance of peridynamics model in predicting fracture behaviors [4-7], a coupled axisymmetric non-ordinary state-based peridynamics (CA-NOSB-PD) model is proposed in this work to predict the ablation, plastic and fracture behaviors of metals. In this model, the governing equations of axisymmetric thermo-mechanical problems are derived based on the separation of the deformations along the in- and out-plane directions. A temperature-associated criterion is developed to determine the ablation evolution. Three kinds of moving boundary models are proposed to handle the varying geometries during the ablation process, including laser, contact and penetration ablation. The Lemaitre's damage model is incorporated into the CA-NOSB-PD model to effectively describe the damage behaviors. A damage-associated criterion is further proposed to determine the crack propagation. Finally, numerical simulations demonstrate that the proposed CA-NOSB-PD model can effectively and accurately capture the plastic response and predict the crack propagation of RPVs under extreme thermal loadings.

KEYWORDS

Peridynamics; reactor pressure vessel; thermoplastic; ablation; fracture

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