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PROCEEDINGS

Development of the FractureX Platform Based on FEALPy and Its Application in Brittle Fracture Simulation

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ABSTRACT

Brittle fracture is a critical failure mode in structural materials, and accurately simulating its evolution is essential for engineering design, material performance evaluation, and failure prediction. Traditional numerical methods, however, face significant challenges when dealing with higher-order fracture models and complex fracture behaviors. To overcome these challenges, this study proposes an innovative simulation framework based on higher-order finite element methods and adaptive mesh refinement, effectively balancing computational efficiency and simulation accuracy.

The research first develops a higher-order finite element method for the continuum damage fracture phase-field model. By incorporating higher-order finite element techniques, the proposed method significantly improves the precision of fracture process modeling, particularly in simulating complex fracture evolution. The integration of the PyTorch automatic differentiation framework further enhances the stability and efficiency of the numerical solution while maintaining high-order computational accuracy. Secondly, to address the high computational demands and the challenge of handling complex geometries, an adaptive finite element method is introduced, combining recovery-based error estimation and adaptive marking strategies. This method successfully implements efficient mesh refinement for triangular and tetrahedral meshes, significantly improving computational efficiency and solution accuracy.

Furthermore, the study investigates the numerical solution of the fourth-order phase-field fracture model and applies the interior penalty finite element method for its discretization, demonstrating the advantages of higher-order finite elements in simulating complex fracture problems. Finally, the research designs and implements the FractureX simulation platform based on the FEALPy framework, providing an efficient and flexible computational tool for simulating brittle fracture and supporting engineering applications.

The findings of this study offer new numerical methods for complex fracture problems and promote the application of domestic computational tools in fracture mechanics. The FractureX platform enables precise fracture behavior simulation in various material and structural models, demonstrating significant engineering application value and promising future research potential.

KEYWORDS

Brittle Fracture; higher-order finite element; adaptive mesh refinement; recovery-based error estimation; FractureX simulation platform

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