Three-Dimensional Crackable Lagrangian Element Method for Simulating Tensile Fracture Processes in Rock-Like Materials (Postprint)

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Abstract

The present study proposes a three-dimensional crackable Lagrangian element method suitable for simulating the deformation-cracking process of rock-like materials, which is essentially a coupling method of the three-dimensional Lagrangian element method and the fictitious crack model in fracture mechanics, mainly applicable to cubic elements. Based on the three-dimensional Lagrangian element method, the specific process of introducing the fictitious crack model mainly includes three key steps: First, the nodal stress is obtained from the stresses of elements surrounding the node, and then nodal separation is judged using the node's maximum principal stress and the rock's uniaxial tensile strength; then, the element boundary closest to the plane perpendicular to the node's maximum principal stress is selected as the crack propagation direction; finally, the fictitious crack model is introduced to simulate the crack initiation and propagation process. Using this method, the deformation-cracking processes of uniaxial tension rock specimens and three-point bending rock beams were simulated, and the effects of Mode I fracture energy, specimen height, and element size were preliminarily analyzed. Meanwhile, the correctness of the proposed method was verified by comparing the results of this study with theoretical solutions for peak stress and critical displacement of uniaxial tension rock specimens and numerical solutions from previous studies for load-displacement curves of three-point bending rock beams under displacement-controlled loading conditions, which lays a good foundation for future work.

Full Text

Preamble

This work presents a systematic investigation of the theoretical foundations underlying the research domain. We develop a comprehensive analytical frame-

work that establishes fundamental relationships between key variables in the system.

The central contribution of this paper is expressed through the following mathematical relationship:

MATH_{0001}

Our analysis provides novel insights into the problem structure and demonstrates the practical applicability of the proposed approach through theoretical validation. The results contribute to advancing the state of the art in the field and provide a foundation for future research directions.

Note: Figure translations are in progress. See original paper for figures.