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Fracture of Soft Materials with Interfaces: Phase Field Modeling Based on Hybrid ES-FEM/FEM

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ABSTRACT

The engineering application prospects of soft materials in key areas such as aerospace and life science have stimulated extensive research interests in the academic community. An important topic here is to predict the service and failure behavior of such materials. Although considerable progress has been made, real-world application scenarios usually involve bi-material as well as multi-material adhesion, with cohesive interface rupture as the main failure vehicle. Inconsistent asymptotic solutions in the context of large deformations pose obstacles to the establishment of a theoretical framework for the interface fracture problem in soft materials [1]. Driven by both engineering and academia, numerical investigations into this issue have gradually gained popularity. Over the past three decades, modeling techniques developed around material damage and fracture have proliferated, in which the phase field variational approach based on Griffith's theory stands out [2]. The sought-after phase-field method(PFM) that relies on the edge-based finite element method (ES-FEM) / finite element method (FEM) hybrid strategy was found to be well applied to large strain fractures of soft materials, which mitigates the mesh distortion of large deformations while considering computational efficiency. This hybrid scheme incorporates the advantages of ES-FEM and FEM and excels in large-strain fracture of soft materials. By analogy to the interface fracture in the linear elastic regime, based on the calculation results of the hybrid strategy, some studies systematically report the fracture behavior of soft materials with interfaces from three aspects: interface strength, tilt angle and interface position. Three different crack morphologies: (i) direct penetration; (ii) penetration with deflection; (iii) deflection without penetration, were identified, bearing a close resemblance to the experimental photographs. On this basis, a brand-new phase diagram of crack behavior was drawn in the parameter space of interface strength versus tilt angle. Besides, from the perspective of stress analysis, a potential explanation for the competing mechanism of penetration vs deflection concerning the crack impinging on an interface was furnished.

KEYWORDS

Phase filed; edge-based finite element method; soft matter; interface

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