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Numerical modeling of fracture propagation in bi-layered materials using an adaptively refined phase-field method

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Fracture propagation in layered subsurface media is actively studied by engineers, and geoscientists. In various geo-engineered systems, such as, unconventional hydrocarbon reservoirs, enhanced geothermal systems, tunnels, and mines, fracture patterns in the subsurface play a critical role. Predictive numerical simulations are an important tool to facilitate well-designed subsurface systems. However, despite significant advances in recent years, numerically predicting fracture propagation in the subsurface remains an outstanding challenge for the computational mechanics community. This is partly because the subsurface is highly heterogeneous and contains several layers with distinct mechanical properties, which dramatically affects the geometry of subsurface fractures. Depending on prevailing conditions of contrasts in elastic moduli, fracture toughness, interface inclination, and in-situ stress of surrounding layers, cracks may either arrest, penetrate, or branch at the material interface [1].

In this study, we will extend a recently developed adaptive phase-field fracture model to bi-layered materials [2]. In this approach, mesh refinement is required only in a small, diffused zone ahead of the crack tip while the rest of the domain is discretized using standard elements. The continuity between refined and standard elements is ensured by means of the Nitsche's method. The key advantages of the proposed methodology include an energetic approach to the crack propagation criteria, a natural crack-tracking framework through a phase-field variable and reduced computational burden due to mesh adaptivity. Several parametric studies will be performed to study the effect of elastic stiffness contrast, toughness contrast, and interface inclination on fracture propagation in bi-layered materials with perfectly bonded layer interfaces.

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