Dynamic fracture simulation of inhomogeneous rock

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Abstract

Realistic fracture simulations in rock as a heterogeneous brittle material with significant inherent randomness, require the use of models that incorporate its inhomogeneities and statistical variability. In ductile materials inelastic deformations re-balance microscale stress field and retard fracture propagation, but for rocks microscale distribution and strength of defects have a very important role in their fracture response. As a result, the same geometry and loading condition can give quite different fracture patterns.

We use a Weibull model to sample random strength values at the vertices of a discrete finite element mesh. The Weibull model is calibrated by the area of elements surrounding the vertex. Once, the applies effective stress at the vertex exceeds the sampled strength value a new crack is nucleated. Fracture strength along the faces of the extending cracks also follows the same random field realization. Through numerical results we demonstrate several important effects of using random fracture strength values. First, since the sampled values create an inhomogeneous field for fracture strength, nonphysical clustered crack nucleation in regions of high stress, independent of the mesh size, is avoided. Second, microcracking, crack path oscillation, and crack bifurcation naturally occur without the use of any heuristic criteria. We also present numerical results that demonstrate the effect of loading rate and duration, and fracture strength anisotropy on fracture pattern. Finally, as for qualitative comparison, we use an explicit approach where microcracks are explicitly incorporated in the computational domain. We use a spacetime discontinuous Galerkin finite element method for our dynamic fracture simulations. An interfacial damage model that incorporates all contact and separation modes is used on fracture surfaces. A regularization scheme is used to smoothen the load transfer from hydraulically loaded crack surfaces to in-situ microcracks when they are explicitly modeled in the domain.