Effects of Material Spatial Randomness on Dynamic Fracturing in Rocks

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Abstract

There is an increasing demand to employ probabilistic models in the simulation of rocks; as many other heterogeneous brittle materials, the fracture of rocks is highly sensitive to the random distribution of defects and inhomogeneities. Rocks have significant inherent material randomness at different scales. Microcracks and granular microstructures describe rocks at small grain scale while different rock types, faults and randomly-oriented natural fractures characterize them at large mass scale.

In this study, we utilize two approaches to address rock inhomogeneities in dynamic fracture simulations. One is based on considering fractures explicitly with random size, location and orientation as the natural pre-existing crack-like defects. In the other one, a probabilistic nucleation technique is applied to implicitly model initial randomness in material and to enable creation and extension of new cracks during the course of analysis. Both approaches can be employed for rocks in which the natural fractures are oriented in a specific angle, which is applicable to the simulation of sedimentary rocks. For the first approach, there will be a bias in initial crack orientations, while for the second one nucleation and extension strengths will be functions of spatial position as well as the angle of a potential crack extension.

Herein, an interfacial damage model implemented in a Spacetime Discontinuous Galerkin (SDG) finite element method is utilized to simulate fracturing in rocks. This robust tool utilizes a powerful mesh adaptivity to track cracks with element boundaries. Besides, the employed model tackles the transitions between different contact modes using a dynamically consistent damage-contact model fitting for rocks under compressive and shear loadings. We will present examples from hydraulic fracturing and rock fracturing under dynamic compressive loading.