Modeling of rock inhomogeneity and anisotropy by explicit and implicit representation of microcracks

Reza Abedi, Philip L. Clarke
Mechanical, Aerospace & Biomedical Engineering, University of Tennessee Knoxville (UTK) / Space Institute (UTSI), 411 B. H. Goethert Parkway, Tullahoma, TN 37388

Abstract

Fracture in rock as a heterogeneous brittle material, having significant inherent randomness, requires including probabilistic considerations at different scales. Crack growth in rocks is generally associated with complex features such as crack path oscillations, microcrack and crack branching events. Two methods will be presented to address rock inhomogeneity and anisotropy. First, microcracks are explicitly realized in a domain based on specific statistics of crack length and location. Second, a statistical model is used to implicitly represent an inhomogeneous field for fracture strength. Both approaches can be used for rocks in which the natural fractures are oriented in a specific angle, *i.e.* an aspect for modeling bedding planes in sedimentary rocks.

In [1], we presented a similar approach for modeling inhomogeneities in rock. The main differences between [1] and the present work are as follows: a) In [1] a phenomenological model based on Weibull distribution was used to represent inhomogeneities in frack strength. Herein, starting with an explicit representation of microcracks, we homogenize their effect on a macroscopic fracture strength field. Thus, the representation of the random field is more realistic; b) In [1] only tensile mode fracture was considered. The anisotropy of fracture strength has a more interesting impact in compressive mode fracture where microcrack surfaces can slide against each other when the tangential stress is greater than friction coefficient times normal compressive stress. We will consider examples in which rock experiences local mode II fracture and transition between stick and slip modes. Such transitions are quite challenging to model in dynamic setting. We use a seamless interfacial contact/fracture model to represent such transitions; c) The model presented in [1] provides reasonable results only under tensile mode. We will present an effective stress (a scalar stress value to derive the damage evolution) that is consistent with Mohr-Coulomb model. The use of Mohr-Coulomb model and the interaction between friction angle and rock bedding planes result in interesting physics. Under a uniaxial stress loading and an isotropic strength for rock, Mohr-Coulomb model predicts cracks at angles $+/-(45 - \phi/2)$, where ϕ is the friction angle. However, introducing anisotropy not only modifies these angles but also favors one over the other. We will present numerical results that demonstrate the effect of anisotropy on compressive rock fracture with explicit and implicit approaches.

References:

[1] R. Abedi, O. Omidi, and P.L. Clarke, “Numerical simulation of rock dynamic fracturing and failure including microscale material randomness” In: Proceeding 50th U.S. Rock Mechanics/Geomechanics Symposium, ARMA 16-0531, 2016.