Assessment of a phase-field model with orthotropy-based energy decomposition to predict mixed-mode fracture in rocks

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In geomechanical applications, determining the fracture growth trajectories in rock formations under complex stress regimes can be challenging, particularly when the rock is anisotropic. Mixed-mode loading and rock anisotropy interact with each other to determine the fracture growth trajectory [1]. This interaction can either strengthen or weaken the individual effects as shown in many studies (e.g. see [1, 2]). To address this complexity, this study employs the phase-field model proposed by [3], in which the strain energy density is decomposed based on the generalized Miehe decomposition for orthotropic materials. The model is used to predict the fracture trajectories in transversely isotropic rocks under fixed mixed-mode loading ratio.

To maintain a constant mode mixity, an asymmetrical semi-circular bend test is used. This test setup was proposed by [4] and has been used in [5] for pure mode I tests. The sample geometry remains constant for different sets of tests, each with a fixed mode mixity, while the orientation of the isotropy plane (i.e. the foliation plane in the Grimsel Granite) with respect to the main notch varies. Here we consider the results from 99 fracture toughness tests on metamorphic Grimsel Granite under four different ratios of mixed-mode $\mathrm{I/II}$ loading.

The performance of the phase-field model is assessed by comparing the results from the simulations with those obtained from the experiments. The comparison focuses on the fracture load, fracture initiation angle, and fracture path. To assess the robustness of the method, we compare the sensitivity of the kink angle predictions to the mesh size and the length of fracture process zone between the phase-field simulations and those performed in [6] with the extended finite element method.

References

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