Modeling fracture reactivation in a mixed dimensional setting: Friction models and numerical challenges

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Fracture reactivation due to anthropogenic injection of fluids in underground reservoirs is a concern in applications such as CO$_2$ storage, enhanced oil recovery and geothermal energy. Reactivation of fractures is a strongly coupled problem involving disparate physical processes such as fluid flow, temperature convection and conduction, deformation of rock surrounding the fractures and the plastic deformation of fractures. One of the large challenges in modeling fractures is the multiple scales involved, from sub-resolution micro-fractures to fractures and faults spanning the whole reservoir. We present a coupled mixed dimensional model where small scale fractures are assumed to be upscaled into effective matrix parameters, such as permeability, while the larger scale fractures are resolved explicitly. The main focus in the work is on the deformation of large scale fractures, which are described as lower-dimensional domains with an associated aperture, embedded in a higher dimensional matrix domain. When the shear forces on a fracture overcome the cohesion and friction force the fracture will slip according a Mohr-Coulomb slip criterion. We will discuss numerical solutions of friction models for the reactivation of pre-existing fracture networks and the treatment of the non-linearities introduced by the slip. We use an empirically validated model of friction and show how the choice of friction model greatly influence the behaviour of the fracture reactivation, e.g., by favouring aseismic vs seismic slip. Numerical examples include a 3D fracture network inspired by realistic data.