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Coupled flow and mechanics in a fractured porous medium

Kundan Kumar[1] and Maarten de Hoop[2]

[1] Department of Mathematics, University of Bergen, Norway, 5007,
kundan.kumar@uib.no

[2] Computational and Applied Mathematics, Rice University, 2035 Duncan Hall Houston,
USA, mvd2@rice.edu

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Numerous applications of subsurface engineering involves injection and extraction of fluids. Examples include geothermal energy extraction, nuclear waste storage, carbon sequestration, petroleum engineering applications, and energy storage. These anthropogenic activities involve a complex set of processes involving flow, thermal, chemical reactions, and mechanical effects all possibly coupled to each other. These complex set of processes interact with the complex geology that involves ubiquitous fractures and faults. The network of fractures form the primary conduit of flow and transport and furthermore, act as the most vulnerable regions for mechanical instability. The interaction of processes and the complex geometry of fractures brings computational and mathematical challenges in the simulation of these processes. The fractured medium is generally anisotropic, heterogeneous, and have substantially discontinuous material properties spanning several orders of magnitude.

Our objective is to study coupling of flow and geomechanics in a fractured porous medium setting. We present a mixed dimensional model for a fractured poro-elasic medium. The fracture is a lower dimensional surface embedded in a bulk poro-elastic matrix. The flow equation on the fracture is a Darcy type model that follows the cubic law for permeability. The bulk poro-elasticity is governed by fully dynamic Biot equations. The resulting model is a mixed dimensional type where the fracture flow on a surface is coupled to a bulk flow and geomechanics model.

We consider well-established contact mechanics models that introduce a resistance when the fracture surface start penetrating (or when the width becomes zero). We prove the well-posedness of the model in appropriate Sobolev spaces. This extends the current models which do not have any mechanism for ensuring that the width remains positive. Moreover, we consider friction between the two fracture surfaces that includes the effect of normal and shear stresses including the effect of fluid pressure.