Nonsmooth Problems with Applications in Mechanics
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Flow degeneracy in a fractured porous medium

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Abstract: Numerous applications of subsurface engineering involve 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 sets of processes interact with the complex geology that involves ubiquitous fractures and faults. The network of fractures forms the primary conduit of flow and transport. The fractured medium is generally anisotropic, heterogeneous, and has substantially discontinuous material properties spanning several orders of magnitude.

We consider degenerate models arising out of an evolving porous media including fractures. When the porosity becomes smaller and reaches zero, the permeability also degenerates including in the fractures. We consider the situation when the porosity as well as the permeability in the porous matrix and in the fracture may vanish on sets of positive measure. We consider a mixed dimensional version of the Darcy flow model that couples the fluid flow on a fractured surface to the flow in the matrix. As porosity vanishes, the pressure becomes uncontrolled due to the absence of fluid phase. By introducing porosity-weighted scaled variables for pressure and velocity, we derive scaled fields that are mathematically well-defined and establish their correspondence with the physical fields. We introduce weighted Hilbert space for both matrix and fractured variables and show the well-posedness of mixed dimensional problem in this weighted setting. For discretization, we consider the lowest order Raviart - Thomas mixed finite element spaces for the Darcy velocity and piece-wise constant pressure on simplexes. Numerical results demonstrate optimal convergence rates.

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