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Coupled Fluid–Solid Interaction and Fracture Propagation in a Poroelastic Medium

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ABSTRACT

Coupled fluid–solid interaction processes do not only play an important role in oil and shale gas industry, but also in the design and effectivity of geothermal power plants and the risk assessment of waste disposals. The numerical simulation of these processes remains challenging due to the complex coupling of the single processes and the hetereogeneous nature of fractured rock.

We consider a low-porous medium which contains a single large scale fracture. We assume that the fracture itself is filled with a porous medium and that the fracture length scale is much larger than the fracture width scale. The mechanical and hydrological equilibrium state of the system is assumed to be mainly influenced by the following three coupled processes:

1. Fluid–Fluid Coupling: The fluid inside the fracture diffuses into the surrounding medium and therefore affects the flow in the bulk medium and vice versa.
2. Fluid–Solid Coupling: Under the assumption that the material properties inside the fracture differs from the material properties outside the fracture, the fluid pressure exerts a normal force onto the fracture boundaries, which induces a deformation.
3. Solid–Fluid Coupling: Due to this deformation, the fracture domain is changed, which in turn affects the flow in the fracture and the surrounding medium.

One important reason for the fracture propagation in porous media is the formation and propagation of micro-fractures in a process zone nearby the crack tip due to a high driving stress. Since the propagation of microfractures leads to an increase of the permeability of the medium, this process again influcences the fluid flow in the fracture as well as the fluid flow and the deformation of the matrix.

We introduce a coupled system of PDEs together with an appropriate fracture criterion modelling the described processes. The fluid flow in the fracture is modeled by a lower-dimensional equation, which interacts with the surrounding rock matrix and the fluid it contains. The resulting weak problem is nonlinear, elliptic and symmetric.

To determine the mechanical and hydrological equilibrium state of the system numerically, we combine an XFEM discretization for the matrix deformation and pore pressure with a lower-dimensional grid for the fracture. The resulting problem is solved using a substructuring method. An efficient fracture propagation algorithm will be presented within this talk.