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ANALYSIS OF INSTABILITIES OF A QUASI-STATIC HYDRAULIC-MECHANICALLY COUPLED FRACTURING MODEL

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The numerical simulation of hydraulic fracturing becomes challenging when all relevant processes, like solid deformation, fluid flow through pores and within the fracture, as well as fluid leak-off into the matrix, are incorporated. It is likewise challenging to choose adequate assumptions under which these processes should be modelled.

If the model is assumed to behave quasi-statically, an inconsistency between the static behavior of the solid and the dynamic behavior of the fluid is introduced. This has been observed to lead to unstable solutions if the fully saturated rock matrix (solid deformation and fluid flow through pores) and the fluid flow within the fracture are modelled separately, but still coupled at the interface.

The static behavior of the solid leads instantaneously to a solution that reaches a steady state, while the fluid within the fracture needs time to achieve equilibrium with its surrounding. This phenomenon leads to an oscillating solution from time step to time step and the solution of the model as a whole becomes unstable.

We analyze the origin of these instabilities with a two-dimensional poroelastic model with an embedded fracture and present a stability criterion that tackles this problem. The solid component behaves linearly elastic and the propagation of the fracture follows the energy release rate criteria. The fluid flow within the pores is described by Darcy’s law. A one-dimensional model is used to simulate the fluid flow within the fracture following the cubic law. The models are fully coupled along the interface via Lagrange Multipliers and are solved iteratively in a staggered manner.

Both models are discretized with the Extended Finite Element Method, which proves to be effective for the simulation of discontinuities with a finite element mesh, without having to adapt the mesh to the discontinuity’s geometry.