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Hydro-mechanical coupled fluid flow in heterogeneous fractures

Project Framework: Understanding hydro-mechanical coupled flow in heterogeneous fractures is crucial for many geo-engineering applications such as geothermal and oil reservoirs, groundwater recharge and nuclear waste storage. Numerous hydro-mechanically coupled experiments on fractures have been performed in the past to relate mechanical deformations such as aperture changes or shear dislocations to changes in fracture conduction or hydraulic aperture. These experiments were typically conducted on natural or artificial fractures that exhibit a heterogeneous fracture surface, and the heterogeneous fracture characteristics were often not taken into account for the analysis. Surface heterogeneities may have, however, a substantial influence on the actual fluid flow path that occurs in the pressurized fracture. Further, the flow path may change as the load on the fracture or the size of the fracture will be increased and may be dependent on the utilized flow rate.

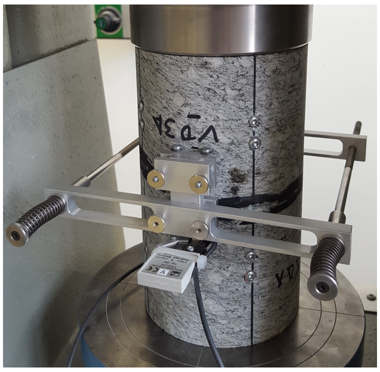

Figure 1: Experiment specimen with fracture normal to cylinder axis (black line half way up the fracture) with sensor system to measure mechanical deformation and top cap to inject fluid pressure into the fracture.

MSc Thesis Project Goals: This study will approach four problems in hydro-mechanical coupled fracture flow: the influence of fracture geometry, the scale dependency of fracture flow, the pressure regime and the flow rate. For the study artificial fractures will be created in a granodiorite stemming from the Grimsel Test Site. The fractures will then be scanned using a high resolution photogrammetric scanner and the initial aperture field will be determined. Further, normal load cycles will be applied incrementally to the fractures (i.e. increments of 1 MPa in a normal stress range between 0.2 and 10 MPa). During each incremental load increase/decrease the fracture conductivity will be tested utilizing a high pressure pump and different flow rates. During the tests the mechanical aperture change will be monitored using high resolution strain gauges. Experiments will be back-calculated with high fidelity numerical simulations that allow an explicit representation of the fracture heterogeneities. The numerical analysis will be intensively supervised by the project supervisors.

Master Thesis Tasks:

- Generate heterogeneous rock fractures.
- Utilize 3D printing and other techniques to replicate the generated fractures on different scales (e.g., different dimensions).

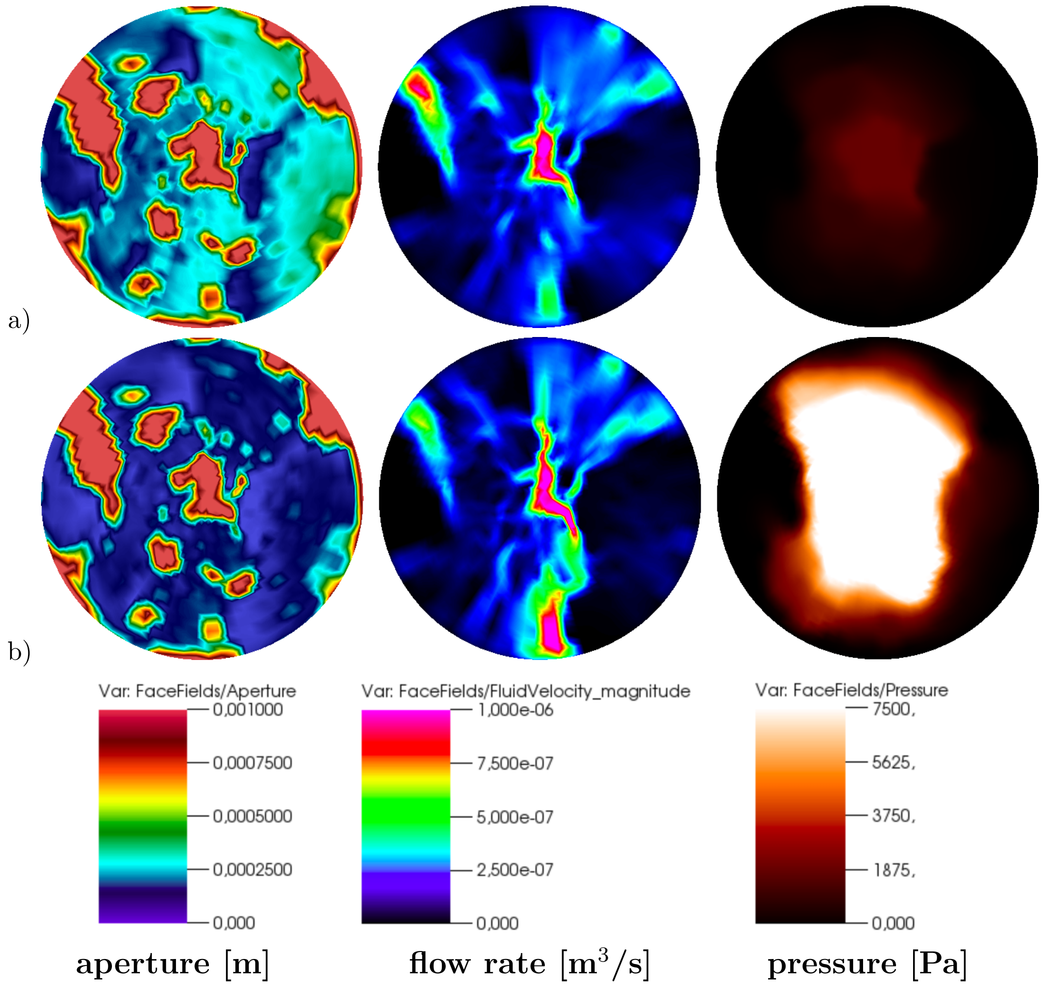

Figure 2: Shown is the compression of a fracture as seen from above with: a) 0.25; and b) 10 MPa axial load. The compression of the fracture effects the aperture field (left column: open space in fracture available for fluid flow and not in contact), flow field (middle column: flow rate transported through the fracture after injection into the fracture center) and fluid pressure (right column: high pressures in the fracture center, where fluid is injected – fluid pressure declines from the fracture center to the outside of the fracture).

- Examine the scale mechanical and hydraulic scale effects of the fractures in the laboratory.
- Numerical simulations will be performed if time permits.
- Additionally, work on contact stress evolution with state of the art laboratory experiment equipment (or simulations) is another option.

Required Student Skills: We are looking for a student with a background in engineering or natural sciences. A background in geology or rock mechanics is not necessary. The successful candidate should have basic computer skills and an interest to work with provided software. The candidate should have a willingness to work in a laboratory environment with a multi-disciplinary team of academic and industry partners.

Supervision:

- Daniel Vogler (contact: davogler@ethz.ch)
- Dr. Florian Amann
- Dr. Claudio Madonna