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Digital Material Laboratory: Determination of fractures and fracture networks from X-ray Computed Tomography

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The study of fractures, fracture networks and especially fracture propagation is of great interest in rock phyiscs and geomechanics. Geothermal and enhanced oil recovery projects rely on the porosity, permeability and storativity properties of the underground rocks. When a rock has a large number of fractures, and these interconnect each other, the amount of fluid that can be transported through is greater as an intact rock or a rock with non-connected fractures. Natural occurring fractures of rocks from geological processes, which require millennia to occur, usually lead to almost impermeable rocks, and it is only possible to have fluid flow through major faults. Modern methods to artificially fracture the rocks rely on pumping large amounts of water into the underground ("hydro-fracking"), which increases the internal pore pressure in the rocks (reducing the effective stresses) and this induces the creation of new fractures. This high fluid pressure also allows the natural pre-existing fractures to propagate.

Although mathematical and numerical models exist for the hydro-mechanical characterization of single fractures and simple fracture networks, the complexity of the underground rock structure and local stress state make it difficult for practical technical applications in engineered geosystems. This limits have been overcome by using large numerical simulations which can more accurately model the fracture process of rocks, together with the fluid flow process in the microstructure. An import step of the process requires the validation of the simulations, e.g. the ability of the simulation to capture more complex process like the creation of secondary tension cracks (wing cracks) from shear fractures. It is also important to compare the resulting fracture network from experiment with the predicted one from the simulations.

In the present work, we show the use of a X-Ray micro Computed Tomography (XRCT) system to determine the geometry of the fractures in porous rocks. One of the limiting factors found in the literature was the low resolution of the tomograms, and the Poisson noise inherent in CMOS detectors. Advances in computational power makes it possible to apply advanced noise reduction techniques to the tomographic sets, and furthermore, apply edge detection algorithms to determine the fractures. The experiments of rock fracturing include in-situ and ex-situ tensile tests to create wing cracks. A rock core with an initial fracture was subjected to a shear stress state, where the wing cracks were created and later on imaged. A second experiment recovers the fracture geometry borehole after the inner pressure exceeded the breakout limit. The last experiment shows the feasibility to image fracture networks at the near resolution limit of the XRCT system.

References

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