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Coupled Hydro-Mechanical Modeling of Fracture Normal Displacement and Fluid Pressures during a SIMFIP (step-rate injection method for fracture in-situ properties) Test

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Characterization of coupled hydro-mechanical (HM) processes in rock fractures is important for several key geosciences applications, such as rock slope stability, enhanced geothermal systems, and hydraulic fracturing. In-situ experimentation of these processes is challenging, and presently very few techniques exist for quantifying the parameters needed to calibrate hydromechanical models for fractured rocks at field scales. One recent field technology is the step-rate injection method for fracture in-situ properties (SIMFIP) developed by Guglielmi et al. (2014). The method measures simultaneously the time evolution of flow rate, pressure and three-dimensional deformation of the test interval at high resolution.

In June 2019 a set of SIMFIP experiments was carried out in Åre, Sweden, in the COSC-1 borehole. This is a 2.5 km deep borehole aimed primarily for scientific investigations and the fractures and intact rock sections in the borehole are well characterized. Based on the earlier characterization work, three sections were selected for SIMFIP testing: one intact rock section, one section containing a conductive fracture and one section containing a non-conductive fracture (Niemi et al., in prep.).

In this study, a coupled HM model is developed to represent the key coupled processes occurring during these SIMFIP tests. A fully-coupled vertex-centered finite volume scheme and a decoupled finite element model are implemented independently to simulate the elastic deformations and changes in pressure induced by the step-rate injection or flow back of given water volumes. Specifically, the two models are implemented in the commercial simulator COMSOL Multiphysics (sequentially coupled FEM), and the free-open source academic code DuMu^X based on the models of Beck (2019). The models are used to match the pressure recorded by the high precision sensors in the test interval. A parametric study is carried out to mimic the fracture extension and step-down stages of the experiments and to investigate the influence of the key hydromechanical parameters (hydraulic aperture, permeability, storativity, and elastic moduli) on the observed data. The resulting coupled hydromechanical model will be further developed to study the three-dimensional deformation of the borehole section under the SIMFIP test.

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