Contribution ID: **419** Type: **Oral Presentation**

Elementary Slip Solutions for Efficient Geomechanical Simulation of Fractured Rock

Wednesday, 15 May 2024 11:10 (15 minutes)

The prediction of the permeability enhancement that can be achieved in a geothermal system (EGS) is challenging and computationally expensive because it requires the quantification of distributed frictional sliding and tensile opening in fracture networks with a practically relevant level of complexity. Yet, modelling these processes is indispensable for determining dynamic fracture aperture that is paramount for the predictive simulation of coupled flow, transport, and geomechanical processes in EGS.
Here we model this deformation assuming that the rock matrix is homogeneous and has a linear elasticity behaviour. Single isolated fractures sheared under a compressive stress are assumed to develop an elliptic slip profile, assuming a linear relationship between maximum slip and induced stress. We employ such simplified single-fracture solutions as basis functions in a framework that attempts to predict complex stresses by superposition. To deal with the stress singularities at the fracture tips, a modification of tip stresses is applied, facilitating correct resolution of the traction forces. Since the basis functions are generated numerically, our model is readily extended to include different slip profile shapes and basis functions; for instance, to model the stresses at fracture intersections. Overall stresses are obtained by mapping the set of basis functions to the discrete fracture domain of interest. This stress field reflects the superposition of the far field- and all slip-induced stress fields. It allows to determine the maximum slip and tensile opening value along each fracture based on local force balance constraints and therefore the fracture aperture distribution.
Importantly, our approach allows to dramatically reduce the number of degrees of freedom as compared to the discrete contact mechanics-based simulation of the same fracture geometry. This opens the door to realistically complex coupled flow and transport computations for the performance prediction of EGS.

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References

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Session Classification: MS03

Track Classification: (MS03) Flow, transport and mechanics in fractured porous media