Contribution ID: **933** Type: **Poster**

Poroelastic response of a stationary fracture subjected to a constant fluid flux

Thursday, 17 May 2018 13:30 (15 minutes)

Fracture permeability that governs fluid flow within fractures is highly sensitive to fracture aperture that is affected by the fluid pressure on the fracture surface and far filed in situ stress. Previous research focused on fracture behavior in poroelastic medium with only stress and pore pressure boundary conditions on fracture surface. A more general solution should take into consideration a fluid flux boundary which is more suitable for fluid injection/withdrawal. We present a poroelastic model coupling geomechanics with fluid flow to investigate the transient fracture aperture of a single fracture subjected to a constant fluid flux in a poroelastic rock matrix. Load decomposition technique is used to separate the contributions to the aperture changes and stress intensity factor at the crack tip from the mechanical loading and fluid flux. Laplace transform is employed to derive a pair of singular integral equations for the coupled crack opening displacement and pore pressure. A semi-analytical solution is obtained in the Laplace domain and numerical results in the time domain is obtained via the Stehfest inversion approach. Asymptotic expressions for short term undrained and long term drained fracture aperture and stress intensity factor are derived. Based on linear fracture mechanics, the critical fluid flux required to propagate the fracture is determined. From the results we can see that the mechanical loading keeps the fracture open but the pore pressure loading induced by the fluid flux tends to close the fracture. The transient fracture opening is determined by the net loading imposed on the fracture surface. We also note that the stress intensity factor differs significantly from that when the fracture is subjected to a constant pore pressure. The present solution may provide useful guidance for hydraulic fracturing design and serve as a new benchmark solution to validate numerical code development in fully coupled poroelasticity.

References

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Session Classification: Poster 4

Track Classification: MS 2.19: Advances in Observation and Modeling of Coupled Flow and Deformation in Fractured Rock