Defense Announcement

The Effects of Proppant, Complex Fluid Rheology, and Rock Anisotropy on the Near-Front Behavior of a Hydraulic Fracture

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Degree: PhD, Civil Engineering

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Location: Zoom, meeting ID: 977 7033 1519

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Hydraulic fracturing is a technology used to enhance oil and gas recovery from low permeability formations. Fracturing fluids often exhibit nonlinear behavior involving yield stress and are usually mixed with granular materials - proppants, which prevent fractures from closing and allow conductive paths for hydrocarbons. The asymptotic behavior of the stress and strain fields in the vicinity of the fracture front plays a significant role in the propagation of a hydraulic fracture (HF). The near-front asymptotics are associated with limiting cases, known as propagation regimes, which compete with each other at distinct distances from the fracture front that are determined by rock and fluid properties. This dissertation reveals the influence of proppant, complex fluid rheology, and multiple sequentially injected fluids on the HF near-front asymptotic behavior, through numerical solutions of the semi-infinite crack pressurized by fluids of various types. First, the problem of Newtonian fluid mixed with proppant particles is solved. A systematic and exhaustive parameter study quantified the effects of proppant volume, particle radius, packed proppant permeability, and bridging criterion. Second, the flow of Herschel-Bulkley fluid with yield stress is considered to establish the regions where the yield stress dominates the solution, derive the analytical limiting solution for this region, and construct a fast approximation that accurately captures limiting solutions for all problem parameters. Third, the problem of multiple sequentially injected immiscible power-law fluids is addressed. Such a situation often occurs in practice, and it is found that the presence of multiple fluids significantly alters the near-front behavior. Finally, the near-front asymptotics are applied to an HF in a transversely isotropic material representing a layered shale rock formation, allowing estimation of the dimensions and aspect ratio of an elliptical fracture in different propagation regimes. The asymptotic solutions developed in this work have already been used to improve computational efficiency and accuracy of HF simulators in both academic and industrial settings.