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Microseismic Incorporated into a 3D Coupled Fluid and Geomechanics Hydraulic Fracture Numerical Model

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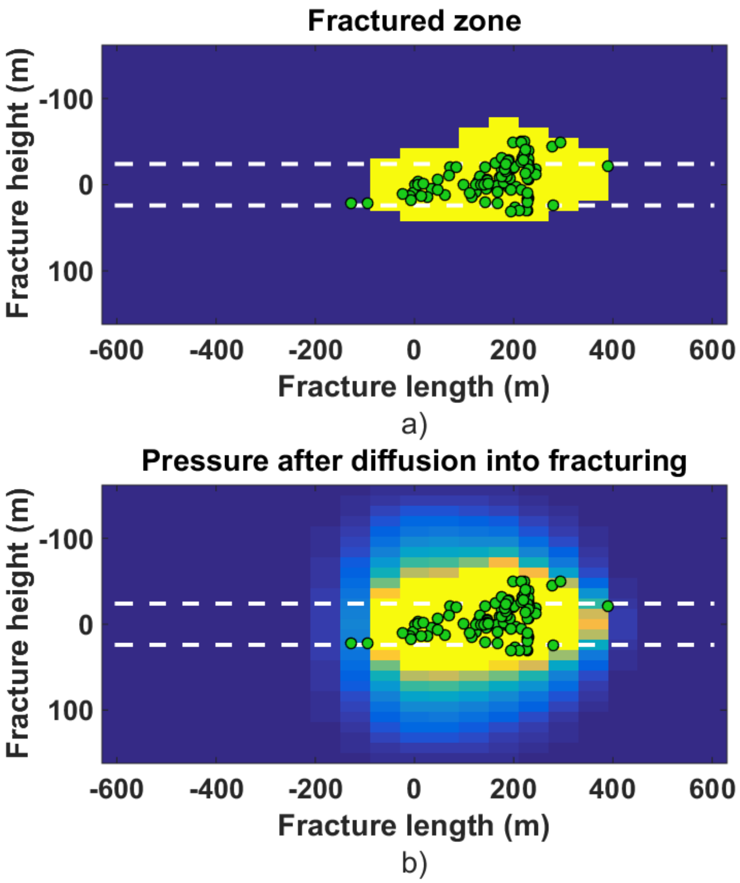
Summary

An iteratively numerical scheme is described that models the coupling of 3D stress with fluid flow to permit the simulation of the evolution of a hydraulic fracture that is induced into a rock unit. The present study also incorporates microseismic observations derived from actual downhole fracture tests as a means to observe the evolution of the fracture. The deformed regions in the stress-strain model, that are caused by fluid diffusion into the rock matrix and by displaced rock due to the propagating hydraulic fracture, are where microseismic activity develops. From the microseismic event locations, the size, shape, level of complexity and orientation of the fracture to be imaged. The evolution of a vertical, 3D, laterally asymmetric, planar, tensile fracture initiating at a set of perforations along a horizontal wellbore is analysed. The developed numerical algorithm makes use of a finite volume method (FVM) to simulate fluid flow and a finite difference method (FDM) to solve the displacement and stress field in the rock. The pressure distribution of the fluid is obtained by solving the diffusion equation while the deformation model is obtained by solving the Navier displacement equation. The method begins by calculating the fluid pressure distribution inside and outside of the fracture using the fluid flow simulator, then the method maps these pressures to the geomechanical model grid and computes the stress, strain and displacement induced by the fracture. The reservoir is characterized by adjusting and fitting model input parameters in the geomechanical model such as stress, fluid, rock and material properties including elasticity moduli to match microseismic observations. A numerical example in considered whereby changes to the stress field and material properties are made to evaluate their influence on fracture propagation with time. The calculated model of the fractured area with time is shown to be consistent with microseismic data acquired in the field recorded during a fracture treatment and show the applicability of the coupled code. This study highlights the important role of microseismic data for constraining hydraulic fracture simulations using the coupled code in order to understand the structural context in which hydraulic fracture growth occurs.

An example of the numerical simulation of the coupling is shown in Figure 1. Figure 1a illustrates the fractured and unfractured nodes of the asymmetric fracture in a 2D vertical slice. Figure 1b shows pressure diffusion in and around the hydraulic fracture. Fracture toughness, resistance of the material to the propagation of a fracture, is reduced in the upper layer to promote upward growth and increased to the left of the injection point to force the model to grow to the right. The microseismic events populate in the upper layer and represent potential upward growth just after t=90min. The coupling mechanism is programmed after Settari and Mourits (1998) and Zhou and Lou (2013).



a)

b)

Figure 1 Simulation of fracture 90 min into the treatment showing a) the fractured (yellow) and unfractured (blue) nodes and b) pressure diffusion in and around the hydraulic fracture. The color map has units of pressure (Pa). The microseismic events (green) are shown after the fracture passed.

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