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Geomechanical Investigation of Hydraulic Fracture Interaction with Pre-Existing Fractures: Geomechanical Impact on Fracture Geometry, Proppant Distribution and Microseismic Response

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Summary

A coupled hydraulic-geomechanical model of a benchmark American Rock Mechanics Association (ARMA) “fracture run-off” scenario is investigated, demonstrating the interaction between the hydraulic fracture and pre-existing fractures including a sensitivity test of mechanical reservoir and fracture properties. The 3D models represent a tutorial documenting changes in hydraulic fracture geometry and associated proppant distribution under different geomechanical conditions, along with differences in the associated microseismic response.

Introduction

A 3D, distinct element model (3DEC) was created of a single, vertical hydraulic fracture within horizontal, mechanical layers as described by ARMA for a specified injection schedule. Two vertical, pre-existing fractures (DFN) were defined surrounding the injection point, with prescribed stress difference and frictional strength. Injection was modeled into the primary hydraulic fracture which opens per the prescribed toughness and geomechanical properties. The primary fracture growth interacts with the DFN, with fluid leaking off into the DFN after slip or opening. Instantaneous fracture deformation is tracked to define a computed microseismic response, including timing, location, magnitude and mechanism.

Results

The base case indicated a primary hydraulic fracture contained by the vertical stress contrast to the injection layer. The DFN experienced shearing induced by pressurization from the hydraulic fracture (Figure 1). As the DFN sheared initially at the intersection with the primary fracture, fluid was transmitted into the fracture and slip and associated microseismicity progressively migrated away. Microseismicity was forecasted along the DFN, predominantly with a shear mechanism (Figure 2). Increased microseismicity rates and magnitude along with vertical flow into adjacent layers occurred in cases of increased slip due to optimal fracture orientation, low frictional strength or high stress difference. Out-of-zone slip and associated flow in the DFN also created some vertical growth in the primary fracture, particularly in the zone between the DFN intersections. Past the DFN intersection point, dilation of the primary was muted to a degree related to the DFN shearing. The restricted aperture also impacted the proppant distribution. The geomechanical strain field was found to be similar to a classic primary fracture opening in tension although overlain with the shearing component. Asymmetric patterns in this strain field can be used to explain the changing hydraulic fracture characteristics around the DFN, dependent on the amount of shear slip.

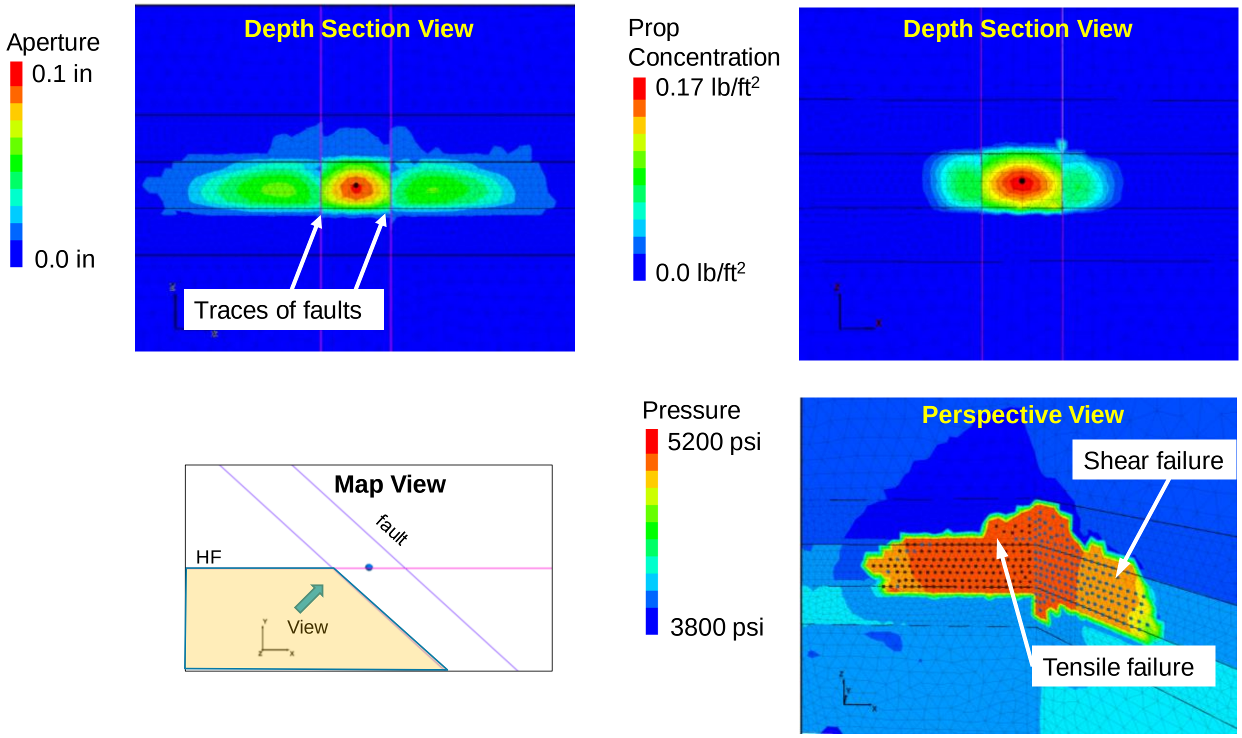

Figure 1. Depth section of the hydraulic fracture aperture (upper left) and proppant concentration (upper right) for the base-case scenario. A perspective view of a portion of the hydraulic fracture and one of the faults (lower right) with contours of pore pressure at the end of the simulation from a view point shown in the lower left. The perspective view is a cut-away as shown by the yellow region, including the left most portion of the hydraulic fracture and bottom most portion of the left fault.

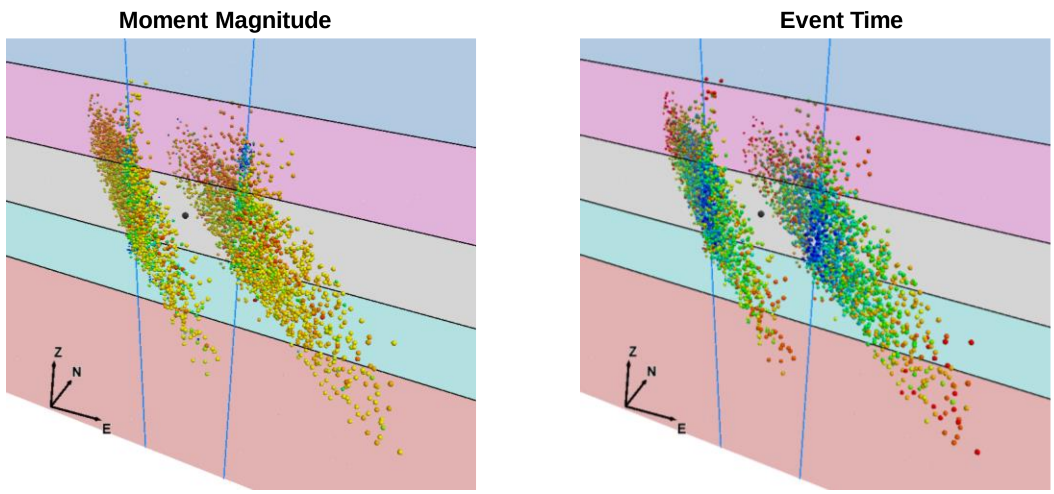

Figure 2. Perspective view of the microseismicity modeled in the base case, defining two clusters associated with each fault. On the left the microseismic are colored by moment magnitude (blue is low and red is high) and right by time (blue early and red is late).

Conclusions

The example highlights a controlled numeric study that demonstrates how a primary hydraulic fracture interacts with pre-existing fractures in different geomechanical conditions, leveraging an ARMA benchmark test. The results provide important insights into growth and proppant distribution of complex hydraulic fracture networks, including the associated microseismic response, that can assist interpretation of microseismic images. The study also has implications to mitigating induced seismicity.