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Energy-Based Hydraulic Fracture Numerical Simulation: Parameter Selection and Model Validation Using Microseismic

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Abstract

This study investigates the use of an energy-based numerical algorithm and its ability to simulate the growth of a single planar hydraulic fracture by matching the modeled dimensions to those inferred from the microseismic map. This approach accounts for the various physical processes, which are expressed as a balance between work expended (input/injected energy) and work done (output/lost energy) during growth of a vertical, three-dimensional (3D), laterally symmetric, planar, ellipsoidal, tensile (mode I) fracture. This canonical fracture model provides a simple but useful proxy for more complex fracture networks that occur in reality. The tensile fracture is positioned in a three-layered, geologic medium defined by elastic, material and stress properties. The fracture half-length, -width, -height and effective crack opening pressure are computed using a time-stepping algorithm that solves energy-balance equations using a Lagrangian formulation. Two sets of parameters are adjusted here in order to calibrate the fracture model based on microseismic data; observed upward growth of the fracture is fit by adjusting stress barrier contrasts, and fracture length is fit by altering empirical parameters such as fracture toughness. In the case of a symmetric model with equivalent stress and material properties above and below the fracture, an increase in fracture toughness results in a corresponding increase in the modeled net-pressure profile and fracture width. In the case of a model with different stress states in the layers above and below the injection level, fracture height growth is enhanced in the layer with lower in situ stress. In both cases, net work is minimized in response to tradeoffs between creation of new fracture surface area and fracture volume. Important geomechanical insights can be achieved by calibrating fracture parameters based on microseismic observations.