

3D Simulation of Stimulated Reservoir Volume Evolution during Hydraulic Fracturing

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Hydraulic fracturing stimulation in the highly heterogeneous and naturally fractured shale formations leads to the development of a complex fracture network with a priori unknown fracture propagation paths. The ability to model this complexity is crucial to the design of a hydraulic fracturing process and mitigation of the potential environmental risks of the reservoir containment breach and induced seismicity. The current dominant modeling approach - explicitly accounting for each fracture with microscale resolution of the fracture network - is a computationally expensive and complex task. There also remain large uncertainties with respect to natural fracture distribution and reservoir parameters. Addressing these issues leads to identification of the need to develop up-scaled continuum model that is able to, in an average sense, capture the irreversible behavior of highly heterogeneous rocks.

We present a novel mathematical approach with the goal of simulating the evolution of the stimulated reservoir volume (SRV) in a 3D geomechanical model. This is achieved by introducing a homogenized non-local poro-elastic-plastic continuum zone for the stimulated region, described by an internal characteristic length scale. Permeability of the stimulated volume is assumed to increase with increasing effective plastic strain. A non-local Drucker-Prager model is implemented within a standard Galerkin Finite Element Method (FEM) framework based on the Biot's Theory.

The performance of the methodology developed is tested by considering examples of 3D hydraulic fracture propagation calculations. For each example, the stimulated zone and the fluid pressure in relation to the local in-situ stress field are quantified. The influence of reservoir complexities, such as sedimentary layering, complex initial in-situ stress field, and near wellbore effects on the evolution of the stimulated volume and fluid pressure will be discussed.