Modeling crack connectivity of induced fractures in a naturally fractured formation

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Abstract

Stimulation in naturally fractured reservoirs is a crucial issue for petroleum industry. Advancing fractures during the stimulation process can have a complicated growth pattern when propagating in a natural fracture network. Induced and natural fracture interaction may result in significant diversion of fracture paths due to this intersection with natural fractures which causes difficulties in proppant transport and eventually job failure.

In this study, employing a disjoint set data structure, we track fracture connectivity and the hydraulic load advancing in the fracture network. The procedure is implemented in a spacetime discontinuous Galerkin finite element scheme which offers greater accuracy and efficiency than continuous (conventional) finite element methods. This dynamic solution utilizing a powerful mesh adaptivity tool enables direct tracking of arbitrary crack propagation patterns. As cracks propagate, their patterns can be modeled analogous to a simplicial complex data structure and geometrical information can be managed with a graph theory approach. In conjunction with graph theory algorithms, a disjoint-set data structure is used to monitor load propagation and transfers between independent sets of fracture inclusions. This not only results in correct modeling of interaction between different cracks, but also allows imposing independent loading conditions for arbitrary sets of fracture sets.

Numerical results from various crack configurations and loading conditions will be presented. The simplest case that will be considered is the interaction of a hydraulically loaded and horizontally oriented crack with an arbitrarily oriented unloaded natural fracture. This has applications in the stability analysis of natural faults close to hydraulic fracturing wells. Using the graph and disjoint-set data structures, the loaded crack will propagate subsequently intersecting the natural fracture allowing the load information to transfer. We will also present more complex examples where the hydraulic load is transferred to already existing natural fissures in rocks and results in the extension of these fissures due to the transferred load.

KEY WORKS: hydraulic fracture, graph theory, disjoint-sets, simplicial complex, spacetime discontinuous Galerkin