Digital Modeling of the Producing the Network of 3D Fractures in Reservoir Rocks with Complex Mineral Composition at the Microscale

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Effective hydraulic fracturing (HF) operations don't always take place even if macro-scale geomechanical modeling suggests favorable operating conditions. To increase the efficiency of HF operations, the authors decided to conduct a study to understand what is happening with a hydraulic fracture at a void scale. There are possible two fundamentally different modes during hydraulic fracture operations. The first mode is when there is one dominant primary fracture and small lateral ones, while the second mode is when there is a branched fracture configuration. This work is aimed to study the propagation of fractures during hydraulic fracturing operations in order to determine the conditions that lead to the most extensive network of secondary fractures along with primary cracks at the pore scale. Authors investigate the occurrence and propagation of 3D fractures, considering the mineral composition and complex texture of elastic-plastic rock such as tight rocks and organic-rich mudstones.

We follow several steps to simulate 3D fracture propagation. At the first step, we started from microstructural characterization using CT, SEM, EDS, and X-ray methods. Geomechanical characterization of the rock involved a suite of laboratory methods such as multi-stage compressive strength tests, direct tensile strength, Brazilian indirect tensile strength tests, micro, and nanoindentation. Then we process obtained data by registering 2D data (SEM and QEMSCAN) with 3D data (CT) and choosing the target representative volumes of interest for simulations. Eventually, we prepared digital rock models through mesh generation, populating the model with mechanical properties, defining contacts, and setting boundary conditions. Finally, we simulate of stress-strain state in the digital rock models and obtain branched fracture configurations.

In the result we propose the integrated model that describes the propagation of 3D fractures at a microscale and accounts for the granular composition, sample structure, elastic-plastic properties, and conditions on the intergranular contacts of minerals contained in the sample. The conducted numerical elastic-plastic modeling reveal features of the fracture initiation and propagation in heterogeneous 2D and 3D models with the complex geometry of contacts between minerals. We proposed a theoretical method for linking the obtained numerical simulation results of the stress-strain state and fracture area with the fluid injection pressure during hydraulic fracturing operations to achieve the maximum fracture opening in the field.

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