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A Computational Investigation of Seismic Wave Focusing as a Means to Fracture Shale

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In unconventional oil and gas reservoirs, hydraulic fracturing can only generate fractures in limited bulk of reservoirs. Moreover, natural and hydraulic fractures are difficult to characterize, and the water disposal process is linked to environmental concerns including induced seismicity. Recent laboratory efforts report on the application of shock-wave comminution to micro-fracture considerable target bulk volumes of various porous materials such as limestone and concrete.
The physical process is similar to lithotripsy; a widely applied kidney-stone treatment procedure. Few studies of rock comminution have been conducted at reservoir conditions. This work 1) develops a coupled seismic-flow simulation model that can predict the initiation of comminution at reservoir conditions, 2) applies the model to design laboratory rock mechanics experiments, and 3) computationally investigates field-scale applications.
We develop a high-resolution, coupled multiphase flow and transient geomechanics
simulator for shale comminution. An unstructured, fully-implicit finite-volume formulation of the coupled equations is proposed in two-dimensions. In this model, the matrix rock is treated as a continuous porous medium and Biot's theory is used to describe the bulk momentum balance. Wells are represented as internal boundaries within the mesh. Periodic or aperiodic deformations may be applied in addition to fluid injection and production. Strain energy release rates are computed and are used to judge the crack initiation and comminution processes.
The simulator is validated numerically for accuracy and correctness and is compared to analytical solutions for simple cases. An investigation is conducted to design rock mechanics laboratory experiments that are projected to span the comminution onset and failure regimes. By controlling the generated seismic waves, comminution can be achieved in our model and can be controlled to initiate at intentional target locations. Compared to hydraulic fracturing that can only stimulate volumes near the wells, seismic waves can generate larger fractured volumes in target locations away from the wells. These preliminary results are encouraging and provide guidance to the development of next steps in the
laboratory.
A computational assessment shows that seismically induced comminution maybe realizable at reservoir conditions. A protocol to examine this in a laboratory setting is proposed. Seismic wave comminution may be a novel technology that will complement hydraulic fracturing in increasing recovery efficiency from unconventional reservoirs.

References

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