Geomechanic modelling of rock failure accounting for seismic emission and its comparison to seismic moment-tensor model

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We present an approach to studying resolvability and limitations of detecting rock failure mechanisms during fracture growth or activation form passive seismic monitoring data. This approach includes numerical geomechanic modeling of incremental rock failure including associated generation and propagation of elastic waves. Then we record these waves in the far field (several wavelengths away from the source) and invert P- and S-wave amplitudes for seismic moment tensor. Thus we can derive an effective point source which gives the approximation of the amplitudes. These results establish connection between geomechanic models of rock failure (hydraulic fracture growth, fracture activation during production) and a passive seismic monitoring data. microseismic monitoring. Thus we can see which scenarios of fracture growth or activation can be resolved from passive seismic monitoring data. In particular, we show examples indicating that the radiation pattern of waves generated by fracture growth can be reasonably described by a point source defined by the moment tensor. On the other hand the moment-tensor inversion may lead to an incorrect interpretation of the hydraulic fracture growth direction depending on regional confining stress field.

In this paper we consider a 2D numeric geomechanic model of the incremental fracture growth accounting for generation and propagation of elastic waves caused by the material failure, i.e. seismic emission. We described the elementary fracture growth explicitly by an incremental advancement with the release of new surfaces by splitting nodes of the computational grid. We chose this approach as it is well suited for describing a fracture opening by different mechanisms including tensile and shear types.

We carried out a series of numerical tests ans came to several observations about seismic wave generation by the fracture growth. The key properties of numerical modelling are: time-increment step, fracture length and its combination with the source-receiver distance. Our observations showed that the ratio of source-receiver and wave-length must be over 50. It was also shown that the presence of shear stress decreases the wave intensity and rotates the main orientation axis of the radiation pattern. Finally, overall the radiation pattern observed from geomechanic modelling can be reasonably well approximated by a moment-tensor point source. Obtained radiation pattern are close to the dipole-type source mechanism which is in good correspondence with the tensile fracture opening mechanism used in gemechanic modeling.

We hope that further studies will help establishing connections and use microseismic data for calibrating geomechanic models of hydrofrac or reservoir modelling.

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