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Fault Plane Solutions from Moment Tensor Inversion for Microseismic Events using Single-Well and Multi-Well Data

Jing Du*, Ulrich Zimmer and Norm Warpinski
Pinnacle – A Halliburton Service
Jing.Du@pinntech.com

Although microseismic monitoring of hydraulic fractures has primarily been concerned with the dimensions, complexity, and growth of the fractures or fracture systems, there is an ever-increasing desire to extract more information about the hydraulic fracturing and/or natural fractures from microseismic data. Source mechanism analysis, which is concerned with deducing details of the failure process from the microseismic waveform data, is therefore attracting more attention. However, most of the studies focus on the moment tensor inversion and much less on extracting fault plane solutions (FPSs) from inverted moment tensors. In general, the full moment tensor inversion requires both P and S-wave data from at least two observation wells. In the case when only single observation well is available, the deviatoric moment tensor inversion could be performed by adding the constraint of zero volumetric component, which is appropriate for pure shear source type.

The FPSs can be extracted from the inverted moment tensor. Mathematically performing the deviatoric moment tensor inversion is enough to extract the FPS, as the angle α, which is defined as the angle between the slip direction and the fault plane, is only a function of the eigenvalues of the deviatoric moment tensor, and fault normal and slip directions are a function of the angle α and the eigenvectors of the moment tensor, which are the same as the eigenvectors of the deviatoric moment tensor. This means that the FPS could be extracted using the deviatoric moment tensor inversion from single-well data, even for non-pure shear source type. However, there are sampling errors that might be inherent in the single-well case caused by the limited coverage on the focal sphere that would potentially prevent doing so using single-well data for non-pure shear source type.

Examples from both dual array data and single array data will be presented to show the application. The comparison between the two-well case and single-well case shows that multi-well analyses will generally give better FPS results and are less affected by noise because the geometry is usually more conducive to extraction of these parameters, as reflected in the condition number.

References

Warpinski, N. and Du, J. (2010). Source Mechanism Studies on Microseismicity Induced by Hydraulic Fracturing. Paper SPE 135254 presented at the SPE Annual Technical Conference and Exhibition, Florence, Italy, 19–22 September.