Algorithm and Experimental System for Arbitrary 3D Fracture Network Detection and Mapping in Tri-axial Through-Casing Induction Measurement

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In unconventional shale gas and oil exploration, electromagnetic (EM) methods are an emerging new technique to nondestructively detect and map the produced hydraulic fractures. However, the thin but very long fracture structure is extremely difficult to simulate by traditional computational methods, such as the finite element method (FEM) and Method of Moments (MoM). Existence of the long borehole and metallic casing further increases much computational costs. Moreover, the effect of the underground layered medium increases the problem complexity.

Recently, studies have been conducted to improve FEM and MoM methods to simulate the produced fractures. Impressive results have been obtained. However, the industry is still demanding faster methods for simulating arbitrary three-dimensional (3D) fractures or fracture networks, and analysis of the effects of casing and the underground layered medium on multi-component EM signals in fracture detection is also an urgent demand.

Previously, we have proposed the hybrid distorted Born approximation and stabilized biconjugate-gradient technique with a fast Fourier transform algorithm (DBA-BCGS-FFT) to simulate arbitrary 3D fracture in tri-axial through-casing detection and mapping. In this work, we further improved the method to efficiently simulate arbitrary 3D fracture networks. The improved method is not only capable of analyzing effects of the metallic casing, but also the effects of underground layered medium. In addition, a new experimental tri-axial induction logging system for through-casing fracture detection will be presented with new detection techniques implemented to directly measure secondary signals from fractures.

The numerical results of the new method will be validated by commercial numerical software. Then experimental results will be validated by the DBA-BCGS-FFT method. Finally, we will show the mapping results generated by the full wave 3D inverse solver based on the DBA-BCGS-FFT method in the black box tests.