Electromagnetic Algorithms for 3D Fracture Evaluation under Planar Stratified Media in Through-Casing Measurement

Yuan Fang[(1)], Yunyun Hu[(1)], Dezhi Wang[(1)], and Qing Huo Liu [(1)]
(1) Department of Electrical and Computer Engineering,
Duke University, Durham, NC, 27708

Due to the nondestructive property, the electromagnetic (EM) methods are usually used to evaluate the produced hydraulic fractures in shale gas and oil detection. However, the traditional computational electromagnetic (CEM) algorithms, including the finite element method (FEM) and Method of Moments (MoM), do not have the capability to simulate the extremely thin and long fracture structures. Existence of long borehole and metallic casing require much more computational cost. Moreover, the effect of the underground layered medium increases the problem complexity.

Previously, we have proposed the hybrid distorted Born approximation and biconjugate-gradient stabilized technique with a fast Fourier transform algorithm (DBA-BCGS-FFT) to simulate arbitrary 3D fracture in tri-axial through-casing detection and mapping in a homogeneous layer. However, the layered medium effect should be considered for the extremely long fracture evaluation. Especially for the fracture evaluation in horizontal borehole environment.

The difficulty is that there is no analytical solution to calculate the Green's function when both cylindrically layered media and planar stratified media exist. In this work, we propose a hybrid pseudo 3D FE-SIE algorithm to model the 3D fracture network with considering the effect of both metallic casing and underground layered medium. This method will combine the advantages of numerical mode matching method (NMM) and the BCGS-FFT method to simulate this multi-scale scenario. Also, a new inverse algorithm based on this new forward algorithm will be presented.

The numerical results of the new method will be validated by commercial numerical software. Then we will further explain the high efficiency of the forward hybrid pseudo 3D FE-SIE method, and analyze the casing and underground layer effect in fracture detection. In the end, we will show the fracture mapping results generated by the full wave 3D inverse solver based on the forward solver in the black box tests.