Application of BCGS-FFT and Distorted Born Approximation for Hydraulic Fracturing detection and imaging

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With the ever increasing number of research on hydraulic fracture aiming at improved oil production, forward and inverse solvers based on electromagnetic method to detect and reveal properties of hydraulic fracture have become an important subject of research. Most of existing forward and inverse methods are developed to simulate the well logging model, such as Method of Moments (MoM) and Born Approximation. Those methods have the advantages to reconstruct the geometrical and electromagnetic information of formation. However, they are not fast enough and the memory cost are large. Moreover, when those methods are used to simulate hydraulic fractures, they are not able to obtain the accurate result.

This work makes use of the biconjugate-gradient stabilized technique with a fast Fourier transform algorithm (BCGS-FFT) and Distorted Born Approximation (DBA) as the forward and inverse solver to study the properties of hydraulic fractures. BCGS-FFT and MoM are forward solvers which are both based on the electric field volume integral equation (EFVIE). However, instead of directly solving a large scale dense matrix as MoM, BCGS solves large scale matrix iteratively. FFT can further reduce the computational and memory cost of the whole forward solver from $O(N^2)$ to $O(N \log N)$.

In homogeneous background, Born Approximation can be directly used as forward solver. However, when cased borehole condition is used in field application, background is not homogeneous because of the existence of metal casing. To simulate this forward problem, Distorted Born approximation is used in this work. Under low frequency application, as long as the incident field through the casing is known, this incident field can be viewed as primary field. Since the casing effect has been considered in the process to calculate the primary field, we can still use homogeneous scalar green function.

The result of this work matched well with Numerical Mode Matching (NMM) Method and the scaled experiment result, which can prove the accuracy of the solvers. Also, these fast solvers can be used in oil industry to detect and reveal the properties of hydraulic fracture with high speed and accuracy.