Weishan Han, "3D Finite Element Simulation Method of Induction and MWD Tools"

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This dissertation focuses on the numerical simulation of induction and MWD logging tool responses in a complicated three-dimensional (3-D) environment. The work presented in this dissertation can be divided into three major parts:

1. As an endeavor to increase the calculating speed, an existing 3-D finite element code "Dracula" is parallelized using both MPI and OpenMP. Nine processors were used to conduct the calculation, which reduce the computing time for one logging point from about three hundred seconds to around one hundred seconds.
2. A new finite element method was developed to simulate the response of induction tools in 3-D formations. Magnetic potential fields are selected instead of *E* fields to obtain more stable solutions. Meanwhile, the Coulomb gauge condition is used to eliminate the spurious solution. In practice, the nodal base is chosen, and the sparse linear system is solved by quasi-minimum residue (QMR) solver with simple Jacobian preconditioning. 1-D and 2-D cases are calculated and compared with existing software packages. Several 3-D cases are also studied using the new algorithm.
3. The new 3-D finite-element method is used to solve controlled-source electromagnetic (EM) measurement-while-drilling (MWD) problems in anisotropic electrically conducting media with multi-layers and invasion zones. The solution is based on a weak formulation of the governing Maxwell's equations. The resulting sparse linear system is solved efficiently using a quasi-minimal residual method with simple Jacobian scaling as a preconditioner. The main aspect of this work includes derivation of the governing functions using edge-based bases and the implementation of a 3-D cylindrical mesh generator, which can separate the different layers and invasion zones into different tetrahedra. These new features made it possible to quantitatively interprete MWD-logs in complicated 3-D logging environments. Examples are given for 1-D, 2-D and 3-D problems in both isotropic and anisotropic formations, and comparisons of the results are made to validate the algorithm using existing software

packages developed by the Well Logging Lab at the University of Houston in 1-D and 2-D cases.

The developed methods are general and can also be adapted for controlled-source EM modeling in mining, groundwater and other applications.