Fast Calculation of the Response of Multicomponent Induction Logging Tool for Hydraulic Fracture and Its Mapping

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Hydraulic fracturing is commonly employed in the wells of tight oil and tight gas to increase exposure to the producing formation, boosting the flow rate of hydrocarbon into the wellbore, therefore, enhancing the productivity of gas or petroleum. Knowledge of the information of hydraulic fracture, such as dimensions, location, orientation and conductivity of filled proppant, will facilitate selecting locations for casing perforation and predicting production.

Because the currently used microseism-based fracture parameter estimation technique is relatively expensive and cannot obtain effective fracture area or conductivity of proppant, an affordable and easy-to-implement tool based on electromagnetic technique, i.e., the multicomponent multi-array induction logging tool, is proposed to study the characteristics of the fractures. When computing the response of triaxial induction logging tool, the conventional 3D full-wave solvers, including MoM, FEM and FDTD, often suffer from heavy computational complexity in the presence of slim structures, e.g. hydraulic fracture and casing, which is used to support the wells.

The numerical mode matching (NMM) method can sophisticatedly treat the fine structures in the model without dramatically increase the number of meshes. Thus, it is applied to efficiently calculate the response of triaxial induction tool due to an electric or magnetic dipole embedded in the open or cased well with the fractures. It is convenient to simulate the electromagnetic wave propagation in the wells together with the orthogonal transverse fractures, which is axis-symmetric with respect to the wellbore center. As for the hydraulic fracture orienting arbitrarily without axis-symmetry, the Green's function without considering the fracture can be acquired numerically using the NMM method. Then the Born approximation or other full wave solvers will be introduced to compute the response of the model containing the hydraulic fracture. The yielded secondary field from the hydraulic fracture has already been validated by comparing that with experiment data, showing very good accuracy. The combined NMM approach is first proposed and applied to the computation of the response of the induction logging tool in the cased wells along with hydraulic fracture. An inversion solver based on Born approximation method will be employed to recover the length, width, thickness and the inclination of the hydraulic fracture as well as the conductivity of the filled proppant. The inverted results agree well with the true models in several scenarios, including the orthogonal or tilted fractures in the open or cased holes.