Thin Dielectric Sheet based Surface Integral Equation for Simulating the Multiscale Hydraulic Fractures in a Layered Medium

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Electromagnetic simulation of fractures in a layered medium is essential to the application of hydraulic fracturing for hydrocarbon exploration. Due to its multiscale feature, simulating a fracture by the traditional finite element method (FEM) or the volume integral equation (VIE) is very challenging and computationally expensive. Recently, the thin dielectric sheet based surface integral equation (TDS-SIE) has been proposed for the efficient simulation of fractures in a homogeneous medium. Since the scattering characteristics of a fracture in a planarly layered medium are of more interest to the geophysical community, we extend TDS-SIE into the layered medium scenario, where layered medium Green's functions are adopted. The resultant TDS-SIE may be referred to as LM-TDS-SIE.

In comparison with the traditional FEM or VIE, for which dense volume meshes are required, only surface meshes are demanded by the LM-TDS-SIE for fracture simulation, and a small number of surface elements suffices to represent the fracture well. This implies that lots of unknowns are saved by LM-TDS-SIE in contrast to both volume discretization based methods.

Recently, with the aid of the impedance transition boundary condition (ITBC), a much more efficient FEM solver is proposed for the fracture simulation. However, in this ITBC based FEM solver, only the burden of discretizing fractures by volume elements is released, and the volume discretization of surrounding medium is still indispensable. More importantly, given that FEM is based on the differential Maxwell's equations, this ITBC based FEM solver is generally less accurate than the integral equation based methods. For some cases, very dense meshes becomes indispensable to obtain good accuracy, which makes FEM less attractive. In contrast, good accuracy can be readily obtained by LM-TDS-SIE with relatively coarse mesh.

Logging curves are computed by LM-TDS-SIE for various fractures in a layered medium, and are compared with reference results to demonstrate the accuracy and efficiency of LM-TDS-SIE.