Enhanced Subsurface Sensing with Nanoparticles as Contrast Agents for Oil Industry

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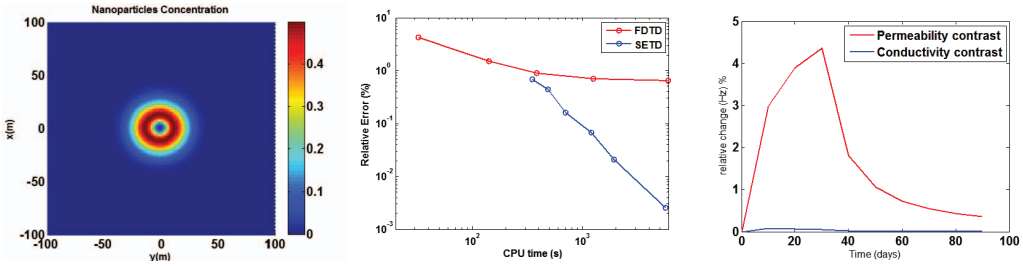
In recent years, the applications of nanotechnology have been extensively researched in many key areas of oil industry, such as exploration, drilling and production. Nanomaterials can be developed as excellent imaging-contrast agents in their magnetic and electric properties. They are able to flush with the injection fluids through the reservoir micro-size pores. Tracing these contrast agents with electromagnetic tomography technology can potentially help tracking the flood-front in waterflood, monitoring enhanced oil recovery process and field characterization.

The flow behavior of nanoparticles in porous medium can be modeled by solving pressure equation and conduction-diffusion equation. In this research, the 3D spectral-element time domain method (SETD) based on Gauss-Lobatto-Legendre (GLL) polynomials is employed to solve these equations to obtain the time-varying pressure and particles distribution in reservoir, as shown in Fig 1(a). The SETD method, by using high order basis functions thus fewer unknowns, is demonstrated to be more computationally efficient than FDTD method (UT-CHEM), given the same accuracy, as shown in Fig 1(b). The conductivity and permeability contrast between nanoparticles and the rock, are able to enhance the resolution of electromagnetic measurements. According to the study, magnetic nanopariticles can be better detected than conductive ones in porous medium, as shown in Fig 1(c). Based on the improved contrast, the flood front and enhanced oil recovery process can be potentially monitored through coupling of flow behavior and electromagnetic imaging.



(a) (b) (c)

Figure 1: Flow-EM coupling results for a 30-day nanoparticles injection. Formation porosity is 0.3.Background and nanoparticle relative permeability is 1 and 30; Background and nanoparticle conductivity is 0.1 S/m and 1000 S/m. Receivers align in the producer at (200,200,-100:100) m, and a vertical magnetic dipole source, operating at 200 Hz, locates at (0,0,0) m. (a) Nanoparticles concentration distribution at 40 days; (b) Computation performance comparison of FDTD and SETD; (c) Relative change of secondary field at producer (200,200,100)m as the nanoparticles injection.