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Pore-scale modeling of multiphase flow in porous media with particle migration

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Multiphase flow in porous media with moving particles is common in many natural and industrial processes, such as low-salinity water-flooding, sand production, and microbial enhanced oil recovery, etc. With complex interactions between fluids, particles and pore surfaces, the flow behaviors in such systems are often distinct. To understand the effects of particle migration on multiphase flow in porous media, a direct numerical simulation study is conducted. In this study, Navier-Stokes equation is coupled with discrete element method (DEM) by directly calculating fluid-particle interaction forces. The volume of fluid (VOF) method is used to capture the evolution of the immiscible two-phase interface. Contacts between solid particles and pore walls with arbitrary topology are modeled by the contact laws. This study demonstrates that particle migration significantly alters the well-known characteristics of two-phase displacement, such as viscous fingering and capillary fingering. Particle plugging in the pore throat compels the invading fluid to enter larger pores, resulting in a higher sweeping efficiency. The role of particle density, injecting velocity, surface tension and other parameters are systematically analyzed. Finally, a mathematical model is established to describe the effects of particle migration on multiphase flow in porous media. The established model is validated against microfluidic experiments.

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