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Numerical Simulation of Nanoparticle effects on Multi-phase System Dynamics

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Solid nanoparticles (NPs) have shown promise to play a major role in novel enhanced oil recovery methods by altering reservoir wettability, reducing interfacial tension and increasing mobility ratio. Solid nanoparticles could be implemented as emulsion stabilizing agents in combination with surfactants and polymers. Stabilized emulsions are a desired state in enhanced oil recovery. In this study, the contribution of NPs in hydrodynamics of multi-phase systems including their effect on interfacial tension and mobility ratio was studied. The free energy Lattice Boltzmann Method was used to solve the Cahn-Hilliard convection-diffusion and the Navier-Stokes equations in a two dimensional Cartesian domain. The NPs were added to the system as point particles with zero volume. A potential function was assumed to represent the chemical potential alteration of the multi-phase system due to the presence of NPs. Attractive and repulsive interaction of the NPS was entered into the model by Morse potential function. The results of spinodal decomposition showed that different types of emulsions (oil in water, water in oil, water in oil in water) could form at the presence of particles with different wettabilities. The effect of the presence of NPs in a capillary tube on contact angle was studied and it was observed that low concentration of NPs does not significantly affect the contact angle. The process of suspended droplets getting coated by neutral-wet NPs was simulated and it was observed that attractive interaction of NPs would result in multiple layers of coating. The Collision and coalescence of two droplets at the presence of different types of NPs was simulated and it was observed that neutral-wet NPs dominate the collision hydrodynamics at high NPs concentrations. It was also observed that the nanoparticles with repulsive forces would stabilize emulsions at lower concentrations comparing to nanoparticles with attractive forces. This work showed that the free energy Lattice Boltzmann method combined with NPs assumed as points is an effective tool to model and simulate the hydrodynamics of multi-phase systems in micro and nano scales. The computation cost of the simulation was also discussed in details.

References

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