Experimental and Numerical Analysis of Nanofluid Dynamics in Microchannels

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The utilization of nanotechnology in the petroleum industry has attracted significant interest for its potential in enhancing oil recovery through the injection of nanofluids. This study explores the utility of micromodel experiments as a means to visually examine how nanoparticles can facilitate the mobilization of oil that is trapped in underground porous layers. Specifically, we assessed the impact of silicon oxide nanoparticles on modifying the wettability properties of micromodels, employing both experimental techniques and numerical simulations for a comprehensive analysis. We explored the effects of injecting nanofluids, with varying concentrations of nanoparticles, into oil-saturated micromodels and compared the outcomes with traditional water flooding techniques to ascertain the advantages of nanofluid application. Additionally, the flooding processes within the micromodels were replicated through computational fluid dynamics (CFD) simulations, utilizing COMSOL Multiphysics software, which is grounded in the finite element method (FEM). The simulations focused on the fluid-fluid interface, adopting the conservative level set method (LSM) to accurately depict the oil-water boundary through level set functions.

In the simulations designed to replicate the conditions of oil trapped in underground layers, we meticulously monitored the behavior of the dispersed phase as it passed through a single-pore geometry. The findings from both the experiments and simulations could enhance the fundamental understanding of how nanoparticles can change wettability, providing insights into the implications of such modifications for the dynamics and efficiency of multi-phase flow fields.

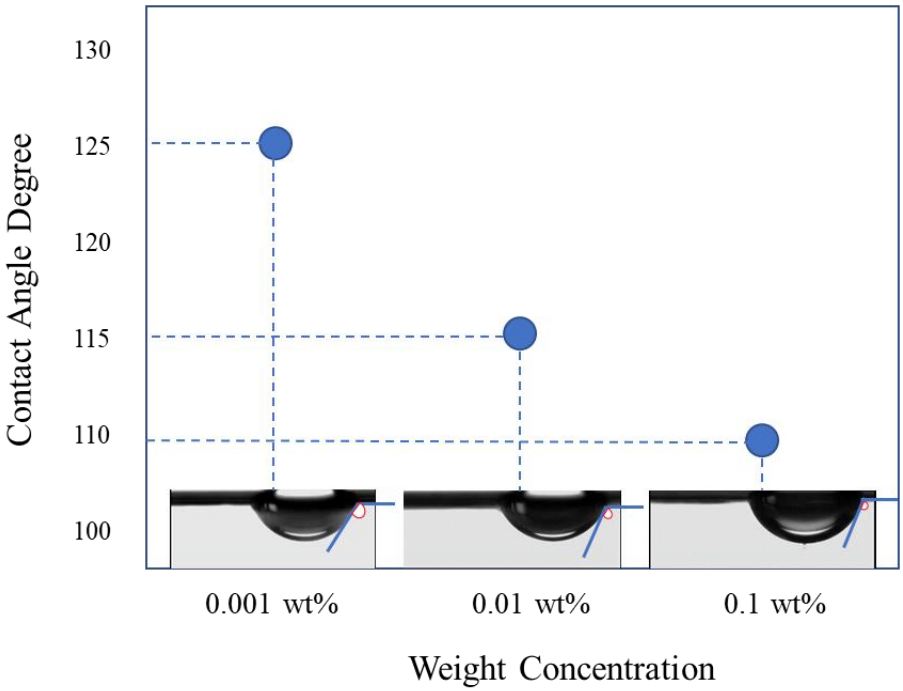

Figure 1: Contact angle between oil droplet and SiO2 nanofluids with different concentration

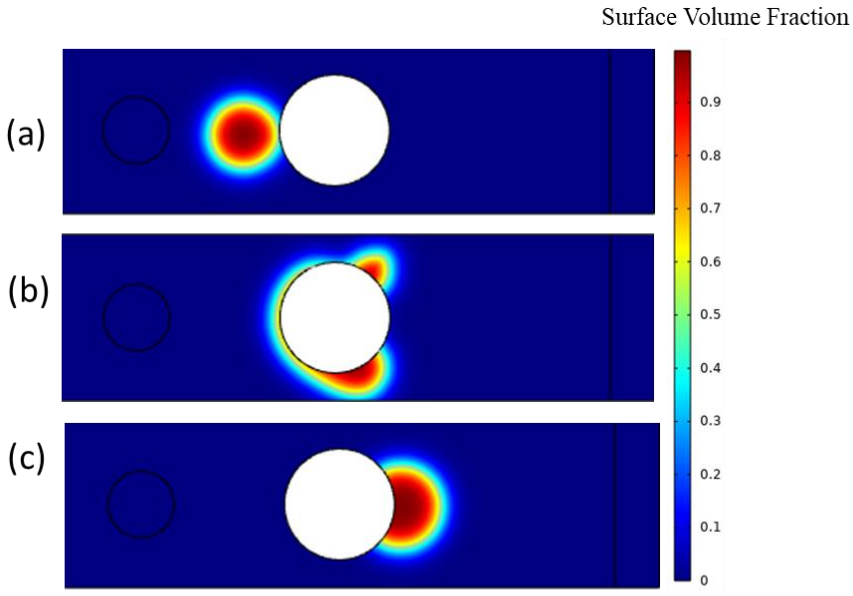

Figure 2: Impact of an oil droplet with 110° contact angle over time
(a) t = 0.625 s, (b) t = 1.25 s, (c) t = 2.7 s