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The mathematical model and analysis of the nanoparticle-stabilized foam displacement

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This work proposes a mathematical model to study the foam displacement in porous media stabilized by nanoparticles [1]. We consider a simplification of the Stochastic Bubble Population balance model in local equilibrium, with nanoparticle dependence inspired by the experimental data from the literature. It consists of a non-strictly hyperbolic system of conservation laws, which is solved for the generic initial and injection conditions. We investigate the existence of a global solution as a sequence of waves following the Conservation Laws Theory and the procedure proposed in [2], where a similar problem was solved for a two-phase flow containing an active tracer (with linear adsorption). When the solution is composed of two or more waves, we present necessary and sufficient conditions to guarantee the compatibility of these wave sequences. The analytical solution for the nanoparticle-stabilized foam displacement in porous media allowed us to quantify the effect of nanoparticles on foam displacement, focusing on the breakthrough time and cumulative water production. In agreement with the literature, when only gas is injected, the breakthrough time and the water production increase with the nanoparticle concentration. Although, we also observe that the effect of nanoparticles is less pronounced for high nanoparticle concentration. Counterintuitively, adding nanoparticles changes the mathematical solution qualitatively, yielding a negligible effect on water production during gas-water co-injection for a certain parameter range. We discuss the most favorable conditions to observe the action of nanoparticles in laboratory experiments.

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References

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mathematical model and analysis of the nanoparticle-stabilized foam displacement, Appl. Math. Model. 125 (2024) 630–649. doi:10.1016/j.apm.2023.10.022.

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