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# Modeling the Damage Caused by Air Penetration During Air Drilling by Using the Lattice Boltzmann Method

Multiphase flows in porous media are crucial in both industrial processes and natural phenomena, impacting hydrocarbon recovery, groundwater flow, catalysts, and fuel cells. Numerous experimental methods have been developed to study these issues, allowing for large-scale observation of dynamic interface behavior. However, accurately describing fluid flow at the pore scale remains challenging. Laboratory micromodel studies can predict fingering patterns and their initial growth but do not provide insights into their later-stage evolution.

Numerical simulators are valuable for complementing theoretical and experimental studies, examining the effects of flow and physical parameters in complex three-dimensional porous environments. However, continuum-based numerical methods fall short in investigating the impact of pore-scale parameters on bulk properties, failing to detail pore-scale flow patterns. The Lattice Boltzmann Method (LBM) is recognized for its ability to simulate multiphase flows at the pore scale, offering advantages over traditional computational fluid dynamics (CFD) methods due to its parallel computational capability and ease of handling complex geometric boundaries.

In this study, LBM with a phase-field approach was used to investigate formation damage during air drilling, considering high density and viscosity differences. A two-phase simulator core was developed in C++ due to the lack of commercial simulators for this approach. Simulation results were initially validated against theoretical solutions for single-phase and two-phase cases, showing acceptable errors. Further simulations in capillary tubes and synthetic porous media examined flow patterns and the effect of density ratio on these patterns.

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