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Pore-scale simulation of H2-brine system relevant for underground hydrogen storage: A lattice Boltzmann Investigation

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Underground hydrogen (H2) storage in saline aquifers is a viable solution for large-scale H2 storage. Due to its remarkably low viscosity and density, the flow of H2 within saline aquifers exhibits strong instability. Therefore, it is crucial to understand the flow processes of H2 and brine at the pore-scale, which can be translated into constitutive relations at continuum-scale to guide field-operations. For the first time, we develop a lattice Boltzmann model tailored for pore-scale simulations of the H2-brine system under typical subsurface storage conditions. The model captures the significant contrast of fluid properties between H2 and brine, and it offers the flexibility to adjust the contact angle to suit varying wetting conditions. The developed model is employed to investigate the pore-scale dynamics of two-phase flow composed of H2 and brine. We show that the snap-off is enhanced in a system with a higher capillary number and a smaller contact angle. These conditions lead to a reduced connectivity of the gas phase, which is unfavorable for H2 production from the aquifer. Moreover, the relative permeability curves, computed from the simulation results, exhibit distinct behaviors for H2 and brine. In the case of the wetting phase, the relative permeability can be quantified solely using the phase saturation, whereas for the non-wetting phase, the phase saturation and Euler number appear to contribute equally to the relative permeability. This implies that different formula, compared to the typically used saturation-based functions, should be considered for continuum-scale simulations.

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References

Primary authors: Dr WANG, Yuhang (China University of Geosciences (Wuhan)); Dr CHAKRAPANI, Thejas (Delft University of Technology); Prof. WEN, Zhang (China University of Geosciences (Wuhan)); Prof. HAJIBEYGI, Hadi (TU Delft)

Presenter: Dr WANG, Yuhang (China University of Geosciences (Wuhan))

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