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3D adaptive modelling of transient multiphase flow experiments using the MOOSE framework

Wednesday, 2 June 2021 10:00 (1 hour)

Fluid-fluid displacements with adverse viscosity ratios are prone to instability, and their interaction with underlying heterogeneity in a porous medium can cause a variety of fingering structures to emerge. The transient dynamics of these processes are both hard to capture experimentally, and difficult to model numerically, leading to conflicting studies with differing mechanisms for their origins [1,2].

In this work, we develop a novel adaptive mesh modelling approach to rigorously and transparently model continuum-scale transient multiphase flow in heterogeneous media. We use the MOOSE framework (www.mooseframework.org) - an open-source multiphysics simulation platform [3]. We use a finite-volume approach with automatic differentiation and adaptive octree meshes, which evolve with the moving front. Petrophysical parameters are pre-computed for multiple levels of the octree structure, allowing efficient and physically accurate refinement of the computational grid as the simulation progresses. The approach allows the simulation of large flow domains with high precision, mesh-independent resolution of unstable fingering structures and moving front interactions with truly heterogeneous regions of a porous media.

We use the simulation approach to model several metre-scale experiments performed in Bentheimer and Boise rock cores. In the experiments, nitrogen-brine flow was imaged dynamically with a novel Medical-CT setup, allowing plume tracking and 3D resolution of fingering structures at mm-scale over the metre-long cylindrical cores. We compare the transient dynamics of the front with those directly from our simulations at a variety of scales, leaving no ambiguity in the efficacy of the modelling approach. We directly visualise the competition between fluid-fluid and fluid-structure based instability, and the onset of fingering at the continuum scale.

Time Block Preference

Time Block A (09:00-12:00 CET)

References

[1] Berg, S & Ott, H (2012). Stability of CO2–brine immiscible displacement. International Journal of Greenhouse Gas Control, 11, 188-203.

[2] Sorbie, K.S., Al Ghafri, A.Y., Skauge, A. et al. (2020). On the Modelling of Immiscible Viscous Fingering in Two-Phase Flow in Porous Media. Transport in Porous Med 135, 331–359.

[3] Wilkins, A., Green, C. P., & Ennis-King, J. (2020). PorousFlow: a multiphysics simulation code for coupled problems in porous media. Journal of Open Source Software, 5(55), 2176.

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