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Development of multiphase flow simulation method in DEM under a movable-grain condition

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Understanding how hydrodynamics of multiphase flow couple porous media deformation is essential to ensure successful engineering practices such as geological carbon sequestration. However, existing hydro-mechanical coupled models face significant challenges in reliably and efficiently capturing fluid-grain displacement patterns. In response, we present a novel two-way coupled hydro-mechanical discrete-element method model that manages fast fluid transport and considers the synchronising pore deformation. This model, which employs the implicit finite volume approach to solve pore pressure under a remarkable timestep, predicts fluid-fluid and fluid-grain interactions unconditionally stable. We design a pressure-volume iteration scheme to balance injection-induced pressure changes with pore structure rearrangements dynamically. Additionally, we incorporate adaptive flow front advancement criteria to enhance the capture of interface motion, particularly in complex flow scenarios where fluid migration surpasses the frontline pores or is impeded by capillary effects. The robustness and reliability of our model, validated against Darcy flow theory and experimental observations from Hele-Shaw tests, demonstrate its capability in accurately analysing multiphase fluid migration and dynamic fluid-grain interactions in porous media. We are confident in considering this model a powerful tool to illustrate the micro-mechanisms of multiphase flow in deformable porous media.

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