

Pore Network Modelling of Gas Flow Processes in Porous Media with Special Application to CO₂ Sequestration

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Abstract

This thesis describes the development of a pore network model and its application to the analysis of the underlying physical mechanisms governing gas flow behaviour in porous media. The main focus of the study is CO₂ and CH₄ injection for EOR and storage applications as well as the evolution of solution gas following depressurization of hydrocarbon-saturated porous media. The model incorporates algorithms that dynamically track interface movements during both steady and unsteady-state flow under the coupled influence of capillary, gravity, and viscous forces. The model has been validated against laboratory experiments and the roles played by key system parameters have been identified.

For injection processes, simulation results show that gravity-driven regimes fall into two broad categories of quasi-stable and migratory regimes, depending on the governing Bond number. The transition from non-dispersive to dispersive migratory flow was found to be largely independent of injection rate but a strong function of pore size distribution variance and system connectivity. CO₂ and CH₄ regimes in brine were found to exhibit striking similarities, suggesting that CH₄-brine relative permeability curves could be used to accurately parameterize simulation models of CO₂ storage in aquifers. Decreasing the interfacial tension was found to dampen viscous fingering but exacerbates gravity override which suggests that standard laboratory methods for analysing CO₂ EOR processes are likely to overestimate displacement efficiency. Other sensitivity studies highlight the pore to core scale variables that control caprock sealing mechanisms, and residual and solubility trapping during CO₂ injection for storage, and their implications at the reservoir scale.

For depressurization, simulations performed on a pore network anchored to measured petrophysical properties of a 0.23mD fractured chalk core from a North Sea reservoir show a very weak correlation between depletion rate and critical gas saturation, contrary to conventional belief. Depressurization oil recovery efficiency was found to increase with increase in initial water saturation but the presence of fractures caused the critical saturation to decrease by approximately 60%.

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DECLARATION STATEMENT

(Research Thesis Submission Form should be placed here)

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