An efficient and robust fully implicit pore-network model for the pore-scale simulation

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Pore-network model (PNM) aims to capture pore-scale phenomena in a computational efficient manner with the help of simplified porous media geometry. Quasi-static PNM focuses on capillary driven flow in the system near the equilibrium state, while dynamic PNM takes also the impact of viscous forces into account to compute transient flow. System of free-flow coupled with porous medium flow is ubiquitous in natural applications (e.g. the evaporation of water from partially saturated soil as wind flowing over). To simulate the flow in the porous medium in such coupled systems, fully implicit dynamic PNM is suitable. That is because it doesn't impose restriction on the time step size during solving the flow, which is normally required by different explicit and semi-fully implicit pore-network algorithms[1][2].

In this study, we introduce a fully implicit pore-network model and discuss the related modeling and numerical challenges. One main challenge is to deal with the discontinuity occurring in local relative permeability of phases due to invasion and snap-off in the pore-throat. This discontinuity causes convergence issues during the simulation. To handle this, we propose approaches such as different kinds of regularization strategies. Furthermore, the new scheme is verified and validated for different test cases.

References

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