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Transport of deformable polymer particle gels in heterogeneous porous media by IB-LBM simulation

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Non-uniform fluid displacements in heterogeneous porous media are commonly observed, while are unfavorable in oil/gas recovery processes. Recently, the deformable polymer particle gels such as preformed particle gel (PPG) [1] and soft micro-gel (SMG) [2] were successfully applied to improve the sweep efficiency under such bad conditions. Although experimental studies presented qualitative observations of their in-depth plugging and flowing diversion capabilities, deeper numerical mechanisms on the deformable polymer micro-gels for enhanced oil recovery (EOR) are still rare [3]. The difficulties mainly lie in the following reasons: (1) the migration of deformable polymer particle gels is non-continuous, invaliding the classical continuum based theories; (2) viscoelastic behaviors of the gel particles should be considered and (3) the problem is confined in the complex porous geometries.

In this paper, an Immersed Boundary-Lattice Boltzmann (IB-LBM) framework is established to capture the motion of viscoelastic polymer micro-gels in porous media. The LB method is used to solve the Navier-Stokes equations in a Eulerian coordinate for the main flow field. The fluid–particle interaction is carried out by coupling with the IB scheme within a Lagrangian coordinate. The viscoelastic deformation and behaviors of the particles are recovered by the capsule model containing a spring-network model and by setting another kind of fluid property.

Primarily, the critical size of a polymer particle gel to deform and pass through one single throat is studied. We find that the different geometry (particle-throat diameter ratio, the length of the throat), pressure gradient and the viscosity ratio are key factors. Thence we investigated the transport of the polymer micro-gels in the cross-shaped channel with heterogeneity. Once the gel is placed in the higher permeable zone, the resistance in this zone will increase. Thus the following injected water will be diverted into the lower permeable zone and help the residual oil displacement there. Our results improve the understandings of the mechanisms of the deformable polymer particle gel for enhancing oil recovery in heterogeneous porous media.

References

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