Contribution ID: **373** Type: **Oral Presentation**

A lattice Boltzmann based Darcy-Brinkman-Stokes method for micro-continuous two-phase flow

Wednesday, 15 May 2024 12:15 (15 minutes)

The transport of immiscible two-phase in porous media involves many scientific and engineering fields, such as hydrogeology, reservoir development and electrochemical energy storage. This kind of flow phenomenon usually occurs in multiscale pores from micro to macro, making direct numerical simulations suffered from huge computational costs. Considering the demand for simultaneously mimicking both porous Darcy flow at micro-continuum scale and free Stokes flow at pore scale, the Darcy-Brinkman-Stokes (DBS) method based on volume-averaged Navier-Stokes (VANS) equation is established recently and it has made great contributions to study seepage flow and imbibition phenomenon in multiscale media [1,2].

Lattice Boltzmann method (LBM), as a mesoscopic numerical technology, has achieved great progress for complex multiphase flow in porous media. Thus, the combination model of LBM and DBS has significant advantages in multiscale flow simulation compared to traditional scheme (FVM, FDM), e.g., it is able to capture the discontinuity of velocity gradient at free-porous interface, and does not need data transmission and special boundary treatment between regions with different scales.

In our work, the improved color-gradient model [3] and a novel volume averaging technique [4] have been applied, which considers the streaming of effective densities, a forcing term for pressure correction and a source term for error correction for two-phase's density ratios. By adding a total force term in moment space including continuum surface force, drag forces induced by porous matrix, we have correctly recovered the multiple-relaxation-time (MRT) LB equation to VANS equation through Chapman-Enskog analysis, and thus a multiphase DBS-LBM model has been newly-established. Meanwhile, a capillary force containing a numerical interaction parameter is implemented to mimic the apparent wettability in the spatially-distributed porosity field within micro-continuous porous areas. The standard validations have confirmed the accuracy and robustness of this new model, such as its flexible adjustability for interfacial tension and relatively low spurious currents, as well as it has good physical continuity at free-porous interface and stable numerical performance, especially in terms of simulating fluids with density/viscosity ratios. Besides, through the static droplet and dynamic capillary effect tests, the proposed interaction force has been demonstrated to be effective for trans-scale simulation of immiscible two-phase's transport and sorption behavior in multiscale pores.

In future study, developing this model to 3D is practical and straightforward, it will allow to simulate a larger multiscale structure at domain scale actually, where the parameters of micro-continuous porous areas can be obtained from grayscale CT scanning and experimental correlation. Moreover, a temporally varying porosity field can be incorporated by coupling the governing equations of solid components to simulate flow-structure problems in soft matter or particle clusters.

Acceptance of the Terms & Conditions

Click here to agree

Student Awards

I would like to submit this presentation into both awards

Country

China

Porous Media & Biology Focused Abstracts

References

[1] Carrillo, F. J.; Bourg, I. C.; Soulaine, C. Multiphase flow modeling in multiscale porous media: An open-source micro-continuum approach. Journal of Computational Physics: X 2020, 8. DOI: 10.1016/j.jcpx.2020.100073. [2] Lu, S. F.; Wang, Y. X.; Ma, M. Y.; Xu, L. Water seepage characteristics in porous media with various conduits: Insights from a multi-scale Darcy-Brinkman-Stokes approach. Comput. Geotech. 2023, 157, 13, Article. DOI: 10.1016/j.compgeo.2023.105317. [3] Ba, Y.; Liu, H.; Li, Q.; Kang, Q.; Sun, J. Multiple-relaxation-time color-gradient lattice Boltzmann model for simulating two-phase flows with high density ratio. Physical Review E 2016, 94 (2). DOI: 10.1103/PhysRevE.94.023310. [4] Bukreev, F.; Simonis, S.; Kummerländer, A.; Jeßberger, J.; Krause, M. J. Consistent lattice Boltzmann methods for the volume averaged Navier–Stokes equations. J. Comput. Phys. 2023, 490. DOI: 10.1016/j.jcp.2023.112301.

Conference Proceedings

I am interested in having my paper published in the proceedings.

Primary author: Mr LIU, Yang (Tsinghua University)

Co-authors: Mr FENG, JingSen; Prof. MIN, JingChun (Tsinghua University)

Presenter: Mr LIU, Yang (Tsinghua University)

Session Classification: MS07

Track Classification: (MS07) Mathematical and numerical methods for multi-scale multi-physics, nonlinear coupled processes