Contribution ID: **279** Type: **Poster Presentation**

Coupling an immersed boundary method with local front reconstruction for modeling highly accurate contact line dynamics

Tuesday, 20 May 2025 15:05 (1h 30m)

Multiphase flows in the presence of complex solid geometries are omnipresent in porous media processes. Resolving the associated phenomena on a pore level requires the accurate capturing of capillary forces, contact line dynamics and viscous resistance. Frequently, front capturing methods are used to present fluid-fluid interactions, i.e. the Volume of Fluid method (VoF). There, the accuracy depends on the reconstruction of the interface from an indicator function, effectively requiring a high resolution to meet common accuracy requirements and special treatment for multiphysics modeling.
As an alternative we implemented three- phase contact line dynamics for the front tracking method Local Front Reconstruction Method (LFRM) [1]. The fluid-solid interactions are accounted for by enforcing the no-slip boundary condition at the solid surface, which is done using a second-order implicit Immersed Boundary Method (IBM) [2]. Coupling of these methods consists of dynamically enforcing the local contact angle of the fluid-fluid interface with the solid surface. Additionally, the existence of a sharp interface allows for a high local control of the application of additional transport phenomena.
Here we describe the numerical model that is used to manipulate the fluid-fluid interface to enforce the local contact angle and assess its performance using droplet spreading simulations on flat and spherical surfaces. The equilibrium droplet shape (i.e. the radius, height and interface outline), interfacial pressure difference, surface tension force and spurious currents are compared to analytical solutions and literature standard front capturing methods. The results show an excellent match with the analytical solutions with error margins below 1% for the interfacial shape and pressure difference of almost all cases, as well as error norms in the order of 0.01% for the surface tension force and spurious currents. These error values are lower than for state-of-the-art front capturing models [3,4]. Furthermore, the model is extended with a coupling to discrete surface meshes, e.g. provided in the STL format. With this additional functionality, the model provides a pathway for modeling interface dynamics in complex geometries and a platform for further coupling with transport phenomena.

Country

Netherlands

Acceptance of the Terms & Conditions

Click here to agree

Student Awards

Water & Porous Media Focused Abstracts

References

[1] S. Shin, I. Yoon, D. Juric. "The local front reconstruction method for direct simulation of two-and three-dimensional multiphase flows". In: Journal of Computational Physics, vol. 230.17 (2011), pp. 6605–6646. Doi: 10.1016/j.jcp.2011.04.040 [2] N. G. Deen, S. H. Kriebitzsch, M. A. van der Hoef, J. Kuipers. "Direct numerical simulation of flow and heat transfer in dense fluid–particle systems". In: Chemical Engineering Science, vol. 81 (2012), pp.329–344. doi:10.1016/j.ces.2012.06.055. [3] S. Afkhami and M. Bussmann. "Height functions for applying contact angles to 2D VOF simulations". In: International journal for numerical methods in fluids, vol. 57.4 (2008), pp. 453–472. [4] H. V. Patel. "Direct numerical simulations of multiphase flow through porous media". PhD thesis. 2019.

Primary authors: RIEDER, David (TU Eindhoven); GARCÍA LLAMAS, Cristina (Eindhoven University of Technology)

Co-authors: Prof. BALTUSSEN, Maike (TU Eindhoven); Mr JANSSEN, Tom (TU Eindhoven); Prof. KUIPERS, Hans (TU Eindhoven)

Presenter: RIEDER, David (TU Eindhoven)

Session Classification: Poster

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