Proceedings of the Canadian Society for Mechanical Engineering International Congress 2020
CSME Congress 2020
June 21-24, 2020, Charlottetown, PE, Canada

Numerical study of drop behavior through a pore space

Fenglei Huang[1,2*], Zhe Chen[1], Zhipeng Li[2], Zhengming Gao[2], J.J. Derksen[3], Alexandra Komrakova[1]
[1]Department of Mechanical Engineering, University of Alberta, Edmonton, Canada
[2]School of Chemical Engineering, Beijing University of Chemical Technology, Beijing, China
[3]School of Engineering, University of Aberdeen, Aberdeen, UK

*e-mail address: fenglei@ualberta.ca

ABSTRACT

Multiphase flow through porous media is widely encountered in numerous processes including oil recovery, pharmaceutical processes with microreactors, flow through porous filters of fuel cells, and filtration processes for water purification. Macroscopic characteristics of such flows depend on microscopic phenomena occurring at the pore level that are micrometer scale and less. Experimental studies of flow at these scales are challenging. Numerical simulations can bring additional insights to the understanding of flow at the pore scale and assist in developing constitutive equations to predict macroscale flow properties and determine flow conditions.

In this study, a phase-field lattice Boltzmann method (LBM) is used to simulate the behavior of a single drop immersed into another immiscible liquid and flowing through a single pore. The well-defined flow conditions allow for comprehensive validation of the numerical model before it is applied to more complex flow configurations. The equation governing the evolution of the phase-field is coupled with a velocity-based LBM scheme equipped with a weighted multiple-relaxation-time collision operator to improve numerical stability and accuracy. Three-dimensional, transient simulations of pure liquids were performed. Several benchmarks were also conducted: (1) recovery of Laplace pressure (the deviation between numerical and theoretical predictions is within 7%); (2) layered flow of two immiscible liquids with viscosity ratio up to 100 (the difference between numerical and analytical results is less than 1%). This is considered as a good agreement with the reference data and the adopted lattice Boltzmann method is capable of handling problems with large density and viscosity ratios. Then the effects of the pore shapes (cylinder and rectangle) on the breakup process are assessed. Velocity and pressure fields are visualized and quantified. The results have a good agreement with the theoretical predictions. The conditions for drop breakup are identified and related to the dimensionless numbers (Reynolds number *Re*, Weber number *We*, capillary number *Ca*, the viscosity ratio η and Cahn number *Ch* (the ratio of interface thickness and drop size)) that govern the flow. Our results show that high *Ca* and drops with sizes comparable to pore size promote drop breakage.