Contribution ID: **1077**

Type: **Poster Presentation**

The Nature of Multiphase Flow in Microfluidic Devices

Tuesday, 23 May 2023 16:10 (1h 30m)

Microfluidic devices offer unique opportunities to directly observe multiphase flow in porous media. However, they face difficulties in representing steady multiphase flow without fluctuating occupancy of locations in the network. The ability of two phases to form steady, intertwined flow pathways is a key property of 3D pore networks (Sahimi, 1994; King and Masihi, 2019). This is not possible in a two-dimensional network (Fisher, 1961) unless the flow paths of the two phases can cross at some locations in the network. Crossings are possible in a microfluidic network if wetting phase can form a bridge across the top and bottom of a gap between grains at a pore throat while nonwetting phase flows through the throat, as illustrated below.

We examine the conditions under which this is possible using the Surface Evolver software (Brakke, 1992) to determine fluid interface shapes in several different throat geometries (Cox et al., 2023). For relatively long straight or curved throats, the most common geometry in microfluidic networks used for modeling flow in geological formations, the capillary pressure for bridging is the same as that for snap-off. This means steady two-phase flow is not possible in these networks without fluctuating occupancy of the pore space. In other words, flow is forced into a regime where phases displace each other in the network, even at the very lowest capillary number.

Concave throats, as between cylindrical barriers, can support bridges over a substantial range of capillary pressure. The range of capillary pressures at which bridging is stable increases as throats become more strongly concave (i.e., pillar radius decreases) and for narrower throats. Steady two-phase flow would be possible in networks of pores with throats of this geometry.

For networks of this geometry, we estimate the range of fractional flows of wetting and nonwetting phase that could be sustained. In addition to bridging, the geometry of the wetting-phase flow paths are complex. To get past pore bodies occupied with nonwetting phase, wetting phase is restricted to the corners at the top and bottom of the pillars, as illustrated below. We input flow geometries determined by the Surface Evolver into the COMSOL numerical flow solver to esimate relative permeabilities of both phases for a given network realization. We choose assumptions that favor the flow of the wetting phase: for instance, penetration of the nonwetting phase just to the point where it connects across the network. The results show that the relative permeability of the wetting phase is roughly 1/10 of that of the nonwetting phase. If viscosities of the two phases were roughly equal, that the maximum fractional flow of wetting phase would be 0.1. For gas-water studies, where the viscosity ratio can be 50:1, the maximum fractional flow of water would be 0.2%. Imposing a fractional flow above this would guarantee fluctuating pore occupancy in the network.

Participation

In-Person

References

K. Brakke. The Surface Evolver. Exp. Math., 1:141–165 (1992).

S. Cox, S., A. Davarpanah, and W. R. Rossen. Interface shapes in microfluidic porous media: Conditions allowing steady, simultaneous two-phase flow. Transport in Porous Media 147:197–216 (2023).

M.E. Fisher. Critical probabilities for cluster size and percolation problems. J. Math Phys. 2: 620–627 (1961).
P.R. King and M. Masihi. Percolation Theory in Reservoir Engineering, World Scientific Publishing Europe Ltd. (2019).
E. M. J. Obbens. Analysis of Two Problems in Network Transport: Flow through static foam in artificial fractures and Steady-state two-phase relative permeabilities in microfluidic devices. MSc thesis, Delft U. of Technology (2022). Available from university archive, https://repository.tudelft.nl/.
M. Sahimi, Applications of Percolation Theory, Taylor and Francis (1994).

MDPI Energies Student Poster Award

No, do not submit my presenation for the student posters award.

Country

Netherlands

Acceptance of the Terms & Conditions

Click here to agree

Energy Transition Focused Abstracts

This abstract is related to Energy Transition

Primary authors: ROSSEN, William (Delft University of Technology); Prof. COX, Simon (Aberystwyth University); DAVARPANAH, Afshin (Aberystwyth University); OBBENS, Ewald (Delft U. of Technology)

Presenter: ROSSEN, William (Delft University of Technology)

Session Classification: Poster

Track Classification: (MS11) Microfluidics and nanofluidics in porous systems