Statistical mechanics of porous media flow

A. Hansen

PoreLab, Norwegian University of Science and Technology, Trondheim, Norway

Immiscible fluids fighting for the same pore space when simultaneously flowing in a porous medium produce complex and correlated structures which today may be modeled with a previously unattainable precision due to the rapid growth of both experimental visualization techniques (CT, MR etc.) and computational techniques (e.g. the Lattice Boltzmann algorithm). What is, however, still lacking today is a theoretical framework that describe these complex patterns; that is able to bind the observations and modeling together so that they become more than catalogues of data. I will in this talk review the current status on using statistical mechanics as a tool to device such a description.

I will demonstrate that the configurational probability, that is the probability that a given distribution of the immiscible fluids is proportional to the inverse of the total flow rate. This paves the way for a new Monte Carlo technique to simulate immiscible flow in porous media. An early version of this Monte Carlo technique was published in Ref. [1]. I will here present a new version of the technique which rectifies some weaknesses that has appeared in the published algorithm.

I will discuss the ensemble distribution relating the joint probability between different pore-scale parameters [2] such as flow rate and position of interfaces in the pores. I will present constraints on the form this distribution may take and demonstrate their physical consequences. I then use the ensemble distribution to construct a generating function that produces among other macroscopic flow parameters, the average flow velocity of each fluid and the volume flow rate of each fluid.

Lastly, I make contact between the statistical mechanics framework presented so far and non-equilibrium thermodynamics based on a budget of the entropy production in the system due to viscous dissipation. The interplay between intensive and extensive variables plays a key role in this discussion.

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[l] I. Savani et al., Transp. Porous Media **116**, 869 (2017).

[2] I. Savani et al., Phys. Rev. E **95**, 023116 (2017).

[3] A. Hansen, ArXiv:1605.02874.