Contribution ID: **107** Type: **Poster Presentation**

Experimental evaluation of percolation in evolution of flow

Wednesday, 1 June 2022 14:50 (1h 10m)

Many real-life applications are dependent on the physics of multiphase flow in porous media. Some important examples are geological carbon sequestration [1], enhanced oil recovery [2] , and remediation of groundwater/soil contaminated by a non-aqueous phase liquid (NAPL) [3]. The predictability and efficiency of the aforementioned scientific and industrial applications rely on developing a robust constitutive theory of two-phase flow in porous media. However, currently-used theories [4, 5], which involve capillary pressure and saturation, are not capturing the process- and history-dependent nature of the flow adequately.

To address this deficiency, some theories of porous media have been extended during the last decades. For instance, Hassanizadeh and Gray [7, 8] developed a macroscale theory for two-phase flow, in which they introduced the interfacial area between the three phases as additional state variable in describing two-phase flow $(P^c = f(a^{ns}, a^{ws}, a^{wn}, s^w))$. Later, Hilfer and Doster [9] showed that with a phenomenological approach they are able to reproduce experimental findings for capillary pressure and saturation, by differentiating between a percolating and a non-percolating saturation for the fluid phases. Although there has been extensive improvement in reproducing the hysteretic behaviour of the processes, the numerical and experimental investigations about the mentioned theories have not been able to prove their unconditional validity and show that they are dependent on the displacement process, the capillary number and the viscosity ratio under which the study was performed [6, 10].

In this work, we aim at examining the two aforementioned theories [7, 8, 9] by combining microfluidic experiments, optical microscopy and image processing techniques. We put the hypothesis of a potential synthesis of these theories at test, by investigating the role of interfacial area as a separate state variable, while making the distinction between connected and disconnected to the reservoir phases (percolating and not). We performed flow-controlled microfluidic experiments, consisting of sequential drainage and imbibition cycles. Subsequently, the images recorded during the experiments were processed and, among other parameters, the interfacial area, the curvature and contact angle of the terminal menisci were extracted. Using Young-Laplace equation, the capillary pressure associated with each wetting/non-wetting interface was calculated and averaged over interfacial area. Then, a simple, but physically-motivated, function was fitted to the experimental data for phase saturation, capillary pressure, and interfacial area. This was done once for all terminal menisci between the wetting and the non-wetting phase, and then separately for the percolating phase only. Our experimental results so far show that by taking the disconnections as a topological measure into account, we are capable of modelling the apparent hysteresis between capillary pressure and saturation more effectively than only having interfacial area as a state variable. The fitting seems to be valid for quasi-static as well as dynamic conditions irrespective of the displacement process, the capillary number and the viscosity ratio. We hypothesize that there can potentially be a single unique surface for a certain solid-fluids system, on which all triplets, for all combinations for the capillary number and viscosity ratio would land.

Acceptance of the Terms & Conditions

Click here to agree

MDPI Energies Student Poster Award

Yes, I would like to submit this presentation into the student poster award.

Country

Germany

References

[1] S. Bachu. Sequestration of CO2 in geological media: criteria and approach for site selection in response to climate change. Energy Conversion and Management, 41:953–970, 2000.
[2] A. Muggeridge, A. Cockin, K. Webb, H. Frampton, I. Collins, T. Moulds, and P. Salino. Recovery rates, enhanced oil recovery and technological limits. Philosophical transactions. Series A, Mathematical, physical, and engineering sciences, 372:20120320, 2014.
[3] S. E. Powers, L. M. Abriola, and W. J. Weber. An experimental investigation of nonaque- ous phase liquid dissolution in saturated subsurface systems: Steady state mass transfer rates. Water Resources Research, 28:2691–2705, 1992.
[4] R. H. Brooks and A. T. Corey. Hydraulic properties of porous media, 1964.
[5] M. Van Genuchten. A closed-form equation for predicting the hydraulic conductivity of unsaturated soils1. Soil Science Society of America Journal, 44, 09 1980.
[6] N. K. Karadimitriou, S. M. Hassanizadeh, V. Joekar-Niasar, and P. J. Kleingeld. Micro- model study of two-phase flow under transient conditions: Quantifying effects of specific interfacial area. Water Resources Research, 50:8125–8140, 2014.
[7] S. M. Hassanizadeh and W. G. Gray. Mechanics and thermodynamics of multiphase flow in porous media including interphase boundaries. Advances in Water Resources, 13:169–186, 1990.
[8] S. M. Hassanizadeh and W. G. Gray. Thermodynamic basis of capillary pressure in porous media. Water Resources Research, 29:3389–3405, 1993.
[9] R. Hilfer and F. Doster. Percolation as a Basic Concept for Macroscopic Capillarity. Transport in Porous Media, 82:507–519, 2010.
[10] V. Joekar-Niasar, S. M. Hassanizadeh, and A. Leijnse. Insights into the Relationships Among Capillary Pressure, Saturation, Interfacial Area and Relative Permeability Using Pore-Network Modeling. Transport in Porous Media, 74:201–219, 2008.

Time Block Preference

Time Block A (09:00-12:00 CET)

Participation

Unsure

Primary authors: VAHID DASTJERDI, Samaneh; Dr KARADIMITRIOU, Nikolaos (Institute of Mechanics (CE), Stuttgart University); HASSANIZADEH, S. Majid (Utrecht University); STEEB, Holger (Universität Stuttgart)

Presenter: VAHID DASTJERDI, Samaneh

Session Classification: Poster

Track Classification: (MS06-B) Interfacial phenomena in multiphase systems