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Micro-PIV Measurements of Pore-Scale Flow of Water and Supercritical CO2 in 2D Circular Porous Micromodels at Reservoir Conditions

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Multiphase flow in porous media is relevant to a range of applications in the energy and environmental sectors. Recently, the interest has been renewed by geological storage of CO_2 within saline aquifers. The coupled flow dynamics of CO_2 and brine in geologic media must be better understood, particularly at the pore scale, because pore-scale phenomena, such as Haines jumps and shear-induced flows, represent a critical component of accurate large-scale modeling and predictions. Recent evidence also shows that wetting properties of the porous matrix significantly affects the multiphase flow and transport in porous media, and therefore challenges microscopic and macroscopic descriptions. To this end, the pore-scale flow interactions of water and liquid/supercritical CO_2 are presently being quantified in 2D circular porous micromodels at reservoir-relevant conditions (i.e., 80 bar, 21°C), in an attempt to accurately mimics the process of CO2 injection into saline aquifers. The circular micromodels used in these experiments were fabricated from silicon, with the porous matrix formed with arrays of 2D poly-disperse cylinders. Circular micromodels (i.e., radial displacement) are superior to rectangle ones (i.e., linear displacement), in the context that the former ones reduce boundary effects that are inherent in linear displacement. Fluorescent microscopy and the micro-PIV method are employed by seeding the water phase with fluorescent particles and tagging the CO_2 phase with a fluorescent dye. Doing so allows for simultaneous measurement of the spatially-resolved instantaneous water velocity field and quantification of the instantaneous spatial configuration of both phases [1]. High-speed cameras and a fast differential pressure transducer are used in order to temporally resolve the pore-scale flow. These spatially and temporally-resolved data are invaluable and imperative to understand the dynamics of certain pore-scale phenomena, such as Haines jumps, which occur with a time scale of no more than a few milliseconds [2]. Finally, measurements are performed under a variety of wettability conditions, in order to quantify the impact of wettability on the physics and to evaluate the role of capillary effects.

References

[1] Kazemifar, F., Blois, G., Kyritsis, D. C., & Christensen, K. T. (2015). A methodology for velocity field measurement in multiphase high-pressure flow of CO2 and water in micromodels. Water Resources Research, 51(4), 3017-3029.
[2] Li, Y., Kazemifar, F., Blois, G., & Christensen, K. T. (2017). Micro-PIV measurements of multiphase flow of water and liquid CO2 in 2-D heterogeneous porous micromodels. Water Resources Research, 53.

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Authors: LI, Yaofa (University of Notre Dame); KAZEMIFAR, Farzan (California State University Sacramento); Dr BLOIS, Gianluca (University of Notre Dame); Prof. CHRISTENSEN, Kenneth (University of Notre Dame); CHEN, Yu (University of Illinois at Urbana-Champaign); KOHANPUR, Amir (University of Illinois at Urbana-Champaign); VALOCCHI, Albert (Univ Illinois)

Presenter: LI, Yaofa (University of Notre Dame)

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