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Wettability effect on Pore-filling events during two-phase flow

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Wettability is a crucial factor for pore-filling events in multiphase flow. If the fluid interface passes an abrupt variation in the cross-section of the porous medium, a sudden redistribution takes place, commonly known as Haines Jump. Different wettabilities of the solid substrate affect the global displacement pattern, the fluid trapping and the hysteretic saturation. Furthermore the effect of wettability needs to be considered in numerical and analytical models to enable the accurate description of the pressure response during such a pore-filling event.

To better understand the effect of wettability, we conduct a series of microfluidic experiments of drainage and imbibition processes with three displacement velocities for two-phase flow. The PDMS micro-models are designed with a depth of 100 μm and with one square pore body of 800 μm in width and length which is connected to 4,000 μm long inlet and outlet channels with a height of 150μm. The models are rendered with three surface wettabilities of 40°, 95° and 150° static contact angle (measured with the sessile drop method for a water droplet on PDMS in air). Three fluids are used, fluorescent-dyed water, Fluorinert-FC 43 and crude oil, to investigate the displacement of: water-air, water-fluorinert and water-crude oil. By reversing the flow direction after each pore-filling experiment, also the corresponding drainage or imbibition process was captured. Confocal laser scanning microscopy (CLSM) is applied to recognize the fluid interface and monitor its movement. With an inserted pressure transducer in the upstreaming plastic tube, the pressure change during the events was continuously measured. The collected pressure curves are compared with existing analytical solutions. Due to the limitations of these solutions and to enable the prediction of the interface movement for a variety of wettabilities, we are correspondingly developing a numerical model based on the volume of fluid method (VOF) which will be validated with the presented experimental data.

We found for the two cases with contact angles of 95° and 150° similar residual saturation levels of the wetting phase for all imbibition and drainage processes. For the case with 40° contact angle, the wetting phase can almost fully saturate the pore after imbibition and can be fully displaced by the non-wetting phase after drainage. Besides, we noticed that wettability plays an important role in thin-film generation and the thickness of the film during displacement. In our case, the crude oil shows non-irregular interfaces in pore-filling behavior during imbibition and drainage, and easily forms a slug flow of water in the micro-channel for the relatively high capillary numbers (3.1E-7 and 1.5E-6). Furthermore, crude oil, which is the wetting phase to PDMS, has remarkable residuals on the top and bottom surfaces of the channel compared to the experiments with fluorinert which is also wetting PDMS, due to the chemical heterogeneity of the components with various adsorption to the PDMS.

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References

Time Block Preference

Time Block B (14:00-17:00 CET)

Participation

Unsure

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