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Investigation of the corner flow development in porous media in the absence of main front movement

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Understanding multiphase flow in porous media is essential in various fields, including hydrocarbon recovery, natural gas and CO2 storage, fibre-reinforced composites, and underground water remediation. Capillary snap-off, i. e., breaking up of the fluid interface and forming isolated non-wetting phase ganglia, plays a crucial role in the non-wetting phase trapping and consequently the two-phase distribution. Many studies have focused on the understanding of corner/film flow that drives snap-off in porous media. Various numerical and experimental analyses show that the corner/film flow, as it develops before the breakthrough, tends to be much dominant at lower capillary numbers.

In this study, fluid flow experiments have been performed in 2.5D borosilicate micromodels with the known contact angle of $42 \pm 2°$. The micromodel consists of uniform circular posts with diameters ranging from 1 to 2 mm, creating a throat to pore aspect ratio of 5. The micromodel is horizontally placed to eliminate the gravitational forces and is initially saturated with drakeol 35 (viscosity 178 mPa.s). Oil is linearly displaced by distilled water at rates of $0.1, 1, 5, 10, 20$, and 30 $\mu l/min$ resulting in the range of capillary numbers from 1.2×10^{-8} to 3.6×10^{-6}. The advancement of the oil-water interface, before and after breakthrough, are recorded using Canon 5DSR camera at 1 frame per minute where the development of corner/film flow is recognized in the form of snapped-off water clusters. Along with recovering known results for displacement before breakthrough where the corner/film flow develops ahead of the main front at low capillary numbers, it is found that the corner/film flow can also develop after breakthrough in the absence of main frontal advancement. This happens when the fluid displacement is done above a critical capillary number.

A quantitative analysis is performed by measuring the changes in the volume of oil displaced by water, the number of isolated water clusters, and their size distribution. For all capillary numbers, the corner flow, quantified by the volume of displaced oil and number of water clusters, develops for sometimes after breakthrough until it reaches a plateau. It is shown that the corner/film flow development rate is an increasing function of capillary number, mainly due to the higher bulk aqueous phase pressure at increased injection rates. The size of isolated water clusters is almost identical between capillary numbers. A close inspection of displacement images shows that the water clusters mostly form in the smallest pores. In contrast, the prominent pores are mainly saturated with oil and the water flow is limited to their corners. Thus, similar to pre-breakthrough cases, the pore geometry may play an important role in the formation and size distribution of water clusters after breakthrough.

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Participation

In person

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