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A Model for Counter-Current Spontaneous Imbibition through Interacting Capillaries

E. Unsal, G. Mason

Department of Chemical Engineering, Loughborough University, Loughborough, Leics, UK
(E.Unsal@lboro.ac.uk / Fax: +44-1509 223 923 / Phone: +44-1509-222513)

We present a study for counter-current imbibition, where the wetting and the non-wetting phases flow spontaneously in opposite directions due to capillary forces; whereas both phases flow in the same direction during the co-current flow. Spontaneous counter-current imbibiton plays an important role in subsurface flow, especially for oil recovery from fractured rocks. We conducted experiments using simple model pore systems to study both co- and counter-current imbibition. The pore geometry was more complex than a regular circular capillary and the pores were interconnected. The capillaries were formed by placing a rod in an angled slot, which was carved at the top surface of the cell. A glass plate was placed to cover the slot to form a capillary on each side and along the rod. Different capillary cross-sections were obtained by changing the rod size, number of the rods, the slot angle and distance between the rod and the glass plate. Two menisci formed when the rod touched the glass, while three menisci formed and the capillaries were interconnected when there was a gap present. The latter geometry made the flow behaviour through the capillaries quite complicated, since cross-flow occurred. The effect of cross-sectional shape of the capillary on the flow was studied. The Mayer & Stowe-Princen method was used to calculate the capillary pressures of the menisci in these complex cross-sections. In addition to the experimental work, a numerical model for counter-current imbibition was developed for all different capillary shapes. The pores were modelled as interconnected capillaries and the fact that the positions of menisci in the capillaries are dependent of each other was considered. Our model gave satisfactory results.