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Experimental and theoretical evidence for energy signal indicating flow regimes for two phase flow in porous media

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Many studies have been dedicated to examining flow regimes using two key parameters: viscous ratios and capillary numbers Ca. However, only a few studies have elucidated mechanisms that govern different flow regimes and how the work of displacement and surface aeras alter within porous media, as well as their influence on flow behavior is still unknown. In this study, we experimentally investigate the combined effect of wettability and flow rates on immiscible fluid-fluid displacement using high-resolution imaging in microfluidic flow cells with two different viscous ratios. We investigate morphology of oil cluster and displacement front and further calculate the relative change of energy conversion based on external work and surface energy. The morphology of invasion patterns in brine-silicone is sharper than that in brine-decane displacement, with the indication of larger ratios of length and width for fingers. The signature of the transition between the three regimes manifests itself in the efficiency of conversion of the external work to surface energy. Efficiency of conversion decreases with the increase of contact angles. With the increase of Ca, Efficiency of conversion reduces greatly to approximately zero. In high M displacement, efficiency of conversion is consistently higher than that in low M displacement. The signature of the transition between the three regimes (viscous flow, capillary dominated flow and capillary -stable displacement flow regime) manifests itself in the fluctuations of the external work and surface energy. We propose that it is possible to determine the nature of multiphase-flow displacement from the energy signal.

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