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Quantitative determination of the threshold pressure for a discontinuous phase to pass through a constriction using microscale simulation

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The displacement of oil by water in a porous rock leads to a disconnection of the oil phase as a result of the competition of viscous and capillary forces. In this study, we performed two-dimensional numerical simulations where the Navier-Stokes equations are coupled with the phase field method to capture the dynamic behavior of a single oil droplet in a capillary channel with a constriction. We investigated the effects of contact angle, the radius of the constriction and droplet size, and their coupled effect. The numerical results indicate that the droplet can be pushed through the constriction at capillary numbers of approximately 10-4 for water-wet condition, while the droplet is observed to break for oil-wet condition at the same capillary numbers. Classical theory states that the viscous pressure must overcome the capillary pressure for a droplet to pass through a constriction. However, the analysis of the two forces have shown that the viscous pressure doesn' t always have to overcome the capillary pressure for a droplet to pass through a constriction, for example in the case where the radius of the constriction of the pore space is less than four times the radius of the widest region, the capillary pressure is larger than the viscous pressure which is contrary to the classical theory. The pressure to be applied for the droplet to pass through the constriction is larger at small constriction radii and for larger droplets. This behavior becomes more significant when the wettability surface condition is strongly water-wet. Through regression analysis, a mathematical model to determine the threshold pressure required to displace the droplet is established.

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Participation

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