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Influence of fluids properties and pore-throat structure on snap-off: microfluidic experiments and theoretical analysis

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The snap-off phenomenon occurs when a non-wetting phase flows from a water-wet constriction into a pore filled with water, resulting in the separation of the non-wetting phase into droplets. This phenomenon is commonly observed in various fields such as petroleum development, chemical engineering, and carbon utilization and storage. Numerous studies have investigated the underlying mechanism and identified critical capillary numbers associated with snap-off. However, there is a limited amount of research that specifically examines the impact of fluid viscosity and pore-throat structure parameters on this phenomenon.
In this work, we study the snap-off process when the oil droplet passing through the microchannel with a rectangular cross-section. The microfluidic chips are made of PMMA and have different constriction widths, heights, and lengths. By compounding silicone oil with different viscosities, we were able to modify the viscosity of the non-wetting phase. Through microfluidic experiments, we analyzed various snap-off patterns. Furthermore, we constructed a phase diagram illustrating the snap-off behavior under diverse oil viscosities and pore throat structural parameters.
The findings demonstrate that there is an inverse relationship between the viscosity of oil and the critical capillary number of snap-off, as well as the range of capillary numbers associated with snap-off. This can be attributed to the fact that the viscous force hinders the snap-off. When the capillary number reaches a certain threshold, the oil flows through the pore throat rapidly, preventing the water film from adequately entering the throat to establish a force equilibrium. The capillary number range associated with snap-off expands as the throat length and depth increase. Snap-off is observed only when the throat depth surpasses a specific threshold value. In addition, the capillary number does not influence the size of daughter droplets, and they are approximately 1.3-1.5 times the diameter of the throat. This investigation could help control the snap-off occurrences in engineering scenarios through the manipulation of fluid parameters and capillary structure.

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