Dynamics of droplet pinch-off in acoustically actuated flow focusing devices

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The evolutions of the interfacial profile in the droplet formation process in a flow-focusing device were investigated (see Fig. 1).

![Fig. 1 Device configuration of flow-focusing geometry](image)

The understanding in how the interface profile evolves assists the accurate prediction of the moment of pinch-off and hence the precise control of the sizes of droplets. Two critical curvature values were discovered from experiments which represent the liquid thread detachment from walls and the onset of pinch-off during the formation process. The rate of curvature evolution depends on the flow-rate ratio between the two immiscible fluids and was modulated by acoustic actuation. Three distinct evolution regions were obtained which represent respectively the periods before and after the liquid thread detachment from walls and after the onset of pinch-off till final breakup. In a bounded fluid, the pinch off process is characterized by a series of equilibriums rather than the capillary instability in an unbounded fluid. In the case under acoustic actuation, the droplet formation process is accelerated; both the time till the liquid thread detachment from walls and the onset of pinch-off are speeded up. Phase-averaged two-phase micro resolution particle-image-velocimetry (μPIV) was applied to extract the oscillating fluid flow velocity fields in the two immiscible phases. Acoustic streaming flow fields were revealed in both the continuous and the dispersed phases (see Fig. 2). A periodic contracting and expanding flow field in the dispersed phase and a steady streaming flow field in the continuous phase were found. The steady streaming flow field in the continuous phase provides an additional driving force which helps to drive the continuous phase into the gutters between the walls of orifice and the liquid thread within the orifice. This additional flow facilitates the onset of breakup and thus smaller droplets are formed upon acoustic actuation. As compared with flow fields without acoustic actuation, droplet breakup is only affected by the flow-rate dependent shearing flows at the fluid-fluid interface.

![Fig. 2 Acoustic streaming flow within the dispersed phase](image)

References