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Droplet Flow Regimes in a T-Section Microchannel: Assessment of Volume of Fluid Formulations

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Droplet flow regimes, Interfacial dynamics, Volume of Fluid method, Parasitic currents, Direct Numerical Simulations

Abstract:
Multiphase flow in microfluidic devices that produce identical droplets/ bubbles at a known frequency has gained attention due to its use in biomedical, chemical and engineering applications.

In this numerical study, we investigate the flow dynamics in a 2D 'T'shaped microfluidic channel where two fluids (wetting and non-wetting) are injected orthogonally and meet at a junction. We use Direct Numerical Simulations (DNS) with the Volume of Fluid (VoF) method where the fluids are distinguished based on a volumetric colour function. DNS-VoF captures the topological changes (ex: pinch-off of an interface) automatically, unlike other methods (ex: Front-tracking) which require manual interventions.
However, *Parasitic currents* (PC) around the interface potentially occur due to inaccurate computations of the capillary force $\mathbf{F}_\sigma$. The *Continuum Surface Force* (CSF) [1] expresses $\mathbf{F}_\sigma$ in a simplistic manner. However, the capillary terms are imprecise and show larger PC. To reduce PC, several formulations are available, such as *Sharp Surface Force* (SSF) [2, 3] and *Filtered Surface Force* (FSF) [3]. These formulations advect the interface numerically while trying to retain a sharp interface. Alternatively, *Piecewise Linear Interface Construction* (PLIC) [4], geometrically constructs and advects the interface. Height functions are used to increase the order of accuracy in computing $\mathbf{F}_\sigma$.

Though a number of DNS-VoF validations with experiments and analytical models are available [5], a systematic investigation of the potential impact of PC on the droplet formation (possibilities of initiating a premature break-up or skipping pinch-off) and on the droplet length for a wide range of capillary number are still not available. Indeed, our numerical simulations show different flow regimes in the microchannel using the above mentioned VoF formulations for the same flow conditions. Further, when there is a pinch-off, the length of the droplet formed also varies for different VoF formulations. To validate the accuracy of the numerical solvers we make use of a solution that can be derived using geometrical and force balancing techniques.

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