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# Fundamental investigation of compound jet pinch-off and double-emulsion formation in glass capillary microfluidic devices.

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**Keywords**: Double emulsion, multi-phase flow, Glass capillary microfluidic device. VOF-CSF model. Dripping regime, Jetting regime.

**Abstract**: A three-phase Volume of Fluid–Continuum Surface Force (VOF–CSF) numerical model has been developed to parametrically study the break up mechanisms of compound jets, and formation of double-emulsions in dripping and jetting regimes within glass capillary microfluidic devices (introduced by Utada et al. 2005). The model was validated with both available analytical solutions, and conducted experiments in this study, and a very good agreement was achieved in terms of predicting formation of double-emulsion droplets in dripping, narrowing jetting and widening jetting regimes. This study firstly focused on the impact of flow rates, fluid properties, and device geometry (13 parameters) on droplet formation regime, droplet size, and shell thickness. Further, the results were used to perform a comparative study on droplet pinch-off mechanisms in the different regimes.

An increase in the outer phase flow rate causes a reduction in droplet size, and a transition from dripping to narrowing jetting regime. However, during the transition a short-term increase in droplet size was observed which was experimentally reported by Utada et al. 2005 as well, but yet to be explained. The reason is caused by a sudden jump in the compound jet velocity while the outer phase velocity is gradually increasing, leading to a reduction in the velocity gradient at the outer interface and consequently lowering the shearing level, and increasing the droplet formation time which results in an increase in droplet size. In dripping and widening regimes the compound jet pinch-off mechanism was accelerated due to the presence of a vortex flow around the neck, while in the narrowing jetting, no vortex flow was observed and the pinch-off occurred because of high level of the velocity at the upper end of the narrowing compound thread compared with the lower end.

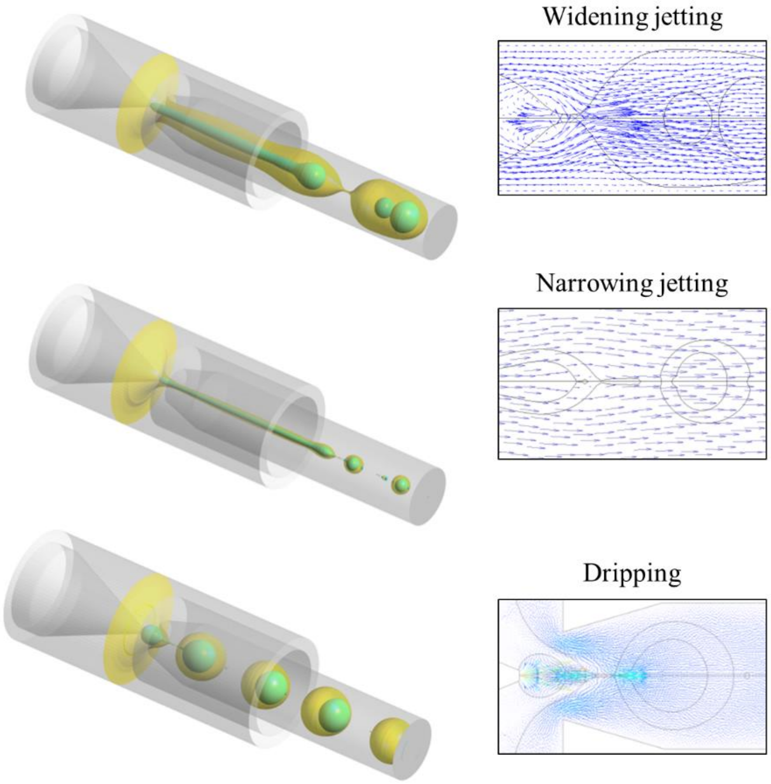


**Figure 1**. Double-emulsion droplet formation in different regimes along with corresponding velocity vectors during the compound jet pinch-off (Nabavi et al. 2015).

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