Numerical Study of Droplet Formation Inside a Microfluidic Flow-Focusing Device

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Abstract

Droplet-based microfluidics has been widely used to synthesize polymer nanoparticles with various sizes, shapes and morphologies [1, 2]. Most commonly used micro-emulsification devices include coflow devices, cross-flow devices (T-junction), and flow- focusing devices [3]. Experimental investigations on the droplet breaking processes have been carried out by many researchers [4, 5], but the effects of operating conditions such as flow rate and viscosity on droplet breaking processes have not been fully understood. Numerical simulations have provided an opportunity to obtain insights of droplet breaking process. In this study, we study the droplet breaking process of silicone-oil in water, which has been studied through experiments by Nie et al. in 2008[4]. The two phase flow is modeled by level-set method, and the simulations are carried out through laminar two-phase flow package, level-set in COMSOL Multiphysics. A typical mesh used in numerical simulations contains 15,934 elements as shown in Figure 1, of which the grid resolutions in the orifice region, the outlet and near wall are refined to capture the gradient changes. In this study, silicone oil of various viscosities (10cp, 20cp, 50cp and 100cp) is injected from the center inlet as the dispersed phase, and water is injected from the side inlets as continuous phase. While remaining the flow rate of dispersed phase (Qi), the flow rate of the continuous phase (Qo) is varied to study the effect of capillary number. As seen from Figure 2, the numerical simulations can capture the droplet breaking process fairly well. The predicted droplet shape and size agree with which were found in experiments. Monodispersed and polydipsersed droplet breaking process are observed from both the experiments and numerical simulations. As shown in Figure 3, the primary droplet sizes matches fairly well. The detailed analysis and parametric studies of the pressure evolution during breaking process will be presented in the final paper (to be submitted later). The numerical simulations show that the flow ratio and viscosity ratio play important role in droplet breaking process. The pressure evolution leading from different operating conditions results in monodispersed and polydipersed droplet breaking processes.

Reference

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Figures used in the abstract

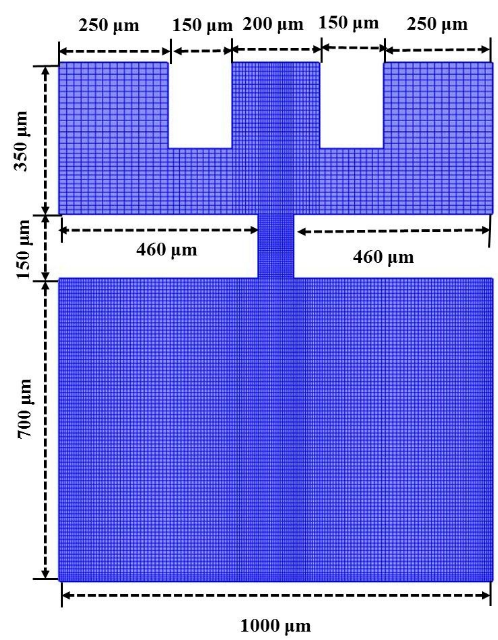

Figure 1: The geometry and mesh used in numerical simulations.

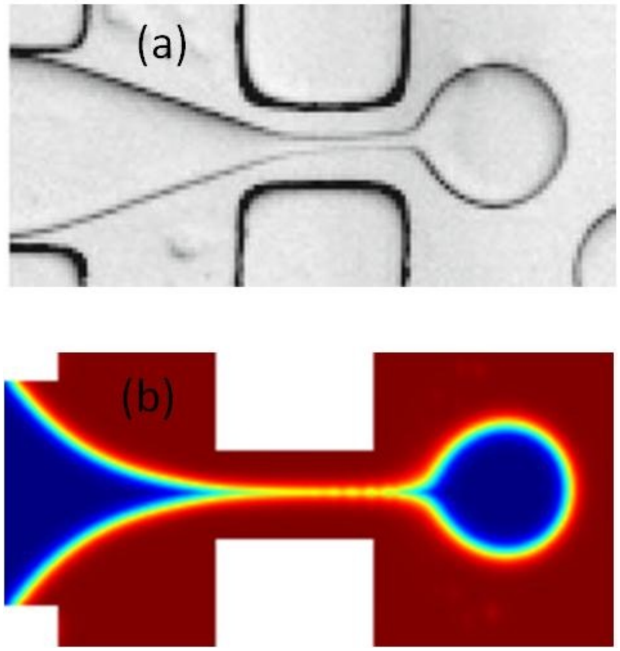

Figure 2: Snapshots of droplets formed from silicone oil with viscosity of 100 cp (a) from experiments carried out by Nie et al. [4] (b) from numerical simulation. The flow condition is Qi = 0.04 mL/h, Qo/Qi = 20.

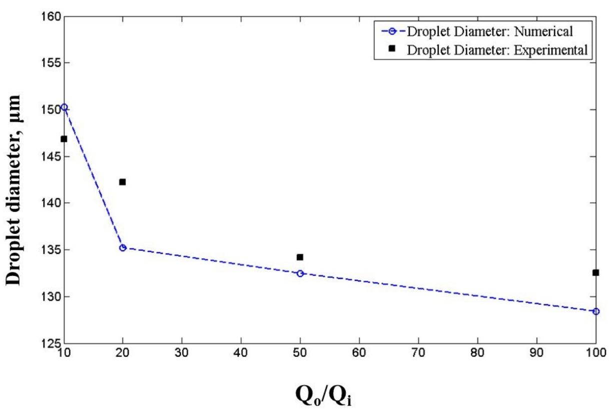

Figure 3: Comparison of primary droplet sizes obtained from both experiments and numerical simulations.