μPIV Study of Passive Droplet Generation in a T-junction in the Squeezing, Transition, and Dripping Regimes

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This paper presents the results from the quantitative examination of liquid droplets generation a T-junction microchannel design with focus on the different generation regimes. The regimes were defined by the capillary number (Ca) of the generation (Xu et al. 2008). The study utilized micro particle image velocimetry (micro PIV) that was triggered with an external system. The triggering assembly is based on optical detection of the liquid droplets at specific stages of the generation process (see Fig. 1). This approach allowed for averaging the micro PIV results of different monodisperse droplets since it is impossible to perform micro PIV result averaging for one droplet with typical micro PIV systems (van Steijn et al. 2007).

The examined droplet generation regimes were: squeezing (Ca = 0.001), transition (Ca =0.005), and dripping regime (Ca = 0.02). There were two types of fluids tested for each generation region: without surfactant and with SDS (Sodium dodecyl sulfate) above the critical micelle concentration (CMC). Experimental results indicate that both squeezing and transition regimes share many similarities in their velocity profile in both filling and start of pinch-off phases. At the planes closer to the channel top and bottom walls the flow field in the droplet phase is dominated by the contact with the lubrication region of the droplet and the maximum velocity occurs close to the channel gutter region. At the mid-plane the velocity field in the squeezing and transition regime differed where high velocity regions were noticed for the transition regime compared to the squeezing regime. This pattern is indicative of the nature of the acting shear force that is present in the transition regime.

Droplet generation in the examined dripping regime differed from the squeezing and slightly from transition regime. During the filling stage of the dripping regime the maximum velocity regions are located at the middle plane of the channel. These patterns are indicative of the high shear that acts on the interface of the droplet phase. Droplet pinch-off in the dripping regime differs from the squeezing and transition where the pinch-off occurs downstream of the T-junction. Also, pinch-off starts with the thinning of the liquid thread close to the top and bottom walls and propagates to the middle region (see Fig. 2). Finally, the presence of a surfactant above the CMC concentration did not have an effect on the general velocity patterns for the examined droplet generation regimes as long as Ca was matched. However, the magnitude of the velocities differed for fluid conditions with a surfactant.

Fig. 1 A schematic illustration of the triggering and micro PIV assembly used in this work. The flow of the signal is indicated in the figure.

Fig. 2 The upper half of the three dimensional velocity vector plots of the start of droplet pinch-off in the dripping regime (Ca =0.02). The velocity magnitudes are in m/s.

References