Flow Focusing Droplet Generation Using Linear Vibration

A. Salari[1], C. Dalton[1]

[1]University of Calgary, Calgary, AB, Canada

Abstract

Droplet based microfluidics is a widely used technique in many industries such as drug delivery and lab-on-a-chip. Microbubble generation is widely used in a range of chemical, water treatment, metallurgy, and medical applications in order to facilitate heat and mass transfer, drug coating, and contrast agent generation. There are three major microchannel geometries that are used to generate micron-sized bubbles/droplets: cross flow focusing, co-flow focusing [1], and T-junction [2]. Fluid flow in microchannel geometries is dominated by viscous stress and pressure gradient, which both take place in low Reynolds numbers. In cross flow focusing, when two side flows reach the orifice, they make the central flow narrow and a jet-like flow is formed. If the side flows are tuned carefully, then the central flow will start to become discrete, and the central jet is converted into tiny droplets. There exists an ambient pressure chamber at the other side of the orifice. Using this mechanism, the central flow can be easily encapsulated. If gas is used as the central flow and liquid as the side flows, this mechanism will produce microbubbles. In this paper, the effect of linear vibration of the microchannel body on the microdroplet generation regime was investigated using 2D COMSOL Multiphysics® software. A two-phase flow regime, with water mixed with surfactant as the continuous side flows, and atmospheric air as the central flow, were used. The effect of vibration was modeled by assuming the vibration in the direction of central flow. Four vibration cycles were modeled using triangle functions to apply wall movement. The orifice dimension was 700×400 µm, and the channels width was 800 µm. In order to decrease the inlet effect on the flow regime, an 800 µm length microchannel was added to all inlets. Laminar flow was assumed for the water, and air was considered compressible. Figure 1 shows different flow regimes obtained in one vibration cycle and for three different inlet velocity ratios (Vg/Vl). It shows that for Vg= 0.007 m/s, the droplet generation occurred during the second half of the vibration cycle, while in Vg= 0.077 m/s and Vg= 0.047 m/s the droplet cannot detach from the central flow jet causing a non-stable flow regime. Figure 2 shows that if the angle between central and side flows is changed, the flow regime can be dramatically affected, resulting in a two-droplet generation mechanism. The simulation showed comparable results with the experimental data taken from our previous works [1, 2]. Also, the new droplet generation mechanism showed a potential application in generation of a wide range of droplet sizes to be used in drug delivery devices, contrast agents, etc. with a low cost fabrication technique. In summary, applying linear vibration to the conventional flow focusing technique can increase the chance of droplet generation, if the flow rate ratio is chosen accurately.

Reference

1. A. Salari et al., "An Experimental Review on Microbubble Generation to Be Used in Echo-Particle Image Velocimetry Method to Determine the Pipe Flow Velocity," J. Fluid. Eng-T ASME, 135, 034501 (2013).

2. M. Samie et al., "Breakup of Microdroplets in Asymmetric T Junctions," Phys. Rev. E, 87, 053003 (2013).

Figures used in the abstract

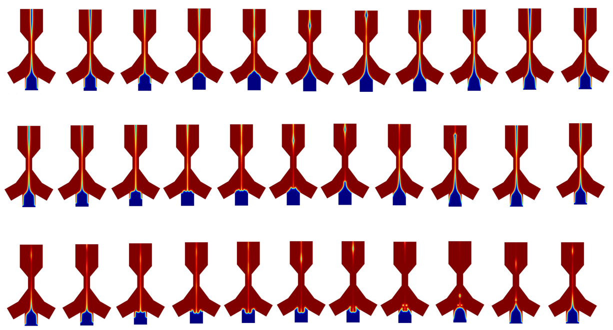

Figure 1: One vibration cycle for the microchannel configuration with 60° between central and side flow channels; vibration frequency and amplitude, and central flow velocity were kept constant at 50 Hz, 1 mm, and Vl= 0.17 m/s, respectively; top: Vg= 0.077 m/s; middle: Vg= 0.047 m/s; bottom: Vg= 0.007 m/s.

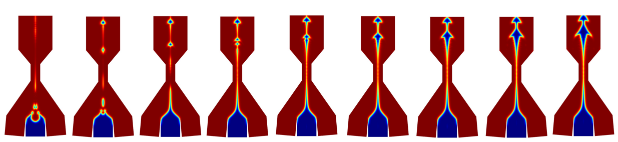

Figure 2: One single shot of the microchannel configuration with 5° between central and side flow channels; vibration frequency and amplitude, and central flow velocity were kept constant at 60 Hz, 1 mm, and Vl= 0.17 m/s, respectively; from left to right: Vg= 0.007 m/s, 0.017 m/s, 0.027 m/s, 0.037 m/s, 0.047 m/s, 0.057 m/s, 0.067 m/s, 0.077 m/s, 0.087 m/s.