Optimized Channel Geometry of a Flow-Focusing Droplet Generator for Parallelization

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Introduction

Microfluidics is a continuously growing research area that has shown promising results to revolutionize the standard and quality of human living. The micro-world, in which these fluidic systems exist, offers great scaling advantages over common macro-scale devices, such as chemical reactors, cell and tissue growth and study, disease diagnostic [1], [2].

Model Design & Simulation

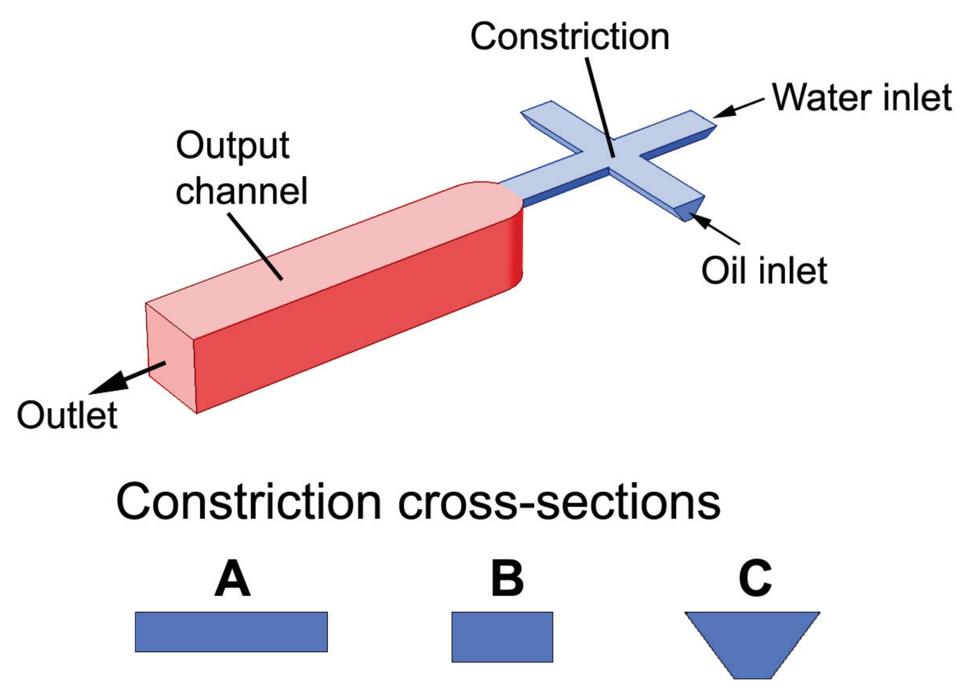

Figure 1. Flow-Focusing Microfluidic Droplet Generator Diagram. The device is comprised of a cross-shape constriction with different cross-sectional areas and a wider and deeper output channel (400x400 µm). A) Rectangular 285x61µm, B) Rectangular 150x75µm, and C) 200x100µm trapezoid with 50µm-wide minor base.

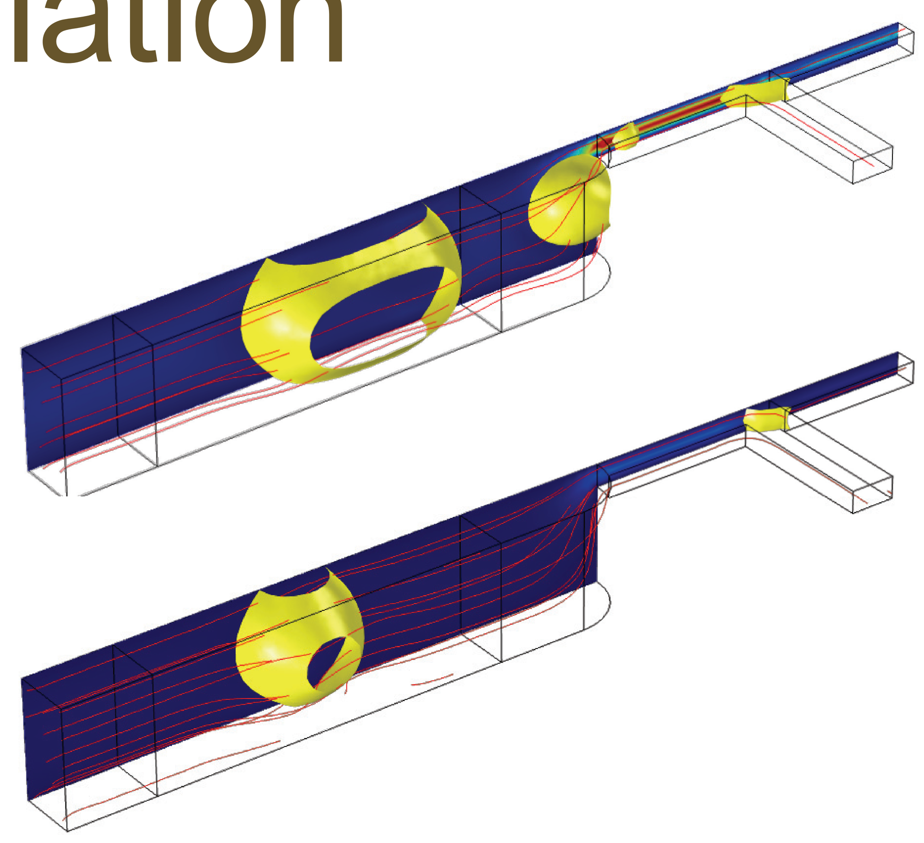

Figure 2. Flow-Focusing Microfluidic Droplet Generator Diagram. The device is comprised of a cross-shape constriction with different cross-sectional areas and a wider and deeper output channel (400x400 µm). A) Rectangular 285x61µm, B) Rectangular 150x75µm, and C) 200x100µm trapezoid with 50µm-wide minor base.

Results

Cross-sections	Dimensions (µm)	ΔD_{eff} @ 300 (µl/min)	ΔD_{eff} @ 30 (µl/min)
A	285x61	1.10	1.67
B	150x75	2.33	2.35
C	200x100, 50	2.12	2.59

Table 1. Droplet size Dynamic Range for the three different cross-sectional areas evaluated.

Using the post processing tools, we were able to create graphics that display the volume fraction of water in oil isosurfaces, velocity field streamlines of flow, and velocity magnitude at the axis of symmetry (Figure 2). The streamlines show a predominantly laminar flow in the channels, however at larger flow rates, stable current vortices appear at the height change where the constriction meets the output channel. The velocity magnitude along the plane of symmetry is higher at the constriction, promoting the focusing behavior of the device

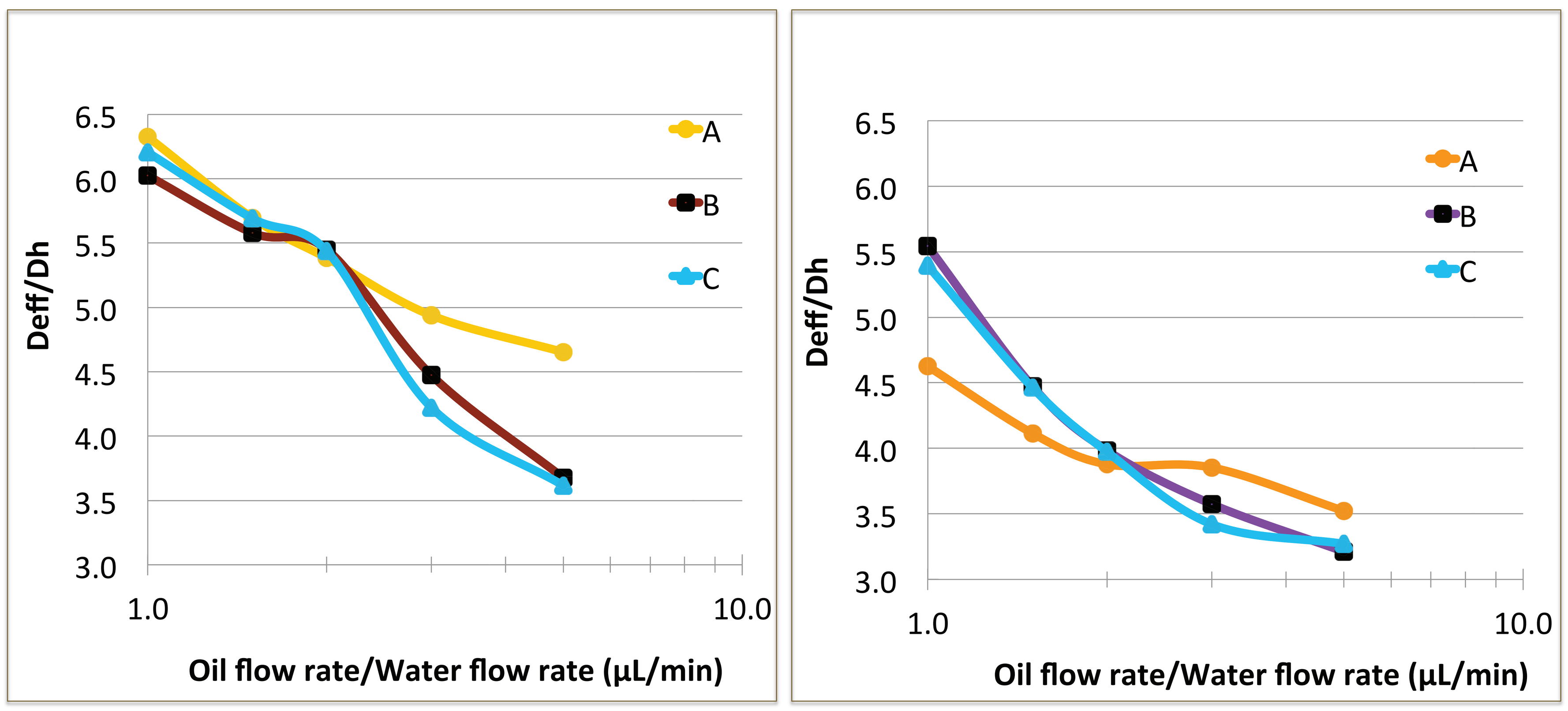

Figure 2. Plots of effective droplet diameter normalized to the channels hydraulic diameter (Dh=100 µm) versus oil and water flow rate ratio at a constant flow rate. Left: Total flow rate = 30 µl/min, and Right: Total flow rate = 300 µl/min. A: Rectangular cross-section 285x61µm, B: Rectangular cross-section 150x75 µm, C: Trapezoidal cross-section 200x100 µm, with 50 µm minor base.

Conclusions

A study of the behavior of a common two-dimensional flow-focusing droplet generator at different flow rates and flow rate ratios for the production of water-in-oil emulsions was conducted. The study evaluates three different channel geometries for a cross-shape constriction to help determine an optimal geometry of an easily manufacturable MFDG for parallelization. The wide and shallow rectangular geometry is preferable over the other geometries evaluated (i.e. narrower rectangular and trapezoidal geometries) since it showed the lowest variability in droplet size with changing water/oil flow rate ratio. This trend was present in both studies performed at different total flow rates, making the shallow rectangular geometry the most adequate for parallelization.

References

1. G. M. Whitesides, "The origins and the future of microfluidics," Nature, vol. 442, pp. 368–373, (2006).
2. H. Song, D. L. Chen, and R. F. Ismagilov, "Reactions in Droplets in Microfluidic Channels," Small, vol. 45, pp. 7336-7356, (2006).

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