Entropic Evaluation of Dean Flow Micromixers

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Abstract

Inducing mixing in microfluidic systems is challenging due to their low Reynolds number and therefore the laminar nature of the flow. The mixing on these scales relies primarily on the slow diffusion process at the interface between the regions containing the various chemical species. Successful strategies for increasing the mixing efficiency rely both on stretching the mixing interface, as well as promoting advection within the fluid stream. In this work, we investigate computationally, using COMSOL Multiphysics®, the CFD Module, and Chemical Species Transport physics interface, the use of spiral channels at Reynolds numbers from 25 to 900 as a mixing structure (Figure 1). In this system, the centrifugal forces experienced by the fluid as it travels along the curved trajectory induce counter-rotating flows (Dean Vortices). The presence of these transversal flows promotes the mixing of chemical species that are introduced in the system at different positions across the section of the channel. COMSOL allows for the simultaneous solving of the Navier-Stokes equations for the fluid flow and the diffusion-convection equations for the concentration of chemical species.

Concentration images (Figure 2) obtained at different positions along the channel are used to evaluate the mixing efficiency using a measure based on the Shannon entropy [1]. We have previously found this measure to be useful in understanding mixing in mixers similar with the staggered herringbone type [2].

Reference

[1] P.S. Fodor, M. Itomlenskis and M. Kaufman: "Assessment of mixing in passive microchannels with fractal surface patterning", Europ. Phys. J.: Appl. Phys. 47, 31301 (2009).

[2] P.S. Fodor and M. Kaufman: "The evolution of mixing in the staggered herring bone micromixer", Modern Physics Letters B 25, 1111 (2011).

[3] P. S. Fodor, M. Itomlenskis, M. Kaufman, The European Physical Journal Applied Physics, 47(3), 31301 (2009)

Figures used in the abstract

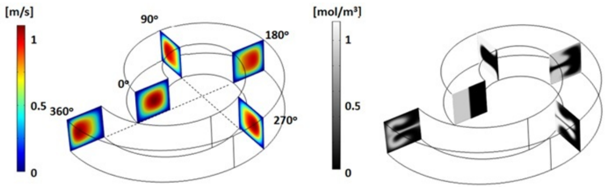

Figure 1: (left) Velocity field slices; (right) concentration slices for a microchannel at Reynolds number Re = 50 (Note: the 0° angle corresponds to the inlet of the mixer).

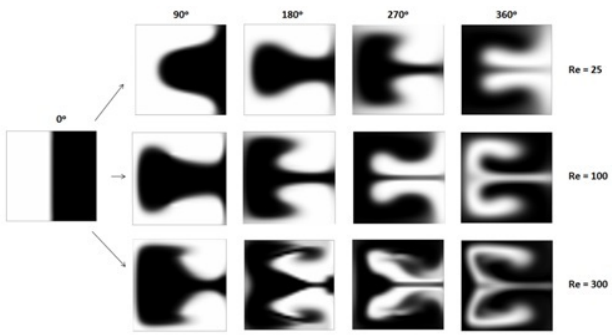

Figure 2: Snapshots of the mixing along the channel of two fluids introduced at different positions across the inlet of the curved microchannel.