Computational study of convection-diffusion mixing in microchannel mixers

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Abstract

The growing research effort in micro mixing devices in recent years has led better understanding and design of more efficient microchannel mixers. Such micro mixers have been widely used in chemical and biochemical applications. Due to the limit in sizes, flows in these devices are dominantly laminar flows and efficient mixing is to create chaotic flows. At such small scales, molecular diffusion is often a key factor in mixing mechanism. It is well know that all numerical schemes introduce false diffusion in CFD solutions. This fact has hindered better understanding of mixing in microchannel mixers. In this presentation, we present a method to quantitatively measure the effect of numerically introduced false diffusion in a CFD solution of a scalar distribution. With this method, we can estimate the mesh size is required to resolve molecular diffusion with a given diffusivity. This method is used to analyze mixing in a topologic microchannel mixer. The mixing structures in the mixer are found in good qualitative agreement with experimental results for the calculated effective molecular diffusivity. The numerical analysis of false diffusion revealed a range of molecular diffusivity that the convective-diffusive mixing in the mixer can be studied with CFD without significant effect of false diffusion. This range covers many practical viscous solutions including many bio and protein solutions. For the topologic mixer studied, the main mixing mechanism at creeping flow range is the baker's transformation. At higher Re, secondary flow is created and the mixing mechanism is the competition of kinematic baker's transformation and the dynamic secondary flow. It was found that the most efficient mixing is the baker's transformation along for Re < 10. This is in agreement with the theoretical findings but first confirmed in a practical mixer. Diffusion in this mixer is important even at a molecular diffusivity smaller than 10^{-11} m^2/s, a typical value for bio solutions. In just a few elements, diffusion broadening will smear the boundary of striations and striation doubling of the baker's transformation ceases. Figure 1 below shows the mixing structure at an effective molecular diffusivity of 6.5 $x10^{-11}$ m^2/s in the mixer.

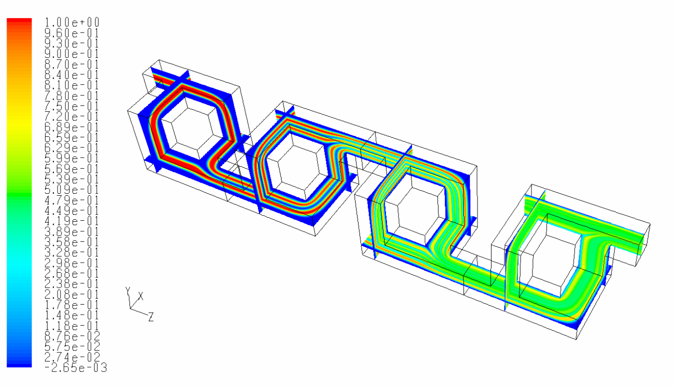

Figure 1.