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Chaotic mixing in microfluidic devices

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Introduction
Mixing plays a vital role in microfluidic devices. The flow in microfluidic devices are predominantly laminar and producing turbulence is almost impractical. Chaotic advection is the way to improve mixing in microfluidics. In passive chaotic micromixers (no moving parts) the geometries are designed to provide transversal components of the flow that stretch and fold volumes (baker’s transformation) of fluid over the cross section of the channel (see Figure 1).

![Figure 1 Staggered herringbone mixer [1].](image1)

Objective
Optimize the mixing performance for staggered herringbone mixer (SHM) by applying different combinations of grooves.

Methods
Mapping matrix method is employed to simulate the evolution of concentration fields. Passive markers are advected in the flow field to compute mapping matrices (Figure 2). If the number of the markers in the donor cell number $i$ is $M_i$ and the number of markers found after tracking in the recipient cell number $j$ equals $M_{ij}$, then the corresponding mapping coefficient $\phi_{ij} = \frac{M_{ij}}{M_i}$.

![Figure 2 Illustration of how to compute mapping matrices [2].](image2)

Results
The small grooves oriented at $45^\circ$ angles on the surface of the mixer generates double helical patterns and the change in the orientation of the grooves between half cycles, exchanges the positions of the centers of rotation (Figure 3). The results of the mapping simulations are calculated for a single groove for both a half cycle element and a transition region. The mapping simulations give flexibility to easily design different combinations of grooves. The concentration evolution for an SHM with 6 grooves per half cycle is shown in Figure 4. Intensity of segregation is used as a mixing measure (Figure 5).

![Figure 3 Effect of change in orientation of grooves on the streamlines.](image3)

![Figure 4 Concentration evolution along the SHM mixer.](image4)

![Figure 5 Intensity of segregation for SHM mixer having 3, 6 and 10 grooves per half cycle respectively.](image5)

Conclusion
Based on our mapping matrix results, we conclude that the design with six grooves is optimal for mixing.

References:

/department of mechanical engineering