Evolutionary optimization of mixing microdevices

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We present single and multiobjective optimization results for fluid micromixing devices used in applications such as bioanalysis and drug mixing.

Two devices are considered via numerical simulations and optimization based on stochastic optimization and dynamical systems theory.

In the first case we consider a microdevice where the flow through the main channel of the mixer is perturbed by three sets of secondary flow channels that are perpendicular to the main channel. Using the Navier-Stokes equations, the flow through the mixer is simulated at Re=5 to compute the mixing rate. Our goal is to enhance the mixing rate by optimizing the parameters that control the time dependent flow from six secondary channels which impart cross flow momentum on the main channel flow thereby altering the trajectories of flow tracing particles. Optimized actuation frequencies are obtained with a stochastic optimization technique, namely an evolution strategy. The resulting control parameters are shown to be consistent with mixing theory that states that the ratios of the frequencies should be irrational to obtain maximum mixing. Figs. 1 and 2 show the concentration of the two fluids for an actuation with the same frequencies at each set of secondary channels and with optimized frequencies whose ratios are irrational, respectively.

In the second case we consider capillary electrophoresis on micro fabricated chips. As separation efficiency increases with the length of the separation channel, it is desirable to use longer microchannels within a small area, thus requiring turns in the microchannel. Using an evolutionary multiobjective shape optimization technique we demonstrate that minimal dispersion can be achieved by using large indentations of the geometry at the corners of the serpentine device. The results verify existing experimental observations in the group of J. Santiago (Stanford University) while providing a wealth of new improved geometrical shapes. Fig.3 shows a Pareto-optimal shape of the channel.

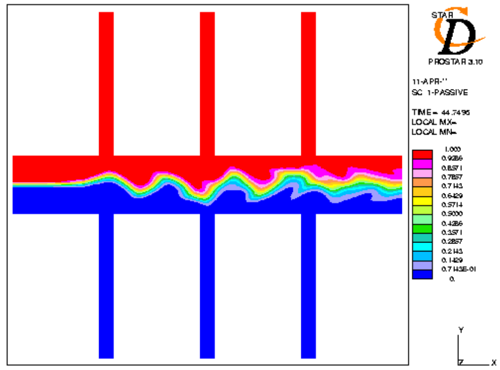

Figure 1: Concentration of the fluids of the original micromixer

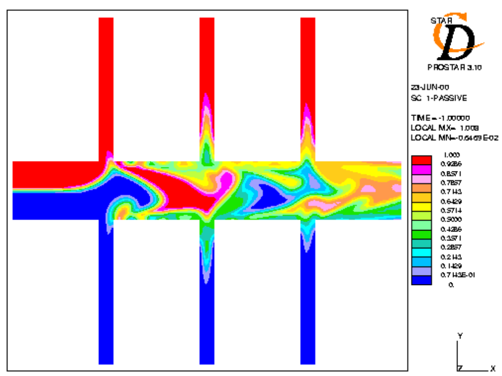

Figure 2: Concentration of the fluids of the optimized micromixer

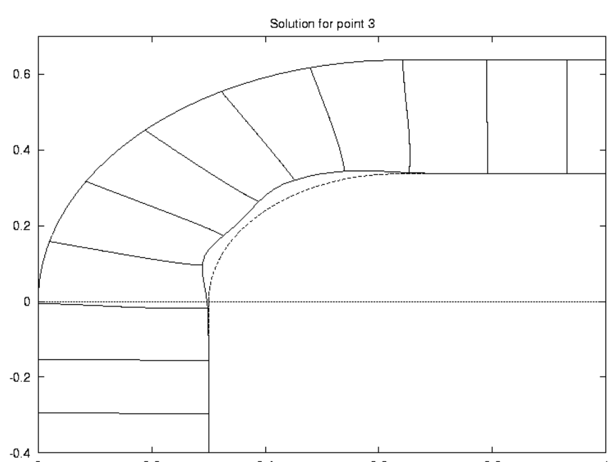

Figure 3: Pareto-optimal microchannel shape