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Optimization of mixing in rotated arc mixers (RAM)

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Introduction

Recently a new mixer- rotated arc mixer (RAM) has been developed, which gives good in-line mixing of viscous materials (Figure 1). The RAM consists of a concentric outer rotating cylinder, and an inner stationary cylinder, the later with several open windows along the circumference. As fluid flows through the inner cylinder, the outer cylinder rotation induces transverse flow via viscous drag at the open windows.

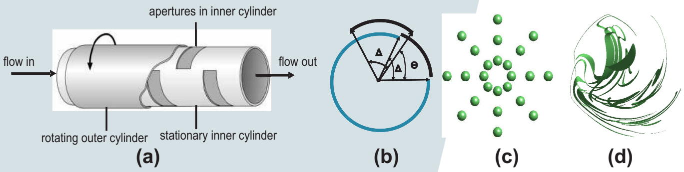

Figure 1 *(a) Schematic of the RAM [1], (b) cross-sectional view showing geometric parameters: Δ is spawn angle of a window, and Θ is offset angle between consecutive windows, (c) array of blobs at the inlet, (d) stretching and folding of blobs after several windows.*

Problem definition

The key parameters to decide quality of mixing are: Δ, Θ, and β (=$\omega \times L$/‹v›, where ω is rotation speed, L length of a window and ‹v› average inlet velocity). The Δ and Θ both can vary in the range of [0, 360^0], while β covers the range [0, 30]. To perform optimization, this large range of parameter space to be analyzed.

Objective

Optimization of distributive mixing in the RAM.

Methodology and validation

The mapping method [2] is used here to perform fast optimization. Each window of RAM is rotated by offset angle Θ with respect to its neighboring window. This is used to compute the mapping matrix $\mathbf{\Phi}$ only for a single window of RAM, and remaining matrices are obtained via rotation ($\mathbf{\Phi}_1$=$R_\Theta \mathbf{\Phi}$, where R_Θ is rotation matrix). This leads evaluation of all the ranges of Θ for fixed value of Δ and β in an efficient way. Figure 2 shows the mixing comparison by the mapping method with that of reported in [1].

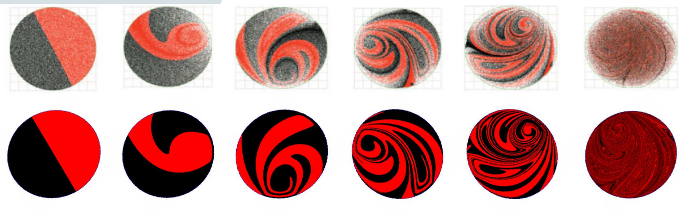

Figure 2 *Validation of the mapping method: top reported in [1] and bottom mapping. Mixing profiles at 0, 1, 2, 3, 4 and 10 windows.*

Results

By adopting above method, we show the concentration evolution for Δ=45^0 as a function of Θ at various values of β (Figure 3a).

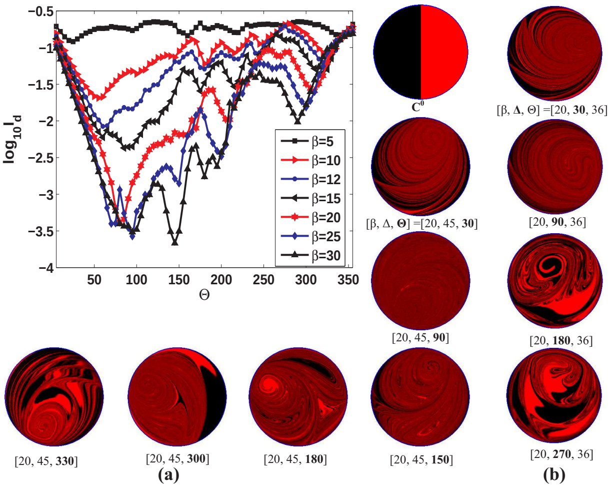

Figure 3 *(a) Optimum Θ for Δ=45^0 for various values of β: flux-weighted intensity of segregation I_d to quantify mixing. In a perfectly mixed system I_d =0, while in a completely segregated system I_d =1, (b) effect of Δ on mixing at fixed value of β and Θ.*

To achieve complete optimization, we repeat the above procedure for all the range of Δ for various values of β. Figure 4 shows the dependence of mixing on design parameters of the RAM, revealing the optimum design parameter space.

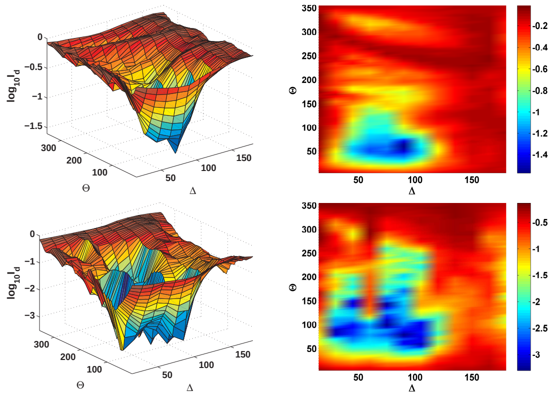

Figure 4 *Optimization of RAM mixer: logarithm of I_d vs. Θ and Δ for β=10 (top), and 30 (bottom). Left side of figure: 3-D surface plots, right side: 2-D respective contour plots.*

Conclusions

An optimal set of parameters to achieve the best mixing in the RAM is determined.

References:

[1] Metcalfe, G., Rudman, M., Brydon, A., Graham, L., and Hamilton,R. AIChE, 2006, 52, 9-28.

[2] Kang, T. G, Singh, M. K., Kwon, T. H., Anderson, P. D., Microfluidics and nanofluidics, 2007, DOI:10.1007/s10404-007-0206-z.