Optimization of Kenics static mixers

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Introduction

The mapping approach was used to optimize the geometry of the in industry widely used Kenics static mixer. The mapping approach [2] describes the concentration evolution from one cross-section to another using pre-computed mapping matrices and combining them in an appropriate sequence.

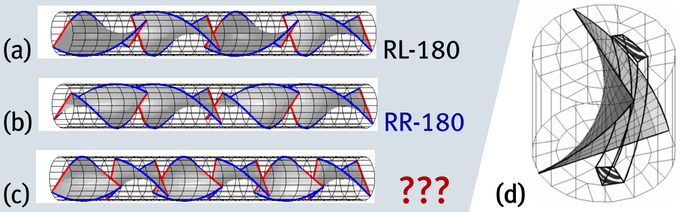

Figure 1 *Steps towards Kenics optimization: **(a-c)** Various layouts of the Kenics static mixer, "RL" and "RR" denote mixers with unidirectional and alternating blade twist; **d)** computing the mapping matrix: tracing the flow tube between two cross-sections.*

Hobbs and Muzzio [3] analysed a few mixer layouts, demonstrating that the key parameter to change is the blade twist and that the standard Kenics mixer with the blade twist $180°$ (fig.1a) can be improved. This work deals with the optimization of the blade twist of the Kenics static mixer.

Mixer optimization

The principles of Kenics mixer operations (distributions obtained using mapping technique) are illustrated in Fig.2: the material striations are repeatedly re-oriented, stretched and cutted. It looks like the standard mixer has *a too large blade twist*, since it is preferrable to have the striations parallel to the trailing edge.

The mixture quality (intensity of segregation, $0 \leq \mathcal{I} \leq 1$, characterizes the concentration uniformity: $\mathcal{I} = 0$ for a prefect mixture, $\mathcal{I} = 1$ for completely unmixed state), obtained by different mixers at the cost of the same pressure drop was compared (see Fig.3a). The mixer with the bades twisted on $140°$ achieves the fastest homogenization. The optimal twist angle is barely influenced by shear-thinning behaviour of the fluid.

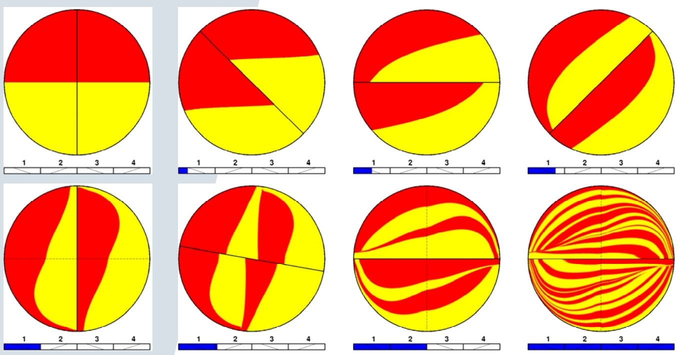

Figure 2 *How the Kenics mixer works: the evolution of concentration patterns within the first four blades of the RL-180 mixer. The total number of the blades passed is shown under each image.*

Interface generation

The incorporation of statistical microstructure description [2] allowed to study the interfacial area generation in the mixer.

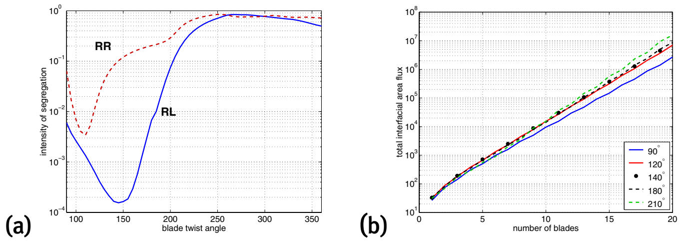

Figure 3 ***a)** Efficiency of RL and RR Kenics mixers: intensity of segregation achieved at the cost of the pressure drop, equivalent to 12 blades of "standard" RL-180 mixer. **b)** The growth of the total interfacial flux with the number of blades.*

The increase in interfacial area flux per blade is nearly the same in the wide range of blade twist angle (see Fig.3b). However, since the longer blades with larger twist (the blade pitch was fixed) require larger pressure drops, the mixers with short blades tend to generate more interface (see Fig.4a). These interfaces, however, are distributed extremely non-uniformly in the mixer cross-section. The most iniform distribution of interfaces across the mixer is achieved when the twist angle is close to $140° - 150°$.

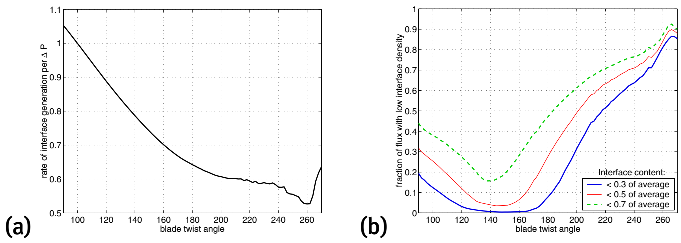

Figure 4 ***a)** The exponential rate of the interface flux growth. **b)** The fraction of the volumetric flux of the fluid, carrying the interface density less then 0.3, 0.5 and 0.7 of the average level.*

Conclusions

- ☐ The Kenics mixer achieves the best macroscopic homogenization efficiency with the blade twist $140°$.
- ☐ This configuration provides also reasonably uniform inreface distribution.
- ☐ Mapping approach is a usefull engineering tool for static mixers optimization.

It was found, however, that the decrease of the blade twist angle in Kenics mixers leads to increased stagnation effects near the tube surface. A possible solution may be to combine short and long blades in a more complex mixer layout.

References:

[1] Galaktionov, O. S., Anderson, P. D., Kruijt, P. G. M., Peters, G. W. M., and Meijer, H. E. H. (2001). *Comput. Fluids*, 30, 271–289.

[2] Galaktionov, O. S., Anderson, P. D., Peters, G. W. M., Tucker III, C. L. A global, multi-scale simulation of laminar fluid mixing: The extended mapping method. *Int. J. Multiphase Flows*. (Accepted).

[3] Hobbs, D. M. and Muzzio, F. J. (1998). *Chem. Eng. Sci.*, **53**, 3199–3213.

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