Numerical and Experimental Characterization of Vortex Mixer for Micromixing Study

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Highlights

- Micromixing of the Villermaux-Dushman/ Iodide-Iodate test reaction studied in a Vortex mixer.
- Chemical reaction experiments and 3D CFD simulation at different Reynolds numbers were performed.
- Hydrodynamics and concentration fields of the reaction of the reaction species was studied.
- Segregation of index, pressure drop, energy dissipation, and mixing time were determined.

1. Introduction

Mixing is one of the most important unit operations in the chemical, biological, pharmaceutical, and food industries. Mixing is often the limiting step in a reactor/mixer design, for example, when the chemical reaction is too fast and so the reaction time is shorter than the mixing time, or in the case of very viscous fluids where mixing generally takes place under laminar regimes. Micromixers are becoming increasingly studied with the widespread industrial applications, especially in the continuous production of nanoparticles [1,2]. The main focus of our work is on the sustainable manufacturing of bioinspired silica nanoparticles in micromixers. For this purpose, a simple device, a Vortex mixer is considered for micromixing and reactive study.

The hydrodynamics and micromixing study with competitive-parallel, Villermaux-Dushman test reaction was performed to characterize the Vortex mixer, to show its dependence. The vortex mixer was characterized with geometrical and operational parameters aiming for the validation of the hydrodynamic model and micromixing models that will be used for the reactive precipitation processes study.

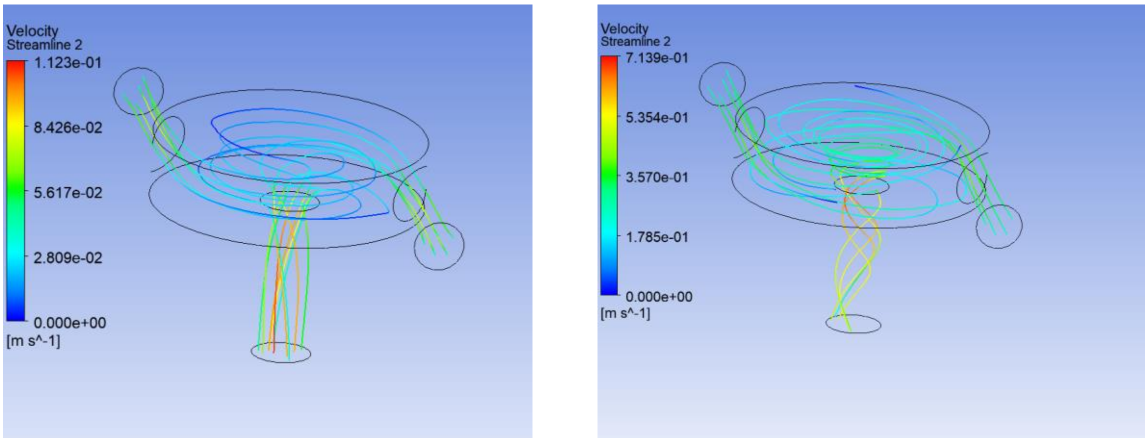
2. Methods

The vortex mixer [3] geometry is a simple device consisting of two tangentially feeding inlets connected to the mixing chamber. The mixing fluids enter tangentially through both the inlets into the mixing chamber and leave perpendicular through the bottom outlet. The experimental and CFD characterization of micromixing was done for three different geometries. For comparison and validation of simulation results with the experiment, CFD simulation was done for one geometry, and the experiment was performed on all three geometries. The study of the influence of geometry was made within a range of Reynolds numbers from 48 to 385.

The experimental setup consists of two pulse-less syringe pumps and the micromixers connected using two PVC pipes. The acid solution was injected via inlet 1 and the bulk solution was fed into the mixer through inlet 2. The experiment was carried out at room temperature and the volumetric flow rate in both inlets was equal and varied from 2.5 ml/min to 20 ml/min corresponding to the *Re* 48 to 385. The online measurement of the absorbance of the outlet product is performed which is the direct measurement of the concentration. The product distribution of the test reaction is used for the characterization of micromixing. 3D CFD simulation was performed using the commercial software ANSYS Fluent™. The main objective of this numerical simulation is to get detailed insight into the flow dynamics involved in the Vortex mixer which is otherwise not so profound in the experiment and enables characterization of the mixer for the reactive processes and continuous nanoparticle synthesis of silica products.

3. Results and discussion

Figure 1 shows the streamline maps obtained from the 3D CFD simulation results for the geometries having a chamber depth/height of 1.5mm, both its inlet diameter of 1.1 mm and outlet diameter of 1.3 mm for two different Reynold numbers, 48 and 289 at $t = 2\ sec$. From Figure 1. we can observe that the two flow streams enter the mixing chamber from its inlet and leave the outlet perpendicular to the mixing chamber. At the outlet, two different flow patterns are visible, where at low Re = 48 the flow stream is more stratified whereas for the same geometry at higher *Re* = 289 the flow stream with swirling streamlines is observed at the outlet of the mixer.



Re=48 ***Re=289***

Figure 1. Caption (colored graphs and figures allowed). [Times New Roman 10].

4. Conclusions

This work will clearly show the critical role of both operational parameters and Vortex mixer geometries on the flow stream and will relate the differences in the 3D flow structures with the flow regimes. Furthermore, mixing will be assessed from Villermaux-Dushman test chemical reaction experiments and 3D CFD model simulations of the Vortex mixer. This work will clearly show the better mixing efficiency obtained under higher flow rates.

References

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Keywords

Micromixing, Villermaux-Dushman reaction, Vortex mixer, Microfluidics