DESIGN AND ANALYSIS OF MICROMIXER FOR ENHANCING ITS MIXING PERFORMANCE

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ABSTRACT:
This poster depicts the summary of the "Design and analysis of various micro-mixers for enhancing the mixing performance by using COMSOL Multiphysics 4.4". The shape of micro channels is an important design variable to achieve the desired mixing performance. However if obstacles and wavy channels are integrated into the channel design, mixing improves. Micro-mixer with obstacles located at the centre of the channel with different configurations is used to enhance mixing performance, so as to reduce the mixing length. Different shapes of obstacles such as rectangle, square and rhombus are analysed by comparing it with plain Y shape circular chamber mixer. For the same boundary conditions, the rectangular obstacles at the centre of the chamber, generally gives minimum mixing length.

KEY WORDS: Micro-mixer, Y channel, Mixing Performance, COMSOL etc.

1. INTRODUCTION:

Mixing is an important process in a microfluidic system such as micro total analysis systems. The aim of microfluidic mixing is to achieve a thorough and rapid mixing of multiple samples in micro scale devices. The term 'mixing' means a physical process where both the stirring and the diffusion occur simultaneously. Here, the word stirring means the advection of material blobs subjected to mixing without diffusive action. In other words, we can say that good mixing of low diffusivity materials occurs in two stages; stirring in the first stage and diffusion in the second stage. These mixers are differentiated by the hydrodynamic principle employed.

Means of mixing	Chaotic Advection	Application range	Fabrication cost	Overall rank
Hydrodynamic focusing	No	Broad	High	4
Alternate injection	No	Broad	Moderate	3
Geometry effect	Yes	Broad	Moderate	2
Electrokinetic method	Yes	Moderate	High	3
Droplet mixing	Yes	Broad	Low	1
Stirring by particles	-	Broad	High	4

Table 1:Summary of various principles for micro mixing

2. THEORETICAL ANALYSIS:

It is essential to consider two characteristic dimensionless numbers, Reynolds number (Re) and the Peclet number (Pe), in order to determine the effective operation condition of a passive micro mixer. So,

$$Re = \frac{\rho \vartheta d}{\mu} \quad \text{and} \quad Pe = \frac{\upsilon d}{D}$$

The transverse diffusion time can be estimated by

$$t = \frac{d^2}{D}$$

Where d = Channel width, D = Diffusion coefficient

The characteristic mixing length (L) of the micro mixer to achieve complete mixing is

$$L = \vartheta t = \vartheta \frac{d^2}{D} = Pe.d$$

3. DESIGN AND ANALYSIS :

The basic design for a micro-mixer is represented by Y shaped channel. The mixing process in this type of micromixer is obtained by guiding the two liquids, to be mixed in a flow channel. Mixing for Y shaped micromixers, solely depends on diffusion of the species at the interface between the two liquids, hence the mixing is rather slow and a long mixing channel is required.

3.1 Geometry of Channel:

Geometries affect on fluid mixing that will enhance advection in the mixing of fluids. If a single straight channel is used the fluid will tend to stay very laminar and have no advective mixing. However if obstacles and wavy channels are integrated into the channel design, mixing improves.

3.2 Specification of Problem:

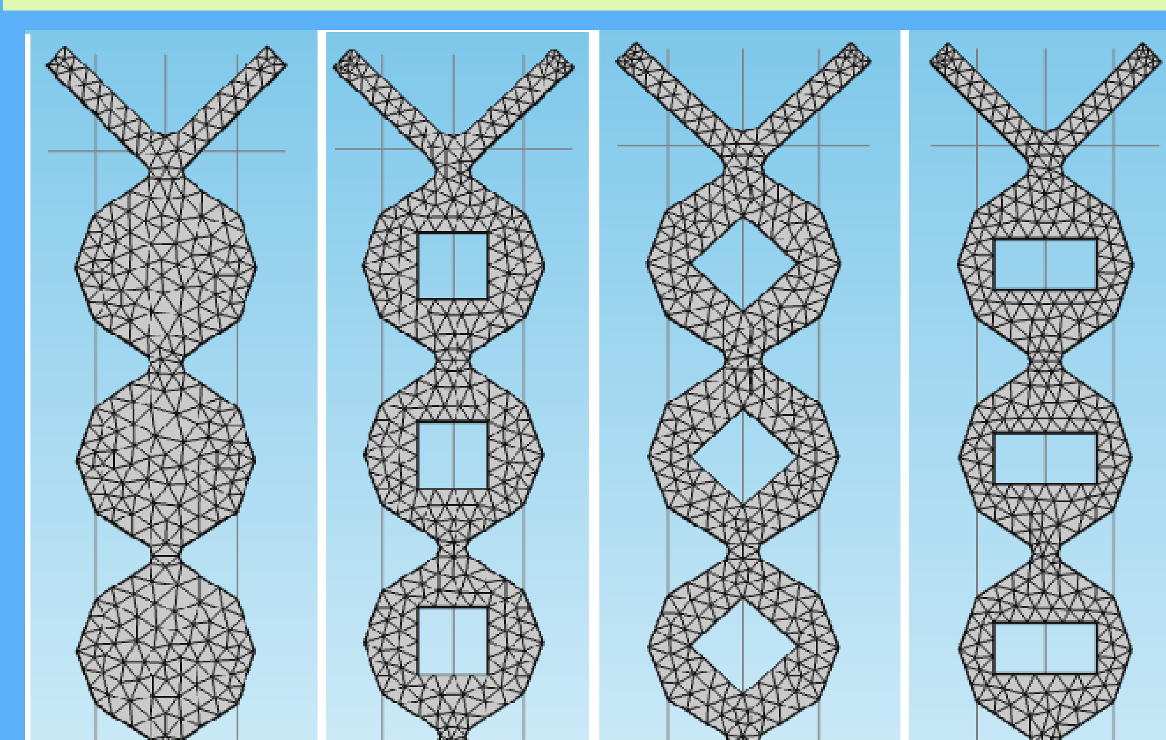
The sample fluids used in the simulation were water and Benzoic Acid.

Channel Inlet 1	Velocity Inlet	0.1 mm/s
Channel Inlet 2	Velocity Inlet	0.1 mm/s
Channel Outlet	Pressure Outlet	1 atm pressure
Channel Bottom	Wall	No slip
Channel Left	Wall	No slip
Channel Right	Wall	No slip
Channel top	Wall	No slip

The molar concentration of one of the fluid species was set to 0 and other to 20. As mixing takes place, the molar intensity on one side of the channel decreases from 20, while on the other side it increases from 0. Near about Complete mixing was achieved when the molar intensity of the two fluids reached to10±0.5 mol/m³.

3.3 Meshing of Geometry:

Structured meshing method is used for meshing the geometry with extremely coarse mesh.

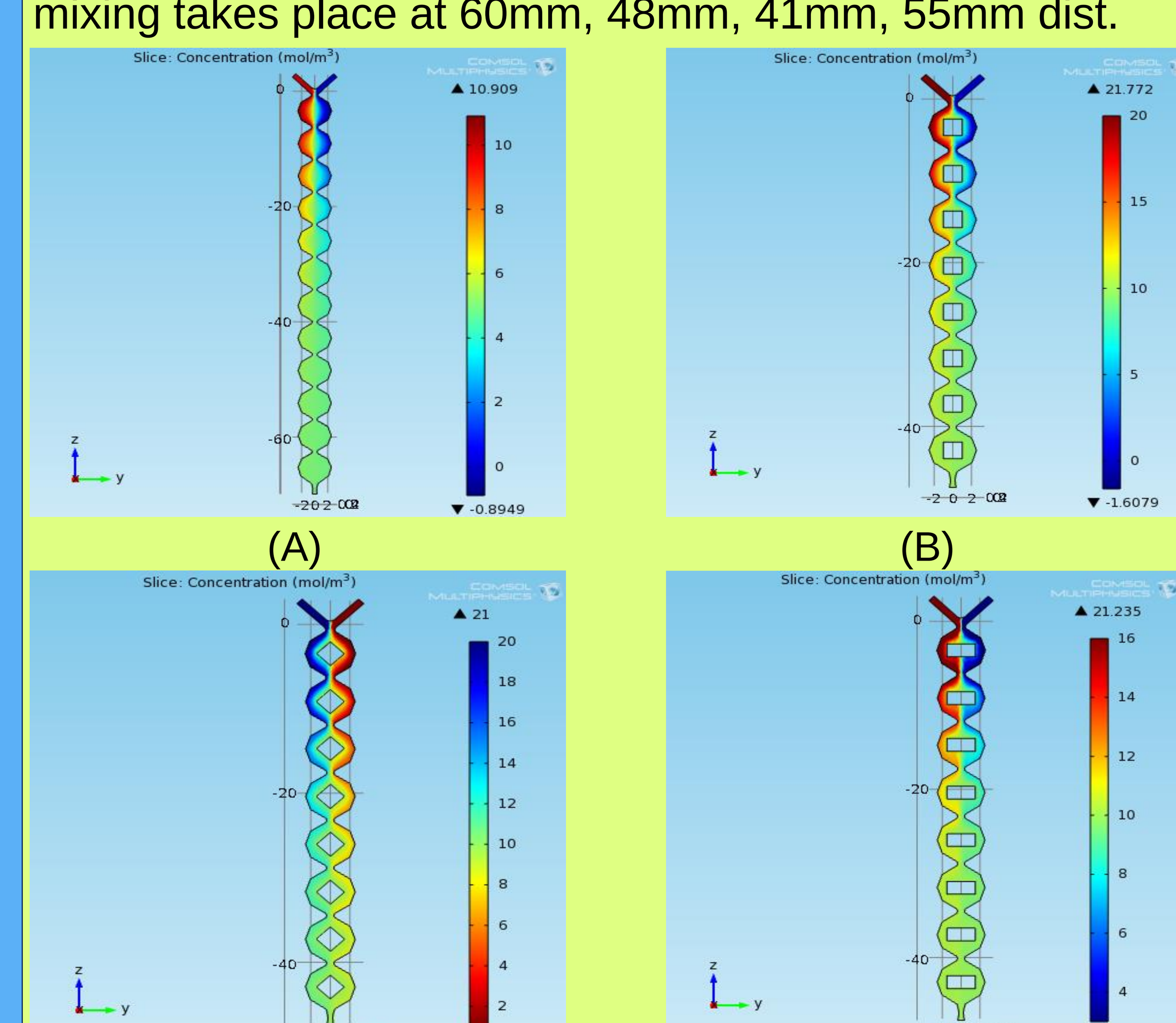


(A) (B) (C) (D)

Figure 1:Mesh of Y Shape Circular Chamber Micromixers
A] Without any obstacle B] Square obstacle
C] Rhombus obstacle D] Rectangular obstacle

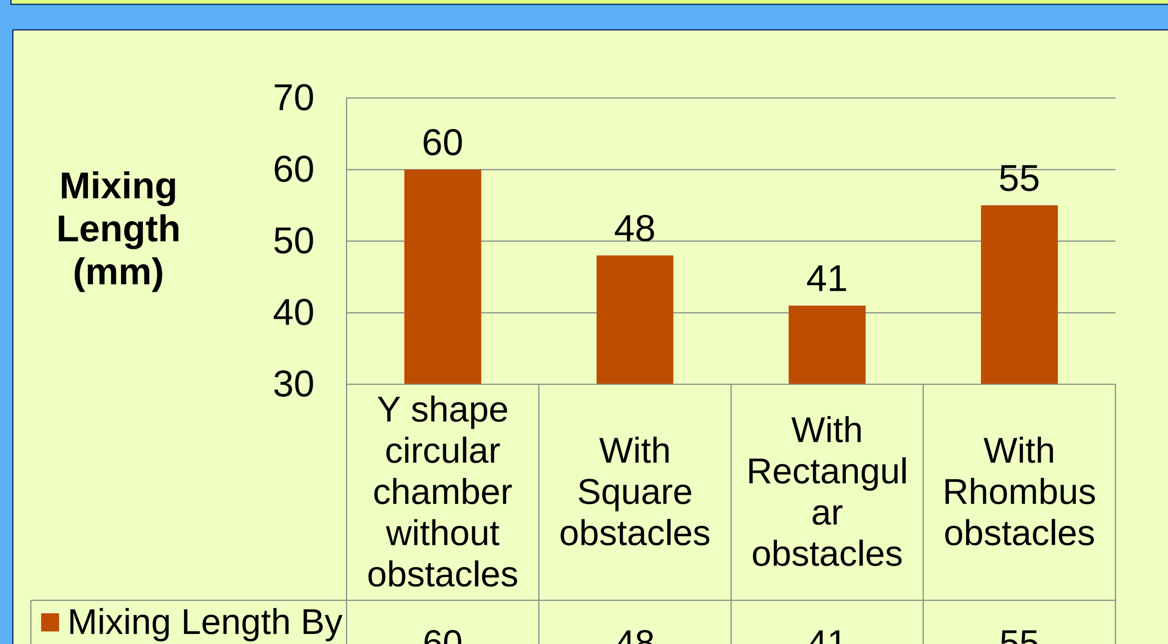
4. SIMULATION RESULTS

Figure 2 shows mixing length and mixing behaviour in circular Y shape micro-mixer. It has been observed that mixing takes place at 60mm, 48mm, 41mm, 55mm dist.



(A) (B) (C) (D)

Figure 2:Simulation Results of Y Shape Circular Chamber Micro-Mixers with obstacles of different shape
A] Without any obstacle B] Square obstacle
C] Rhombus obstacle D] Rectangular obstacle



5.FABRICATION OF MICRO-MIXER:

The AutoCAD drawing of Y shape circular chamber channel is printed on a transparency sheet which is called mask at a resolution of 12000 dpi.

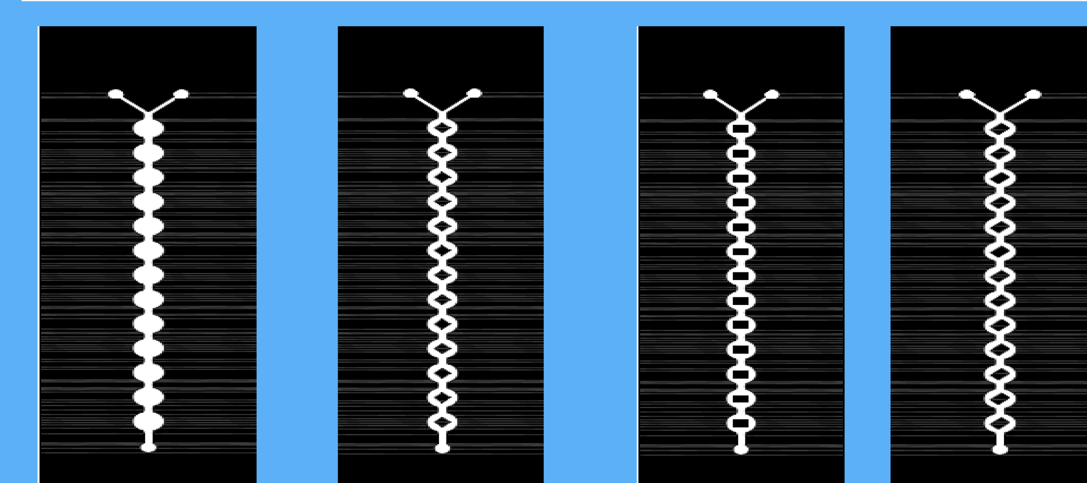


Figure 4:Mask used for Circular Y shape Micromixer

Steps require to carry out Photochemical Machining and PDMS Mold making are shown in following flow charts A and B respectively.

Cleaning of metal Substrate:
→ Coating of a negative photoresist LPR on substrate
→ Exposed substrate to UV source for about 2 min.
→ Developed in developer solution for 1 min.
→ Etching of substrate is done using $FeCl_3$solutiontion for 1 min.

Flow chart A :Photochemical Machining Process

Pour the required amount of curing agent and PDMS base in 1:10 proportion
→ Whisk this mixture vigorously with a spatula about 10 mins
→ Kept in a desiccator to make the trapped air bubbles escape
→ Spin it over the molds.
→ For curing place the PDMS with mold on a hotplate at 150°C for about 6-8 mins.
→ After cooling ,Peel off PDMS with holder

Flow chart B :PDMS Mold Making

6.CONCLUSION:

Mixing length in the channel generally depends upon diffusion coefficient, width and height of the channel, inlet velocities of the fluids, viscosity of fluids and geometric layout of micro-mixer. As the width of channel increases, the mixing length of micro-mixer channel is increases. Increase in diffusion coefficient leads to decrease in mixing length of micro-mixer channel. Decreasing the inlet velocities of the incoming fluids, decreasing the mixing length of micro-mixer channel. Different obstacles like rectangular, square and rhombus when placed at the centre of the channel also affect the mixing length of the channel. The shape and size of the obstacles also affecting the mixing length. For the same boundary conditions, the rectangular obstacles placed on the wall of the channel, generally gives minimum mixing length.

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