Effect of Geometric Parameters in a Newly Designed Microchannel

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Abstract

In this study a microchannel with various arrangement of blocks is newly proposed. This design comprises periodically arranged simple blocks. In this configuration, the stirring is greatly enhanced at a certain geometric parameter set.

To characterize the flow field and the stirring effect both the numerical and experimental methods were employed.

To obtain the velocity field, three-dimensional numerical computation to the Navier Stokes equations are performed by using a commercial code, FLUENT 6.0. The fluid-flow solutions are then cast into studying the characteristics of stirring with the aid of Lyapunov exponent.

The numerical results show that the particles' trajectories in the microchannel heavily depend on the block arrangement. It was shown that the stirring is significantly enhanced at larger block-height and it reaches maximum when the height is 0.8 times the channel width. We also studied the effect of the block stagger angle, and it turns out that the stirring performance is the best at the block angel 45 °

Keyword: *Microchannel, stirring effect, chaotic advection, Lyapunov exponent.*

1.Introduction

Microchannel is one of the most frequenly used conduits for fluid transport between micro devices . It transports biological materials such as proteins, DNA, cells and embryos, and chemical samples etc. Its role lies not only in the fluid transport but in stirring of different species of fluids. In general in macro scales, the fluid stirring is accomplished by artificially or naturally made fluid turbulence. However in micro scales, the fluid turbulence cannot be in most cases expected to occur because the relevant Reynolds numbers are very small due to a very small scale in the reference length. Therefore in the micro scales the fluid stirring becomes one of the most crucial factors in design and operation of the micro devices, and its importance becomes more pronounced as the scale is decreased.

Up to now, various configurations for microchannels have been studied. Mala and Li[1] and Weilim et al [2] investigated the flow characteristics within microtubes and trapezoidal microchannels, respectively at low Reynolds numbers. The staggered herringbone mixer (Strook et al [3]) was also proposed to serve as an effective mixer at low Reynolds numbers.

In this study, referring to the study on the enhancement of stirring by chaotic advection in a screw extruder with a staggered flight geometry (Suh & Kim [4]). We propose a new design for the microchannel. The design is simply composed of a rectangular-sectioned channel with multi blocks attached in a series on the bottom wall.

2. Flow model and numerical methods

Figure 1 shows the shape of the new model and the coordinates x, y, and z along the height, width, and length of the channel, respectively.

The simulations are performed by using a commercial code (FLUENT 6.0) based on the implicit finite volume method.

The grid system is composed of about 500,000 tetrahedral meshes. On the channel walls including the block surfaces, the fluid is set subjective to no-slip and impermeable conditions. Water is chosen as an operating fluid and the inlet velocity profile in uniform with the velocity 2 cm/s or 0.01 cm/s so that ; for H = 0.045cm, the Reynolds number becomes Re = 10 or 0.05 . At the outlet, zero gradient for all the flow properties is applied. Fluid is assumed to satisfy the continuum hypothesis

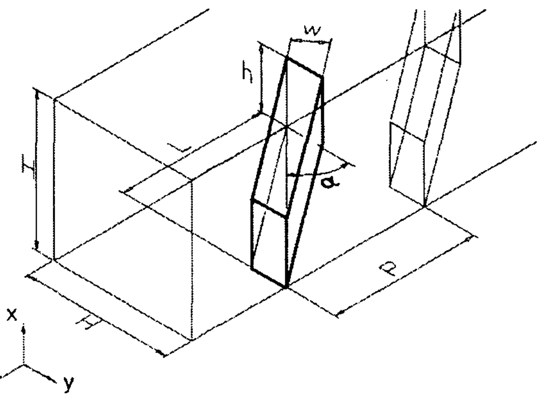

Fig. 1 Perspective view of the flow domain surrounded by a channel with multi blocks inside at the bottom wall.

3. Results and discussions

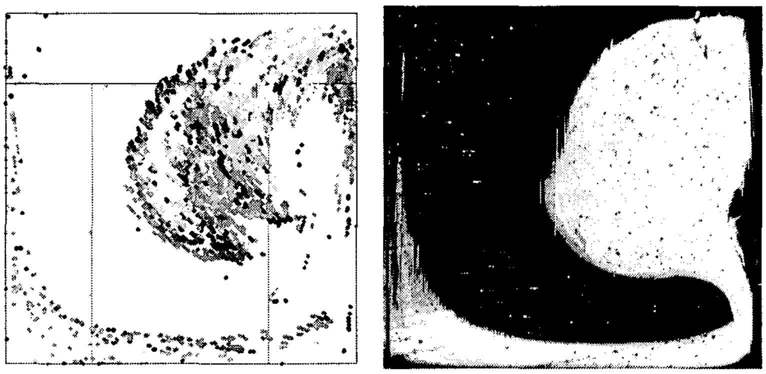

Fig. 2 Numerical (left) and experimental (right) results of material deformation after two blocks for h = 0.8 H and α = 45°.

Figure 2 shows deformed fluid materials after two blocks at h = 0.8 H and α = 45° obtained by numerical computation and experimental visualization . At the entrance the left half of the section is filled with colored particles in the numerics while it is colored light green in the experiment. To effectively visualize this pattern only two blocks are built in the experiment and the pattern is taken at the downstream section of the second block. It is seen that materials are deformed by the counter clockwise spiral motion of the secondary flows. As a future work, we may have to check if the deformation involves not only stretching but also folding, so that the stretching is indeed exponential in time which is known to be indicative of the chaotic advection

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