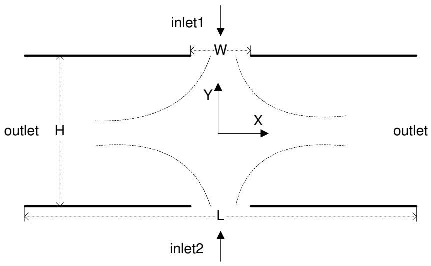

Figure 1. configuration of impinging streams

LATTICE BOLTZMANN STUDY OF FLOW AND MIXING CHARACTERISTICS OF TWO DIMENSIONAL CONFINED IMPINGING STREAMS

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Summary The objective of the paper is to compare the influences of two different inlet velocity boundary conditions (uniform velocity profile and parabolic velocity profile, two representatives of many practical applications) on the flow and mixing characteristics of two dimensional confined impinging streams. The lattice Boltzmann method (LBM), which is a relatively new method in modeling fluid flow and has many advantages over conventional computational fluid dynamics methods, is used as a solver. Numerical validation shows that the velocity at the cross section of channel and Nusselt number along the wall for symmetric confined impinging streams are in good agreement with previously reported results. Moreover, the flow and mixing characteristics for different Reynolds numbers are presented, and the inlet velocity boundary condition is found to have strong influences on these characteristics.

INTRODUCTION

Impinging streams configurations have found applications in several different processes such as reaction injection molding (R.I.M.) and entrained-flow coal gasification, etc. Motivated by these applications, many works (cf.[1, 2]) have focused on the flow and mixing characteristics of impinging streams. But in nearly all previous works, the uniform velocity profile was imposed at the jet inlets. In the present work, the lattice Boltzmann method is used to study the influences of two different inlet velocity boundary conditions on the flow and mixing characteristics of impinging streams for different hydrodynamics parameters. With the parabolic velocity profile imposed at the jet inlets, the flow and mixing characteristics are found to be quite different from those in the uniform velocity case.

PROBLEM DESCRIPTION AND NUMERICAL METHOD

The configuration of impinging streams is illustrated in Fig.1. The basic phenomenon is that two identical jets with bulk velocity U are ejected from inlet1 and inlet2 and then collide with each other. After the jets change their flow direction, they begin to flow out. As shown in Fig.1, W is the width of the inlet, H is the separation between two jets, L is the total length of the channel. Based on the assumptions that the fluid is incompressible and Newtonian, the dimensionless governing equations can be written as follows, $\nabla \cdot \mathbf{u} = 0$, $\partial \mathbf{u}/\partial t + \mathbf{u} \cdot \nabla \mathbf{u} = -\nabla p + \nabla^2 \mathbf{u}/Re$, $\partial \Theta/\partial t + \mathbf{u} \cdot \nabla \Theta = \nabla^2 \Theta/(RePr)$ (1), where $\mathbf{u} = (u, v)$, p and Θ are the velocities, pressure and temperature, respectively. The dimensionless numbers in Eq.(1) are defined as, $Re = WU/\nu$ and $Pr = \nu/D$, where ν and D are the kinematic viscosity and coefficient of thermal diffusion. The no-slip boundary condition is applied on the insulated solid walls, the length of the horizontal channel is fixed long enough to ensure both flow and thermal fully developed conditions. Two inlet velocity boundary conditions, uniform velocity profile and parabolic velocity profile, are considered. The initial values of u,v,p and Θ were set to be zero everywhere except two jet inlets. In this work, configuration parameter α (H/W) is fixed to be 4. In addition, instead of solving the continuum hydrodynamics equation, LBM deals with the evolution of discrete single-particle velocity distribution functions in time and space, the thermal lattice BGK model presented in Ref.[3] is used in our study and details can be found there.

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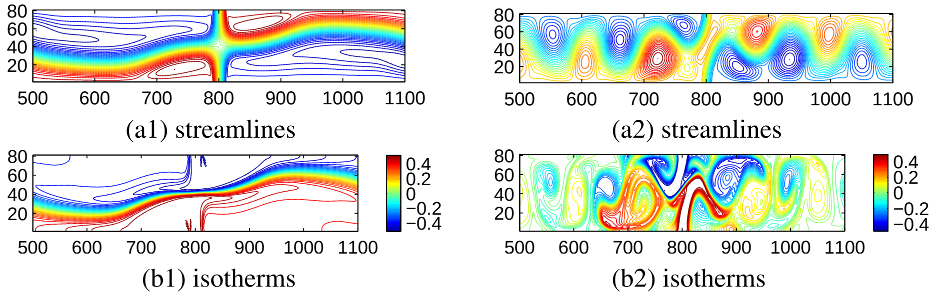

Figure 2. streamlines and isotherms of impinging streams with two different inlet velocity profiles for $\alpha = 4$, $Pr = 1.0$, $Re = 200$, figures at the left and right columns are corresponding to the cases of uniform and parabolic inlet velocity profiles, respectively.

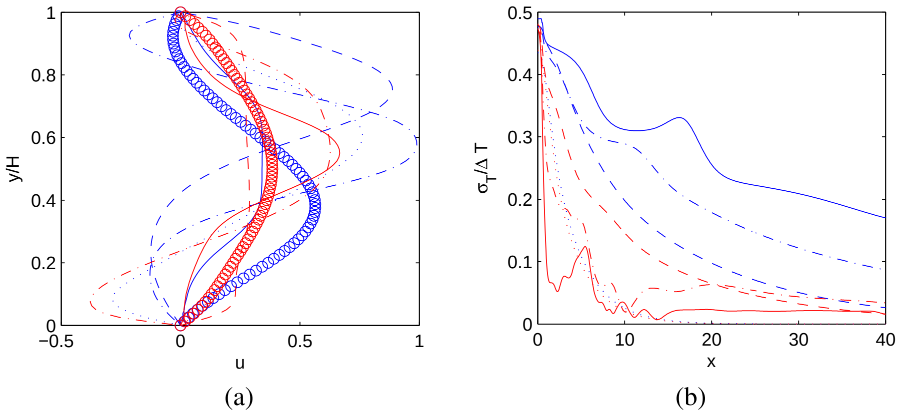

Figure 3. (a) horizontal velocity distributions at cross sections $x/H = 0.1$ —-, $1.0 - \cdot -$, $2.0 - -$, $4.0 \cdot\cdot\cdot$, $8.0 \circ$, $Re = 200$ (b) mixing effectiveness criterion versus x for $Re = 10 \cdot\cdot\cdot$, $50 - -$, $100 - \cdot -$, 200 —-, σ_T is the standard deviation of the fluid temperature across the channel at any specific axial location and ΔT is the temperature difference of the two inlet streams. In (a) and (b), blue and red lines are corresponding to the cases of uniform and parabolic inlet velocity profiles, respectively, $\alpha = 4$, $Pr = 1.0$.

NUMERICAL RESULTS AND DISCUSSION

The structures of flow and temperature fields in the domain center are shown in Fig.2, it can be seen that many vortices appear in the flow fields in parabolic velocity case while in the uniform velocity case the flow is laminar. In addition, the horizontal velocity distribution at different cross sections shown in Fig.3 (a) are quite different. All the evidence indicate that the inlet velocity boundary condition has strong influences on the flow characteristics. In Fig.3 (b), index $\beta = \sigma_T/\Delta T$ is used to evaluate the mixing effectiveness at different axial locations, the smaller β means the better mixing state. As seen from Fig. 3 (b), the mixing effectiveness is nearly the same at $Re = 10$. When Re is increased to 50, the mixing effectiveness in the parabolic case becomes evidently better than that in the uniform velocity case. With the further increase of Re, the difference of mixing effectiveness becomes larger and larger for two different inlet velocity conditions. In fact, the better mixing effectiveness in the parabolic case can be attributed to the vortices appearing in the temperature field (see Fig.2 (b2)). Above findings show that the inlet velocity boundary condition has strong influences on the mixing characteristics.

CONCLUSIONS

In this paper, the influences of two different inlet boundary conditions on the flow and mixing characteristics of impinging streams for different hydrodynamics parameters are studied. The structures of flow and temperature fields, the horizontal velocity distribution at different cross sections and the mixing index along the axial location are compared in details, the comparisons show that the inlet velocity boundary condition has strong influences on the flow and mixing characteristics.

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