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Dispersion of Pollutant in an Air Flow along a Channal

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Abstract: In this study we investigate a dispersion of a pollutant ejected by a chimney in an air flow in laminar forced convection at the inner of channel. For this, we develop a code of finite volume method to simulate the dispersion phenomena. Then we test the performance of this code by comparing our results to those of M.C Melaaen in a case of fluid flow behind a march. The study of the dispersion of pollutant can be undertaken by considering certain numbers of parameters which have a direct influence on the distribution of pollutant in the channel. In our case, we have limited the study to the effect of Reynolds number on the pollutant repartition in the channel.

Key words: Forced convection, finite volumes, pollutant, and mass dispersion, repartion

INTRODUCTION

The pollutant distribution in air has aroused in these last years a very greater interest by researchers (Levi and Sini, 1992; Dulal and Khan, 1990; Wells and Stock,1983; Summerfield and Krebs, 1990; Sini *et al*., 1996) because of the degrading air quality by tail gazes, forest fires, industries and others sources. During some years, there are few researches in this field, only studies experimental in wind tunnel or in site, have make it possible to study the wind in the atmosphere boundary layer.

Improvement of calculator efficiencies in memories and in speeds of calculus, the numerical fluid mechanics is developed and the idea to use the mathematical models for describe the wind in the atmosphere is imposed. Some models (Levi and Sini, 1992; Sini *et al*., 1996), which describe also the pollutant diffusion in the atmosphere. In this domain, Sini *et al.* (1996) have study the dispersion of pollutant cloud in a street.

An other study has been conducted by Summerfield and Kreb (1990) that they are treated the particle dispersion case in a turbulent flow caused by a brusque increase diameter of pipe.

By means of this study, we try to study numerically, at location scale, the pollutant dispersion ejected by a chimney in flow into channel. We establish a code of calculus to simulate the dispersion phenomenon by the means of the finite element volumes presented by Patenkare (Sini *et al*., 1996).Then us after, study the Reynolds effect on the pollutant repartition in the channel.

MATHEMATICAL ANALYSIS

We consider a chimney which ejects, in permanence, a pollutant in an air flow into a horizontal channel. The air is an incompressible fluid, and obeys the boussinesq approximation. The flow is considered laminar. In addition, we suppose that the dimension in the direction the axis z of the channel has not effect on the flow to consider a bi dimensional flow and the length of the channel is very long so that the was totally developed.

The hydrodynamic limit conditions are characteristic of wall rigid impermeable and the particle adherence on the wall, these mean that u = v = 0

$$\frac{\partial C}{\partial Y} = 0$$

The boundary layer conditions for mass fraction are mentioned in the (Fig. 1).

The study conuration and the boundary layer conditions are showed in the (Fig. 1).

MATHEMATIC MODEL

The governing equations of the problem are represented by the continuity, Navies Stokes equations associated with mass transfer equation. After the simplifications based on the above assumptions, this equations are transformed in non dimensional form, in this way:

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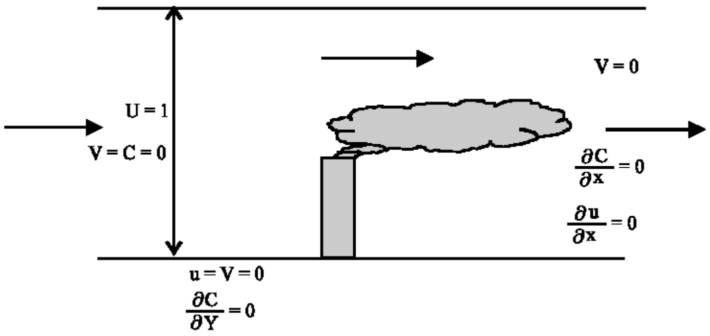


Fig. 1: Schematic diagram

$$\frac{\partial u^*}{\partial X^*}+\frac{\partial v^*}{\partial Y^*}=0 \qquad (1)$$

$$\frac{\partial C^*}{\partial t^*}+\frac{\partial u^*C^*}{\partial X^*}+\frac{\partial v^*C^*}{\partial Y^*}=\frac{1}{\mathrm{Sc.Re}}\left[\frac{\partial^2 C^*}{\partial X^{*2}}+\frac{\partial^2 C^*}{\partial Y^{*2}}\right] \qquad (2)$$

$$\frac{\partial u^*}{\partial t^*}+\frac{\partial u^*u^*}{\partial X^*}+\frac{\partial v^*u^*}{\partial Y^*}=-\frac{\partial P^*}{\partial X^*}+\frac{1}{\mathrm{Re}}\left[\frac{\partial^2 u^*}{\partial X^{*2}}+\frac{\partial^2 u^*}{\partial Y^{*2}}\right] \qquad (3)$$

$$\begin{aligned}&\frac{\partial v^*}{\partial t^*}+\frac{\partial v^*u^*}{\partial X^*}+\frac{\partial v^*v^*}{\partial Y^*}=-\frac{\partial P^*}{\partial Y^*}+\\ &\frac{1}{\mathrm{Re}}\left[\frac{\partial^2 v^*}{\partial X^{*2}}+\frac{\partial^2 v^*}{\partial Y^{*2}}\right]+\frac{1}{\mathrm{Re}}(\mathrm{Gr}_m.C^*)\end{aligned} \qquad (4)$$

We obtained these equations by choosing the following characteristic parameters.

$$(X^*,Y^*)=(x,y)/D,(u^*,v^*)=(u,v)/u_0,$$
$$t^*=t/(D/u_0),P^*=P/\rho u_0^2,$$

$$C^*=(c-C)/\Delta C,\mathrm{Gr}_m=$$
$$\frac{g\beta_m\Delta CD^2}{\nu^2},\mathrm{Re}=\frac{u_0 D}{\nu},\mathrm{Sc}=\frac{\nu}{D_m}$$

The numerical resolution of the Eq. 1,4 is based on the finite element volumes method derived by Patenkar (1980) and the power low scheme. The method consists to discrete the domain of the calculus in some volume elements surrounding the grid nodes in which, we integrate the differential equations. This method conserves the global and local flow conservative properties and has an important role in the calculus stabilization when solving these equations. We have also adopted the SIMPLEC algorithm (Van and Raithby, 1984) for the coupling between the conservation momentum and continuity equations.

We were interesting in the Reynolds number effect n the repartition of a pollutant ejected by a chimney. The numerical simulations have been performed in a domain defined by x = 0 and x = 500D.The thickness and the high of chimney are considered constants. The fluid carried the pollutant is the air Sc = 0.2. We have neglected the mass Graschoff and the range of Reynolds is 0, 1000, flux of pollutant is supposed constant at the entry of the chimney.

RESULTS AND DISCUSSION

Our code is valued by taken the experimental results obtained by M.C. Melaaen as reference, in the case of a flow behind a step march. The graphs of the (Fig. 2 and 3) represent the velocity profiles at different positions behind the step, are obtained for a Reynolds number equal to 150. We assist to a good agreement between the experiment results and our results.

The Fig. 4-6 present the mass fraction and stream lines fields obtained at stationary regime for the Reynolds numbers 100, 500 m and 1000. We remark that the stationary state is characterized by a vortex which is appears behind the chimney and constitute an obstacle in front of the flow.

Into the channel, this vortex localized at neighborhood the chimney, invades a large region in the channel when the Reynolds number increases. This vortex has a harmful role for the evacuation of pollutant ejected by the chimney. In fact, a quantity of particles of pollutant are trapped in this vortex, this is drive thus to an accumulation of the particles of pollutant near the chimney. It is then important to ventilate this region for carrying out this vortex far from the chimney.

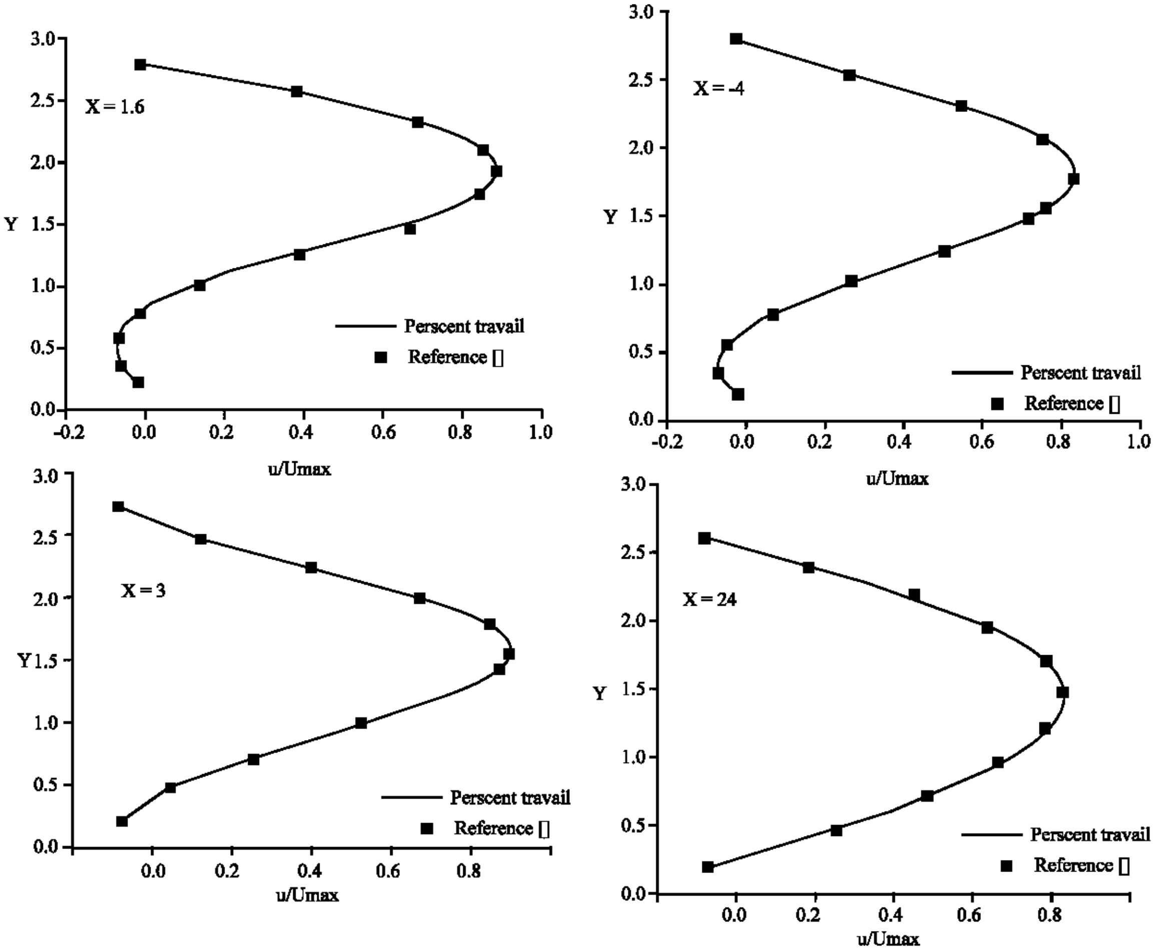
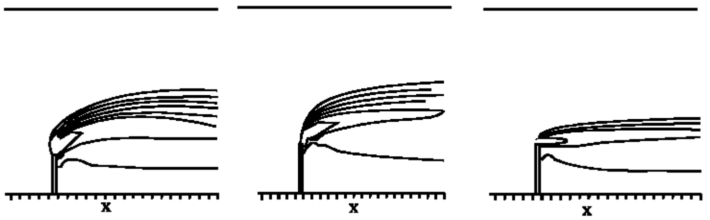
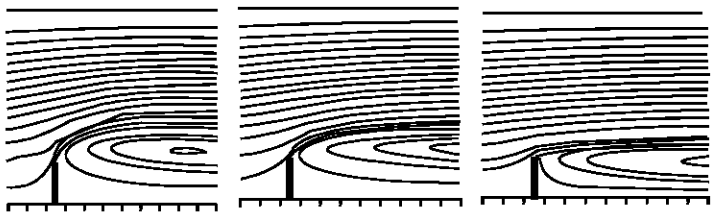


Fig.2: Velocity profiles at different positions behind the step of march (Re = 500)



a). Mass fration (Re = 100) b). Mass fration (Re = 500) c). Mass fration (Re = 1000)

Fig. 3: Mass fraction fields



a). Streamlines (Re = 100) b). Streamlines (Re = 500) c). Streamlines (Re = 1000)

Fig. 4: Streamlines

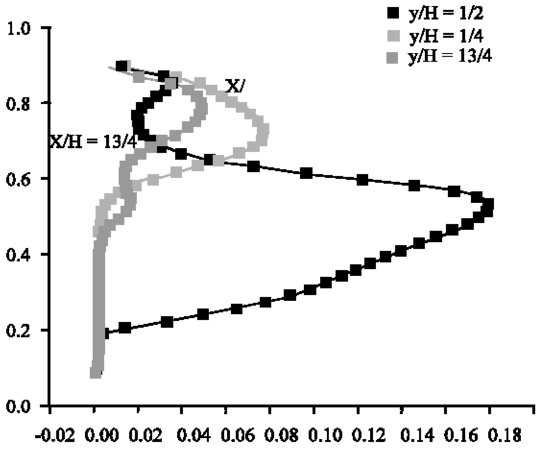


Fig. 5: Mass fraction profiles in function y at different positions x

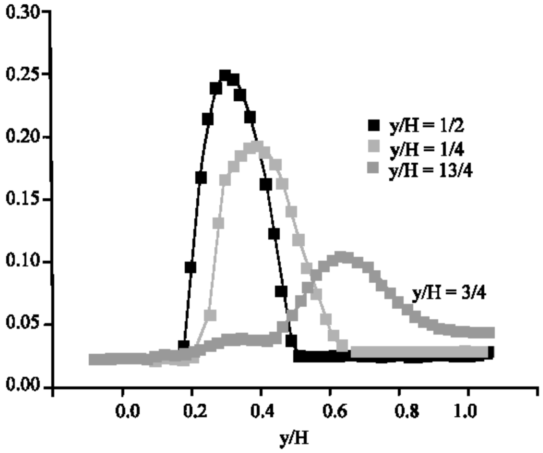


Fig. 6: Mass fraction profiles in Function xat different positions y

CONCLUSION

The results obtained by this study shows that the Reynolds number perform an important role in the dispersion of pollutant in air. In our research studies carry on with instigate the impact of the mass Grashof number, high chimney and the mass flux to dimensioned the chimney in the specify conditions of its functioning.

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