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Influence of perforated baffles on the performance of a solar collector

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***Abstract*— The improved performance of the solar collectors is to limit heat loss between the absorber and the ambience. This paper presents a study to an air flat plate solar collector with perforated baffles with a numerical study of the dynamic and thermal stationary air flow using the k-Epsilon turbulence model. We present afterwards the mathematical formulation of the problem studied and the numerical solution finite volume method using the Fluent solver.The results are presented in terms of the contour of pressure coefficient, the evolution of friction factor and the temperature distribution in the solar collector.**

***Keywords*— flat plate solar collector, k-Epsilon turbulence model, finite volume method, Fluent solver**

I. INTRODUCTION

In the solar air flat plate collector, the insufficiency of the thermal exchange between the fluid and the absorber obliges the user to enhance their optimization. This low thermal exchange does not allow these systems to obtain their best performance or the best thermal efficiency.

[1], improve the efficiency–temperature rise couple of the flat plate solar collector by considering several types of obstacles disposed in rows in the dynamic air vein of the flat collector. By comparing with the collector without obstacles, the thermal transfers and, consequently, the output temperature (TOC) and the collector efficiency are clearly improved. The drying times obtained with the proposed systems are very interesting.

[2], the influence of collector aspect ratio on the collector efficiency of upward type baffled solar air heaters has been investigated theoretically. With constant collector area, the collector efficiency increases with collector aspect ratio. This is the same results as those obtained in the previous work for flat plate solar air heaters without fins and baffles. Although the collector efficiency of baffled solar air heaters is larger than that of flat plate heaters without fins and baffles, the improvement of collector efficiency by increasing the collector aspect ratio is the reverse.

[3], in an experimental study, of a solar energy simulation, they have sought to improve the efficiency–temperature rise couple of the flat plate solar collector by considering several types of obstacles disposed in rows in the dynamic air vein of the collector. Thus, they have proceeded to the application of the best two systems for drying an agricultural product. By comparing with the collector without obstacles, the thermal transfers and, consequently, the output temperature and the collector efficiency are clearly improved. The drying times obtained with the proposed systems are very interesting. The heat quantities obtained are very important compared with the collector without obstacles.

[4], a comprehensive parametric study has been carried on the thermal performance of cross-corrugated solar air collectors. These collectors consists of a wavelike absorbing plate and a wavelike bottom plate which are crosswise positioned to form the air flow channel. Two types of these collectors are considered.

For the Type 1 collector, the wavelike shape of the absorbing plate is along the flow direction and that of the bottom plate is perpendicular to the flow direction, while for the Type 2 collector it is the wavelike shape of the bottom plate that is along the flow direction and that of the absorbing plate is perpendicular to the flow direction. The aim of the use of the cross-corrugated absorbing plate and bottom plate is to enhance the turbulence and the heat transfer rate inside the air flow channel which are crucial to the improvement of efficiencies of solar air collectors. Three types of solar air collector are analyzed and compared under various configurations and operating conditions. The results show that although the thermal performance of the Type 2 collector is just slightly superior to that of the Type 1 collector both of these cross-corrugated solar air collectors have a significantly superior thermal performance to that of the flat-plate one. It is also found that to achieve a higher collector efficiency, it is essential to construct the collectors having slender configurations along the air flow direction, to maintain a small mean gap between the absorbing plate and bottom plate, to use selected coatings on the absorbing plate and glass cover, to maintain a higher air mass flow rate, and to operate the collectors with the inlet fluid temperature close to that of the ambient fluid.

[5], study the numeric analysis of the turbulent flow inside a channel of rectangular section, with two types of obstacles in the two-dimensional case: a rectangular block obstacle and a rectangular obstacle with upstream round edge getting radius curvature 0.2 times the height of the obstacle. Several boundary conditions were explored, being the more realistic

results obtained by prescribing the inlet velocity field and atmospheric pressure at the exit. The objective of this paper is to compare the special round obstacle impacts on the recirculation zone and velocity profiles considering those of the rectangular block obstacle in the two-dimensional case. The existence of the obstacle in a flow certainly causes a recirculation zone located upstream and downstream of the obstacle. These zones may represent pollution areas, where the pollution remains retained.s.

[6], Performance improvement dynamics of a solar collector with rectangular perforated baffles. The orientation of the fluid to the top wall (absorber) slows down the fluid velocity,heating a maximum of coolant..

II. Problematic

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A. Geometry

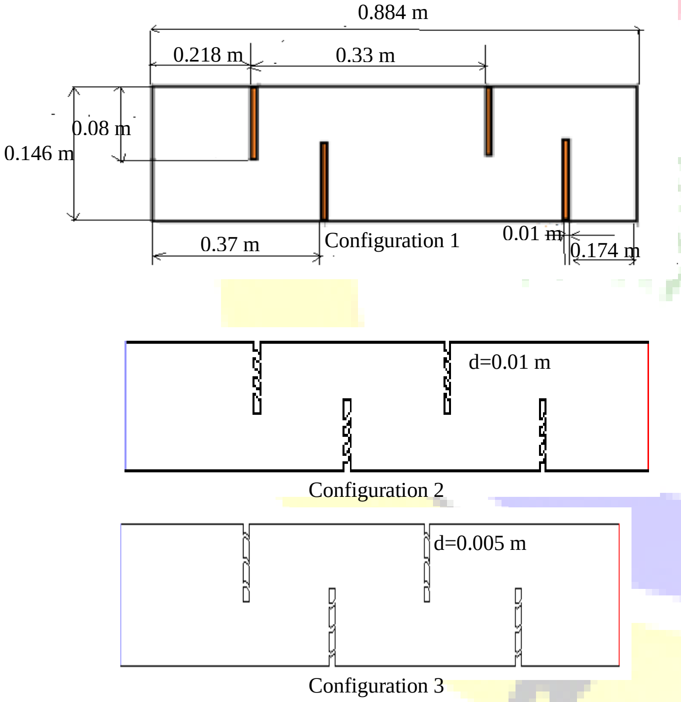

Fig. 1 Schematic of the physical problem

B. Governing equations

In Cartesian coordinates, the continuity, momentum, energy, and turbulence equations for a steady incompressible flow can be written as:

Continuity equation

$$\frac{\partial \rho}{\partial x}+\frac{\partial \rho}{\partial y}=0 \tag{1}$$

x-Momentum equation

$$\rho u\frac{\partial u}{\partial x}+\rho v\frac{\partial u}{\partial y}=-\frac{\partial p}{\partial x}+\frac{\partial}{\partial x}\left[(\mu+\mu_t)\left(2\frac{\partial u}{\partial x}\right)\right]+\frac{\partial}{\partial y}\left[(\mu+\mu_t)\left(\frac{\partial u}{\partial y}+\frac{\partial v}{\partial x}\right)\right] \tag{2}$$

y-Momentum equation

$$\rho u\frac{\partial v}{\partial x}+\rho v\frac{\partial v}{\partial y}=-\frac{\partial p}{\partial y}+\frac{\partial}{\partial y}\left[(\mu+\mu_t)\left(2\frac{\partial u}{\partial y}\right)\right]+\frac{\partial}{\partial x}\left[(\mu+\mu_t)\left(\frac{\partial u}{\partial y}+\frac{\partial v}{\partial x}\right)\right] \tag{3}$$

Energy equation in the fluid region

$$\rho u\frac{\partial T}{\partial x}+\rho v\frac{\partial T}{\partial y}=\frac{\partial}{\partial x}\left[\left(\frac{\mu}{p_r}+\frac{\mu_t}{\sigma_T}\right)\frac{\partial T}{\partial x}\right]+\frac{\partial}{\partial y}\left[\left(\frac{\mu}{p_r}+\frac{\mu_t}{\sigma_T}\right)\frac{\partial T}{\partial y}\right] \tag{4}$$

Energy equation in the solid region

$$\left(\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}\right)=0 \tag{5}$$

C. Turbulence Model

The k-Epsilon low-Reynolds number closure model is used.This model implies two transport equations i.e. turbulent kinetic energy and the dissipation of turbulent kinetic, as follows :

Transport Equation for Turbulent Kinetic Energy k

$$\rho u\frac{\partial k}{\partial x}+\rho v\frac{\partial k}{\partial y}=\frac{\partial}{\partial x}\left[\left(\mu+\frac{\mu_t}{\sigma_k}\right)\frac{\partial k}{\partial x}\right]+\frac{\partial}{\partial y}\left[\left(\mu+\frac{\mu_t}{\sigma_k}\right)\frac{\partial k}{\partial y}\right]+P_k-\rho\varepsilon \tag{6}$$

Transport Equation for Turbulent Dissipation Rate ε

$$\rho u\frac{\partial \varepsilon}{\partial x}+\rho v\frac{\partial \varepsilon}{\partial y}=\frac{\partial}{\partial x}\left[\left(\mu+\frac{\mu_t}{\sigma_\varepsilon}\right)\frac{\partial \varepsilon}{\partial x}\right]+\frac{\partial}{\partial y}\left[\left(\mu+\frac{\mu_t}{\sigma_\varepsilon}\right)\frac{\partial \varepsilon}{\partial y}\right]+\left(C_{\varepsilon 1}f_1P_k-\rho C_{\varepsilon 2}f_2\varepsilon\right)\frac{\varepsilon}{k} \tag{7}$$

and the eddy viscosity is define as :

$$\mu_t=f_\mu\rho.c_\mu\frac{k^2}{\varepsilon} \tag{8}$$

The model coefficients are as follows :

C_μ=0.09, $C_{\varepsilon 1}$=1.44, $C_{\varepsilon 2}$=1.44, σ_k=1.0,

σ_ε=1.3, σ_T=0.9, f_1=f_2=f_μ=1.

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is 210mm (8.27") wide and 297mm (11.69") long. The margins must be set as follows:Top = 19mm (0.75")

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III. Results and Discussion

The problem was numerically solved using the finite volume method with FLUENT 6.3

The standard k-є model can successfully predict the characteristics of the flow and heat transfer for this study.

To verify our numerical simulation, a comparison between the present results with those reported by Demartini [7],Fig 2.

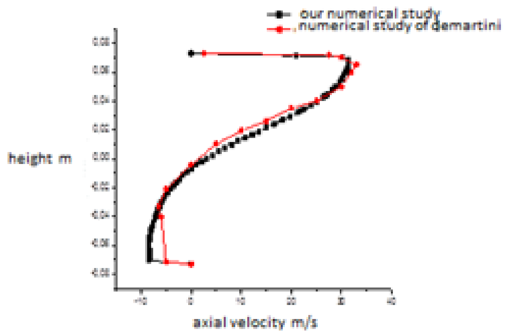

Fig. 2 Comparison between the modeling results and demartini for x = 0.525m

A. *Streamlines*

The figure 3 shows the Behaviour of streamlines in the duct of solar collector.

Appearance of secondary flow on the level of the perforations (configuration 2, configuration 3).

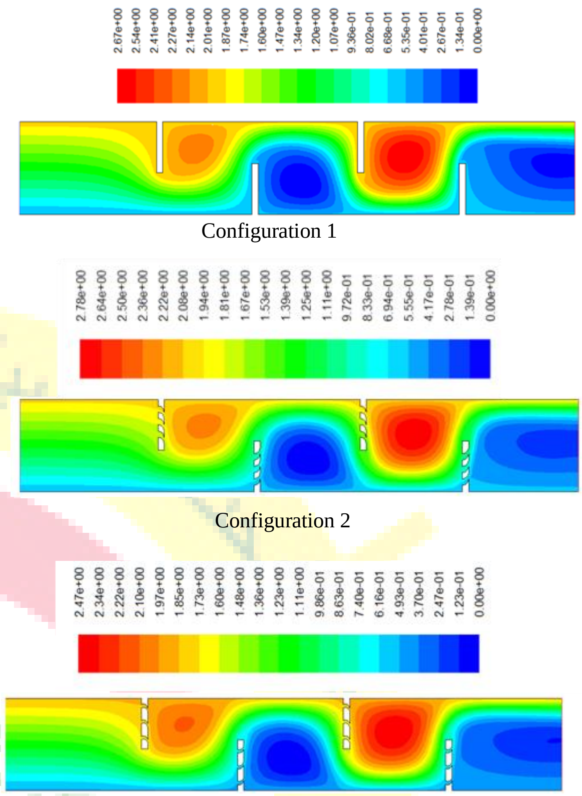

Fig. 3 Contour of streamlines for the three configurations of the solar collector

B. *Axial velocity*

The evolution of axial velocity is illustrated in Figure 4 for the three configurations of the solar collector.

The presence of the perforated baffles (configuration 2 and configuration 3) leash increased the axial velocity at the level of baffle perforations.

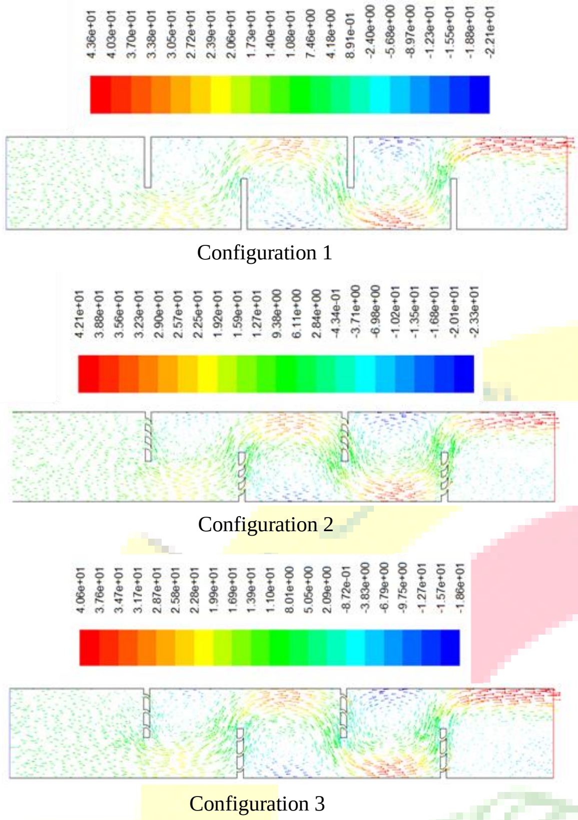

Fig. 4 Contour of pressure coefficient for the three configurations of the solar collector

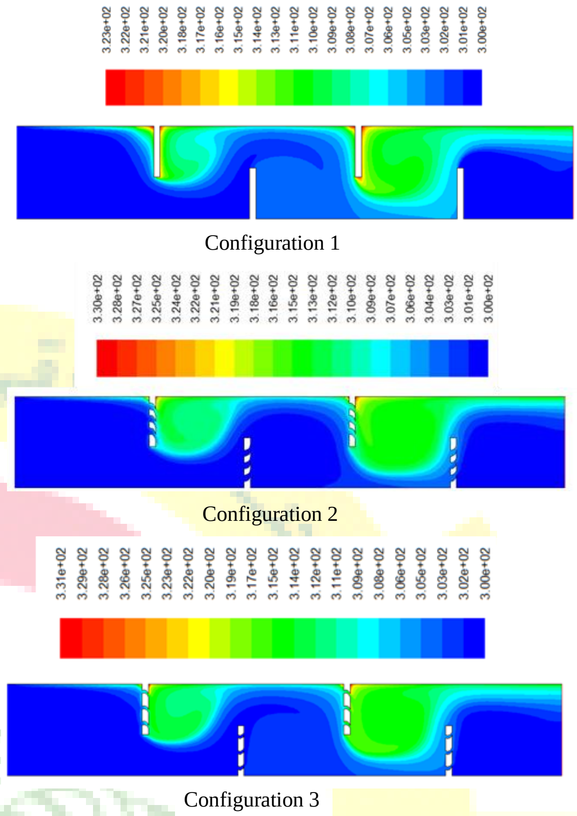

Fig. 5 Contour of temperature for the three configurations of the solar collector

C. *Temperature distribution*

The evolution of the temperature distribution is shown in Figure 5 and Figure 6.

The figure 5 shows that the perforated baffles plates of the configuration 2,3 play an effective factor to dissipate the heat from the solid walls and the temperature of the flow increases in the regions occupied by the baffles and between the baffle plates compared with the configuration 1

As show in figure 6 the temperature the temperature of the coolant in the solar collector with perforated baffles plates configuration 2,3 increase to 316 K at the outlet.

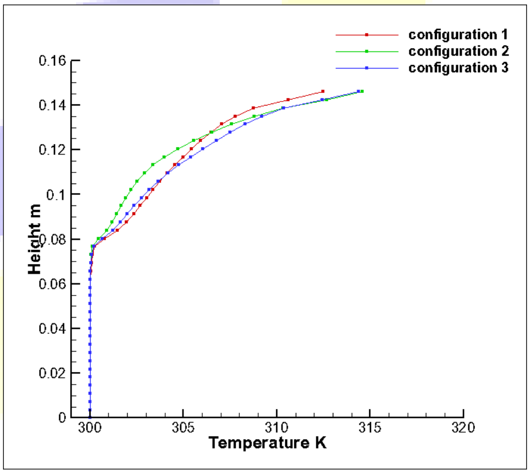

Fig. 6 Profiles of temperature for the three configurations of the solar collector to the position of the section x=0.884 m to the position of the section to the position of the section

IV. Conclusions

In this study the k-є turbulence model has been adopted to predict the details of the turbulent flow and heat transfer through a flat plate solar collector with simple baffles and perforated baffles for three configurations plates. The objective of this study was an numerical investigation of the turbulent flow in a rectangular channel provided with the simple baffles and perforated to study the thermal effects between the different configurations.. The comparison of pressure coefficient, friction factor and Temperature in the solar collector

The solar collector with perforated baffles is the most efficient.. has allowed us to visualize the best performance of the solar collector with perforated baffles (six perforations in the baffles configuration 3.

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