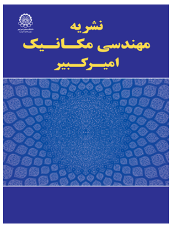

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Numerical Investigation of Fin Position Effect on the Forced Convection Heat Transfer Inside a Channel in Turbulent Flow

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ABSTRACT: The using of fins for convection heat transfer enhancement is one of the effective approaches of heat transfer enhancement in a 2 dimensional channels. In this investigation, five different geometries for fins have been considered; numerical results were presented for fluid flow variables and heat transfer. For this purpose, governing equations of fluid flow and heat transfer were discretized with finite volume method; also for linking of velocity and pressure of fluid flow, SIMPLE algorithm was employed. Turbulent flow modelling was applied by turbulent model. Sensitivity of numerical results from computational grid and validation of numerical results were provided in compare of experimental and other numerical investigation. Then, geometries were investigated for fins include of triangle with different angle, trapezoidal and square. For these geometries, numerical results for velocity vector, pressure drop and temperature of fluid have been presented. Finally, heat transfer results were studied with regards to Nusselt number. Triangle fin with angle of 60 degrees respect to angle of 90 degrees has more Nusselt number and trapezoidal fin has much Nusselt number among five studied fins. From the investigation of the heat transfer to pressure drop ratio, it was observed that the trapezoidal fins have the best performance.

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1- Introduction

Heat transfer enhancement in channels by using various fin geometries has been an interesting field of research in recent years. Marvasti et al. [1] studied natural convection heat transfer inside a channel having inclined parallel plates numerically. They found that triangular fin with angle 120° has better performance with respect to fins having angles 45° and 60°.

Ayli et al. [2] investigated forced convection heat transfer on an array of rectangular fins by numerical and experimental methods and evaluated the effects of geometrical parameters on Nusselt number. Yang et al. [3] studied the effects of Reynolds number, conduction and entry length in a forced convection channel flow having parallel plates with various arrays of fins. Yang et al. [4] also used finite difference method on a non-uniform mesh to study forced convection heat transfer in a channel with side fins. Abu-Hijleh [5] studied forced convection heat transfer and flow in a cylinder for various Reynolds and Nusselt numbers and optimized the number of fins and their position. Cucchi et al. [6] studied forced convection heat transfer in a channel having plates positioned at angle 60°. Amghar et al. [7] conducted a numerical simulation of turbulent forced convection in a channel with side baffles for cooling the walls. They used k-ε model and SIMPLE algorithm.

In this paper, the turbulent flow and heat transfer in a channel for various fin geometries (including triangular, square, and trapezoidal fins) are studied numerically. The numerical simulation is carried on by Fluent software and the results of Nusselt number and pressure drop are presented.

2- Methodology

To simulate the turbulent forced convection heat transfer, it was assumed that flow is incompressible and steady, the physical properties are constant, the entrance velocity is uniform, and the radiation heat transfer is negligible. The governing equations of the problem are continuity, momentum, and energy equations which are in the following form:

$$\frac{\partial}{\partial x_i}(\rho u_i)=0 \qquad (1)$$

$$\frac{\partial}{\partial x_i}(\rho u_i u_i)=-\frac{\partial \rho}{\partial x_i}+\frac{\partial}{\partial x_i}\left[\mu\left(\frac{\partial u_i}{\partial x_i}+\frac{\partial u_j}{\partial x_j}-\frac{2}{3}\delta_{ij}\frac{\partial u_k}{\partial x_k}\right)\right]+\frac{\partial}{\partial x_j}\left(-\rho\overline{u_i' u'_j}\right) \qquad (2)$$

$$\frac{\partial}{\partial x_i}\left[\rho u_i\left(h+\frac{1}{2}u_j u_j\right)\right]=\frac{\partial}{\partial x_j}\left[k_{eff}\frac{\partial T}{\partial x_j}+u_i(\tau_{ij})_{eff}\right], \qquad (3)$$

$$k_{eff}=K+\frac{c_p\mu_t}{Pr_t}$$

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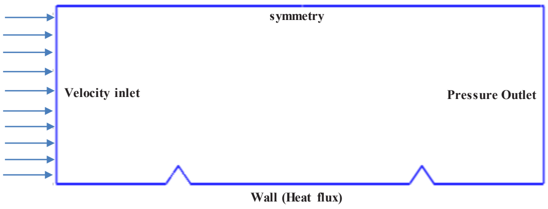

Fig. 1. The geometry of problem and the boundary conditions

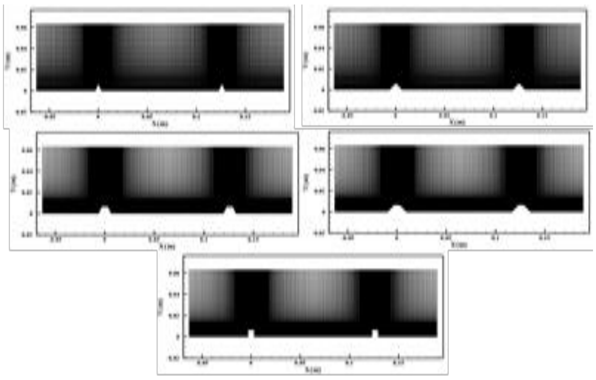

Fig. 2. The grid generated for five fin geometries

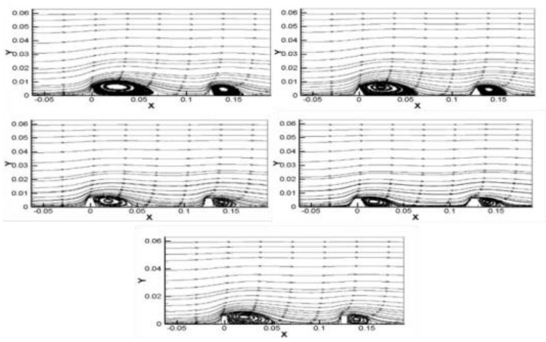

Fig. 3. Streamlines for different types of fin geometry

where ρ is density, u_i is the mean velocity, p is pressure, u' is the fluctuating component of velocity, h is the mean enthalpy, τ_{ij} is the effective shear stress, and k_{eff} is the effective conduction coefficient. To model the Reynolds-averaged stress and the effective shear stress, Re-Normalization Group (RNG) k-ε model is used.

The grid is generated using the Gambit software. The second order approximation is used to discretize the convective terms. The convergence criteria for continuity and momentum equations is set to 10^{-6} and for energy equation is set to 10^{-9} in the Fluent software. The inlet velocity and temperature are set to 3.6 m/s and 300 K respectively. The bottom wall has no slip boundary condition and a constant heat flux of 28 W/m^2.

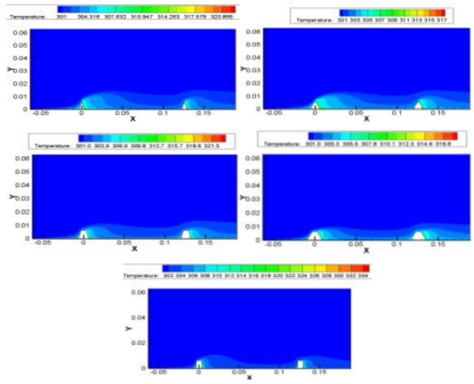

Fig. 4. Fluid temperature for five different fins

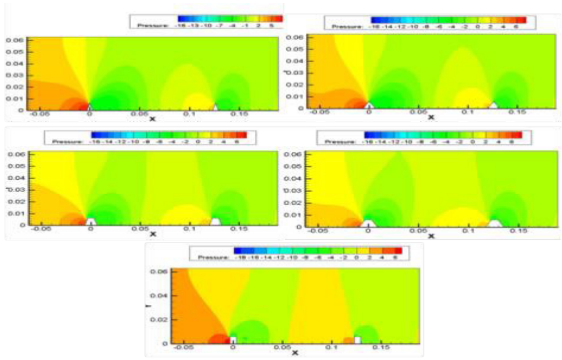

Fig. 5. Pressure coefficient for different types of fin geometr

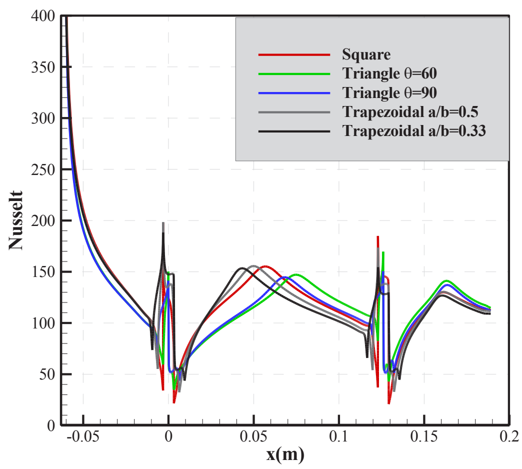

Fig. 6. Comparison of total moment vs. azimuth angle for 60 RPM

3- Results and Discussion

As seen in Fig. 3 a comparison has been made among streamlines of different types of fin geometry. As seen in this figure, the triangular fins have larger flow separation zone due to their sharp corner. The triangular fin with angle 60° has the highest vortex elevation among studied fins.

In Fig. 4 the fluid temperature profile of different types of fin geometry is presented. It is observed that the trapezoidal fins have the maximum heat transfer.

In Fig. 5 the pressure coefficient profile of different types of fin geometry is shown. As seen in this figure, the triangular fins have the maximum pressure drop.

In Fig. 6 the variation of Nusselt number near in the channel is depicted. As seen in this figure, trapezoidal fins have the highest average Nusselt number. Considering both Nusselt number and pressure drop coefficient as two important parameters for heat transfer enhancement, one can compare the ratio of Nusselt number to pressure drop coefficient for different types of fins to find the best performing fin. This comparison reveals that the trapezoidal fin with a/b=0.33 has the best performance among the studied fins.

4- Conclusions

In this paper the effect of five different fin geometries on heat transfer enhancement for a turbulent forced convection flow in a 2 dimensional channel was investigated. It was found that the triangular fins have the maximum pressure drop and the trapezoidal fins have the highest average Nusselt number. By the comparison of heat transfer to pressure drop ratio, it was observed that the trapezoidal fins have the best performance.

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