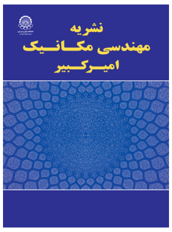

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Hydrothermal performance of trapezoidal fin equipped with vortex generator and hole: Investigation of the effect of vortex generator and hole position

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ABSTRACT: Today, the issue of increasing heat transfer has attracted a great deal of attention from researchers for the development of a variety of heat exchangers to achieve high efficiency, low cost, lightweight. In this paper, the hydrothermal performance is investigated by incorporating vortex generator and hole and their proper positioning on trapezoidal fin. For this purpose, numerical modeling of water flow in a rectangular channel is performed in two laminar and turbulent flow regimes and for 5 models with different positions of vortex generator and hole in constant size geometric parameters. The results showed that in both flow regimes, the pressure drop was increased by inserting the hole on top and bottom. To create a better comparison, the ratio of the Colburn factor to friction factor was defined and applied in two simple and powerful ways and the best hydraulic-thermal performance was obtained for the trapezoidal fin with the vortex generator on the right and the hole in the middle, so that in the turbulent flow regime, the highest value for the ratio of Colburn factor to friction factor (simple ratio and power ratio) was reported as 0.0539 and 0.01504 for this position, respectively.

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1- Introduction

In recent years, the use of Vortex Generators (VGs) in heat exchangers is one of the effective methods in increasing the rate of heat transfer. On the other hand, the use of VGs increases the overall pressure drop. Researchers who have used cavities or holes in the fins found that this method can reduce the pressure drop and weight of the fins in addition to increasing the heat transfer surface [1, 2].

The effect of VG and hole position on a Trapezoidal Fin (TF) in the channel has not been investigated in the past. For this purpose, in the present study, 5 models with different VG and hole positions were designed and compared in two laminar and turbulent flow regimes.

2- Methodology

2.1. Computational Domain

The geometry studied in this paper consists of a channel with a width (*W*) of 20 mm and length (*L*) of 500 mm respectively. A trapezoidal fin with corrugation amplitude (*a*) and corrugation length (*l*), equipped with VGs and holes are embedded in the center of this channel. The middle part of the computational domain of the channel is shown in Fig. 1. Also, two other parts are added at the upstream and downstream of this structure as inlet part and outlet part, respectively.

The geometric dimensions in Fig. 1 are optimized using the Taguchi method [3]. These parameters including *a*, *l*, *h*, *t* and *w* are selected as 2.5, 120, 3.75, 15 and 15 mm, respectively.

2.2. Numerical Method And Governing Equations

In the present work, ANSYS-Fluent v.18 software is applied to solve the governing equations. The water flow is used in two laminar ($200 \leq Re \leq 1600$) and turbulent ($4000 \leq Re \leq 10000$) flow regimes. The governing equations are solved using the finite volume method, and the standard discretization scheme is used in the modeling following the second-order upwind of the momentum and energy discretization. Also, the SIMPLE algorithm is applied to solve the pressure and velocity coupling. The conservation equations for continuity, momentum, and energy for incompressible flow are generally expressed as follows:

$$\frac{\partial}{\partial x_i}\left(\rho u_i\right)=0 \tag{1}$$

$$\frac{\partial}{\partial x_i}\left(\rho u_i u_j-\mu \frac{\partial u_j}{\partial x_i}\right)=-\frac{\partial p}{\partial x_j} \tag{2}$$

$$\frac{\partial}{\partial x_i}\left(\rho u_i T\right)=\frac{\partial}{\partial x_i}\left(\frac{\kappa}{c_p} \frac{\partial T}{\partial x_j}\right) \tag{3}$$

Also, in the current study, the RNG k–ε model [4] is used as the turbulent model.

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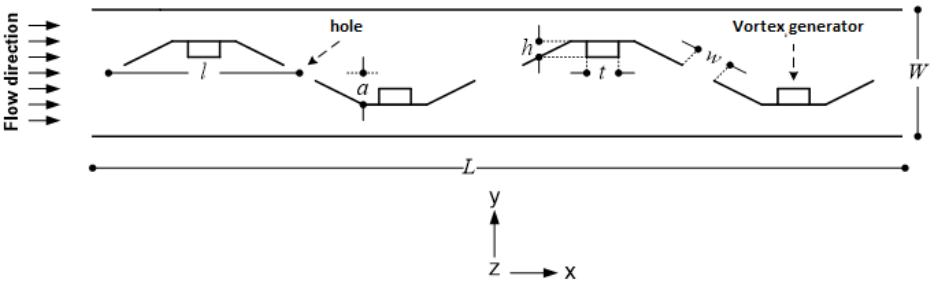

Fig. 1. The middle part of the computational domain

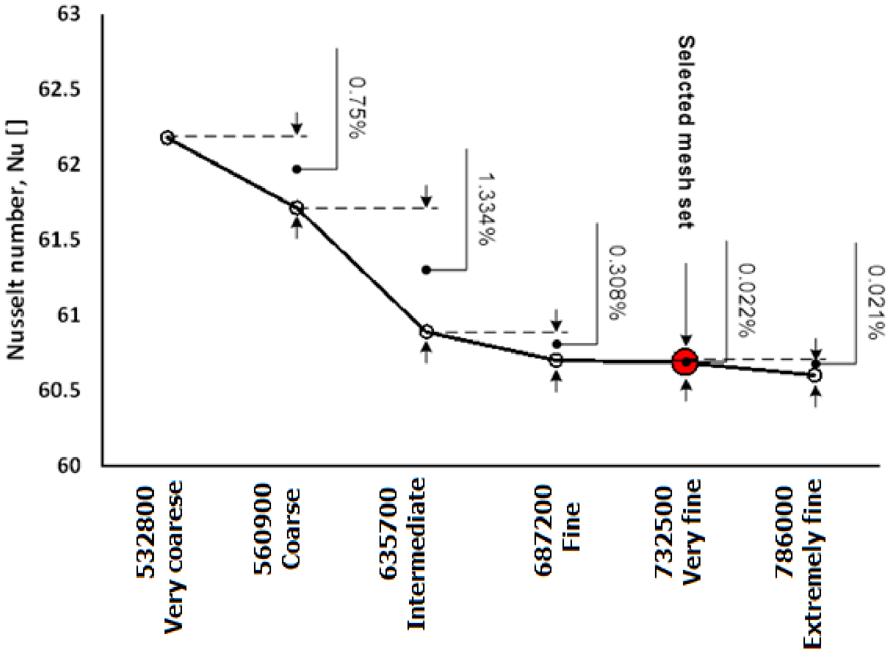

Fig. 2. Effect of mesh number on Nusselt number

2.3. Mesh Study And Grid Dependence Check

In the current study, irregular triangular meshes are used. These meshes are intensified well around the VGs and holes of the TF as well as near the sidewalls of the channel. As presented in Fig. 2, it was found that the results of the Nusselt number are insensitive to mesh number (with a maximum deviation of 0.021%) beyond the very fine set. Hence, this set of meshes is chosen for the current numerical simulation.

2.4. Boundary Conditions

In the inlet part, the velocity inlet condition is used with variable velocity values and constant bulk temperature of 303.15 K. In the outlet part, the outlet boundary condition is pressure outlet (Outlet gauge pressure=0). The adiabatic with no-slip boundary condition is applied at the sidewalls of these two parts. In the middle part of the channel, a constant temperature of 368.15 K with no-slip boundary condition is used at the solid surfaces of both the channel and the TF with VGs.

3- Results and Discussion

In order to analyze the numerical results, 5 models with different positions of VG and hole including VG in left and right, hole in top and bottom and finally, both the VG and the hole in the middle of the TF have been compared in two laminar and turbulent flow regimes. Two ratios are introduced using the carbon factor and friction factor to compare the hydrothermal performance results. Fig. 3 shows different models of the VG and hole position on the TF.

3.1. Laminar Flow

The results of the j/f ratio of all models in the laminar flow are presented in Fig. 4 against the Reynolds number. It can be seen that j/f ratio for the position of the hole at the top and bottom, has the lowest values relative to the other positions due to high-pressure drop.

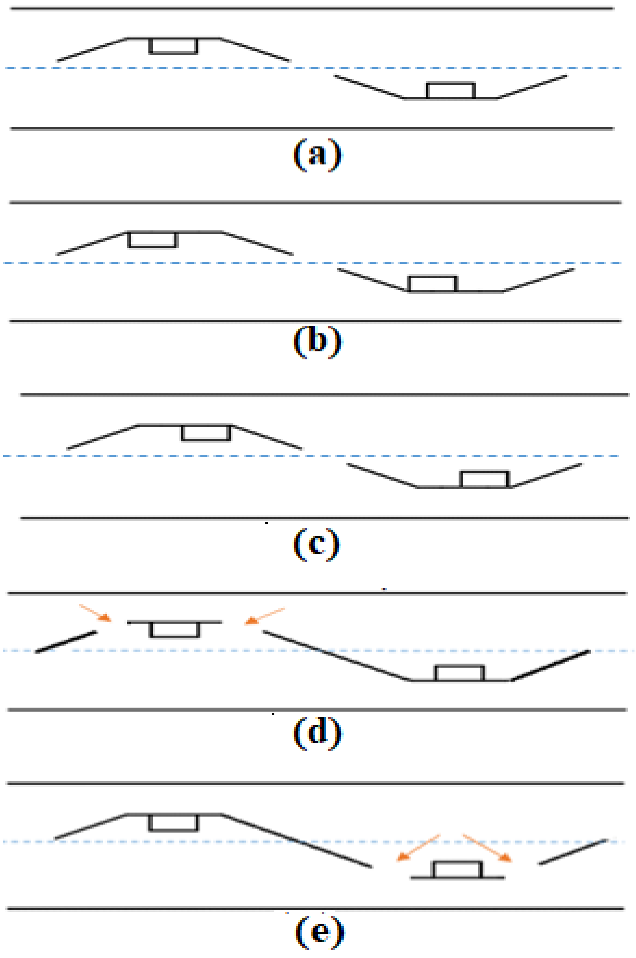

Fig. 3. Different models of VG and hole position (a) VG and hole in the middle, (b) VG on the left, (c) VG on the right, (d) Hole on the top, (e) Hole on the bottom

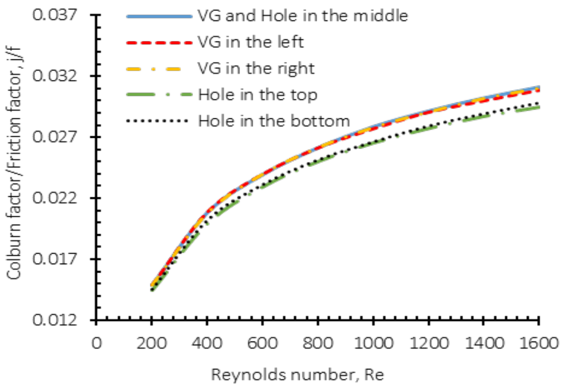

Fig. 4. j/f ratio-Reynolds number in the laminar flow

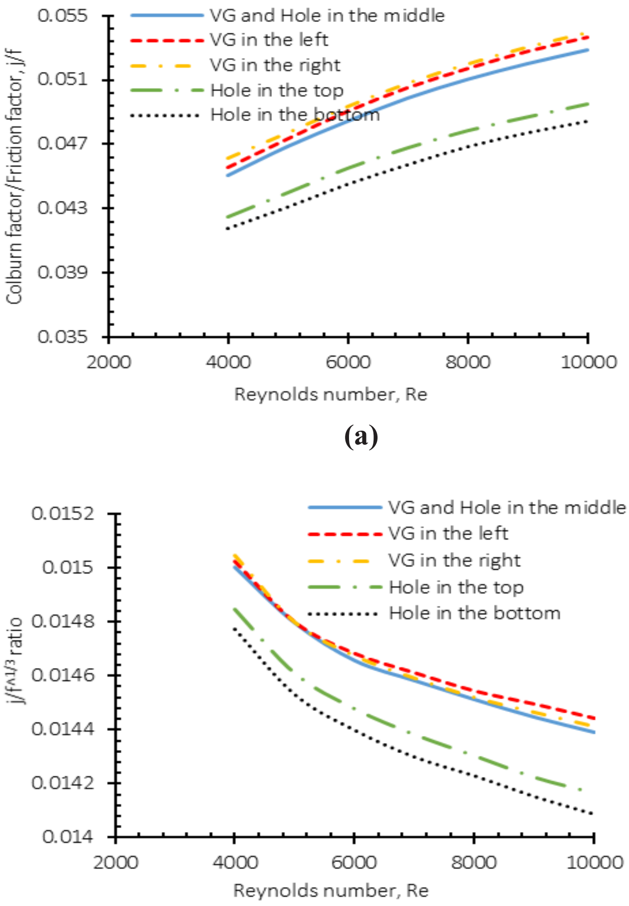

Fig. 5. (a) j/f ratio, (b) j/f1/3 ratio in the turbulent flow

3.2.Turbulent Flow

The results of the *j/f* and $j/f^{1/3}$ ratios of all models in the turbulent flow are displayed in Figs. 5(a,b). It is found that for three positions of VG where the hole is inserted in the middle of the inclined section, the fluid flow is timely transferred from the top to the bottom section, and leading to a decrease of the pressure drop and increase of the hydrothermal performance.

4- Conclusions

The following conclusions can be made from the current study:

- In both flow regimes, by inserting the hole in the top and bottom of the trapezoidal fin, the hydrothermal performance decreased.
- The TF has the best hydrothermal performance when the VG is in the left and right and the hole in the middle, so that the highest values of 0.0539 and 0.01504 are obtained, respectively, at the maximum and minimum Reynolds numbers for *j/f* and $j/f^{1/3}$ in the turbulent flow.

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