Numerical Simulation Research on Flow and Heat Transfer of Air Sweeping Slit Fin-Tube Heat Exchanger

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Abstract. In this paper, three types of physical models of fin-tube heat exchanger are established, including the rectangular fin, slit fin of > < type and slit fin of < > type. The flow and heat transfer law of air sweeping across all the three fins are simulated with ANSYS Fluent, temperature field and Nussle number distribution under different wind speed are obtained. Take the properties of heat transfer and resistance into consideration and contrastively analyze the convective heat transfer coefficient and flow loss, conclusions can be drawn that: compared with other two kinds of fins, the slit fin of > < type has a better function in increasing the effect of heat transfer, providing a reference for optimizing the new type of fin-tube heat exchanger.

Keywords: Strengthening heat transfer, slit fin, numerical simulation, heat transfer characteristics, resistance characteristics.

1. Introduction

In the field of fin-tube heat exchanger, air-side heat transfer enhancement has broad prospects for development. The domestic and foreign scholars have conducted a lot of research work on the flow and heat transfer properties of the fin-tube heat exchanger [1].

This paper will study the impact of changes in the structure of the fins on the heat transfer performance at different wind speed based on the existing research results. In order to enhance the heat exchanger of the air side of the finned tube, the numerical simulation method was adopted to study the heat transfer performance of the slit-type finned tube heat exchanger in the process of the operation in dry conditions [2].

2. Calculation Model

2.1. Governing Equations.

With the fin-tube heat exchanger's heat transfer simulated numerically, it can be simplified and made the following assumptions[3]:(1) Working medium is incompressible Newtonian fluid; (2) Ignoring the gravity and buoyancy caused by density difference; (3) Ignoring the thermal effect caused by viscous dissipation of fluid motion. The calculation mathematical model uses the standard k-ε equation model. The turbulent kinetic energy equation k:

$$\frac{\partial(\rho k)}{\partial t}+\frac{\partial(\rho k u_i)}{\partial x_i}=\frac{\partial}{\partial x_j}\left[\left(\mu+\frac{\mu_t}{\sigma_k}\right)\frac{\partial k}{\partial x_j}\right]+G_k+G_b-\rho\varepsilon-Y_M \tag{1}$$

The diffusion equation ε :

$$\frac{\partial(\rho \varepsilon)}{\partial t}+\frac{\partial(\rho \varepsilon u_i)}{\partial x_i}=\frac{\partial}{\partial x_j}\left[\left(\mu+\frac{\mu_t}{\sigma_\varepsilon}\right)\frac{\partial \varepsilon}{\partial x_j}\right]+C_{1\varepsilon}\frac{\varepsilon}{k}\left(G_k+C_{3\varepsilon}G_b\right)-C_{2\varepsilon}\rho\frac{\varepsilon^2}{k} \tag{2}$$

G_k -the turbulence kinetic energy caused by the laminar flow velocity gradient;

G_b -the turbulence kinetic energy caused by the buoyancy;

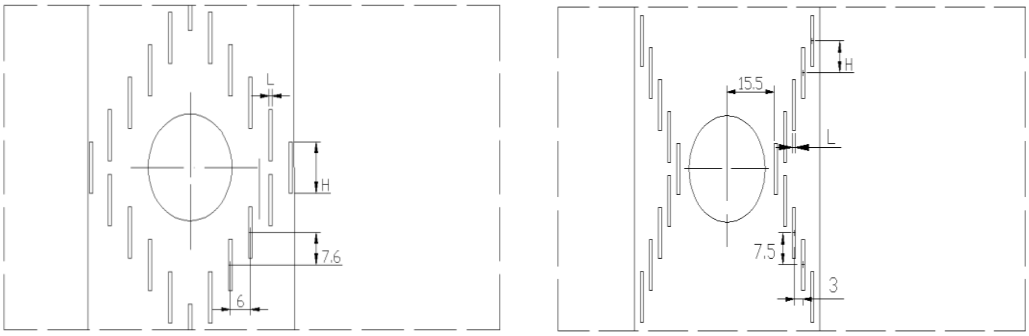
Y_M -the volatility caused by the transition spread in the compressible turbulent flow.

2.2 Boundary Conditions.

In this paper, numerical simulation is carried out under dry conditions. Obtaining the following boundary conditions based on the experimental situation[4]: (1) Ignoring the contact thermal resistance and radiation heat transfer between the fin and tube. Keep the hot water temperature constant in the tube; (2) The pressure and velocity on the outflow boundary are unknown, so it uses free flow boundary conditions. All variables' diffusion flux on the export are 0 in the vertical direction surface. In other words, $\frac{\partial \phi}{\partial x}$ =0; (3) The thermal boundary of the fin surface uses the calculation which is coupled with thermal conductivity and surface convective heat transfer; (4) Two narrow sides of the fin and four lateral surfaces of the air area use symmetrical boundary conditions.

2.2 Material Parameters.

Assuming that the channel between the fins is uniform, just take a fin unit as calculated area as shown in Fig.1.The air flow area is fluid field. Besides, the fins and the base tube are solid area, and their material are aluminum[5]. Fins size: tube diameter D_0 =25mm, fin thickness b=0.5mm, tube spacing Y=76mm, fin spacing S=10mm, fin width W=61mm. Slit size: slit width L=1mm, slit length H=12mm.



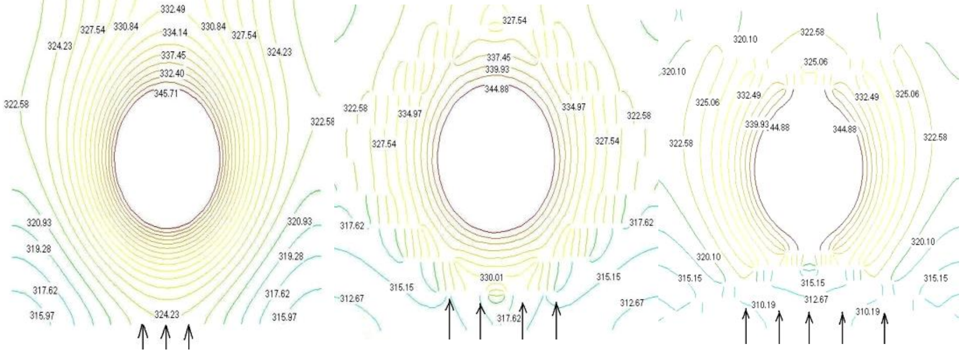
a) slit fin of < > type b) slit fin of > < type

Fig.1 The analogue units

3. Simulation Result Analysis

3.1 Temperature Field

The temperature on the leading edge of the fin is lower. However, closer to the base tube, the higher the temperature of the fin is, while the back area of the base tube forms a larger high-temperature region, which is an air circulating vortex wake region. Circulating air can not effectively remove heat, making the back of the base tube fin surface temperature high. Obviously, wake region is weak areas of heat transfer. When the wind velocity is 4m/s, the distribution of three fins' temperature field is shown in Fig.2.



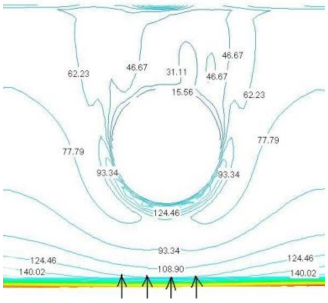
a) the rectangular fin b) slit fin of < > type c) slit fin of > < type

Fig.2. The distribution of fins' temperature field

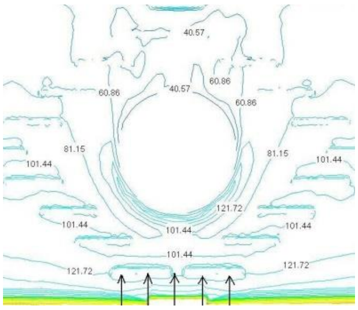
3.2. Nusselt Number.

The closer to the base tube, the higher the temperature of the fin is, Nusselt number indicates the strength of fluid's convective heat transfer. As shown in Fig.3, the wind velocity is 4m/s, and the

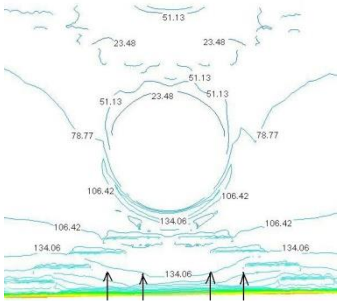
Nusselt number in the inlet section of the fin is maximum. Along the flow direction, the Nusselt number is gradually decreased. The reason is that the gradual thickening of the boundary layer resulted in heat transfer reduced. The minimum Nusselt number appears in the wake region behind the tube. In the wake region which is the weakest of the fin heat transfer part, the air can not effectively remove heat and heat transfer temperature difference is maximum. Therefore, the heat transfer effect is worst and Nusselt number is minimum.



a) the rectangular fin



b) slit fin of < > type



c) slit fin of > < type

Fig.3 The distribution of fins’ Nusselt number

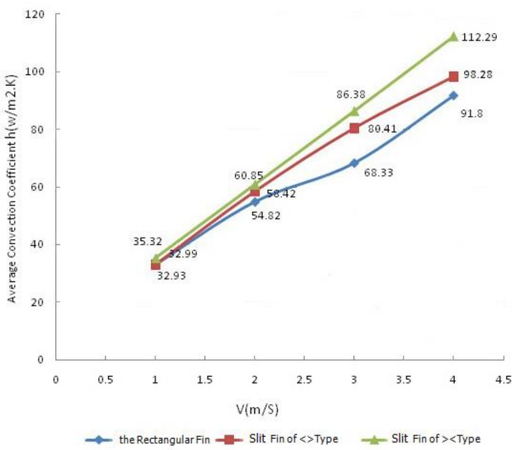
Slit fin of < > type and slit fin of > < type, their heat transfer effect is better than the rectangular fin’s, it’s due to the disturbance of slit which destroy the boundary layer and increase the nusselt number. Slit fin of > < type’s heat transfer effect is better than slit fin of < > type’s, because it improve the wake region which heat transfer is weak and behind the base tube.

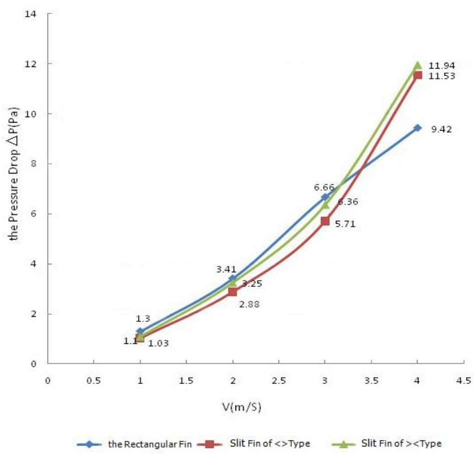
3.3. Characteristic Evaluation.

Slit fin of < > type and slit fin of > < type, their heat transfer effect is better than the rectangular fin’s. Under the same conditions, the air mass flow through the heat exchanger is substantially equal, therefore the comprehensive comparison of the heat exchanger's heat transfer and resistance is necessary. The heat transfer coefficient mean and the pressure mean of the fin air-side can be calculated by FLUENT. So it will evaluate the heat transfer characteristics and resistance characteristics of the three fins. The average values of simulation results calculated under different wind velocity are tabulated in Table 1. And Heat transfer performance and resistance performance are shown in Fig.4.

Table 1 The average convection coefficient of the three fins at different wind

u/(m/s)	h_1/(w/m^2 K) (the rectangular fin)	h_2/(w/m^2 K) (slit fin of < > type)	h_3/(w/m^2 K) (slit fin of > < type)	h_2/ h_1	h_3/ h_1
1	32.99	32.93	35.32	1.00	1.07
2	54.82	58.42	60.85	1.07	1.11
3	68.33	80.41	86.38	1.18	1.26
4	91.80	98.28	112.29	1.07	1.22





a) The relation curve of average convection coefficient and wind velocity; b) The relation curve of pressure drop and wind velocity

Fig.4. Heat transfer performance and resistance performance

By compared with their heat transfer performance, the following conclusions can be drawn: (1) In the range of wind velocity 1-4m/s, compared with the same dimensions of the rectangular fin, the slit fin of > < type’s average convective heat transfer coefficient maximally increase of 26.42%, and slit fin of < > type’s maximally increase of 17.68%. (2) The slit fin of < > type’s average convective coefficient increases 7.87% than the rectangular fin, and the slit fin of > < type’s increases of 16.75%. In summary, slit fin of > < type has excellent enhanced heat transfer effect;(4)In general, since slit enhances spoiler, the larger the wind velocity is, the better slit fin of > < type and slit fin of < > type’s enhanced heat transfer effect is.

By compared three different fins’ resistance properties, the following conclusions can be drawn: (1) In the range of wind velocity 1-3m/s, compared with the same dimensions of the rectangular fin, the minimum pressure drop of slit fin of > < type on the air area entrance is only 85.30 percent of the rectangular fin’s. However, the value of slit fin of < > type is only 79.53%. (2) In the range of wind velocity 1-3m/s, due to the stronger spoiler effect of slit fin of > < type, the pressure drop of slit fin of > < type air region entrance is slightly larger than that of slit fin of < > type, and it's approximately 1.09 times larger than slit fin of < > type. (3) When the wind velocity is large, both slit fin of < > type and slit fin of > < type enhance spoiler. Thereby it results in an increase of resistance loss growth. When it reaches a certain velocity, and their resistance loss will be greater than the rectangular fin’s.

4. Conclusion

(1) Slit fin have had the effect of strengthening heat transfer. Setting up to some slits on the heat transfer weak positions of the fin surface have destroyed the boundary layer. So it have decreased the wake zone area, and achieved the purpose of strengthening heat transfer.

(2) When the air flow velocity increases gradually, the effect of fin heat transfer will get better, but the flow resistance will also increase.

(3) When the air flow velocity is small, the resistance loss was mainly caused by a boundary layer; when the flow velocity is large, the slit will enhance the spoiler of air flow, and the pressure loss will also increase.

(4) The comparison of the heat transfer characteristics and resistance characteristics of these three fins indicates that slit fin of > < type has more efficient heat transfer enhancement property than slit fin of < > type and the rectangular fin. Thus it is a better type.

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