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Research Article

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The Influencing Factors Analysis of Heat Exchanger in Engineering Practice

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ABSTRACT

This thesis uses CFD software FLUENT to simulate the movement and heat transfer of the heat exchanger and get the temperature distribution. This thesis simulates the movement and heat transfer of the heat exchanger in steady work state, and compares the twisted-model's heat transfer performance with the no-twisted-model's. It points out that the design parameter of heat exchanger has deficiency, and suggests that the heat exchanger can be improved by reducing the velocity of air or by using short twisted tape instead of long twisted tape. The effect of the velocity of air to the twisted-tube's or no-twisted-tube's surface heat transfer coefficient is analyzed through the simulation to the single tube model. This thesis compares the difference between twisted-tube's and no-twisted-tube's heat transfer performance and points out that the velocity of air in the tube should be controlled below 20m/s.

Key words: Heat exchanger; Temperature field; Heat transfer simulation

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INTRODUCTION

Heat exchanger is the essential processing equipment in petrochemical industry, improving the heat transfer performance of heat exchanger means the temperature gradient will be larger, the increase of the temperature gradient will inevitably lead to greater thermal deformation on structure [1]. In the process of actual heat exchanger design and production, design and production personnel are still according to the empirical formula to design the heat exchanger, and the heat stress and heat distortion of the heat exchanger are harder to predict [2].

At present most of the literature about the numerical study of heat exchanger most analyse simplified mode, boundary conditions most uses the average temperature or the average convective heat transfer coefficient,these data is usually based on manual data or empirical data, not the strict numerical calculation of fluid mechanics and heat transfer [3].This thesis uses CFD software FLUENT to simulate the movement and heat transfer of the heat exchanger and get the temperature distribution, then use it as a load to analyse the structure of the heat exchanger, bu this way, it can improve the accuracy of the analysis greatly [4].

THE WORKING PRINCIPLE OF HEAT EXCHANGERS

Figure 1 shows the tubular heat exchangers ,the tube pass is made up of inlet and outlet bellows, transistion bellows and tube bundles, air comes into it from the inlet bellow, flows in the tubulation and bellows and comes out from the outlet bellows after 3 times turn back [5].The shell pass is made up of tube-sheet, wall and sealing device, the smoke fllows into from the left inlet and flows out from the right outlet. Installing the link type plug-in in heat exchanger tube and welding two sides of plug-in and tube together by using the plug-in technology can improve surface coefficient of heat transfer in tube, thus reducing the area of heat transfer and the volume of the heat exchanger [6].

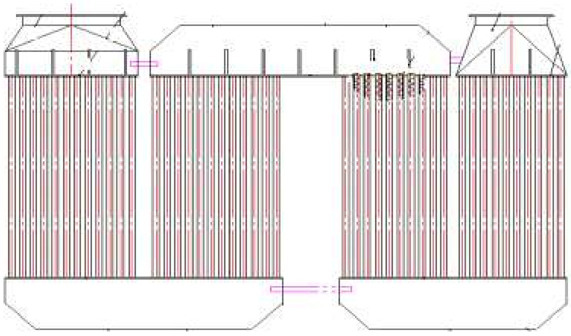

Fig.1 The working principle of heat exchangers

ANALYSIS AND CALCULATION BASIC CONDITION OF HEAT EXCHANGER

Heat exchanger length×wide×high: 4619×1600×2918mm;heat exchange tube inner diameter 43mm, external diameter 53mm, thickness of pipe wall 5mm,length 1950mm; transverse space of heat exchanger tube 90mm, the number of transverse equal amounts is 22, lengthways space of heat exchanger tube 70mm.Material used by tubulation and tube-sheet is Q235.

THE EQUATION OF HEAT TRANSFER PROCESS

1. Heat conduction

The inside of object or the surface contacted with each other, the phenomenon of heat transfer caused by the thermal motion among microscopic particle like molecule, atom, free electron. Heat conduction follow fourier law [7].

$$q^* = -\lambda_{nn} \frac{\partial T}{\partial n} \cdot \tag{1}$$

where q^* is heat flux(W/m2). λ_{nn} is the heat conductivity[W/(m・K)]. $\frac{\partial T}{\partial n}$ is the heat temperature change rate on the normal direction of isothermal level. "-" is heat flow to the direction of the temperature decrease.

2. Heat convection Heat radiation

Heat exchange between water and pipe wall or indoor air and radiator surface and wall. When the fluid flows through the object surface, because of adhesive effect，the fluid closed to the surface is static, heat transfer just proceed in heat conduction. leaving the surface of the object, the fluid has a macroscopic movement, the way of heat convection will militate. Newton cooling equation [8].

$$q^* = h_f (T_S - T_B) \tag{2}$$

where h_f is surface coefficient of heat transfer,W/(m2・K). T_S is the the temperature of solid surface,K. T_B is the temperature of surrounding liquid,K.

3. Heat radiation

When the temperature of two objects is different, the high temperature object sends thermal radiation to low temperature object and the low temperature object sends thermal radiation to high temperature object too,even if the temperature of the two objects is same, the radiant heat is zero, but the thermal radiation between them is still in progress, it is just in a state of dynamic balance. The net heat between objects can use Stefan boltzmann equation to calculate [9].

$$Q = \varepsilon \sigma A_1 F_{12} (T_1^4 - T_2^4) \tag{3}$$

where Q is the rate of heat flow. ε is absorptivity. σ is stefan-boltzmann constant. A_1 is air of radiant surface. F_{12} is form factor from radiant surface 1to radiant surface 2. T_1 is thermodynamic temperature of radiant surface 1. T_2 is thermodynamic temperature of radiant surface 2.

3. The process of heat transfer and heat exchange

In the practical heat transfer problems, three ways of heat transfer is often not exist alone, but two or three kinds of work at the same time. For single-layer circular tube, the inner and outer radius is r1and r2,length is *l*, thermal conductivity is λ, without internal heat source, the fluid temperature on either side of the circular tube is t_{f1} and t_{f2} ,the inside surface heat transfer coefficient is h_1 ,the outside surface heat transfer coefficient is h_2 .This heat transfer process is made up of the convective heat transfer inside circular tube, heat conduction round tube wall and convective heat transfer outside of the pipe, according to the Newton cooling formula and computational formula of steady heat conduction round tube wall can get the heat transfer coefficient based on single circular tube's outer wall area [10].

$$k = \frac{1}{\frac{d_2}{d_1}\frac{1}{h_1} + \frac{d_2}{2\lambda}\ln\frac{d_2}{d_1} + \frac{1}{h_2}} \quad (4)$$

BUILDING WHOLE AND SINGLE TUBE MODEL

The model in this paper, air import and export is simplified to a rectangle, in order to facilitate the convergence, extend the length of export appropriately, only take a heat transfer characteristic lengthways, which contains a row of pipe and the surrounding smoke and air, the picture 2 is the flow field chart of smoke passageway's cross section. Divide into two sections breadthwise, do analog computation respectively, but it need to do a experiment to let the parameter of two connection parts to be same mainly. The picture 3 is the left model and left grid model(left model after divided grid, the node number is 739481, the grid number is 2007070.), the parameters of left model's air inlet and smoke outlet is corresponding to the parameters of right model's air outlet and smoke inlet. The compute mode of right model is similar to the left model, we only go into detail with left for example.As shown in picture 4 is the end view of no plug-in model and plug-in model. External is smoke passageway, the middle is heat exchange tube, the internal is air passageway, exchanging heat for fair current.

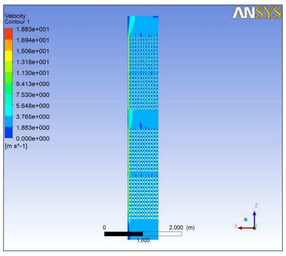

Fig.2 flow field of smoke passageway

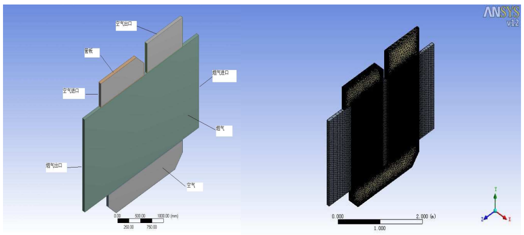

Fig.3 left grid model

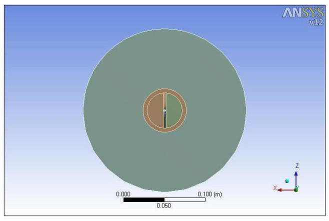

Fig.4 the end view of single tube

RESULTS

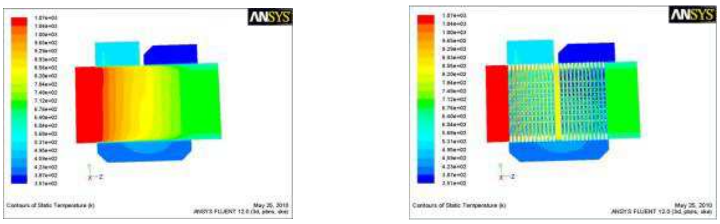

Fig.5 x=-70mm and x=-35mm section temperature distribution in the cloud

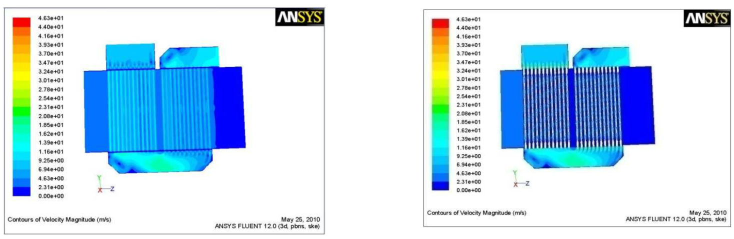

Fig.6 x=-70mm and x=-35mm section speed distribution in the cloud

We can see from picture 5, in the process of heat exchange, the temperature of smoke is highest at the entrance and lowest at the exit, the temperature of smoke is highest at the exit and lowest at the entrance, with a trend of increasing gradually, both of them change equably. From the picture 6, we can see that the speed of air changes little on the whole, the speed of air increases more when it flows in tube. From the picture 7, the maximun of total pressure is at air inlet, the change of whole pressure is uniform.

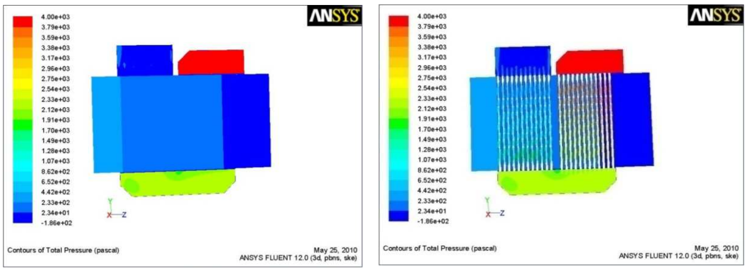

Fig.7 x=-70mm and x=-35mm section stress distribute in the cloud

From the picture 8, we can see the temperature of tube's inner wall and outer wall, the temperature of the place tube contacted with under tube is lowest, on the influenced air(about 200mm) under tube to tube, the temperature of tube rises sharply and then rise gradually and changes equably, the temperature of the tube fall drop sharply when it arrives at the influenced air of upper tube. From the picture 8, we can see that the temperature of the second tube is highest, instead of the first tube contacted with smoke. From the picture 9 and 10, we can see the temperature's variation tendency of tube's surfaces is similar, and the difference is little, this is the reason that the tube wall is thin.

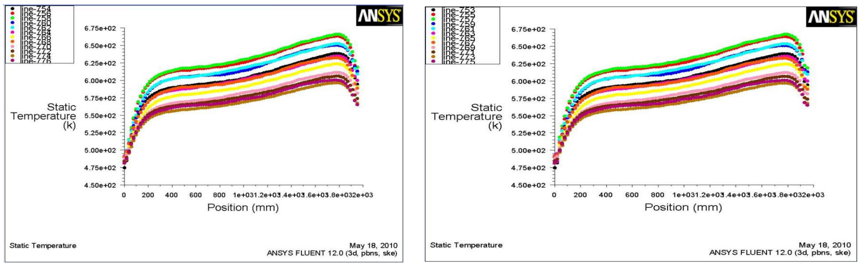

Fig.8 inwall and outwall of tube temperature distribution

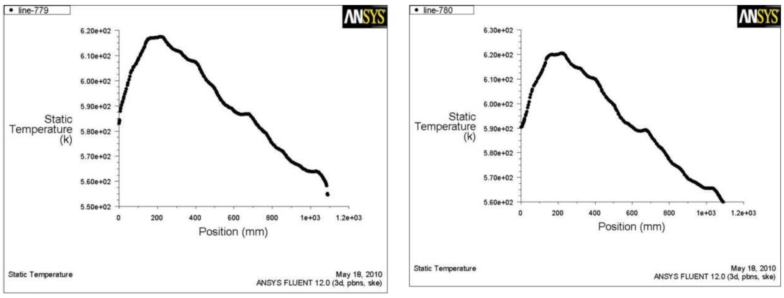

Fig.9 the surface temperature distribution of the upper tube

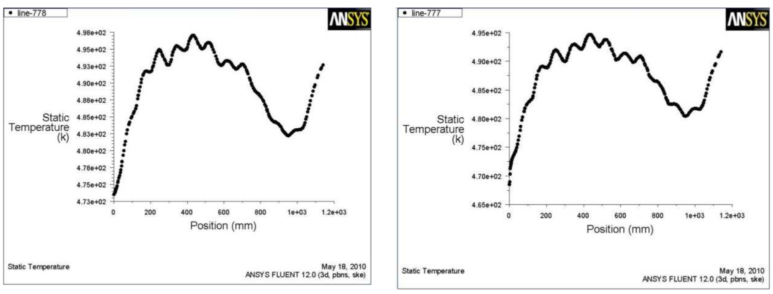

Fig.10 the surface temperature distribution of the under tube

The solving result of single tube main contains the temperature of air outlet under corresponding wind speed, differential pressure of air import and export, the average surface thermal conductance of inner wall, we can see the influence to pressure and surface thermal conductance caused by wind speed from the solving sheet. In order to observe the variation trend of differential pressure and surface thermal conductance caused by wind speed, we will solve the picture drawed with differential pressure and surface coefficient of heat transfer and used wind speed for abscissa.

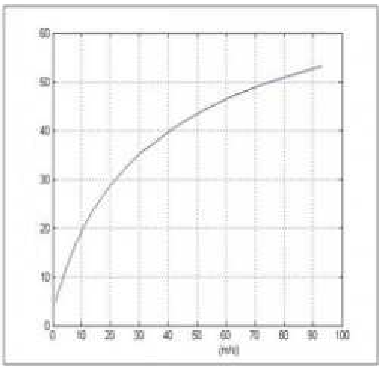

Fig.11 the relationship between no plug-in tube wall surface and heat transfer

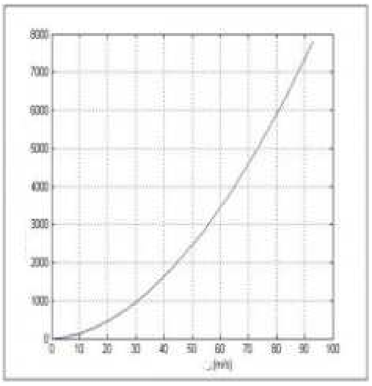

Fig.12 the relationship between air pressure drop of no plug-in tube and wind speed of air inlet

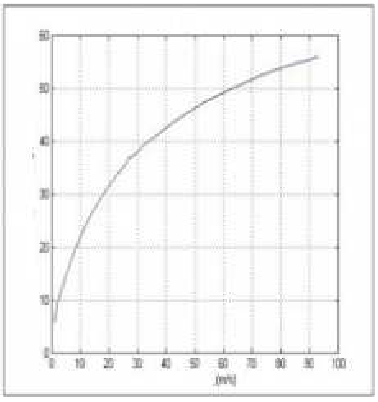

Fig.13 the relationship between plug-in tube wall surface and heat transfer

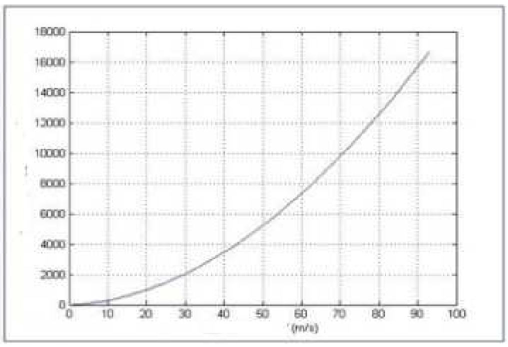

Fig.14 the relationship between air pressure drop with plug-in and wind speed of air inlet

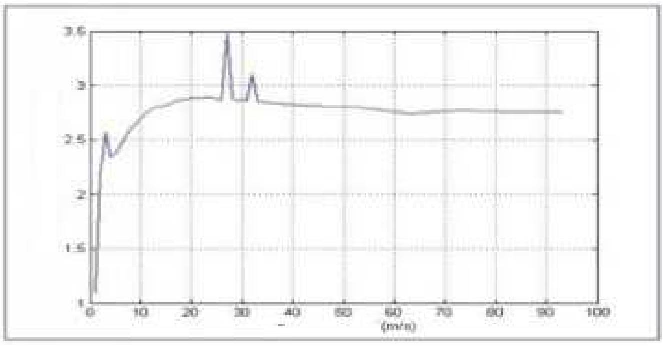

Fig.15 the surface coefficient of heat transfer of inner wall with plug-in or not

From the picture 11 and 13, we can see that the surface coefficient of heat transfer of heat exchange tube's inner wall with plug-in or not increases by the increase of air speed, but the cure slop is becoming more and more small, the surface coefficient of heat transfer of tube's inner wall increases more and more slowly. From the picture 12 and 14, we can see that the air import and export's differential pressure of the model with plug-in or not increases by the increase of air speed, and is becoming more and more large, the air import and export's differential pressure increases faster. From the picture 15,we can see the inlet velocity of air is in 1m/s~20m/s, the effect of increasing the surface of heat transfer is more and more obvious by inserting the plug-in, the difference of the two is basically stable in 2.8W/(m2·K) after 20m/s.

CONCLUSION

This article makes a numerical simulation for the model heat exchanger under the condition of design basis, makes a comparison of heat exchange performance for models with plug-in or not and makes a numerical simulation for heat transfer of single tube, including the influence of plug-in tube and no plug-in tube's surface coefficient of heat transfer and differential pressure caused by wind speed, and contrast the difference of heat exchange performance between plug-in model and no plug-in model, draw the following conclusions:

We should control the air velocity in 20m/s when designing heat exchanger, because when the air velocity more than 20m/s, the surface coefficient of heat transfer of inner wall increases little, but the stress increases sharply, this will increase the requirements for the fan.

When you design the heat exchanger, if the air velocity is more than 20m/s limited by space, you can insert a plug-in within a length of air inlet and use light pipe directly for others, by this way, turbulence effect is produced in tube, it not only keeps inner wall's surface coefficient of heat transfer high, but also reduces the pressure and lowers the requirements of fan.

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