Numerical Simulation on Heat Pipe Heat Exchanger: Effects of Different Ambient Temperature

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Abstract. Heat pipe heat exchanger is one of the widely used equipment in the industrial field with effective heat transfer. Based on the advantages of the numerical simulation software FLUENT, the design and numerical simulation are carried out. Six cases of different ambient temperature have been studied in this paper include summer and winter. Heat recovery rates are not the same in different seasons. For the larger temperature difference between inside and outside, the rate of heat recovery can reach 56.14% in winter.

Introduction

Energy shortage is a serious problem in the world. Saving energy and protecting the environment is the two major problems facing the national economy [1,2].Heat pipe is a new type of high efficiency heat transfer element. In recent years, due to the shortage of energy and the rapidly development of heat pipe technology, the application of heat pipe heat exchanger in heat recovery of heat energy has achieved good results[3].In order to create a comfortable shopping and working environment, the air-conditioned buildings need for a large amount of ventilation[4-6].The heat pipe ventilation heat exchanger is a kind of ventilation equipment, which integrates heat recovery and air purification[7-9].Based on the advantages of the numerical simulation software FLUENT, the design and numerical simulation are carried out. In this work, different cases of ambient temperature outside include summer and winter had been studied [10-11].

Model design and establishment

Heat pipe heat exchanger designs purposes for preheating the fresh air and save energy. According to the working principle of the heat pipe, it should be divided into evaporation section and condensation section, which is separated into the hot air chamber and the cold air exchange chamber[12-13].The following parameters should be determined prior to design：volumetric flow rate of hot air in standard condition(V^h_f),volumetric flow rate of cold air in standard condition(V^c_f),hot air temperature(t_{hf}),lowest temperature of hot air(t_{h2}),inlet temperature of cold air(t_{c1}),heat pipe arrangement, geometry parameter of heat pipe, fins parameter, heat released by hot air(Q_h), heat absorption by cold air(Q_c),outlet temperature of cold air(t_{c2}), logarithmic mean temperature difference($\triangle t_m$),etc. The following formulas are used to calculation:

$$Q_h = V^h_f \cdot \rho^h_f \cdot C_{ph}(t_{h1} - t_{h2}) \tag{1}$$

$$Q_c = (1 - \eta)Q_h \tag{2}$$

$$t_{c2} = t_{c1} + \frac{Q_c}{V^c_f + C_{pc} \cdot \rho^c_f} \tag{3}$$

$$\triangle t_m = \frac{(t_{h1}-t_{c2})-(t_{h2}-t_{c1})}{\ln\frac{t_{h1}-t_{c2}}{t_{h2}-t_{c1}}} \tag{4}$$

CFD software for calculating the three-dimensional turbulent flow is used in this paper. The whole model has two channels of cold air and hot air flow respectively. Indoor parts include cold air inlet and hot air outlet，and cold air outlet and hot air inlet to the outdoor part. Model design size is 550mm×300mm×100mm, which includes 12φ8 heat pipe. Heat pipes through the hot and cold air flow between the two channels and maintain a triangular arrangement of cross row. The fins of adjacent rows staggered to keep uniform distribution.

Heat pipes and fins are arranged into the fluid-solid coupling wall surface and the heat pipe is arranged for solid region especially. In order to ensure the accuracy of the calculation of the internal heat pipe and fins are carried out the grid encryption and the final grids are divided into 620 thousands. The simulation is based on unsteady, implicit solution based on pressure. Turbulence model is modeled by the standard k-epsilon method. Cold and hot air inlet are both provided with boundary conditions for velocity inlet boundary conditions at the velocity of 0.04m/s. Six cases have been studied in this paper as depicted in Table 1.

Table 1.Cases of different ambient temperature

Season		Summer			Winter		
Case		1	2	3	4	5	6
Temperature (K)	cold air inlet	299	299	299	260	265	270
	hot air inlet	303	308	313	294	294	294

Simulation results and analysis

Case 1. Summer 299K-303K   Case 2. Summer 299K-308K   Case 3. Summer 299K-313K

Case 4. Winter 260K-294K   Case 5. Winter 265K-294K   Case 6. Winter 270K-294K
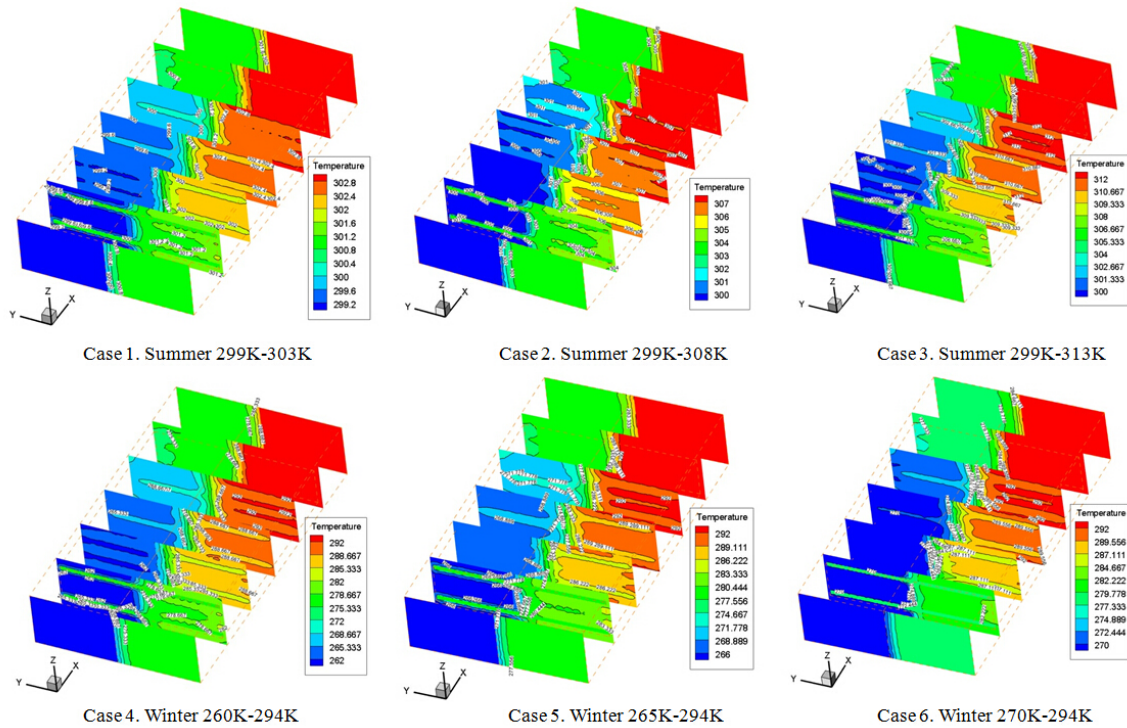
Fig.1. Temperature diagram of sections perpendicular to the Y axis at different cases

It is the temperature distribution in the heat exchanger at different ambient temperature as shown in Fig.1.The temperature difference between air inlet and outlet is decreased, and the heat transfer effect of the baffles obviously. In the cases of summer, the temperature of hot air outlet is

decreased with the increasing of the ambient temperature outside. It also can be described as the temperature of cold air outlet is increased with the decreasing of the ambient temperature outside in winter. For the analysis mentioned above, a conclusion can be found that the higher temperature difference between inside and outside, the higher heat transfer for this model.
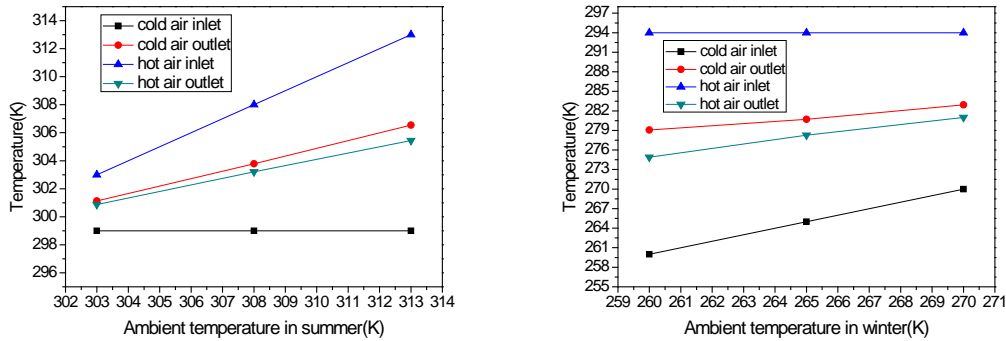

Fig.2.The average temperature of air inlet and outlet in different cases

Fig.2. shows that in the cases of summer, the temperature of cold air inlet is a constant value. With the increases of ambient temperature outside, the temperature of cold outlet and hot outlet is increasing. The temperature of hot air inlet reaches up to 305.4K when the ambient temperature outside is 313K. It also can be described as the similar pattern in the cases of winter. By contrasting the different cases of winter, it can be found that, temperature of hot air inlet is a constant value. With the increases of ambient temperature outside, the temperature of cold outlet and hot outlet is increasing. The temperature of cold air inlet reaches up to 279.08K when the ambient temperature outside is 260K.
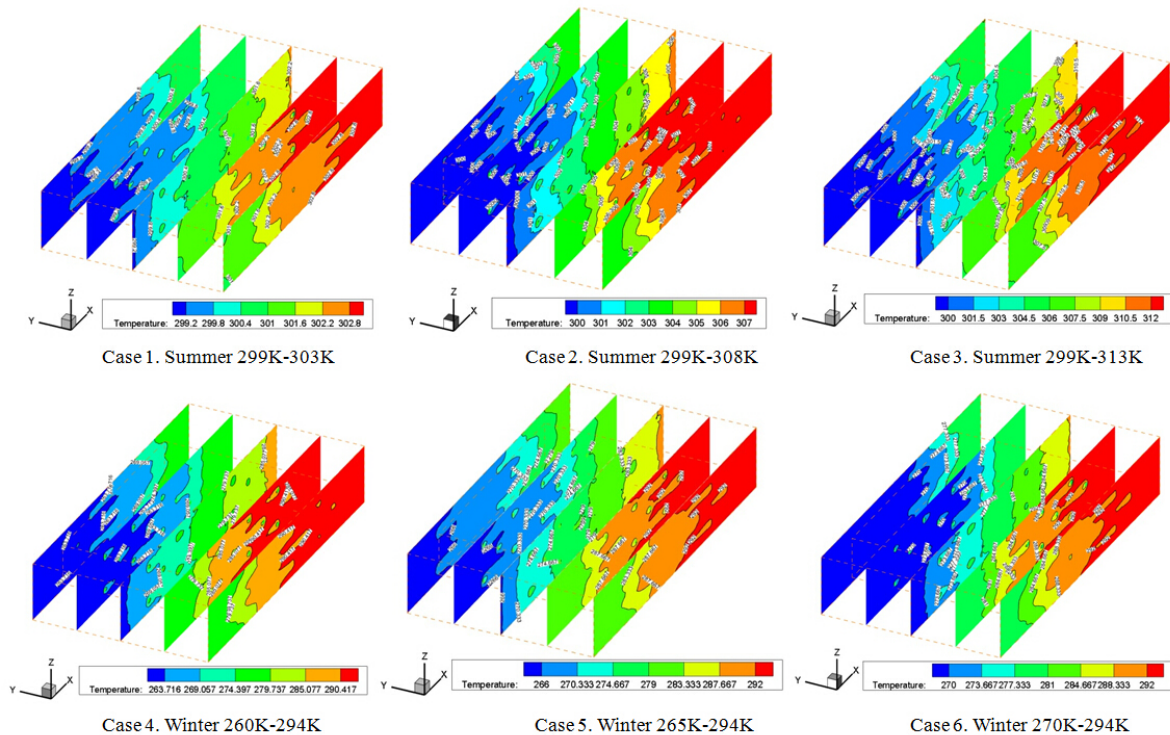

Fig.3. Temperature diagram of sections perpendicular to the X axis at different cases

Temperature distribution in the heat exchanger of sections perpendicular to the X axis at different cases are show in Fig.3.Whether it is summer conditions or winter conditions，the effects of heat transfer are more obviously with the increasing of the temperature difference of inside and outside. Through the analysis of temperatures distribution, the conclusion above can also be verified.

For the summer case, the temperature of cold air increases only 2.21K at the case of the ambient temperature of outside is 303K. And for this case, the temperature difference is the lowest in this simulation.
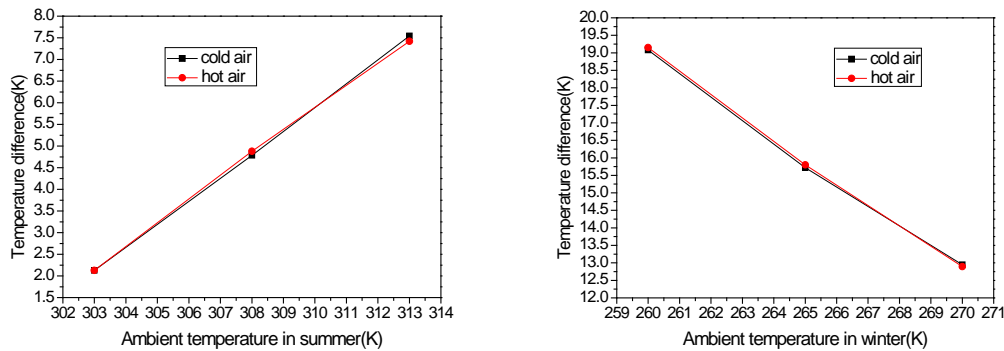

Fig.4. Temperature difference of air inlet and outlet in different cases

Temperature difference of air inlet and outlet are show in Fig.4. In winter, temperature difference between inside and outside is higher that summer. And for this case, through the heat exchanger, the temperature of cold air at the outlet reaches up 19.08K at most.

By contrasting the heat recovery rates of different cases in Fig.5, it can be found that, heat recovery rate is 53.91% at the lowest temperature difference between inside and outside in case of summer. While for winter, heat recovery rate can reaches 56.14% at the largest temperature difference in the case of winter. Through the analysis above, it can be found that the rate of heat recovery in winter is higher that summer for the larger temperature difference of inside and outside.
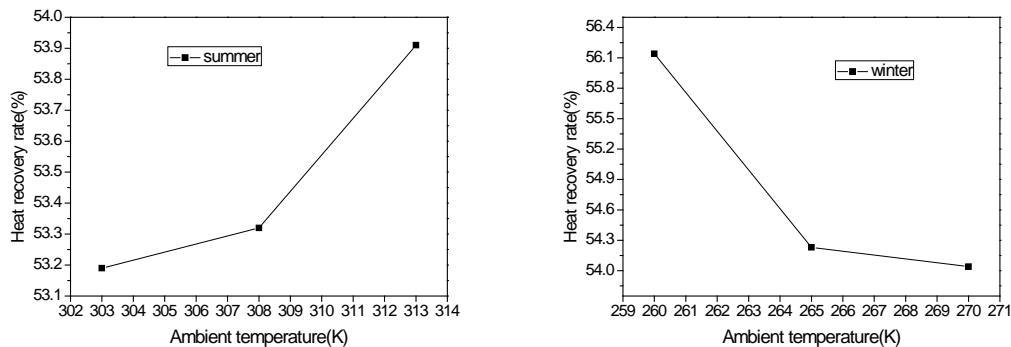

Fig.5. Heat recovery rate of different cases

Conclusions

(1)The heat pipe heat exchanger is a kind of ventilation equipment, which integrates heat recovery and air purification. Based on the advantages of the numerical simulation software FLUENT, the design and numerical simulation are carried out.

(2)In this model, the ambient temperature has great influence to the air temperature through the heat pipe heat exchanger. The temperature of hot air outside can decreases 7.54K in summer case. In winter, the temperature of cold air outside can increases 19.08K at most. Heat exchange effect is better in winter case in this research.

(3)Heat recovery rates are not the same in different seasons. For the larger temperature difference between inside and outside, the rate of heat recovery can reach 56.14% is higher in winter, and it can reach 56.14% at most.

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