Experimental Investigation of Heat Pipe Heat Exchanger

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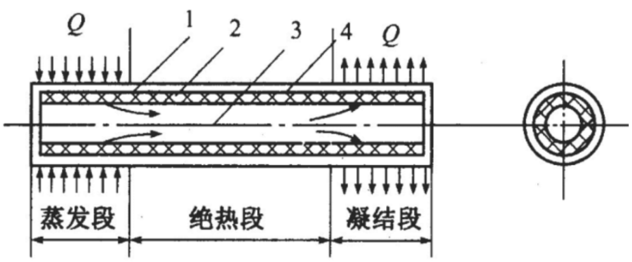
Ⅰ.Objectives and Requirements

Be familiar with the working principle and usage of the heat pipe heat exchanger test equipment.

Master the testing and calculation methods of heat transfer Q and heat transfer coefficient K of gas-gas heat pipe heat exchanger.

Understand the relationship between heat exchange and air temperature, wind speed, and other parameters.

Ⅱ.Principles



The above figure is the basic structure of a heat pipe.

Principle of operation: when the two ends of the heat pipe are heated (in contact with the hot fluid) and cooled (in contact with the cold fluid), the liquid inside the tube at the heated end (called the evaporation section) absorbs heat and evaporates into vapor. The vapor flows down the central passage of the tube to the other end (known as the condensing section) and condenses to release heat. Due to gravity, the condensed liquid automatically flows back along the core of the tube to the evaporation section. In this cycle, heat is transferred from the hot liquid to the cold liquid by evaporation and condensation of the working medium. In this experiment, the internal working medium of the heat pipe is ethanol and the condensed liquid flows back due to gravity.

The heat transfer:

$$Q_C = q_C \rho_C (C_{C2} T_{C2} - C_{C1} T_{C1})$$
$$Q_H = q_H \rho_H (C_{H1} T_{H1} - C_{H2} T_{H2})$$
$$\bar{Q} = (Q_C + Q_H)/2$$

$Q_C$heat exchange at the cold end

$Q_H$heat exchange at the hot end

$\bar{Q}$ the average heat exchange

q_C the flow rate

ρ_C the air density

T_{C2} the cold outlet end temperature

T_{C1} the cold inlet end temperature

C_{C2} the specific heat capacity of air at constant pressure at the cold outlet end temperature

C_{C1} the specific heat capacity of air at constant pressure at the cold inlet end temperature

The symbol for the hot end is similar

The air density:

$$\rho_{air} = \rho_0 \frac{273}{273 + t}, \quad \rho_0 = 1.293$$

The specific heat capacity can be obtained from the table in the end of this report.

The heat transfer coefficient:

$$K = \frac{\bar{Q}}{A_H \Delta t_m}$$

A_H the surface area of the heat pipe at the hot end

$\Delta t_m$the logarithmic mean temperature difference

$$\Delta t_m = \frac{\Delta t_{max} - \Delta t_{min}}{\ln\left(\frac{\Delta t_{max}}{\Delta t_{min}}\right)}$$

$$\Delta t_{max}, \Delta t_{min} = \{T_{H1} - T_{C2}, T_{H2} - T_{C1}\}$$

The thermal balance error:

$$\Delta = \frac{Q_H - Q_C}{\bar{Q}} \times 100\%$$

Ⅲ.Data processing and results

1.Record the data in the record sheet

Cold end inlet temperature (°C)	Cold end outlet temperature (°C)	Hot end inlet temperature (°C)	Hot end outlet temperature (°C)	Hot end flux (m^3/h)	Cold end flux (m^3/h)
26.90	30.70	86.80	79.90	577.55	671.35
25.70	31.10	86.90	79.90	555.26	425.18
26.40	31.00	89.90	79.80	342.95	415.64
26.60	30.30	88.00	77.00	358.88	662.08
26.40	27.40	71.70	65.50	577.28	669.17

2.Process the data and fill in the following sheet

Heat exchange at hot end (W)	Heat exchange at cold end (W)	Average heat exchange (W)	Thermal balance error	Surface area (㎡)	Heat transfer coefficient (W/(㎡*°C))
1120.80	839.66	980.23	28.68%	1.72	10.45
1093.00	756.68	924.84	36.37%	1.72	9.78
970.10	629.49	799.80	42.59%	1.72	8.29
1112.93	807.21	960.07	31.84%	1.72	10.34
1044.93	221.64	633.29	130.00%	1.72	8.84

3.Discuss the result and make a conclusion

From the experimental results, the heat transfer coefficient of this gas-gas heat pipe heat exchanger is around 8-10 W/(㎡*℃) under the given working conditions, while changes in the air flux at the hot and cold ends and the outlet temperature at the hot end will affect the heat transfer and heat transfer coefficient at the hot and cold ends of this gas-gas heat pipe heat exchanger.

All other conditions being equal, a decrease in the air flux at the hot and cold ends and the hot end outlet temperature will reduce the heat transfer coefficient.

It is worth noting that the thermal balance errors obtained from all five sets of data are large, with the heat balance error obtained for the fifth set of conditions being significantly larger than the first four sets, probably because the temperature had not yet reached stability when the data was recorded, resulting in larger values of heat balance error.

Ⅳ.Questions

1.Analyze the causes of thermal balance errors

1) During the experiment, due to the time constraints of the experiment, each set of data was recorded at intervals of 15-20 minutes, during which time the temperature may not have reached stability, resulting in thermal equilibrium errors.
2) As the first four sets of data changed the condition of the air flux, the data was recorded at similar intervals, so the thermal equilibrium error was also relatively close. The fifth group of data changed the condition of the hot end outlet temperature, and its value has been fluctuating after the setting was completed, the temperature during a similar time interval was less stable than the first four groups, and the heat exchange at the cold end is smaller, so the heat balance error value is significantly larger.
3) During the experiments, the air fluxes fluctuate considerably, and the data recorded are instantaneous, which may lead to a change in the calculated heat transfer values and consequently to fluctuations in the heat balance error values. To be precise, from the experimentally recorded data, when the frequency converter is the same (the first, third, and fifth sets of data), the air flux at the hot and cold ends are not close, and the deviation can reach $100m^3/h$. The air flux at the cold end is higher than that at the hot end, which may lead to a higher heat transfer at the cold end and a lower heat transfer at the hot end, resulting in a smaller value of the heat balance error obtained.
4) It is worth mentioning that comparing the data and results of this experiment with those of the companion, it is found that the value of the heat balance error obtained from this experiment (approximately 30-40%) is smaller than that obtained by the companion (more than 100%), which is probably because the cold end outlet temperature recorded and the difference between the cold end inlet and outlet temperatures in this experiment are both higher than that obtained by the companion, which leads to a higher heat exchange at the cold end and a smaller heat balance error than that obtained by the companion. As to why the cold end outlet temperature recorded in this experiment was higher than the companion, it may be

due to an undetected fault in the experimental apparatus during use, for example, the thermometer at the cold end outlet is faulty.

2. According to the experimental results, discuss the influence of adjustable parameters (air fluxes and hot end temperature) on the heat transfer (or heat transfer coefficient) of the heat pipe.

Air fluxes:

Reducing the air flux at both the hot and cold ends will result in a reduction in the heat transfer and heat transfer coefficient, with reducing the air flux at the cold end resulting in a more significant reduction in the heat transfer coefficient.

Hot end temperature:

The data results show that lowering the temperature at the hot end results in a significant reduction in the heat transfer at the cold end compared to the heat transfer at the hot end, resulting in a reduction in the heat transfer coefficient.

Experimental Data Log Sheet

Experimental Investigation of Heat Pipe Heat Exchanger Data Log Sheet

1. Basic Information

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2. Data Record

Cold end inlet temperature (℃)	Cold end outlet temperature (℃)	Hot end inlet temperature (℃)	Hot end outlet temperature (℃)	Hot end flux (m^3/h)	Cold end flux (m^3/h)
26.9	30.7	87.8	79.9	577.55	671.35
25.7	31.1	86.9	79.9	555.26	425.18
26.4	31.0	89.9	79.8	342.95	415.64
26.6	30.3	88.0	77.0	358.88	662.08
26.4	27.4	71.7	65.5	577.28	669.17

赵晓争

The specific heat table

干空气在压力为100kPa时的参数

温度t ℃	密度ρ kg/m³	比热容Cp kJ/(kg·K)	导热系数λ 10^{-2}W/(m·K)	热扩散率D_T $10^{-2}m^2h^{-1}$)	动力粘度μ 10^{-6}Pa·s	运动粘度ν $10^{-6}m^2s^{-1}$
-150	2.817	1.038	1.163	1.450	8.730	3.100
-100	1.984	1.022	1.617	2.880	11.770	5.940
-50	1.534	1.013	2.035	4.730	14.610	9.540
-20	1.365	1.009	2.256	5.940	16.280	11.930
0	1.252	1.009	2.373	6.750	17.160	13.700
1	1.247	1.009	2.381	6.799	17.220	13.800
2	1.243	1.009	2.389	6.848	17.279	13.900
3	1.238	1.009	2.397	6.897	17.338	14.000
4	1.234	1.009	2.405	6.946	17.397	14.100
5	1.229	1.009	2.413	6.995	17.456	14.200
6	1.224	1.009	2.421	7.044	17.514	14.300
7	1.220	1.009	2.430	7.093	17.574	14.400
8	1.215	1.009	2.432	7.142	17.632	14.500
9	1.211	1.009	2.446	7.191	17.691	14.600
10	1.206	1.009	2.454	7.240	17.750	14.700
11	1.202	1.010	2.461	7.282	17.799	14.800
12	1.198	1.010	2.468	7.324	17.848	14.900
13	1.193	1.010	2.475	7.366	17.897	15.000
14	1.189	1.011	2.482	7.408	17.946	15.100
15	1.185	1.011	2.489	7.450	17.995	15.200
16	1.181	1.012	2.496	7.492	18.044	15.300
17	1.177	1.012	2.503	7.534	18.093	15.400
18	1.172	1.012	2.510	7.576	18.142	15.500
19	1.168	1.013	2.517	7.618	18.191	15.600
20	1.164	1.013	2.524	7.660	18.240	15.700
21	1.161	1.013	2.530	7.708	18.289	15.791
22	1.158	1.013	2.535	7.756	18.338	15.882
23	1.154	1.013	2.541	7.804	18.387	15.973
24	1.149	1.013	2.547	7.852	18.437	16.064
25	1.146	1.013	2.552	7.900	18.486	16.155
26	1.142	1.013	2.559	7.948	18.535	16.246
27	1.138	1.013	2.564	7.996	18.584	16.337
28	1.134	1.013	2.570	8.044	18.633	16.428
29	1.131	1.013	2.576	8.092	18.682	16.519
30	1.127	1.013	2.582	8.140	18.731	16.610
31	1.124	1.013	2.589	8.191	18.780	16.709
32	1.120	1.013	2.596	8.242	18.829	16.808
33	1.117	1.013	2.603	8.293	18.878	16.907
34	1.113	1.013	2.610	8.344	18.927	17.006
35	1.110	1.013	2.617	8.395	18.976	17.105
36	1.106	1.013	2.624	8.446	19.025	17.204
37	1.103	1.013	2.631	8.497	19.074	17.303
38	1.099	1.013	2.638	8.548	19.123	17.402
39	1.096	1.013	2.645	8.599	19.172	17.500
40	1.092	1.013	2.652	8.650	19.221	17.600
50	1.056	1.017	2.733	9.140	19.610	18.600
60	1.025	1.017	2.803	9.650	20.400	19.600
70	0.996	1.017	2.861	10.180	20.400	20.450
80	0.968	1.022	2.931	10.650	20.990	21.700
90	0.942	1.022	3.001	11.250	21.570	22.900
100	0.916	1.022	3.070	11.800	21.770	25.780
120	0.870	1.026	3.198	12.900	22.750	26.200
140	0.827	1.026	3.326	14.100	23.540	28.450