ISSN: 2414-1895 DOI: 10.6919/ICJE.201911_5(12).0029

Feasibility Analysis of Micro Heat Pipe Array Radiator in High Altitude Area

Li Wan, Zewei Pu, Yuqun Wang, Wenya Wang

Tibet Autonomous Region Energy Research Demonstration Center, China.

Abstract

In this paper, using the physical model,The feasibility of using the micro heat pipe array radiator in the high altitude and cold area is verified.And through the relevant experimental test research,the following conclusions are obtained:Compared with the traditional radiator, the micro heat pipe array radiator has faster temperature rise speed and more efficient heat transfer performance, and its thermal response time is only 95s.The thermal flux of the micro heat pipe array radiator filled with acetone has a limit value of 10.7×105W/m2.Micro heat pipe array radiator can be combined with conventional energy-saving clean energy sources such as air source heat pumps compared to conventional radiators.

Keywords

Micro heat pipe array,radiator,Temperature rise rate,thermal flux.

1. Introduction

With the rapid development of China's economy, people increasingly pursue the comfort level of indoor environment, and the improvement of comfort level will inevitably lead to the increase of building energy consumption. By May 2014, China's heating and air conditioning energy consumption has accounted for about 20% of the total energy consumption [1].For high-altitude and cold areas, building types are mainly heating buildings. Therefore, continuous research and development of new heating terminal devices with efficient heat dissipation performance is conducive to energy saving transformation of heating buildings, energy saving and emission reduction, and easing the increasingly tense relationship between environment and energy. Meanwhile, with the development of heat pipe technology, the application field of heat pipe is expanding. Zhao Yaohua, Wang Hongyan et al [2] developed a compact micro-heat pipe array with microstructures, and tested the heat dissipation performance of four working fluids of methanol, ethanol, acetone and R141b respectively. The results show that the flat micro heat pipe array has a good heat dissipation effect and an optimum liquid filling rate of 0.3 is obtained. The invention of microheat pipe array with more efficient heat dissipation capability has greatly improved the practical application field of heat pipe technology.

Huang Xiaoming, Shi Chunyu, et al. [3] combined the micro heat pipe array with the heat end of semiconductor refrigeration, and simulated a fin heat pipe radiator applied to the heat end of semiconductor refrigeration sheet by using numerical calculation method, explored the influence of different fin parameters on the heat transfer characteristics of the radiator under the condition of natural convection, obtained that the influence of fin efficiency on the performance of the radiator was limited, and improved the surface heat transfer coefficient can significantly reduce the total heat resistance of the radiator. Xu Jiaqi and Zhang Xiaofeng [4] applied the flat plate micro heat pipe array to the solar heat collection system, and designed a new flat plate heat pipe solar heat collection technology. The results showed that the solar heat collection system greatly improves the efficiency of the solar heat collector, and has the characteristics of high cost performance, maintenance free,

ISSN: 2414-1895 DOI: 10.6919/ICJE.201911_5(12).0029

water tank and collector separation, simple structure, etc., which is one of the options for building integration. Wang Jing, Shu bifen et al [5] applied the micro heat pipe array to the high power concentrated photovoltaic (HCPV) module to solve the problem of heat dissipation and the uniformity of working temperature. The results showed that the output power of the HCPV module using the micro heat pipe array as the heat dissipation device must be increased by about 22% for the conventional HCPV module under the optimized condition, which indicated that the heat dissipation structure has a good application prospect. Dong Ruixue, Quan Zhenhua et al. [6] replaced the traditional floor heating pipe array with the flat plate micro heat pipe array as the end device of the floor heating system, designed and built a new floor radiation heating system based on the micro heat pipe array. The results showed that the floor surface temperature and the heat dissipation increased significantly with the increase of the water supply temperature, and increased slowly with the increase of the flow rate. The floor radiant heating system can meet the heating demand under the lower water supply temperature, and the heat exchange is more efficient. Based on the above research and exploration in various fields, and the domestic and foreign has not yet applied the micro heat pipe array to the indoor radiator cooling device, so this paper analyzes the feasibility of the micro heat pipe array radiator in the high altitude area, and provides a theoretical basis for the design and development of the new radiator.

2. Experimental system

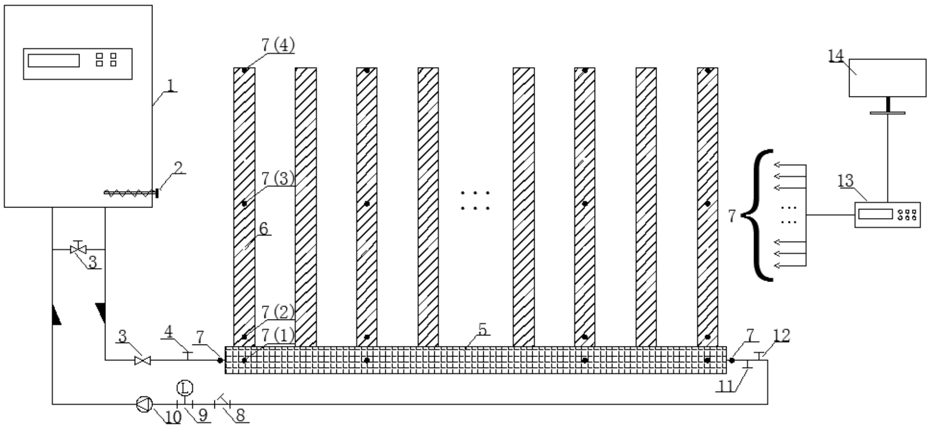
2.1 System principle

In this paper, the experimental heating system is mainly divided into the following four parts: heating source, heating pipeline and accessories, heating object and heating end. The constant temperature water tank is used to simulate the heating heat source, and the special micro heat pipe array radiator is used as the heating end (its size is 1100mm × 620mm × 3mm, a total of 17 micro heat pipe arrays, each with a center distance of 65mm). The working principle of the heating system is shown in Figure 1. The hot water of the required water supply temperature is generated by the constant temperature water tank, and then flows into the special shaped pipe after the control valve is adjusted to the required water supply flow. The hot water is convective with the evaporation section of the micro heat pipe array in the special shaped pipe. The heat is transferred from hot water to the evaporation section of the micro heat pipe array. After the liquid acetone working medium in the evaporation section absorbs the heat, it changes from liquid state to gas state. Under the effect of pressure, the gaseous acetone working medium is transferred to the condensation section of the micro heat pipe array, and the heat is transferred to the room through convection and radiation heat exchange in the condensation section. After the heat dissipation, the gaseous acetone working medium becomes liquid state again, and in the heavy state Under the action of force and capillary force, it returns to the evaporation section of the micro heat pipe array again. So repeatedly, to achieve the effect of indoor radiator cooling. The selected equipment and instrument parameters in this paper are shown in Table 1.

Table 1 Parameters of instruments and equipment used in the experiment

Name	Model	Range	Accuracy
Constant temperature water tank	DC-0506	-5～100℃	±0.1℃
Thermocouple	Copper / constantan thermocouple	-35～95℃	±0.1℃
Flowmeter	316L	0.1～10m/s	Level 0.3
Circulating pump	FS32X25-11	0～4m3/h	Level1
Data acquisition instrument	Agilent 34972A	100mV～300V	0. 004%

ISSN: 2414-1895 DOI: 10.6919/ICJE.201911_5(12).0029



Constant temperature water tank;2-electric heater;3-control valve;4-Cleaning import;5-Special-shaped tube;6-Micro heat pipe array;7-Copper / constantan thermocouple;8-Y filter;9-Flowmeter;10-Circulating pump;11-Cleaning outlet;12-Exhaust valve；13-Data acquisition instrument;14-Computer

Figure 1 Schematic diagram of experimental system

2.2 Experimental steps and calculation formula

2.2.1Test steps

In this experiment, the electric heater is used to heat the constant temperature water tank. When the constant temperature water tank reaches the set value, the circulating water pump is turned on， hot water for the system is supplied. The hot water flow is adjusted to the demand of the experimental conditions through the circulation control valve. The Agilent data acquisition instrument is started to collect data. According to the experimental conditions, setting different water supply temperature and flow rate, and continuing to run for a period of time to stabilize the data. when the surface temperature of the radiator and the average temperature of the indoor air reach a stable state, After completing a test of a set of experimental conditions, First turn off the electric heater, then turn off the circulating water pump, suspend the continuous heating of the constant temperature water tank; wait until the surface temperature of the radiator and the indoor air temperature are restored to the initial state; restart the appeal test step, by changing the different water supply temperature or water supply flow, To achieve experimental testing under different conditions.

2.2.2 The calculation formulas involved in this paper are mainly as follows:

Calculation formula for heat dissipation of micro heat pipe array radiator:

$$Q = cm(T_j - T_c) \tag{1}$$

Where: Q is the heat dissipation capacity of the micro heat pipe array radiator, W/m,c is the specific heat capacity of water, J/(kg·°C),m is the mass flow of hot water, kg/s, Tj is the water inlet temperature of the micro heat pipe array radiator, °C, Tc is the water outlet temperature of the micro heat pipe array radiator,°C.

Calculation formula of heat flux of micro heat pipe array radiator [2]:

$$q_a = \lambda(T_2 - T_1) / \Delta X_1 \tag{2}$$

$$q_b = \lambda(T_3 - T_2) / \Delta X_2 \tag{3}$$

$$q_c = \lambda(T_4 - T_3) / \Delta X_3 \tag{4}$$

$$q = (q_a + q_b + q_c) / 3 \tag{5}$$

Where:q is the average heat flux of a single piece of micro-heat pipe array radiator,W/m2.qa is the heat flux between temperature measurement point 2 and temperature measurement point 1,W/m2.qb is the heat flux between temperature measurement point 3 and temperature measurement point

ISSN: 2414-1895 DOI: 10.6919/ICJE.201911_5(12).0029

2,W/m2.qc is the heat flux between temperature measurement point 4 and temperature measurement point 3,W/m2.λ is the heat transfer coefficient, W/m·℃. ΔX_1 is the distance between temperature measurement points 2 and 1,60mm. ΔX_2 is the distance between temperature measurement points 3 and 2,300mm. ΔX_3 is the distance between temperature measurement points 4 and 3,300 mm. T1, T2, T3, T4 are respectively the test temperatures of temperature measurement points 1, 2, 3, 4,℃.

3. Result Analysis

3.1 Comparison of surface temperature rise under the same working condition

Selected existing traditional radiator size:1150mm×635mm×80mm, the specific size of the micro heat pipe array radiator is 1100mm×620mm×3mm, the spacing of each radiator is 65mm, a total of 17 micro heat pipe arrays, and the water supply pipe diameter is Φ 25mm.At the same time, refer to the recommended value of hot water flow rate in the pipe in the design manual of heat supply network. When the water supply pipe diameter is Φ 25mm, the hot water flow rate is 0.6-0.7m/s. Therefore, for two different kinds of radiators, the same working conditions are selected: the water supply temperature is 60 ℃ and 80 ℃, the water supply flow is 4.95m3/h, and the water supply flow rate is 0.7m/s. From the start-up of the constant temperature water tank to the stable surface temperature of the two kinds of radiators, the thermal response time of traditional radiators and micro heat pipe array radiators is explored to analyze their temperature rise performance. In this paper, two kinds of radiators near the water inlet are selected for temperature rise analysis. As shown in Figure 2, whether the water supply temperature is 60 ℃ or 80 ℃, the temperature rise speed of micro heat pipe array radiator is far faster than the traditional radiator, and the temperature loss is smaller, and the temperature rise is higher. For example, when the temperature of water supply is 60 ℃, the time for the surface temperature of traditional radiator to reach stability is about 310S, and the temperature stability value is about 42.1 ℃; while the time for the surface temperature of micro heat pipe array radiator to reach stability is only about 95s, and the temperature stability value is about 57.6 ℃. Therefore, under the same working condition, the heat response time of the micro heat pipe array radiator is shorter and the heat utilization rate is higher. At the same time, with the increase of water supply temperature, the thermal response time of micro heat pipe array radiator will not only be further shortened, but also the temperature loss value will be smaller. For example, when the water supply temperature increases from 60 ℃ to 80 ℃, the thermal response time will be reduced from 95s to 80s, and the temperature loss value will be reduced from 2.3 ℃ to 1.8 ℃. Therefore, whether from the surface temperature rising speed or the degree of heat loss, the micro heat pipe array radiator has more advantages than the traditional radiator, which is effective and feasible.

3.2 Heat flux of micro heat pipe array radiator

In order to explore the effective heat flux of the micro heat pipe array radiator, the working conditions of the test are: the water supply flow is 4.95 m^3/h, the water supply flow rate is 0.7 m/s, the water supply temperature distribution is set as: 40 ℃, 45 ℃, 50 ℃, 55 ℃, 60 ℃, 65 ℃, 70 ℃, 75 ℃ and 80 ℃. When the surface temperature of the micro heat pipe array radiator is stable, test the heat flux of the first radiator near the water inlet, and calculate the test results. The data is shown in Figure 3.The micro heat pipe array radiator filled with acetone working medium has very good heat transfer performance in the relative low temperature range, and the overall change trend of its heat flux value is first rising and then gentle, so its heat flux has a limit value, the limit value is when the water supply temperature is 52.5℃, the maximum heat flux is 10.7×105W/m^2.In view of the good heat transfer performance of the micro heat pipe array radiator in the low temperature area, and the heat flux is far greater than that of the traditional radiator, the new radiator can be used in combination with the air source heat pump, which has a high energy efficiency ratio, but the water supply temperature is relatively low. For example, when the water supply temperature of the air source heat pump is 60 ℃, its COP is 2.8 [7], at this time, the micro heat pipe array radiator can be coupled with it, but the

ISSN: 2414-1895 DOI: 10.6919/ICJE.201911_5(12).0029

traditional radiator cannot, which is the advantage that the traditional radiator (required water supply temperature: 70-85 ℃) does not have. The relationship between energy efficiency ratio of air source heat pump and water supply temperature is shown in Figure 4. Therefore, compared with the traditional radiator, the micro heat pipe array radiator has a wider range of matching and advantages, no matter from the heat transport capacity or the combination with other clean energy.

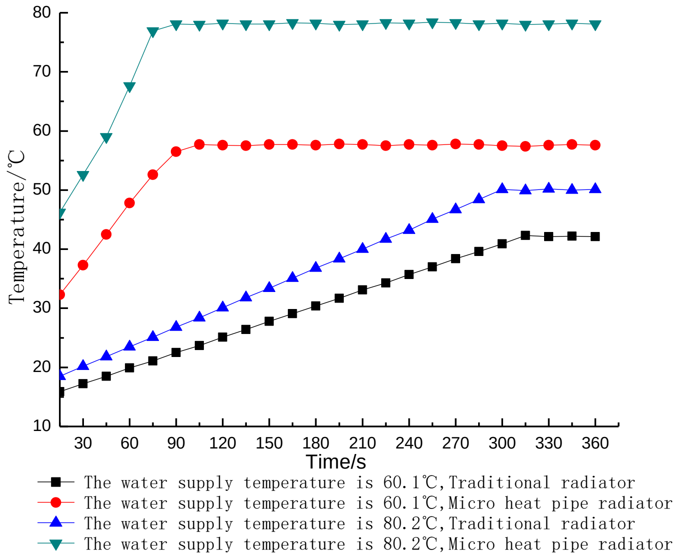


Figure 2 Comparison of surface temperature rise under the same working condition

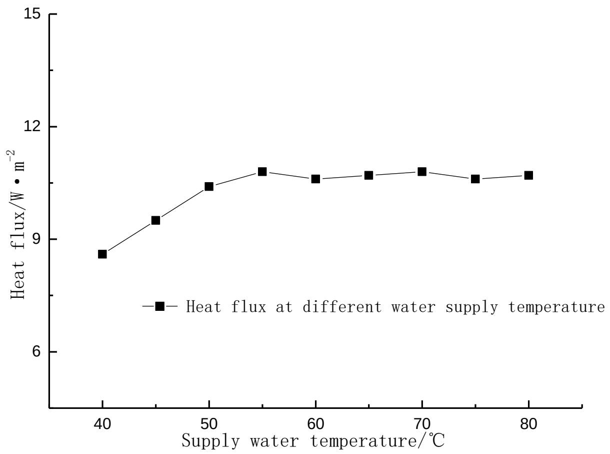


Figure 3 heat flux values at different water supply temperatures

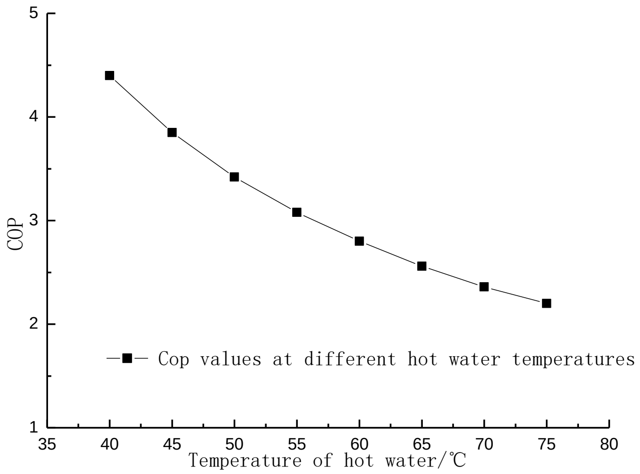


Figure 4 COP values of air source heat pump under different hot water temperature

ISSN: 2414-1895
DOI: 10.6919/ICJE.201911_5(12).0029

4. Conclusion

In this paper, the feasibility of micro heat pipe array radiator in high altitude and cold regions is studied by experimental comparison analysis. The experiments on the temperature rise performance and heat transfer performance of the micro heat pipe array radiator are carried out, and the advantages of the micro heat pipe array radiator compared with the traditional radiator are obtained. At the same time, the following conclusions are obtained:

Compared with the traditional radiator, the micro heat pipe array radiator has a faster temperature rise speed. When the water supply temperature is 60 °C, it only takes 95s for the surface temperature to reach a stable state, and with the increase of the water supply temperature, the temperature rise speed and temperature attenuation will be further shortened.

The micro heat pipe array radiator has a more efficient energy utilization efficiency, its heat flux is far greater than the traditional radiator, and the heat flux of the micro heat pipe array radiator filled with acetone working medium has a limit value, the overall change trend of the heat flux value is first rising and then slowing down, the limit value is 10.7×105W/m^2.

Because of its good performance in low temperature area, the micro heat pipe array radiator can be combined with clean energy such as air source heat pump with high energy efficiency ratio and low water supply temperature, which is the advantage that the traditional radiator does not have.

Acknowledgements

Project fund: Experimental Research on solar heating system based on micro heat pipe array (XZ2018ZRG-126).

References

[1] Research Report on annual development of building energy efficiency in China in 2015[M]. Beijing:Chinese Building Industry Press,2015

[2] Zhao Yaohua, Wang Hongyan,et al.Heat transfer characteristics of flat micro-heat pipe array[J].Journal of Chemical Engineering,2011,(62)2:336-343

[3] Huang Xiaoming,Shi Chunyu,et al.Analysis on natural convection heat transfer characteristics and multi-objective optimization of structure-parameters for finned heat pipe radiator[J].Thermal science and technology,2018(17)5:359-365

[4] Xu Jiaqi,Zhang Xiaofeng.Research on solar energy collection system of flat plate with micro heat pipe array[J].Annual meeting of Jilin civil construction society in 2013,2013:13-15

[5] Wang Jing,Shu Bi-fen,et al.A New Heat Dissipation Experimental Research of High Concentrated Photovoltaic Based on Micro-heat Pipe[J].Science technology and Engineering,2018(18)15:105-111

[6] Dong Ruixue,Quan Zhenhua,et al.Experimental Research on Performance of Radiant Floor Heating System Based on Micro Heat Pipe Array[J].Architectural Science,2018,34(8):32-37

[7] Dong Zhongcheng,Li li,et al.The heating technology of air source heat pump[M].Technology exchange,2016:60-64

Author brief introduction:Wan Li(1990-),male,Sichuan,master,Research Intern,Mainly engaged in renewable energy research.

Contact information:853969982@qq.com;Tel:15892660773.

Mailing address: No.105, North Deji Road, Chengguan District, Lhasa city.