Experimental study of Thermal performance on heat pipe radiator

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Abstract: The heat pipe radiator has become an effective way to solve the heat dissipation problem of electronic components due to its advantages of good reliability and high-heat dissipation efficiency. So it is necessary to explore the thermal performance of heat pipe radiators. In this paper, gravity radiators with two, four, and six heat pipes are used as the research object. The thermal performance of the three heat pipe radiators with different numbers of heat pipes is compared and analyzed through experiments. It mainly includes the influence of a different number of heat pipes on the heat dissipation power, thermal resistance, temperature uniformity, start-up time and other parameters of the radiator. Research shows that the number of heat pipes is one of the main factors affecting the thermal performance of a radiator. The more heat pipes, the better the thermal performance.

1. Introduction

With the development of electronic technology, the integration degree of semiconductor devices is becoming higher. The CPU power is getting bigger and bigger, while the physical size remains unchanged, making the heat flux density increasing. The high-heat flux brings higher thermal control requirements for electronic components. Therefore, how to ensure the effective heat dissipation of the high-performance CPU has become a key issue to be solved in the development of electrical and electronic equipment.

The heat pipe radiator has a variety of forms due to the shape of the heat pipe, the location of the fan, the style of the fin and the placement of the heat source. The oscillatory heat pipe heat exchanger applied to the energy storage type inserted heat pipe solar water heating system was studied by Gao Xuna[1]. The experiment showed that the circulating water temperature of the oscillating heat pipe heat exchanger filled with different working fluids will increase with the heating power. The performance analysis of a new structure of tube-fin heat pipe heat exchanger by Ren Changzai[2], showed that the use of spiral fin heat pipes improves heat exchange efficiency and has a certain degree of dust removal ability. A gravity heat pipe radiator has been experimentally studied by Zhukai[3] under different wind speeds and different heat flux conditions, and the total thermal resistance of the radiator is compared with the horizontal heat pipe radiator. A radiator with a fan placed in the middle of two sets of radiating fins were proposed by Jeehoon[4]. The heat pipe is in the shape of "Ω". The experimental results showed that the cooling capacity of the radiator was improved when the overall size was similar or equal to the traditional design. A loop heat pipe radiator with a heat transfer coefficient of 35~50kW/(m²·K) was proposed by Sing et al. Two-dimensional and three-dimensional oscillating heat pipes were experimentally studied by LingYun-Zhi[5], and the temperature change at the evaporation end of the oscillating heat pipe was summarized into three stages. Adnan[6] carried out an experimental
and simulation study on heat pipe radiators for the injection of nano-fluid of oblique zeolite and compared with the heat pipe radiator for the deionized water. The oscillating heat pipe using LiCl salt solution as the working medium was experimentally studied by Zhang Hang et al.\cite{7}, and it was concluded that the oscillating heat pipe with LiCl salt solution had better heat transfer performance than that with deionized water under the condition of moderate liquid filling rate. Solomon\cite{8} has studied a heat pipe radiator with copper-water nanofluid as working a medium.

Various heat pipe radiators were studied in the above literature. In this paper, the parameters of three heat pipe radiators with a different number of heat pipes are found about its heat dissipation power, average temperature and starting time under the same wind speed are obtained by experiment.

2. Experimental

The experimental objects of this experiment are three different types of gravity type of a brand CPU heat pipe radiator. The number of heat pipes is two-tube, four-tube and six-tube, heat pipes are processed”U” type, The heat pipe is made of copper and the fin is made of aluminum.

![Diagram of experimental system](image)

Diagram of the experimental system as shown in Figure1. The experimental instruments used include a voltage regulator and a power meter to supply the electricity needed for the heating plate and read out the heating power; thermometer and computer used to measure and record the temperature in the evaporation end, condensation end and air duct of heat pipe; two small axial flow fans supply a certain amount of air in the air duct to cool the condensing end of the radiator; the experimental duct is made of plexiglass plate, and the air duct is rectangular. Thermocouple temperatures measuring points are arranged at the evaporation and condensation ends of heat pipe radiators.

At constant wind speed 1.7m/s, the voltage of the heating pad is successively increased to change the heat flux. Experiments were carried out on three heat pipe radiators until the radiators reached their working limit. The parameters of each measuring point are recorded, and then the maximum heat dissipation power, temperature uniformity, thermal resistance and starting characteristics of heat pipe radiator are analyzed.

3. Experimental Results and Analysis

3.1 Relationship between the evaporation end temperature and heat flux

At the wind speed 1.7m/s under working conditions, the relationships between the evaporation end temperature and the heat flux of three heat pipe radiators are shown in Figure2. When the temperature at the evaporation end reaches 65°C, the heating power is read out by the power meter, and then the heat flux is calculated. According to the measurement, when the evaporating end temperature of the
heat pipe radiator reaches 65℃, the heat dissipation power of two heat pipes, four heat pipes and six heat pipes was respectively 12.58 W/cm², 18.21 W/cm² and 34.82 W/cm².

Figure 2. Relationship between evaporating end temperature and heat flux

Figure 3. The relationship between evaporating end temperature and total thermal resistance

3.2 Relationship between the evaporation temperature and thermal resistance

It can be seen from Figure 3 that the total thermal resistance of the six-tube radiator is the smallest, that of the two-tube radiator is the largest, and that of the four-tube radiators is in the middle. And when the bottom temperature increases from 35℃ to 65℃, the thermal resistance of the three radiators decreases to a small extent. Therefore, the thermal resistance of the heat pipe radiator will decrease with the increase of the heating power, but compared with the changing trend of the curve in the figure; it can be seen that the reduction speed of thermal resistance will decrease with the increase of the heating power, because the steam in the heat pipe tends to be saturated and the phase transformation heat gradually approaches the limit value. At this point, further increase the heating power, heat pipe exchange of the heat pipe will not increase.

3.3 Uniformness of the evaporating end of the heat pipe radiator

Figure 4 shows the three heat pipe radiators simulating the temperature difference between the center and the edge of the CPU when the heating surface temperature increases from 35℃ to 75℃. The temperature difference between the bottom surface of radiator of two tubes increases from 7.1℃ to 18.2℃, the temperature difference between the bottom surface of four tubes radiator increased from 4.56℃ to 15.21℃, The temperature difference between the bottom surface of the six-tube radiator increased from 3.14℃ to 11.23℃. As can be seen, with the continuous rise of the temperature of the heating surface, the temperature difference of the simulated CPU is also increasing. Among them, the evaporation end of the six-tube radiator has the best average temperature, while the evaporation end of the two-tube radiator has the worst. This is because the heat pipe at the evaporating end of the six-tube radiator is densely distributed, and the analog chip is in direct contact with the heat pipe, and the contact area is large, so the heat can be more evenly distributed.
3.4 Condensation end temperature and heat flux

The relationship between the temperature of the condensing end of the heat pipe radiator and the increase of heat flux is shown in Fig5. With the increase of heat flux, the temperature of the condensing end of the three heat pipe radiators also began to rise gradually. It can be seen that the temperature at the condensing end of the three heat pipe radiators rises slightly slowly at the initial stage, but with the increase of heat flux, the temperature at the condensing end also rises faster. It shows that the distilled water inside the heat pipe radiator is not completely vaporized in the initial stage, and the steam condenses before reaching the top of the heat pipe. With the further increase of heat flux, the distilled water in the heat pipe is completely vaporized, and the steam temperature does not fall below the condensation point temperature during the rising process, so the condensing end temperature continues to rise.

3.5 Uniformness of the condensing end of the heat pipe radiator

In the experiment, the temperature of the heat pipes on the windward side and the leeward side of the condensing end of the radiator heat pipe was measured, and the average temperature difference of the heat pipes at the condensing end was measured, as shown in Fig6. The temperature difference between the windward side and the leeward side of the condensing end of three heat pipes increases with the increase of heat flux. When the three heat pipes reach the working limit, the maximum temperature difference between the condensing end of two heat pipes, four heat pipes and six heat pipes is 1.24°C, 1.17°C, and 1.1°C respectively. The temperature difference between the condensing end of three heat pipe radiators is very small, indicating that the condensing end can be fully cooled after the air flows through the condensing end of the heat pipe. The length and fin area of the condensing end of the three heat pipe radiators can meet the heat dissipation requirements of the heat pipe radiators at the working limit.

3.6 Starting characteristics of the heat pipe radiator

When all three heat pipe radiators are in the working limit, the evaporation temperature rises from room temperature to 65°C in the process. The time response characteristics of the heat pipe radiator are shown in figure7.

In the process of heating from the beginning to the heat balance, the temperature of the evaporation end of the six heat pipe radiators rises the fastest in the initial stage, and the temperature of the evaporation end of the two heat pipe radiators rises the slowest. In the 10 minutes later, the evaporation end temperatures of the three types of heat pipe radiator rise almost synchronously until the simulated CPU reaches its limit temperature of 65°C. When the simulated CPU temperature
exceeds 65°C, the temperature rising trend of the heating surface of the two heat pipes is faster than that of the four heat pipes. The experimental results show that under the limit working condition, the heat pipe radiator of the three types reaches the heat balance time of about 17min.

4. Conclusion
With the purpose of cooling the computer CPU, the heat dissipation performance of two heat pipes, four heat pipes and six heat pipe radiators were experimentally studied, and the experimental data were compared and analyzed, and the following conclusions were drawn:

(1) The maximum heat dissipation powers of two heat pipes, four heat pipes and six heat pipes are 78W, 116W and 240W respectively; the corresponding maximum heat flux are 12.58 W/cm², 18.71 W/cm², 37.71 W/cm².

(2) When the wind speed is 1.7m/s, the total heat resistance of the three types of heat pipe radiators decreases slightly with the increase of heat flux. After the thermal stability is reached, the thermal resistance of the two-heat pipe heat exchanger is 0.57 K/W, the heat resistance of the four heat pipe radiator is 0.39 K/W, the heat resistance of the six heat pipe radiator is 0.19 K/W.

(3) The time for the three heat pipe radiators to reach the heat balance is about the same, all about 17 minutes.

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