Experimental study on the temperature uniformity of radiator based on micro heat pipe array in plateau area

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Abstract. In order to study and analyze the surface temperature uniformity of micro heat pipe array radiator, through comparative experiments, we found that: When the water supply flow is 1600 L/h, and the water supply temperature is 65 \degree C to 85 \degree C, the temperature difference between the head end and the end of the array radiator filled with R141b in the horizontal direction is only 1.9 \% to 2.1 \%, the temperature drop ratio in the vertical direction is only reduced from 1.3\% to 0.9\%; The temperature drop ratio of the first end and the end of acetone filling is 4.2\% to 2.5\%, the temperature drop ratio in the vertical direction is 3.2\% to 1\%; The temperature drop ratio of the head end and the end of the copper aluminum composite radiator is 36.5\% to 20.9\%, the temperature drop ratio in the vertical direction is 9.5\% to 1.2\%. When the water supply temperature is 75 \degree C, the water supply flow is 1050L/h to 2200L/h, the maximum temperature drop ratio of the head end and the end of the micro heat pipe array radiator is only reduced from 3.4\% to 2.6\%, the temperature drop ratio in the vertical direction is only reduced from 0.8\% to 0.6\%; The temperature drop ratio of the head end and the end of the copper aluminum composite radiator decreased from 35.1\% to 19.4\%, the temperature drop ratio in the vertical direction decreased from 5.7\% to 1.5\%. Therefore, the temperature uniformity of the micro heat pipe array radiator in the horizontal and vertical directions is better than the existing copper aluminum composite radiator.

Keywords: Micro heat pipe array; radiator; thermal homogeneity; temperature rise performance.

1. Introduction
With the continuous development of heating technology in China, it has become the mainstream development trend of social economy to not only meet the indoor heating demand of buildings, but also achieve the goal of energy saving and emission reduction to achieve "green building". As the end device of the heating system, the existing radiators on the market mainly include: Steel radiators and Copper aluminum composite radiators, however, they all have the disadvantages of occupying indoor space, high demand for water supply temperature and uneven distribution of radiator temperature [1], which greatly affects the energy-saving performance and comfort. Therefore, it is necessary to study more efficient radiator. At the same time, with the continuous development of heat pipe technology, Zhao
Yaohua and others invented the flat plate micro heat pipe array with stronger heat transfer performance, better temperature uniformity and wider application range [2], and made relevant research on its heat transfer characteristics. Kou Zhihai, Liu Chenxi et al. [3] analyzed the influence of heating power, cooling strength, working angle and other factors on the heat transfer performance of flat heat pipe radiator. For the terminal equipment of indoor heating system, Dong Ruixue, Quan Zhenhua et al. [4] used flat plate micro heat pipe array as the terminal equipment of floor heating system. Through experimental research, when the water supply temperature is 40 ℃, the flow rate is 300 L/h, under the same indoor design temperature, the heat transfer power can reach 154.93 w/m², which is 29.33 w/m² higher than the traditional floor heating system. But the combination of heat pipe technology and indoor radiator, or even the research on the heat transfer performance of the radiator itself is still blank. Only Jian Yiwen and Li Wang [5-6] did relevant research and analysis on the selection of radiator and the design of heat metering system. Therefore, a new type of indoor radiator based on flat plate micro heat pipe array is proposed, and its temperature uniformity in the indoor heating system of plateau area is studied.

2. Experimental System
In this experiment, the calibrated Φ0.1mm copper/constantan thermocouples were used to collect data. The main collected data are: the inlet and outlet water temperature of the micro heat pipe array radiator, the evaporation section temperature of the micro heat pipe array, the longitudinal and transverse temperature of the condensation surface of the micro heat pipe array, and the indoor environmental average temperature. On the array radiator of micro heat pipe, temperature measuring points are arranged at intervals, with a total of 45 temperature measuring points arranged, as shown in Figure 1. 9 temperature measuring points are arranged in the whole evaporation section, and the transverse spacing of each temperature measuring point is 130mm. 4 temperature measuring points are arranged in each condensation section (i.e. heat dissipation section), and the distance from the special-shaped pipe is 20mm, 220mm, 420mm and 620mm, respectively. Set 36 temperature measuring points. At the same time, the water temperature at the inlet and outlet of the micro heat pipe array radiator and the indoor environment temperature are all collected by using Φ0.1mm copper/constantan thermocouple, in which the indoor environment temperature measuring point is located in the center of the experimental room, and its height is 1.7m from the ground [7]. All temperature measuring points are connected with Agilent 34972A data acquisition instrument, and then collect and summarize data through computer.

Fig.1 Arrangement of temperature measuring points on the array radiator of micro heat pipe
3. Experimental results and analysis

3.1. The temperature uniformity of the micro heat pipe array radiator in the horizontal direction

3.1.1. Test horizontal temperature uniformity of the same water supply flow and different water supply temperature. The selected water supply flow is 1600L/h (water supply flow rate is 0.9m/s), and the set water supply temperature is 65°C and 85°C, respectively. After the operation of the micro heat pipe array radiator filled with R141b and acetone respectively and the existing copper aluminum composite radiator (upper supply and lower return on the same side) are stable. Then collect the temperature data of the three kinds of radiators in the same horizontal direction of the surface and the water inlet pipe, and analyze the influence of different water supply temperature on the temperature uniformity of the three kinds of radiators in the horizontal direction. As shown in Figure 2, when the water supply flow is 1600L/h and the water supply temperature increases from 65°C to 85°C: In the horizontal direction, the temperature difference between the head end and the end of the micro heat pipe array radiator filled with R141b is only 1.9~2.1°C, the temperature drop ratio of the head end and the end is almost unchanged, and the average temperature is increased from 60.8°C to 81.1°C. Therefore, under the same flow rate, increasing the temperature of water supply will directly affect its average temperature in the horizontal direction, but hardly affect its temperature uniformity in the horizontal direction. The temperature difference between the head end and the end of the micro heat pipe array radiator filled with acetone decreased from 2.6°C to 2.0°C, the temperature drop ratio of the head end and the end decreased from 4.2% to 2.5%, and the average temperature increased from 59.9°C to 80.7°C. Therefore, increasing the water supply temperature will not only directly affect its average temperature in the horizontal direction, but also affect its temperature uniformity in the horizontal direction. The temperature difference between the head end and the end of the copper aluminum composite radiator decreased from 17.8°C to 14.9°C, the temperature drop ratio of the head end and the end decreased from 36.5% to 20.9%, and the average temperature increased from 39.8°C to 63.1°C. The increase of heat medium temperature is beneficial to enhance its heat transfer performance, so the average temperature and temperature uniformity can be improved by increasing the water supply temperature.

3.1.2. Test horizontal temperature uniformity of the same water supply temperature and different water supply flow. The selected water supply temperature is 75°C, and the set water supply flow rates are 1050L/h and 2200L/h respectively. At this time, the water supply flow rates are 0.6m/s and 1.2m/s respectively. After the operation of the three kinds of radiators is stable, collect the relevant temperature data as above. The influence of different water supply flow rate on the temperature uniformity of the three kinds of radiators in horizontal direction is analyzed. As shown in Figure 3, when the water supply temperature is 75°C, the water supply flow increases from 1050L/h to 2200L/h: The maximum temperature difference between the head end and the end of the micro heat pipe array radiator filled with R141b is only reduced from 2.3°C to 2.0°C, the temperature drop ratio of the head end and the end decreased from 3.4% to 2.6%, and the maximum average temperature is increased from 70.4°C to 71.1°C. Therefore, compared with the water supply temperature, the water supply flow has little effect on the micro heat pipe array radiator. The temperature difference between the head end and the end of the copper aluminum composite radiator decreased from 20.2°C to 11.7°C, the temperature difference decreased by 42.1%, the temperature drop ratio of the head end and the end decreased from 35.1% to 19.4%, and the average temperature increased from 47.6°C to 53.8°C. Therefore, under the same water supply temperature, increasing the water supply flow is conducive to reducing the "blocking effect" of the "upper supply and lower return" type copper aluminum composite radiator on the same side, and improving its temperature uniformity and average temperature. To sum up, under the same constant flow and variable temperature or constant temperature and variable flow conditions, the average temperature and temperature of the micro heat pipe array radiator in the
horizontal direction are better than the existing copper aluminum composite radiator (upper supply and lower return on the same side).

![Fig.2](image1)
![Fig.3](image2)

3.2. The temperature uniformity of the micro heat pipe array radiator in the vertical direction

3.2.1. Test the vertical temperature uniformity of the same water supply flow and different water supply temperature. The selected water supply flow is 1600L/h (the water supply flow rate is 0.9m/s), and the water supply temperature is set as 55℃, 65℃, 75℃ and 85℃, respectively. After the three kinds of radiators operate stably, select the middle position of the radiators, test and collect their temperature data in the vertical direction. The influence of different water supply temperature on the temperature uniformity of the three kinds of radiators in the vertical direction is analyzed. As shown in Figure 4, under the same experimental conditions, the average temperature of the micro heat pipe array radiator in the vertical direction is much higher than that of the existing copper aluminum composite radiator (upper supply and lower return on the same side). For example, when the water supply flow is 1600L/h and the water supply temperature is 55℃: For R141b filled micro heat pipe array radiator, its average temperature in the vertical direction is 49.8℃; The average temperature of micro heat pipe array radiator filled with acetone is 46.9℃; But the average temperature of the composite radiator is 23.2℃. In the temperature range of 55-85℃ for water supply: The temperature uniformity of the micro heat pipe array radiator filled with R141b is good in the vertical direction, and the vertical temperature drop ratio is only reduced from 1.3% to 0.9%. Therefore, the temperature of water supply has little effect on its temperature uniformity. The temperature drop ratio of the micro heat pipe array radiator filled with acetone in the vertical direction is reduced from 3.2% to 1%, so the water supply temperature has little effect on its vertical temperature uniformity. The reason why its average temperature in the vertical direction is lower, the proportion of temperature drop is larger, and the temperature uniformity is poor at 55℃ is that the boiling point of acetone is 56.5℃, and the lower water supply temperature can not make the acetone medium reach the saturated steam state, which reduces its heat transport capacity. The average temperature of the copper aluminum composite radiator in the vertical direction is increased from 23.2℃ to 62.6℃, and the proportion of temperature drop in the vertical direction is reduced from 9.5% to 1.2%. Therefore, increasing the water supply temperature is not only conducive to improving the vertical average temperature, but also to improving the vertical temperature uniformity.
The water supply temperature is 55℃ (a)
The water supply temperature is 65℃ (b)
The water supply temperature is 75℃ (c)
The water supply temperature is 85℃ (d)

Fig.4 The temperature uniformity of three kinds of radiators in vertical direction at the same flow rate and different temperatures

3.2.2. Test the vertical temperature uniformity of the same water supply temperature and different water supply flow. The water supply temperature is still selected as 75℃, and the water supply flow is set as 1050L/h and 2200L/h respectively. After the operation of three kinds of radiators is stable, collect relevant temperature data as above, and analyze the impact of different water supply flow on the temperature uniformity of the three radiators in the vertical direction. As shown in Figure 5, under the same experimental conditions, the average temperature of the micro heat pipe array radiator in the vertical direction is much higher than that of the existing copper aluminum composite radiator (upper supply and lower return on the same side). For example, when the water supply temperature is 75℃ and the water supply flow is 1050L/h: The average temperature of the micro heat pipe array radiator filled with R141b in the vertical direction is 70.2℃, that filled with acetone is 70.0℃, and that of copper aluminum composite is 46.3℃. When the water supply flow increases from 1050L/h to 2200L/h: The average temperature of the micro heat pipe array radiator filled with R141b in the vertical direction increased from 70.2℃ to 70.9℃, and the proportion of temperature drop in the vertical direction decreased from 0.8% to 0.6%. The average temperature of acetone in the vertical direction is increased from 70.0℃ to 70.6℃, and the proportion of temperature drop in the vertical direction is maintained at about 0.7%. The average temperature of copper aluminum composite in the vertical direction increased from 46.3℃ to 53.4℃, and the rising proportion of temperature was 15.3%, while the decreasing proportion of temperature in the vertical direction decreased from 5.7% to 1.5%. Therefore, under the same water supply temperature, increasing the water supply flow has little effect on the average temperature and temperature uniformity of the micro heat pipe array radiator in the vertical direction,
but has great influence on the average temperature and temperature uniformity of the copper aluminum composite radiator in the vertical direction. To sum up, under the same constant flow and variable temperature or constant temperature and variable flow conditions, the temperature uniformity and average temperature of the micro heat pipe array radiator in the vertical direction are superior to the existing copper aluminum composite radiator (upper supply and lower return on the same side).

![Fig.5 The temperature uniformity of three kinds of radiators in vertical direction at the same temperature and different flow rate](image)

### 4. Conclusion

The micro heat pipe array radiator in this paper has the advantages of small volume, less indoor space occupation, and reducing the probability of scale and bubble blockage. The main conclusions are as follows:

When the water supply flow is 1600L/h and the water supply temperature is 65°C to 85°C. The average temperature of the micro heat pipe array radiator filled with R141b increases from 60.8°C to 81.1°C in the horizontal direction, the temperature difference between the head end and the end is only 1.9~2.1°C, and the proportion of temperature drop in the vertical direction is only reduced from 1.3% to 0.9%. The average temperature of acetone in the horizontal direction increased from 59.9°C to 80.7°C, and the temperature drop ratio of the first and the end decreased from 4.2% to 2.5%, while the temperature drop ratio in the vertical direction decreased from 3.2% to 1%. However, the average temperature of the existing copper aluminum composite radiator (upper supply and lower return on the same side) in the horizontal direction is increased from 39.8°C to 63.1°C, the temperature drop ratio of the first end and the end is reduced from 36.5% to 20.9%, and the temperature drop ratio in the vertical direction is reduced from 9.5% to 1.2%. Therefore, under the condition of the same water supply flow and different water supply temperature, the temperature uniformity and average temperature of the micro heat pipe array radiator in the horizontal and vertical directions are better than the existing copper aluminum composite radiator (upper supply and lower return on the same side).

When the water supply temperature is 75°C, and the water supply flow is 1050L/h to 2200L/h. The maximum average temperature of the micro heat pipe array radiator in the horizontal direction is increased from 70.4°C to 71.1°C, the maximum temperature difference between the head end and the end is only reduced from 2.3°C to 1.9°C, the maximum temperature drop ratio between the head end and the end is only reduced from 3.4% to 2.6%, and the temperature drop ratio in the vertical direction is only reduced from 0.8% to 0.6%. The average temperature of the existing copper aluminum composite radiator in the horizontal direction increased from 47.6°C to 53.8°C, the temperature difference between the head end and the end decreased from 20.2°C to 11.7°C, the temperature drop ratio of the head end
and the end decreased from 35.1% to 19.4%, and the temperature drop ratio in the vertical direction decreased from 5.7% to 1.5%. Therefore, under the condition of the same water supply temperature and different water supply flow, the temperature uniformity and average temperature of the micro heat pipe array radiator in the horizontal and vertical directions are better than the existing copper aluminum composite radiator (upper supply and lower return on the same side).

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