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Study on Temperature Uniformity of Geothermal System Based on Micro Heat Pipe Array in Tibet

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Abstract

In this paper, a special-shaped tube is used to enhance the heat transfer performance between the evaporation section and hot water of the micro heat pipe array, and the temperature uniformity of the ground heating system of the micro heat pipe array is studied experimentally. The results show that the temperature uniformity of the longitudinal surface of the micro heat pipe array is good, and the temperature difference between the evaporation section and the water supply is 0.2 ~ 0.8℃; The non-uniformity of temperature distribution in the transverse plane increases with the increase of water supply temperature. At the same time, the maximum temperature difference is 2.7-4.6℃, and the average difference between the peak temperature and the valley temperature is 2.3-4.3℃. Therefore, the temperature uniformity of the whole micro heat pipe array is poor. The temperature gradients in the lower and upper layers of the room increase with the increase of water supply temperature and indoor height, respectively. At the same time, for the vertical temperature distribution of indoor air, the higher the water supply temperature, the more obvious the vertical temperature of indoor air increases with the increase of flow rate.

Keywords

Tibet; Micro heat pipe array; Temperature uniformity in longitudinal plane; Temperature uniformity of transverse plane.

1. Introduction

This paper focuses on the optimization of indoor heating system terminal device. Common end devices of heating system are: radiator and floor heating, and floor heating is favored by more and more people because of its indoor temperature uniformity and comfort (heat starts from feet). However, there are some problems in the traditional floor heating pipeline, such as long laying pipeline, high flow resistance, and the main materials are: PE-X, PAP, PP-B and other plastic pipes, with high thermal resistance.

Therefore, with the maturity of heat pipe technology, people gradually consider applying heat pipe technology to floor heating system. By using the oscillating heat pipe as the end of the floor heating system, Jung Soo Kim et al[1], compared with the traditional plastic pipe floor heating system, it is concluded that the performance of the oscillating heat pipe floor heating system is better than that of the traditional floor heating system. Zhang Yufeng, Hao bin et al[2], combined the circular heat pipe with the end of the floor heating system, and through a series of experimental studies, it was concluded that the water supply temperature of the circular heat pipe was 4-6℃ lower than that of the traditional floor heating system, and the heat storage time of the floor was three times of the preheating time. The circular heat pipe is applied to the floor radiant heating system by Wen Hui[3], and the optimal operation condition of the floor heating system with the circular heat pipe is obtained

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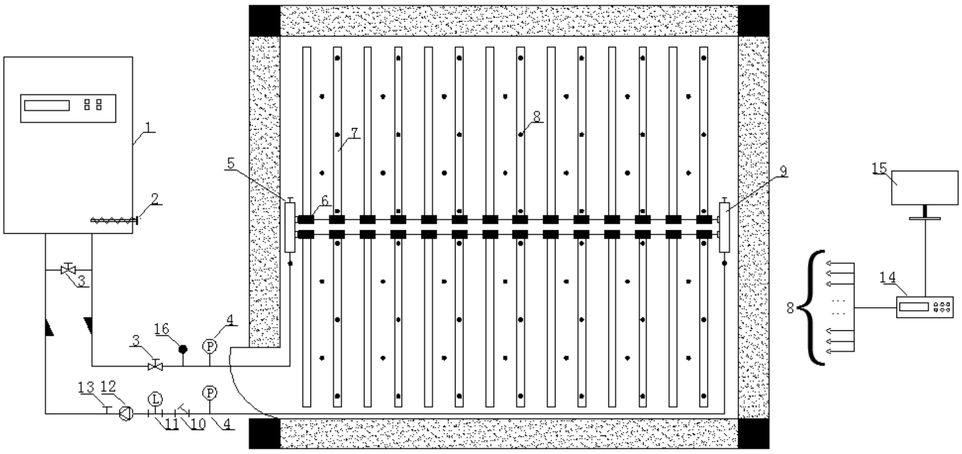
through the relevant experimental research. With the continuous development of heat pipe technology, Zhao Yaohua and others invented the micro heat pipe array with stronger heat transfer performance and applied it to the solar air collector[4], and invented a more efficient solar air collector. After that, Dong Ruixue and Quan Zhenhua[5] used the micro heat pipe array at the end of the floor heating system. Through the change of different water supply flow and water supply temperature, the heat transfer power reached 154.93 W/m2 when the water supply temperature was 40℃ and the flow rate was 300 L/h, which was 29.33 W/m2 higher than that of the traditional floor heating system.

In this paper, in view of the characteristics of flat plate micro heat pipe array (MHPA) with high heat transfer efficiency and strong pressure bearing capacity, and the research on the application of micro heat pipe array in ground heating system at home and abroad is relatively small[4], so it is proposed to apply the micro heat pipe array to the ground heating system in high altitude and cold regions.

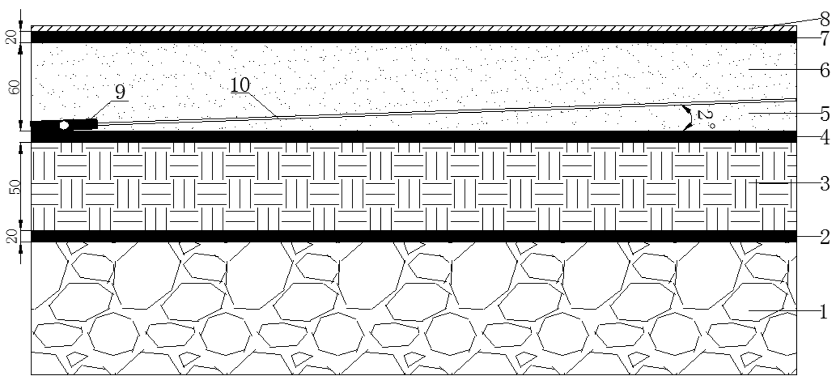
2. Experimental system

The experimental system in this paper is mainly composed of four parts: heating source, heating object, heating system and collecting system. The principle of the experimental system is shown in Figure 1.



1-thermostatic water tank; 2-electric heater; 3-control valve; 4-pressure sensor; 5-water separator; 6-shaped pipe; 7-micro heat pipe array; 8-copper / constantan thermocouple; 9-water collector; 10-Y-shaped filter; 11-flowmeter; 12-circulating water pump; 13-exhaust valve; 14-data acquisition instrument; 15-computer; 16-flow meter

Fig.1 The schematic diagram of the experimental system



1-Original structural layer; 2-leveling layer (cement mortar); 3-insulation layer (foamed polystyrene); 4-reflective layer (reflective film); 5-inclined layer (cement mortar); 6-backfill layer (cement mortar); 7-leveling layer (cement mortar); 8-floor; 9-special-shaped pipe; 10-micro heat pipe array

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Fig.2 Structure of MHPA in the floor

(a) Heat source of heating: Use electric heater to heat constant temperature water tank.

(b) Heating object: The experimental room is brick concrete structure, the indoor size is 3m × 2.5m × 2.2m (length × width × height). The outdoor air temperature is - 2℃, the initial indoor air temperature is ± 2.5℃, the initial indoor floor temperature is ± 1℃, and the relative humidity is 11%.

(c) Heating system: In this experiment, the micro heat pipe array is inserted into the special-shaped pipe to form the heating end, and the heating system is composed of circulating water pump and pipeline system. The indoor floor is heated by direct heat transfer, thus the experimental room is heated. The size of the micro heat pipe array is 1100mm × 50mm × 3mm (length × width × thickness), the length ratio of evaporation section to condensation section is 1:10, the length of evaporation section is 100 mm, and the length of condensation section is 1000 mm. Under the same heating conditions, the pipe spacing of the floor heating system using traditional plastic pipes is generally 200mm, and the pipe diameter is Φ16mm. Therefore, the experimental room is arranged with 2 rows of micro heat pipe arrays (14 in each row, 28 in total), with the center spacing of 200 mm. The structure of the micro heat pipe array in the floor is shown in Fig. 2. The size of the special-shaped pipe is 150mm × 50mm × 16mm (length × width × thickness), and the inlet and outlet diameters of hot water are all Φ16 mm. In order to prevent leakage and improve the sealing and reliability of the system, the micro heat pipe array is connected with the special-shaped pipe by special rubber pad. At the same time, considering the gravity reflux principle of the micro heat pipe array, that is, the condensate in the condensation section flows back to the evaporation section by gravity, so the whole micro heat pipe array must form a certain inclination angle (1~3°) with the horizontal ground[5], and the inclination angle is set at 2° in this experiment.

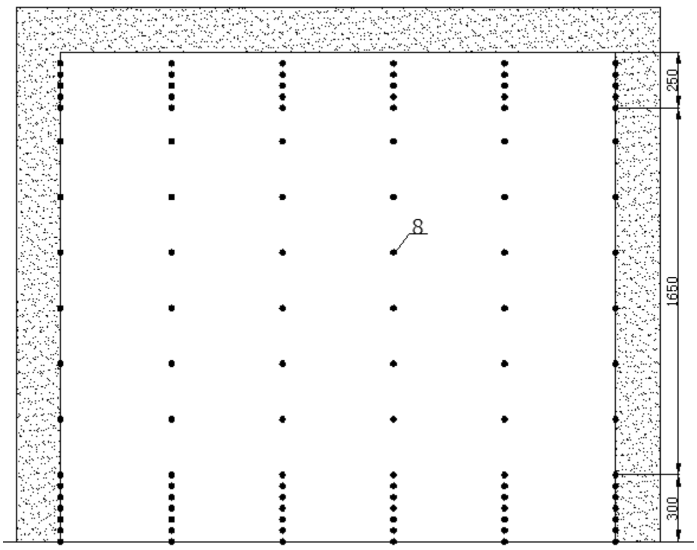

Fig.3 Profile of indoor air temperature measurement points in vertical direction

(d) Data acquisition system: In this experiment, calibrated Φ0.1mm copper / constantan thermocouple was used to collect data, and the measured data are as follows: The temperature of the water supply and return water on the main pipeline, the water supply and return water temperature of the experimental room, the temperature of the longitudinal plane of the micro heat pipe array, the temperature of the transverse surface of the micro heat pipe array, the temperature of the indoor ground, and the vertical temperature of the indoor air. The temperature measurement points on the micro heat pipe array are arranged at intervals, as shown in Fig. 1. Four temperature measuring points are arranged in the longitudinal plane of a single micro heat pipe array (1 temperature measurement point in the evaporation section; 3 temperature measurement points in the condensation section; the first temperature measurement point is 30 mm away from the evaporation section, and the other two

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points are 530 mm and 1030 mm apart). In the floor of the transverse plane of the micro heat pipe array, the temperature measurement points are also arranged evenly, with a total of 28 temperature measuring points, as shown in Fig. 1. The temperature measurement points of indoor air in the vertical direction are arranged as shown in Fig. 3. The temperature gradient of the lower layer, the temperature uniformity of the middle layer and the temperature attenuation of the upper layer are mainly considered. All temperature measurement points are connected with Agilent data acquisition instrument, and the test data are collected into the computer.

3. Results of the experiment

3.1 Temperature uniformity in longitudinal plane of micro heat pipe array

The water supply flow rate is 250 L/h and 400 L/h, and the water supply temperature is set at 35°C, 40°C, 45°C, 50°C and 55°C. After the system runs stably, the temperature changes of longitudinal surface of micro heat pipe array with different water supply flow and different water supply temperature are analyzed. As shown in Fig. 4, point 1 represents the temperature of the evaporation section, and points 2, 3 and 4 represent the three temperature measurement points of the condensation section respectively. When the water supply flow is 250 L/h and the water supply temperature rises from 35°C to 55°C, the temperature of evaporation section rises from 34.2°C to 54.5°C, and the average temperature of condensation section increases from 32.7°C to 53.1°C. Therefore, under the same water supply flow, the average temperature of evaporation section and condensation section rises with the increase of water supply temperature. When the water supply temperature is 40°C, the water supply flow increases from 250 L/h to 400 L/h, the temperature difference between the evaporation section and the condensation section decreases from 1.8°C to 1.3°C. Therefore, under the same water supply temperature, with the increase of water supply flow, the temperature difference between evaporation section and condensation section will decrease. Under the experimental conditions, the temperature difference range of evaporation section and condensation section is 0.9~1.8°C, the maximum temperature drop ratio is 4.6%, and the temperature difference range between evaporation section temperature and water supply temperature is 0.2~0.8°C, which is better than 2~3°C proposed by Dong Ruixue et al[5]. Therefore, the floor heating system with micro heat pipe array with special-shaped tubes has better heat transfer performance.

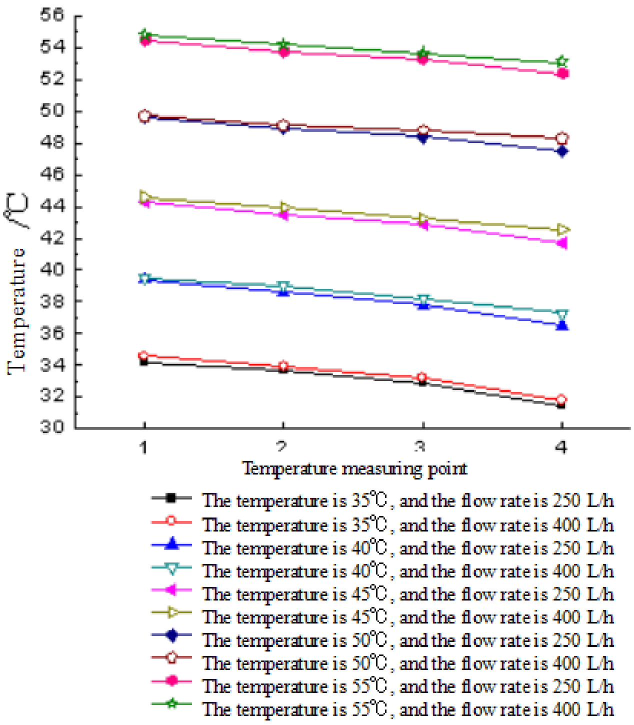

Fig.4 Longitudinal Temperature Distribution of MHPA

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3.2 Temperature uniformity in transverse plane of micro heat pipe array

The water supply temperature is 35℃, 45℃ and 55℃, and the water supply flow is 250 L/h and 400 L/h respectively. After the system runs stably, the temperature changes of the transverse surface of the micro heat pipe array with different water supply flow and different water supply temperature are analyzed. As shown in Figure 5, the wave crest in the figure represents the average temperature of the condensation section of the micro heat pipe array, the wave trough represents the average temperature of the transverse surface of the micro heat pipe array, and the direction of hot water supply is from left to right in the figure. It can be seen from Fig. 5 that under different working conditions, the temperature change trend of the transverse surface of the micro heat pipe array is basically the same, which decreases with the direction of hot water supply. Under the same water supply temperature, the average temperature of the transverse surface of the micro heat pipe array increases slightly with the increase of the water supply flow. For example, when the water supply temperature is 55℃, the water supply flow rate increases from 250 L/h to 400 L/h, the average temperature of the transverse surface of the micro heat pipe array increases from 48.8℃ to 50℃. Under the same water supply flow rate, the average temperature of the transverse surface of the micro heat pipe array increases with the increase of the water supply temperature, and the temperature fluctuation intensifies, and the nonuniformity of the temperature distribution increases. For example, when the water supply flow is 250 L/h and the water supply temperature is increased from 35℃ to 55℃, the maximum temperature difference of the transverse surface of the micro heat pipe array increases from 2.7℃ to 4.6℃ The average temperature difference between peak and valley increases from 2.3℃ to 4.3℃, so the temperature uniformity of the whole micro heat pipe array is poor.

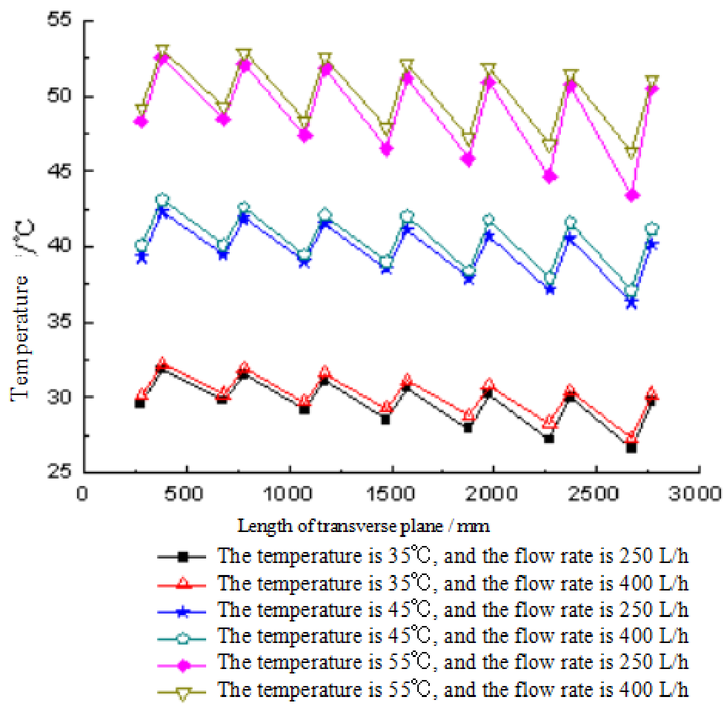

Fig.5 Transverse temperature distribution of MHPA

3.3 Temperature distribution of indoor air in vertical direction

When the water supply flow is 250 L/h and 400 L/h, and the water supply temperature is 35 ℃, 45 ℃ and 55 ℃, the vertical temperature distribution of indoor air is shown in Fig. 6. Under different conditions of water supply flow and water supply temperature, the overall change trend of all curves is consistent. The lower layer temperature of indoor air (from the ground to 15 cm above the ground) drops linearly. Under the same flow rate, the temperature gradient increases with the increase of water supply temperature, and the temperature basically reaches stability at 15 cm away from the ground.

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For example, when the water supply flow is 250 L/h and the water supply temperature is 35°C, the lower layer temperature gradient of indoor air is 0.39°C/cm, while when the water supply temperature is 55°C, the temperature gradient is 0.9°C/cm. The temperature in the middle layer of indoor air (15-160 cm away from the ground) remains flat, and the temperature gradient is the smallest. At the same time, with the change of water supply flow and water supply temperature, the line type moves in parallel. The upper temperature of indoor air (160-220 cm above the ground) decreases rapidly with the increase of height, and the temperature gradient increases with the increase of height. For example, when the water supply flow is 250 L/h, the water supply temperature is 35°C, and the average temperature gradient is 0.043°C/cm at 160-190 cm above the ground, and 0.28°C/cm at 190-210 cm above the ground. At the same time, for the vertical temperature distribution of indoor air, the higher the water supply temperature, the more obvious the vertical temperature of indoor air increases with the increase of flow rate.

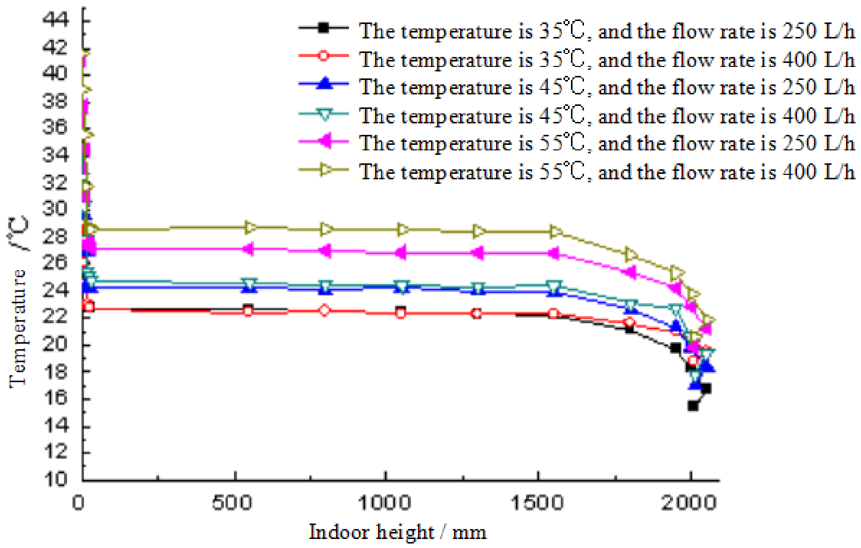

Fig.6 Temperature Distribution of Indoor Air in Vertical Direction

4. Conclusion

In this paper, the special-shaped tube is used in the floor heating system of micro heat pipe array, which makes the evaporation section of micro heat pipe array contact with hot water directly, thus enhancing the heat transfer effect. The main conclusions are as follows:

(a) Under the same water supply temperature condition, with the increase of water supply flow, the temperature difference between evaporation section and condensation section will be reduced, the temperature difference range is 0.9 ~ 1.8°C, the maximum temperature drop ratio is 4.6%, and the temperature difference range between evaporation section and water supply section is only 0.2 ~ 0.8°C. When the water supply flow is 250 L/h and the water supply temperature is increased from 35°C to 55°C, the temperature of the transverse surface of the micro heat pipe array increases with the increase of the water supply temperature, and the maximum temperature difference increases from 2.7°C to 4.6°C. The nonuniformity of temperature distribution increases, and the average difference of temperature peak and valley increases from 2.3°C to 4.3°C. Therefore, the longitudinal surface of the whole micro heat pipe array has good temperature uniformity, while the transverse surface is relatively poor.

(b) The temperature of the lower layer of indoor air (from the ground to 15 cm above the ground) decreases linearly, and the temperature gradient increases with the increase of water supply temperature, but the temperature is basically stable at 15 cm above the ground; The temperature in the middle layer of indoor air (15-160 cm above the ground) is gentle, and the temperature gradient is the smallest. With the change of water supply flow and water supply temperature, the line shape

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moves in parallel; The upper temperature of indoor air (160-220 cm above the ground) decreases rapidly with the increase of height, and the temperature gradient increases with the increase of height.

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