EXPERIMENT ANALYSIS OF MULTI-FUNCTIONAL TROMBE WALL MODUL BASED ON ENHANCED HEAT TRANSFER MICRO-CHANNEL PLATE

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Abstract: A traditional trombe wall has the problems of single purpose and temperature-high in summer which affects human comfort and increases energy consumption of air conditioning. This study puts forward a kind of multi-function trombe wall,which means that the venetian blinds made from several paralleled microchannel plates are installed in the air gap of the trombe wall. Water is circulated in the microchannel to take away excessive heat in hot summer. which can not only alleviate the problem of overheat in summer and but also generate the domestic hot water at the same time. The experimental results show that the temperature of the back plate of the multifunction trombe wall is 24.4% lower than that of the traditional trombe wall,and the average water temperature in the water tank reached 46.80 ℃. Therefore,the multi-function trombe wall can utilize the solar energy efficiently because of supplying hot water and simultaneously reducing overheat in summer.

Keywords: solar energy Trombe wall building envelope microchannels enhanced heat transfer space heating

Fund: Hefei University of Technology 2019 provincial college students ' innovation and entrepreneurship training program (S201910359122)

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Date of receipt: 2020-01-14

0 Introduction

At present, China 's building energy consumption accounts for about 28 % of the total energy consumption, and with the improvement of people 's living standards and living comfort requirements, building energy consumption accounted for the proportion of total energy consumption increased year by year [1]. In building energy consumption, the proportion of heating and hot water demand is 60 % ~ 87 % in heating season and 30 % ~ 40 % in non-heating season [2]. Due to the differences in lifestyle and living standards, the per capita domestic hot water consumption of urban residents in China was less than 1 / 4 of that in Japan in 2010.With the improvement of living standards, how to efficiently prepare domestic hot water to meet the growing demand for residential hot water is the main problem to maintain the low energy consumption level of residential buildings in the future [3].

The high consumption of energy is in contradiction with the demand of improving people 's living comfort and improving living environment. Therefore, it is very important to study the building energy saving technology using renewable energy and improve the utilization rate of renewable energy in buildings. Passive solar collector wall has been the research focus in the field of building energy saving because of its functions of heating, natural ventilation, reducing building heat load and zero energy consumption [4-5] . Passive solar wall heating air using solar radiation in winter to achieve better heating effect [6] , can effectively reduce the indoor thermal load, however, in summer, passive solar wall overheating problem has not been solved. Heating wall overheating not only affects the indoor human comfort, but also increases the energy consumption of air conditioning system. In view of the above problems, domestic and foreign scholars have done a lot of theoretical and experimental research. Li [7] attached the phase change material to the backplane of the solar collector wall to reduce the heat transfer to the room at noon in summer, and studied its effect on indoor load and natural ventilation. Ji Jie et al. [8] pasted dark blue polysilicon photovoltaic cells on the back of the glass cover of the traditional solar collector wall to form a photovoltaic-collector wall, using solar power generation while reducing the wall overheating problem. Wang Chun et al. [9] proposed a composite system of solar collector wall and basement, which uses air flow from the basement to alleviate the problem of overheating of solar collector wall in summer.

In order to solve the problem of overheating of the solar collector wall in summer, and to meet the growing demand for domestic hot water, this paper constructs a multi-functional louvered solar collector wall based on the traditional solar collector wall, which is enhanced by microchannel plate and collects hot water. In summer, on the one hand, the active water circulation is used to take away the excess heat, alleviate the overheating problem of the collector wall in summer, and reduce the indoor cooling load ; on the other hand, the collected hot water is stored in the water tank to meet the family ' s demand for hot water.

1 Experimental overview

1.1 Experimental platform

The comparative experimental platform is located in the southern campus of Hefei University of Technology (Hefei, 31 ° 51 ′ N, 117 ° 17 ′ E). As shown in Figure 1, the experimental platform includes a multi-functional louvered solar collector wall module and a traditional collector wall module of the same size. As shown in Fig.2, the front of the wall is sealed by a glass cover plate of 1600 mm × 900 mm, and the back of the wall is a black insulation board of 50 mm thickness. There is a 100 mm thick air interlayer between the insulation board and the glass cover plate. The middle position of the air interlayer is a plurality of microchannel plates of 1200 mm (length) × 30 mm (width) × 3 mm (thickness). The inclination angle between the microchannel plate and the horizontal plane is 30 °, and the left and right sides are respectively connected to the flat water collecting pipe. The inlet and outlet of the two water collecting pipes and the heat preservation water tank are connected by PPR pipes to form a closed circulation system, in which the circulation pipeline is also equipped with pumps, valves and other components, and the PPR pipes are all treated with heat preservation cotton. In order to make the water in the collecting pipe flow evenly through each microchannel plate, the whole water system is designed as a synchronous closed-loop loop.

Typically, conventional solar wall thermal storage wall in the inner wall and the outer glass cover has vents. The heat collecting wall is in the heating mode in winter. At this time, the outdoor air outlet of the heat collecting wall is in a closed state, and the indoor upper and lower air outlets are in an open state. Under the action of thermosyphon, the indoor air enters the air interlayer from the lower air outlet and is heated circularly and then flows into the room from the upper air outlet. In summer, the indoor air outlet of the heat collecting wall is usually closed, and the outdoor air outlet is opened to take away the heat of the wall by using the natural convection cycle of the outside air. However, in the practical application of heat collecting wall, the opening and closing of multiple vents is more cumbersome, especially in summer, the opening and closing of the outer vent is not easy to operate, and it also brings a certain aesthetic effect to the exterior wall. Compared with the traditional heat collecting wall, the multi-functional louver type heat collecting wall proposed in this paper takes away the heat absorbed by the heat collecting wall by forced water circulation in summer and transition season, reduces the indoor cooling load, simplifies the removal of outdoor tuyere, and reduces the complexity of operation.

Fig.1 Appearance of experimental platform

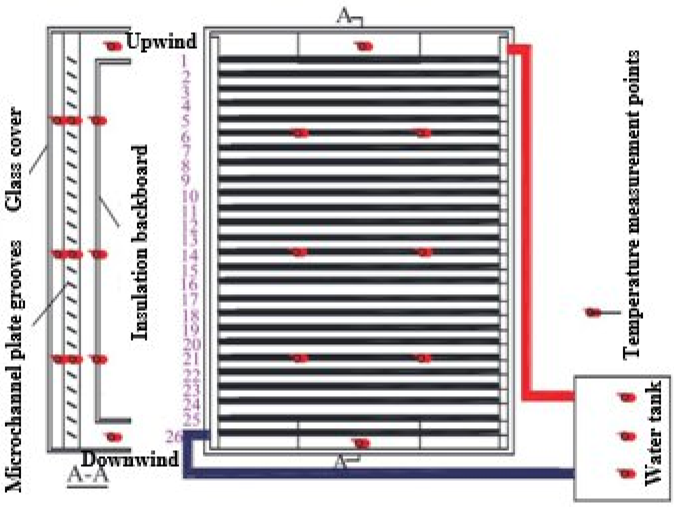

Fig.2 Schematic diagram of multi-functional Trombe wall and temperature testing points

1.2 Experimental test process

During the experiment, the copper-constantan thermocouple (measurement accuracy of ± 0.5 °C) was used to measure the ambient temperature, the temperature of the inner wall of the solar collector wall (insulation board), the surface temperature of the microchannel, the air temperature inside the cavity and the water temperature in the water tank in real time. The distribution of the main thermocouples is shown in Fig.2. The vertical solar radiation intensity is measured by Jinzhou Sunshine TBQ-2 total solar radiometer, and the installation position is parallel to the solar collector wall. All test parameters were recorded and saved by a portable data acquisition instrument HOIOKI (LR8402-21) with a time interval of 1 min. For the collector with water as the heat transfer medium, the water flow rate has little effect on the photothermal efficiency. Therefore, according to the ASHRAE93-2010 standard, the circulating water flow rate is set to 0.04 kg / s [10] , and the water tank capacity selected in this paper is 100 L. In the whole experimental test process, the summer operation mode is simulated, that is, the multi-functional louver heat collecting wall collects hot water. The upper and lower air outlets are closed during 09 : 00-16 : 00 to reduce the loss of heat and store more heat in hot water. For the traditional heat collecting wall, in order to reduce the heat transfer to the room, both air outlets are opened, and natural ventilation is formed in the cavity. The test time for the experimental data selected in this paper is from September 30 to October 3, 2019, and the pump opening time of the multifunctional heat collecting wall during the test is 09 : 00, and the pump closing time is 16 : 00.

2 Analysis of experimental results

2.1 Multifunctional heat collecting wall and traditional heat collecting wall inner wall (insulation board) temperature comparison

During the experiment, the temperature change of the insulation backing plate of the multifunctional heat collecting wall and the traditional heat collecting wall is shown in Fig. 3. Before the pump is opened, the temperature of the insulation backing plate of the multifunctional heat collecting wall and the traditional heat collecting wall is at a lower temperature. When the pump is turned on (09 : 00-16 : 00), the multi-functional heat collecting wall is in hot water collecting mode. During this period, the average temperature of the insulation backboard of the wall on the first to fourth days was 46.38, 41.18, 32.42 and 47.99 °C, respectively. The average temperature of the thermal insulation backplane of the corresponding traditional collector wall is 61.41,52.08,36.05,63.24 °C, respectively. The temperature of the thermal insulation backplane of the multifunctional collector wall is 24.41 %, 20.92 %, 10.07 % and 24.11 % lower than that of the traditional collector wall. Dynamic experimental data show that the temperature of the thermal insulation backing plate of the multi-functional heat collecting wall is significantly lower than that of the traditional heat collecting wall, mainly because the multi-functional heat collecting wall adopts the microchannel plate louver structure inside, forming a certain degree of shading effect, which can reduce the direct solar radiation on the thermal insulation backing plate of the heat collecting wall, thus effectively alleviating the overheating problem of the heat collecting wall in summer. Compared with the traditional collector wall with air natural convection cooling method, the back plate temperature of the multi-functional collector wall with louver structure formed by microchannel plate is significantly lower.

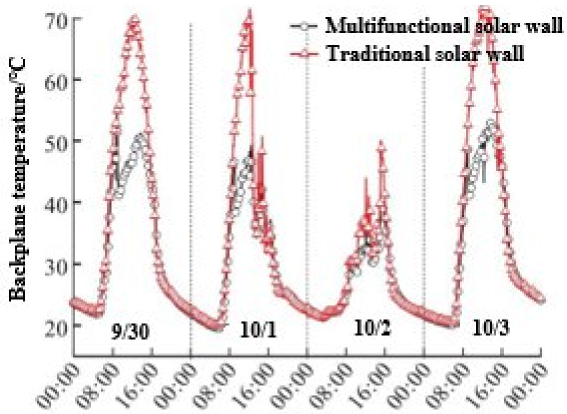

Fig.3 Comparison of internal wall(insulation board)temperature between multi-function Trombe wall and traditional Trombe wall

2.2 Multifunctional heat collecting wall and traditional heat collecting wall air interlayer temperature comparison

Figure 4 shows the comparison of the temperature of the air layer between the multi-functional heat collecting wall and the traditional heat collecting wall. It can be seen from the figure that in the 4-day experiment, the temperature change trend of the internal air layer of the two heat collecting walls is consistent, and the values are basically equal. During the four-day pump opening period (09 : 00-16 : 00), the average temperature of the air interlayer of the multi-functional collector wall was 41.03,38.45,30.80 and 44.27 °C, respectively. The corresponding air interlayer temperatures of the traditional collector wall are 41.80,37.71,29.67 and 43.36 °C, respectively. Figure 5 shows the surface temperature of the microchannel plate inside the multi-functional heat collecting wall within 4 days. After sunrise, the temperature of microchannel aluminum plate coated with high absorption rate coating rises sharply because of absorbing solar radiation. Taking the test data on September 30 as an example, the highest temperature in the morning reaches 57.22 °C. After that, the surface temperature decreases rapidly. This is because after the circulating pump of the system is turned on, the active circulating water flow takes away the heat absorbed by the microchannel plate, and the efficient heat transfer structure of the microchannel plate makes the surface temperature of the microchannel plate decrease rapidly. The average daytime temperature of the microchannel plate surface after the opening of the pump was 37.80,36.74,29.78 and 41.22 °C, respectively. This shows that the flow of water in the microchannel plate of the multi-functional heat collecting wall can well take away the heat of the air interlayer in the heat collecting wall when the air interlayer of the heat collecting wall is closed, and will not cause a sharp increase in the temperature of the confined space due to smoldering. On the other hand, Figure 5 shows that the peak temperature of the air interlayer in the multi-functional collector wall has a certain delay in time compared with the traditional collector wall. This is because the water in the microchannel plate of the multi-functional collector wall has a higher specific heat capacity, and the temperature rise is slower than that of the air, while the traditional collector wall has been connected with the outside world, and the temperature of the interlayer air will rise rapidly due to the increase of solar radiation intensity.

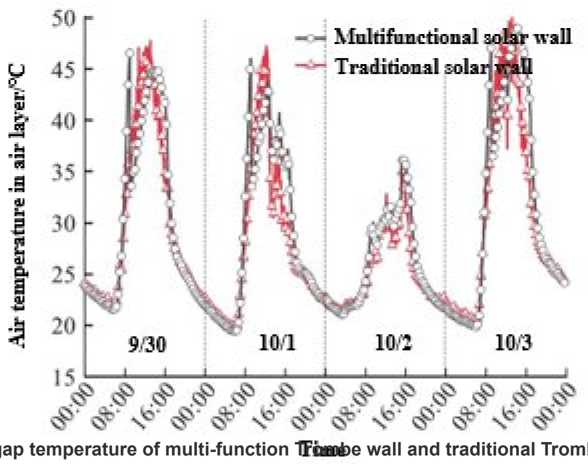

Fig.4 Air gap temperature of multi-function Trombe wall and traditional Trombe wall

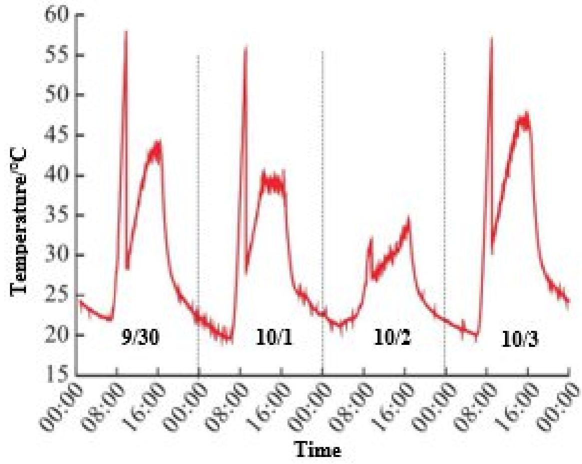

Fig.5 Temperature of micro-channel plate insidemulti-function Trombe wall

2.3 System photothermal performance analysis

Taking the test data on October 3 as an example, the temperature of water in the tank, the ambient temperature, the inlet and outlet water temperature of the water circulation system of the multi-functional collector wall and the solar radiation intensity are shown in Figure 6. The temperature of water in the water tank is the average value of the temperature measured by three thermocouples evenly placed in the upper, middle and lower positions of the water tank. At 09 : 00 in the morning, the pump is turned on and the water in the system pipe begins to circulate actively. As shown in Fig. 6, the initial water temperature in the tank and the inlet water temperature of the heat collecting wall are significantly lower than the outlet water temperature of the heat collecting wall. The water is heated through the inner hole of the microchannel of the heat collecting wall, and the heated water enters the water tank, but the overall water temperature in the water tank is low, and the heated water is mixed with the water in the water tank, which is not enough to cause the overall water temperature of the water tank to rise. With the increase of solar radiation intensity, the water temperature in the tank increases gradually. As the water continues to be heated, the water temperature at the inlet of the heat collecting wall begins to gradually fall below the average temperature of the tank after 11 : 00, mainly because the water in the tank will gradually appear temperature stratification, and the inlet of the heat collecting wall and the lower part of the tank are connected to a lower temperature. At about 15 : 00 p. m., the water temperature in the tank tends to be stable as the solar radiation intensity decreases. When the pump is closed at 16 : 00, the overall water temperature of the tank is 46.80 °C.

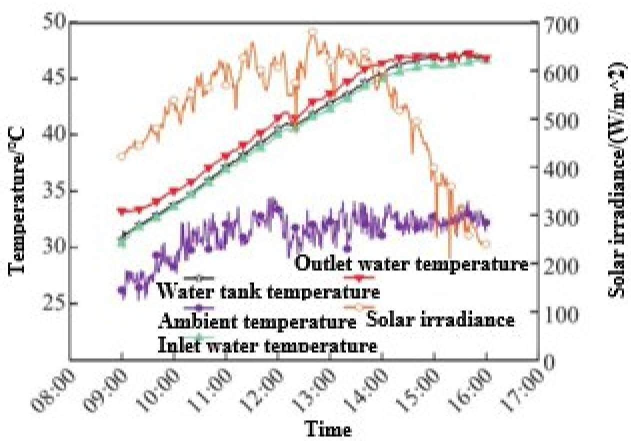

Fig.6 Solar irradiation intensity,ambient temperature andwater temperature variations with time

The experimental results of the multi-functional louvered wall are summarized in Table 1. It is calculated that the efficiency of hot water collection is above 30 % in the 4-day experiment. On the first and fourth days of sufficient solar radiation, the thermal efficiency of the water system reached more than 40 %, and the overall water temperature in the tank exceeded 45 °C. On the third day when the daily cumulative solar radiation intensity was 3.65 MJ / m ^{2} , the thermal efficiency of the water system reached 37.40 %. The water tank capacity is 100 L.Under the natural conditions of sunny weather and sufficient solar radiation, the multi-functional collector wall can meet the family 's demand for hot water to a certain extent.

Table 1 Experimental results of multi-function Trombe wall

Note : $T_{initial}$ - tank initial temperature ; t_{final} - tank final temperature ; δT-water tank daily temperature rise ; q-tank daily total heat ; g-daily total radiation intensity ; η - Daily average heat collecting efficiency (hot water).

Parameter	9/30	10/1	10/2	10/3
$T_{initial}$/℃	27.34	27.77	27.2	30.09
T_a/℃	30.15	28.84	25.6	30.92
T_{final}/℃	45.22	38.65	31.36	46.8
ΔT/℃	17.88	10.88	4.16	16.71
Q/(MJ/m^2)	5.87	3.57	1.37	5.48
G/(MJ/m^2)	13.35	9.19	3.65	12.97
η/%	43.9	38.85	37.40	42.27

3 Conclusion

This paper presents a multifunctional louvered heat collecting wall which uses microchannel plate water to collect heat in non-heating season and air to collect heat in heating season. On the basis of the traditional air sandwich heat collecting wall, a microchannel plate is introduced to form a microchannel plate louver. The active water circulation system is used inside the microchannel plate to take away the excess heat of the heat collecting wall, solve the overheating problem of the heat collecting wall in summer, and convert the excess heat into hot water production to meet the needs of heating, ventilation and hot water production throughout the year, and extend the application time of the traditional heat collecting wall.

In order to explore the performance of multi-functional louver heat collecting wall, the experimental platforms of heat collecting wall with microchannel plate as louver and traditional air interlayer were set up respectively. The system performance of multi-functional louver heat collecting wall is explored through experiments, and the following conclusions are obtained :

1) The use of microchannel louver effectively reduces the temperature of the back plate of the heat collecting wall. In the experiment, the temperature of the back plate of the multifunctional heat collecting wall is 24.41 % lower than that of the traditional heat collecting wall, which solves the overheating problem of the heat collecting wall, thereby improving the indoor thermal environment and reducing the building cooling load.

2) The hot water system achieves good thermal efficiency under good weather conditions, and the overall water temperature in the tank reaches 46.80 °C.

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