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THE SEPARATED HEAT PIPE SOLAR HEATING SYSTEM

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Abstract

It is established a separated heat pipe solar indoor heating system .The system is divided into three parts: solar collector, separated heat pipe and indoor heating terminal. The system uses separated heat pipe as heat transfer component. It transfers solar energy from solar collector into the indoor heating terminals. So by the separated heat pipe the system will heat the indoor air with solar energy. The related experiments were carried out. The results showed that the solar thermal utilization efficiency can reach 56% when the solar radiation is at 725W/ ㎡, the evaporation and condensation temperature of heat pipe kept constant at 44.8 ℃ and 40.2℃ respectively. When the system started to run, it took three or more hours to make the indoor air temperature reach 22℃-24℃ at sunny or cloudy days. By the experimental data, it is proved that the system is a promising and feasible heating mode in the spacing heating.

Keywords: Separated heat pipe; Solar energy; Indoor air heating

1. Introduction

Solar energy is one of the renewable energy resources that hold a great potential for developed and developing countries in the future. Solar energy resources are very rich in China. Nowadays, it is being widely used for both heating and electricity generation, and has no restrictions as to the uneven distribution and the shortage of conventional resources. With the development of solar heating, the traditional heating mode has some disadvantages such as complex structure and low efficiency. It can't keep up with the development of housing construction.

Heat pipe has been used in plenty of solar hot water system for its special thermal performance and even in the space heating system. Susheela and Sharp (2001) designed and tested a heat pipe system that could be installed on existing homes without demolishing the wall of the building. The absorber portion was mounted on the outside of a south-facing wall, with water contained in tanks as the thermal mass on the inside of the wall. Experiments were performed outdoors, and system efficiencies (defined as the ratio of power delivered to the room over incident insolation) reached as high as 60% during sunny days. Computer simulations were also performed to model the performance of the unit. Primarily based on design improvements recommended by Susheela and Sharp, Albanese et al. (2012) tested a bench-scale experimental model. Experimental variations included fluid fill levels, addition of insulation on the adiabatic section of the heat pipe, and fins on the outside of the condenser section. Filling the heat pipe to 120% of the volume of the evaporator section and insulating the adiabatic section achieved a system efficiency of 85%. Addition of fins on the condenser of the heat pipe did not significantly enhance overall performance. The heat pipe system provided substantial gains in performance relative to conventional direct and indirect gain passive solar systems and, thus,

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presents a promising alternative for reducing building energy use. To better understand system performance in realistic weather conditions, in particular, the relatively cloudy and cool conditions, Robinson et al. (2013) designed, built and installed a full-scale prototype of the heat pipe system in a classroom on the University of Louisville campus in Louisville, KY. During the spring heating season of 2010 (January–April), maximum daily peak thermal efficiency was 83.7% and average daily peak thermal efficiency was 61.4%. The maximum hourly average room gain achieved during the season was 163 W/m2. On days with good solar insolation, the thermal storage was heated to temperatures sufficient to provide significant energy to the classroom – even during the coldest days of the season. During the longest period (4 days) of low insolation during the season, average hourly heat delivery to the room from storage remained positive, and was never less than 16.6 W/m2.

In these system heat pipe had shown its great heat transfer ability. In order to develop much more heat pipe solar heating system, the separated heat pipe would be introduced into the solar space heating system in this paper. Separated heat pipe solar heating system is a promising technology which has simple structure and high efficiency. It can be divided into three parts: solar collector, separated heat pipe and heating terminal. Separated heat pipe can transfer solar energy from outside to inside of the room. Solar collectors receive energy and transfer heat to the heat pipe, and heat pipe delivers heat to the indoor heating terminals. There is no other transfer medium in the system. Compared with the traditional solar heating system, it has not second heat transfer with water and reduce irreversible loss at the process of heat transfer. As separated heat pipe can extend the length of the pipe, the system has some flexible when it is designed and mounted.

Especially in rural areas and cold in northern China, the distance between buildings is far and the rainy season is short. The surrounding residential buildings have no space restricted and can get sufficient sunlight. It can provide basis for residential heating temperature and reduce fuel consumption. So separated heat pipe solar heating system has broad application prospects in these districts. In this paper, some theory analysis and experiments about the new system were carried out and the performance of the separated heat pipe solar heating system was analyzed.

2. Experimental study

2.1. System introduction

Separated heat pipe solar heating system is composed of solar collector, separated heat pipe and heating terminal as Fig. 1 shows. The evaporation section is placed in the solar collectors. When it is received the solar energy, the working fluid in the evaporator will absorb the heat and evaporate to gas, and then enters into the condensation section. The working fluid in the condensing section sends heat to the indoor air and turns into liquid, finally it returns back into the evaporator by gravity. Then the new cycle will carry on and then the solar energy was transferred from outside to inside.

In the test of separated heat pipe solar heating system, it used separated heat pipe as heat transferring component, this system is mainly composed of solar collector, the separated heat pipe evaporation section 1, the separated type heat pipe condensing section 2, the adjustment of valve 3. The solar collector is basically the same as the ordinary plate type solar collector, which mainly consisted of the solar collector, heat insulation material the separated heat pipe evaporation section, heat absorbing layer and the transparent glass cover. The evaporator section was placed in the flat panel solar collectors with 2m x 1m.The separated heat pipe condenser is composed of copper aluminum fin tube. The condensation section of the separated heat pipe is placed in the room as the indoor terminals providing heat into the room with 0.952 ㎡. Valve 3 is designed to close the circulation channel when the system doesn't work in summer. To avoid affect the indoor lighting, the solar collector is placed on the outside wall with inclined or vertically installation. The working fluid of the separated heat pipe is R600a which is the environmental friendly. The limit on the system installation is that the height of the evaporator must be lower than that of the indoor condenser to ensure the working fluid can flow back to the evaporator. The heating room is in the fourth floor of the office building with the area $40m^2$.

Compared with the traditional solar heating system, the separated heat pipe solar indoor heating system works with gravity separated heat pipe to transfer solar energy into the room without any energy consumption. It belongs to distributed system like air-conditioner installed outside wall in every room. So it is easy installation and has no effect on daylight.

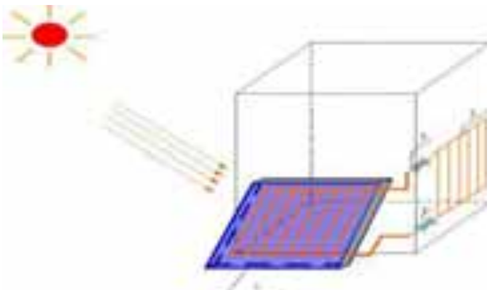


Fig. 1 the principle of the separated heat pipe solar heating system

1—flat-plate collector with separated heat pipe; 2—Control valve; 3—indoor heating terminal

2.2. Test method

The experimental apparatus was set up in the campus of Nanjing Normal University, China. Twenty J-type thermocouples were placed in the evaporator and condenser respectively, to assess temperature difference between of them at the same time. Another two J-type thermocouples were placed in the inside and outside of the room to monitor the indoor air and outside air temperature. One Hukseflux LP02 solar pyranometers was used to measure insolation values with the sensitivity is 12.13μV/(w•m^{-2}). All data was collected using Agilent 34972 a.

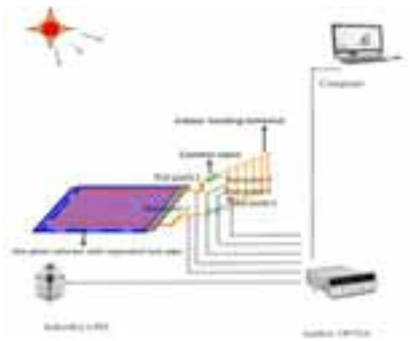
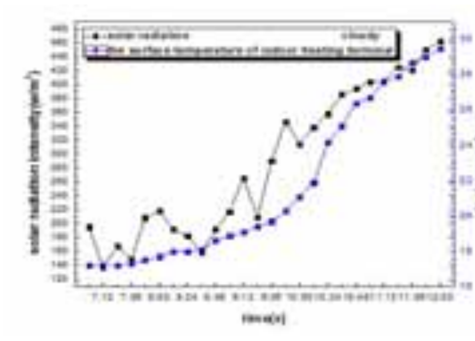


Fig.2: The experimental process of separated heat pipe solar heating system

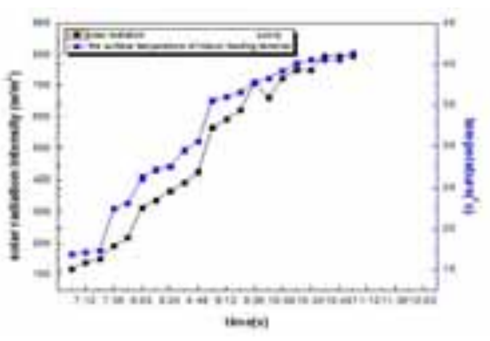
3. Results and discussion

3.1. *Effect of solar radiation intensity on the surface temperature of indoor heating terminal and indoor air temperature at different weather conditions*

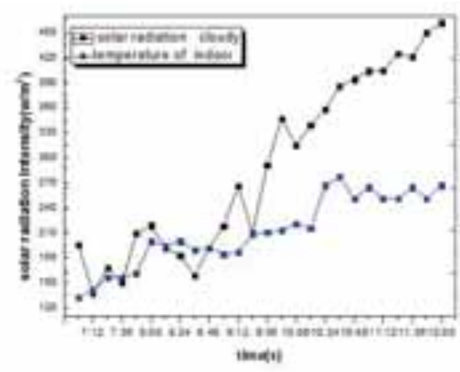
The experimental system was tested under different weather conditions including sunny and cloudy days, in the winter of 2014, in China. We counted the experimental data and chose the cloudy and sunny day as sample to analyze the performance of the system. It is the experimental data of solar radiation and surface temperature of heating terminal in the cloudy days as fig.(a) shown. When the solar radiation intensity exceeds 190W/m2 in the morning, the system starts to run. After four hours, solar radiation intensity reaches about 462W / ㎡ at noon and the system reaches stable conditions, the surface temperature of the condenser (indoor heating terminal) almost remains 29℃; the sunny day's experimental data is shown in fig.(b). When the solar radiation intensity exceeds 150W/m2 in the morning, the system starts to run. After three hours, solar radiation intensity reaches about 800W / ㎡ and the system is in the stable conditions, the surface temperature of the condenser almost remains 41℃, which is much higher than that of cloudy days. The indoor air temperature is shown in fig.(c) and fig.(d) respectively. It takes three or more hours to make the indoor air temperature reach 22--24℃ at sunny or cloudy days after the system starts to work respectively. And there is 5℃ and 9℃ temperature difference in the cloudy and sunny days respectively. So the solar radiation has great effect on the indoor air temperature. In the sunny days, according to six hours sunlight, the room temperature rising will attain 18℃, which will meet the demand of thermal comfortable temperature even the starting indoor temperature is 0℃. The better the thermal insulation of the room is, the higher the heating performance of the system is. Even in the cloudy days, the system has good thermal performance at the maximum solar radiation 462W / ㎡ and the room temperature rising 5℃ in four hours. It will be good auxiliary heating style to the electricity heating in the room, which will save much energy consumption in the south of china where is no centralized heating.



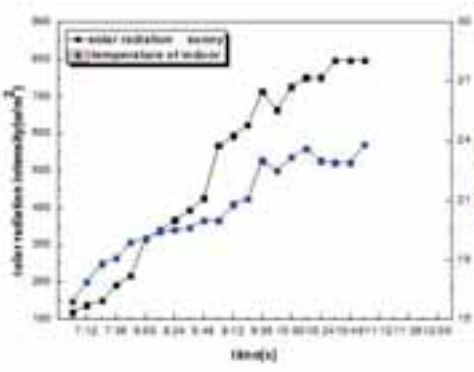
(a) Solar radiation intensity and the surface temperature of indoor heating terminal with time (cloudy)



(b) Solar radiation intensity and the surface temperature of indoor heating terminal with time (sunny)

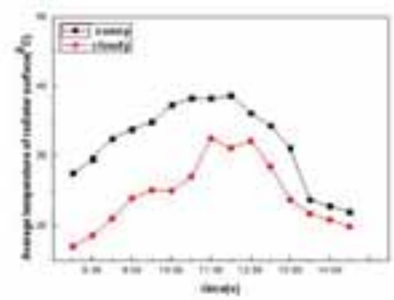


(c) Solar radiation intensity and the room temperature with time

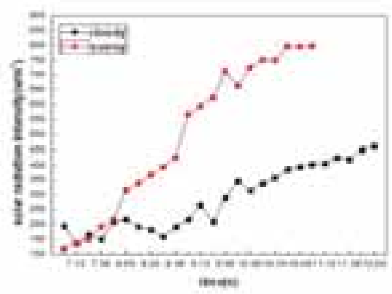


(d) Solar radiation intensity and the room temperature with time

Fig.(e) and (f) shows that solar radiation and climatic conditions have a great impact on the utilization of system thermal. It can be seen that there is 10℃ temperature difference from 8:00 to 11:00 with the large solar radiation difference. The main reason is that the amount of the working fluid at different weather days. In the sunny days, more working fluid absorbs solar energy and starts to work and transfers more heat energy to the condenser. On the other way, less working fluid transfer heat energy to the condenser and cause to the less working pressure and low working temperature in the cloudy days.

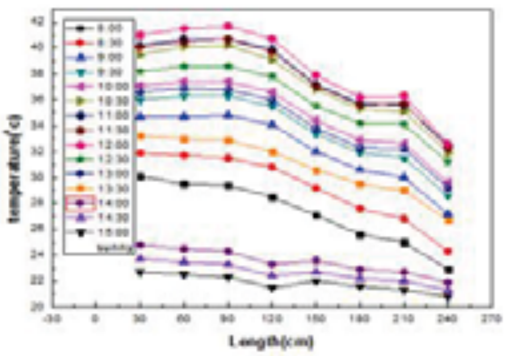


(e) Radiator surface average temperature variation at different solar radiation

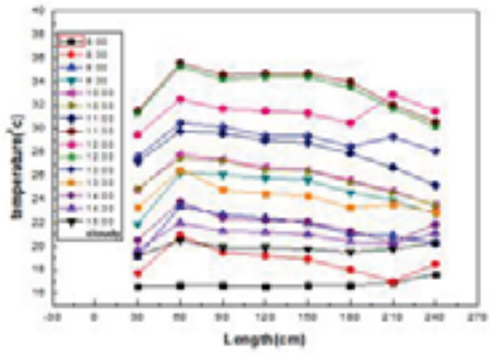


(f) Solar radiation variation at different weather condition

3.2. The profile of the radiator surface temperature at different length



(g) The radiator surface temperature distribution at different length (sunny)



(h) The radiator surface temperature distribution at different length (cloudy)

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Fig.(g).(h) shows that the radiator surface temperature distribution at different the length. 0cm represents the terminal of the radiator the nearest distance to the solar collector. And the 240cm is the length of the radiator and also the longest distance to the solar collector. In the sunny days, the surface temperature of the radiator changes from 27.5 to 41.7℃ at 8:00~12:00, and the temperature changes from 41.7 to 20.8℃ at 12.30~15:00. In the cloudy days, the surface temperature of the radiator changes from16.6 to 34.7℃ at 8:00~12:00, and the temperature changes from 34.7 to 20.2℃at 12.30~15:00. The main reason that causes the surface temperature variation is the change of the solar radiation intensity. At the same time, the surface temperature of the radiator decreases with the increase of the radiator length. This director cause is the flow resistance. The more the length of the radiator is, the more the flow resistance of the working fluid is. Then the surface temperature is the lowest at 240cm with different solar radiation.

Tab. 1: Table of heat transfer performance at different weather conditions

Weather	Solar thermal efficiency	Evaporating temperature (℃)	Condensing temperature (℃)	Solar radiation intensity (w/m^2)	Heat flow (w)
cloudy	46.5%	30.2	25.2	358	333
sunny	56%	44.8	40.2	725	820
sunny	54%	40.1	36	672	727

The table 1 shows that the solar thermal utilization efficiency can reach 56% when the solar radiation is at 725W/ ㎡ and heat flow is at 820W, and the evaporation and condensation temperature of heat pipe keep constant at 44.8 ℃ and 40.2℃ respectively. The evaporator and condenser surface temperature difference can keep 4~5℃。

4. Conclusion

This work focuses on the testing of the performance of separated heat pipe solar indoor heating system and gets the following conclusions:

(1) Compared with the traditional solar heating system, the separated heat pipe solar indoor heating system works with gravity separated heat pipe to transfer solar energy into the room without any energy consumption. With the experimental investigation, it takes three or more hours to make the indoor air temperature reach 22--24℃ at sunny or cloudy days after the system starts to work. And there is 5℃ and 9℃ temperature difference in the cloudy and sunny days respectively in four hours.

(2) The solar thermal utilization efficiency can reach 56% when the solar radiation is at 725W/ ㎡ and heat flow is at 820W, and the evaporation and condensation temperature of heat pipe keep constant at 44.8 ℃ and 40.2℃ respectively

(3) The room temperature rising can attain 9℃ in three hours in the sunny days at the solar collector only 2m2 and the room area 40m2 in Nanjing , China.

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