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Study on Solar KANG Heating System for Cold Areas

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Abstract

The current rural traditional heated kang cannot meet people's increasing requirements of comfort and environmental protection. This paper propose solar kang heating system in cold regions. System performance and heating effect were analyzed. We selected two typical rooms. One was set in traditional kang, and the other one was solar Kang type. Using temperature recording instrument and 64 roads inspection instrument and other instruments, we test the indoor temperature and the kang surface temperature of two rooms. Solar kang thermal resistance, heat storage, heat dissipation and heating effect were analyzed and compared. The results of the study show this system have the smaller fluctuation, more comfort while alleviating the kang surface overheat or super-cooling problem. It satisfied the requirements of indoor thermal comfort. The warming rate is 5.17 ℃/h, and the cooling rate is 3.01 ℃/h. These are slower than traditional Huokang speed. It improved the heat storage capacity of kang body with surface heat dissipation 1237W. Average temperature of the solar kang heating room was improved 3.28℃. It gets the smaller indoor temperature fluctuation. PMV values are concentrated about -0.5, and this basically meet the requirements of the user comfort.

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Keywords: Solar kang; Capillary network; thermal comfort; energy-saving emission reduction.

1. Introduction

With the rapid development of rural economy, rural energy saving has become a serious content of national energy-saving and emission reduction. At present, the winter heating is the main rural energy consumption[1]. Traditional heated kang as the main facility of rural heating, which burn the straw as heat source, has a few disadvantages like

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fuel consumption, low thermal efficiency and heavy environmental pollution. In order to fundamentally solve these problems existing in traditional Kang, the most important is to use the new clean energy, so enhancing thermal performance of the kang body and reducing pollution has become a hot spot in the research of rural kang[3].

2. The Experimental System Structure

Solar kang heating system is comprised of solar collectors, mixing tank, the end of the heating system, automatic control system, auxiliary heating device, circulating pump, and connecting pipes. The principle of solar kang heating system is shown in Figure 1.

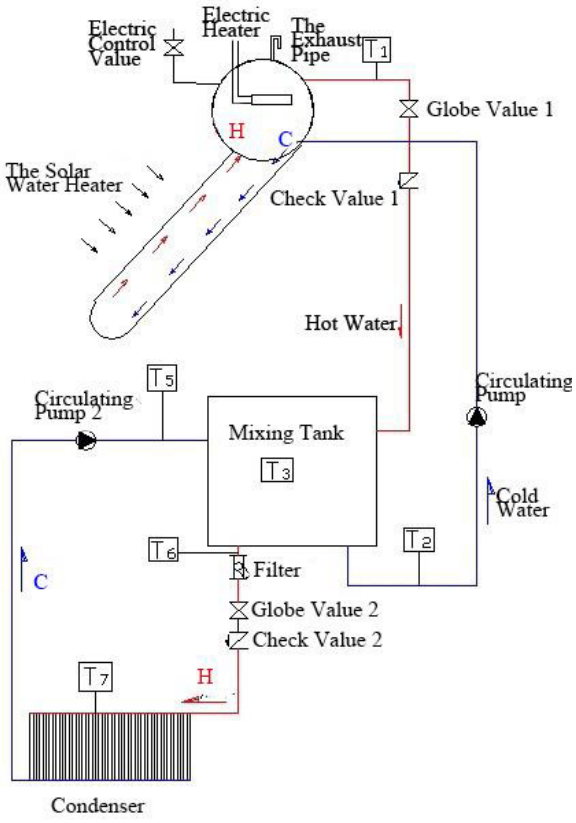

Fig. 1.Solar kang heating system

3. Test

In order to investigate the effect of the application of solar kang heating system, the comparison test was compiled in two adjoining rooms. One room was installed with solar kang heating system, and the other room was the traditional kang. Experiment location was in Dandong City, a farmers. Room space dimensions are as follows. Length is 5.3 m. Width is 3.8 m and height is 3 m. Kang was heated with the same amount of firewood in two rooms. Heating time lasted 60 minutes every time, 3 times a day. Time span was from 7:30 am to 8:30, 11:30 noon to 12:30 and 17:30 pm to 18:30. The indoor test points were listed as Figure 2. The kang face test points were listed as Figure 3.

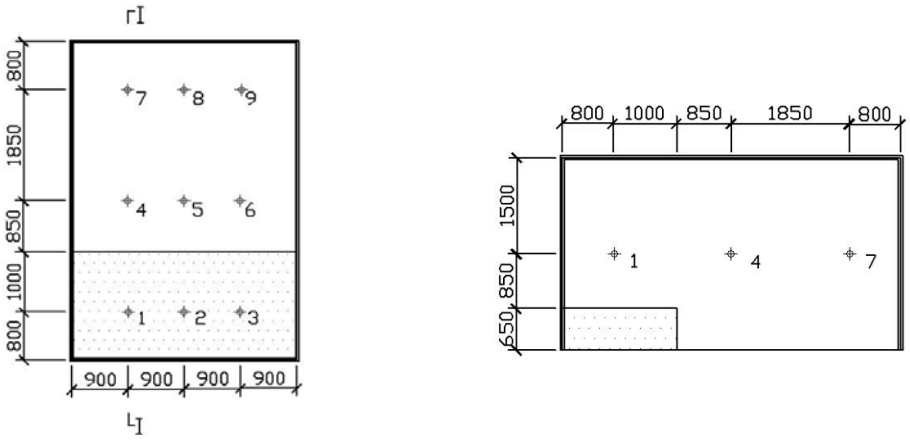

Figure 2. Measuring points of Firewall

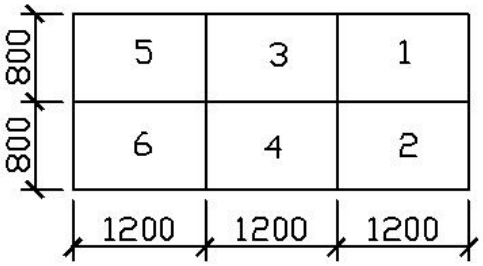

Figure 3. Measuring points of Kang

4. Analisis of Test Date

4.1. Kang surface temperature standard deviation

From the analysis of requirements of the comfortable degree of human body, Kang surface temperature fluctuations in time and space should be within a certain range[4]. The mean deviation of one point temperature in kang surface and the mean kang surface temperature was defined as σ. It can reflect the degree of dispersion of each measuring point deviation from he kang surface mean temperature, the formula is as follows.

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n} A_i \left(t_{i\tau} - t_p\right)^2}{A}} \tag{1}$$

Formula: σ—the standard deviation of Kang surface temperature,℃; n—Kang panel is divided into n; tiτ—the surface average temperature of ,℃; tp—the mean temperature of kang surface at τ moment ,℃; Ai—the area of each small portion of the kang surface, m²; A—the total area of the kang surface, m².

Standard deviation σ can reflect the uniformity of kang surface temperature of the distribution in space. The value is larger, the distribution is more uneven, the value is smaller ,the distribution is more uniform; the changes curve of

σ with time reflects the uniform of kang surface temperature distribution in time, the curve more flat, the more uniform distribution in time, the curve more steeply Description, kang surface temperature uniformity is worse in time. Kang surface temperature standard deviation based on a formula.

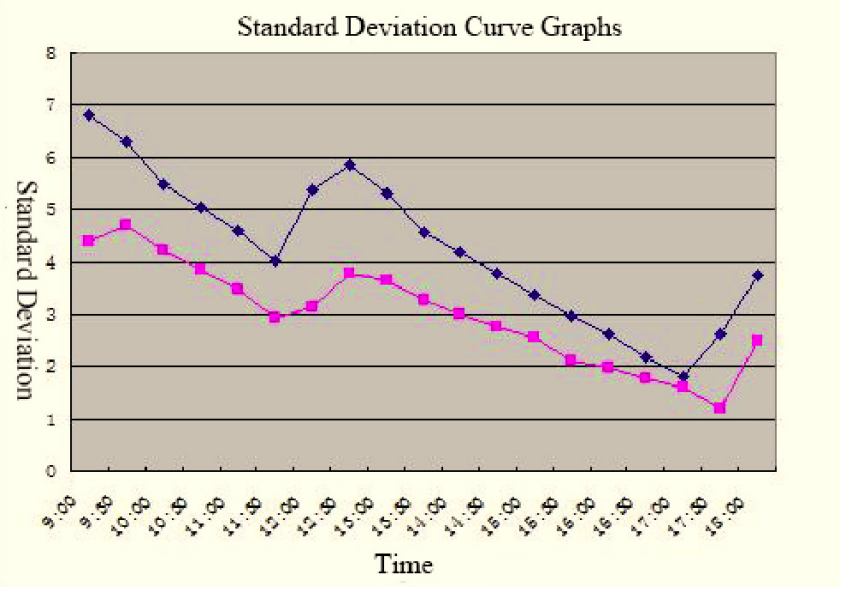

Figure 4. Standard deviation curve graphs of Kang surface temperature

Figure 4 is changed curve with time of kang surface temperature in two heating way, as depicted as the figure, the standard deviation of the traditional kang is above solar kang show traditional kang temperature fluctuations bigger in space; solar kang surface standard deviation curve is flat indicating the solar temperature fluctuations is small in time.

4.2. The kang surface heating rate, cooling rate

Kang surface average heating rate formula is given according to national standards[4].

$$\phi = \frac{T_{km.av}^{t_2} - T_{km,av}^{t_1}}{t_2 - t_1} \tag{2}$$

Formula: t1 -the time of the initial of heating stage, h; t2- the time of the end of kang heating stage, h; Tkm.av1-t1 kang average surface temperature, ℃; Tkm.av2- t2 kang average surface temperature , ℃.

The heating of traditional kang is calculated according to equation (3.2) three times a day, ψ = 8.57 ° C / h. The heating of the solar kang is calculated twice a day, ψ = 5.17 ° C / h. The heating rate of traditional kang is higher than the solar kang 3.46 ℃ / h, traditional Huokang heating faster.

The formula of Kang surface average cooling rate is given according to national standards (GB7651-2008).

$$\psi = \frac{T_{km.av}^{t_2} - T_{km,av}^{t_1}}{t_3 - t_2} \tag{3}$$

Formula: T3-the end time of kang cooling stage, h; t2- the end time of kang heating stage, h; Tkm.av1-t1 kang surface average temperature, ℃; Tkm.av2-t2 kang surface average temperature,℃.

The heating of traditional kang is calculated according to equation (3) three times a day. Ψ = 4.58 ℃ / h. The cooling of solar kang is calculated twice a day. Ψ = 3.01 ℃ / h. The traditional kang cooling speed is faster 1.49 ℃ / h. The Solar kang rates of heating and the cooling both are less than the traditional kang. The ability of the heat storage of solar kang is better the traditional kang.

Kang body thermal analysis showed that the solar kang surface temperature more comfortable than traditional kang. Solar kang surface temperature on the spatial and temporal fluctuations are smaller than traditional kang. The rate of heating and the cooling of solar kang both are less than the traditional kang. Solar kang temperature fluctuation is smaller, the capacity of heat storage is better, the thermal comfort is better.

4.3. The kang body heat resistance

The heating capacity of Huokang is depended on the heat dissipating capacity. The heat dissipation of the kang includes convection and radiation heat transfer. On the one hand, indoor air was heated by kang surface convection heat transfer. On the other hand, each face was heated by the radiation. Both convection and radiation couple together to heat the indoor air. The kang heats indoor air while indoor air heats human body by convection. The analysis of Convection and radiation of kang body are as follows.

The integrated heat transfer of Kang surface approximation derived by adding the heat transfer of radiation and convection. It was defined the indicator of the intensity of heat emission[5].

$$q = q_f + q_r \tag{4}$$

Heat flux is 238.5 W/m2 at the head of kang. It is 170 W/m2 at middle of the kang, and it is 95 W/m2 at the end of the kang. These are traditional Huokang data. Heat flux is 223W/m2 at the head of kang. It is 198 W/m2 at middle of the kang, and it is 139 W/m2 at the end of the kang. These are solar Huokang data. The total amount of heat is 1237W. It is 1148W to traditional Huokang.

5. Conclusions

Solar kang thermal resistance, heat storage and heat dissipation were researched in this experiment. Kang surface temperature standard deviation of solar kang heating system is smaller than traditional kang. Curvature is relatively gently. Evenness is better than traditional kang. It relieved the overheating problem of kang surface. Heating rate of kang surface is 5.17 °C/h. Cooling rate is 3.01 °C/h. These rate is slower than traditional kang. This system increased the capacity of heat storage. Heat dissipation of kang surface is 1237W, and heat is uniform. It has the better comfort.

Acknowledgements

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