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Experimental Test on a New Integrated Rural Energy Usage Mode

Gang Li[a, *], Lan Chi[a], Changxiang Liu [a], Canming She [a], Ying Luo [a], Jianing Du [a]

[a]*School of Municipal and Environmental Engineering, Shenyang Jianzhu University,China, 100168*

Abstract

INTRODUCTION: At present, the most common way for rural heating is conjunction coal-fired boiler with Kang. Due to the economic restriction, the boiler's operation time is limited, which lead to low indoor temperature and poor indoor air quality. Base on this situation, the paper presents a new rural energy usage mode based on biomass briquette boiler, which integrated cooking, water heating bed, water-water heater exchanger into a system. The new model meets the functions of cooking, domestic hot water, heating etc., improving the convenient and efficient of daily life.
METHODS: In order to analyze the feasibility and performance of this new system, a contrast experiment has been made on two houses with basically the same size and structure in Chifeng, to test the bed's surface temperature of new mode, Kang's surface temperature under traditional heating system and their indoor temperatures.
RESULTS: The test data show that the bed surface temperature of new mode is 4.2℃ higher than traditional Kang; Indoor temperature of the room with new mode is 5.1℃ higher than the room with traditional heating system; The cooling speed of new mode room is 1.4℃/h slower than the traditional Kang heating system room during night.
CONCLUSIONS: The experiment results indicate the thermal performance of new mode is better than traditional mode. What's more, the water-water heat exchanger in new system can satisfy the basic domestic hot water demands, which has a strong practical.

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Keywords: Integration, Energy usage mode, Biomass briquette boiler, Thermal comfort

* Corresponding author. Tel.: +86-15998265661;
E-mail address: hj_lg@126.com

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1. Introduction

In the north of our country, coal consumption for winter heating in rural residential is 1.5-2 times as heating energy consumption in city[1]. What's more, the direct combustion of extensive rural heating causes low indoor temperature, large temperature difference between day and night, low energy efficiency and serious pollution. Therefore, it is important to improve the efficiency of rural energy use in order to improve the indoor thermal comfort of residential and reduce carbon emission of rural heating. Chen Rongyao[2] studied the test method and evaluation index of Kang' heating system, proposed a evaluation method for thermal performance of Kang. Guo Jiye[3, 4] from the Rural Energy Office of Liaoning province, explored the construction technologies of Kang system on north cold area of our country. Through rational modification of Kang's structure can effectively improve the heat energy utilization rate by more than 70%. Ren Hongguo[5] studied the heating characteristics of the residential buildings in China northern cold rural area which integrated of Kang and ventilating. He used a catheter connected indoor and outdoor, hot air transported from kitchen to Kang through the catheter then discharged to outdoor by chimney. He pointed out that this technology is applicable to the rural heating. Zhuang Zhi, Li Yuguo and Chen Bin[6] from Dalian University of Technology studied the theory of elevated Kang heating system, established a heat transfer model and coupled flow thermal process, and carried on simulation analysis. Duanmu Lin[7] from Dalian University of Technology investigated thermal performance of Kang and putted forward a new evaluation method based on heat transfer and fluid mechanics theory. Zhang Peihong, Xia Fulong and Fu Jingyu[8] of Shenyang Jianzhu University used fire dynamics simulation software to simulate Kang's surface temperature, indoor temperature, inlet and outlet air temperature under different Kang's structure to determine the ideal model.

Rural biomass energy is a kind of clean energy which is renewable and can be large-scale produced, this make it rare in all kinds of energy [9]. Take full advantage of biomass energy for rural winter heating has great significance for improving the rural heating condition. This paper presents a new rural energy usage mode based on biomass briquette boiler, and used experimental methods of texting to analyze it's feasibility and performance, proposed a scientific and rational new model for renewable energy using and rural heating energy saving.

2. Composition and principle of this new rural energy usage mode

2.1. Composition of new rural energy usage mode

The main components of this system include biomass briquette boiler, water heating bed, heat radiator and water-water heat exchanger. Water is heated by biomass briquette boiler then sent to water heating bed and heat radiator to heat the bed and indoor air by mechanical circulation. The water-water heat exchanger is used for bath and other domestic hot water, which great facilitates the lives of farmers and improves famers' life quality.

2.2. Operation of new rural energy usage mode

According to the way of rural life, biomass briquette boiler is used three times every day, respectively in morning, noon and evening as conventional cooking time, worked as intermittent heating system. Winter morning, when farmer starts cooking, the biomass briquette boiler heats water, the hot water is been sent to water heating bed and heat radiator to heat the bed and indoor air. At this time the households' requirement for domestic hot water is low, so the water-water heat exchanger valve can be closed to priority ensure indoor thermal comfort, till indoor heat wealthy then open this valve to heat domestic hot water. According to the actual demand, when the user needs massive hot water, the water heating bed and heat radiator can be closed temporarily in order to speed up the heating rate of domestic hot water. During lunch cooking time, according to indoor temperature and room usage to adjust the switch of water heating bed, heat radiator and water-water heat exchanger. After the end of the evening cooking, biomass briquette stove fire, close the valve of water-water heat exchanger and parts of heat radiator according to the actual use in order to maintain the comfortable of water heating bed and bedroom as possible. The principle diagram of the system is shown in Fig. 1.

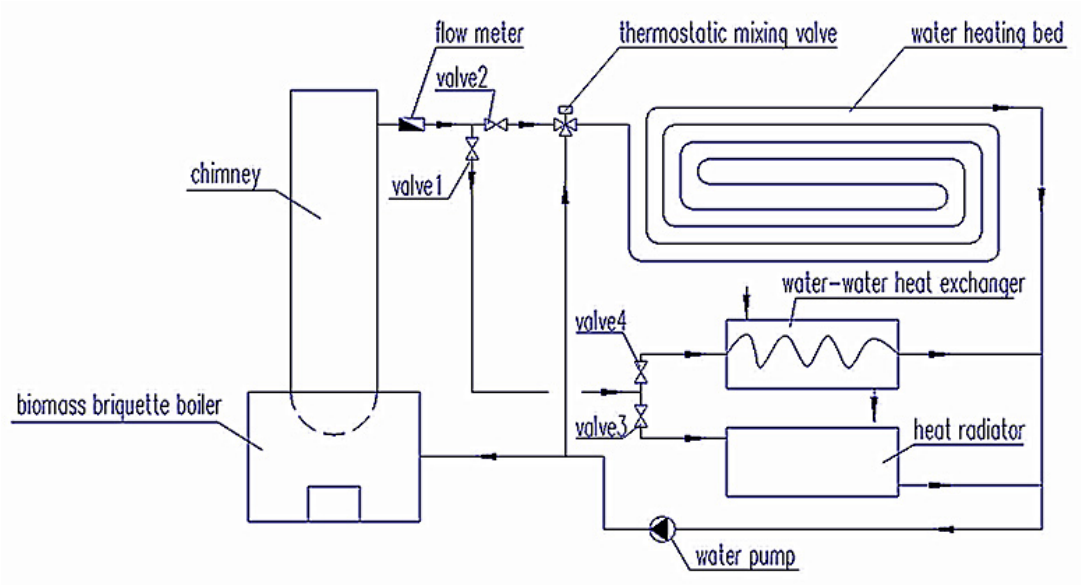

Fig. 1. System principle diagram.

3. Experiment of new rural energy usage mode

In order to test practical application effect of this new rural energy usage mode, XMZ*-J series universal input circuit detector and rotor meter were used on experiment to conduct field tests for contrastive analysis about thermal performance and indoor thermal environment under traditional Kang heating system and the new rural energy usage system.

3.1. Set-up experimental platform

This paper selected two households which mostly have the same pattern and envelope structure in rural town of Chifeng City, Inner Mongolia as research objects, named Room 1 and Room 2. The outside view and plan of two experimental houses are shown as Fig.2 and Fig.3. In this experiment, the temperature of Kang's surface and water heating bed's surface, indoor temperature, the supply and return water temperature of water-water heat exchanger were measured by copper constantan thermocouple. The flow rate of water-water heat exchanger was measured by rotor flow meter. XMZ*-J series universal input circuit detector was used to test experimental data and recorded the data by computer.

Fig. 2. The outside view of Room 1

Fig. 3. The outside view of Room 2

3.2. Experimental scheme

This In order to compare the practical application effect of the biomass briquette boiler heating system and traditional Kang's heating system, two experimental rooms burned the same calorific value of fuel and have the same heating time, fired three times every day, each time lasted 90 minutes respectively as 7:30-9:00, 11:30-1:00 and 17:00-18:30, conducted the following 2 groups of experiments:

(1) Scheme 1: Room 1 was used biomass briquette boiler heating system, tested and recorded its thermal characteristic parameters.

(2) Scheme 2: Room 2 was a comparison room, used traditional Kang heating system, also tested and recorded its thermal characteristic parameters.

Test time: November 10th, 2014 - November 15th, 2014.

3.3. Main points' location and measurement parameters

(1) Points' location of water heating bed and Kang: The living room in southeast corner of these two experiment rooms were selected as research objects. Arranged six temperature measuring points in the corresponding surface position of water heating bed and Kang, respectively named as point 1-6 and point 1'-6', as shown in figure 4. These points were used for testing head (points 1-2 and 1'-2')、medium (points 3-4 and 3'-4') and tail (points 5-6 and 5'-6') temperature of water heating bed and Kang, in order to analysis the difference in surface temperature of water heating bed and Kang.

(2) Points' location of water-water heat exchanger: In order to analysis the performance of water-water heat exchanger and study the feasibility of it's practical application, the water-water heat exchanger was arranged four temperature measuring points respectably at high temperature water inlet, high temperature water outlet, low temperature water inlet and low temperature water outlet. A rotor flow meter was installed in the low temperature water outlet to monitor the low water's flow condition.

4. Analysis of experimental results

4.1. Performance of water heating bed and Kang

Scheme 1 and scheme 2 were continuously running four days, chose the last day's data when systems under stable operation. The test data were transferred to Excel to draw line chart correspondingly. Surface temperature distributions of water heating bed as scheme 1 are shown in Fig. 4.

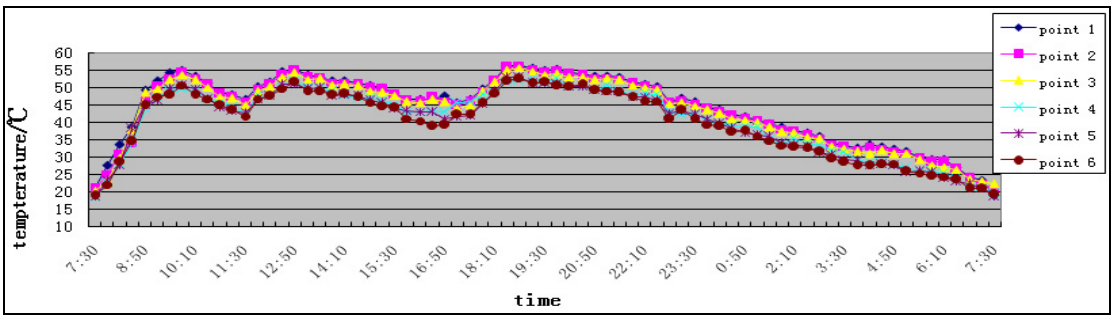

Fig. 4. Surface temperature distributions of water heating bed as scheme 1

The analysis of experimental data shows, when the biomass briquette boiler started at 7:30am-9:00am, the surface temperature of each point in water heating bed raised rapidly, after the end of cooking the temperature began

to drop. At noon and evening the situation of water heating bed were roughly the same as morning. There were three times of temperature fluctuation during a day. Slope of the line between measuring points were basically the same and the temperature difference was small, which illustrated that the bed surface has uniform temperature distribution. Surface temperature distributions of Kang as scheme 2 are shown in Fig. 5.

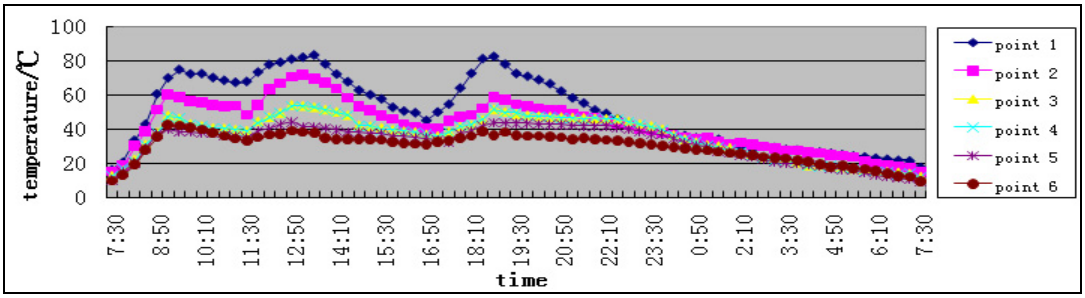

Fig. 5. Surface temperature distributions of Kang as scheme 2

Analysis results of experimental data shows the temperature distribution of scheme2 have the same trend as scheme1. The temperature fluctuation of Kang's head (point 1 'and 2') was large, the temperature fluctuations of Kang's trail (point 5'and 6 ') was small. The temperature of Kang's head was in a high range during the whole day while the temperature of Kang's tail was too low, the temperature difference between Kang's head and Kang's trail was reached 15℃, which is obviously can't meet the comfort requirements. Surface temperature distributions of water heating bed and Kang as scheme 1 and 2 are shown in Fig. 6.

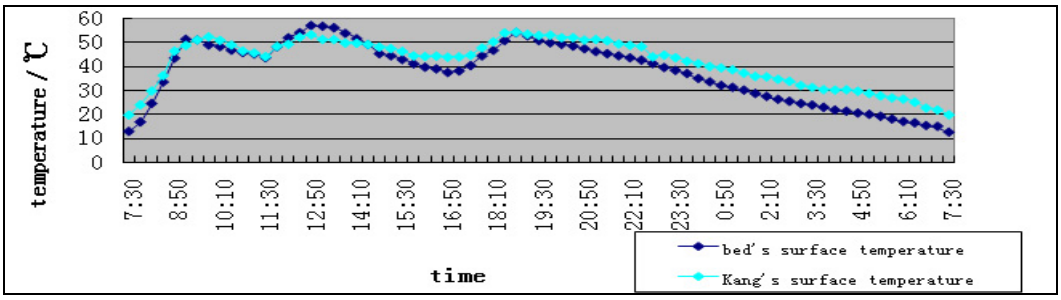

Fig. 6. Average surface temperature of water heating bed and Kang

The comparison of two curves shows that: during daytime the surface temperature fluctuations of water heat bed in scheme1is small, the heating speed of scheme1 is 26℃/h while the heating speed of scheme2 is 22℃/h; During night time, the cooling rate of scheme1 is 2.1 ℃ /h while the cooling rate of scheme2 is 3.5 ℃ /h, and the average surface temperature of bed in scheme1 is higher than Kang in scheme2.

The heating speed of scheme1 is slower than scheme2 during daytime, but the cooling rate of scheme1 is also 1.4℃/h lower than scheme2. The people's main activities during daytime is not in bed so the bed's temperature is not so important at that time, but the bed is the main places for people's activities in nocturnal which requires to slow it's cooling speed to ensure the quality of people's sleep at night. The full day average surface temperature of bed in scheme1 is 4.2℃ higher than Kang in scheme2.

4.2. Comparison of indoor temperature under new heating mode and traditional Kang's heating system

Indoor temperature mainly influenced by thermal insulation performance of building envelope, house orientation, outdoor temperature and heating ability of indoor equipments. This experiment was tested the temperature

distribution of new heating mode and traditional Kang's heating system at different times under the same condition of above first three variables, the test results are shown in Fig. 7.

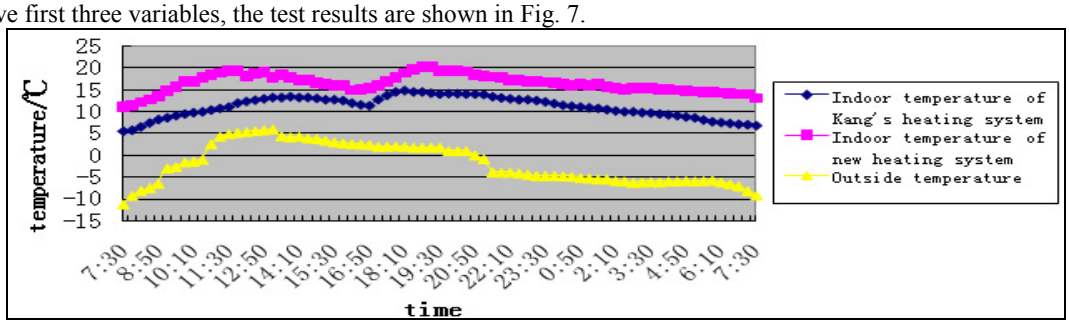

Fig. 7. Temperature distribution of indoor and outdoor

As shown in Fig. 8, the maximum indoor temperature of Kang's heating room is 14.8℃, the minimum value is only 5.5℃, the average temperature is 11℃; While the maximum indoor temperature under the new heating mode is 21.9℃, the minimum value is 12.5℃, the average value is 16.3℃. The thermal comfort of new heating mode has remarkable enhancement compared with Kang's heating system. In addition, we can get the conclusion that the indoor temperature fluctuation of new heating mode is smaller than traditional Kang's heating system through the different smoothly degree of two curves, the new heating mode has better constant temperature performance.

4.3. Performance of water-water heat exchanger

The water-water heat exchanger is an important terminal equipment in this system for providing domestic hot water. The largest demand for domestic hot water is bathing. Adult men's bathing water under normal conditions is approximately 30L, water consumption for adult women is approximately 50L, and the optimum temperature of bath water is between 35℃ to 37℃. The test was under the most disadvantage situation: started using the hot water when the outlet water temperature reached 37 ℃, adjusted the water temperature through the mixing valve, stopped using the water when the outflow water temperature lower than 35℃. Recorded the changes of water temperature on water heater side, as shown in Fig. 8:

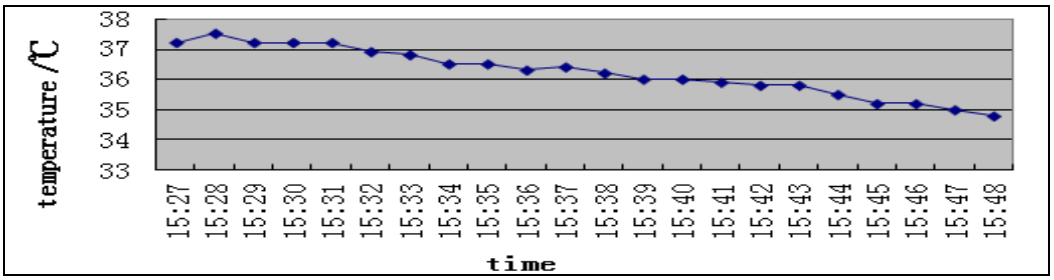

Fig. 8. Temperature change of water-water heat exchanger

According to the records, the water outflow last 21 minutes from temperature reached 37℃ till lower than 35℃, and the meter registered 0.15m^3/h, which can work out that the water volume of water-water heat exchanger which met the requirements was 0.0525m^3, namely 52.5L, enough for an adult to take a shower. Therefore, even in the most unfavourable situation water-water heat exchanger can meet basic demands for domestic hot water. If the water-water heat exchanger gets more heat or reduces water temperature standard appropriately, domestic hot water supply will be increased to some extent.

5. Conclusion

This paper aiming at the problems of traditional Kang heating system in northern rural, put forward a new rural energy usage mode which based on biomass briquette boiler, and used experiment to verify the feasibility of this system. Following conclusions can be drawn through further analysed of the experimental data:

(1) Because traditional Kang heating system can't meet the indoor thermal comfort demands, this paper put forward a new rural energy usage mode based on biomass briquette boiler. The test data show that the bed surface temperature of biomass briquette boiler heating system is 4.2℃ higher than traditional Kang heating system , and the biomass briquette boiler heating system has more uniform in temperature distribution. The night cooling speed of biomass briquette boiler heating system room is 1.4℃/h slower than the traditional Kang heating system room. The full day average indoor temperature of the room with biomass briquette boiler heating system is 5.1℃ higher than the room with traditional Kang heating system. Thermal performance of biomass briquette boiler heating system is better than traditional Kang heating system.

(2) Even under the most unfavourable situation, the water-water heat exchanger still can meet an adult's bath need. The water-water heat exchanger can satisfy the basic domestic hot water demands, and has a strong practical.

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