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Experimental on a novel solar energy heating system for residential buildings in cold zone of China

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Abstract

The traditional Chinese Kang system is a kind of ancient domestic heating system, which is still widely used in nearly 85% of rural homes in northern china. However, this system has the disadvantages of heating the room by burning biomaterials directly, which will cause serious environmental pollution. Inspired by the Chinese Kang system, a novel contacting heating sys-tem was proposed in this research. Solar-assisted air source heat pump was employed as heating source for the system. By change the temperature of supplied water, this system can be served as a heating bed, a heating chair or a radiant heating terminal for residential buildings. In order to verify the feasibility of the system, an experimental system has been set up and a series of experimental tests were carried out. The experimental results shown that this system can satisfy all the residents' heating demands in residential buildings. Moreover, the proportion of the solar energy to the total energy consumption of the system even greater than 60%. These results may lead to the development of designing and distributing the solar energy for building heating during winter.

Keywords: Heating system; Solar energy; Residential Building；Local heating system;

1. Introduction

Building energy consumption has a large proportion in total energy consumption. In EU, USA and UK, the building energy consumption accounts for 40% of global energy[1,2]. In China, over one-third of total energy is

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used in buildings [3,4]. Moreover, the energy consumption for heating and cooling is about 63% of the overall energy consumption in buildings in China [5].

Meanwhile, China is a large agricultural country with rural population covers about 50% of the national population. The rural energy consumption ac-counts for a large proportion of China's total energy consumption, especially in the northern rural areas, more than 80% of the total energy consumptions were used to satisfy the heating requirements in winter [6]. The main energy consumption in buildings in China is attributed to large and inefficient heating, ventilation, and air conditioning (HVAC) systems, especially for cooling and heating applications. The progressive depletion of fossil fuels, the growing energy demand and government policies for reducing environmental pollution emissions have in-creased the urgency of finding alternative energy sources and technology solutions to reduce energy consumption and to use energy more efficiently. Currently, renewable energy, especially solar thermal energy is receiving much attention as an energy source option.

Among various renewable energies, solar energy has the advantages of being high potential with long sunlight hours and workable intensity and so has been widely used in energy supply for buildings in China. However, solar energy is instable and intermittent due to the influences of random factors, such as available daylight hours, seasonal fluctuation, and weather change. Moreover, solar energy generally has a relatively low energy density and heat flux, particularly in winter. The efficiency of using solar energy is greatly limited by the supplied water temperature. The application of solar energy for building heating in winter is therefore restricted. In this research, a novel contacting heating system was proposed in this research. An experimental system has been set up and a series of experimental tests were carried out to verify the feasibility of the system.

2. Experiment system

The experimental tests were carried out in Xi'an, which is located in the northwest of China. The test room was built in a common residential house to evaluate the actual performance. The north- and east- facing walls of the test room were the exterior façade, composed of 200 mm thickness reinforced concrete and aerated concrete blocks and 30 mm thickness glass wool. The heat transfer coefficient of the façade is 1.03 W·m-2·K-1. The west- and south-facing walls are composed of 120 mm hollow brick and these are the interior structure connecting to the rest of the house. The heat transfer coefficient of the interior envelope is 1.11 W·m-2·K-1. The area of the test room was 11.88 m2, and the adjacent room was not heated. There was a bay window with an area of 4.2 m2 in the north-facing wall. The window is double glazed, to improve the heat insulation properties of the room; the heat transfer coefficient of the window is 2.70 W·m-2·K-1.

The experimental structure of the heating system driven by solar energy and heat pump is shown in Fig.1. The system consisted of all-glass vacuum-tube collectors, an air source heat pump, phase change thermal storage unit, a test room and a heating terminal. The heating terminal is a capillary mat, as shown in Fig.2. The exterior diameter of main manifold is 20mm and capillary tubes are of 3.35 mm, respectively. The interval distance between the capillary tubes was 10 mm, and the total length was approximately 1650 mm. The operation modes of the system are as follows: i) Mode 1. When the solar radiation is insufficient, the heating sys-tem will be driven by the air source heat pump, ii) Mode 2. In the case the solar energy is sufficient, the heating system will be operated by using both solar energy and heat pump.

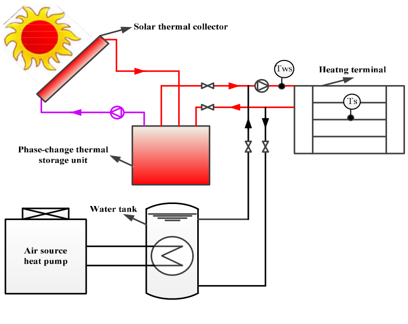

Fig. 1. The flow diagram of the integrated system