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Research of a rotary desiccant wheel based hybrid air conditioning system with natural cold source

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Abstract

Air-conditioning systems combined with rotary dehumidification were widely used in industrial buildings with low humidity requirements. In this paper, a rotary desiccant wheel based hybrid air conditioning system with natural cold source was presented, which was used in civil buildings. In this system, sensible load was undertaken by the natural cool source, and latent load was undertaken by rotary dehumidification wheel. The performances of rotary desiccant wheel based hybrid air conditioning system with natural cold source were studied in two typical outdoor meteorological conditions. The results showed that the system under both high temperature high humidity and high temperature low humidity conditions can satisfy the indoor environment demand for civil buildings, while the energy consumption on high temperature high humidity condition is less. While waste heat or solar energy is adopted as regeneration heat source, the energy consumption of rotary desiccant wheel based hybrid air conditioning system can further reduce.

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Keywords: rotary desiccant wheel, natural cold source, surface air cooler, air conditioning system

1. Introduction

The rotary desiccant wheel based hybrid air conditioning system was an air conditioning system with the combination of a rotary dehumidifier, surface air cooler, an evaporative cooling or other cooling devices. The results show that compared with conventional vapor compression refrigeration system, the rotary desiccant wheel based hybrid air conditioning system can achieve energy saving [1-2].

Ghali et al. studied on the system with combination of the rotating dehumidification equipment and the traditional compressed air conditioning system, compared with the conventional air conditioning system, the power of the compressor was reduced from 23kW to 15kW under the condition of maximum load [3]. Sumathy et al. studied on the performance and energy consumption for the combined system of the rotating dehumidification equipment and the traditional compression refrigeration air conditioning [4]. The rotary desiccant wheel based hybrid air conditioning system combined with rotating dehumidification equipment and evaporative cooling system had a variety of operating modes such as recirculation mode, ventilation mode, Dunkle mode and so on [5-7]. The recirculation mode was used for indoor return air. The ventilation mode was used for outdoor fresh air, and the system arranges more a heat recovery device that was used for recovering cold energy of indoor exhaust air. The Dunkle mode was constructed with two-stage desiccant wheel to increase the dehumidification capacity and dehumidification efficiency of the system. In addition, Waugaman et al. proposed a combination of direct and indirect evaporative coolers and rotary dehumidifier, and coefficient of performance of the air conditioning system can be up to 1.6[8]. Henning et al. discussed the different forms of

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solar energy and solid desiccant air conditioning. The results showed that the combination was feasible in a warm climate [9]. Bourdoukan et al. employed tubular solar collector that completely provided heat energy for the regeneration of the dehumidifier. When the overall efficiency of the solar energy device was 0.55, coefficient of performance of the system was 0.45[10].

The rotary desiccant wheel based hybrid air conditioning system with combined evaporative cooling had many disadvantages, such as high initial investment, high energy consumption and complex equipment. The rotary desiccant wheel based hybrid air conditioning system which was combined with a conventional surface cooler was widely used in industrial buildings. The rotary desiccant wheel based hybrid air conditioning system with natural cold source was proposed in this paper, and it was applied to common civil buildings. In the system sensible load is undertaken by the natural cool source, and latent load is undertaken by rotary dehumidification wheel. The system has good quality in terms of less occupied area and low energy consumption, and it makes full use of natural cold source.

2. System scheme and working principle

The rotary desiccant wheel based hybrid air conditioning system using natural cold source mainly consists of desiccant wheel and surface air cooler. In order to make full use of natural cold source, two-staged surface air coolers was employed.

The rotary desiccant wheel based hybrid air conditioning system using natural cold source was showed in Fig. 1. The outdoor fresh air and the indoor return air are mixed into first-stage surface air cooler to cool air, and then cooled air is pumped into desiccant wheel. Desiccant wheel absorbs moisture from air due to difference between partial pressure of moisture in the air and desiccant materials, thus latent load of process air was removed and humidity ratio of the air was low. Some common adsorbent materials are LiCl, Silica gel and Zeolite. The desiccant wheel was regenerated by the application of heat to release the moisture, which is exhausted to the outdoors. After that, process air pass into second-stage surface air cooler to deep cool air. In order to reduce the area and initial investment, the system does not consider the heat of exhaust air, but when outdoor fresh air volume is large, the heat recovery device can be added on the basis of the system to further reduce the energy consumption of the air conditioning system.

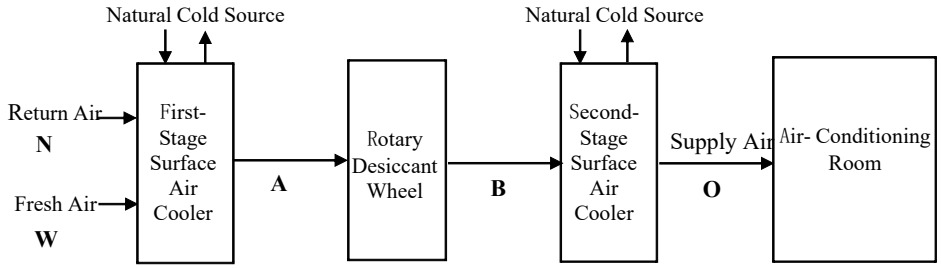

Fig.1. Schematic of the rotary desiccant wheel based hybrid air conditioning system with natural cold source

3. Thermodynamic analysis

In the psychrometric chart, the point W represents the state outdoor fresh air, the point N the state of return air and C is the state of mixed air. In order to take full advantage of dehumidification ability of the rotary desiccant wheel, without affecting the indoor thermal comfort, design temperature of the rotary desiccant wheel based hybrid air conditioning system is slightly higher than the conventional air conditioning system, while the relative humidity is slightly lower.

The air handling process of the rotary desiccant wheel based hybrid air conditioning system using natural cold source can be expressed as C_2 -A-B-O_2 -N_2 on the psychometric chart in Figure 2. The subscript 1 represented the air state point of the rotary desiccant wheel based hybrid air conditioning system, and the subscript 2 represented the air state point of the conventional air conditioning system. C_2 -A is a dry-cooled process. The process air is cooled by first-stage surface air cooler which uses the natural cold source, such as ground water, and so on. A-B represents an isenthalpic humidification process. The process air of the point A goes through the process area of Desiccant Wheel where the humidity content is absorbed and adsorption heat is released. As a result, the air temperature increases and humidity content decreases. B-O_2 is also a dry-cooled process. The process air is cooled by second-stage surface air cooler, which uses the natural cold source. The supply air of the state of O_2 point is dry and low-temperature. The supply air absorbs heat and moisture of the air-conditioned room so that the air-conditioning room reaches the required indoor air condition.

In order to compare with the conventional air conditioning system, the air handling process of conventional air conditioning can be expressed as C_1 -L_1 -O_1 -N_1 on the psychometric chart in Figure 2. C_1 -L_1 is a wet-cooled process. Water vapor of air is removed by surface air cooler. In order to get the air supply, L_1 -O_1 is a reheating process after dehumidification. The supply air of the state of O_1 point is dry and low-temperature. The supply air absorbs heat and moisture of the air-conditioned room so that the air-conditioning room reaches the required indoor air condition of conventional air conditioning system.