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ScienceDirect

Procedia Engineering 205 (2017) 497–502

Procedia Engineering

www.elsevier.com/locate/procedia

10th International Symposium on Heating, Ventilation and Air Conditioning, ISHVAC2017, 19-22 October 2017, Jinan, China

Study on the Dehumidification and Indoor Air Cleaning Performance of Rotary Desiccant Rotor

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Abstract

With the improvements of living standards, people's demand for indoor environment is not only confined to thermal comfort, but also spread to health-oriented aspects. However, the indoor environment in major parts of China face challenges of atmospheric pollutions and building energy consumptions. In the present paper, a novel adsorption ventilation system which combines air thermal conditioning and indoor air cleaning was proposed. The proposed system utilizes the moisture and gaseous pollution adsorption potential of desiccant material to realize indoor air dehumidification and cleaning, and aims at improving indoor air quality and reducing energy consumption of building ventilation. Literature review study on the performance of desiccant rotor commonly used as adsorption equipment was conducted. An experimental system was designed and developed to validate the performance of desiccant rotor and investigate the key influence parameters. A system which combine the desiccant rotor with heat pump was discussed.

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Peer-review under responsibility of the scientific committee of the 10th International Symposium on Heating, Ventilation and Air Conditioning.

Keywords: Indoor air purification; Solid desiccant cooling; Silica gel; Desiccant wheel; Energy consumption

1. Introduction

Traditionally, indoor occupants require air-conditioning system which can provide comfort indoor air temperature, humidity and appropriate amount of outdoor air. However, a building meeting these requirements is still not considered having a healthy indoor environment. In-door air quality is particularly important since people consume

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Peer-review under responsibility of the scientific committee of the 10th International Symposium on Heating, Ventilation and Air Conditioning.
10.1016/j.proeng.2017.10.402

90% of their time indoor. In recent years, many people have realized that staying in an air-conditioned room for a long time will get the "Air conditioning disease". People reflected that living in the air conditioning in-door environment will easily get symptoms such as dry eyes, throat irritation, rhinitis, chest tightness, headache, mental concentration and allergies, etc. WHO (World Health Organization) calls this phenomenon "Sick Building Syndrome" [1]. In academia, the impact of indoor air quality on people's health has been fully affirmed. The ministry of health has also put forward new requirements for public health regulations of centralized air conditioning and ventilation systems. Therefore, to create a healthy, comfortable, energy efficient and environ-mental friendly indoor environment represents the developing direction in HVAC (heating, ventilation and Air Conditioning) field.

Most of the existing ventilation systems use outdoor air to remove indoor air contaminants. However, higher ventilation rates lead to more energy use. Ventilation accounts for 30% of the total energy consumption in existing buildings. Another important point is that outdoor air in modern cities is not clean anymore. Particles, oxynitride and sulfur oxides make ventilation invalid or even harmful in the atmospheric air polluted cases. On the other hand, the existing air-conditioning system normally use temperature and humidity coupling conditioning method. In this kind of system, cooling coil entrain cooling medium whose temperature is lower than the dew point of process air to realize sensible cooling and dehumidification which results in mismatch of sensible and latent cooling load. In some cases, reheating is required to meet comfortable indoor environment and lead to energy waste. Therefore, alternative methods such as solid desiccant cooling have attracted wide attentions. As a dehumidification technology, solid adsorption desiccant rotor has been applied widely with its unique structure and advantages. But the high regeneration temperature is limiting the further promotion of solid desiccant cooling system. In recent years, it has been found that silica gel, molecular sieves and activated carbon, often used as absorbent materials, have the ability to adsorb chemical pollution as well as moisture [2]. When desiccant rotor carries water vapor from the ventilation system to outdoor by adsorption and desorption, indoor air pollutants could be taken outdoor as well. In this way, the indoor air is purified. Therefore, it maybe a new air treatment technology which can improve indoor air quality and reduce building energy consumption. Nie et al. has proposed a ventilation system which combined the air purification functions of desiccant rotor [3]. However, the parameters which influence the combined in-door air dehumidification and cleaning performance still need further research.

The parameters which influence the air dehumidification and purification performance of desiccant rotor should be well research before integrating it into ventilation system. Wang et al. has improved the structure of traditional desiccant wheel, tested the dehumidification performance and its energy consumption, established a mathematical model of desiccant wheel dehumidification system, and analyzed the effects of some important parameters on system dehumidification and energy dissipation [4]. Cong et al. has analyzed the influence of regenerated air temperature on dehumidification effect of desiccant rotary dehumidifier [5]. Zhang et al. has used theoretical simulation method to analyze the dehumidification performance of new composite desiccant rotor, and the results were validated with experimental study [6]. Yang et al. has tested a new type of organic-inorganic composite dehumidification material [7]. In the studies above, regeneration temperature was found to be a key factor limiting the promotion of desiccant rotor, and great efforts have been conducted to decrease the regeneration temperature either with new materials or with new constructing methods.

In the study proposed by this paper, an experimental setup was designed and developed to investigate effectiveness of rotor operation parameters such as rotating speed, air speed, re-generation angle on regeneration temperature and air dehumidification, purification efficiencies.

2. Experimental methods

In view of the above problem such as the effectiveness of rotor operation parameters on regeneration temperature and desiccant rotor performance, an experimental setup was designed and developed. Regarding the high regeneration temperature, three improvements were identified including:

- Choose more efficient, lower regeneration temperature adsorbent material.
- Improve the wheel structure and adopt a new type of desiccant wheel.
- Combine the evaporative refrigeration cycle with air sensible cooling and wheel regeneration.

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