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THERMODYNAMIC ANALYSIS OF AIR CONDITIONING SYSTEM USING SOLID DESICCANT DEHUMIDIFIER WHEEL

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Abstract
The Rotary desiccant air conditioning system, which combines together the technologies of desiccant dehumidification and evaporative cooling,. Compared with conventional vapor compression air conditioning system, it preserves the merits by controlling humidity and temperature like energy saving, comfortable, healthy, environment-friendly etc. The performance model relates the wheels design parameters such as the wheel dimension, the channel size and the desiccant properties.In this paper, the development of experimental setup of hybrid air-conditioning system is carried-out and the results are analyzed. It is seen that, hybrid air-conditioning system can handle the latent load very efficiently without effect on the total load over the cooling coil of air-conditioning system. The cop of the hybrid system was found to be 0.92.The conventional vapour compression based air-conditioning system consumes high grade electricity power. Under high ventilation loads or low sensible heat ratio conditions, the conventional system is not designed to provide the continuous supply or increased volume of outdoor air necessary.

Keywords:*Desiccant, dehumidifier wheel, heat exchanging wheel, air handling units, Sensible heat ratio, Psychrometric analysis*.

1. Introduction

One of the important tasks of air conditioning is to provide the comfort environment for the mankind in all the conditions. A comfort condition not only improves human living but also improves the performance. Comfort is primarily decided by temperature and humidity. For comfort feeling, the relative humidity must be in the range of 55% to 60% and dry bulb temperature 22 to 26°C. To maintain comfort conditions by controlling temperature and humidity, conventional air conditioner are most commonly employed where the dehumidification of air is achieved by bringing the temperature below the dew point in the cooling coil to condense water vapor. The reheating is needed in most of the cases due to high latent load. A conventional air conditioner consumes large amount of electrical energy especially in hot and humid climatic conditions due to high latent load.

When desiccant wheel is integrated with conventional vapour compression system, it is known as hybrid air conditioning system where before reaching the hot and humid air to cooling coil, moisture of the air is removed at desiccant wheel and then allowed to go over the cooling coil. In this way latent load is taken care by the desiccant wheel while the sensible load is taken care by the cooling coil.

Air conditioning loads can be divided into two components, namely the sensible and the latent loads. An air conditioner must counterbalance the two types of load in order to maintain the desired indoor conditions. When the sensible heat ratio (SHR) of the conditioned space is low, the sum of these two components increases. The desiccants are natural or synthetic substances which have capacity of absorbing or adsorbing water vapour due the difference of water vapour pressure between the surrounding air and the desiccant surface. Desiccant materials attract moisture based on differences in their vapor pressure. Solid desiccant are succinct, less corrosion and carryover. Recently, the design and development of desiccant air conditioning technology, which can handle sensible and latent heat loads independently without using CFCs and consuming a large amount of electric power, and thus meet the current demands of occupant comfort, energy saving and environmental protection, has expanded desiccant industry with applications such as hospitals, supermarkets, restaurants, theaters, schools and office buildings. Desiccant air conditioning is energy efficient and environment-friendly as well as cost-competitive, especially for hot dry and hot humid areas. As desiccants can be either solid or liquid, desiccant air conditioning systems can be grouped into two categories, namely, solid desiccant air conditioning systems and liquid desiccant air conditioning systems. Due to being merits in handling latent heat load, all these technologies have been used widely. Especially, rotary desiccant air conditioning systems, which are succinct and less corrosion and can work continuously, attract more moisture. Currently, ongoing design and development works for rotary desiccant air conditioning technology have been directed at: (1) advanced desiccant materials; (2) optimum system configurations and corresponding practical applications.

Osman Kara[1] investigated the a desiccant based air-conditioning system was considered to determine the system performance by using second law analysis (exergy analysis) for Yozgat province. It was found from the results that maximum exergy destruction occurs in electric heater unit and the total exergy destruction of the system is 24.66 kW. It was also found that the exergy efficiency of this system is 19.87

%. From the result obtained, it is observed that the greatest exergy destruction on the system basis occurs in the electric heater unit (12.29 kW), followed by regeneration air fan (3.86 kW), the fresh air fan (2.98 kW), heat exchanger 1 (0.07 kW) and the whole system (24.66 kW). COP of the system was calculated to be 0.66.Exergy efficiency of the system and the heat exchanger 1, which is maximum, are calculated to be 19.87% and 86.6%, respectively.

Dr.Suhas c kongre [2] conducted the design & development of experimental setup of hybrid air-conditioning system is carried-out and the results are analyzed and compared with the conventional VCRS based air-conditioning system. It is seen that, hybrid air-conditioning system can handle the latent load very efficiently without effect on the total load over the cooling coil of air-conditioning system. The cop of the hybrid system was found to be 1.13. The conventional vapour compression based air-conditioning system consumes high grade electricity power. Under high ventilation loads or low sensible heat ratio conditions, the conventional system is not designed to provide the continuous supply or increased volume of outdoor air necessary .

AlirezaZendehboudi[3]In this paper performance assessment of a solid desiccant based on dehumidifier system coupled with air conditioning in a tropical climate zone of Iran have been evaluated. Results indicate that when the hybrid system is used,the efficiency increases 0.76 and energy consumption reduce 3.03kW.The cop of the system is found to be 2.51.

NiyatiWadkar[4] investigated the Desiccant based hybrid A/C system, the air is moved through desiccant material where it dehumidifies the air to absorb moisture from air and then air is cooled up to required temperature. By incorporating desiccant dehumidification with traditional VCR system, it reduces the energy cost which is required in traditional VCR system to cool the air up to its Dew Point Temperature (DPT), for dehumidifying it. The latent load can be minimized by desiccant material. From the experimental results it is concluded that the silica gel is absorb more amount of moisture than other two desiccant materials used. The energy consumption with desiccant system is less compared to conventional VCR system. The energy saved with desiccant dehumidification is 40-45%.

Mr. Anoopkumar[5] This paper represents the Performance Evaluation of Hybrid Air Conditioning system using Indirect Evaporative Cooling Approach. In desiccant wheel, if the regeneration temperature increases, the loads gets completely separated, thereby performance of cooling coil improves a lot i.e. 70% to 80%. However, system performance reduces due to increased power at higher regeneration temperature and the latent load does not get minimize in the same proportionate. Performance of cooling coil is significantly governed by latent load. Dehumidification is more at low humidity and it decreases with increasing regeneration temperature.

2. Problem definition

The important aspects of air conditioning are to provide the comfort environment for the mankind in all the conditions. A conventional air conditioner consumes large amount of electrical energy especially in hot and humid climatic conditions due to high latent load. Also a conventional air conditioner only provides cooled air and does not provide the dry air for comfort feeling. The warm air is uncomfortable for human being.Comfort is primarily decided by temperature and humidity. To maintain comfort conditions by controlling temperature and humidity, desiccant wheel is integrated with conventional vapour compression system, it is known as hybrid air conditioning system where before reaching the hot and humid air to cooling coil, moisture of the air is removed at desiccant wheel and then allowed to go over the cooling coil.

3. Methodology

Design and development of solid desiccant assisted hybrid air conditioning system. It mainly consists of solid desiccant dehumidifier wheel, heat exchanging wheel, cooling coil of conventional air conditioner, heater,blowers,digital temperature indicator, anemometer etc.The Psychrometric analysis has beencarried out to determine the sensible, latent and total heat load. The coefficient of performance of the system has also been calculated.

4. Mathematical Modeling

Outside air sensible heat:

OASH=0.02044*V1*(td1-td2) kW

Outside air latent heat:

OALH=50*V1*(W1-W2) kW

Outside air total heat:

OATH=OASH+OALH

Sensible heat load on cooling coil:

SHCC=m1*Enthalpy difference

Latent heat load on cooling coil:

LHCC=m1*Enthalpy difference

Total heat load on cooling coil:

THCC= SHCC+LHCC

Room sensible load to be handled:

RSH= m1*Enthalpy difference

Room latent load to be handled:

RLH= m1*Enthalpy difference

Room total load to be handled:

RTH= RSH+ RLH

The COP of the system:

$$COP=\frac{RTH}{\text{Energy Meter Reading}}$$

5. Experimental setup

Figure1: Experimental setup

Experimental setup consists of solid desiccant dehumidifier wheel, heat exchanging wheel, cooling coil of conventional air conditioner, heater, blowers, digital temperature indicator, anemometer etc.

Table 1:Experimental setup specification

Desiccant wheel	Silica gel(Rotor speed – 16 rph)
conventional air conditioner	Capacity 1.5ton
Heater(3Nos)	Capacity 6kW
Temperature sensor	Range 0 to 200^{0}C
Anemometer	Wind speed range 0-30m/s and temperature range -10 - 45^{0}C
Hygrometer	Humidity range 0 to 99%RH

6. Experimental procedure

Testing is done on solid desiccant assisted hybrid air-conditioning system setup which is shown in fig.1.

For experimentation, the heater, blower, rotation of desiccant wheel and heat exchanging wheel, conventional air conditioner is switched on.As switched is on, desiccant wheel and heat exchanging wheel will rotated.The outside hot & humid process air 'ODC' is passed through the desiccant dehumidifier wheel. The desiccant dehumidifier wheel removes the moisture from the process air and the heat of adsorption gets released in the process air, thereby increasing the temperature of process air leaving the desiccant wheel, point '2'. The process air leaving the desiccant wheel is sensibly cooled by the re-generation air stream (outside air) in the heat recovery wheel. Heat recovery wheel is an air-to-air heat exchanging wheel, where the process air gets sensibly cooled by exchanging heat with the regeneration air stream. The high temperature re-generation air stream; which is preheated in the heat recovery wheel and heater section, is passed through the desiccant dehumidifier wheel to remove the adsorbed moisture for reacti-vation. The sensibly cooled process air in heat recovery wheel '3' is then passed over the cooling coil; maintained at requisite apparatus dew point temperature as per the sensible heat factor ratio, to maintain the conditioned space as per the comfort conditions to be achieved. The condition '4' represents the condition of air entering the conditioned space.

Therefore the ODC and IDC are to be measured. Also the temperature and relative humidity of process air after desiccant wheel, after heat exchanging wheel and after cooling coil are to be measured.

Table 2: Experimental Readings

Parameter	Temperature(^{0}C)	Relative Humidity(%)
Outside design condition(ODC)	37^{0}C	56%
Inside design condition(IDC)	24^{0}C	49%
Condition of process air after desiccant wheel(2)	48^{0}C	25.2%
Condition of process air after heat recovery wheel(3)	42^{0}C	34.8%
Condition of process air leaving evaporator coil(4)	10^{0}C	92%
ADP	5^{0}C	
Energy meter reading	2kW	

7. Results

The results obtained are tabulated in the following table 3 as follows:

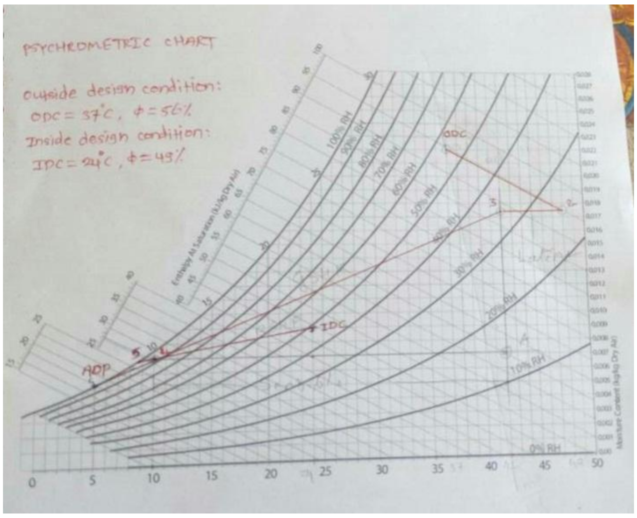

Figure2: Psychrometric Plot of Process

Table3: Load Calculations From Psychrometric Chart

Description about various loads	Value In kW
Sensible heat load of infiltrated outside	1.40
Latent heat load of infiltrated outside process	3.43
Sensible heat load on cooling coil	3.19
Latent heat load on cooling coil	2.61
Total heat load on cooling coil	5.81
Room sensible load to be handled	1.46
Room latent load to be handled	0.38
Room total load	1.84

8. Conclusions

From the results obtained, it is observed that the sensible load on the cooling load with the hybrid air-conditioning system increases but the latent heat load to be handled by the system decreases. The cop of the system was found to be 0.92. The conventional vapour compression based air-conditioning system consumes high grade electricity power. Under high ventilation loads or low sensible heat ratio conditions, the conventional system is not designed to handle the continuous supply or increased volume of outdoor air necessary to comply with minimum ventilation standards as recommended by ASHRAE.

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