ISSN: 0974-5823 Vol. 7 No. 1 January, 2022

International Journal of Mechanical Engineering

A STUDY AND EXPERIMENTAL PERFORMANCE OF SILICA GEL BASED DESICCANT ROTOR MACHINE

Lakhan Agarwal[1], Ashok Yadav[2]

[1,2]*Mechanical Engineering Department, DEI, Dayalbagh, Agra-282005, India*

ABSTRACT

The objective of the present experimental work is to study and analyse the relative humidity in a bounded space by means of (silica gel) dehumidifier at different operating conditions. For this experimental work and analysis of different parameter during experimentations we can measure and identify some psychometric parameters. In this work study of desiccant machine and analysis of relative humidity is done with various conditions. The experimental set up consist of a desiccant dehumidifier, an enclosed sealed cabin of dimensions (Length=14.5ft, Breadth=8ft, Height=7ft). Desiccant dehumidifier is a machine which is used to remove the moisture from the air and control the relative humidity of the air. In an enclosed space the air is intake by the machine, it humidifies at certain rate and after dehumidification different parameters at different location is calculated by different means for required air properties. The silica based rotor i.e. silica gel it is inert, nontoxic, non-inflammable and do not avail any disturbance in the property of the air and it is having maximum moisture removal capacity. The desiccant dehumidifier series is used to lower the air humidity and produce optimum air conditions as per human comfort at ambient air conditions. By this process of adsorption the rotor is saturated. Once they become saturated with the water at the same time it will regenerated with different sources simultaneously.

Keywords: Desiccant, silica-gel, adsorption, atmospheric air. Moisture content, temperature, relative humidity.

I INTRODUCTION

A desiccant wheel is related to a thermal wheel, but with a covering applied for the only purpose of dehumidifying or ‘drying’ the air stream. The desiccant is generally Silica Gel. As the wheel turns, the desiccant passes consecutively through the incoming air where the moisture is adsorbed, and through a “regenerating” zone, where the desiccant is dried and the moisture expelled. The wheel continues to rotate and the adsorbent process is repetitive. Regeneration is normally carried out by the use of a heating coil, such as a water or steam coil. Thermal wheels and desiccant wheels are regularly used in series configuration to provide the required dehumidification as well as recovering the heat from the regeneration cycle. A desiccant material is a material that naturally attracts moisture from both gases and liquids. This moisture is then adsorbed or recollected within the desiccant and can be released again when heated. There are various types of desiccant available on the market, but all Aggreko dehumidifier’s use what is known as Silica Gel as the desiccant within the drying wheels. Eccentrically silica gel is not a “gel” as the name implies, but in fact a porous granular form of silica which is made from sodium silicate. The internal structure of each silica granule is made up of a network of interrelating microscopic pores, which by a process called physical adsorption or capillary condensation, attract and holds moisture within each granule. This imprisoned moisture can then, with the addition of heat, be released from the desiccant. This desiccant can then be used again and again. As low ambient temperatures do not limit the material, it makes it a more all season drying system. A thermal wheel, also known as a rotary heat exchanger, or heat recovery wheel, is a type of energy recovery heat exchanger, in order to recover the heat energy.

II LITERATURE REVIEW

Miller (1983) reviewed the applications of combining solar energy and desiccant energy storage. Energy storage has become an important consideration in adopting solar energy or providing energy during interruptible service of fossil fuels. Desiccants are potential media suited for dehumidification. Both liquid and solid desiccants are manufactured. Various physical and thermal properties have been complied and a cost comparison revealed that energy storage via desiccants was competitive with phase-change materials, rock-bed storages and water systems.

San et al. (1994) tested the regeneration of a silica gel packed bed. The optimum operating time, after which the maximum amount of moisture had been removed, was determined at three regeneration temperatures, 65℃, 75℃ and 85℃.

Zheng et al. (1995) investigated the effects of desiccant sorption properties, heat and mass transfer characteristics and size of the wheel on dehumidification performance. They also discussed the isotherm shape of desiccant and it was found that to obtain maximum dehumidification, separation factor should be 0.07.

BabusHaq et al. (1996) used the waste heat of a natural gas fired combined heat and power (CHP) system to regenerate a desiccant wheel which was used for the dehumidification of moist air in a swimming pool.

Dai et al. (2001) evaluated the dehumidification performance of desiccant wheel on the basis of wave shape through wave analysis using psychrometric rate) to its operating performance.

Madhiyanon et al. (2007) developed a desiccant rotary wheel coupled with a hot-air drying system and used to dry coarsely chopped coconut pieces. Silica gel was selected as the desiccant material.

Kabeel (2007) studied a solar assisted desiccant wheel made up of iron wire and cloth layer (cloth layer was the layer of cloth wrapped on iron wire) impregnated with calcium chloride solution. In this system a solar air heater containing a porous material was used for regeneration purpose and the effect of the air flow rate and the solar radiation intensity on the system for regeneration and absorption process was analyzed.

Catalano et al. (2008) proposed the system consists of humidity and temperature control during the food drying process by using a particular dehumidifier equipped with a desiccant rotor containing silica gel. In each experiment the humidity, temperature and velocity of air is controlled and the moisture content and temperature as function of time is monitored.

Zhai et al. (2008) developed a one-dimensional transient heat and mass transfer equations for a desiccant wheel allowing lumped formulation.

Jeong et al. (2010) developed and analysed the concept of utilizing the exhaust heat (50°C) from fuel cell or air conditioning system as the heat source in a four partition desiccant dehumidification system which led to considerable saving of energy.

Yadav et al. (2012) proposed that the air needed for regeneration was heated in an evacuated tube solar collector with a surface area of 4.44 m2. The desiccants were regenerated at temperatures in the range of 54.3–68.3°C.

III MATERIAL AND METHODS.

A rotary bed desiccant dehumidifier as shown in Fig1.It is a device that removes moisture from air but do so without cooling the air below its dew point. In case of a desiccant dehumidifier, water vapour from a process stream of moist air adsorbs onto the surface of a desiccant material. In desiccant dehumidifier, the process and regeneration air streams operate at the same time and a wheel of desiccant material rotates between the streams. At any given time, a portion of the desiccant is being regenerated while the remainder is adsorbing water from the process stream. The regeneration air comes from the same source as the process air and is heated to lower its relative humidity. The process air enters the dehumidifier at a certain state (usually relatively cool and moist). As water adsorbs onto the desiccant, it gives up its heat of sorption, warming the surrounding air. The process air leaves the dehumidifier drier and warmer than it entered. The air source for the regeneration stream and the process stream can be same and that the regeneration stream has been sensibly heated. Their generation stream goes through an opposite process to the process stream. Moisture on the desiccant is subjected to low relative humidity warm air and consequently desorbs, taking the heat of sorption out of the surrounding air. The regeneration stream exits the dehumidifier cooler and moister than it entered. Dehumidifier dries the process stream and adds moisture to the regeneration stream (Mitchell et al. 1997). In reality, the sorption and desorption processes are not isenthalpic because “waves” of moisture, temperature and enthalpy travel through the desiccant matrix contained in the wheel. Moist air flows over the matrix during, the desiccant heats up and increases in moisture content. Eventually the entire desiccant matrix becomes saturated with moisture and the outlet process air state tends towards the inlet state. A second, much faster moving wave front moves through the desiccant just as the process air and regeneration airstreams begin to flow. When the process stream is not flowing, the air in the dehumidifier comes to equilibrium; no moisture is being added to 11 the desiccant by the process stream and the regeneration stream, while heat does not completely dry the desiccant. Desiccant dehumidifiers are quite different from cooling-based dehumidifiers. Instead of cooling the air to condense its moisture, desiccants attract moisture from the air by creating an area of low vapor pressure at the surface of the desiccant. The pressure exerted by the water in the air is higher, so the water molecules move from the air to the desiccant and the air is dehumidified.

Fig 1. Rotary bed desiccant dehumidifier

The working of the rotary bed desiccant dehumidifier has been explained in Fig2. The desiccant picks up moisture from the surrounding air, the desiccant surface changes to the condition described by point two. Its vapor pressure is now equal to that of the surrounding air because the desiccant is moist and warm. At point two, the desiccant cannot collect more moisture because there is no pressure difference between the surface and the vapor in the air. Then the desiccant is taken out of the moist air, heated, and placed into a different airstream. The desiccant surface vapor pressure is now very high, higher than the surrounding air, so moisture moves off the surface to the air to equalize the pressure differential. At point three, the desiccant is dry, but since it is hot, its vapor pressure is still too high to collect moisture from the air.

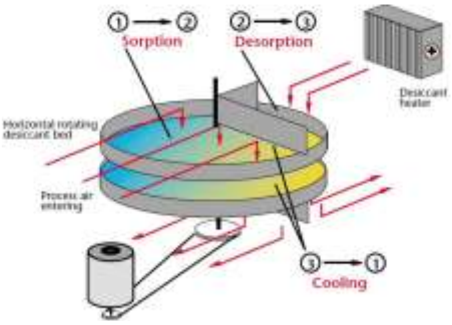

Fig.2Rotary bed desiccant dehumidifier process

3.1 DESICCANT MATERIAL

A range of materials are used for today's desiccant rotor constructions. The synthetically-produced silica gel is a fine pored solid silicic acid which consists of 99 % silicon dioxide. It can adsorb up to 40 % of its dry weight in water when in equilibrium with air at saturation. Silica gel can withstand temperatures up to 400°C and is a solid, insoluble desiccant. No special precautions are required when it is exposed to air at 100 % relative humidity. It is also possible to wash a wheel in water if dust or other particulate block the air passageways. Silica gel does not undergo any chemical or physical change during the adsorption process. It is inert, non-toxic, stable and resistant to most chemicals.

IV PARAMETRICAL STUDY OF DESICCANT DEHUMIDIFIER MACHINE

Regeneration Heater

Heater is used at the regeneration side, heater warms the air entered in desorption side and lower the humidity in the air, and then warm air is applied to the saturated desiccant bed to remove out the moisture from the bed.

Operating Variables

Desiccant dehumidifiers remove moisture from one airstream, called the "process" air and move it to another airstream, called the "reactivation" air. The amount of moisture moved depends on the operating variables. High initial moisture in the process air, high reactivation air temperature and low process air velocity combine to remove the largest amount of moisture from the process air. On the reactivation side, a smaller air volume enters the dehumidifier from the weather. It passes through a heater and proceeds to the desiccant wheel. It heats the desiccant, which gives up moisture.

Process air moisture

The lower the moisture in, the lower the moisture level of the leaving process air with increase in temperature. This is because the temperature rise of the process air is proportional to the amount of moisture removed from the air. Conversely, if the entering moisture is higher than the base case, the air will leave the dehumidifier slightly more humid, but also warmer, since more moisture will have been removed.

Process air temperature

Desiccant surface vapor pressure depends on the temperature of the material as well as on its water content. Lower temperatures improve moisture removal. The moisture removal performance is improved because the desiccant is cooler, and therefore has a lower surface vapor pressure so it can attract more moisture. The relationship of inlet temperature to performance is clear, when all other variables are constant, lower inlet temperatures enhance performance and higher temperatures reduce performance.

Process air velocity

The slower the air moves through the desiccant bed, the drier the outlet moisture will be. Dehumidifiers are generally selected at the highest velocity that will accomplish the 14 moisture removal because high velocities mean smaller, less costly equipment. Increase in process inlet air velocity leads to reduction in process removed moisture due to lesser contact of inlet air on the desiccant surface. At low speed, desiccant wheel has better moisture removal with low process inlet air velocity.

Reactivation air moisture

The mechanical concern is air leakage between the moist air entering reactivation and the dry air leaving the process side of the unit. Any air leakage from reactivation to process will raise the moisture level in the process air considerably. Desiccant dehumidifiers must have good air seals between reactivation entering air and the dry process air leaving the unit. Any leakage at this point can raise the moisture level of the dry process air. The performance of some other desiccants, notably molecular sieves and activated alumina, is considerably more sensitive to moisture in reactivation air.

Reactivation air temperature

In a desiccant dehumidifier, the desiccant is heated by air entering reactivation. The hotter the desiccant, the more easily it gives up moisture, so the reactivation air temperature has a strong effect on performance. Essentially, the drier the desiccant can be made in reactivation, the more moisture it can absorb when it rotates into the process airstream.

Reactivation air velocity

In a rotary dehumidifier, the reactivation air carries heat to the desiccant as well as carrying away moisture once it is released by the desiccant. More air (higher velocity) is 15 necessary for heating than for carrying away moisture.

V RESULT AND DISCUSSION

Working Parameters of Rotary Bed Desiccant Dehumidifier

For the study of relative humidity we use Rotary Bed Desiccant Dehumidifier of capacity of 180 cfm (cubic feet per min.) in an enclosed room of dimensions specified above.

Temperature: The temperature was recorded using digital thermometer located at the ambient, process inlet, process outlet, reactivation inlet, reactivation outlet. Over the entire period of study, the data was recorded at an interval of (minutes).

Temperature: range from - 20°C to 200°C with accuracy ±3 %.

Relative humidity: The RH of air was measured with digital thermo hygrometer located at the ambient, process inlet, process outlet, reactivation inlet, reactivation outlet. Over the entire period of study, the data was recorded at an interval of (minutes).

Relative humidity: range from 0 to 100 % with resolution 0.1 % RH and accuracy ± 3.5 % RH.

Air flow rate: The velocity of air was measured with digital anemometer located at the process inlet, process outlet, reactivation inlet, reactivation outlet. The air mass flow rate of air was calculated by multiplying air velocity with duct area and density of air.

Performance evaluation of rotary bed desiccant dehumidifier: The performance of the rotary bed desiccant dehumidifier was evaluated for different air flow rates of 0.32, 0.63, 0.95 and 1.30

Observations Recorded in tabular form-

We take readings of relative humidity (%) on time interval of 20 min in an enclosed sealed room of dimensions

Length=14.5 ft

Breadth=8 ft

Height=7 ft

So the Volume=812 ft^3.

Time Interval (Min.)	Relative Humidity (%)
0	62
20	48
40	33
60	27
100	25

Table 1: Time interval And Relative Humidity (%)

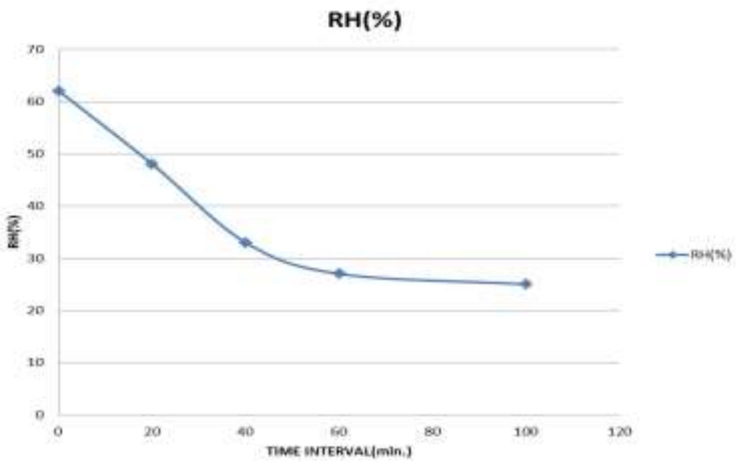

Figure 3: Relative humidity and Time interval

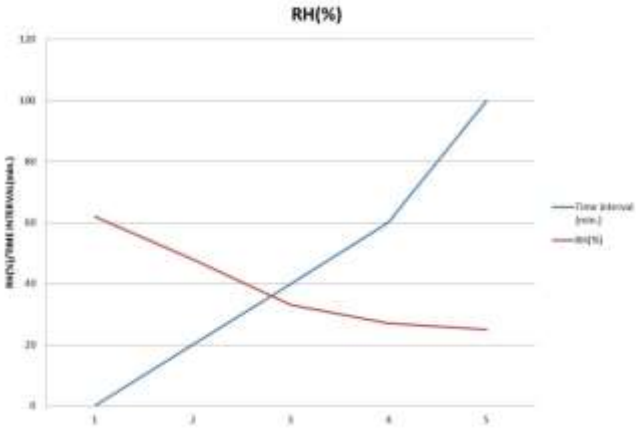

Figure 4: Variation of Relative humidity at time interval of 20 min.

<u>Observations Recorded in tabular form-</u>

We take readings of relative humidity (%) and temperature (^{0}C) on time interval of 10 min in an enclosed sealed room of dimensions

Lenghth=14.5 ft

Breadth=8 ft

Height=7 ft

So the Volume=812 ft^3.

Time interval (min)	Relative humidity(%)	Temperature (Deg. Cel)
0	62	23
10	37	27
20	33	28
30	29	29
40	26	30
50	24	31

Table 2: Practical results of Relative Humidity (%) at different temperature levels

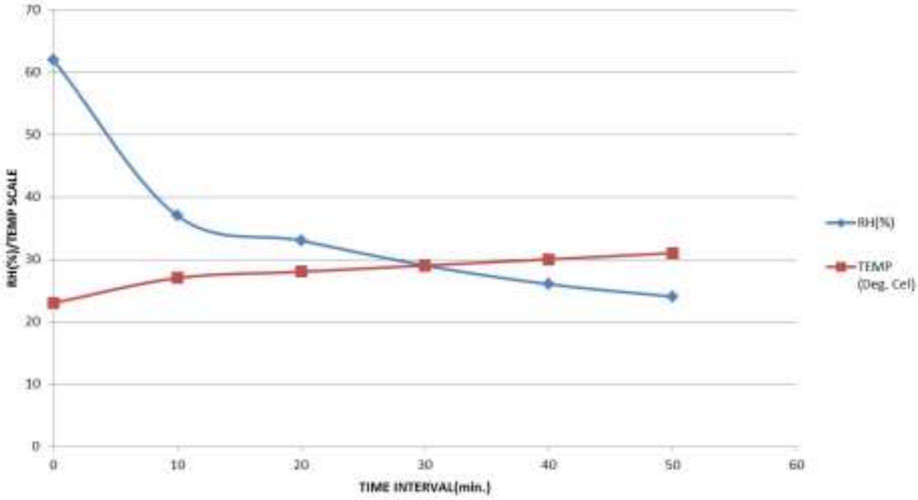

Figure 5: Relative humidity and temperature

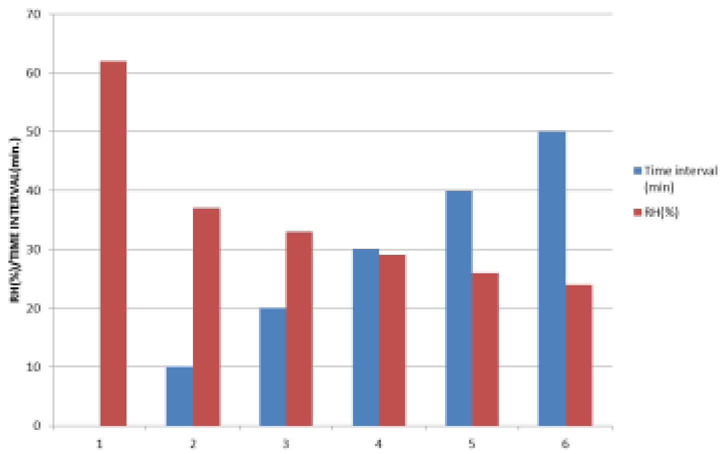

Figure 6: Relative humidity and time interval(10 min)

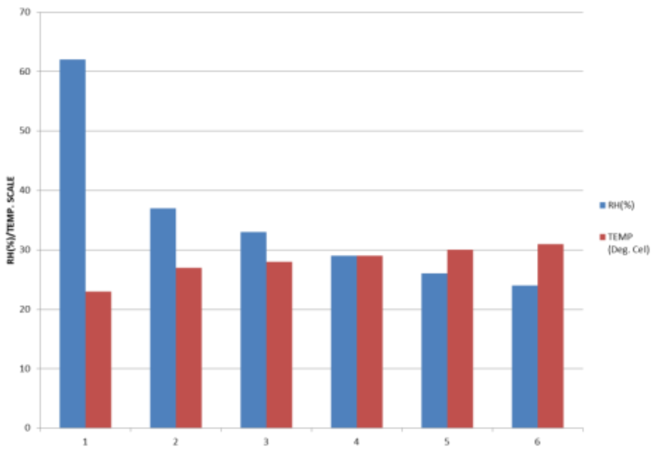

Figure 7: Relative humidity and temperature

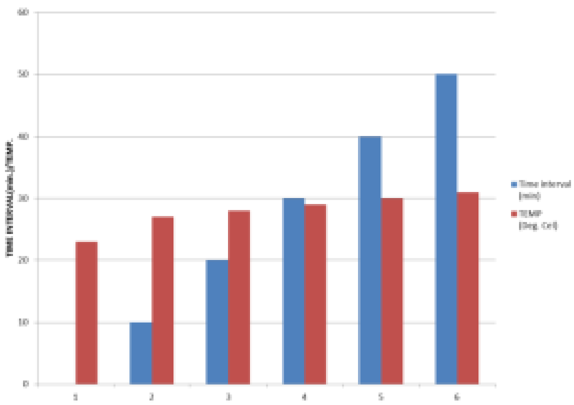

Figure 8: Time interval and temperature

VI. CONCLUSION

In this study we compare the relative humidity of Rotary Bed Desiccant Dehumidifier and window Air conditioner based on VCRS provided same initial conditions i.e. (volume of enclosed space, relative humidity, and temperature and time interval).

From above results we conclude that rate of dropping of relative humidity in case of Rotary Bed Desiccant Dehumidifier is much higher as compared to window Air conditioner based on VCRS.

We achieve Minimum value of relative humidity in case of Rotary Bed Desiccant Dehumidifier is 24% (table no.2). It is not possible to achieve so much lower value of relative humidity in case of window Air conditioner.

REFERENCES

[1]. Miller WM (1983) Energy storage via desiccant for food agricultural applications. *Energy in Agri Vol.2, pp. 341–354*

[2]. Zheng W, Worek WM (1995) Performance optimization of rotary dehumidifiers. *J Solar Energy Engg Vol.117, pp 40-44*

[3]. BabusHaq RF, Olsen H, Probert SD (1996) Feasibility of using an integrated small-scale CHP unit plus desiccant wheel in a Leisure Complex. *Applied Energy Vol 53, pp 179-192*

[4]. Dai YJ, Wang RZ, Zhang HF (2001) Parameter analysis to improve rotary desiccant dehumidification using a mathematical model, *Int J Thermal SciVol 40, pp 400-408*

[5]. Madhiyanon T, Adirekrut S, Sathitruangsak P, Soponronnarit S (2007) Integration of a rotary desiccant wheel into a hot-air drying system: drying Performance and Product Quality Studies. *ChemEnggProcgVol, 46, pp 282-290*

[6]. Kabeel AE (2007) Solar powered air conditioning system using rotary honeycomb desiccant wheel. Ren Energy 32: 1842-1857

[7]. Catalano P, Fucci F, Giametta F, La Fianza G (2008) A system for food drying using humidity control and low temperature. AgrilEnggInt Manuscript Fp, Vol, 10, pp 07 012.

[8]. Zhai C, Archer DH, Fischer JC (2008) Performance modeling of desiccant wheels: Model Development, Energy Sustainability, August 10-14, 2008, Jacksonville, Florida USA.

[9]. Jeong J, Yamaguchi S, Saito K, Kawai S (2010) Performance analysis of four partition desiccant wheel and hybrid dehumidification air conditioning system. Int J RefgnVol, 33, pp 496-509

[10]. Yadav A, Bajpai VK (2012) Experimental Comparison of Various Solid Desiccants for Regeneration by Evacuated Solar Air Collector and Air Dehumidification. Drying TechnolVol,30(5), pp516-525.

[11]. AroraDomkundwar,(2016) refrigeration and air conditioning.

[12]. Khurmi R.S (2015) refrigeration and air conditioning..

[13]. Bry-air(2016) compact desiccant dehumidifier

[14]. www.nptel.com.