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A Review on Solid Desiccant Dehumidification Systems Using Composite Material

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Abstract:

This paper shows the performance of adsorbent beds desiccant wheels for air dehumidification with various solid desiccant wall materials, from a viewpoint of system operation. It is found that the beginning late enhanced composite desiccant wheel performs than the standard one and can expel more moisture from air all around half. Composite desiccants can be made into any shape, so a low-pressure drop desiccant wheel with air flow channels can be designed to reduce the power consumption of the system. Moreover encouraging is that the new desiccant wheel can be driven by a lower recovery temperature for securing a low measure of moisture release. The reason is that the composite desiccant materials, which are worked with composite material joining silica gel is a flawless technique, bear on superior to anything silica gel alone in moisture adsorption. This paper presents a combined analytical study on dehumidification, cooling and circulating air through cooling systems using distinctive solid composite desiccant with focus on different air flow rates, dehumidification of moist air and regeneration of solid desiccant wheel. A comparable examination of various solid desiccants has low operating and maintenance cost and its condition friendly.

Keywords — Desiccant wheel, silica gel, moisture, dehumidification.

I. INTRODUCTION

To accomplish determined scope of human comfort there is a need to control the temperature and relative humidity (RH) in the indoor condition of building. Air conditioning in hot and humid environment is a basic part for human health & comfort. Humidity control is a real task for air conditioning. Outside air humidity remains above 80-90% persistently for twelve of days in subtropical areas like South China. It is important to dehumidify natural air before it can be provided to buildings [1]. Air dehumidification has assumed an essential part in present day aerating and cooling industry which tends to isolate the treatment of latent load from sensible load. Indeed, air dehumidification represents 40-60% of the cooling load for aerating and cooling in hot and humid districts like Southern China. It is additionally of incredible significance to control the temperature and relative humidity in specific businesses, for example, the food, healing, and electronic enterprises [2].

In Singapore, the utilization of cooling has turned into a standard in essentially every building. Truth be told, around half of a building's vitality utilization is credited to aerating and cooling alone. With the rising cost in power and the exhaustion of petroleum products, it is in this manner, important to build the effectiveness of ventilation systems to lessen the vitality utilization for the shoppers. Many research works have been led on the distinctive sorts of desiccant accessible for the

dehumidification procedure [3]. These desiccants could be extensively classified into liquid and solid states. Everyone has its own qualities and weaknesses. Fluid desiccants are generally sent in their use because of their capacity to cause bring down weight drop and to recover at bring down temperature. Be that as it may, fluid desiccants are additionally known to be harmful, toxic and corrosive in nature which renders them to be unsatisfactory for air conditioning applications. Likewise, fluid desiccants are additionally found to have remainder impacts [4]. A few cases of fluid

desiccants are lithium chloride, lithium bromide and calcium chloride. Solid desiccants are more conservative and compact above all, there is less porosity for them to erode and give remainder impacts. Solid desiccants are subject to its permeable frame, surface area, surface energy and crystalline structure to adsorb moisture from the air. Cases of solid desiccants incorporate silica gels, zeolites, activated carbon. The most normally utilized desiccants in the market today for aerating and cooling application is silica gel because of their extraordinary star surface territory and great moisture adsorption limit [5].

Many experiments have also been conducted for composite desiccants consisting of calcium chloride being contained in the pores of silica gel .the moisture adsorption capacity of this composite desiccant is better than that of silica gel. It is also established that the deciding factor in the improvement of the adsorption capacity is the percentage of calcium chloride content in the mixture

[6]. Combinations of silica gel and lithium chloride have also been experimented Similar to calcium chloride, the lithium chloride content in the composite desiccants plays a huge role in the moisture adsorption capacity. It is also a well-known that lithium chloride is corrosive in nature and this halts the progress of lithium chloride as a liquid desiccant however, by impregnating it in silica gel, its corrosive effect is kept to the minimum and the combined desiccant also benefits in terms of moisture regeneration. Another type of composite desiccant that is of great commercial interest is the low cost composite desiccant [7].

Since solid desiccants and fluid desiccants have their points of interest and drawbacks, it is proposed that consolidating both by blending them synthetically or physically will beat the individual weaknesses of each sort. For example, blend of silica gels with lithium chloride will diminish the impact of harmfulness and to lessen the recovery temperature accomplishing the middle of the road trademark. Many research works have been done in this field where these desiccants are alluded to as composite desiccants. Generally utilized strong desiccants, for example, silica gel, activated carbon and molecular sieve, for example, zeolites were led in a few experiments [8]. Composite desiccants made by impregnating hygroscopic substance in the pores of strong adsorbents have been observed to be viable in expanding the moisture adsorption limit of the adsorbents and they are called specific water sorbents.

II. DESICCANT DEHUMIDIFICATION AND COOLING SYSTEM

In desiccant dehumidification and cooling framework, moist air stream is permits to move through desiccant material and after that dry air leaves the desiccant material. In the event that the adsorption procedure is proceeded with, capacity to adsorb moisture of desiccant material declines. Therefore, to keep framework working constantly, the water vapor adsorbed must be removed. This is finished by warming the desiccant material to its temperature of recovery relying upon the sort of desiccant material used. Desiccant material can be produced by second rate warm source like sun based energy, waste heat, natural gas and so on when solid desiccant is employed, the desiccant dehumidification framework comprise of gradually rotating desiccant wheel of adsorbent bed. In liquid desiccant based dehumidification liquid desiccant is gotten contact with the moist air stream [9].

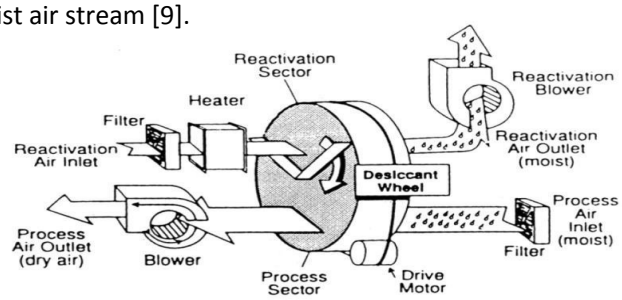

Fig.1. rotary desiccant dehumidifier [9]

DESCRIPTION OF THE DESICCANT WHEEL

The concentrated novel desiccant wheel isn't new however a turning dehumidifier manufactured with one sort of new composite desiccant material. The composite desiccant is a two-layered material that comprises of a host matrix with open pores (silica gel) and a molecular sieve impregnated into its pores. Because of its physical structure the composite desiccant takes an intermediate position between solid adsorbent and unadulterated hygroscopic salt and can be sorted out in an approach to exhibit the best highlights of the two frameworks. To shape a desiccant wheel, a honeycombed framework, which can follow the desiccant materials and have a mass of parallel small scale air channels, is amazingly fundamental. The air channel, for which the dividers are covered with bottomless desiccant materials, is fit for expelling the moisture from the passing procedure air [10]. The air channels and the created desiccant wheel are appeared in fig. 1. In any case, when the desiccant is immersed with water vapor, the unit can't dehumidify the procedure air any more, therefore a recovery segment, which can drive the adsorbed water vapor out by warming and make the desiccant dynamic once more, ought to be considered. As appeared in fig. 2A, the work in this makes a division, and lets 1/4 of the surface zone of the wheel presented to recovery air. Also the airproof and heat insulation in the air tunnel are important to ensure the good performance of a rotary desiccant dehumidifier. Here, protection felt, fiberglass plastic and settled steel ring are fundamental for the airproof and heat insulation [11]. To drive the wheel, a retardment rotor and equipping framework ought to be considered with the outfitting arrangement of the examined desiccant wheel. The schematic view of the experimental equipment is shown in fig.2

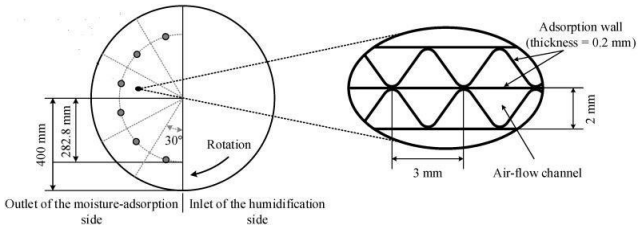

Fig.2.A schematic view of desiccant wheel [24]

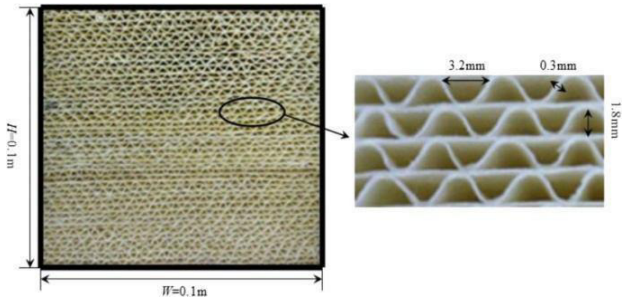

Fig.3. Geometry of the honeycomb type adsorbent bed for air dehumidification [21]

DEHUMIDIFICATION

The procedure in which the moisture or water vapor or the stickiness is expelled from the air keeping its dry bulb (DB) temperature steady is called as the dehumidification procedure. This procedure is spoken to by a straight vertical line on the psychometric diagram beginning from the underlying estimation of relative mugginess, expanding downwards and finishing at the last estimation of the relative humidity. Like the pure humidification method, in real observe, the pure dehumidification method is not conceivable since the dehumidification is consistently joined by cooling or heating of the air [12]. Dehumidification process alongside cooling or heating is utilized as a part of number of air conditioning applications.

METHOD OF DEHUMIDIFICATION

1) Cooling the air-

The procedure in which the air is cooled sensibly and in the meantime the moisture is removed from it is called as cooling and dehumidification process. Cooling and dehumidification process is obtained when the air at the given dry bulb and dew point (DP) temperature is cooled beneath the dew point temperature [13].

2) Absorption of water vapor in the air-

A porous which changes either physically, chemically or both accompanied by the absorption procedure. Lithium Chloride is a case of strong retentive. At the point when water is retained on this material it changes to a hydrated state. In fluid adsorption dehumidification framework, the air is gone through showers of a fluid adsorbent, for example, lithium chloride or glycol arrangement. The sorbent in an active state has a vapor pressure below that of the air to be dehumidified and absorbs moisture from the air stream [14]. The sorbent solution during the process of absorption becomes

weak with moisture which during regeneration is given up to an air stream in which the solution is heated. Commonly absorbent utilized is lithium chloride is either in liquid form or as solid crystal in honeycomb shell.

3) Adsorption of water vapor in the air-

An adsorbent which does not change physically or chemically amid the adsorption procedure. Adsorbents are typically granular beds or solids with permeable structures making them fit for holding a lot of water on their surface. The guideline behind desiccant dehumidification is that the desiccant is presented to moisture loaded air, from where it is removed by the desiccant and held [15]. The saturated desiccant is heated, which drives off the gathered moisture into the fumes air stream. The recovered desiccant is prepared for utilize once more. In this way, a nonstop cycle of adsorption and recovery can be set up, giving low dew focuses. Typical adsorbents used are Silica gel, Molecular Sieve and Activated Alumina. Therefore it can be seen that chemical dehumidifiers based on the guideline of physical adsorption offer the most basic, immediate and economical strategy for humidity control [16].

DESICCANT

Any material that pulls in and holds water vapor is a desiccant. Composite desiccants draw in and discharge a lot of water vapor relying upon moisture accessible in nature they are uncovered too. solid desiccant are strong desiccants are more conservative as well as compact and in particular, there is less inclination for them to erode and give remainder impacts. Solid desiccants are, when all is said in done, subject to its porous form, surface zone, and surface energy and crystalline structure to adsorb moisture from the air [17]. Cases of strong desiccants incorporate silica gels, zeolites, activated carbon and initiated dirt, for example, bentonite. The most usually utilized desiccants in the market today for aerating and cooling application is silica gel due to their extraordinary expert surface area and great moisture adsorption limit. Since strong desiccants and fluid desiccants have their favorable circumstances and disservices, regularly utilized strong desiccants, for example, silica gel, activated carbon and molecular sieves, for example, zeolites were led in a few examinations [18].

DESICCANT TYPES

Many analysts have additionally been led for composite desiccants comprising of various material with silica gel [38-49]. Up to date, exceptionally restricted research work has been done on looking at changed composite desiccants under the same working condition. in this article, the mix of two to four layered composite desiccants will be investigated to decide the most noteworthy moisture removal limit at different temperatures and RH and furthermore the most outstanding regenerative moisture capacity limit under various temperature environments[19].

Many research works have been led on the distinctive sorts of desiccant accessible for the dehumidification procedure. These desiccants could be extensively sorted into fluid and strong states. Everyone has its own particular qualities and deficiencies. Liquid desiccants are broadly sent in their usage because of their capacity to bring about lower weight drop and to recover at bring down temperature [20]. In any case, fluid desiccants are likewise known to be harmful and destructive in nature which renders them to be unsatisfactory for aerating and cooling applications. Likewise, fluid desiccants are additionally found to have remainder impacts.

1) Solid dessicant

2) Solid absorbant

3) Organic liquid absorbants

4) Inorganic liquid absorbants

III. ROTARY DESICCANT WHEEL

In rotary desiccant wheel, in revolving desiccant wheel, heat and mass exchange happens, at low revolution speed. Wheel comprises of an edge with thin layer of desiccant material. The channels of desiccant wheel outline are created in different structures like honeycomb, triangular, sinusoidal etc. Fig. 6 represents the fundamental working standard of rotating desiccant dehumidifier schematically .the cross segment of wheel is partitioned into moist (process) air side and regeneration air side.

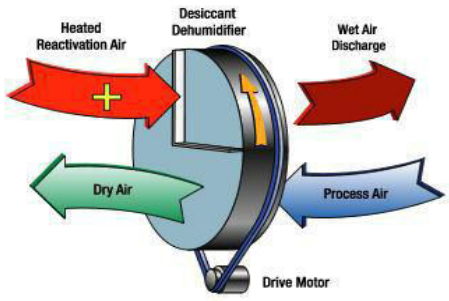

Fig.4.Rotery desiccant dehumidifier [32]

At the point when the wheel always pivots through two separate areas, the procedure air is dehumidified by the desiccant because of the adsorption impacts of the desiccant material. In the meantime, the recovery air is humidified subsequent to being heated by a heater and desorbing the water from the wheel [46]. Adequacy of desiccant wheel diverse meanings of desiccant wheel's warm feasibility has been presented by various analysts. Thermal effectiveness

$$\varepsilon_t = \frac{(T_2' - T_1)}{(T_3 - T_1)} \quad \text{----------(1)}$$

T_1,$T_2$and ϵ_t are inlet and outlet temperature of process air and inlet temperatures of regeneration air separately. Another outflow of recovery adequacy of desiccant wheel is given by eq. (2) [47]

Regeneration effectiveness,

$$\eta_{Dh} = \frac{(\omega_1 - \omega_2')}{(\omega_1 - \omega_{2,ideal})} \qquad (2)$$

Where h and w is the latent heat of vaporization of water and humidity ratio individually. The heater required to vanish the water adsorbed by desiccant can be computed by eq. (2).above condition is appropriate to both process and recovery mass stream rate. where different process and recovery mass stream rates exist, the accompanying connection (changed equation)incorporates more parameters and gives better comprehension of the framework adequacy is proposed here [48].

$$\dot{m}_w = \dot{m}_a(\omega_1 - \omega_{2'}) \quad (3)$$
$$= \rho \bar{V} A(\omega_1 - \omega_{2'})^*$$

Where, m_w and m_a are process and recovery mass stream rates. Van lair mass proposed the condition of desiccant wheel viability considering the dehumidification [49]. See eq. (4). Dehumidification viability

$$W\alpha=(W_{pi}-Wpo_{ideal}) \quad (4)$$

Where Wα is the perfect particular humidity of air stream at the outlet of desiccant wheel. In the result that its esteem is taken zero, one gets a perfect desiccant wheel in which air is totally dehumidified.

We have discovered the basically of administration figure for an incentive on be MRC standardized by volume stream rate (MRC/Q). [50] This figure for legality will be essentially comparable to on grain wretchedness (ΔGPP). Applying two or three constants followers' lbs/hr/cfm on grains/lb.

$$\Delta GPP \text{ (grains/lb)} = .MRC/Q = 1555\ MRC/Q \quad (5)$$

The dehumidification rate, MRC, portrayed in the gages in lbs/hr, can moreover be conveyed as a cooling rate (btu/h or tons)

$$MRC_{Btuh} = 0.7.Q.\Delta GPP \quad (6)$$

This is an estimate, in light of the fact that a grain's enthalpy esteem is subject to its area on the psychometric outline. the guess is precise to inside 5% for instances of interest. MRC $_{Btuh}$ would then be able to be joined with vitality input rate to compute an inert coefficient of execution

$COP_{LATENT} = MRC_{BTUH}/E_{REGEN}+_{EPARA}$

Where:

- COP $_{latent}$ = coefficient of performance for latent cooling
- COP_{LATENT} = cooling rate equivalent to moisture removal capacity, (kbtu/hr)
- MRC_{BTUH} = thermal energy input, (kbtu/hr)
- $E_{REGEN}+_{EPARA}$ = parasitic vitality contribution for fans, wheel drive, and so forth, (kbtu/hr)

CONCLUSION

In the present paper an effort has been made to survey distinctive desiccant material. Desiccant dehumidification is a setup and effective innovation utilized for some years. However, decreasing the cost of desiccant dehumidification frameworks and enhancing the implementation will give more chances to desiccant dehumidification technology.

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