Solid Desiccant Dehumidification Systems Using Composite Material – A Review

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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].

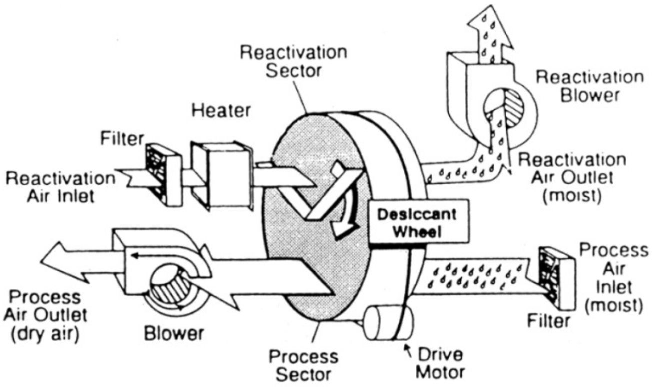

Fig.1. rotary desiccant dehumidifier [9]

III. 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

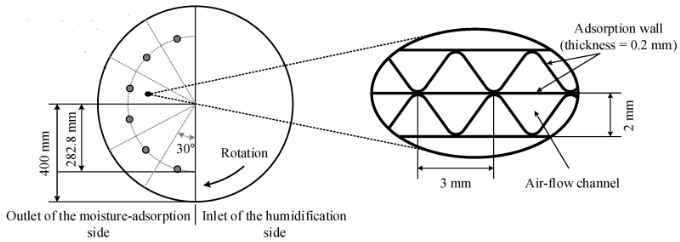

Fig.2.A schematic view of desiccant wheel [24]

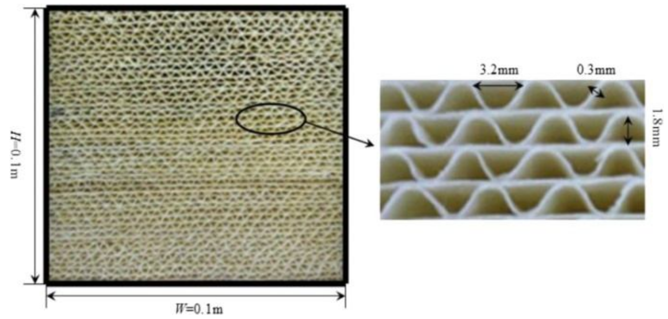

Fig.3. Geometry of the honeycomb type adsorbent bed for air dehumidification [21]

IV. 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.

V. 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].

VI. 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].

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VII. 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

1)Solid dessicant-

1.1 Silica gel –

Silica gel has high moisture adsorption limit and low regenerative temperature of 120°c. It is additionally settled that adsorption limit of silica gel by and large reductions with the rise in temperature. It is proposed that consolidating both by blending them chemically or physically will conquer the individual deficiencies of each sort. For example, blend of silica gels with lithium chloride will diminish the impact of danger and to lessen the recovery temperature accomplishing the halfway trademark [21]. Many research works have been completed in this field where these desiccants are referred to as composite desiccants.

Combinations of silica gel and lithium chloride have likewise been tested. Like calcium chloride, the lithium chloride content in the composite desiccants assumes a enormous part in the moisture adsorption limit. It is likewise a notable that lithium chloride is destructive in nature and this stops the advance of lithium chloride as a fluid desiccant. However, by impregnating it in silica gel, its corrosive impact is kept to the base and the joined desiccant likewise benefits as far as moisture recovery [22]. Another sort of composite desiccant that is of extraordinary commercial interest is the low cost composite desiccant.

1.2 Molecular sieve-

1.2.1 3A molecular sieves-

A 3A Molecular sieve has a pore size of 3å or 3angstrom.it is striking to assimilate any particle bigger than3å.molecular sieve is an antacid metal alumino-silicate, the potassium for sort a precious stone structure. 3a molecular sieve is utilized fundamentally to remove moisture from liquefied and gaseous materials. It has turned out to be a standout amongst the most dependable desiccants for different applications [23].

1.2.2 4A molecular sieves-

A 4A molecular sieve has a pore size of 4å or 4 angstrom. It doesn't adsorb any particle bigger than 4å.4 angstroms are the sodium types of the sort a crystal structure. 4A atomic strainer is principally utilized for expelling moisture from liquefied and gaseous materials [24]

1.3 Zeolites (Natural)-

Zeolites are micro porous, alumino-silicate minerals ordinarily utilized as business adsorbents and impetuses common zeolites shape where volcanic shakes and fiery remains layers respond with antacid groundwater. Zeolites likewise take shape in post-depositional environment over periods running from thousands to a huge number of years in shallow marine bowls. Normally happening zeolites are once in a while unadulterated and are polluted to fluctuating degrees by different minerals, metals, quartz, or different zeolites [25]. Therefore, normally happening zeolites are barred from numerous vital business applications where uniformity, consistency and purity excellence are fundamental.

Zeolites are the alumino-silicate group from the gathering of miniaturized scale permeable solids known as "molecular sieve" on a very basic level containing Si, Al, O and metals including Ti, Sn, Zn and so on the term molecular sieve refers to a particular property of these materials, i.e., the capacity to specifically sort particles construct basically with respect to a size rejection process. This is because of an exceptionally consistent pore structure of molecular dimension measurements. The most extreme size of the atomic or ionic species that can enter the pores of a zeolite is controlled by the measurements of the channels of molecular sieve, for example, zeolites are found to have the biggest sum in moisture adsorption limit because of its vast pore estimate and exceptionally outer surface. Notwithstanding, the hindering component for utilizing it as desiccant is the high regenerative temperature of 350°c that it requires. Composite desiccants made by impregnating hygroscopic substance in the pores of strong adsorbents have been observed to be viable in expanding the dampness adsorption limit of the adsorbents and they are called particular water sorbent [26].

1.4 Activated alumina-

Activated alumina is a porous, solid type of aluminum oxide, also called Al2O3 or alumina. This is a similar mineral that makes up the valuable pearls ruby and cobalt, with impurities being the source of the stones' bright colors. After activated alumina has been cleared of existing moisture by heating it, the high surface zone and many pores of the material take into consideration the take-up of water and different atoms through adsorption. enacted alumina is made from aluminum hydroxide by dehydroxylating it in a way that creates an exceedingly permeable material; this material can have a surface range essentially more than 200 m^2/g. the compound is utilized as a desiccant you can reestablish the first adsorption effectiveness of enacted alumina by warming it to any temperature from 350° to 600°F (177° to 316°c) [27].When the desiccant is warmed as portrayed over, the water put away in it is discharged. Initiated alumina has a wide range of uses, a standout amongst the most essential of which being parching, the adsorption of water. As a desiccant, activated alumina can be utilized to dry compacted air and different gas and fluid streams. Also, the adsorbent is regularly used to decontaminate gas streams by the particular adsorption of particular particles. Enacted alumina additionally has water filtration and impetus applications [28].

1.5 Activated carbon-

Like other desiccant, activated carbon is additionally used to remove the moisture from an extensive variety of modern and business items. Be that as it may, it gives exceptionally viable outcomes, highly effective results in removing the odor particles from the product packaging and large shipping containers. They have exceptionally large surface area as compared to other desiccant; therefore they act as an excellent adsorbent. This desiccant is ordinarily utilized as a part of number of uses where packaging items bundling may give smell when they are opened.So as to show signs of improvement result, activated carbon desiccant must be utilized as a part of blend of silica gel desiccant to productively control both smell and moisture[29].

Activated carbon is broiled natural material (coconut shell, bone, wood) that structures permeable granules. It is an adaptable and reasonable adsorbent that comes in many sizes and has a scope of utilizations from gas, water, and metal cleaning to air filtration. Enacted carbon has been utilized widely for a long time as an adsorbent of scents and lethal gasses. Moisture adsorption limit of this composite desiccant is superior to anything that of silica gel. It is likewise settled that the main factor in the change of the sorption limit is the level of calcium chloride content in the blend. One illustration is the mixture of activated carbon with inorganic salts, for example, lithium chloride and calcium chloride [30]. For a similar measure of lithium chloride substance and calcium chloride content added to the activated carbon, the previous has a superior moisture adsorption capacity. At a similar state of 84% relative humidity, initiated carbon impregnated with lithium chloride can adsorb moisture as much as 194% of its mass when contrasted with the one with calcium chloride where its dampness adsorption is 170% of its mass. Initiated carbon and alumina required a higher recovery temperature of 250°c for a less adsorption limit when contrasted with silica gel. It is clear from the specified writing that the essential concentrate is on the dehumidification and recovery limit of either fundamental adsorbents, for example, silica gel and zeolites and fundamental adsorbents-halides [31].

2)Solid absorbant-

2.1 Calcium chloride-

Hygroscopic materials, implying that they promptly assimilate moisture from their surrounding condition. Each however owes its hygroscopicity to various normal standards. It is the property of calcium chloride that causes it to attract moisture and dissolve itself during the process into watery brine. Silica gel on the other hand over attracts moisture through the system of adsorption in which water is pull in to smooth surfaces revealed by pores all through the material. Water appends itself to the silica surfaces yet does not change them. Calcium chloride breaks up into fluid brackish water incompletely because of the way that it can pull in a few times its own particular weight in water. Interestingly, silica gel stays dry to the touch even at full preservation limit, since it is just capable under perfect conditions to hold a greatest of 40% of its weight in water inside its inner pore structure. Practically speaking, the amount consumed might be even lower than this, depending upon temperature and relative humidity [32].

Many tests have likewise been directed for composite desiccants comprising of calcium chloride being contained in the pores of silica gel. Calcium chloride desiccants function admirably finished a temperature run from solidifying up to at least 80°c. At low temperature the salt does not retain moisture under dry conditions. In down to earth terms calcium chloride desiccants are powerful at relative humidity over 30%, while being more successful under moist conditions. The moisture adsorption limit of this composite desiccant is superior to anything that of silica gel [33].It is likewise settled that deciding factor in the improvement of the sorption capacity is the percentage of calcium chloride content in the mixture.

2.2 Lithium chloride-

At the point when the pure lithium chloride shapes strong crystalline hydrate LiCl & H_2O, its adsorption limit is 0.43 kg. Past this level, the spillover phenomenon generally happens. In the interim, the composite desiccant beats the imperfection of pure lithium chloride the new composite material in light of silica gel– lithium chloride is a contrasting option to silica gel or pure lithium chloride desiccants. Dissimilar to the solid adsorption of silica gel and the liquid absorption of lithium chloride [34]. The composite desiccant essentially includes three sorts of sorption systems:

(i) Classical heterogeneous adsorption on the pore surface,
(ii)Chemical response bringing about the development of salt crystalline hydrates,
(iii) Liquid absorption.

The trial composite desiccant material is a two layered material that comprises of a permeable silica gel and a haloids salt impregnated into its pores. The composite adsorbent takes a transitional position between the strong adsorbent and the unadulterated hygroscopic salt and can be sorted out in an approach to exhibit the best highlights of the two frameworks. Water vapor adsorption isotherms were explored to assess the property of the composite desiccant. The tests were led in a thermo-humidistat chamber in which a steady temperature and relative humidity condition can be created and maintained. A superior moisture adsorption limit of the composite desiccant material is seen in examination with the pure silica gel. The adsorption limit of the composite desiccant material is roughly three times higher than that of silica gel at high relative humidity [35]. For example, blend of silica gels with lithium chloride will diminish the impact of poisonous quality 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. Mixture of silica gel and lithium chloride has additionally been tested. Similar to calcium chloride, the lithium chloride content in the composite desiccants assumes a colossal part in the moisture adsorption limit. It is likewise a notable that lithium chloride is corrosive in nature and this ends the advance of lithium chloride as a liquid desiccant. In any case, by impregnating it in silica gel, its corrosive impact is kept to the base and the combined desiccant additionally benefits as far as moisture recovery [36].

3)Organic liquid absorbant-

3.1 Glycol-

Another sort of composite desiccant that is of extraordinary commercial interest is the ease composite desiccant glycol drying out is a fluid desiccant framework for the removal of water from flammable gas and gaseous petrol fluids. It is the most widely recognized and conservative methods for water removal from these streams. Glycols commonly found in industry incorporate triethylene glycol, diethylene glycol, ethylene glycol and tetraethylene glycol. triethylene glycol is the most ordinarily utilized glycol in industry[37].

3.2 Clay-

Since clay is shoddy in cost and can adsorb moisture moderately, by combining it with the hygroscopic substance, its moisture removal limit will likewise be moved forward. Inquire about has likewise been done and it is found to have sensible exhibitions. For small scale application, where moisture removal isn't clearly identifiable, this desiccant is sufficient for application. In any case, it is watched that subsequent to experiencing cycles of sorption and desorption process, breaks are made on the surface of the desiccant while the general structure stays in place. Its recovery temperature is observed to be under 100°c and poor quality waste warmth can be used to recover it. The four sorts of parching materials are silica gel, bentonite, lithium chloride and calcium chloride [38].

VIII. LITERATURE REVIEW

8.1. T.S.Ge et al. (2016) have been proposed to explain experimental study on carbon based composite desiccants for desiccant covered heat exchangers. A DCHE (desiccant covered heat exchanger) is a novel strong desiccant cooling segment with desiccant covered onto the surface of a balance tube heat exchanger. In the paper, carbon based composite desiccants were produced and examined for DCHE frameworks.

Composite desiccants were manufactured by impregnating LiCl into pores of initiated carbon and actuated carbon fiber. Due to impregnated salt, composite desiccants were found to have littler surface zone and pore volume. Sorption isotherms were measured and reproduced in view of potential hypothesis. Water sorption isotherms demonstrated that composite desiccants had improved sorption amount. Sorption energy was likewise explored and fitted with the direct driving model. Composite desiccants demonstrated higher dynamic water takes-up and sensible rate coefficients. At long last, to anticipate dehumidification carrying out of composite desiccants in DCHE frameworks, a scientific model was constructed. Restoration comes about demonstrated that composite desiccant covered DCHEs can remove more moisture from the process air [39].

8.2. Sih-Li Chen et al. (2016) carried out an investigation on Polymer/alumina composite desiccant joined with intermittent heat exchangers for ventilating systems. The intermittent aggregate heat exchanger framework comprise of four diffusive fans and two desiccant beds. Amid the half-time frame, one fan drives air through one desiccant bed for adsorption and the other fan working the other way prompts air through the other desiccant bed for desorption. In the following half-time frame, both wind stream bearings are switched by the other two fans. In this work, occasional operations are tried under various recovery temperatures (40℃ and 25℃) alongside six distinctive desiccant beds: silica gel, polyacrylic acid, activated alumina, molecular sieve, diatomite and a polymer/alumina composite. A silica gel-stuffed bed gives alternate option to high-cost honeycomb silica gel in 40℃ recovery temperature frameworks. Alumina indicates practically identical execution to honeycomb silica gel and has additionally advantage in low recovery temperature. The power utilization of low weight drop composite desiccant frameworks demonstrates a change of 33% over pressed bed frameworks [40].

8.3. K.J. Chua and M.R. Islam (2015) cover wide verity of desiccants materials. Many theories have been proposed to clarify Experimental Study on Composite Desiccants wheel for energy efficiency and dehumidification. This paper exhibits the advancement and execution portrayal of new composite desiccants. The primary pieces for the composite desiccants incorporate silica gel, lithium chloride, calcium chloride and bentonite. Diverse rate syntheses of these four parts were tried to decide the ideal material synthesis for enhancing moisture removal limit under fluctuating inlet air temperature and stickiness, and measure of moisture removal under various regenerative temperature. For the first time, four-layered composite desiccants were created and tried tentatively to decide their moisture removal limit and moisture regeneration limit at temperature of around 60°C under inlet air condition Singapore's tropical atmosphere.

It was watched tentatively, that utilizing a four layered composite desiccant, containing silica-gel (SiO_2), Bentonite, Lithium Chloride (LiCl), and Calcium Chloride ($CaCl_2$), has empowered more prominent moisture removal limit with respect to fluctuating inlet air temperature and moistness running from 25°C to 35°C and 55 to 95% relative humidity (RH). The rate changes, as opposed to pure silica gel, are 14 to 22.5%, and 10 to 26.3% for shifting inlet air temperature and fluctuating RH respectively [41].

8.4. K.J. Chua et al. (2015) carried out experimentation in order to enhance heat and mass trade of composite desiccants for essentialness powerful air dehumidification: Modeling and trial silica gel calcium chloride, silica gel lithium chloride, and silica gel polyvinyl liquor Desiccant dehumidification innovation gives a strategy for drying air before it enters a molded space. This paper shows a joined trial analytical think about on the heat and mass exchange progression of composite desiccants amid air dehumidification. The composite desiccants are silica gel calcium chloride, silica gel lithium chloride, and silica gel polyvinyl liquor (PVOH). The determined model is approved against test perceptions of different desiccant compose with silica-gel as the host desiccant. The impacts of process air speed, inlet air temperature and humidity evacuation limit, recovery rates and the related weight drops were examined

Depending on a comprehensive vitality execution list, desiccant coefficient of performance (DCOP), comes about have shown that the moisture removal limit, recovery rates and the related weight drops of composite desiccants beat that of pure silica gel by at least 11%. Furthermore, the moisture removal limit of composite desiccants including silica gel lithium chloride and silica gel PVOH beat that of business pure silica gel in any event 55%. Ultimately, energy related performance index, DCOP, bookkeeping for vitality data sources and yields along with adsorbing and desorbing operations, represented the benchmark performance of composite desiccants contrasted with silica gel as far as energy efficiency was concern [42].

8.5. Chih-Chieh Chen et al. (2014) the literature speaks to verity of context like Silica gel polymer composite desiccants for cooling frameworks. The creator essentially centered around built up a composite material to be utilized as a part of aerating and cooling frameworks by joining silica gel with both polyacrylic acid and sodium polyacrylat. A test was performed to decide the ideal blending proportion. The outcomes demonstrated that the ideal composite material was delivered at a blending proportion of 10:1:1. Under a shut domain of 25◦C and a relative humidity of 70%, the material displayed sorption limit 41% higher than silica gel without anyone else. Thus tests were performed to survey the dehumidification carrying out of the material at different air speeds, recovery temperatures, and inlet temperatures and moistness.

After 15 min of use under states of a inlet air temperature of 30°C, a relative humidity of 70%, and a regeneration temperature of 40°C, the execution of the composite material kept up 80% of its most elevated dehumidification performance. What's more, the normal dehumidification sum achieved 2.73 g/min, which was higher than silica gel stuffed bed at 2.46 g/min. Moreover, the air flow stream outline of the composite material encouraged a weight drop of 149 mm Aq/m, which was 0.69 times lower than the silica gel pressed bed framework. Given the above outcomes, utilization of the silica gel/polymer composite desiccant to aerating and cooling frameworks has awesome energy saving potential [43].

8.6. X.J. Zhang, K. Sumathy (2013) primarily focused on Dynamic hygroscopic effect of the composite material used in desiccant rotary wheel. In this analysis, silica gel (SG), calcium chloride ($CaCl_2$) and composite desiccant (SG–$CaCl_2$) connected to a corrugated paper (CP) based desiccant rotational wheel are contrasted for their capacities with remove moisture from wet air. Additionally, it shows an amazing increment in moisture removal contrasted and the silica gel wheel. Despite the fact that chloride desiccants, for example, $CaCl_2$ have a significantly more noteworthy hygroscopic limit than natural desiccants, for example, silica gel, the $CaCl_2$ has poor moisture and heat diffusion rates, and will break up in the water cried, after the development of strong crystalline hydrate $CaCl_2$& $2H_2O$. Subsequently with the aqueous solution overflowing, the $CaCl_2$ is expelled from its host matrix, resulting in a $CaCl_2$ loss in the adsorption process, and accordingly lowering the system performance.

To conquer this deformity, another silica gel–chloride composite that consists of a permeable silica gel and a hygroscopic chloride impregnated into the pores were proposed as an alternative option to the existing silica gel or chloride desiccant. Because of its novel physical structure, the composite desiccant takes an intermediate position between the permeable silica gel and the pure chloride, and can be sorted out in an approach to show the best highlights of the two frameworks. The point of the present examination is to research and compare the adsorption properties of composite desiccant in a dynamic procedure, and analyze its dehumidification performance in contrast with the regular silica gel turning wheel [44].

8.7. C.X. Jia (2006) has been relatively research on Solid desiccant dehumidification and regeneration methods. Author carried out experimental investigation on two honeycombed desiccant wheels manufactured with silica gel and composite desiccant material to be specific, a customary one treated with silica gel and another one manufactured with another sort of composite desiccant material, was made in this paper.

It is discovered that the recently created composite desiccant wheel performs superior to the customary one and can evacuate more moisture from air by roughly half. Additionally supportive is that the new desiccant wheel can be driven by a lower regeneration temperature for securing a similar measure of moisture removal. The reason is that the composite desiccant materials, which are developed with LiCl and silica gel arrangements in an ideal way, carry on superior to anything silica gel in moisture adsorption, as per the discoveries from the filtering scanning electron microscope(SEM) pictures and additionally the balance adsorption test comes about. A few parameters, for example, inlet air humidity, regeneration temperature, air mass stream rate, and so on Which may influence the performance of the desiccant wheels, are likewise examined and talked about. It is additionally distinguished that the new composite desiccant wheel has potential for dehumidification applications in many fields [45].

IX. 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.

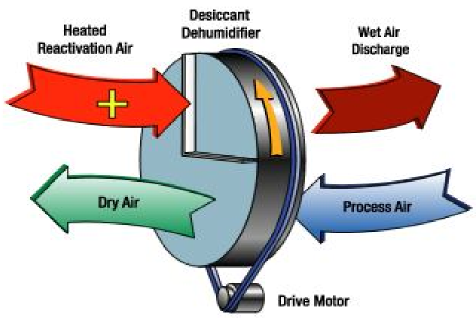

Fig.4.Rotery desiccant dehumidifier [32]

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

$$\epsilon_{W1} = \frac{T_{po} - T_{pi}}{T_{ri} - T_{pi}} \quad (1)$$

T_{po}, T_{pi} and T_{ri} 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,

$$\epsilon_{W2} = \frac{(W_{pi} - W_{po})\, h_{fg}}{h_4 - h_3} \quad (2)$$

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].

$$\epsilon_{W2'} = \frac{m_{process}(W_{pi} - W_{po})\, h_{fg}}{M_{reg}(h_4 - h_3)} \quad (3)$$

Where, $m_{process}$ and $M_{regeneration}$ 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

$$\epsilon_{W3} = \frac{(W_{pi} - W_{po})}{(W_{pi} - W_{po_{ideal}})} \quad (4)$$

Where W_{po} 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.

$$\Delta GPP\ (\text{grains/lb}) = \frac{7000}{60\rho_{std}}.MRC/Q = 1555\ MRC/Q \quad (5)$$

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

$$COP_{latent} = \frac{MRC_{Btuh}}{E_{regen} + E_{para}} \quad (7)$$

Where:

- COP_{latent} = coefficient of performance for latent cooling
- MRC_{Btuh}= cooling rate equivalent to moisture removal capacity, (kbtu/hr)
- E_{regen}= thermal energy input, (kbtu/hr)
- E_{para}= parasitic vitality contribution for fans, wheel drive, and so forth, (kbtu/hr)

X. 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. The best in class advances possible to choose right desiccant materials, desiccant wheel geometry and strategy for dehumidification and recovery.

The accompanying conclusions can be expressed:

(1) Sorption limit expanded as the proportion of silica gel and atomic sifter in the composite desiccant expanded, yet the composite desiccant wind up plainly softer;
(2) A little extent of molecular sieve (70:30) was utilized to accomplish a similar change in the sorption limit of the composite desiccant, which was joined with a vast master segment of silica gel ,enabling the composite desiccant to look

after hardness, even with a low proportion of molecular sieve in the get up of adsorbing water;

(3) The aggregate mass of water adsorption of every composite desiccant was higher than the silica gel desiccant, yet the most

Noteworthy transient dehumidification capacity was lower than the silica gel desiccant [51]

(4) The composite and silica gel desiccants had a similar tendency at regeneration temperatures of 40◦c and 50◦c. the higher there regeneration temperature, the higher the relative humidity, the lower the inlet temperature, and the faster the velocity, which combines to cause a superior dehumidification performance.

(5) The composite desiccants with air channels had a much lower pressure drop than the silica gel stuffed and reduce the fans energy consumption.

(6) Low material expenses, environmentally-friendly posses with low temperatures, a longer extended dehumidifying time of operation, and a low pressure drop are perfect for use in the residential air conditioning framework [52].

Table1. Comparative study of solid desiccant air dehumidification and regeneration system

Author	Year of work	Work carried out	Desiccant used	Purpose
X. Zheng et al.	2017	Execution investigation of composite silica gels with various pore sizes and distinctive impregnating hygroscopic salts	Silica gels and different salts in terms of lithium chloride, calcium chloride	Air dehumidification
Alireza Zendehboudi et al.	2016	Implementation of GA-LSSVM modeling approach for estimating the overall performance of solid desiccant wheels	Silica gel, molecular sieve	Air dehumidification
Sih-Li Chen et al.	2016	Polymer/alumina composite desiccant joined with intermittent aggregate heat exchangers for ventilating frameworks	silica gel, polyacrylic acid, activated alumina, a molecular sieve, diatomite and a polymer/alumina composite	Air dehumidification
T.S.Ge et al.	2016	Experimental study and performance predication of carbon based composite desiccants for desiccant coated heat exchangers	carbon based composite desiccants and lithium chloride	Air dehumidification
Manoj Kumar et al.	2015	Trial examination of sunlight based controlled water creation from climatic air by utilizing composite desiccant material $CaCl_2$/saw wood	calcium chloride, Saw wood, Water	Air dehumidification
K.J. Chua et al.	2015	Heat and mass exchange of composite desiccants for vitality effective air dehumidification: Modeling and trial	silica gel, calcium chloride, lithium chloride and polyvinyl alcohol	Air dehumidification
K.J. Chua and M.R. Islam	2015	Experimental study of composite desiccants for air energy efficient & dehumidification	silica gel, calcium chloride, lithium chloride and Bentonite	Air dehumidification
Chih-Hao Chen et al.	2015	Silica gel/polymer composite desiccant wheel joined with heat pump for air conditioning frameworks	silica gel/polymer composite desiccant	Air dehumidification
Chih-Chieh Chen et al.	2014	Silica gel compound composite desiccants for air conditioning systems	silica gel with both polyacrylic acid and sodium polyacrylate	Air dehumidification
X. Zheng et al.	2014	Trial examine on silica gel-lithium chloride composite desiccants for desiccant covered heat exchanger	Silica gel and lithium chloride	Air dehumidification
L.M. Hu et al.	2014	Performance study on composite desiccant material coated fin-tube	Silica gel and lithium chloride	Air dehumidification

		heat exchangers		
Giovanni Angrisani et al.	2014	Trial evaluation of the vitality execution of a energy performance of desiccant cooling framework and examination with other cooling technologies.	Natural Gas	Desiccant cooling
Li-Zhi Zhang et al.	2013	Performance examinations of honeycomb-sort adsorbent beds (wheels) for air dehumidification with different desiccant divider materials	Solid desiccant	Air dehumidification
X.J. Zhang et al.	2013	Dynamic hygroscopic impact of the composite material utilized as a part of desiccant turning wheel	silica gel , calcium chloride and corrugated paper	Air dehumidification
C.X. Jia et al.	2012	Experimental correlation of two honeycombed desiccant wheels created with silica gel and composite desiccant mater	Silica gel and lithium chloride	Air dehumidification
T.S. Ge et al.	2012	Performance of two-arrange rotating desiccant cooling framework with various recovery temperatures	Natural refrigerant	Desiccant cooling
S.S. Me et al.	2010	A scientific model for anticipating the execution of a compound desiccant wheel (A model of compound desiccant wheel)	silica gel haloid compound	Desiccant regeneration
C.S. Tretiak et al.	2009	Sorption and desorption attributes of a packed bed of clay– calcium chloride desiccant particles	Clay and calcium chloride	Air dehumidification
T.S. Ge et al.	2008	Performance examination on a novel two-organize solar powered driven revolving desiccant cooling framework utilizing composite desiccant materials	Silica gel haloid compound	Desiccant regeneration
C.X. Jia et al	2006	Utilization of compound desiccant to grow superior desiccant cooling framework	Silica gel and lithium chloride	Desiccant cooling

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