Experimental Study Of Desiccant Dehumidifier System With Focus On Wheel Base Material

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***Abstract*— The environment humidity absorption and its control have always been a major concern for air conditioning engineers& researchers. This concern becomes more pronounced when dealing with the humidity control in specific environments. Medicine & laboratories, electronic parts production lines, museum and libraries, hospitals, cinema and theaters salon and lithium battery production lines are part of these kind of specific environments. The desiccant wheels are a good substitution for absorption systems due to their very special characteristics such as: low energy consumption, almost no air and acoustic pollutions. A new kind of desiccant wheel has been designed, fabricated and tested under different operational conditions. The main focus was on the absorbent material and base material selection and also the procedure of wheel production. The experimental results confirm the high operational characteristics of the fabricated system. This could be a good guideline for national companies which are active in this field.**

Keywords—component; Air conditioning, dehumidification systems, rotary wheel

I. INTRODUCTION

A major part of every human's life activities takes place in indoor spaces.Reports indicates In western countries, about 90% of life time is spent indoors. Therefore, in recent years, attention to the quality of the internal environment has been seriously pursued by the organizations and associations of the mentioned countries. Since the quality of indoor spaces directly affects the health of residents, it is very important to pay attention to this concept in its various dimensions such as indoor air quality, thermal comfort, as well as visual and acoustic comfort. A major part of the quality of the indoor environment of the building depends on the characteristics of the air inside the building in which we breathe. Now we have to answer the question of when it can be said that the surrounding environmental conditions are satisfactory? In order to answer this question, the effective parameters in the feeling of comfort should be studied. Some of the most important parameters are Temperatures, relative humidity, air velocity, Density of CO_2 and volatile organic compound.

Practically, there are various national and international guidelines that set the permissible range for each parameter. For example, temperature between 20 and 27 degrees Celsius and relative humidity between 40 and 60 percent are suitable. When these quantities are outside the mentioned limits, the human body is damaged. In addition, in industrial applications limits are considered for these quantities.
For example, in the pharmaceutical industry as well as the industry of manufacturing lithium batteries, the humidity of the environment should be close to zero. Therefore, humidity control is particularly important in industrial and domestic applications. So far, extensive studies have been done in this field. Zhang et.al investigated Thermodynamic modeling of a novel air dehumidification system. The proposed system that studied in this research incorporates a membrane-based total heat exchanger into a mechanical air dehumidification system, where the fresh air flows through the enthalpy exchanger, the evaporator and the condenser subsequently.
Also Thermodynamic model for the performance estimation of the combined system is investigated[1]. Pietro et.al analyzed HVAC dehumidification systems in their research. This paper, on the basis of the main

literature indications, deals with moisture control in buildings during the summer season[2]. Also Jain et.al have an Experimental performance of a liquid desiccant dehumidification system under tropical climates. The liquid desiccant system that investigated in this research incorporates a double channel-exchanger for air to liquid desiccant heat and mass transfer.
It provides a large surface area for air/desiccant contact and reduces the carryover as direct contact between desiccant and air is minimized unlike spray towers, packed bed and falling film designs. Desiccant is heated in a plate heat exchanger using hot water and then regenerated in a regenerator. The set-up comprises of a dehumidifier, along with a regenerator, a cooling tower, plate heat exchangers and a control unit. Experiments were conducted on the system using calcium chloride and lithium chloride as desiccants by varying parameters like inlet air conditions, hot water temperature and desiccant concentration in order to evaluate the performance of the system under different operating conditions [3].

Patnaik et.al investigated Performance for an experimental solar open-cycle liquid desiccant air dehumidification system. In this research a nominal 10.5-kW (3-ton) open-cycle liquid desiccant dehumidification system has been designed, installed and successfully operated at the Solar Energy Applications Laboratory, Colorado State University. These studies thus provide data and correlations useful for design guidance and performance analysis of similar open-cycle liquid desiccant cooling systems, particularly for the liquid/vapor contact units [4].

Su et.al investigated an Experimental study on the performance of an improved dehumidification system integrated with precooling and recirculate and regenerative rotary desiccant wheel [5]. A rotary dehumidifier consists of a rotating porous matrix made of a desiccant with mechanically supporting materials. The dehumidification performance of a rotary dehumidifier wheel depends on its rotational speed, the sorption properties of the desiccant, the heat and mass transfer characteristics of the matrix, and the size of the dehumidifier [6]. this system is designed to allow two different air flow to pass through a cylinder containing absorbent material (rotating dehumidifier wheel).one is the wet air stream that need to be dried and the other is the hot air flow that regenerates the absorbent material. The most important part of a desiccant dehumidification system is the grid or wheel structure.
This structure should be such that air flow can easily pass through it and be exposed to absorbent materials so that the rate of pressure drop in the fluid flow can be ignored[7]. The rotating wheel is known as the core of these dehumidifier systems. At the wheel absorbent base material made of glass or metal foams and this surface covered with moisture-absorbing material. Absorption occurs when the absorbent forces absorb a water vapor. The steam sticks to the surface of the dryer. In this process moisture is converted adiabatically from steam to liquid and stored inside the dryer. Depending on its type and the amount of water in the air an absorbent material absorbs water vapor between 10% and 100% of its dry weight to reach equilibrium with surrounding air. Humidity is usually removed by heating the adsorbent to a temperature between 50 and 260 degrees of Celsius. The adsorbent must be cool before resuming dehumidification [8]. Therefore in current research we investigate and design rotary wheel dehumidifier system with focus on wheel material.

II. DESIGN OF ROTARY WHEEL DEHUMIDIFIER

As mentioned above in current research we investigate and design rotary wheel dehumidifier system with focus on wheel material. In order to make rotating dehumidifier wheel it is necessary that the moisture absorbing material is layered on a suitable base material. Metal foams are one of the materials used by scientists to create a new industrial space. Metal foams, especially aluminum-based ones, are considered an advanced material in the world recently. Metal foams possess remarkable properties, such as lightweight, high compressive strength, lower specific weight, high stiffness, and high energy absorption. In this research investigations showed that according to the physical properties of the metal foam, this material is a suitable choice for use as the base material of the dehumidifier wheel.

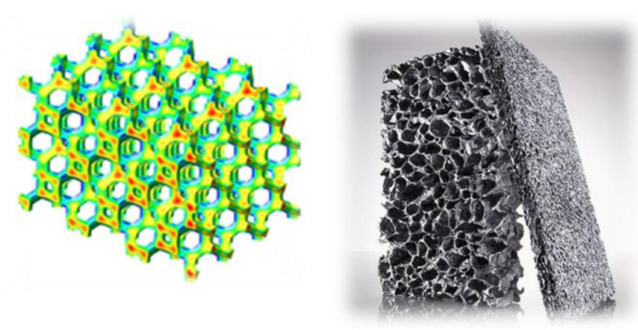

Figure 1-metal foam structure

As mentioned, the material used to make the wheel structurally must be able to withstand high humidity and temperature between 50 and 120 degrees Celsius and even more to repeat in a short period of time. The adsorbent used in this research is a suspension of a combination of chemicals including sodium sulfate with aluminum sulfate as well as sodium silicate with magnesium sulfate. The substrate used for absorbent, can be mineral/organic materials or non-organic fibers such as fiberglass and paper or metals such as aluminum mesh.

Various techniques are used to place (combine or load) the adsorbent layers on the substrate are Covering, Fertilization and IN-SITU synthesis. The first two methods are use in placing ready-made desiccant powder on the bed and the in situ synthesis method is used for cases such as silica and metasilicate. In this research moisture absorbing material is created by in situ method and then impregnated with oxidizing or reducing acid or alkaline materials for special purposes (removal of gases and odors) [9].

The stages of composition of absorbent materials and its layering on metal foam were as follows respectively.

- Use ready- made aluminum foam.
- Contact of the base material (aluminum foam) with a neutral grade sodium silicate solution
- Dip the dried plate in the previous step into the solution of the metal salts such as aluminum sulfate to form hydrogels.
- Rinse with water to remove excess material from the piece
- Drying gel matrix produced
- Create specific properties
- Final drying

Figure 2-materials are used for make wheel's base material

III. DESIGN AND MANUFACTURE OF LABORATORY SAMPLES OF ROTATING DEHUMIDIFICATION PACKAGE

In this research first using a humidifier including pumps and fog nozzles the air humidity of a galvanized sheet tank with a volume of 5 cubic meters is saturated and then the fan is turned on. The wet air is sucked into the package. Rotating dehumidification is done. In the next step the humidity level of the inlet air to the system is measured again using the sensor located at the entrance of the wheel. In this example, first, using a dehumidifier including pumps and nozzles, the air humidity of a tank made of galvanized sheet with a volume of 0.5 cubic meters is saturated, Then when the fan is turned on, the wet air is sucked into the rotating dehumidifier package. In the next step, the humidity of the inlet air to the system is measured again using the sensor located at the inlet of the absorber wheel. Then, as the air passes through the adsorbent plates, which are placed parallel to the wheel, the second sensor, which is installed right at the exit of the wheel, measure the humidity of the air leaving the wheel.

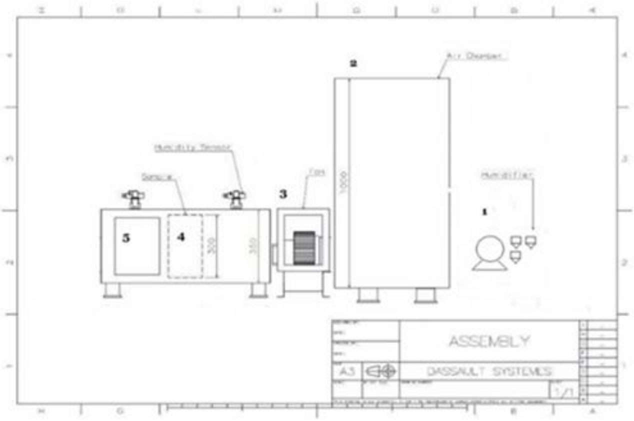

Figure 3-schematic of package component

The five component of system that presented above are:

- Moisture source
- Wet air storage compartment
- Supply and fan air intake chamber
- Laboratory sample
- Supply air outlet and recovery air inlet

IV. TEST AND RESULT ANALYZING

In this experiment variables such as supply air inlet, fan speed, percent of moisture absorption, wheel rotation velocity have been selected and investigated. The fan installed in the system has a maximum power of 1250 rpm and a minimum of 200 rpm. In the first stage of the experiments, two constant parameters were considered and the fan speed was considered as a variable from 200, 400, 600 and 800 rpm. In these experiments, the pump, fan and heater were switched on. As the moisture from the bottle containing distilled water was added to the tank, the humidity was measured. After reaching the steady state, the number shown in the humidity sensor is recorded and then the amount of moisture in the inlet air is measured after suction of the fan. Due to the fact that in the distance between the outlet nozzle of the chamber with humid air and the suction fan distillation is performed and the humidity is reduced. Humidity difference was also measured after reaching stable at the wheel inlet. The first stage of experiment and results are shown in figure as follow.

Table 1-stage and results of the first part of the test

Fan velocity per minute	Chamber's humidity	Percentage of relative humidity input	Percentage of relative humidity output	Temperature in degree's Celsius	Difference between input and output humidity of air flow
200	89.8	79.1	39.00	20.0	40.0
400	85.2	80.0	33.00	23.0	47.0
600	79.6	60.9	41.7	18.5	20.0
800	84.4	67.00	46.00	17.3	19.0

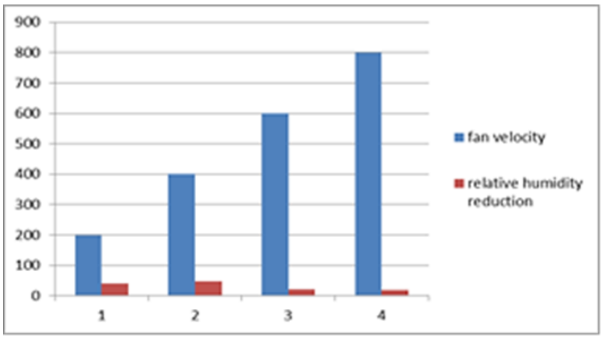

Figure 4-moisture absorbed based on the fan speed

As can be seen in figure 5 in tests performed with variable fan speed the highest moisture absorption rate occurred, When the fan velocity is set at 400 rpm. In this test the humidity has reached from 80% of the relative humidity to 33% of it. So in general the moisture absorption rate has been reported to be 47%. According to published reports on the efficiency of devices with similar function this amount of moisture absorption is desirable. In other test performed with a fan velocity of 800,600 and 200 the moisture absorption rate was reported to be 19, 20 and 40% of the relative humidity. Respectively due to the fact that the moisture absorption rate when the fan velocity was 200 (rmp) compared to 600 and 800 rpm. The difference is less than the maximum moisture absorption (400rpm). Therefore it can be seen that the device shows better efficiency in period with lower fan speed. In another comparison between the process temperature and amount of moisture absorbed by the wheel the following diagram (figure 8) was obtained.

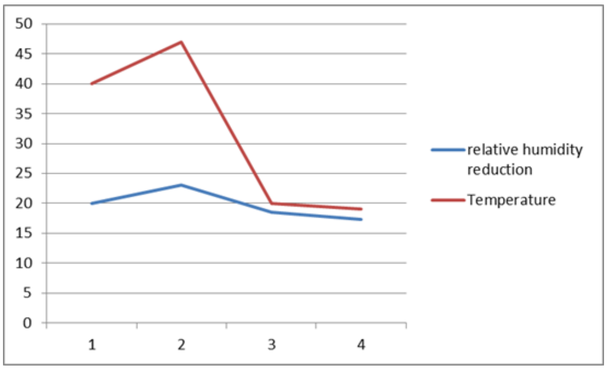

Figure 5-moisture absorbed by temperature

The rate of moisture absorption has also increased with increasing process temperature, which is a decreasing trend is wheel revival at lower temperatures, leading to a decrease in absorption efficiency. This is obvious as increasing the moisture content of the wheel during dehumidification, that's efficiency reduced. In the second stage of experiment, the fan speed was considered as the constant and rotational speed of wheel is variable. According to the results of the previous stage tests with rotation speed of the fan on 400 rpm, we observed the best moisture absorption rate. In the second stage, this velocity was selected as the constant speed of the fan. in this stage, the rotation of the wheel was set as a variable on the numbers 3, 6 and 12 rpm. It should be noted that in the first series of tests, the rotational speed of the dehumidifier wheel was constant at 6 rpm. The results of the second series of experiments are shown in table presented below.

Table 2-results of the second series of experiments

Wheel rotational speed per minute	Chamber's humidity	Percentage of relative humidity input	Percentage of relative humidity output	Temperature in degree's Celsius	Difference between input and output humidity of air flow
3	87.0	80.0	40.0	26.0	40.0
6	85.2	80.0	33.0	23.0	47.0
12	87.5	78.0	34.6	21.0	43.4

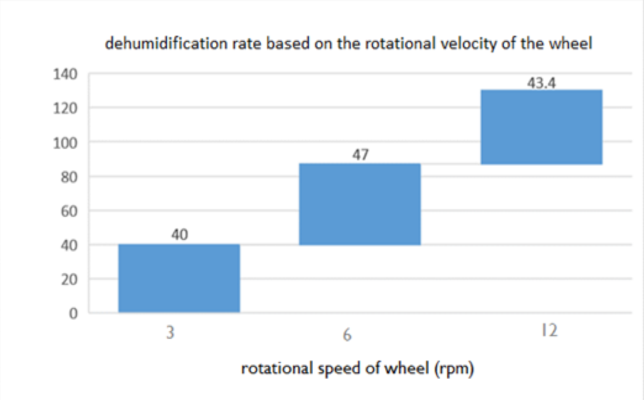

Figure 6-Dehumidification based on the rotational speed of wheel

According to the diagram and tables provided, it can be seen the best percentage of dehumidification is for 6 rpm rotation velocity of wheel. . It should be note that by increasing the efficiency the velocity of fan reduced. Another point of the result is by increasing the wheel's velocity The rate of moisture absorption is higher than the lower velocity. Obviously with the increase in fan velocity the input air to the system has increased.

It can be concluded increasing the input flow rate will be useful as long as dehumidification capacity. and by controlling the input flow rate to the system it is possible to improve the system efficiency And avoid reducing its efficiency.

V. CONCLUSIONS

- Closed cell metal foams were used due to the lack of access to the open cell type. However, as expected, it did not have a suitable porous structure but the good moisture absorption is possible.
- In the construction of the rotating dehumidifier wheel, the use of a combination of sodium silicate and aluminum sulfate as a base material in the manufacture of silica gel has created the acceptable capacity to absorb the moisture (up to 50% relative humidity).
- In metal foam coating operation by moisture absorbing compound, Metal foam absorbs silica gel as much as its mass weight. This indicates the high quality of the on-situ synthesis coating operation.
- In the construction of the laboratory sample, it is possible to achieve the desired level of moisture absorption (47% relative humidity) by carefully controlling the flow parameters such as the velocity and flow rate input, the rotational speed of the adsorbent wheel and also the process temperature.

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