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Desiccant Wheel Cooling System

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ABSTRACT

The project aims at developing a hybrid solar-assisted air conditioner system for performance enhancement and energy efficiency improvement. To increase sub-cooling of the refrigerant at partial loads, we propose a new discharge bypass line together with an inline solenoid valve, installed after the compressor to regulate the mass flow rate of the refrigerant vapour passing through a hot water storage tank. For control design, a lumped parameter model is first developed to describe the dynamics of the system in an explicit form of input-output relationship. The system has been fully-instrumented to examine its performance under different operation conditions. The system model is then validated by extensive experimental tests. The predictions from the models exhibit a good coincidence with experimental results, judging by an RMS error less than 15%. Based on the obtained dynamic model, a linear quadratic regulator (LQR) is applied to optimize a cost function of the output errors and control efforts. The key challenge is to regulate the temperature entering the condenser by controlling the valve opening. The design approach is then tested in a transient simulation tool to predict the system performance in transient conditions. The experimental results obtained from implementation with PLC demonstrate that the proposed system delivers higher system efficiency owing to the higher refrigeration effect in the direct expansion evaporator. Thus, the novel development is promising for improvement of energy efficiency, enhancement of the system performance while fulfilling the cooling demand. Consequently, between 25 and 43% of monthly electricity can be saved on average.

Keywords: Saving, Linear Quadratic Regulator, Solar-Assisted Air-Conditioner, Sub-Cooling

INTRODUCTION

Air Coolers are used in peak summer season for cooling in rooms, offices, hotels and restaurants etc. In general Air Coolers are used for cooling similar areas and desert coolers are used for larger area. Air cooler is giving the cooling air but the cooling air is with lots of moisture having in it. Because of this moisture there will be lots of humidity in the any room where we are using the air cooler. Climate control refers to the control of temperature and relative humidity in buildings, vehicles and other enclosed spaces for the purpose of providing for human comfort, health, and safety and of meeting environmental requirements of machines and technical processes. Humans are sensitive to high humidity because the human body uses evaporative cooling, enabled by perspiration, as the primary mechanism to rid itself of waste heat. Perspiration evaporates from the skin more slowly under humid conditions than under arid conditions. Because humans perceive a low rate of heat transfer from the body to be equivalent to a higher air temperature, the body experiences greater distress of waste heat burden at high humidity than at lower humidity, given equal temperatures.

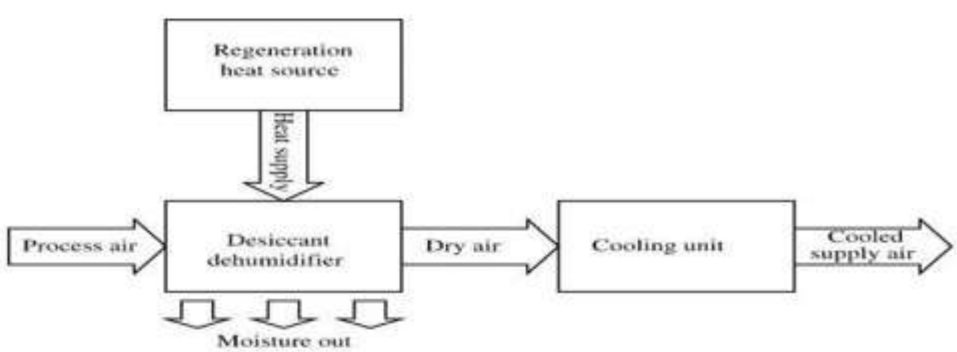


Figure 1 Principal of Desiccant Cooling

LITERATURE REVIEW

In February 2012, Armin Rudd presented ―Residential Humidity Control Strategies. According to this paper there are mainly two goals of humidity control (1) Comfort and Indoor air quality (2) Durability and Customer satisfaction. He considered conventional humidity control techniques and give limitation of it also. [1]

In March 2010, Mark Hydeman, P.E., Fellow ASHARE and David E. Swenson published a guideline ―Humidity Controls for Data Centers. According this paper the humidity must be controlled for better performance of servers. When the data and studies were studied, controlling humidity in data centers is actively difficult. The operating installed cost increase the control that reduce the reliability of data centers, and have no benefits that are in published paper or comprehensive forensic analysis. There is proof that ESD is responsible for data centers, mostly where components inside the servers are being handled. In this they conclude that effective means to prevent ESD failures. High humidity levels are seldom an issue in most data centers. [2]

In December 2013, Dr. Ayman Mohamed Afifi, High Institute of Applied Science, Egypt published a paper ―Handy Air Cooler Design to Face Rising Temperature Outside the Home. In International Journal of Scientific and Research Publication, Volume 3. In Summer Egypt hot, and to be a characteristic by weather day strong heat, which increase pain and hotter with the act of passing summer days, but a little wind refreshing and increase suffocation to the inability of most of them to go to the resorts a as result of the summer in the intense heat. The problem with this research is high temperature in summer day and shines strongly the length of the day and open spaces is difficult to control or deodorants out, causing disturbance to the people and their sense during the walk cause overheating damage for chronic diseases. This research aims to contribute to solving the difficulty of high temperature in hot areas or to minimize the effects and to design the air cooler that can be carried out during the walk in the outdoor spaces. The researchers would able to design air cooler manually to cope with rising heat in summer days and especially outside areas. [3]

In 2013 Tarunkumar Das and Yudhjit Das said that the exhaust fan and humidifier is controlled and maintain the correct humidity level for that temperature. This research work will increase the capability of fuzzy logic control system in process automation with benefits. The model consists of two fuzzy logic controllers to control the temperature and humidity respectively. In this first controller accepts the two inputs values like the current temperature as detected by temperature sensor and its deviation from user set temperature and control the speed of heat fan and cool fan accordingly. When the current temperature in the room reaches set point, it serves as one of the inputs for second fuzzy logic controller that controls the humidity. Current humidity in % as detected by the humidity sensor in the room serves as the second input to the controller. The exhaust fan and humidifier are controlled to maintain the correct humidity level for that temperature. This research work will increase the capability of fuzzy logic control system in process automation with benefits. [4]

In September 2004 K. Daou, R.Z Wang, Z.Z. Xia presented a paper on Desiccant Cooling Air Conditioning. In which they concluded the feasibility of the desiccant cooling in different climates and the advantages it can offer in terms energy and cost savings. [5] A Review Paper on ―Desiccants Cooling Systems‖ by Minalal Sahlot and Saffa B. Riffat. In this review they concluded that Desiccant cooling systems do not use any ozone- depleting refrigerants. Moreover, they can operate successfully on low-grade heat from solar energy, combined heat and power plant or waste heat from factories or chimneys. [6] A Review Paper on ―Desiccant Chart Comparisons‖ by IMPAK Corporation. In this paper the different dehumidifier‘s properties are shown and the indicating silica gel of the Dri-Box canister has been tested and identified and concluded as a best desiccant for cooling system.[7]

METHODOLOGY

In Evaporative cooling process of rooms, Cool air from direct evaporative cooling systems is usually called washed air. It enters the room in large volume at considerable velocity, circulating vigorously. This cool air on being delivered into the room absorbs sensible heat from the room's air, walls, floor and the ceiling. The washed air's sensible heat content and temperature rise accordingly. The washed air's latent heat also increases as water vapour generated in the room is absorbed. It originates as evaporation. From indoor plants, human skin or from laundering, cooking or industrial processing. While actual dehumidification will not occur, all washed air is removed by it. It induces rapid air motion which intensifies skin sensation of coolness. The comfort chart is provided i.e., for best comfort. When washed air is arisen 10 to 15 C in temperature. It is permitted to escape freely outdoors, usually through open windows or doors, but preferable i.e., through attic space, not only to flush out humidity and heat gained in the room but also to avoid built up of pressure due to continuous fan or blower operation. A rule of thumb is that 1 m of exhaust of opening (window, Went or Door) must be provided for every 70 m of air supplied. After some time, air may be sufficiently cooled by evaporating process, results in considerable increase of humidity.

Problem Definition

In cold climates, the outdoors temperature causes lower capacity for water vapor to flow about. Thus, although it may be snowing and at high humidity relative to its temperature outdoors, once that air comes into a building and heats up, its new relative humidity is very low, making the air very dry, which causes discomfort and can lead to ill health. Dry cracked skin can result from dry air.

Low humidity causes nasal passages to dry and become susceptible to cold viruses. Low humidity is a common cause of nose bleeds. The use of a humidifier in your home, especially the bedrooms can help with these symptoms. Relative humidity (RH) is the ratio of the partial pressure of water vapor to the equilibrium vapor pressure of water at a given temperature. Relative humidity depends on temperature and the pressure of the system of interest. It requires less water vapour to attain high relative humidity at low temperatures; more water vapor is required to attain high relative humidity in warm or hot air.

Indoor relative humilities should be kept above 30% to reduce the likelihood of the occupant's nasal passages drying out. Humans can be comfortable within a wide range of humilities depending on the temperature—from thirty to seventy percent. When the temperature is low and the relative humidity is high, evaporation of water is slow. When relative humidity approaches 100 percent, condensation can occur on surfaces, leading to problems with mold, corrosion, decay, and other moisture-related deterioration. Condensation can pose a safety risk as it can promote the growth of mold and wood rot as well as possibly freezing emergency exits shut.

Both desiccant dehumidifiers and mechanical refrigeration systems can remove moisture from the air, so the question is which type is best suited for a given application? There really are no simple answers to this question but there are several generally accepted guidelines which most dehumidifier manufacturers follow. Both desiccant-based and refrigeration-based dehumidification systems work most efficiently when used together. The advantages of each compensate for the limitations of the other.

Refrigeration-based dehumidification systems are more economical than desiccants at high temperatures and high moisture levels. In general, mechanical refrigeration systems are seldom used for applications below 45% RH. For example, in order to maintain an outlet condition of 40% RH it would be necessary to bring the coil temperature down to 30º F, which results in the formation of ice on the coil and a reduction in moisture removal capacity. Efforts to prevent this (defrost cycles, tandem coils, brine solutions etc.) can be very cumbersome and expensive.

Objective

Evaporative cooling, being used by mankind for centuries is based on a very simple principle that when a hot and dry air is allowed to pass through a desiccant wheel, the temperature of incoming air is reduced with an increase in specific humidity as some water from the wheel is evaporated taking the latent heat of vaporization from the incoming air.

India's energy demands are expected to be more than double by 2030, and there is a pressing need to develop ways to conserve energy for future generations. Thus, energy consumption can be reduced drastically by using energy efficient appliances. In India, the Union ministry of power's research pointed out that about 20-25% of the total electricity utilized in government buildings in India is wasted due to unproductive design, resulting in an annual energy related financial loss of about Rs. 1.5 billion.

Conventional heating ventilation and air conditioning systems (HVAC) consume approximately 50% of the building energy. This type of air conditioning is therefore neither eco-friendly nor sustainable. Selection of proper air conditioning system for buildings can not only help the country save electrical energy but also reduce greenhouse emissions.

1. Cost-effective cooling system that would be reliable.
2. To reduce harmful greenhouse gas emissions.
3. In extremely dry climate, evaporative cooling of air has the added benefit of conditioning the air with more moisture for the comfort of building occupants.
4. It can be used for domestic as well as industrial applications.
5. Brings in outside air and exhausts stale air, smoke, odors, and germs. Helps maintain natural humidity levels, which benefits both people and furniture and cuts static electricity.
6. Does not need an air-tight structure for maximum efficiency, so building occupants can open doors and windows.

System Description

A single stage vapour compression solar air-conditioner consists of six major components: a compressor, a condenser, an expansion device, an evaporator, a solar vacuum collector and a solar storage tank. The schematic diagram of the arrangement is shown in Fig. 1. The cycle starts with a mixture of liquid and vapour refrigerant entering the evaporator (point 1). The heat from the warm air is absorbed by an evaporator coil. During this process, the state of the refrigerant is changed from a liquid to a gas and becomes superheated at the evaporator exit. The superheat vapour enters the compressor (point 2), where the increasing pressure causes to raise the refrigerant temperature. A vacuum solar panel installed after the compressor uses the sun radiation to heat up the water. An insulated water storage tank is connected to the vacuum solar collector to maintain the water temperature. The refrigerant from the compressor goes through the copper coil inside the tank and undertakes a heat exchange (point 3).The vacuum solar collector reheats the refrigerant to reach the necessary superheat temperature in order to reduce the electrical energy to run the compressor. The system is extensively equipped with sensors and data logging device as a demonstrator for green automation technologies for building HVAC [Ha, 2012]. However, the refrigerant temperature that results from the smaller compressor is 5 to 10 degrees less than what is required for the condenser heat rejection to be effective; this shortfall is made up by an additional heat input from solar collectors. At this point, the high pressure superheated gas travels to the condenser for heat rejection to the ambient air. A further reduction in temperature happens in the condenser and causes it to desuperheat; thus, the refrigerant liquid is sub-cooled as it enters the capillary tube. The high pressure sub-cooled refrigerant flows through the capillary tube, which reduces both its pressure and temperature. A disadvantage of this approach is that the storage tank tends to increase the refrigerant vapor temperature entering the condenser at any time, even under partial load conditions where there is no benefit.

In fact, under certain conditions, this can even reduce performance, as the condensing temperature is not constant, but influenced by changes in the ambient air temperature. For optimum performance, the refrigerant temperature at the condenser inlet can be lower at partial loads than it needs to be at full load. For this reason, a new discharge bypass line together with its two-way on/off solenoid valve is installed after the compressor to regulate the refrigerant mass flow rate [Ha and Vakiloroaya, 2012]. Therefore, the solenoid valve can adjust the temperature of the refrigerant entering the condenser. During a high cooling demand when the condensing temperature is high, the solenoid valve is closed, directing the refrigerant vapor from the compressor into the copper coil inside the storage tank, where it acquires additional heat from the hot water. The decrease of the refrigerant temperature entering the condenser leads to a reduction in the refrigerant temperature leaving the condenser. This means a more substantial sub-cooling at the outlet and therefore a reduction of the refrigerant temperature entering the evaporator. This the system refrigeration effect and thereby its coefficient of performance. The following section describes the mathematical model for system components for the control purpose, by applying the energy and mass balance to obtain a lumped-parameter moving-boundary dynamics of the system.

Solar open-loop Air Conditioning using desiccants

Air can be passed over common, solid desiccants(like silica gelor zeolite) or liquid desiccants (like lithium bromide/chloride) to draw moisture from the air to allow an efficient mechanical or evaporative coolingcycle. The desiccant is then regenerated by using solar thermal energyto dehumidify, in a cost-effective, low-energyconsumption, continuously repeating cycle.[4] A photovoltaicsystem can power a low-energy air circulation fan, and a motor to slowly rotate a large disk filled with desiccant.

Energy recovery ventilationsystems provide a controlled way of ventilating a home while minimizing energy loss. Air is passed through an "enthalpy wheel" (often using silica gel) to reduce the cost of heating ventilated air in the winter by transferring heat from the warm inside air being exhausted to the fresh (but cold) supply air. In the summer, the inside air cools the warmer incoming supply air to reduce ventilation cooling costs.[5] This low-energy fan-and-motor ventilation system can be cost-effectively powered by photovoltaic, with enhanced natural convectionexhaust up a solar chimney- the downward incoming air flow would be forced convection (advection).

A desiccant like calcium chloridecan be mixed with water to create an attractive recirculating waterfall, that dehumidifies a room using solar thermal energy to regenerate the liquid, and a PV-powered low-rate water pump. [6]

Active solar cooling wherein solar thermal collectors provide input energy for a desiccant cooling system. There are several commercially available systems that blow air through a desiccant impregnated medium for both the dehumidification and the regeneration cycle. The solar heat is one way that the regeneration cycle is powered. In theory packed towers can be used to form a counter-current flow of the air and the liquid desiccant but are not normally employed in commercially available machines. Preheating of the air is shown to greatly enhance desiccant regeneration. The packed column yields good results as a dehumidifier/regenerator, provided pressure drop can be reduced with the use of suitable packing.[7]

Desiccant cooling systems

Desiccant cooling systems are basically open cycle systems, using water as refrigerant in direct contact with air. The thermally driven cooling cycle is a combination of evaporative cooling with air dehumidification by a desiccant, i.e., a hygroscopic material. For this purpose, liquid or solid materials can be employed. The term 'open' is used to indicate that the refrigerant is discarded from the system after providing the cooling effect and new refrigerant is supplied in its place in an open-ended loop. Therefore, only water is possible as refrigerant with direct contact to the surrounding air. The common technology applied today uses rotating desiccant wheels, equipped either with silica gel or lithiumchloride as sorption material.

Cad drawing.

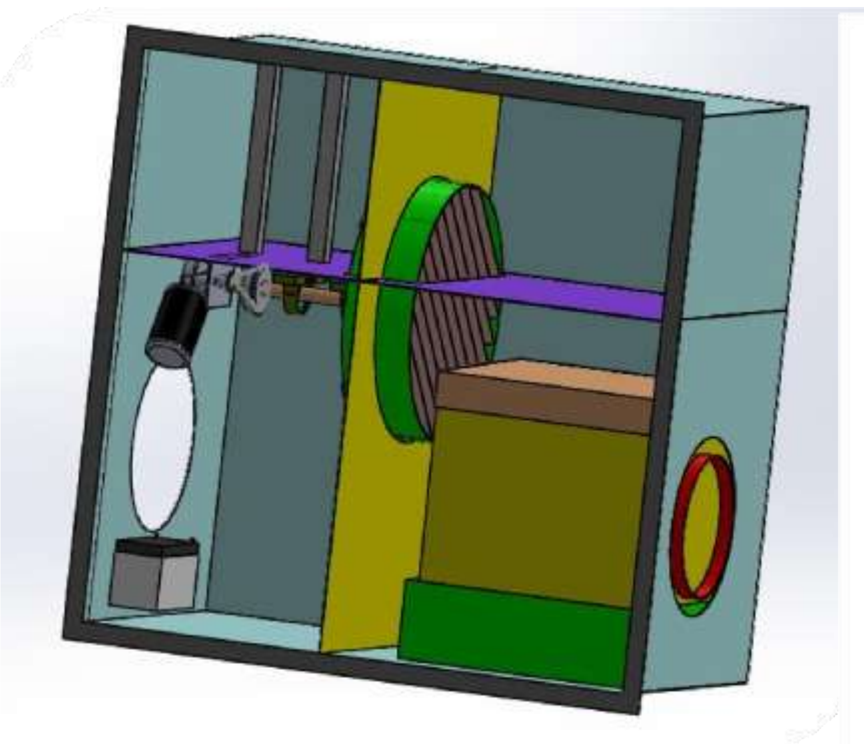
Procedure

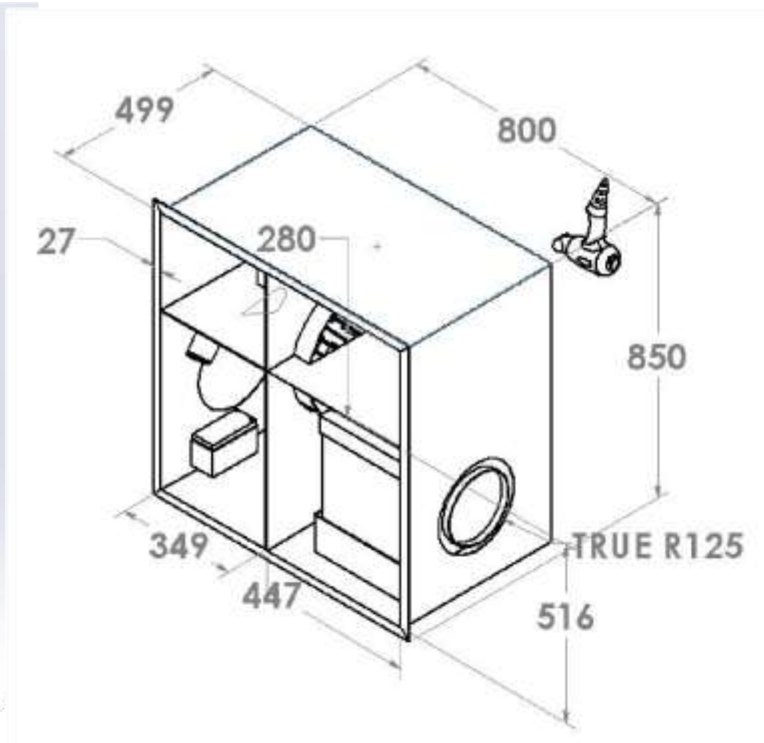
- The entire model has been designed with the help of designing software solid works.
- With the help of colour feature the colours are given to the entire model.

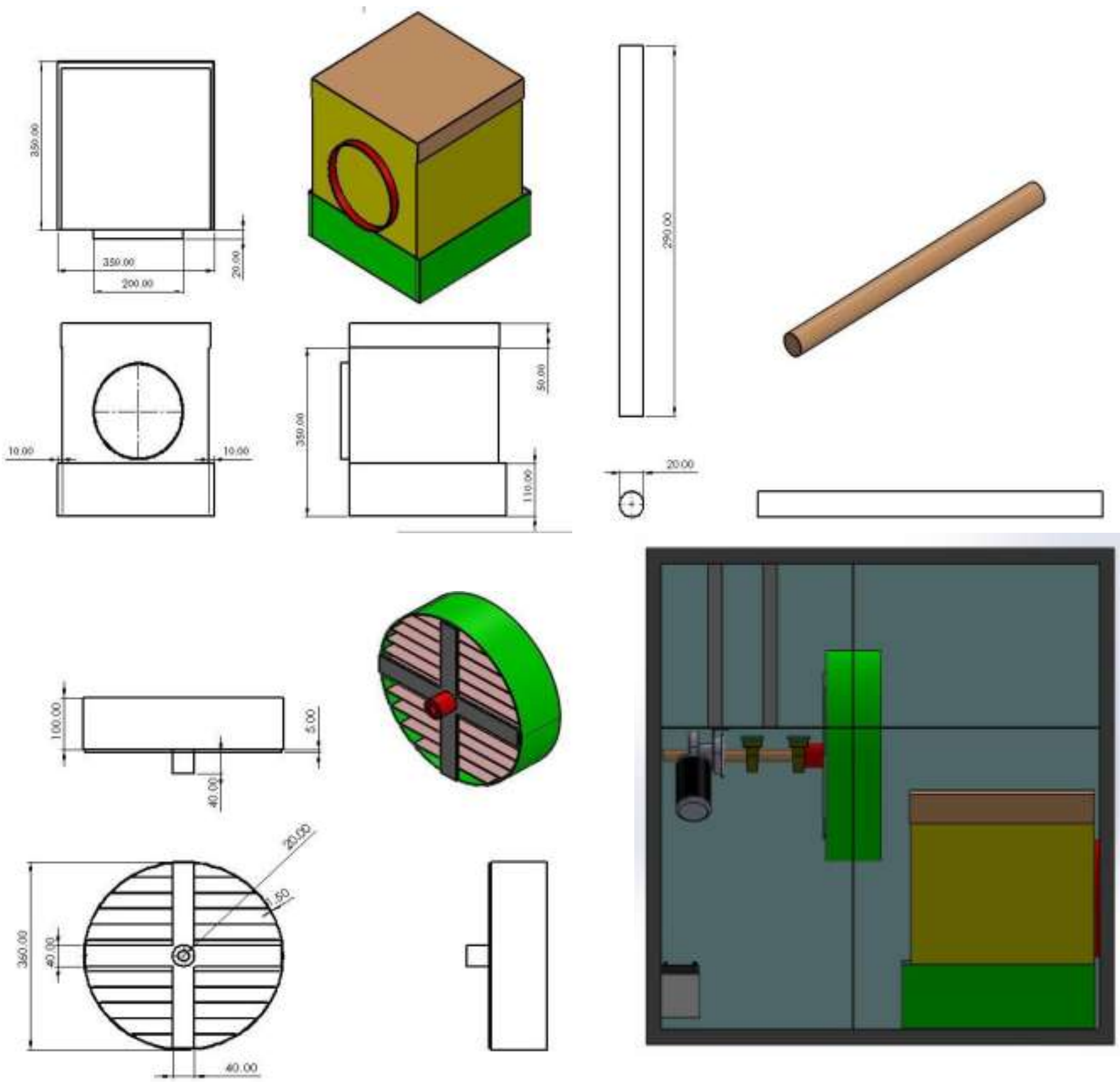
Figure- Cad model of the assembled project is designed on Solid works 2023 software

SOLID MODELING

The entire model has been designed with the help of designing software solid works.







A desiccant wheel is a common type of sorption dehumidifier using asolid desiccant. It is also known as a rotary dehumidifier. The desiccant material is coated, impregnated, or formed in place on the supporting rotor structure. The desiccant wheel is called a passive desiccant wheel or enthalpy wheel or rotary energy wheel, when there is noregeneration airheater. It is called an active desiccant wheel when it is provided with an air heater and the regeneration and process air side are separated by clapboard. The wheel is installed withthermal insulationand air-proof material, so no mass and energy exchange takes place with the surroundings

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4.3 Raw Material & Standard Material

Table 2 Bill of Material

SR NO	PART NAME	MAT	QTY
1	SHEET METAL	MS	2 SHEETS
2	EVAPORATIVE COOLER	STD	1 NOS
3	SHAFT DIA 20 MM	MS	1 KG
4	CHAIN	SS	1 SET
5	SPROCKET	SS	2 NOS
6	HEATING BLOWER	STD	1
7	DESSICENT WHEEL	STD	1 NOS
8	BEARING	CI	2 NOS
9	SOLAR PANEL	STD	1
10	NUT BOLT WASHER M 10	MS	20 NOS
11	BATTERY	STD	1 NOS
12	PMDC MOTOR	STD	1 NOS
13	SILICON BEEDS	SI	250 G
11	MS ANGLE	C-45	10 KG
12	WIRE	CU	4 M
13	MISCELLINOUS	-	-

4.4 Time Plan

F.Theory of Direct Evaporative Cooling

Evaporative cooling is considering as an adiabatic system therefore the process therefore occurs at constant enthalpy. The cooling of air is the result of transferring the sensible heat of air to the evaporated water carried by with the air and this sensible heat is transferred in the form of latent heat. The latent heat required to evaporate the water carried with the air, when it is passing through a spray of water is taken from the sensible heat of air. The constant enthalpy adiabatic evaporative cooling is represented on psychometric chart as Point 1 represents the condition of ambient air and point 2 is the condition of air leaving the evaporative cooler as the system in adiabatic cooling. Sensible heat lost by air = latent heat given by air

Cp (T1-T2) = hfg (w2-W1)
Cp -------- Specific heat of moist air (0.244)
T1 = T2 ----- Dry bulb temperature of air entering and leaving the cooler.
Hfg ---------- Latent heat of evaporisation of water at T2
W1 =W2 ---------- Specific humidities of air before entering and leaving the cooler.

Higher drap in dry bulb temperature (T2-T1) is possible with greater increase in specific humidity (W2-W1). The maximum outlet specific humidity is limited to W2 shown by point 3. The evaporative cooling for same dry bulb temperature of outdoor air is much more effective if relative humidity of air is lower. The point is cleared as shown below. The low relative humidity of air is much more preferable for evaporative cooling. The maximum drop in temperature of air with evaporative cooling is 18 c when the outdoor temperature is 40 c and relative humidity 20 c.

Following points should be noted in case of evaporated cooling: -
There is transfer of sensible heat of air into the latent heat of water, so total heat of air remains constant.
Wet bulb temperature is constant, dry bulb temperature decreases and dew point rises.

The initial water temperature in evaporative cooler has no effect of the efficiency of the cooler because heat involved in cooling 1 kg of water to the wet bulb is less than 5 kcal, while the heat of evaporation of 1 kg of water is of the order of 540 kcal.

If the water enters the collar at temperature lower than W.B.T. of air. Then it is first warmed to the W.B.T. and then evaporates. It the water enters at a temperature higher the W.B.T. of air then it is first cooled to the W.B.T. and then evaporates.

Working

COOLING PROCESS & EXPERIMENTATION INVESTIGATION

Evaporative cooling process in rooms: -
Cool air from direct evaporative cooling systems is usually called washed air. It enters the room in large volume at considerable velocity, circulating vigorously. This cool air on being delivered into the room absorbs sensible heat from the room's air, walls, floor and the ceiling. The washed air's sensible heat content and temperature rise accordingly. The washed air's latent heat also increases as water vapour generated in the room is absorbed. It originates as evaporation. From indoor plants, human skin or from laundering, cooking or industrial processing.

While actual dehumidification cannot occur, all washed air is removed by it. It induces rapid air motion which intensifies skin sensation of coolness. The comfort chart is provided i.e. for best comfort. When washed air is arisen 10 to 15 C in temperature. It is permitted to escape freely outdoors, usually through open windows or doors, but preferable i.e., through attic space, not only to flush out humidity and heat gained in the room but also to avoid buildup of pressure due to continuous fan or blower operation. A rule of thumb is that 1 m of exhaust of opening (window, Went or Door) must be provided for every 70 m of air supplied. After some time, air may be sufficiently cooled by evaporating process, results in considerable increase of humidity.

First start the pump which sucks water from bottom tank which was already filled with water. Water goes on stationery pad which are placed on backside of two side door, through delivery pipe. After that, the exhaust fan starts & sucks the atmospheric air, which is passed through wet pad. In this process cooling is achieved by direct contact of water particles & moving air stream. In complete contact process the air would become saturated at WBT of entering air. In other words, sensible heat of air is carried by water in the form of latent heat, when it is brought intimate contact with water. After some time, air may be sufficiently cooled by evaporative process, results in considerable increase of humidity. For better effect add ice cube or chilled water in bottom tank.

Pad problems and their solutions:

The pad material slowly but surely clogs from air borne dust and water borne minerals deposited in it. The water that evaporates leaves behind its entire content of dissolved minerals. This remains in the circulation water and makes it a brine of ever-expanding concentration. Not only is the water corrosive, but also every drop of this on drying, leaves scale on its site. The addition of scale and dust reduces surface capillarity, localizes the wetting and gradually channelizes the water flow. The semi-dry areas accumulate the deposit until the air flow is blocked. The wettest area on the other hand clogs more slowly in the process increasingly channelizing water, washing away the deposits. Thus, as clogging progresses the main water sources admits the moist air, though at growing velocity resulting in sprays of water, damaging the electrical equipment inside. Pod clogging needs to be checked if good cooler performance and minimum maintenance are desired. Yearly or seasonally pad replacement is one solution, though an expensive one.

Apart from this there are two other alternatives:

1] Perpetual wetting of the fibers
2] Use of purest water

Almost all evaporative coolers operating with circulation of water and inadequate drain are bound to deliver foul odor from algae and bacterial growth in the tank and pad. These odors are predominated when the pads are partially dry at the start and shut down.

CONCLUSION

From the present investigation it is evident that for drip type evaporative cooling the performance characteristics cooling the performance characteristics can be related to the variables like and thickness and the atmospheric conditions such as humidity control and comfort. It is also possible to determine the optimum value of these design parameters but location and one needs to optimize the design parameters for corresponding outdoor conditions. The result also indicates that a considerable saving in power consumed is possible and at the same time the cooling effectiveness can be enhanced. The procedure detailed in the present study can be used to advantage in designing evaporative air cooler of larger capacity to economically cool bigger endorsers, because the various parameters can be changed with ease the approach can be employed to analyze any piece of equipment and improve its performance.

ACKNOWLEDGMENT

The preferred spelling of the word "acknowledgment" in American English is without an "e" after the "g." Use the singular heading even if you have many acknowledgments. Avoid expressions such as "One of us (S.B.A.) would like to thank ... ." Instead, write "F. A. Author thanks..." **Sponsor and financial support acknowledgments are placed in the unnumbered footnote on the first page**.

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