Design and Development of Energy Efficient Solar Regenerated Desiccant Dehumidifier

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Abstract—The indirect evaporative cooling system does not dehumidify the inlet air. This project is mainly focused on the design of the desiccant system which dehumidifies the air supplied to the indirect evaporative cooling system. The software used in this work is Catia v5. So, by application of theoretical knowledge and guidance of experts in the particular field, we will get the result in terms of reduction in humidity.

Index Terms— Catia V5 , Desiccant Wheel , Heat Exchanger , IEC.

1 Introduction

The Desiccant cooling can be an environmentally attractive alternative to conventional mechanical air conditioning. The desiccant cooling cycle contains no harmful synthetic refrigerants and it can be driven by low greenhouse gas emissions solar or low grade waste heat sources. This enables the displacement of fossil fuel derived electricity that would otherwise be used in a conventional system. In addition to greenhouse gas emissions savings, thermally driven desiccant cooling can potentially reduce peak electricity demand and associated electricity infrastructure costs. Compared with other thermal cooling technologies, desiccant cooling appears to have potential for significant cost reduction. It contains only a small number of simple, robust components, there are no dangerous materials, it operates at atmospheric pressure and the control system is relativity straight forward. However, key challenges facing developers include:-

a. Minimizing parasitic electricity consumption.

Recent experience with thermal cooling applications has shown that parasitic electricity consumption from fans and other ancillary equipment can be significant compared with those for conventional air conditioners. Indeed if the parasitic electricity consumption of the thermal cooling system is not significantly less than the total electricity consumption of a conventional system, then there is no justification to change from the existing technology. Desiccant cycle selection and flow optimization are important opportunities for minimizing electricity consumption at the design stage.

b. Cost reduction.

Thermal cooling technologies generally incur higher initial cost than the equivalent conventional system. Cost reduction potential can be achieved through simplified cycle selection, size reduction and increasing thermal efficiency. The latter is particularly important where capital intensive solar collectors are used to provide the required heat. Size reduction can be achieved through optimizing air flow-rates and velocities.

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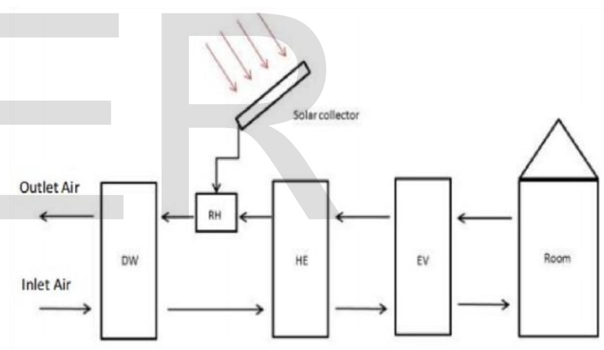


Fig.1.3 Simple Dehumidification System Block Diagram

In above figure;
DW= Desiccant wheel
HE= Heat Exchanger
EV= Evaporative Cooler
RH= Regenerative Heater

2 PROBLEM STATEMENT:

The desiccant wheel has been design to ensure the moisture or humidity will be under control. Most of the humidity will be cause by the nature; for example according to weather forecast website in Malaysia the humidity level is around 60% while in South America region is about 40% based on weather forecast. From literature survey it has been found that humid air decrease efficiency of indirect evaporative cooling system. Electric consumption is more in conventional air conditioning systems as compare to desiccant dehumidified system. There are several health problem caused by humid air. Thus this project is undertaken to design desiccant wheel which is energy efficient to control the humidity level together with saving the energy to operate this system.

3 OBJECTIVE:

The main purposes of this project are listed below:

1. To understand the Physics (mechanics) of Desiccant Wheel based dehumidification system.

2. To create CAD model of Desiccant Wheel dehumidification system.

3. To predict the variation of input variables on the performance of Desiccant Wheel through created model.

4 LITERATURE SURVEY

Avadhesh Yadav, Laxmikant Yadav[1] Comparative performance of desiccant wheel with effective and ordinary regeneration sector using mathematical model. Objective is to conduct a comparative performance of desiccant wheel with effective and ordinary regeneration sector. For all the given rotational speeds of desiccant wheel the moisture removal for effective regeneration sector is better as compared with ordinary regeneration sector. At low speed of rotation, effect of effective regeneration sector is less and it increases within crease in rotational speed of desiccant wheel.

Gholamreza Goodarzia, Neelesh Thirukonda[2] Performance evaluation of solid desiccant wheel regenerated by waste heat or renewable energy. Performance of solid desiccant wheel is evaluated and affecting factors consisting of air humidity ratio, regeneration process and air process temperatures, mass flow rates, and wheel revolution are investigated. From this it is realized that increase in wheel speed to 25 RPH is considerably effective to promote MRC and this positive influence is decreased in speeds above 25 RPH.

Yasin Khan, Gaurav Singh, Jyotirmay Mathur, Mahabir Bhandari, Prateek Srivastava[3] Performance Assessment of Radiant Cooling System Integrated with Desiccant Assisted DOAS with Solar Regeneration. This paper describes an alternate solution for dehumidification, with the substitution of the desiccant wheel with solar regeneration in place of a chilled water coil based dehumidifier. Energy savings are achieved due to modification in the ventilation cycle. This paper describes the feasibility of solar integration with the radiant cooling system to regenerate the desiccant wheel which is installed in DOAS. Chilled water coil and rotary desiccant wheel based dehumidification.

ARFIDIAN RACHMAN, SOHIF MAT, TAIB ISKANDAR[4] Solar Air Conditioning System Using Desiccant Wheel Technology. A new design of desiccant cooling is being developed at the Solar Energy. The new conception of desiccant cooling can be an energy saving and permits to produce heat or cool by using solar energy without polluting the environment. Rotary desiccant air conditioning is a typical thermally activated technology, which mainly consumes low grade heat sources as solar energy, district heating, waste heat, etc., thereby alleviating the peak electric demand caused by traditional air conditioning systems.

Stefano De Antonellis, Cesare Maria Joppolo, Luca Molinaroli[5] Simulation, performance analysis and optimization of desiccant wheels. The optimization of air handling units based on desiccant wheels instead of conventional components is complex and it requires adequate simulation tools. In this desiccant wheels performance and optimization are investigated. The analysis is carried out through a one-dimensional gas side resistance model which considers developing temperature and velocity profiles along the channels. A one-dimensional GSR desiccant wheel model which solves heat and mass transfer equations is developed and good agreements between simulations and experimental data are achieved. The validation is done in a wide range of working conditions and sorption wheel configurations.

Bhatu Borane, Dr. V.H. Patil[6] Thermal Investigation of Solid Desiccant Wheel based Dehumidification used in Air Conditioning. A description of the principle operation for solid desiccants and different types of desiccant materials is given first. For best performance, the wheel must be rotated at an optimum speed.

N.M. Kattab, M. Fouad[7] Evaluation and optimization of solar desiccant wheel performance. A numerical model is developed to study and discuss the effect of the design parameters such as wheel thickness, wheel speed, and regeneration to adsorption area. The wheel can be designed with an average regeneration fraction area of about 0.8 and 0.3 at regeneration temperatures of 60 and 90 degree.

Giovanni Angrisani, Francesco Minichiello, Carlo Roselli[8] Experimental analysis on the dehumidification and thermal performance of a desiccant wheel. Analysis on this component is presented, with particular attention to the variation of the performance as a function of the process and regeneration air flow rates. The performance of a desiccant wheel regenerated by low-temperature thermal energy has been obtained by means of an experimental investigation carried out.

Nazri Kamsah, Haslinda Mohamed Kamar[9] Performance assessment of a solid desiccant air dehumidifier. Analysis has been carried out under steady-state conditions to investigate the effects of different operating parameters on solid desiccant wheel system performances. Examine the effects of the reactivation air inlet temperature and process air outlet velocity on the thermal effectiveness, dehumidification efficiency, and moisture removal rate of the desiccant wheel system.

5 MATERIAL SELECTION

The materials used in the project setup have been chosen according keeping in mind their viability and availability. The materials used are listed and explained below:

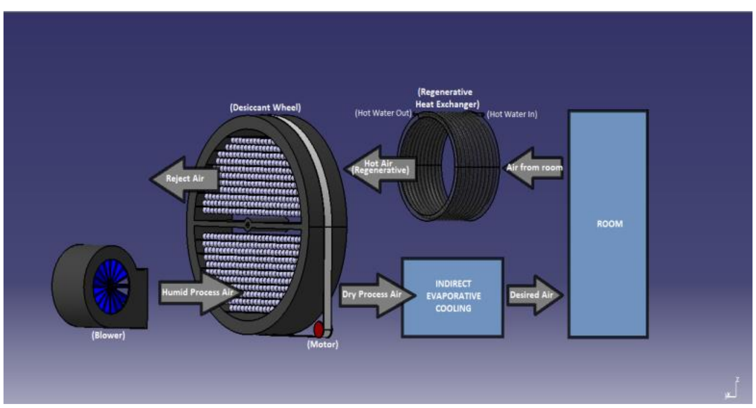
Silica gel

Silica gel is a granula, vitreous, porous form of silicon dioxide made synthetically from sodium silicate. Used as a desiccant, it works by a process called adsorption. The water in the air actually absorbs between the tiny passages as the air passes through them. If the silica gel desiccant is heated to ~180°F, it will release the trapped water. This process is called regenerating the desiccant.

6 Working

The working mechanics of desiccant dehumidifier,
Desiccant dehumidifier system consists of desiccant wheel silica gel as desiccant, blower, heat exchanger, etc. The system is divided into two sections:-
1. Cooling section
2. Regenerated section
In between this section desiccant wheel rotates at speed of 5 to 25 rph such that half part in cooling section and other in regenerated section. In cooling section we passed the air through desiccant wheel with the help of blower where all the moisture present in air is absorbed by silica gel present in it and the dehumidified air is passed to IEC to get cooled and fresh air. As wheel is rotating moisture part of desiccant wheel come into regenerated section. In regenerated section we regenerate the desiccant wheel by passing heated air (upto 70'c to 150'c) with the help of blower through desiccant wheel using heat exchanger. The moisture present in silica gel of desiccant wheel is removed and humidified air is passed to the surrounding. Thus, as wheel is rotating regenerated part of desiccant wheel come in cooling section and all the process get repeated. This cycle is continued to get fresh and dehumidified cool air.

Fig : Desiccant Dehumidification System Working



6 Dimensions

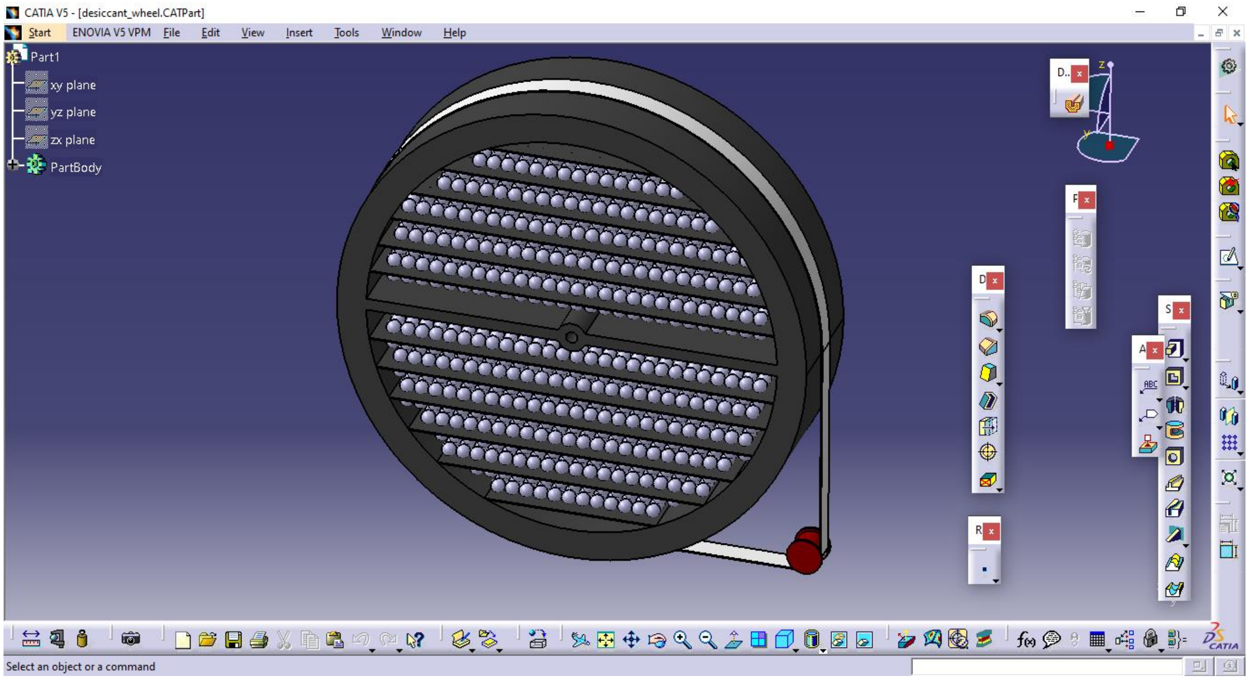
Desiccant Wheel:
  Wheel diameter: 400mm
  Wheel width: 100mm

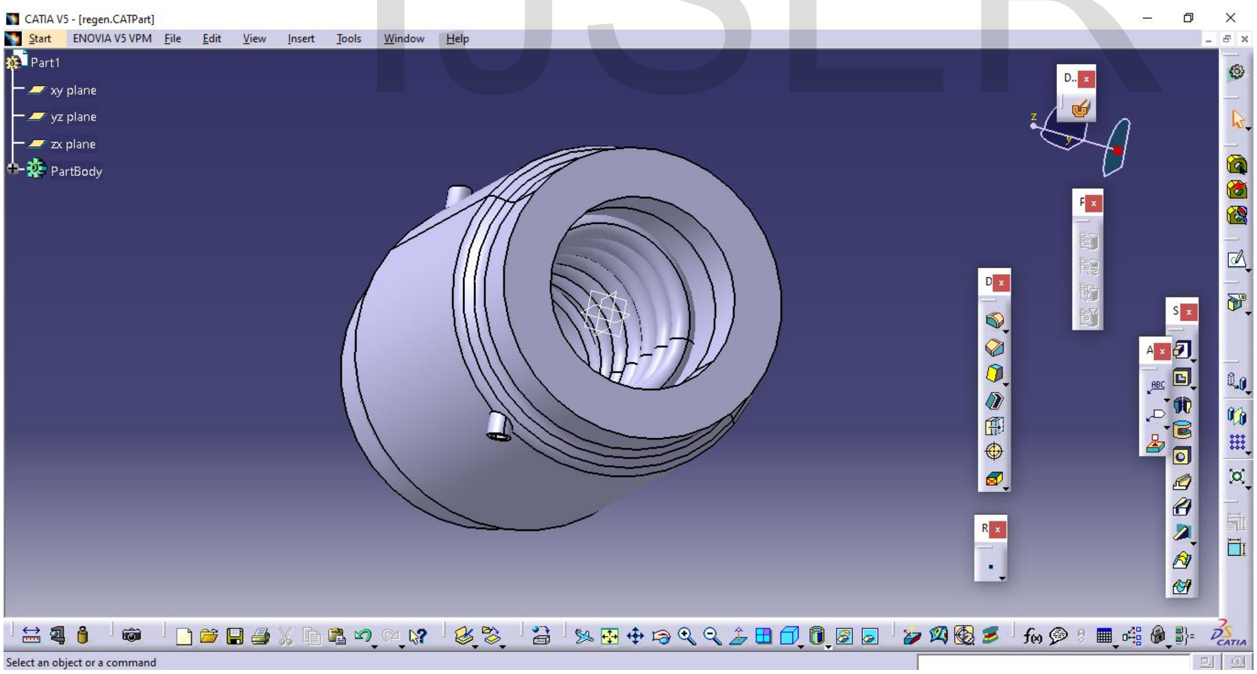
Heat Exchanger:
  Internal diameter of shell: 60mm
  Thickness of shell: 12.7mm
  Radius of coil: 20mm
  Internal diameter of tube: 4mm
  Thickness of tube: 1mm

7 Result

CAD model of Desiccant Wheel

CAD model of Heat Exchanger





Effect of parameter

1. Effect of Process & Regeneration inlet temperatures on desiccant wheel performance:-

Increasing temperature causes air vapor pressure to be decreased and adsorption potential, which is positively correlated with pressure difference between desiccant surface and air vapor pressure, goes down.

2. Effect of Process air humidity and wheel speed on desiccant

wheel performance:-
The more humid air, the higher air vapor pressure and the higher pressure difference between desiccant surface and process air.
3. Effect of Process air and regeneration air mass flow rates on desiccant wheel performance:-
Increase in process air mass flow rate provides desiccant wheel with more humid air of which moisture should be removed. More mass flow rate in regeneration process causes more moisture from desiccant to be released and its surface vapor pressure decreases.

8 Conclusion

The rate of reduction in the thermal effectiveness is slightly smaller than that of the dehumidification efficiency. Consumption of energy is less due to the use of solar system. In this study, both the thermal effectiveness and dehumidification efficiency drop as the reactivation air inlet temperature increases. The dehumidifying capacity depends on the rotational speed of the wheel. Increase in inlet air moisture increases the moisture removal capacity.

9 Reference

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