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Solar Air Conditioning System

Hitesh Thadani[1], Bhanu K. Chasta[2], Hari Om Mahiya[3], Komal Yadav[4], Mr. Chandra Mohan Kumar[5], Mr. Trivendra Kumar Sharma[6]
[1, 2, 3, 4,5,6]*Swami Keshvanand Institute of Technology, Management and Gramothan*

Abstract: Rotary desiccant wheel are used to regulate the relative humidity of air streams. These are commonly integrated into heating ,ventilation and air conditioning unit to reduce the relative humidity of incoming ventilation air. Passive ventilation system are able to deliver adequate ventilation air but cannot control the humidity of the incoming air. To overcome this, the honeycomb water structure of rotary desiccant wheel was redesigned. In addition to this, the temperature of the regeneration air for desorption was lowered. Cooling pads were introduced in between the spokes of the wheel and filled with silica gel particles to form a rotary desiccant wheel. Computational fluid dynamics (CFD) model of the design was validated using experimental data.

I. INTRODUCTION

Up to 50 percent of a person time is spent to indoors in a closed environment. This means that the indoor conditions to which occupants are subjected must confirm to comfort demands. Thermal comfort good air quality to maintain health, reliability and control of the system are all key to delivering satisfactory internal conditions for occupants. Mechanical HVAC system are capable of delivering necessary conditions but contribute a significant amount of greenhouse gas to the climate and account for 40 percent of the global energy consumption. The relative humidity of incoming supply air can have a significant impact on the energy consumption of the HVAC system. Rotary desiccants wheels are energy recovery heat exchanger that operate with regard to relative humidity reduction and are often utilized in mechanical air conditioning system.

A new and previously untested, structure for rotary desiccant wheel was conceptualized, designed and tested to achieve these aims. By replacing the traditional sinusoidal have matrix structure of the desiccant wheel termed as cooling pad design was analyzed using experimental testing to validate CFD models for the same geometry.

II. PREVIOUS RELATED WORK

Factors include the type of desiccant used ,the amount of desiccant used ,the rotation speed of the wheel ,the depth of the wheel and the structure of the matrix have been worked on earlier .

Though maximizing the amount of desiccant within the rotary desiccant wheel leads to maximum moisture transfer, the structure design and depth of the matrix results in the high pressure drop in the airstream. The high pressure drop in the incoming airflow results in inadequate ventilation rates to the building. Additional high powered fans are installed in mechanical HVAC system to overcome the high pressure drop. The regeneration temperature to which the exhaust air is raised to is another places which require high energy demands for successful operation of the system. The typical air regeneration temperature required for desorption of the silica gel takes place can be as high as 120 degree C. Therefore this week will coadress the current research gap by investigating a new design of rotary desiccant wheel into passive ventilation and ensuring that the system can supply the required fresh air rates while maintaining the dehumidification.

III. DESIGN OF A ROTARY DESICCANT WHEEL

The geometry of the cooling pads design was limited by the constraints of the equipment used for the construction of the experimental design. The external wheel diameter was 250 mm with a depth of 60 mm. An inner diameter of 20 mm was made to allow to be inserted about which the wheel could rotate. Silica gel beads will approximately 4 mm diameter were placed in between the space of the cooling pads. The outer body was covered with a fencing wire having gap of 2 Mesh. These formed the desiccant structure of the wheel.

Inlet Air Channel	Regeneration Air Channel

Before Wheel		After Wheel		Before Wheel		After Wheel	
Humidity (%RH)	Temp. (°C)	Humidity (%RH)	Temp. (°C)	Humidity (%RH)	Temp. (°C)	Humidity (%RH)	Temp. (°C)
32.70	32.00	26.20	34.20	7.10	47.90	10.20	44.60
33.33	30.80	25.81	32.31	7.04	47.98	10.20	44.14
34.23	30.00	26.74	32.47	6.80	48.79	10.64	44.37
35.71	29.00	25.98	31.83	6.70	49.03	10.83	44.28

TABLE 1
Measurement of Relative Humidity and Temperature

Outlet Air channel	
Humidity (%RH)	Temp. (°C)
27.32	25.80
26.72	25.49
27.41	25.32
26.98	25.03

IV. EXPERIMENTAL SETUP

In order to access the absorption/desorption and pressure drop properties of the rotary desiccant wheel, experimental testing was conducted. The flow through the duct work was controlled by tour 160 mm diameter, axial air fans two mounted on each end of the duct work.

Different properties were required for each of the air channel to access the characteristics of the rotary desiccant wheel, so different inputs were required for each air stream. As the regeneration air is required to be at a higher temperature and low relative humidity. Therefore, air fed in from the upper compartment passing from heat exchanger attain a maximum temperature and after passing from the wheel gets reduced. The ambient air of the laboratory was measured at 30 degree C with a relative humidity of 35 percent. Measurements of air humidity and air temperature were simultaneously taken at six points before and after the rotary desiccant wheel in both the inlet and regeneration air channel and at outlet of air channel.

V. CONCLUSION

The ability of new design of rotary desiccant wheel with cooling pads filled with silica gel to reduce the relative humidity and the pressure drop across the wheel was tested experimentally.

Adsorption of moisture in the inlet airstream up to 15 percent was noted while increasing the air temperature of the inlet air. Furthermore, constant regeneration of the desiccant material was achieved at the regeneration temperature. The result from the experiment shows that the new design of the rotary desiccant wheel has many potential that could help to significantly improve the conditions of incoming air as well as reduce energy demands for building operators. Despite the success of the design, significant more areas of research and optimization are required.

VI. ENERGY DEMAND

The demand for energy is expected to increase worldwide over the next 24 years, both in the industrial countries and particularly in the developing countries like where rapid economic growth is expected. Fig. 1 shows the energy demand for in the year 1999, 2002, 2005 and estimated values for 2010. It can be seen that the energy demand increases rapidly as the energy demand increase almost 20% within the last 3 years (from 1999 to 2002).

The energy demand is further expected to increase to 18,000MW by the year 2010. In order to meet the increasing demand of energy, a major challenge facing the power industry will be having an effective and sustainable energy policy. An effective and sustainable energy policy has two main considerations. The first consideration is to increase access to affordable, modern energy services in countries that is lacking and secondly, to find the mix of energy resources and technologies (efficiencies) that will reduce the adverse environmental impacts of providing necessary energy services. Since all the urban areas and 93% of the rural areas have access to electricity, the crucial challenge facing the power sector currently is the issue of sustainability that is to ensure the security and reliability of energy supply and the diversification of the various energy resources.

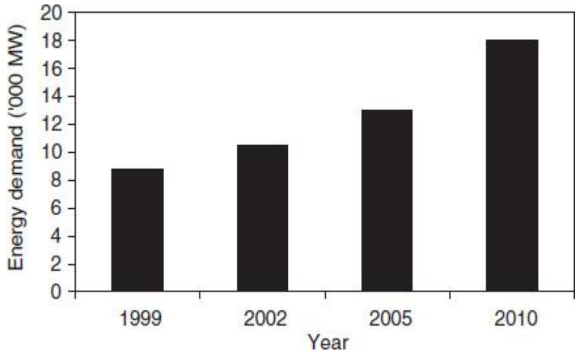

Fig.1 Energy Demand, Sources: Thaddeus (2002) And Uk Trade & Investment (2003)

The question of security and reliability of supply is critical, to ensure smooth implementation of development projects to spur economic growth while diversification of energy resources is critical to ensure that the country is not dependent only on a single source of energy. At the same time, these challenges must be met without having adverse effect on the environment to ensure sustainability. Therefore, the aim of this paper is to describe the various energy policies adopted to ensure long-term reliability, sustainability and security of energy supply. The role of both, non-renewable and renewable sources of energy in the current Five-Fuel Diversification Strategy energy mix will also be discussed. Apart from that, this paper will also describe the various alternative energy and the implementation of energy efficiency program .

VII. ALTERNATIVE ENERGY

A. Solar

Solar power or also known as photovoltaic (PV) system is estimated to be four times the world fossil fuel resources [7]. , the climatic conditions are favorable for the development of solar energy due to the abundant sunshine throughout the year. The solar radiation ranges from 6.5 kwh/m^2 in the months of January and drops lower to 6.0 kwh/m^2 in the months of August. A PV system consists of several solar cells that convert light energy into electricity. Photovoltaic are an elegant means of producing electricity on site, directly from the sun, without concern for fuel supply or environmental impact. Solar power is produced silently with minimum maintenance, no pollution and no depletion of resources. Photovoltaic system are also exceedingly versatile and can be used to pump water, grind grain and provide communications and village electrification in situations where no electricity is available. At the moment, the utilization of solar power or PV system is only limited to solar water heating systems in hotels, small food and beverage industries and upper middle class urban homes. It was estimated that there are more than 10,000 units of domestic hot system using PV system at the moment. Although PV system has tremendous potential, especially for remote areas, the cost of PV panels and technology is still too expensive for mass power generation. In order to reduce the cost of PV system Energy Center (PTM) embarked on a project named Building Integrated Photovoltaic(MBIPV). The aim of the project was to incorporate PV system into the design of the building and become the main-stream of power production for the building. However, a cost reduction of 20% is required before PV system can become a viable source of energy as compared to the energy produced from fossil fuels or natural gas .

B. Desiccant Cooling

Desiccant cooling consists in dehumidifying the incoming air stream by forcing it through a desiccant material and then drying the

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air to the desired indoor temperature. To make the system working continually, water vapour adsorbed/absorbed must be driven out of the desiccant material (regeneration) so that it can be dried enough to adsorb water vapour in the next cycle.

This is done by heating the material desiccant to its temperature of regeneration which is dependent upon the nature of the desiccant. A desiccant cooling system, therefore, comprises principally three component, namely the regeneration heat source, the dehumidifier (desiccant material), and the cooling unit.

The efficiency of desiccant system depends strongly on the Sensible heat Ratio (SHR). The SHR is defined as the ratio of the sensible heat gain to the sensible and latent heat gain of the space being conditioned. A low value of this quantity means that the total cooling load is predominately the latent load, in which situation desiccant cooling is demonstrated to be effective and economical.

VIII. WORKING PRINCIPLE OF A SOLID DESICCANT COOLING SYSTEM

Solid desiccants are impregnated in a dehumidifier bed, usually a rotary disc which slowly rotates between the process and regeneration air streams. As the hot and humid process air passes through the desiccant wheel, the moisture is removed by the desiccant, and its temperature increases.The temperature of this process air, which is now hotter and drier, is reduced to the desired comfort conditions by means of sensible coolers (e.g. rotary heat exchangers, evaporative coolers, and cooling coils). The warm and humid return air from the conditioned space is further heated up to the required regeneration temperature of the desiccant and this regeneration stream of air is passed through the desiccant wheel to remove the moisture from the desiccant.

Advantages of using desiccant cooling systems include the following: (1) very small electrical energy is consumed and the sources for the regenerating thermal energy can be diverse (i.e. solar energy, waste heat, natural gas); (2) a desiccant system is likely to eliminate or reduce the use of ozone depleting CFCs (depending on whether desiccant cooling is used in conjunction with evaporative coolers or vapour compression systems since sensible and latent cooling occur separately; and, (4) improvement in indoor air quality is likely to occur because of the normally high ventilation and fresh air flow rates employed. Also, desiccant systems have the capability of removing airborne pollutants.

IX. MODELING OF THE DESICCANT AIR- CONDITIONING SYSTEM

Performance of a desiccant system for space air- conditioning depends to a group of parameters and/or conditions, implicating the system's operation parameters, environmental conditions and space requirements. The development of models is necessary tool for the study of the relation of the above-mentioned parameters, on a design, control strategies, as well as performance analysis basis.

The modeling of the desiccant system, for presented in Fig.2, refers actually to integration of models of individual's components of the system (desiccant wheel, rotary heat exchanger, and humidifier.

Figs. 2 and 3 show a schematic installation of the solar desiccant cooling system and the air evolution in the psychometric chart. In order to maximize the effect of the latent heat of vaporization of water, the ventilated air flow is first of all dried out in a "desiccant wheel" [A→B]. It is next cooled in a sensible heat exchanger (recovery wheel) [B→C] and at last cooled down adiabatically [C→D through a humidifier. The operating of such a system necessitates a regeneration air flow. The air is first extracted from the building, then after being cooled down adiabatically [E→F] in a humidifier, it cools the air of the process in the recovery wheel [F→G]. The last operation is to regenerate the desiccant material [H→J] with the return air stream that has been heated [G→H→I]. The generation heat can be taken from solar collector's back-up energy, via a storage tank.

The required temperatures are in between 50 and 85°C and therefore vacuum tube solar collectors can be used. The desiccant air-conditioning system is open cooling cycle, which means that the refrigerant fluid is the ambient air. That is why the outdoor and indoor air conditions influence strongly its operation. The operation principle of the desiccant wheel, the dehumidifying capacity of the wheel depends to the rotational speed of the wheel, flow rate (actually the velocity of air in the face of the wheel) and the temperature of the conditions (temperature, absolute humidity), as well as to the absolute humidity of the regeneration stream.

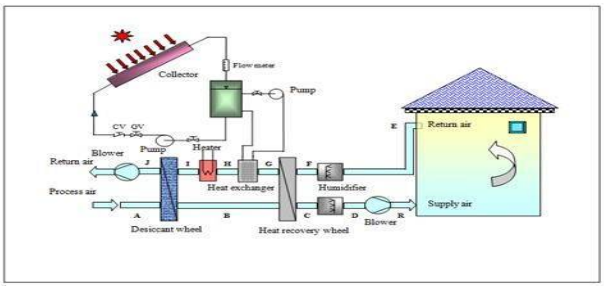

Fig. 2 schematic of the solar air conditioning system using desiccant wheel.

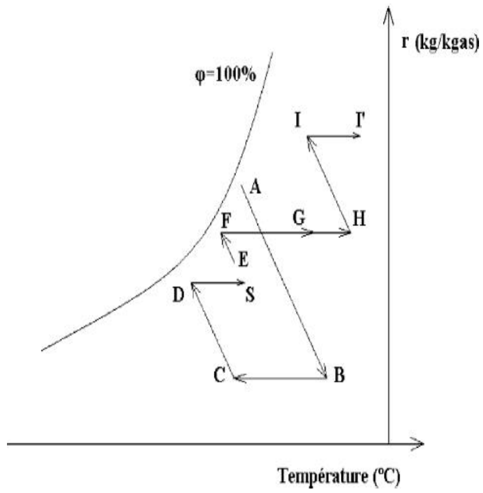

Fig.3 Cycle's Psychometric Representation

X. ECONOMIC ISSUES

All solar air cooling technologies (SAC) system present good figures for primary energy consumption. The best performance are seen in system with integrated heat pumps and small collector areas. The economics of these SAC system at current equipment costs and energy prices are acceptable. They become more interesting in the case of public incentives of up to 30% of the investment cost (Simple Payback Time from 5 to 10 years) and doubled energy prices [1].

XI. CONCLUSION

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. Especially, based on the recent progress in desiccant material and system configuration, more and more practical applications have been implemented around the world. While the most widely used desiccant materials in market, namely silica gel and lithium chloride, are either limited by dehumidification capacity or problematic for crystallization and corrosion, composite desiccants combine the merits of existing desiccants and overcome these problems by confining salt to porous host adsorbent, and have been recognized as a better choice. Additionally, the reduction in regeneration temperature and the increment in dehumidification capacity over a wide range will be of great benefit to utilizing low- temperature heat and expanding the application of desiccant air conditioning.

The majority of existing rotary desiccant air conditioning systems originates from the typical basic configurations, such as ventilation cycle, recirculation cycle and Dunkle cycle. And these cycles are appropriate for different applications, for example, ventilation cycle is recommended for conditioned-space with high outside air requirement, whereas recirculation cycle is suitable to space requiring much less fresh air. Besides, on the basis of the basic system configurations, some advanced technologies, namely, staged regeneration, isothermal dehumidification, hybrid desiccant air conditioning, and desiccant air conditioning producing both dry air and chilled water, have been developed and investigated to lower the reactivation requirement, ensure the operation stability, and improve the thermal utilization rate and energy saving potential. Among these technologies, staged regeneration reduces the consumption of high temperature heat by pre-heating and pre- regenerating the desiccant and is advantageous in reducing the size and effectiveness requirement of heat exchanger; isothermal dehumidification minimizes the irreversibility of dehumidification via adopting multi-stage design and intercoolers, which results in much lower regeneration temperature and less heat consumption; hybrid desiccant air conditioning is most researched due to it integrates the merits of desiccant dehumidification system and other air conditioning systems, downsizes system size and improves system performance significantly; desiccant air conditioning producing both dry air and chilled water is a novelly proposed technology using desiccant dehumidification and regenerative evaporative cooling and is worthwhile for future research for its outstanding property of realizing independent temperature and humidity control without any assistance from VAC unit.

In conclusion, further improvement in energy utilization rate, reduction in cost and size, and standardization in design and production are the key issues faced by the rotary desiccant air conditioning technology for achieving more extensive application.

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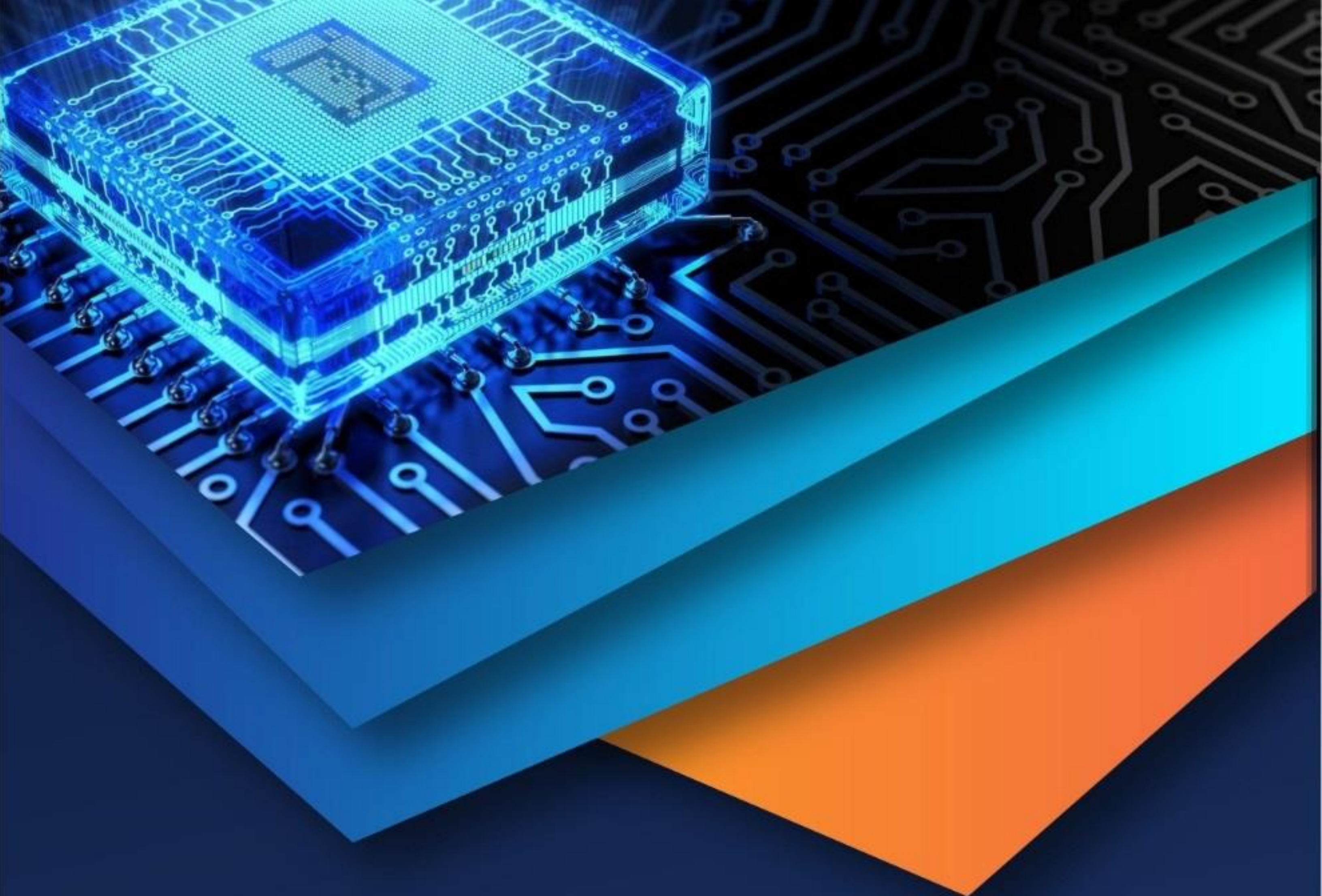

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