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Solar Assisted Desiccant Cooling System – A Critical Review

T.Venkateshan[1], N. Madhan kumar[2], P. Pandiyarajan [2], J. Praveen kumar[2], N.Elangovan[2],
[1]Assistant Professor, [2]UG Students
Department of Mechanical Engineering, Nandha Engineering College, Erode-52,
Tamil Nadu, India
[1]venkateshaneil@gmail.com , [2]elangovan030995@gmail.com

Abstract:The climatic conditions prevailing nowadays urge us to opt for a proper air conditioning system to maintain the indoor air comfortable for human being. Poor indoor air quality results in several diseases. In order to avoid this, the people go for proper air conditioning system. But the huge power consuming electrically operated air conditioning system poses to be an economic threat. This could be solved by Desiccant Cooling System result in a pollution free environment. This desiccant cooling system assisted by renewable energy source will be further helpful.Desiccant cooling system improves the overall performance of the system, particularly dehumidification and refrigeration capacity. Desiccants are of two types, solid and liquid desiccants. According to the present system we can go for the solid desiccant materials. In this work, an attempt has been made to study about the Desiccant cooling systems and their current status of development.

Keywords: Desiccant materials, Silica gel, Dehumidification.

I.INTRODUCTION

Air conditioners and Refrigerators have toxic and dangerous gases such as ammonia methyl chloride, carbon monoxide. Air conditioners and refrigerators contain potent greenhouse gases known as hydro fluro carbon (HFCs).The new research shows global emissions of HFCs have risen by more than half between 2007 and 2012.Scientists had found the gases were depleting the ozone layer, the atmospheric shield that filters the sun's harmful ultraviolet radiations from reaching the earth surface. By using HFC, emissions from 303 to 463 million tonnes of carbon dioxide equivalent between 2007 and 2012.This equates to an increase of 33 million tons per year. Developing countries are responsible for around 42% of HFC emissions, the study finds East Asian countries including china and SouthKorea, make up around a third of emissions, the research say. The researchersfound that the largest contribution of HFC-32 and HFC-125 have been highly used in air conditioning units. In developed countries, emission rose by 63% and 44% for two gases hydro fluro carbon (HFC) and chlorofluorocarbon (CFC) respectively. The same two gases HFCs and CFCs have increased by 166% and 100% in developing countries over the same period.

In order to address the issues, reduce the pollution, we can go for the desiccant cooling system. Desiccant materials like Silica gel, Bentonite, Zeolite, Superabsorbent polymers, etc. by using the desiccant materials the purpose of using the refrigerants material was restricted.

Research conducted by international institute of refrigeration in Paris led to the conclusion that the proportion of energy used by the air conditioning systems in the household and commercial buildings now accounts for nearly 45%.

The total final energy consumption in India, which was nearly 394 million tons. Power sector consumed 36% of primary energy. World average was nearly 35% in 2007 in terms of primary energy consumption in power sector. Biomass had the largest proportion of 41% followed by oil of 27% of the 12% of electricity; energy consumed in the residential sector was 21%, which is 9.93 million tons.

II. LITERATURE REVIEW

[1] Ali A.Jalalzadeh-Azar et al. (2005) had conducted the performance assessment of a desiccant cooling system in a CHP application by an IC engine. Performance of a desiccant cooling system was assessed with regards to combined heat and power (CHP). The desiccant unit was recovered through heat recuperation from a gas-let go responding inside burning motor. Cooling execution and the warm productivity, which are basic for fuel use change. The most extreme cooling limit of the desiccant cooling system wasaround 28.5 kW, happening at high temperature and humidity conditions. Accomplishing this limit required establishment of a 60-kW motor for a thermal load following CHP model. The electrical COP of the system was resolved to be more greater than 5, contrasted with under 3.5 for conventional systems.

[2] K.Sopian et al. (2014) had conducted the experiment in solar assisted desiccant air conditioning system for hot and humid areas. To find impact of dehumidification limit on the execution of cooling system, four setups of desiccant cooling systems have been investigated. The four configurations models are i)Schematic of two-stage solar desiccant cooling system-ventilation mode, ii)Simulation modeling of solar desiccant cooling system-ventilation mode, iii)Schematic of two stage solar desiccant cooling system-recirculation mode, iv)Simulation modeling of solar desiccant cooling system-recirculation mode. These models were stimulated for 8,760 hr of activity under hot and humid climate in Malaysia. The capacity of cooling loads and furthermore the sensible heat ratio of the zone was 1 ton, and 0.25 respectively. In this manner, because of high dehumidification limit, the two stage ventilation mode with 1.06 of COP was considered as the best model among alternate configurations. In view of the state of surrounding air (30°C and 0.0200 kg/kg), the two stage solar based desiccant cooling system under the ventilation mode is more suitable than other configurations.

[3] Avadhesh Yadev and V.K.Bajpai (2011) had conducted the experiment in operating the parameters of desiccant wheel for rotation speed. To perform air dehumidification activities by using low grade quality heat source. The execution of an adiabatic rotary dehumidifier is parametrically considered and the ideal rotational speed is controlled by inspecting the moisture removed by process area in the desiccant wheel. The basic parameters for a specific wheel of thickness 200 mm and breadth 550 mm are surrounding air at 30 C DBT and 17 g/kg humidity ratio, process ambient air flow rate between 1.5 m/s to 5.5 m/s, reactivation air flow rate lies between 1.5 m/sec to 5.5 m/sec and rotational speed of wheel differs from 10 RPH to 40 RPH. Low speed of process air (1.5 m/s to 2.5 m/s), 10RPH and 20RPH are observed to be ideal for activity. If there should arise an occurrence of high speed (>2.5), little impact of RPH is watched, however the most ideal RPH is observed to be 20. For both high and low reactivation inlet speed, 20 RPH is the most ideal turn speed. In any case, the best outcomes are seen at 3.5m/s to 4.5m/s reactivation inlet speed. The emphasis is on expanding the procedure expelled moisture and for the given desiccant wheel demonstrate, the ideal procedure inlet velocity is found to lie between 1.5 and 2.5 m/s. It was watched that for low speed of process air (1.5 m/s to 2.5 m/s). In the eve nt of high speed (>2.5), little impact of RPH is watched, however the most ideal RPH is observed to be 20.

[4] R.Narayanan (2011) had conducted the comparative study of different desiccant wheel designs. Similar investigation of the different desiccant wheels are designed to be considered in this paper. It is utilizes a strong desiccant for dehumidification with silica gel being the most broadly used. In this paper two heat and mass exchange methods of counter flow desiccant wheel one considering just the gas side resistance and other considering both strong side and gas side resistance are developed. The percentage of dehumidification rate of parallel flow, simple counter flow and counter flow with cooling area are 16.27 percentages,25.05 percentages,29.77 rates respectively. Therefore counter flow desiccant wheel has much better dehumidification execution over parallel flow, where as the expansion of axial cooling section can enhance both dehumidification and cooling execution further.

[5] Er.Amit Tiwari (2015) had conducted the experimental investigation in design and fabrication of desiccant wheel dehumidifier. It is found that the optimal rotation speed is lower for lithium chloride or compound rotors than for silica gel rotors. The impact of the recovery air humidity was also notable and low relative humidity increment the dehumidification potential. While the dehumidification effectiveness isn't much affected and both specific regeneration heat input and latent heat change of the process air decrease. For desiccant cooling applications in humid climates this is a positive pattern. Hybrid air condition can be great alternative when the humidity level is high.

[6] Avanesh Yadev and V.K.Bajpai (2011) had conducted the experiment in operating parameters of desiccant wheel for refrigeration temperature. Desiccant wheels are utilized as a part of commercial and industrial applications to perform air dehumidification activities by using low grade heat source. Programming gave by the maker is utilized to choose a honeycombed rotational desiccant wheel according to necessities of the customer on the website by Novel Air Technologies. The fundamental parameters for a specific wheel of thickness 200 mm and measurement 550 mm are ambient air at 30C DBT and 17 g/kg humidity ratio, regeneration temperature differs from 650C to 850C, process air flow rate change between 1.5 m/s to 5.5 m/s, reactivation air flow rate lies between 1.5 m/sec to 5.5 m/sec. Process/reactivation zone was observed to be optimum between of 1 and 1.5, flow rate of process air between 1.5 m/s and 2.5 m/s and reactivation air between 2.5 m/s and 3 m/s. The focus is on maximizing the process removed moisture and for the given desiccant wheel model, the optimum process inlet speed is found to lie in the between of 1.5 and 2.5 m/s. The expansion in process removed moisture removed remains almost steady after 2.5 m/s. Best outcomes are acquired at higher regeneration temperature i.e. 85 C.

[7] Alireza Zendehboudi at el. (2014) had conducted a study on performance of solar desiccant cooling system by TRNSYS in IRAN. Increase in air humidity leads to discomfort and can cause health problems. This paper computed the execution of a basic desiccant evaporative cooling cycle in four chose urban communities in Warm and Humid climatic zone of IRAN (i.e. Kish, Bandarabbas, Bushehr and Gheshm).The coefficient of performance (COP) has been processed for every area and compared. The outcomes demonstrate that for Kish, this framework indicates high potential for comfort cooling in structures contrasted with different areas in the same climatic zone. It might be concluded that, the execution of desiccant cooling system is very affected by surrounding air moistness proportion. Higher is the ambient air humidity ratio bring down is the COP.

[8] Gholamreza Goodarzia et al. (2017) had conducted a performance of a solid desiccant wheel regenerated by waste heat or renewable energy. To remove moisture, solid desiccant wheel innovation shows a energy efficient alternative to traditional systems particularly when solar energy and waste heat come into play. Solid desiccant wheels can be combined with different systems to give provide air quality. Programming gave by Novel Aire Company is utilized to compute outlet ventilates. Utilizing the product, the execution of a rotary dehumidifier is studied based on effective parameters including moisture removal capacity (MRC), sensible coefficient of execution (COPSen), inactive coefficient of execution (COPLat) and total coefficient of execution (COP Total). In addition, affecting factors change as described inlet air temperature between 15 °C to 40 °C, regeneration temperature between 65 °C to 110 °C, humidity ratio between 10 to 20 g/kg, air flow rates between 0.72 Kg/s to 1.28 m/s, and rotational speed of wheel between 10 to 40 RPH. DW programming gave by Novel Aire Company is utilized to investigate desiccant wheel execution in view of various parameters consisting of COPlat, COPsen, COPtotal, and MRC. All influencing factors expect inlet process air temperature have positive relationship with COPs and MRC.

[9] Hao Hong et al. (2011) had conducted the performance of solar hybrid desiccant cooling system. Two types of hybrid systems are investigated here. One was composed of vapor compressor and desiccant (VC+D) cooling system, and the other was composed of vapor compressor, desiccant and direct evaporative cooler (VC+D+EC) cooling system. The system regenerated by power and solar energy was conventional and solar oriented hybrid system respectively. It was found that under the same working condition, compared with conventional vapor compression (VC) cooling system, Coefficient of performance (COP) and energy saving of two VC subsystem for hybrid systems are expanded 16.09%,

28.71% and 58.37%, 78.71% energy saving of entire loads for conventional hybrid and solar hybrid systems are 11.76%, 20.51% and 38.22%, 53.62%. It was also found that with the inside temperature expanded and relative humidity unchanged, energy saving potential of VC subsystems and of the whole loads for conventional hybrid cycles was strengthened. While the solar oriented hybrid cycles always saved more energy than conventional VC cycles. VC+D+EC hybrid systems saved more energy than VC+D hybrid systems did.

[10] R.Narayanan (2011) had conducted the modeling and experimental validation in a non-adiabatic desiccant wheel. Desiccant wheel is the core of this heat driven cooling system. The main drawback of conventional desiccant wheels is the over the top warming of the provider and desiccant materials during dehumidification. Reduces the measure of moistures that can be removed from the air. Internal heat exchange structure with alternative channels for dehumidification and for indirect cooling of the dehumidification process. Beginning outcomes propose that the cooled non adiabatic desiccant wheel can increase dehumidification levels by around 45-53% under generally identical supply air and regeneration air condition.

[11]Maatouk Khoukhi (2013) had conducted a desiccant based cooling and dehumidifying system in hot humid climate. The objective of this feasibility of using desiccant cooling system as an option HVAC solution in building to achieve thermal comfort. This solution is more attracting when the solar energy is used to regenerate the desiccant wheel. A TRNSYS model of the desiccant cooling system joined with the heat wheel and heat source has been simulated and compared with experimental data. Combining the fundamental desiccant model with IEC and DEC permits reducing significantly the DBT to 29°C and keeping Rh inside the accepted value esteem 59 % considering hot-humid outside climate at 36°C and 70%. Improvement can be done by combine withthedesiccant cooling system a solar powered air heating system for the DW regeneration.

[12] A.S.A. Mohamed et al. (2015) had conducted the performance evaluation of an incorporation of a compact liquid desiccant system into an evaporative cooling assisted 100% outdoor air system. The essential objective of this paper is to suggest incorporate of a compact liquid desiccant system into an evaporative cooling assisted 100% outdoor air system as an alternative proposal to the traditional vapor compression refrigeration system, particularly with small loads, as well as the counteract the variation of climates. Current study presents an experimental analysis for building air conditioning with using a LiCl fluid arrangement as a liquid desiccant. Four air flow rate values are used for obtaining variable benefits of cooling capacity. Thermal and electrical COP is adopted to evaluated the system performance. In the compact system proposed, the separation of operating time between the dehumidification and the regeneration process contributes essentially in decreasing size and initial cost where the same unit is for two processes. The electrical COP of the compact system was improved significantly reaching 4.4 as a mean value for the air flow rate 0.273 kg/s. The mean estimation of the thermal COP ranges from 1.3 to 1.6.

[13] Shankar Kumar et al. (2015) had conducted the simulation of air conditioning system for variable rotational speed of desiccant wheel. This paper presents a study on different kinds of air conditioning in association to one to use through the year. Basically the system imparts all three regular weather conditions. Like hot and dry, hot and wet and cool and dry. For this the out let condition will be settled 25C dry bulb temperature (DBT) and half relative humidity. The variation in supply condition of air, volume of cellulose cooling of evaporating cooler temperature of cooling coil in hot and wet weather conditions as for rotational speed of desiccant wheel (6 to 24 RPH).The outlet temperature of desiccant wheel expands 52.96 to 63.28°C.The efficiency of desiccant wheel increases where as immersion efficiency of evaporative cooler decreases. The volume of cooling pad decreases from 547.99 to 439.54 cm3 w.r.t. the rotational speed of desiccant wheel. DBT of supply air remain constant with the increase of rotation speed of desiccant wheel for hot and wet weather condition. The DBT of supply air is 22.79491.The particular humidity of supply air also remain constant with increase of desiccant wheel and which is equal to 10.33 to g/kg for hot and wet climate condition. The volume of cellulose cooling pad decreases from 547.9984to 439.5406 cm3 for hot and wet weather condition with increases in RPH (6 to 24) of desiccant wheel. The immersion efficiency of evaporative cooler decreases from 33.30311 to

29.62732% for hot and wet weather condition with increases in RPH (6 to 24) of desiccant wheel. The efficiency of desiccant wheel increases from 0.639865 to 0.670562 for RPH esteem 6 to 21 of desiccant wheel that it decreases i.e. most efficiency exits at the seed 21RPH.The cooling coil temperature decreases from 17.76364 to 15.50114 with increases in rotational speed of desiccant wheel(6 to 24RPH).

[14] K. R. Aglawe et al. (2013) had conducted the experimental analysis of window air conditioner using evaporative cooling system. Coefficient of execution improvement and reduction of energy consumption of a window air conditioning system when retrofitted with evaporative cooling in the condenser of window air conditioner is reviewed in this paper. The condensing unit is retrofitted with a corrugated pad. The evaporative cooled condenser can exchange heat with the cooled ambient air cooled with evaporative cooling which is much lower in temperature than atmospheric air. In this paper a window air conditioner system is introduce by putting two cooling pads in the both sides of the air conditioner and injecting water on them in order to cool down the air before it passing over the condenser. The execution of air conditioner was experimentally investigated with and without media pad evaporative cooling on the condenser and it is discovered that. By Applying Evaporative cooling pressure in the condenser decreases to 20%. Pressure in the evaporator reduces 12%.Pressure proportion over the cycle decreases 18% .This pressure reduction is the indication of power reduction in the system.

[15] L. Bellia et al. (2000) had conducted the air conditioning systems with the desiccant wheel for italian climates. Hybrid air conditioning systems based on chemical dehumidification are characterized by high energy efficiency and low environmental effect. In this paper, first evaluation of operating costs is carried on Italian climates. For this reason, a business PC program, DesiCalcTM, has been utilized from the European document known as TRY, hourly climatic information have been determined and adequately process. For retail store application, for four Italian sites, maximum saving about 22% has been obtained, while for theater realistic saving is greater and has been evaluated between 23% and 38%. For both the applications, the required far reaching electric power is reduced (up to around 55%), and also the hours during which the system does not well control indoor relative humidity are strongly reduced. Energy savings obtained using the hybrid systems with desiccant wheel depends upon, climatic conditions of the considered sites ,system setup, latent loads due to external air flow rate and occupancy level, used desiccant wheel execution.

[16] Ankit Srivastav (2016) had conducted a performance of desiccant cooling system.Desiccant cooling system is one of the choices in our day by day life to provide the best indoor air quality and thermal comfort with the base utilization of energy. In this paper, essentially the standards of desiccant cooling systems have been discussed and studies through execution investigations of desiccant cooling system, it has proven its possibility and advantages of energy and cost saving in various climatic conditions. Desiccant cooling system could replace other cooling systems such as traditional vapor compression air conditioning system, the evaporative cooling. Direct and indirect evaporative cooling methods can be utilized for various cycles of desiccant cooling system. It has been seen that the desiccant cooling is a basic innovation which can reduce the working expense in examination with the present system. Desiccant cooling is not just suitable in comfort cooling but can also usedsuccessfully in preservation of cereals and warehouses.

III. CONCLUSION

The Desiccant cooling system cools the indoorwith reduced electrical energy usage. We achieved improved indoor quality by implementing this system. It has huge application in food processing industry, dairy, schools, and meteorological laboratories and in many other domestic applications. In conclusion, further improvement in energy utilization rate, reduction in cost and size, standardization in design and production are the key issues faced by the rotary desiccant air conditioning technology for achieving more extensive application.

The following points are concluded from the literature survey:

1. The COP was shown to slightly improve with the increasing ambient temperature, a notion contrary to the performance behavior ofconventional systems.

2. The two-stage solar desiccant cooling system under the ventilation mode has been found to be more suitable than the other configurations under the condition of ambient air (30°C and 0.0200 kg/kg).
3. 20 RPH is found to be the most optimum rotation speed for both high and low reactivation inlet velocity.
4. The best results are observed at 3.5m/s to 4.5m/s reactivation inlet velocity.
5. The counter flow desiccant wheel has much better dehumidification performance than parallel flow,whereas the addition of axial cooling section can improve bothdehumidification and cooling performance further.

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