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A REVIEW OF EMERGING TECHNOLOGIES FOR SOLAR AIR CONDITIONER

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Abstract: This paper represents a review of new solar based air conditioning techniques. These techniques used solar energy to produce cold or hot air and do not pollute the environment. Thermally driven cooling system is the key component of these systems. The use of solar powered air conditioning systems for heating and cooling requirements in the buildings would be more economical. Though various air conditioning systems run on solar power have been tested extensively, there have been very less focus on the use of solar powered air conditioning systems. Aim of this paper is to review the literature on emerging technologies for solar air conditioner and provide knowledge which will be helpful to initiate the study in order to investigate the influence of various parameters on the overall system performance.

Keywords: Absorption, Adsorption, Desiccant, Solar air conditioner, thermally driven chiller.

I. INTRODUCTION

There is a tremendous pressure on the air conditioning industries of following the norms and conditions of economics, environment and regulatory. Now days improving standards of ventilation, global environmental awareness and increasing concerns about indoor air quality have tremendous impact on changing the design thinking. Many clients and consultants are steered away from full air conditioning to natural ventilation and mixed-mode solutions in new and refurbishment projects with the help of professional guidance. Overheating is the predominant design consideration for new offices because of the increase in computing equipment, inefficient lighting and architectural fashion. Day by day, it is getting worse and worse if global warming scenarios are accurate. Hence seeking innovative methods of maintaining and improving the quality of the indoor environment, under potentially more demanding performance criteria, is vitally important and that too without hammering the environment. Solar air conditioner is one which use solar energy to produce cold or hot air and do not pollute the environment. A solar cooling installation consists of a typical solar thermal system has solar collectors, storage tank, control unit, pipes and pumps with a thermally driven cooling machine. In solar cooling systems, solar heat is used to drive the thermally driven cooling machines, such as absorption, adsorption chiller and desiccant cooling systems.

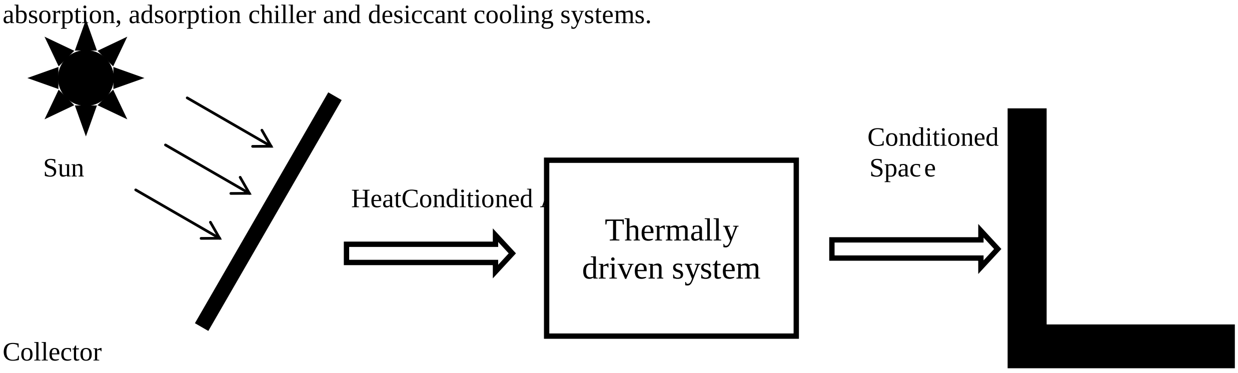

Fig. 1: Basic system scheme

I. 1 Absorption chiller

Mostly, absorption chillers are used throughout the world. Electric power consumption of a mechanical compressor is replaced by the liquid refrigerant or sorbent solution and heat source to achieve the thermal compression of the refrigerant. The refrigerant (water) evaporates in the evaporator at very low pressure, producing the cooling effect. In the absorber, vaporized refrigerant is absorbed with dilution of the H_2O/Li-Br solution.

I. 2 Adsorption chiller

Solid sorption materials are applied in the place of a liquid solution here, whereas in conventional systems water is used as a refrigerant and silica gel as a sorbent. There are two sorbent compartments (shown as A and B in the figure below) as an evaporator and a condenser. By using hot water from the external heat source, the sorbent in the first

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compartment is regenerated. The water vapors entering from the evaporator are absorbed by the sorbent in the absorber and cooling of this compartment is required for uninterrupted absorption process. For producing useful cooling, the water in the evaporator is transferred in to the gaseous phase being heated by the external water cycle.

I. 3 Desiccant cooling systems

Desiccant cooling is a kind of technology which can be used to condition the internal environment of buildings. The cooling power in phase with cooling load works in favour of consideration of air conditioning powered with sun displacing peak load electricity. The use of desiccant cooling is one of the emerging aspects of heat driven cycle air conditioning, unlike conventional air conditioning systems which rely on electrical energy to drive the cooling cycle.

The desiccant cooling systems is one of the open cycle systems, where water is used as a refrigerant in direct contact with air. The thermally driven cooling cycle is run by the combine effect of evaporative cooling and air dehumidification by a desiccant, which is a hygroscopic material. Liquid and solid material can be utilized for this purpose. In an open-ended loop, the refrigerant is discarded from the system after providing the cooling effect and new refrigerant is supplied in its place. Therefore water is the only option as a refrigerant since the direct contact to the atmosphere exists.

Desiccant cooling system using Water/Lithium Chloride solution as sorption material is one of the new development close to market introduction. The possibility of high energy storage by storing the concentrated solution and higher air dehumidification at the same driving temperature are the highlights of this system. Further improvement in the technology and for increasing the exploitation of solar thermal systems for air-conditioning, this technology has a promising future.

Solar air conditioners are broadly classified as shown in Table 1

Table 1: Classification of solar air conditioner

Method	Closed cycle		Open cycle	
Principle	Chilled water		Humidification of air and evaporative cooling	
Phase of sorbent	Solid	Liquid	Solid	Liquid
Typical material pairs	water - silica gel	water – water/Li-Br,NH_3/water	water – silica gel, water/Lithium-chloride	water – calcium chloride, water/Lithium chloride
Market available technology	Adsorption chiller	Absorption chiller	Desiccant cooling	Close to market introduction
Solar collectors	Vacuum tubes, flat plate collectors	Vacuum tubes	flat plate collectors, solar air collectors	flat plate collectors, solar air collectors

II. SOLAR AIR CONDITIONER

Davangere et al. (1999) simulated a solid desiccant cooling system with a backup vapour compression system and its performance is evaluated to study its feasibility in four cities in U.S. also derived the relevant psychometric calculations. To access the economically feasibility thermal performance of the system is simulated.

Sumathy et al. (2000) made efforts to produce Air Conditioning effect by using solar powered air conditioning systems with the absorption pair of Lithium-Bromide & water. As generator inlet temp of chiller is the most important parameter in the design and fabrication of the solar powered air conditioner, have been successively resolved for operation at temp lower than 1008 C. emphasis is placed on cooling technology rather than on thermal technology for improving COP of refrigeration system. Results showed that the single effect system accumulates refrigerant during long hours of high solar insolation, the double effect convertible system has higher COP which improve system performance.

Bach et al. (2003) used is a solid adsorption system to describe a new solar based air conditioning techniques. Suggested design procedure is simple and does not require a high technology. This type of unit can be used widely in the regions with an abandoned solar resource.

Leite (2005) proposed a system basically composed of a cold & hot water storage tanks, produced by activated carbon methanol adsorption chiller, heat exchanger. A design inlet temperature of 105 C, the mass flow rate during the regenerating period was of 0.38 kg/s and heat transfer coefficient over the tubes of the absorber was of 690 W/m2K. Designing of thermal parameters of an adsorption chiller, had been established and analysed, which showed that the adsorption cycle duration has a great influence on the thermal parameter, but required about 70% of solar coverage.

Younes et al. (2005) studied Lithium – Bromide absorption machine thoroughly, showing the amount of fuel used in last few years for air conditioning. Also by studying each main part of the machine and different parameter; it was found that the length of the tubes required can be calculated to ensure the transfer of heat. This study showed that the machine needs six years and eight months to retain its costs with an annual payback of $120000. It is concluded that the back time is nearly the same (especially powers between 100 and 1000 tons.)

Mittal et al. (2005) tested and reviewed various solar powered absorption cooling systems which serves both the purpose of heating and cooling. Many efforts have been made to make it economically & technically viable to provide fundamental knowledge on absorption system with Lithium-bromide paired with water. This results in parametric study to find out the influence of key factors on the overall system performance.

Andrew Lowenstein (2006) developed a novel liquid desiccant air conditioner. It can be packaged as a roof-top air conditioner. In roof-top installation of air conditioner, it should be compact to fit. For the compactness energy storage done with concentrated desiccant rather than hot water. In such systems, collectors can be installed near the system which reduces the cost of installation. Low desiccant flooding rate is the distinguishing characteristic of the new technology. Due to low desiccant flooding rate, it has much lower pressure drop & be more compact. Results showed that it produces greater cooling effects with more deeply dry process air has a higher COP.

Abdalla et al. (2006) described solar driven liquid desiccant evaporative cooling system and the method used for investigating its performance. Performance of the system is evaluated in humid as well as dry climate and found suitable in both. This system avoids pressure sealed units as the whole system operates at atmospheric pressure. This system utilized very low temperature heat source efficiently. Results obtained showed that system dehumidifies 1.6 kg/sec of process air at 30.1^0C dry bulb temperature and 6.6gm/kg humidity ratio; by using this process air evaporative water cooler produced 1.92 kg/sec of water at absolute 22 C. cooling duties required in system is provided by this water.

Vargalet al. (2009) carried out a theoretical study to assess refrigeration efficiency of a solar assisted ejector cycle using water as an operating fluid. For different operating condition ejector performance was evaluated; in order to achieve an acceptable coefficient of performance, evaporator temperature should not fall below 108 C and condenser temperature over 358 C resulted in a significant drop in system efficiency. The result indicated that COP and system efficiency increased with generator temperature. The approach is a simplified one and is needed to go in detailed i.e. CFD, ejector geometric can be optimized to improve COP by increasing entrainment ratio.

Koroneos et al. (2009) the use of solar energy to drive cooling cycles for space conditioning of most buildings constitutes an attractive concept since cooling load coincides generally with solar energy availability. This resulted into “zero emission” and CO2 emission. Today approximately 120 solar thermal assisted cooling systems are presently installed worldwide; with total cooling capacity estimated at 10MW. Their specific collector is 3m2/kW for water chiller or 10m2/1000m3/h of air volume flow in desiccant system.

Umberto et al. (2009)analysed the system comprises an absorption chiller coupled to solar flat plate collectors, a hybrid tri-generation plant, known as thermo solar tri-generation, which allows greater operational flexibility. Almost 40% energy consumption & 20% of CO2 emissions is because of the residential & tertiary sectors throughout the European Union.

Ghali et al. (2010) modelled and simulated the operation of the combined solar distillation and air conditioning system to predict distillate output from the cooling coil for the combined system for a residential space application in the suburbs of Beirut. An optimization problem is formulated and analysed to integrate system operation for minimum energy consumption while meeting the hourly cooling load. It showed that the cost of fresh water production of the combined system is 0.108kWh/litre for the month of August and 0.12 kWh/ litre for fresh water in October.

Gommedet al. (2012) studied the utilization of low grade for cooling and dehumidification of air conditioning in open absorption system. The heat and mass exchanger (HME) with an improved solution flow design facilitates the use of adiabatic absorption/de-absorption with reducing wetting problem & circulation heat losses. It satisfied the aim of minimizing the time constant of the system, helped in correct idling and level control problem ensuring maximum solution concentration on absorber side. Within the average dehumidification capacity of about 0.8, with parasite losses of about 20%, the system works well.

Hurdoganet al. (2012) showed the novel desiccant based air conditioning system was considered to investigate the temperature from experiments over the cooling season of 2008 and solar radiation data from State Meteorological Affairs (DMI) between 1986 and 2006 years at Adana.It may be concluded from the study that utilization of solar energy increases the COP between 50-120%. Exergetic and exergo-economics analysis of the system are recommended for future study.

Nkwettaet al. (2012) suggested that the internal low concentrating evacuated tube heat pipe solar collector was designed with truncated upper part of the reflector giving geometrical concentration ratio of 1.95 with borosilicate glass tube having 100mm outer and 93mm inner diameter respectively. The overall angular acceptance of incoming rays from transverse angle of 0o to 20o was 93.72%. Cost of the reflective material and reflective losses were reduced by truncated internal reflector design. The combine use of concentration and evacuation increased the irradiance level on the heat pipe absorber allowing higher temperatures and improved thermal performance.

Crofootet al. (2012) showed that a low flow parallel plat liquid desiccant air conditioner and a 0.95m2 evacuated tube solar collector array. Overall solar collector efficiency of 56%, solar fraction of 63%, thermal COP of 0.47 with cooling 12.3kW and average latent cooling was 13.2kW recorded for five test days. Performance is expected to improve as weather gets hotter, and humid. 18800kWh were collected with an average efficiency of 61% over the winter (Oct-March) the solar array was operated with dry cooler.

Abduljalil et al. (2013) worked and investigated on triplex tube heat exchanger with PCM in the middle tube to power a liquid desiccant air conditioning system. Three techniques viz. heating side tube, outside tube and both side tube with PCM temperature gradient in radial, angular and axial direction were analysed.it resulted that both sides heating achieved complete PCM melting within less time and used lower inlet heat transfer fluid temperature. The temperature variation in the radial as well as angular direction was observed whereas no significant variation in axial direction.
Goa et al. (2013) compared the performance of adiabatic and internally cooled dehumidifiers were done which showed that the internally cooled dehumidifiers can improve the performance when solution is at a high temperature and/or low concentration in the downstream section of the liquid desiccant flow. Internally cooled dehumidifier can increase dehumidification effectiveness and moisture removal rate with ideal temperature of solution is 20-25o C and for dehumidifier 25-30oC. Discrepancies between experimental data and predicted value were almost all within ±20%.
Abdel-Salam et al. (2013) studied liquid-to-air membrane energy exchangers (LAMEE's) are used as a dehumidifier using the TRNSYS energy simulation platform. The system COP is 0.68 at design condition, with sensible heat ratio between 0.3-0.5. Results conclude that proposed membrane is capable of obtaining recommended supply air conditioner. It is recommended to set the solution inlet temperature at 15-20oC and 45-50oC to the dehumidifier and regenerator. The removal of latent load can be achieved effectively in application of required efficient humidity control.

III. CONCLUSION

The human comfort relies heavily on the air conditioning. Most of the air conditioning systems are electrically driven. But time has come to look for an alternative solution for electric power and solar energy is the best one. So, the review is made for the recent trends and technologies in the solar air conditioning for the further work in this field.

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