Regeneration of Solid Desiccant Materials by Parabolic Dish Collector: A Review

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ABSTRACT-In India, southern part are hot and humid, so air conditioning is needed and it cots high consumptions of electricity. Besides conventional system dry air may be produced by using desiccant materials like silica gel, activated alumina, activated charcoal lithium chloride, calcium chloride etc. having low operating and maintenance costs with environmental friendly system. In this article various methods for desiccant regeneration are discussed. Solar collectors are used for the regeneration of the desiccant materials and have better efficiency. Use of solar energy also eco-friendly with the environment thus it reduces the environmental issues.

Keywords: Regeneration rate, adsorption, irradiation

INTRODUCTION

In tropical countries the demand of air conditioning is high, which results in high consumption of electricity. High humid air in tropical countries results high latent cooling load. Desiccant materials are used for the moisture removal from the humid air. Use of desiccant materials in air conditioning for moisture removal is very economical in terms of energy saving, a large part of energy in air conditioning is used in sensible cooling of air. In past days vapour compression refrigeration system is used in air conditioning for controlling of both loads, dehumidification load and sensible load. Dehumidification load and sensible load can be reduced by handling it separately [1].

Desiccants are used in many industries for dehumidification of air. Desiccant materials may be used for many times by regenerating it. Hot air is needed for dehumidification of desiccant materials, and hot air may be produced by using both: high grade energy and low grade energy. Use of high grade energy in dehumidification is too much expensive on other hand use of low grade energy is beneficial and eco-friendly to the environment also.

Dry air may be produced effectively by using chemical dehumidification process using solid desiccant materials. Desiccant material absorbs moisture due to difference in vapour pressure without any physical and chemical change. As much as the surface area of the desiccant the vapour absorbing capacity will be more [2]. After absorbing the moisture desiccant becomesaturated and can be reused by regenerating it. These saturated desiccants can be regenerated by flowing hot air through it. Desiccant materials like as silica gel, zeolite, activated alumina and activated charcoal can be used [3].

Kut (1970) recommended that silica gel regenerated in a packed bed dehumidifier, with a velocity range (bed-air) of 0.25m/s–0.40m/s [4]. Siato (1993) investigated dehumidification of silica gel by an integrated desiccant collector [5].Dupont et al. (1994) investigated simultaneous dehumidification of silica gel and activated alumina and proposed that silica gel absorbed 30% more water as compared to activated alumina [6]. Singh and singh advised that the regeneration air temperature and bed air velocityenergy efficient [9]. Mazzi et al. (2002) suggested to saves 35% more energy than the conventional system by reheating with the waste heat, thus 87% electricity saved [10]. Jalazadeh-Azar et al. (2004) proposed that regeneration of desiccant material can be done by using heat recovered from IC engine[11]. Ando et al. (2005) investigated a desiccant cooling process with four-rotor with a double stage dehumidification which can work at around 70^0C regeneration temperature and high ambient humidity [12].Ahmed et al. (2004) investigated the performance of desiccant wheel with a solar air heater (with a perforated plate) along with electric heater [13]. Jia et al. (2006) investigated hybrid desiccant air conditioning and found that it economized 37.5% electric energy by maintaining 30^0C temperature and 55% relative humidity [14]. Kabeel (2007) studied the effect of air flow rate and solar intensity (irradiation) on the regeneration and absorption process on the honeycomb desiccant wheel prepared by iron wire and clothes [15]. Jia et al. (2007) developed a new model of desiccant wheel which can work on low regeneration temperature with high moisture removing capacity [16]. Pramuang and Exell (2007) suggested that silica gel can be regenerated with a compound parabolic concentrator at 40^0C regeneration temperature [17]. Bourdoukan (2008) experimentally investigated the Heat Pipe Vacuum Tube collector and Flat Plate Collector and found that Heat Pipe Vacuum Tube gives 0.6-0.7 efficiency for one working days, and the same efficiency can be achieved on flat plate collector by increasing its collector area by 20%-25% [18]. Ghali et al. (2008) studied the economical feasibility of desiccant wheel with conventional vapour compression regeneration system in city of Beirut. In this system regeneration of desiccant wheel is done by dissipated heat by condenser and natural gas and its economic variability increases for hybrid system with low sensible heat ratio [19]. Khalid et al. (2009) investigated experimentally and pre cooled hybrid desiccant cooling system and its application and also simulate it [20]. Ge et al. (2009) evaluated the performance of two-stage rotary desiccant cooling and a new desiccant (silica gel-haloids) adopted and found that the required regeneration temperature was low and COP was high [21]. La et al. (2010) experimentally investigated desiccant wheel and evacuated solar air collector with 15 m^2 area for solar heating and humidification. This system converts 50% solar radiation for space heating in winter sunny day and increased 10^0C indoor temperature [22]. Yadav and Bajpai (2011) experimentally investigated the regeneration of various desiccants with evacuated tube collector and found better performance of these desiccants on high air flow rate, and also found that silica gel was better among them [23]. Om and Kumar

(2012) presented various model of solar dryer. Natural circulation solar energy dryer and forced convection solar energy dryer are the two major classifications [24]. Kumar et al. (2016) experimentally investigated the regeneration of various solid desiccants like silica gel, activatedalumina, and activated charcoal and found regeneration rate 0.216 kg/hr, 0.156 kg/hr, and 0.156 kg/hr, respectivelyand regeneration time 40 minute, 90 minute, and 120 minute respectively [25]. The further reviews of researchers are given in the given table.

Regeneration Methods for Solid Desiccants

There are many methods used by the researchers to regenerate the desiccant materials for reuse it. But mainly these three methods are preferred for regenerating solid desiccant materials.

- Regeneration of solid desiccant by hot air from a solar air heater with a compound parabolic concentrator
- Regeneration of solid desiccant by air from an evacuated tube solar air heater.
- Regeneration of solid desiccant by Electro-osmotic system.

Regeneration of solid desiccant by hot air from a solar air heater with a compound parabolic concentrator:

Pramuang et al. have experimentally investigated the regeneration of solid desiccant (silica gel) by using a solar air for an air conditioning system. In that system a compound parabolic concentrator was set (aperture area: 1.44 m^2 and receiver area 0.48 m^2) for producing hot air. In that system regeneration of silica gel was started at 40^0C temperature. Silica gel with initial moisture contents and number of silica gel beds slightly affect the regeneration rate and regeneration efficiency but it mostly affected by solar radiation. CPC collector for regeneration of silica gel is suitable for a tropical climate where the availability of diffused solar is higher for full year. Each collector has 0.6 m width and height, and 1.2 m length. The receiving surface which forms the top surface of a rectangular air flow duct (0.03 m depth) made by aluminum sheet was painted with non-selective matt black. The bottom surface of duct was covered with 50 mm thick fiber glass for insulation. The used collector has 0.68 optical efficiency, and 8.51 W/m^2K heat losses. Speed of air (v) was measured by a hot wire anemometer. The flow of air is set to be constant by controlling the value of air blower. The average regeneration rate for the different weather conditions were 0.19 kg/h for per square meter of the aperture area for the time duration of 9:00-16:00. The highest rate of regeneration for silica gel with an air velocity of 0.007 kg/s was 0.51 kg/h. It is concluded that the 2 hours are sufficient to regenerate silica gel at the temperature up to 80^0C produced by CPC collector. A turncated CPC air heater which have a concentration ratio of 3 are able to produce 10^0C higher temperature in cloudy days and 50^0C higher temperature than ambient temperature in sunny days. And this air may be usedin the regeneration of silica gel.

Regeneration of solid desiccant by using evacuated tube solar air collector:

Yadav et al. investigated regeneration rate for different solid desiccants like as activated alumina, activated charcoal and silica gel experimentally. The purpose of this investigation is to check the feasibility for regeneration of the different materials with solar evacuated tube collector. In this experiment the performance of this setup analyzed. At different air flow rate for regeneration of various solid desiccants this evacuated tube solar collector have used. Comparison of different desiccant materials for dehumidification performance in Indian climate has been investigated experimentally. Although, the main aim of this experiment was to investigation the regeneration rate of different solid desiccant materials.

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Although, the main aim of this experiment was to investigation the regeneration rate of various solid desiccants but, there was still some moisture present. The desiccant should expose to the environment for the absorption process and it should be carried out just after the regeneration process.

This setup have evacuated tube integrated solar air collector and collector produces hot air for the regeneration of different solid desiccants. Regeneration of desiccants by solar energy has done in day time and the absorptions in the evening. The surface area of collector was 4.44 m^2 and the regeneration have done in the temperature range of 54.3 – 68.3^{0}C. The regeneration of desiccant materials was influenced by the influence in the temperature but it also depends on the on presence of moisture in the desiccant, desiccants temperature and the flow rate of hot air. At high flow rate of hot air minimize the regeneration and absorption time than at low flow rate and silica gel had better rate than others.

Electro-osmotic regeneration of solid desiccant:

Qi et al. have set up an experimental setup for the study of performance and for checking the possibility of a novel electro-osmotic method for the regeneration of solid desiccants. In this system the absorption of moisture from air and the generation of electro-osmotic forces occurred at the same time**.** The adsorptive and electro-osmotic property of zeolite powder was used to fabricate the solid desiccant. The moisture removal is measured with and without the use of electric field application to validate the possibility of regeneration by electric-osmotic method. The rate of maximum removal of water per electric strength was 1.1 X 10^{-7} kg m^{-1} s^{-1} V^{-1}. By the test it was clear that the regeneration have done by electro-osmotic effect. This regeneration process can be divided in three phases due to electrode corrosion and joule heating effect and electrode corrosion restrict the performance of the experimental setup. A cloth under the cathode was used to make a superior effect of electro-osmotic regeneration. By the experiments it is illustrated that this system have capacity of energy saving and regeneration on low temperature. This method seems to a potential regeneration method in the case of solid desiccants. For improving the performance of electro-osmotic regeneration system some more work future work should be done in designing of this system.

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Author	**Work Carried Out**	**Desiccant Used**	**System Type**	**Regeneration Source**
Rush et al. (1975)	Installation of MEC field test using solar energy [26]	Silica gel	Single stage	Solar energy
Joudi et al. (1987)	Desiccant-evaporative air-conditioning system using solar energy [27]	Silica gel	Single stage	Solar energy
San et al. (1994)	Silica gel packed-bed system-Modeling and testing [28]	Silica gel	Two stage	Solar energy
Singh et al. (1998)	Silica gel regeneration in multi-shelf regenerator [29]	Silica gel	Single stage	Solar energy
Techajunta et al. (1999)	1999 Air dehumidification and air-conditioning in a tropical humid climate using solar energy [30]	Silica gel	Single stage	Solar energy
Zhuo et al. (2006)	Desiccant air conditioning using solar energy-experimental investigation and system design [31]	Composite Silica gel	Single stage	Solar energy
Kabeel (2007)	Rotary desiccant wheel (honeycomb matrix) air conditioning using solar energy [32]	Calcium chloride	Single stage	Solar assisted
Yilmaz et al. (2010)	Two stage novel desiccant cooling system - Experimental investigation [33]	Silica gel	o stage	Electric heater
Ge et al. (2008)	desiccant cooling using one rotor two stage rotary system [34]		One rotor two stage	Solar energy
Ge et al. (2010)	Comparison of Solar powered rotary desiccant and conventional vapor compression cooling system – desiccant cooling Performance study [35]	Silica gel and lithium chloride	Two stage	Solar energy
Angrisani et al. (2015)	Comparison of hybrid desiccant cooling and other air-conditioning technology Experimental assessment [36]	Silica gel	Single stage	Thermal waste of the cogeneration and by natural gas boiler

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CONCLUSIONS

In the above article, an attempt for review on different desiccant's regeneration methods has been made. Many researchers have analyzed the regeneration experimentally and gives their suggestions. Some of them uses different types of collectors to produce the hot air for the regeneration of the solid desiccants. In all methods Regeneration by Parabolic dish collector is much beneficial and gives the higher concentration ratio and so higher temperature at the exit. By the parabolic solar dish collector the concentrated sun light may directly use for the regeneration of the desiccant materials.

In the parabolic solar dish collector by using the automatic solar tracking mechanism with the high reflective material at the reflective surface and by using the great absorbing material at the absorber, the regeneration efficiency may be increased and also the efficiency of the solar collector may be enhanced.

It is also concluded that silica gel have better adsorption and the regeneration performance so it can be preferred over other solid desiccants.

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