DESICCANT DEHUMIDIFICATION AND SOLAR THERMAL REGENERATION AIR CONDITIONING SYSTEM

Narendra J Giradkar[1], Vivek Korde[2], Dhanashree S Dongre[3], Ragini M Katre[4], Suddhanshi S Kale[5]

[1,2]Assistant Professor, Mechanical Engineering Department, YCCE, Nagpur, India;
[3,4,5]Student, Mechanical Engineering Department, YCCE, Nagpur, India;

Abstract - *Solar energy has become an attractive alternative to drive cooling devices such as air-conditioners, refrigerators, cooling & heating liquids. Over 50% of greenhouse gas emissions in households are caused by heating, Air conditioning and hot water. Cooling loads have direct correlation with the amount of solar irradiance. Use of solar energy for cooling purposes can reduce load on conventional systems. This review research paper gives description of solid desiccant dehumidification system (DEC) with conceptual visualization of system & working of silica gel as dehumidifier. Thermodynamic and chemical properties of desiccant material has been analysed with focus on regeneration of desiccant using solar energy.*

Key Words: Dehumidification, Desiccant, Silica Gel Dehumidifier, Solar Energy, Regeneration.

INTRODUCTION

The rising demand of air conditioning involves huge consumption of fossil fuel in return causing climatic change & enhancing air-conditioning needs all over the world. 30% to 40% of overall electrical energy produced is consumed by cooling and heating appliances. solar powered desiccant dehumidification air conditioning system is a concept of using heat of sun to condition the air Air-conditioning deals with controlling the humidity ratio and temperature of air. Air dehumidification can be achieved by following methods :-

1) COOLING BASED DEHUMIDIFICATION:- In cooling based dehumidification cycle (VCRS) air is cooled below its dew point temperature. As a result water vapour gets separated from dry air and gets condensed reducing the moisture content of air. But a drawback of this method is cooling air below its dew point temperature which consumes a lot of electric high grade energy.

2) COMPRESSION BASED DEHUMIDIFICATION:- When air is compressed its dew point temperature raises to a point where moisture can be condensed from the air at a higher temperature.

3) SORPTION METHODS:- Different thermally driven sorption technologies used currently are
- a) Desiccant cooling
- b) Adsorption method
- c) Absorption method

All of the above sorption cycles use sorption material which performs function of refrigerant in VCRS. Sorption material can be solid or liquid which has the natural affinity to absorb or adsorb moisture. This property aids to removal of moisture from the moist air. The sorption cycle can be open cycle or close cycle evaporative cooling. A Closed cycle gives chilled water or liquid eg. Lithium bromide absorption cooling cycle Whereas Close system gives direct chilled conditioned air eg. Solid desiccant dehumidification and evaporative cooling system. Solid desiccants use adsorption process for dehumidification. During the past few years many efforts have been made to develop DEC through different system configuration & integration. DEC can facilitate effective temperature & humidity control for vast domains at climatic conditions. This paper aims at thermodynamic study of DEC systems assisted by solar thermal power to regenerate desiccant material. This paper deals with study of solid desiccant Dehumidification Method.

WORKING MATERIAL

Desiccants are the material that upon contact with moist air at moderate temperature exhibit a great affinity to water vapour. Nearly all material qualifies as desiccant even glass can attract a small amount of moisture from air. However, space conditioning materials must be able to hold as much moisture as possible .Commercial solid desiccant can hold upto 50% of their weight in water. Liquid desiccants can absorb more than that of solid desiccants. Silica Gel,molecular sieve and activated carbon are common commercial solid desiccant. Other widely used desiccant materials are activated alumina,calcium chloride,natural and synthetic zeolites etc. Lithium Chloride is a common liquid desiccant used in the commercial industry.

The two key properties for selecting desiccant are -

1.It should possess large saturation sorption amount to be adsorbed.

2.Thermally stable

3.Dessicants can be regenerated or reactivated easily.

In building applications, solid desiccants are more convenient to use. Solid desiccants are porous material with very small pores & large surface area which helps to adsorb more water molecules onto it. The solid desiccant can be regenerated by passing hot and less humid air over it Both adsorption & desorption processes are heat and mass transfer process. Characteristics of desiccants are defined by their Isotherms. Adsorption by desiccants leads to thermal elevation of the air passes through and reduces its relative humidity. Adsorption goes on till the vapour pressure on desiccant surface reaches vapour pressure of surrounding air reaching its saturation point. The energy needs to dehumidify air inside room is equal to energy required to regenerate desiccant by hot air at regenerating temperature. During regeneration hot and less humid air passed through it losses temperature and has elevated relative humidity. The amount of water vapour adsorbed depends on

1. Material property

2. Temperature of air to be dehumidified.

3. Surface area and design of desiccant wheel.

4. Amount of water held by desiccant at that instant of time.

DESICCANT EVAPORATIVE COOLING SYSTEM

DEC systems produces cooling effect by principle of evaporative cooling, however odds of using evaporative cooling is increased due to the dehumidification distraction of air by desiccant. Desiccants used can be either solid or liquid. Solid desiccant air conditioning system which consists of fixed bed type & rotary wheel type desiccants. This wheel consists of a matrix made of metal with molecular sieve, silica gel or paper impregnated into it.

Typically, this desiccant loaded wheel rotates slowly between the dry air stream (process) & the heated air stream (reactivation). The wheel is split into two sections, Adsorption & Desorption. The area being divided into two sections in the compartment can be different according to requirement. The wheel performance & dehumidification achieved is influenced by various operating parameters such as rotational speed, regeneration temperature, volumetric air flow rate of inlet process air and reactivation air, humidity content of surrounding air and its temperature.

DEC are efficient dealing with latent load but consider less in sensible load hence used for hot & humid climates. Thus for making system efficient for sensible load, following addition in system & changes can be done:-

1) Combining thermally driven sorption wheel to remove latent heat with sensible coolers which will work on sensible load.
2) Improving the performance of the desiccant wheel & make process air sufficiently dry so that the sensible heat can be removed entirely by means of evaporative cooling.

Dehumidification process has two purposes

1) Dehumidification in order to match indoor comfort criteria.
2) An extra dehumidification in order to allow for subsequent humidification to produce a cooling effect. Desiccant sorption is a heat & mass transfer process which is shown by isotherms of different materials. Hence, after passing through the wheel air becomes hot in turn increasing efficiency for chillers to work.

SOLID DESICCANT REGENERATION

Desiccant regeneration is the process of expelling moisture from the desiccant material & drying it, making it useful for further operation. Desiccant can be regenerated via various low grade thermal energy sources available such as solar thermal waste heat, etc. The separate heating system passes heated air through the desiccant bed causing desiccant to lose moisture. In solid desiccant cooling based devices desiccants wheel is rotated between two compartments which aids simultaneous activation & re-activation of desiccant for smooth & even operation. Ambient air after passing through a heat exchanger gains temperature. With the same humidity ratio & increased temperature results in low relative humidity.

This hot air with low relative humidity will tend to attract & knock off moisture from silica bed resulting in its regeneration. The outlet air will have lower temperature & higher humidity ratio.

To perform process of regeneration various methods can be employed such as:-

1) Regeneration of silica gel desiccant by air from solar heater with compound parabolic concentrator.
2) Regeneration by evacuated tube solar air collector.
3) By heating air using a solar heated water tube type heat exchanger.

CONCLUSIONS

Desiccant dehumidification & evaporative cooling technology is efficient & well emerging technology in which institutional & industrial applications can rely on. Solar is an efficient alternative for regeneration of desiccant. With further improvement in the designing of molecular sieve & experimenting with different chemical composition of desiccant material continuous improvements are witnessed.

Further research & advancement will lead to lowering of cost of desiccant dehumidification system. The replacement of compressor cooling systems by solar cooling systems may continue to replace fossil fuel demand, leading to decreasing carbon footprints. All those properties discussed will help to emerge this technology with various advances in the market.

From the review paper & studying detailed properties of solid desiccant evaporative system, it has been found that the emerging areas for research in field of desiccant dehumidification & cooling system are:-

1) Compounding & designing of desiccant wheel.
2) Solar assisted cooling system for sensible cooling of air for required comfort.
3) Thermodynamic modelling of desiccant material & studying their property.
4) Numeric analysis of the whole solid desiccant dehumidification & cooling system.
5) Hybrid desiccant dehumidification assisted with solar cooling & regeneration with good efficiency.

REFERENCES

1) Antonio Gagliano, Francesco Patania, Francesco Nocera, and Aldo Galesi, “Performance Assessment Of A Solar Assisted Desiccant Cooling System”, DOI: 10.2298/TSCI120526067G , THERMAL SCIENCE: Year 2014, Vol. 18, No. 2, pp. 563-576.

2) Arjit Sharma, “Solar Air Conditioning System Using Desiccants”, International Journal Of Core Engineering & Management(IJCEM) ISSN: 2348 9510, Volume 1, Issue 2, May 2014.

3) K. S. Rambhad, V. P. Kalbande, P. V. Walke, “Solid Desiccant Dehumidification And Regeneration Techniques”, International Journal of Analytical, Experimental and Finite Element Analysis (IJAEFEA), Issue. 1, Vol. 2, March 2015. e-ISSN: 2394-5141, p-ISSN: 2394-5133, pp 1-5.

4) Hai-Yun Helen Xing, “Desiccant Dehumidification Analysis”, Thesis submitted to the Department of Architecture on August 4, 2000 in Partial Fulfillment of the Requirements for the Degree of Master of Science in Building Technology.

5) Muzaffar Ali, Vladimir Vukovic, Nadeem Ahmed Sheikh, Hafiz M. Ali, Mukhtar Hussain Sahir, “Enhancement And Integration Of Desiccant Evaporative Cooling System Model Calibrated And Validated Under Transient Operating Conditions”, Elsevier Applied Thermal Engineering, http://dx.doi.org/10.1016/j.applthermaleng.2014.10.064 1359-4311/

6) Muzaffar Ali, Vladimir Vukovic, Nadeem Ahmed Sheikh, Hafiz M. Ali, "Performance Investigation Of Solid Desiccant Evaporative Cooling System Configurations In Different Climatic Zones", Elsevier Energy Conversion And Management, http://dx.doi.org/10.1016/j.enconman.2015.03.025 0196-8904/©2015 Elsevier Ltd. All Rights Reserved.

7) Mahendran A/L Moorthy, "Performance Of Solar Air-Conditioning System Using Heat Pipe Evacuated Tube Collector", Report submitted in partial fulfilment of the requirements for the award of the degree of Bachelor of Mechanical Engineering, December 2010.

8) Avadhesh Yadav, Laxmikant Yadav , "Comparative Performance Of Desiccant Wheel With Effective And Ordinary Regeneration Sector Using Mathematical Model", Heat Mass Transfer (2014) 50:1465–1478 DOI 10.1007/s00231-014-1349-6

9) Ali Alahmer, Samer Alsaqoor, Gabriel Borowski, "Effect Of Parameters On Moisture Removal Capacity In The Desiccant Cooling Systems", Elsevier Case Studies In Thermal Engineering http://doi.org/10.1016/j.csite.2018.11.015 2214-157X/©2018 THE AUTHORS Elsevier Ltd. All Rights Reserved.

10) S.J.Slayzak, J.P.Ryan, "Desiccant Dehumidification Wheel Test Guide", Technical Report, NREL/TP-550-26131, December 2000.