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Solar adsorption and Intermittent Refrigeration System

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Abstract:-

Sun contains huge amount of energy and this energy is transmitted to the earth in the form of solar radiation. A solar cooling and refrigeration system is an excellent system and very useful in areas with high insolation levels where there is a demand for cooling and there is not electricity to supply conventional power system. This paper deals with the use of this solar energy for cooling and refrigeration purpose by the use of a solar refrigerating system. This paper tries to present a review about the solar adsorption and solar intermittent refrigeration system and using PCM as the storage media for different applications in solar refrigerating system.

Keywords: - Solar Refrigerating System; PCM; TES; Solar Adsorption Refrigeration System

Introduction

Now a days, energy requirement is very high either in urban or rural areas and solar energy is a very good means of energy to meet with the demand .Solar energy is a non conventional energy and this solar energy may be used for cooling and refrigeration purpose by the most suitable storage of solar energy. Thermal storage of solar energy is done by suitable solar collector, which collects solar radiation coming from the sun. A solar cooling and refrigeration system is an excellent system and very useful in areas with high insolation levels where there is a demand for cooling and there is not electricity to supply conventional power system.

Solar refrigeration represents an important application of solar energy due to the excellent matching between the high sunshine and the refrigeration needs. It constitutes the best manner of utilization of solar energy due to the in-phase rapport between the availability of the solar radiation and the cooling requirements. Roughly 80% of our energy consumption comes from fossil fuels and therefore nonrenewable resources [1]. The use of such refrigeration systems in the remote part of developing countries, where there is a shortage of electricity supply, is useful for storage of medical products, foods or habitat comfort [2].An alternative solution for this problem is to make use of solar energy which is available in most areas and represents a good source of thermal energy [3].

An adsorption refrigeration system is an excellent means, which produces cooling or refrigerating effect using solar energy. A solar refrigeration system consists of all the essential elements of a simple vapor compression cycle with the addition of a solar collector. Adsorption bed is a kind of environmental friendly refrigeration that can use solar energy effectively and do no harm to the environment. While its structure is simple, without moving parts, low noise, long service life, so it is very potential refrigeration. Adsorption refrigeration system is based on the consumption of heat source; adsorption bed is the core component of adsorption refrigeration system. [4,5] .

Solar energy is time dependent, the main disadvantage of this energy resource is the mismatch between the energy supply and the energy demand. In solar vapor absorption systems, the energy received from the solar collector is given as heat input to the generator; hence it has to assure a constant heat input

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to the absorption chiller during all the process. Therefore, when energy is available but cannot be given to the process, thermal energy storage (TES) may become an important issue. TES is a widely studied and used technology due to its potential load reduction, energy savings, and ability to overcome the disadvantage of the intermittent energy supply and demand [6,7]. Storage systems could be based on sensible, latent or thermo-chemical heat. Here, a TES system based on phase change materials (PCM) which absorb or release heat when the PCM undergoes a phase change is analyzed. Moreover, PCM systems have high-energy storage capacity and isothermal behavior during both charging and discharging processes. There are different ways through which heat energy can be stored [8]:

- External heat storage:
o Storing hot energy to supply the generator.
o Storing of produced cool energy.
- Internal heat storage:
o In external thermal storage systems, the HTF from the solar collectors could be circulated to the hot thermal storage tank to store energy for later use.

Solar Adsorption Refrigeration System

The adsorption refrigeration system using an adsorbent /adsorbent working pair, is composed by different elements: a solar collector which contains the adsorbent /adsorbate working pair (in our case it is the activated carbon/methanol), a condenser where the adsorbate vapor condenses, an evaporator where water plates are laid out to be transformed into ice, in order to store cold for deferred use, and a refrigeration compartment. The development of solar adsorption refrigeration systems appeared in the late 1970s, following the needs of non-oil countries, and several studies have been undertaken [9] since that time a solar ice maker based on adsorption/desorption phenomena which operates intermittently and uses the working pair activated carbon /methanol. A solar adsorption refrigerator was built and tested in 2000 by Hildbrand [9] in Switzerland using the pair Silica gel-Water. The system does not contain any movable part, and the author has obtained a COP between 0.12 and 0.23. Mayor [10] made an adsorption refrigerator working with the pair silica gel/water. This refrigerator is characterized by its compactness and its ability to be transported. The working volume of this refrigerator is 100 liters, the surface of the solar collector is 1m2 and its mass reaches 150 kg. This machine was built with materials to minimize the mass of the system. For better insulation of refrigeration compartment, vacuum panels (VIPs) were used, while a large storage volume capacity was maintained. An independent valve was developed to eliminate any human manipulation. Abu-Hamdeh [11] investigated some work on solar adsorption refrigerator using parabolic trough collector and uses olive waste as adsorbent with methanol as adsorbate. The author showed, from the COP values, that the optimal adsorbent mass varied between 30 and 40 kg while the optimum tank volume varied between 0.2 and 0.3 m3. Wang [8] developed a novel two-stage adsorption freezing machine, which is powered by the heat source with the temperature below 100°C. The composite adsorbents of CaCl2 and BaCl2 developed by the matrix of expanded natural graphite were chosen as adsorbents. The experimental results showed that the optimal coefficient of performance (COP) and specific cooling power (SCP) at 15 °C refrigeration are 0.127 and 100W.kg-1, respectively. COP and SCP increased with the increasing heat source temperature and decreased with the decreasing evaporating temperature.

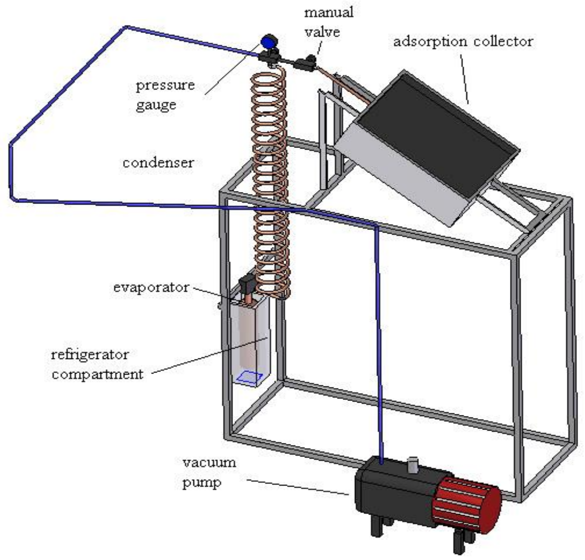

Fig.1.The adsorption Refrigerator [9]

The following figure shows the prototype of the machine adsorption in semi pilot scale manufactured. The realization and test of a prototype at this scale allows evaluating the feasibility of the pilot scale adsorption refrigerator and its operating parameters. The prototype has the following components: a thermally insulated refrigeration compartment, an evaporator, a condenser and an adsorption tube collector (see Fig.1). The operation principle of the machine consists in heating by solar radiation the adsorbent contained in the adsorption collector, which is disposed horizontally. This energy should be sufficient to desorb the molecules of the adsorbate (methanol) and to be transformed from its liquid phase into vapour. Then, the methanol vapours are condensed in a condenser and collected in a tank then evacuated towards the evaporator in a liquid phase. The adsorbent starts to cool gradually when solar radiation begins de decrease in the evening to reach the ambient temperature. This decrease in temperature involves the adsorption phenomenon of the activated carbon with the methanol. Cold production is the result of the energy needed to evaporate the methanol in the evaporator, which will Be absorbed by the activated carbon. This phenomenon will cease when the adsorbent is completely saturated with methanol for a temperature slightly higher than the environmental temperature and the initial vacuum pressure.[9]

Solar Intermittent Refrigeration system

The basic concepts of solar refrigeration appeared since about five decades, to date there are only a limited number of developed systems reported in the open literature, some of the most important works are the following. Erhard et al. [12] reported the performance of a solar refrigeration system operating with $NH_3/SrCl_2$. The main part of the device is an absorber/desorber unit which is mounted inside a concentrating solar collector in which the heat of absorption is transported out of the solar collector by means of two horizontally working heat pipes. The overall efficiency defined as the cooling capacity to the solar radiation received by the solar collectors of the cooling system varied from 0.05 to 0.08. Wang et al. [13] published the results of a combined adsorption heating and cooling system which operated with activated carbon/methanol. The system was tested with electric heating and it was found that with 61 MJ heating it was able produce up to 9 kg ice were made. The calculated Coefficient of Performance (COP) which is defined as the cooling capacity to the heat supplied to the generator of the system was 0.0591. Li et al. [14] published the experimental study on dynamic performance of a flat-plate solar solid-adsorption refrigeration for ice maker operating with activated carbon/methanol. The experimental results showed that this machine can produce 4–5 kg of ice after receiving 14–16 MJ of radiation energy with a surface area of 0.75 m^2, while producing 7–10 kg of ice after receiving 28–30 MJ of radiation energy with 1.5 m^2. Hildbrand et al. [15] reported the results of the performance of an adsorptive solar refrigerator built in Yverdon-les-Bains, Switzerland operating with the adsorption pair silicagel + water. Cylindrical tubes function as both the adsorber system and the solar collector. The condenser is air-cooled and the evaporator contains 40 l of water that can freeze. The results showed that the gross solar coefficient of performance defined by the authors varied between 0.1 and 0.25 with a mean value of 0.16. Khattab [16] presented the description an operation of a novel solar-powered adsorption refrigeration system operating with activated carbon/methanol. The system consisted of a modified glass tube having a generator (sorption bed) at one end and a combined evaporator and condenser at the other end and a simple arrangement of plane reflectors to heat the generator. The daily ice production was 6.9 and 9.4 kg/m^2 and the net solar COP was 0.136 and 0.159 for cold and hot climate respectively. Li et al. [17] developed a no valve, flat plate solar ice maker on the basis of previous research achievements. The system operated again with activated carbon/methanol. The authors reported that the no valve solar ice maker prototype was approached to practical application of mass production from view of cost and techniques.

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Rivera et al [18] published a paper about the development of a solar intermittent system operating with the ammonia/lithium nitrate mixture. The authors reported that solar coefficients of performance as high as 0.08 can be obtained whit the developed system

From the literature review it is clear that although has been relevant research on developing solar refrigeration systems the most of them have been focused in adsorption systems which have in general low coefficients of performance. Because of this in the present paper the system developed previously by Rivera [18] was evaluated but using now the ternary mixture ammonia/lithium nitrate/water with the purpose to increase the mixture conductivity and to decrease the mixture viscosity trying to increase the system efficiency. Physical and thermodynamic properties of the ternary mixture were taken from Libotean et al [19,20].

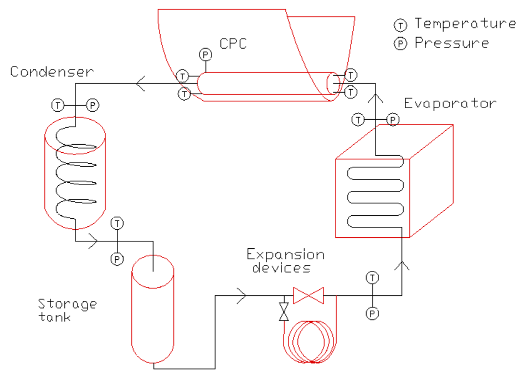

Fig. 2. Schematic diagram of the solar intermittent absorption refrigeration system[21]

Fig. 3.Photograph of the solar intermittent absorption refrigeration system developed[21]

Materials for Solar cooling and Refrigeration System

Material selection process for the solar cooling or refrigerating system is very crucial stage selected according to temperature range. Different PCM with phase change temperature in the range for solar cooling applications were selected as candidates from literature review [22-23]. Many researchers have dealt with both experimental and numerical analysis of different configurations of TES systems using PCM as the storage media for different applications. Medrano et al. [24] experimentally investigated the heat transfer process during the melting and solidification RT35 as PCM in five small heat exchangers. The highest average thermal power was obtained for the compact heat exchanger which was a shell-and-tube which incorporated fins. Later on, Adine and Qarnia [25] presented a numerical analysis of the thermal behavior of a shell-and-tube PCM system comparing the utilization between one and two PCM. Similarly, Trp et al. [26] analyzed numerically and experimentally the transient phenomenon during both charging and discharging processes of the shell-and-tube latent energy storage system using paraffin as PCM. The authors concluded a general statement saying that the selection of the operating conditions and geometric parameters dimensions depends on the required heat transfer rate and the time in which the energy has to be stored or delivered. Moreover, and due to the solar radiation intensity variation over time, the phase change process can occur under the non-steady-state inlet boundary conditions. Tao and He [27] performed a numerical study on TES performance of PCM using a shell-and-tube unit under non-steady-state inlet boundary conditions. Their main conclusion was that when the average HTF inlet temperature is fixed at a constant value, the melting time decreases with the increase of the initial inlet temperature. Most of the researchers worked with PCM having low phase change temperature however, some other investigations using PCM with higher melting point have been performed. Agyeneim et al. [28] compared the performance of a multi-tube system with that of a single tube shell and tube system using a PCM with a phase change temperature of 117.7 ºC. The main conclusion of their study was that the multi-tube system improved the heat transfer rate during charging, and produced an output temperature suitable to operate the absorption cooling system, but showed large sub cooling effect. Moreover, an eutectic mixture of KNO3/NaNO3 as PCM with a melting temperature of 221 ºC in a storage prototype with an expanded graphite sandwich configuration for direct steam generation in solar thermal power plants was experimentally tested by Bayón et al. [29].

CONCLUSION

A solar refrigeration system is a very effective system to produce refrigerating effect using solar energy. The TES system is targeted for solar cooling applications. The conclusion of this paper is an adsorption refrigeration system for cold production able to answer the socioeconomic requirements, in particular in term of total low costs as the economical solar collector, equipment, and maintenance cost and technological simplicity. Cold thermal storage is used in order to store cooling energy use while shifting. Simulation of the phase change phenomena is undertaken in order to determine the quantity of PCM (ice) required to counteract the heat losses at the walls during its melting cycle (night period). A solar intermittent refrigeration system for ice production has been evaluated with the ammonia/lithium nitrate/water mixtures at the evaporator temperatures as low as - 11°C were obtained for a period of time up to 8 hours. The solar coefficient of performance reached values up to 0.098, which is 24% higher than the maximum obtained previously by Rivera [18] operating the system with the ammonia/lithium nitrate mixture.

Reference

[1] Desideri U, Proietti S, Sdringola P. Solar-powered cooling systems: technical and economic analysis on industrial refrigeration and air-conditioning applications. Apply Energy 2009;86:1376–86.

[2] Tamainot-Telto Z, Metcalf SJ, Critoph RE, Zhong Y, Thorpe R. Carbon–ammonia pairs for adsorption refrigeration applications: ice making, air conditioning and heat pumping. Int J Refrig2009;32:1212–29.

[3] Abdulateef JM, Sopian K, Alghoul MA, Sulaiman MY. Review on solar-driven ejector refrigeration technologies. Renewable Sustainable Energy Rev 2009;13:1338–49.

[4] Tchemev D I ,Einerson D T.High efficiency regenerative zeolite pump.ASHRAE rna

[5] Y.L.LIU,R.Z.Wang,Z.Z.Xia,Experimental study on a continous adsorption water chiller with novel design, International Journal of Refrigeration,2005,28(2),218-230

[6] Gil A, Medrano M, Martorell I, Lázaro A, Dolado P, Zalba B, Cabeza LF. State of the art on high temperature thermal energy storage for power generation. Part 1-Concepts, materials and modellization. *Renewable and Sustainable Energy Reviews* 2010;14:31-55.

[7] Medrano M, Gil A, Martorell I, Potau X, Cabeza LF. State of the art on high-temperature thermal energy storage for power generation. Part 2-Case studies. *Renewable and Sustainable Energy Reviews* 2010;14:56-72.

[8] Chidambaram LA, Ramana AS, Kamaraj G, Velraj R. Review of solar cooling methods and thermal storage options. *Renewable and Sustainable Energy Reviews* 2011;15:3220-3228.

[9] Mohand Berdja, Brahim Abbad, Ferhat Yahi, Fateh Bouzefour, Maamar Ouali. Design and realization of a solar adsorption refrigeration machine powered by solar energy Energy Procedia 48 (2014) 1226 – 1235

[10] Mayor J, Dind P. Construction et test d'un réfrigérateur solaire à adsorption transportable. Laboratoire d'Energétique Solaire et de Physique du bâtiment, HES-SO/EIVD (2003). Yverdon-les-Bains. Suisse.

[11] Abu-Hamdeh NH, Alnefaie KA, Almitani KH. Design and performance characteristics of solar adsorption refrigeration system using parabolic trough collector: Experimental and statistical optimization technique. Energy Conversion and Management 74 (2013) 162–170.

[12] A. Erhard, K. Spindler, T. Hahne, Test and simulation of a solar powered solid sorption cooling

machine, Int. J. Refrigeration 21(2), 1998, pp. 133-141.

[13] R. Z. Wang, Y. X. Xu, J. Y. Wu, M. Li, H. B. Shou, Research on a combined adsorption heating and cooling system, Applied Thermal Engineering 22, 2002, pp. 603–617.

[14] M. Li, R. Z. Wang, Y. X. Xu, J. Y. Wu, A.O. Dieng, Experimental study on dynamicperformance analysis of a flat-plate solar solid-adsorption refrigeration for ice maker, Renewable Energy 27, 2002, pp. 211–221.

[15] C.Hildbrand, P Dind, M. Pons, F. Buchter, A new solar powered adsorption refrigerator with high performance. Solar Energy 77, 2004, pp. 311–318.

[16] N. M. Khattab, A novel solar-powered adsorption refrigeration module, Applied Thermal Engineering 24, 2004, pp. 2747–2760.

[17] M. Li, C. J. Sun, R. Z Wang, W. D Cai, Development of no valve solar ice maker, Applied Thermal Engineering 2004;24:865–872.

[18] W. Rivera, G. Moreno-Quintanar, C. O Rivera, R. Best, F. Martínez, Evaluation of a solarintermittent refrigeration system for ice production operating with ammonia/lithium nitrate, Solar Energy 85(1), 2011, pp. 38-45.

[19] S. Libotean, D. Salavera, M. Valles, J. Esteve, A. Coronas, Vapor-liquid equilibrium of ammonia+lithium nitrate+water and ammonia+lithium nitrate solution from (293.15 to 353.15) K, Journal Chemical and Engineering Data 52, 2007, pp. 1050–1055.

[20] S. Libotean, D. Salavera, M. Valles, J. Esteve, A. Coronas, Densities, viscosities, and heat capacities of ammonia + lithium nitrate and ammonia + lithium nitrate + water solutions between (293.15 to 353.15) K, Journal Chemical and Engineering Data 53, 2008, pp. 2383–2393.

[21] G. Moreno-Quintanar, W. Rivera*, R. Best. Development of a solar intermittent refrigeration system for ice production. *Centro de Investigación en Energía, Universidad Nacional Autónoma de México*
A.P.34, 62580 Temixco, Mor., México

[22] Zalba B, Marín JM, Cabeza LF, Mehling H. Review on thermal energy storage with phase change: Materials, heat transfer analysis and applications. *Applied Thermal Engineering* 2003;23:251-283.

[23] Sharma SD, Sagara K. Latent heat storage materials and systems: A review. *International Journal of Green Energy* 2005;2:1-56.

[24] Medrano M, Yilmaz MO, Nogués M, Martorell I, Roca J, Cabeza LF. Experimental evaluation of commercial heat exchangers for use as PCM thermal storage systems. *Applied Energy* 2009;86:2047-2055.

[25] Adine HA, Qarnia HE. Numerical analysis of the thermal behaviour of a shell-and-tube heat storage unit using phase change materials. *Applied Mathematical Modelling* 2009;33:2132-2144.

[26] Trp A, Lenic K, Frankovic B. Analysis of the influence of operating conditions and geometric parameters on heat transfer in water-paraffin shell-and-tube latent thermal energy storage unit. *Applied Thermal Engineering* 2006;26:1830-1839.

[27] Tao YB, He YL. Numerical study on thermal energy storage performance of phase change material under non-steady-state inlet boundary. *Applied Energy* 2011;88:4172-4179.

[28] Agyenim F, Eames P, Smyth M. Heat transfer enhancement in medium temperature thermal energy system using a multitube heat transfer array. *Renewable Energy* 2010;35:197-207.

[29] Bayón R, Rojas E, Valenzuela L, Zarza E, León J. Analysis of the experimental behavior of a 100 kWth latent heat storage system for direct steam generation in solar thermal power plants. *Applied Thermal Engineering* 2010;30:2643-2651.