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Solar Assisted Adsorption Refrigerating Machine with Composite Adsorbent

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ABSTRACT

The adsorption refrigeration is based on the evaporation and condensation of a refrigerant combined with adsorption. This project will describes the design and fabrication of the experimental chamber, the experimental procedure and its feasibility towards development of an alternative eco-friendly refrigeration cycle for replacement of chlorofluorocarbons. The objective of this project is to establish an alternative eco-friendly refrigeration cycle for producing a temperature usually encountered in a conventional refrigerator. By manufacturing such type of refrigerator adds new dimension to the world of refrigeration. This refrigerator gives some amount of relief to the refrigeration world by making it independent of electric power supply and zero running cost. This system designed by using pair of silica gel as adsorbing material and water as a refrigerant. This system is capable of cooling down a load of 10 liters initially at 35°C; down to 08°C Causing only solar energy produced by a flat plate solar collector.

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I. INTRODUCTION

Refrigeration is defined as “the process of cooling of bodies or fluids to temperatures lower than those available in the surroundings at a particular time and place”. It should be kept in mind that refrigeration is not same as “cooling”, even though both the terms imply a decrease in temperature. In general, cooling is a heat transfer process down a temperature gradient; it can be a natural, spontaneous process or an artificial process. However, refrigeration is not a spontaneous process, as it requires expenditure of exergy (or availability). Thus cooling of a hot cup of coffee is a spontaneous cooling process (not a refrigeration process), while converting a glass of water from room temperature to say, a block of ice, is a refrigeration process (non-spontaneous). “All refrigeration processes involve cooling, but all cooling processes need not involve refrigeration”. Refrigeration is a much more difficult process than heating; this is in accordance with the second laws of thermodynamics. This also explains the fact that people knew ‘how to heat’, much earlier than they learned ‘how to refrigerate’. All practical refrigeration processes involve reducing the temperature of a system from its initial value to the required temperature that is lower than the surroundings, and then maintaining the system at the required low temperature. The second part is necessary due to the reason that once the temperature of a system is reduced, a potential for heat transfer is created between the system and surroundings, and in the absence of a “perfect insulation” heat transfer from the surroundings to the system takes place resulting in increase in system temperature. In addition, the system itself may generate heat (e.g. due to human beings, appliances etc.), which needs to be extracted continuously. Thus in practice refrigeration systems have to first reduce the system temperature and then extract heat from the system at such a rate that the temperature of the system remains low. Theoretically refrigeration can be achieved by several methods. All these methods involve producing temperatures low enough for heat transfer to take place from the system being refrigerated to the system that is producing refrigeration.

II. LITERATURE REVIEW

Fatiha et al. [01] For countries with a high potential of solar energy, producing cold using solar energy is a promising way to sustainable development since the energy used is free and not harmful for the environment. This work proposes a solar adsorption refrigerator using the pair activated carbon–methanol, which has been totally built and is under experimental tests in the solar laboratory of the Faculty of Sciences of Rabat, the capital of Morocco with Mediterranean climate. The solar adsorption refrigerator is mainly composed of a collector containing the adsorbent, an evaporator and a condenser. The results show that the refrigerator gives good performance in Rabat. The unit produces cold even in rainy and cloudy days and the temperatures achieved by the unit can be less than 11.1ºC for days with a very high irradiation. The solar coefficient of performance (COP) (cooling energy/solar energy) ranges between 5% and 8% for an irradiation between 12,000 and 28,000 kJm2 and a daily mean ambient temperature around 20.1ºC.

Tiago et al. 2008 [02] studied the use of solar energy in buildings is an important contribution for the reduction of fossil fuel consumption and harmful emissions to the environment. Solar thermal cooling systems are still in their infancy regarding practical applications, although the technology is sufficiently developed for a number of years. In many cases, their application has been conditioned by the lack of integration between cooling and heating systems. This study aims to evaluate the potential of integrated solar absorption cooling and heating systems for building applications. The TRNSYS software tool was used as a basis for assessment. Different building types were considered: residential, office and hotel. The TRNSYS models are able to run for a whole year (365 days), according to control rules (self-deciding whether to operate in heating or cooling modes), and with the possibility of combining cooling, heating and DHW applications. Three different locations and climates were considered: Berlin (Germany), Lisbon (Portugal), and Rome (Italy).

Both energy and economic results are presented for all cases. The different local costs for energy (gas, electricity and water) were taken into account. Savings in CO2 emissions were also assessed. An optimization of solar collector size and other system parameters was also analysed.

M. Li et al. 2002 [03] presented a uniform pressure model to describe the heat and mass transfer in an adsorbent bed for a flat plate solar ice maker. This model accounts for heat and mass transfer in a porous bed in a two dimensional transient process. An experiment has been conducted to validate this model and the calculated results are in good agreement with experiments. With the help of this model, the transient analysis and performance prediction of an intermittent solar powered solid refrigerator can be presented. A flat plate solar adsorption solid ice maker was developed in Shanghai Jiao Tong University for demonstration purposes. Thermocouples were equipped within the adsorbent layer, condenser, and evaporator, so that all the experimental data, such as the condensing temperature, the evaporating temperature and the adsorbent temperature, can be obtained automatically with the help of a computer. This makes it possible to validate calculated data with experimental data.

M. Li et al. 2001[04] flat-plate solid-adsorption refrigeration ice maker has been built for demonstration purposes. The working pair consists of methanol used as the refrigerant and activated carbon as the adsorption medium. The adsorbent bed is constructed of two flat-plate collectors, with a total surface area of 1.5m². Solar radiation can be simulated with quartz lamps and some important parameters such as temperature and pressure of each subsystem can be handled by a computer. The experimental results show that this machine can produce 4–5 kg of ice after receiving 14–16 MJ of radiation energy with a surface area of 0.75m², while producing 7– 10 kg of ice after receiving 28–30 MJ of radiation energy with 1.5m². These are the most advanced results for a solar ice maker so far. All these successful achievements will speed up the commercial processing of a solar ice maker. A flat-plate solar-powered ice maker was fabricated for demonstrating and analyzing the properties of solar solid-adsorption refrigeration.

Luo et al. 2005 [05] studied the solar cooling technology is attractive since cooling load of building is roughly in phase with solar energy availability. In this study, a solar adsorption chiller was built and tested with aim of developing an alternative refrigeration system used for grain cooling storage. This solar adsorption chiller consists of four subsystems, namely, a solar water heating unit with 49.4 m² solar collecting area, a silica gel–water adsorption chiller, a cooling tower and a fan coil unit. In order to achieve continuous refrigeration, two adsorption units are operated out-of-phase with mass recovery cycle in the adsorption chiller. Field test results show that, under the climatic conditions of daily solar radiation being about 16–21 MJ/m2, this solar adsorption chiller can furnish 14–22ºC chilled air with an average cooling output ranging from about 3.2–4.4 kW, its daily solar cooling COP (coefficient of performance) is about 0.1–0.13.

Zhai et al. [06] presented the solar adsorption cooling system which can be switched between a system with heat storage and a system without heat storage was designed. In the system with heat storage, a heat storage water tank was employed as the link between the solar collector circulation and the hot water circulation for the adsorption chillers. However, the heat storage water tank was isolated in the system without heat storage, and the hot water was directly circulated between the solar collector arrays and the adsorption chillers. It was found that the inlet and outlet temperatures for the solar collector arrays and the adsorption chillers in the system without heat storage were more fluctuant than those of the system with heat storage. Also found was that the system with heat storage operated stably because of the regulating effect by the heat storage water tank. However, under otherwise similar conditions, the cooling effect of the system without heat storage was similar to that of the system with heat storage. Compared with the system with heat storage, the system without heat storage has the advantages of higher solar collecting efficiency as well as higher electrical COP.

III. **DESIGN AND EXPERIMENTATION**

The tests were carried out at the Pune at 25º44' latitude and 28º 11’ longitudes. The adsorber was facing north and tilted at 30º to the horizontal. Figure 4.2 below illustrates the valve arrangement for the test rig. Prior to the experimentation, a preliminary test was carried out to verify the system performance and fix all undesirable problems. Leakages were located and fixed. The experiment was run according to the procedure as set out in table 5.1 and the explanation below:

Table 1: Procedure for operating the fridge

Time	Valve 1	Valve 1	Valve 1	Process
08.00	Close	Close	Close	Heat Adsorbant
11.00	Close	Open	Close	Heat Adsorbent : Condensation
19.00 – 07.00	Open	Close	Open	Evaporation: Cooling. One Cycle

i) The adsorber was filled with silica gel and sealed, was heated by solar energy to about 116ºC, and then the system evacuated by a vacuum pump to a pressure of -84 kPa for 24 hours during three consecutive days. This was done to dry the silica gel.

ii) All vacuum valves and adsorber end covers were then closed. Distilled, boiled water was introduced into the evaporator pipes to act as a refrigerant. This was done to remove as much air as possible.

iii) At the beginning of each test, the adsorbent was heated with the aid of available solar energy from 8 am to 11 am, then valve 2 was opened to effect silica gel desorption and vapour condensation. Valves 1 and 4 remained closed.

iv) Silica gel desorption and vapour condensation were allowed to continue for about four hours after the maximum cycle temperature was realized.

v) When desorption was complete, the collector box end cover plates were opened to allow ambient air to flow and start cooling the adsorber. As cooling progressed, valve 4 was opened to let the condensate into the evaporator pipes. The adsorber was allowed to cool until the difference of pressure between evaporator and adsorber was lower than 90 Pa. Then valve 2 was closed while valve 1 was opened to permit evaporation to begin.

vi) The cooling load of 10 liters of water at temperature of 35ºC was introduced in the cooling cabinet before the commencement of any adsorption processes.

vii) During evaporation of the vapour in the evaporator pipes, the cooling effect chilled the water (load) placed in the cooling chamber. When the adsorbent became saturated, a single intermittent cycle of adsorption cooling was completed.

IV. RESULT AND ANALYSIS

I = 5026.26 W/m² per day.
A = 1.478 m^2. (Adsorber area).
ITotal = I x A
= (5026.26 x 1.478 x 3600) /1000
= 26743.72 W
Ti = 40.45°C
Tout = 8.02°C
Cp = 4.2 kJ/kg.K
M = 10 kg (Load mass)
Qe = m x Cp x (Tin - Tout)
Qe = 10 x 4.187 x (40.45 – 8.02)
= 1357.84 W
COP = Q_e / I_{Total}
= 1357.84 / 26743.72
= 0.051

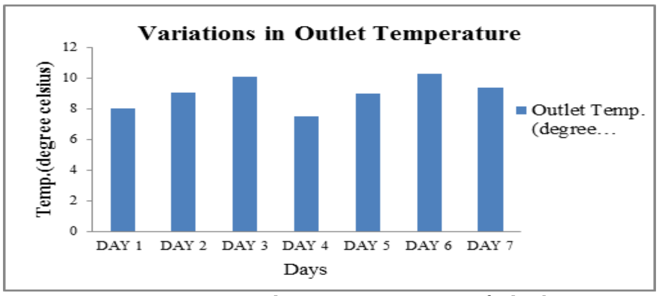

Figure 4.4: Measured temperature–pressure of adsorber

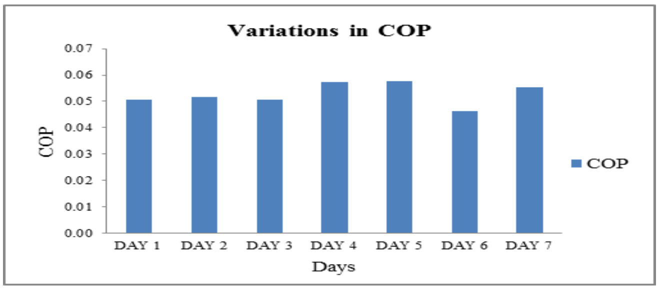

Figure 4.6 Represents variations in system COP.

Maximum COP of system is achieved up to 0.058. Variation in system COP depends on the solar intensity.

V. CONCLUSION

- Test results show that the fridge is capable of cooling down a load of 10 liters initially at 35°C; down to 8°C causing only solar energy produced by a flat plate solar collector; which was the main objective of this study.
- Test results show that only chilled water with temperatures between 6°C and 12°C is produced.
- Final analysis shows that the process of solar adsorption-assisted cooling could be an alternative for vapour compression system for cold room applications.

REFERENCES

[1] Dupont M., Guilleminot J. J., Menuier F., & Nguyen P. 1982. Study Of Solar Ice Conservators Using Day Night Intermittent Zeolite 13x–Water Cycle In Temperate And Tropical Climates. Paper Presented At The International Institute Of Refrigeration.

[2] Tangkengsirisin V., Kanzawa A., & Watanabe T. 1998. A Solar Powered Adsorption Cooling System Using A Silica Gel–Water Mixture. Energy, 23(5), 347-353.

[3] M. Li, R.Z. Wang, Heat And Mass Transfer In A Flat Plate Solar Solid Adsorption, Renew. Energy 28 (2003) 613–622.

[4] M. Li, R.Z. Wang, A Study Of The Effects Of Collector And Environment Parameters On The Performance Of A Solar Powered Solid Adsorption Refrigerator, Renew. Energy 27 (2002) 369–382.

[5] Núñez T., Mittelbachand W., & Henning M. 2005. Development Of An Adsorption Chillers And Heat Pump For Domestic Heating And Air-Conditioning Applications. Applied Thermal Engineering, 27(13), 2205-2212.

[6] Wang R. Z., Wu J. Y., Luo H. L., Dai Y. J., Xu Y. X., & Shen J. M. 2006. Experimental Investigation Of A Solar Adsorption Chillers Used For Grain Depot Cooling. Applied Thermal Engineering, 26(11-12), 1218-1225.

