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Experimental Investigation of Cascade Refrigeration System with PCM

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Abstract: *If vapour compression system are to be used for the production of low temperatures, the best alternative to stage compression is the cascade system. If very low temperature is desired, then the corresponding evaporator pressure is also low and this results in a higher pressure ratio, there is a reduction in volumetric efficiency. In order to avoid this problem, cascade refrigeration system is used. Again question was of energy. In day to day life, the challenge was to save electrical energy along with the increasing performance of the system. So the development was done by using the Phase Change Material (PCM). In this paper the experimentation was done on cascade refrigeration system with PCM and without PCM. Also calculated the energy efficiency of the system using different PCMs and different size and shape of the PCM boxes. For this experimentation, the PCM box was made of aluminium sheet having a 2cm and 3cm thickness, whereas ethylene glycol-water solution and NaCl solution was used as a PCM*

I. INTRODUCTION

If vapour compression system are to be used for the production of low temperatures, the best alternative to stage compression is the cascade system. A cascade refrigeration system is a multistage application in which two separate refrigerant systems are connected in such a manner that one provides the means of heat rejection (condenser) for the other. The lower system may, therefore operate at a much lower temperature. Phase change materials (PCM) are substances with high latent heat storage that melts and freezes at nearly constant temperature, releases large amount of energy during freezing (discharging) and absorbs large amount of energy during melting (charging) when the material changes from liquid to solid and vice versa i.e, phase change. In conventional system the heat releasing environment for evaporator is usually air but using a Phase Change Material (PCM) surrounding the evaporator coil work as a liquid or solid medium to release the heat. PCM is touched with the evaporator coil the stored heat energy of PCM will be extracted by the refrigerant through conduction method during compressor on mode. The conduction transfer is faster than the natural convection heat transfer. In the conventional refrigerator the cabinet heat is extracted by the refrigerant through natural convection. So the PCM will improve the heat transfer performance of the evaporator.

II. LITERATURE REVIEW

Mahmood Mastani Joybari et al. [1] Domestic refrigerators are among the most widely used household appliances and a great portion of energy is used by these systems. Reduction of temperature fluctuation and enhancement of system performance is the main reason of using phase change materials (PCMs) in refrigeration systems. Different approaches have been used to improve the thermal performance of these systems by integration of PCM. A number of studies have focused on the application of PCM at evaporator for cold storage. This paper presents a review of the experimental efforts as well as modelling approaches to study the application of PCMs in domestic refrigerators. Moreover, advantages and disadvantages of each type of storage are presented and, the future and potential promising applications of PCMs in domestic refrigerators are discussed. David C. Onyejekwe [2] Analysis of the optimal form of a container of PCM is carried out. A series of experiments which include thermal characterisation of the freezer, appropriate volume of PCM, effect of stratification and cyclic storage are shown. Optimisation of parameters for latent heat storage is made, and both experimental and parametric optimisation results are compared. The results show the possibility of using NaCl/H_20 eutectic mixture for thermal storage at low temperatures, ranging from - 15 to -20°C. From the results of the experiments carried out, optimal performance is achieved if the container of the PCM is placed vertical, close to the walls with evaporators and very low to the base of the freezer.

K.Azzouz et al. [3] This paper presented a first step in the design of an improved refrigeration system using phase change material. In this paper a 5mm thick slab of water is used as PCM on one side of the evaporator of a household refrigerator. There is a significant increase of efficiency due to enhanced heat transfer from the evaporat or by conduction to the PCM that replaces the previously natural convective heat transfer to the air. There is 25% decrease in the global working time of the compressor. COP of the system without PCM was 1.09 and COP of the system with PCM was found out to be 1.9. Low phase change temperature decreases the corresponding compartment temperature. This is more important for fresh food compartment since its temperature should never fall below zero (to prevent freezing and food quality loss). Therefore, an admissible phase change temperature range exists between these two high and low extremes. K.Azzouz et al. [4] This paper presents a first step in the design of an improved refrigerator using phase change material as a cold storage. A simplified dynamic model based on differential equations is developed for predicting the energy impact due to the addition of the PCM. Benjamin Gin et al. [5] An investigation for effect of phase change material (PCM) panels placed against the internal walls of a freezer during repeated power loss every 24 hours over a 2 week period was conducted. Comparisons of the freezer air temperature and product temperature in a freezer containing PCM panels showed lower temperature fluctuations than in a freezer without PCM.

B. Gin et al. [6] An investigation into the effectiveness of phase change material (PCM) panels against the internal walls of a freezer to maintain stable temperatures in the presence of heat loads such as door openings, defrosting and loss of electrical power was carried out. Temperature response was studied during loss of power, a defrost cycle lasting 30 min, and a door openings scheme of 13 door openings over an 11h period.

A.C. Marques et al. [7] Integration of 5mm PCM slab into the refrigerator allowed for 3-5h of continuous operation without a power supply. The numerical model was found to be in good agreement with the experimental results, with the error between the simulation and tests below 5% for most experiments. Deni Thomas Boban et al. [7] This work investigates about the performance enhancement of a domestic refrigerator by incorporating phase change materials (PCM) inside the evaporator. A U-shaped PCM box is used to contain the PCM, to improve its efficiency and to provide a storage capacity allowing several hours of refrigeration without power supply. This system has been tested with water, ethylene glycol mixture and eutectic solution as PCM. It has been found that the addition of PCM results in an enhanced conduction heat transfer from the PCM to the evaporator coil. A U Shaped box is fabricated and is fitted inside the evaporator cabin to contain the phase change material. It is fitted in such a way that it is fully in contact with the evaporator coils. The box is made of galvanized iron sheets with a thickness of 5mm. R. Elarem et al. [8] In this work, a novel design of a PCM heat exchanger was made. Based on this design, an experimental test rig was developed to conduct a series of experimental studies in order to minimize the energy consumption of the household refrigerator.

The experimental results show that under the standard test conditions, the power consumption of the household refrigerator with PCM heat exchanger is reduced by 12% and the COP is increased by 8% compared to the refrigerator without PCM. M.I.H. Khan et al. [9] Here evaporator coils were immersed in PCM. In such cases, faster heat transfer is achieved which is due to the faster nature of conduction/convection in PCMs than natural convection of air. Therefore, due to the high thermal inertia of a PCM, the refrigerant pressure and temperature do not fall as much as the case with no PCM which in turn gives higher refrigerant mass flow rate. M. Berdja et al. [10] However, if the evaporator is immersed in a PCM with a phase change temperature higher than the compartment set-point temperature, a high thermal resistance is created around the evaporator which, in turn, brings more frequent compressor start/stop.

In domestic refrigerators, the evaporator works based on either free or forced convective heat transfer. The former (also known as naturally-cooled evaporator) has low heat transfer rate and could result in temperature stratification inside the compartment, while the latter gives better temperature stability. However, its main drawbacks are higher energy consumption, the spread of odour, and the food weight loss due to high air circulation. One approach to overcome these drawbacks is the application of thermal energy storage (i.e. PCMs) and for low temperature application in the range of -400c to -800c, cascade system with PCM will be analysed.

III. Experimental Analysis

In a cascade system a series of refrigerants with progressively lower boiling poi nts are used in a series of single stage units. The condenser of lower stage system is coupled to the evaporator of the next higher stage system and so on. The component where heat of condensation of lower stage refrigerant is supplied for vaporization of next level refrigerant is called as cascade condenser. The cascade system is divided in to three parts. These are as follows: High side, Intermediate stage and low side. The refrigerant used on the high side is R -404a and the refrigerant used on the low side is R-22. On the high side a hermetically sealed compressor, shell and coil type condenser, drier/filter, flow meter, expansion device and cascade condenser are connected to each other. A dimmer is also provided to control the input of the heater. Flow meter in liquid line is incorporated to measure the refrigerant flow. In this, experimentation was done by using the 2cm and 3cm of aluminium sheet is used for the 2 PCM. PCM1 is 50-50% Ethylene glycol and PCM2 is NaCl aqueous solution.

Figure 1: Pictorial view of Experimental Setup

IV. Result And Discussion

The experimentation was done on the cascade refrigeration system using two PCM materials named as Ethyl Glycol and Sodium Chloride mixture. These two PCM is stored in the aluminium boxes having fins and without fins. Total 9 experiments were performed on the experimental setup. After observations, the COP is calculated for the different configurations and observed the optimum design from the energy saving point of view.

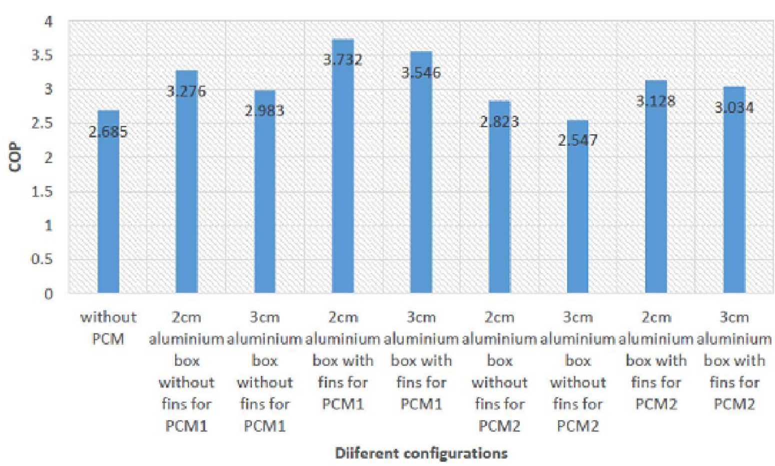

Figure 2: Comparative study of effect of different configurations on COP for PCM1 & PCM2

From the above graph we can say that the COP for the PCM1 is more than that of the PCM2. Again for the PCM1 it is observed that the maximum value of COP has been recorded as 3.732 for the 2cm of aluminium box with fins. So we

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can say that the PCM 1 i.e. ethyl glycol is more effective than that of the PCM2 i.e. NaCl aqueous solution. It is observed that the increase in COP of the cascade system with PCM is about 38.99 %.

V. Conclusion

From the above experimentation we can put the following conclusions,

1. The COP of the PCM 1 i.e. Ethylene glycol is more than that of the PCM2 i.e. NaCl aqueous solution. This value for the PCM1 is recorded as 3.732.
2. From the configuration of the PCM box point of view, the aluminium box of 2cm thickness with fins has the maximum value of COP.
3. The COP of the cascade refrigeration system with PCM is increased by the percentage of 38.99. so it is effective than the cascade system without PCM.

References

[1]. S., Anandan, V., Ramalingam, "Thermal Management of Electronics: A Review of Literature thermal Science", 2008, Vol. 12, pp: 5-26.

[2]. A., Sharma, V., Tyagi, C., R., Chen, D., Buddhi, "Review on Thermal Energy Storage with Phase Change Material and applica tions", Renewable

[3]. And Sustainable Energy Review, 2009, vol13, pp: 312-345.

[4]. C., J., M., Lasance, "The Need for A Change In Thermal De Sign Philosophy, of Electronics Cooling", 1995, pp: 24 -26,

[5]. El-Kassaby, Ahmed, "Modelling of Heat Exchanger Using Phase Change Material for Short Term Storage", Mechanical Engineering

[6]. Department, Alexandri University, Agriculture Engineering Department 1993, Vol 3 No.8, pp: 88-93.

[7]. T., O., Leimkuehler, R., A., Stephan, "Experimental Investigation of Ice Phase Change Material Heat Exchangers" Journal published in American

[8]. Institute of Aeronautics and Astronautics, 2008. pp: 453-456.

[9]. V., B., Choudhari, R., S., Powar, "A Review on Performance Investigation of Phase Change Material in Heat Exchanger for Latent Cool

[10]. Storage", 2015, E-ISSN: 2454-9916, Volume: 1, Issue: 5, pp:765-769.

[11]. R., Kandasamy, X., Q., Wang, A., S., Mujumdar, "Transiant Cooling of Electronics Using Phase Change Materials", 2007, pp: 1048-50.

[12]. A., Joulin, Z., Younsi, L., Zalewski, S., Lassue, D., R., Rousse, J., P., Cavrot, "Experimen tal and numerical investigation of a phase change material: Thermal-energy storage and release", Applied Energy, 2011, 88, pp: 2454–2462.

[13]. X., Duan, G., F., Naterer, "Heat transfer in phase change materials for thermal management of electric vehicle ba ttery module", International Journal of Heat and Mass Transfer, 2010, 53, pp. 5176–5182.

[14]. V., Shatikian, G., Ziskind, R., Letan, "Numerical investigation of a PCM -based heat sink with internal fins: Constant heat flux", International Journal of Heat and Mass Transfer, 2088, 51, pp. 1488–1493

[15]. X., Q., Wang, C., Yap, A., S., Mujumdar, "A parametric study of phase change material (PCM) -based heat sinks", International Journal of Thermal Sciences, 2008, 47, pp. 1055–1068.

[16]. R., Kandasamy, X., Q., Wang, A., S., Mujumdar, "Transient cooling of electronics using phase change material (PCM)-based heat sinks", Applied Thermal Engineering, 2008, 28, pp. 1047–1057.

[17]. M., Liu, W., Saman, F., Bruno, "Validation of a mathematical model for encapsulated phase change material flat slabs for cooling applications", Applied Thermal Engineering, 2011, 31, pp. 2340-2347.

[18]. Y., T., Yang, Y., H., Wang, "Numerical simulation of three-dimensional transient cooling application on a portable electronic device using phase change material", International Journal of Thermal Sciences, 2012, 51, pp. 155-162.