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Review Paper on Phase Change Material for Lower Temperature Application used in Domestic Refrigerator

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Abstract

Domestic refrigerators are widely used household appliances and a large extent of energy is consumed by this system. A phase change material is a substances that can store or release significant amount of heat energy by changing the phase liquid to vapour or vice versa. So, reduction of temperature fluctuation and improvement of system performances is that main reason of using PCM enhances the heat transfer rate thus improves the COP of refrigeration as well as the quality frozen food. The release and storage rate of a refrigerator is depends upon the characteristics of refrigerators and its properties using phase change material for a certain thermal load it is found that COP of conventional refrigerator is increased . The phase change material used in chamber built manually and which surrounds the evaporator chamber of a conventional refrigerator the whole heat transfer for load given to refrigerator cabin (to evaporator) evaporator to phase change material by conduction. This system hence improves the performances of household refrigerator by increasing its compressor cut-off time and thereby minimizing electrical energy usage. The main objective is to improve the performance, cooling time period, storage capacity and to maintain the constant cooling effect for more time during power cut off hours using phase change material.

Keywords: PCM, COP, Frozen Food, Energy Usage

I. INTRODUCTION

In refrigeration system lesser the friction losses, the higher evaporation and lower condensation temperature, as well as reduction of losses associated with pressure equalization during of working condition of the compressor can be achieved [1]. Generally PCM, the phase change material is latent heat storage and achieved through solid-solid, solid-liquid, solid-gas, liquid-gas phase change. In which sole phase change used for PCM is that the solid-liquid change thermal energy storage through phase change material has been used for wide applications in the field of refrigeration and air conditioning a phase change material (PCM) may be substances with a high heat of fusion that, melting and hardening at a particular temperature, is a capable of storing and releasing large amount of energy [2].

The household refrigerators are the most extensively used appliances and its consuming massive portion of the total world energy. In which improving the energy efficiency of household refrigerator is an important issue in terms of energy saving. The refrigerant inside the evaporator coils takes the cabinet heat during compressor on mode and during the off mode of the compressor, the temperature inside the evaporator cabinet starts rising due to heat released from the material inside the refrigerator and also due to heat in leak from atmosphere. This on/off stage of compressor makes temperature fluctuation inside the evaporator cabinet which ultimately decreases the quality of the food [3].

In which reduction of temperature fluctuation inside the evaporator cabinet, that is makes a continuous and stable temperature inside the cabinet [4]. Using Phase Change Materials (PCM) as a latent heat thermal energy storage (TES) system could be a new

option for performances improvement of a household refrigerator by increasing heat transfer of the evaporator and reducing efficiency losses of the compressor. [2]

The major loss related to compressor is due to migration of refrigerant. The efficiency losses due to refrigerant migration are noted from 5 to 30% as using PCM. This can be compensated. In off mode condition of compressor phase change material gives refrigerant effect. This reduces the on/off time of compressor, which results in less temperature fluctuation. As compared to the conventional refrigeration system in a cabin for specific time, the average air temperature fluctuations are significantly reduced with the application of phase change material [1].

II. LITERATURE REVIEW

A. F.Alzuwaid, Y.T.Ge[5]

Experimentally investigated the performance of a refrigerated open type multi deck display cabinet the PCM (water gel) was purposely selected and made by mixing different compositions at specific mass ratios to obtain the appropriate melting and freezing temperature for the particular application. The setup was then charged into two single panel radiators, installed immediately after the cabinet evaporator in the main backflow channel, such that the cooled air flow pass through both external radiator sides. Then the tests are carried out for two conditions that are with PCM and without PCM radiators, the test result shown that by installing PCM radiators up to 5% energy saving and lower cabinet temperature were achieved. The system also given a greater stabilization of product temperature during deforest period for modified display cabinet.

1) Concluding Remark

The performance of the refrigerated open type of multi deck display cabinet investigated for chilled food. It was found that with PCM the energy saving of the cabinet significantly improved to around 5% at climate class 3 conditions (25°C and 60% RH) the defrost length was found to be 5 minute longer than basic cabinet, which represented 70% of original defrost time.

Fig. 1: Multi Deck Display Cabinet

B. Y. Yusufoglu., T. Apaydin [6]

Designed, fabricated and investigated performance of household refrigerators by incorporating phase change material. The efforts made to increase the energy efficiency of refrigerator that directly reduces the energy consumption in residential building. Incorporating phase change materials (PCM) is new approach to improve the performance of refrigerator. The test were conducted on two different refrigerator models the test showed results are as, the compressor on/off time was optimized and better energy efficiency was achieved. Increasing condenser surface area by 20% enhanced the PCM effect. The use of only 0.95kg of PCM has resulted in 9.4% energy saving.

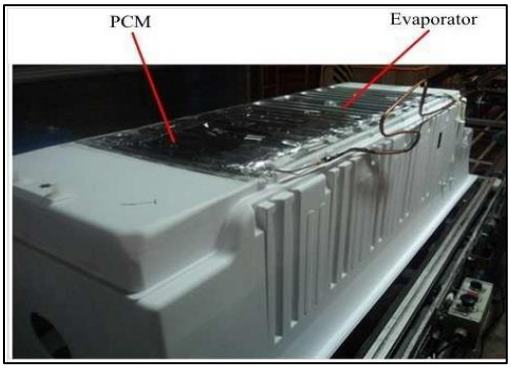

Fig. 2: PCM Compartment for Evaporator

1) Concluding Remark

Performance of two types of refrigerators was investigated, using different PCMs developed for the study. The evaporator and condenser temperatures were increased order of 2-4°C of all PCMs compressor on/off time was optimized. The best saving achieved for the both refrigerators were 8.8% and 9.4% respectively.

C. Eduard Oro, Laia Micro[7]

Evaluated the thermal response of low temperature storage and food transportation. It was mainly used for frozen food transportation and storage at low temperature. Also the thermal response of low temperature chamber incorporating phase change material having low freezing temperature is evaluated when subjected to refrigeration system failure. The system was tested with two different PCM with different melting temperature, the result shown that when there is no refrigeration, both the air and frozen product temperatures remained at lower values for much longer time when PCM was employed.

1) Concluding Remark

Experiment conducted resulted; the use of phase change material in lower temperature storage food chamber shows significant benefits in minimizing temperature rise and product in chamber. The result from the experimentation are shown that the PCM storage are very helpful in all transportation like ice-cream trolley, beverages, non-refrigerating vans, catering and frozen food trolleys.

D. Md. Imran Hossen Khan[8]

Experimented at different thermal loads with two different PCMs (Water and Eutectic solution (90% H2O + 10% NaCl) of melting point 0°C and -5°C respectively) which shows the effect phase change material (PCM) on temperature fluctuation inside the evaporator cabinet of a household refrigerator The PCM is placed around the five sides of the evaporator cabinet in which the evaporator coil is immersed. The experimental results with PCM confirm the notable reduction of the fluctuation of the cabin temperature at lower load but at higher load this effect is not so significant. Between two PCM, the reduction of temperature fluctuation for Eutectic solution is better than water PCM. This reduction of temperature fluctuation ultimately improves the food preservation quality of the refrigerator.

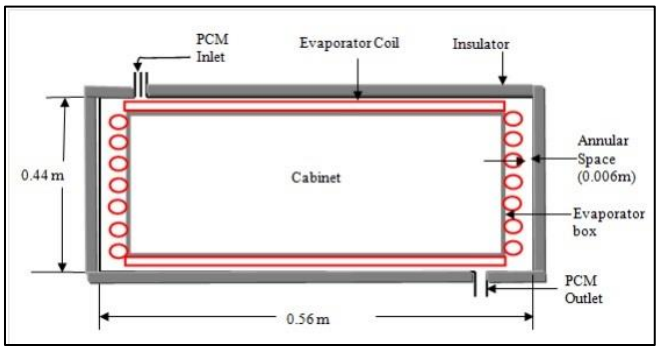

Fig. 3: Evaporator Cabinet

1) Concluding Remark

Experimental tests have been carried out to investigate the temperature fluctuation inside the evaporator cabin a household refrigerator using two different phase change materials at different thermal loads. The following conclusions have been drawn from these experimental tests:

- Use of PCM in a household refrigerator decreases the fluctuation of the cabinet temperature.
- The reduction of temperature fluctuation between two PCM, Eutectic solution is higher than water.
- At higher thermal load this effect is not so significant.

E. Firdaus Sheikh[9]

Investigated the performance improvement by a phase change material associated with the evaporator in a domestic refrigerator. The usage of PCM will help to improve the COP (Coefficient of performance). The use of phase change materials (PCMs) is an effective way of storing energy in the form of thermal energy. PCM materials have large amount of heat energy stored in them in form of latent heat. The heat energy associated with PCM is a natural phenomenon. The latent heat of the PCM can be used for various thermal energy storage applications. It has the advantages of high-energy storage density and the isothermal nature of the storage process. The energy consumption of the refrigerator during experiment with mixed refrigerant was measured. The lowest electric energy consumption was achieved using mixed refrigerant with heat level is less than -15°C. This mixture achieved higher volumetric cooling capacity and lower freezer air temperature. The effect of condenser temperature and evaporation temperature on COP, refrigerating effect, condenser duty, and work of compression and Heat Rejection Ratio were investigated.

Fig. 4: Evaporator Cabin

1) Concluding Remark

By using phase change material (PCM) sudden rise in temperature due to power failure can be retarded and can maintain constant temperature of 10 ºC for 27 hrs after compressor cut off. Depending on the thermal load with phase change material the average compressor running time per cycle is reduced significantly and COP is found to be increased to about 10.6% as compared to without phase change material. The fluctuation of refrigerated space temperature is maintained with in working temperature range with the help of PCM material, during power failure.

F. K. Azzouz, D. Leducq[10]

Carried out tests to investigate the performance of a household refrigerator using a phase change material (PCM). The PCM is located on the back side of the evaporator in order to improve its efficiency and to provide a storage capacity allowing several hours of refrigeration without power supply. The system has been tested with water and with a eutectic mixture (freezing point_3 _C) and for a range of operating conditions (PCM thickness, ambient temperature, thermal load). The analysis of the results shows a significant improvement of the performance compared to a conventional system.

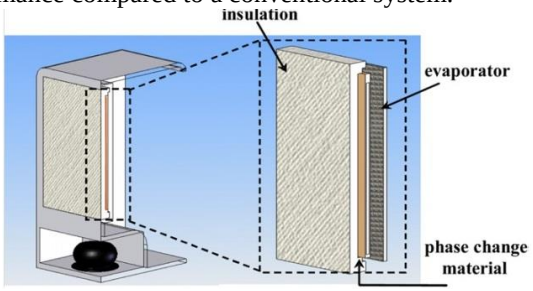

Fig. 5: Implementation of PCM along with evaporator side

1) Concluding Remark

Performance results and cold storage capacity measurements have been obtained and compared with the original system without storage. The results indicate that the response of the refrigerator to the addition of PCM and its efficiency are strongly dependent on the thermal load. The integration of latent heat storage allows 5–9 hrs of continuous operation without electrical supply (to be compared to 1–3 h without PCM) and a 10–30% increase of the coefficient of performance, depending on the thermal load.

G. Rezaur Rahman, Adnan Hasan[11]

Investigated the performance improvement PCM coupled with the evaporator in a domestic refrigerator. The heat release and storage rate of a refrigerator is depends upon the characteristics of refrigerant and its properties. The usage of phase change material (PCM) enhances the heat transfer rate thus improve the COP (Coefficient of performance) of refrigeration. Using water as PCM and for a certain thermal load it is found that the COP (Coefficient of performance) of the conventional refrigerator increased by 18-26% on average. The phase change material (PCM) used in a chamber built manually and which surrounds the Evaporator chamber of a conventional refrigerator, whole heat transfer from load given to refrigerator cabinet to evaporator, evaporator to phase change material (PCM) by conduction. So the heat transfer rate of evaporator refrigerant increases remarkably which improves the COP (Coefficient of performance) the refrigeration system.

1) Concluding Remark

The experimental investigation resulted that the use of water as PCM imposes a great impact on COP improvement at certain thermal loads. Using water as PCM and certain thermal load it is found that the 18-26% COP improvement has been achieved by the PCM in respect without PCM in conventional refrigerator. Depending on the PCM and the thermal load around 18-26% COP improvement has been achieved by the PCM in respect to without PCM.

H. Deni Thomas Boban, Jijo George[12]

Investigated about the performance enhancement of a domestic refrigerator by incorporating phase change materials (PCM) inside the evaporator. They used a U-shaped PCM box which contains 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. The result shows that the performance of the system has improved up to 19%. The energy stored in the PCM is yielded to the refrigerator during the off time and allows for several hours of continuous operation without power supply. This model shows a 5 to 19% increase in coefficient of performance(COP) and significant decrease in no. of starts and stops of the compressor and consequently of the temperature fluctuation inside the evaporator.

1) Concluding Remark

The experimental study of refrigeration system with phase change material shows enhancement of the system performance and reduction of temperature fluctuations in the evaporator using three different phase change materials of different quantities. Depending on the PCM around 19% COP improvement has been achieved by the PCM respect to with-out PCM. As quantity of PCM increases, COP also increases about 6%. The maximum COP improvement is 19% for eutectic solution followed by ethylene glycol and water. The recommended temperature of evaporator or storage depends on the type of the food products or any other storage material. This melting point should be slightly below the recommended temperature in evaporator or storage.

III. CONCLUSION

A review of PCM application for cooling purpose and the factors affecting on its effectiveness were discussed in this paper. Many experimental and modeling simulation studies have been presented, showing the effect of PCM on COP of refrigerator. The use of PCM in refrigerator seems to be very beneficial. PCM can decreases energy consumption, temperature fluctuation and reduce compressor on/off time. By integrating PCM in refrigerator at evaporative side it gives continuous cooling effect during power cut-off. The effectiveness of PCM increases with decreasing thickness of PCM and the increase of surface area until the certain optimum level. Most of the studies have shown that during the power cut time, the PCM can be used to minimize the temperature losses as well as temperature fluctuations also. As the PCM uses the conduction heat transfer mechanism, it is a faster process than that of the convection heat transfer process. As compared to the conventional system the refrigeration system with PCM has shown more promising and long lasting results. Also the system increases the compressor off timing, which alternatively reduces the electrical energy consumption. The reduced energy consumption results in the increased COP of refrigerator.

The use of PCM for the transportation purpose of food supplies is also very helpful as it does not harm the food products in any manner. The hygiene of the food product is not hampered in any way. From all the studies it can be seen that the utilization of PCM for lower temperature application has shown very successful, promising results and further it is also very useful element for the refrigeration industry.

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