ISSN: 2348 - 2117

International Journal of Engineering Technology and Computer Research (IJETCR)
Available Online at www.ijetcr.org
Index Copernicus Value 2016: 69.88
Volume 5; Issue 6; November-December: 2017; Page No. 49-55

"ANALYSIS OF PCM MATERIAL IN HEAT TRANSFER SYSTEM": A REVIEW

Shriyansh Arjaria[1], Mr. Lijo Varghese[2]

[1] M.Tech Scholar, Department of Mechanical, Engineering, OIST, Bhopal

[2] Assistant Professor, Department of Mechanical, Engineering, OIST, Bhopal

Abstract

Domestic refrigerators are among the foremost wide used household appliances and an excellent portion of energy is employed by these systems. Reduction of temperature fluctuation and improvement of system performance is that the main reason of using phase change materials (PCMs) in refrigeration systems. Totally different approaches are used to improve the thermal performance of these systems by integration of PCM. Despite large number of studies, a comprehensive literature review specifically that specializes in the application of PCM in domestic refrigerators is missing. This paper presents a review of the experimental efforts also as modeling approaches to review the application of PCMs in domestic refrigerators. Moreover, benefits and drawbacks of each kind of storage are given and, the future and potential promising applications of PCMs in domestic refrigerators are mentioned. The study investigates the performance improvement provided by a phase change material (PCM) associated with the condenser in a domestic refrigerator. The heat release and storage rate of a refrigerator is depends upon the characteristics of refrigerant and its properties. In this study we also investigated the performance improvement provided by Phase Change material associated with the evaporator in a domestic refrigerator. In both cases it is found that use of phase change material considerably increases the performance of the domestic refrigerator.

Keywords: Phase change material, Domestic refrigeration system, Thermal storage, Condenser.

1. INTRODUCTION

Ideal products for thermal management solutions are Phase Change Materials (PCMs). This is because they store and release thermal energy during the process of melting & freezing (changing from one phase to another). When such a material freezes, it releases large amounts of energy in the form of latent heat of fusion, or energy of crystallization. Conversely, when the material is melted, an equal amount of energy is absorbed from the immediate environment as it changes from solid to liquid.

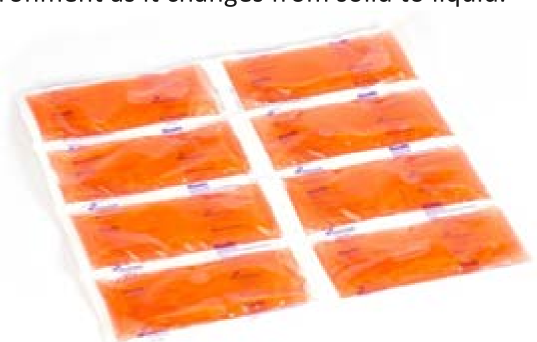

Fig.1. Phase Change Material –PCMs

Phase change material is classified as:

A. Organic Phase Change Materials

B. Inorganic Phase Change Materials

C. Eutectic Phase Change Materials

A. Organic Phase Change Material: Organic phase change materials are classified as paraffin's and non-paraffin. Organic PCMs are characterized by their ability to melt and freeze many times without phase segregation and degradation of their latent heat of fusion.

1. Paraffin's: Paraffin of type CnH2n+2 are a group of saturated hydrocarbons with very similar properties, Paraffin between C5 and C15 are liquids and the rest are waxy solids, Paraffin wax is one of thermoset popular organic heat storage PCM for commercial applications, it consists of a straight chain hydrocarbons having melting temperatures ranging between 23 ℃ and 67 ℃.

2. Non Paraffin's: The non-paraffin organic PCMs are distinguishes by their mixed properties; each of these materials has its own properties. These organic materials are subdivided into fatty acids and other non-paraffin organic.

B. Inorganic Phase Change Materials:- Inorganic phase change materials are classified as salt hydrates and metallic.

1. Salt Hydrates: Salt hydrates consist of a salt and water that combine in a crystalline matrix when the material solidifies. There are many different salt hydrates having melting temperature ranges between

15°C - 117°C,

2. Metallic: Metallic includes the low melting metals and metal eutectics. Metallic have not been strongly studied as PCM for latent heat storage because of their heavy weights.

C. Eutectics Phase Change Material: The eutectics consist of two or more components where each of them melts and freezes congruently forming a mixture of a component that crystal during crystallization process.

Thermo-Physical Properties:-

a) Phase Change temperature fitted to the application b) High Latent Heat of fusion

c) Low volume change during the phase change d) High density

e) High value of specific heat to give additional benefits of sensible heat

Chemical Properties:

a) Chemical Stability After many cycles of operation
b) No Phase separation or chemical deposition

c) No Degradation after many cycles of operation

d) Nonflammable, non-corrosive and non-toxic

2. LITERATURE:

Shiming et. al. [2018] [1] Confronted with the crises of the growing resource shortages and continued deterioration of the environment, building energy performance improvement using phase change materials has received much attention in recent years, in phase change materials used to optimize building envelope and equipment. This is followed by reporting articles on building equipment optimized with phase change materials to reduce regular energy consumption. Series of air cooling, heating, and ventilation systems coupled with thermal energy storage were comparatively investigated. Finally, the existing gaps in the research works on energy performance improvement with phase change materials were identified, and recommendations offered as authors' viewpoints in 5 aspects. We believe this comprehensive review might provide an overview of the analytical tools for scholars, engineers, developers, and policy designers, and shed new light on the designing and performance optimization for PCMs used in building envelope and equipment.

Ding-QuanNg et. al. [2017] [2] A novel phase change material (PCM) microcapsule possessing a thermally conductive but electrically insulated shell is synthesized. The vinylsilane compound is polymerized with the acrylic monomer to first form a copolymer, with the thermally conductive inorganic material subsequently added. Thereafter, the PCM microcapsule with the paraffin core and the thermally conductive but electrically insulated material- containing copolymer as the shell is prepared through mini-suspension polymerization.

Yutao Huo et. at. [2017] [3] The phase change material (PCM) can be used in thermal energy storage (TES) with large latent heat. However, due to the heat accumulation in the upper region, the solid-liquid phase change process will be slowed down. In this paper, in order to enhance the heat transfer of nanoparticle-enhanced PCM (NEPCM) in TES, a separate plate is applied to weaken the heat accumulation. The phase change multiple-relaxation- times lattice Boltzmann (MRT-LB) model is employed to solve the numerical problem and the effects of separate plate location, nanoparticle volume fraction and Rayleigh number are investigated.

A. Inés Fernández et. al. [2017] [4] The use of paraffin, salts and salt hydrates as phase change materials (PCMs) have been researched extensively and used in a number of commercial applications. However, metals and metal alloys, which possess a high storage density on a volume basis as well as a substantially higher thermal conductivity, have received much less attention. Although some pure metals and metal alloys present interesting thermal properties to be used as PCMs in thermal storage systems, changes in thermal properties and undesired reactions. Further research is needed before these materials can be used as PCMs in thermal energy storage systems in industry.

Lei Shao et. al. [2016] [5] In this work, we utilize a figure-of-merit (FOM) to compare the performance of various phase-change materials (PCMs) in managing short bursts of high-power heat flux, particularly those associated with microprocessors undergoing bursty operation on a time scale of approximately one second. We numerically investigate the FOM for applications that have realistic boundary conditions and lack analytical solutions.

Aziz Babapoor et. al. [2016] [6] Phase change materials are widely used in various thermal management applications. Conductive nanoparticles can be added to phase change materials to improve their thermal conductivities. The selection of suitable nanoparticles and weight percent is important from thermal performance point of view. In this study, various nanoparticles (e.g. SiO_2 (11 nm, 20 nm), Al_2O_3, Fe_2O_3, ZnO). Thermal properties of the synthesized nanocomposites were characterized by differential scanning calorimetric technique. Experimental measurements showed that the presence of nanoparticles can improve thermal conductivity of the nanocomposite,

Pierre Noé et. al. [2016] [7] Chalcogenide phase change materials (PCMs) have outstanding properties, which has led to their successful use for a long time in optical memories (DVDs) and, more recently, in Phase Change Random Access Memories. The latter are the most promising candidate to replace the current FLASH memories. The main feature of PCMs is fast and reversible phase transformations between crystalline and amorphous states with very different transport and optical properties. Controlling their crystallization, however, is a challengeand hence control the stability of the amorphous phase in PCMs.

Marco Casini et. al. [2016] [8] This chapter focuses on the importance of the heat capacity of the building envelope for energy efficiency and indoor thermal comfort, presenting the most innovative smart materials for latent heat storage in new and existing buildings. An overview of phase-change materials is provided, explaining their classification, technical specifications, encapsulation methods, functional models, and application inside or outside the building, even combined with advanced insulating materials. Lastly, there is an in-depth look at future prospects and developments.

Kinga Pielichowska et. al. [2014] [9] Phase change materials (PCMs) used for the storage of thermal energy as sensible and latent heat are an important class of modern materials which substantially contribute to the efficient use and conservation of waste heat and solar energy. Many different groups of materials have been investigated during the technical evolution of PCMs, including inorganic systems (salt and salt hydrates), organic compounds such as paraffins or fatty acids and polymeric materials, e.g. poly (ethylene glycol).

Yanping Yuan et. al. [2014] [10] Fatty acids as phase change materials have attracted much attention for their various applications in building energy efficiency, solar heating systems and air-conditioning systems. After summarizing the basic characteristics of fatty acids, eutectic mixtures of fatty acids and fatty acid esters, as well as the preparation and characteristics of fatty acid composites as phase change materials (PCMs). It also points out the future research direction of fatty acids as PCMs as a solution of the insufficiency and flaws of current researches.

Joseph Stalin et. al. [2014] [11] Energy is an important phenomenon in today's hectic world. A lot of researchers are doing research in this field due to its wide importance and also due to the scarcity of sources of energy in modern world, which in turn needs new inventions and discoveries to satisfy the demands of this scientific world. Reducing the wastage and utilizing the energy completely depicts the overall efficiency of any system. In today's modern world, air conditioning plays a major role due to the rapid increase in the earth's temperature and therefore, people long for comfort cooling. Nowadays, a lot of energy is wasted in the form of heat which eventually reduces the overall efficiency of any system. Therefore a system should be designed which shows a maximum efficiency by reducing its wastage to a very minimal amount. By using the industrial waste heat from industries and solar heat, an air conditioning system is designed in such a way that the input given to it is used completely without any wastage and the system uses Vapour Absorption System for conditioning of air.

Weihuan Zhao et. al. [2013] [12] Solar energy is receiving a lot of attention recently since it is a clean, renewable, and sustainable energy. Solar energy is used for space heating, power generation and other applications. A major limitation however is that it is available for only about 2000 h a year in many places. Using encapsulated phase change materials is potentially a better way to store thermal energy with the associated reversible heat transfer Diffusion and phase change computations are reported here in the form of temperature profiles of the phase changing and encapsulated materials for spherical capsules.

Min Li [2013] [13] Nano-graphite (NG)/paraffin composites were prepared as composite phase change materials. NG has the function of improving the thermal conductivity of the composite. The microstructure and thermal properties of the materials were examined with environmental scanning electron microscopy and differential scanning calorimetry. The results indicated that the NG layers were randomly dispersed in the paraffin, and the thermal conductivity increased.

Yuefeng Li et. al. [2013] [14] An analytical temperature model and an enthalpy difference function, based on lumped parameter method and assumption of rectangular effective specific heat, are presented in this study, which can measure the enthalpy change of inorganic salt high temperature. It can be seen that with this method it is possible to obtain both melting point and heat of fusion in a simple way which will be of great help in selecting heat storage material in solar-energy and industrial waste heat utilization and in the subsequent design of a thermal energy storage system.

X. H. Yang et. al. [2011] [15] This study reports on an analytical estimation of the effective thermal conductivity of phase change materials (PCMs) and its dependence upon temperature. During the phase change process, two distinctive phases (solid to liquid) co-exist and the effective thermal conductivity of the PCM varies significantly with temperature. To analytically estimate the variation, the classical Series model assuming one-dimensional (1D) heat conduction normal to the solid–liquid interface was employed. For model validation, experimental measurements with paraffin were conducted covering a wide range of temperature (including the phase change temperature

Yifen QIU et. al. [2011] [16] To investigate thermal protection effects of heat sinking vest with phase-change material (PCM), human thermoregulation model is introduced, and a thermal mathematical model of heat transfer with phase change has been developed with the enthalpy method. The uniform energy equation is constructed for the whole domain, and the equation is implicitly discreted by control volume and finite difference method. Then the enthalpy in each node is solved by using chasing method to calculate the tridiagonal equations, and the inner surface temperature of PCM could be obtained. According to the human thermoregulation model of heat sinking vest, the dynamic temperature distribution and sweat of the body are solved.

Omar Sanusi et. al. [2011] [17] Phase change materials (PCMs) are known to be excellent candidates for thermal energy storage in transient applications. However, enhancement of the thermal conductivity of a paraffin-based PCM is required for effective performance, particularly during solidification where diffusion is the dominant heat transfer mode. This research indicates that GNF impregnation into phase change materials is an effective method for the enhancement of the thermal energy storage and the solidification of paraffin- based phase change materials.

Bogdan M. Diaconu et. al. [2010] [18] A new microencapsulated phase change material slurry based on microencapsulated Rubitherm RT6 at high concentration. Some heat storage properties and heat transfer characteristics have been experimentally investigated in order to assess its suitability for the integration into a low temperature heat storage system for solar air conditioning applications. An experimental set-up was built in order to quantify the natural convection heat transfer occurring from a vertical helically coiled tube immersed in the phase change material slurry. It was found that the values of the heat transfer coefficient for the phase change material slurry were higher than for water, under identical temperature conditions inside the phase change interval.

C. Muriset et. al. [2010] [19] A PCM dephaser and storage module based on a melting/freezing model was built and implemented into the Dymola-Modelica software. This software offers thermal libraries with standard components as tubes, pumps, heat exchangers, etc. Main simulation results of interest include the phase shift (delay time) caused by cylinders filled with a PCM and positioned in the storage/dephasing device. Furthermore, an entire Minergie house was modeled by a rather simple (economic in terms of CPU time), but still very effective thermal model.

Guobing Zhou et. al. [2010] [20] Thermal characteristics of shape-stabilized phase change material (SSPCM) wallboard with sinusoidal temperature wave on the outer surface were investigated numerically and compared with traditional building materials such as brick, foam concrete and expanded polystyrene (EPS). One-dimensional enthalpy equation under convective boundary conditions was solved using fully implicit finite-difference scheme. Phase transition keeping time of inner surface and decrement factor were applied to analyze the effects of PCM thermophysical properties (melting temperature, heat of fusion, phase transition zone and thermal conductivity), inner surface convective heat transfer coefficient and thickness of SSPCM wallboard.

L. Xia et. al. [2010] [21] Expanded graphite (EG)/paraffin composite phase change materials (PCMs), with mass fraction of EG varying and characterized. Polarizing optical microscope investigation showed that compact EG networks formed gradually with increase in the mass fraction of EG. These networks provided thermal conduction paths which enhanced the thermal conductivity of the composite PCMs, e.g., an addition of 10 wt.% EG resulting in a more than 10-fold increase in the thermal conductivity compared to that of pure paraffin. Thermal characterization of the composite PCMs with a differential scanning calorimeter (DSC) revealed the effect of the porous EG on the phase change behavior of paraffin. The shifts in the phase change temperatures were observed. The DSC investigation also showed an anomaly in the latent heat of the paraffin in the composite PCMs in that it first increased and then decreased with increase in the EG fraction.

3. METHODOLOGY

Computational fluid dynamics (CFD) is a branch of fluid mechanics that uses numerical analysis and data structures to solve and analyze problems that involve fluid flows. To simulate the interaction of liquids and gases with surfaces defined by boundary conditions Computers are used to perform the required calculations. With high-speed supercomputers, better solutions can be achieved. For the present work ANSYS 15.0 software is used. ANSYS Fluent software is the most-powerful computational fluid dynamics (CFD) tool available, empowering you to go further and faster as you optimize your product's performance. To deliver fast Fluent includes well validated physical modeling capabilities, accurate results across the widest range of CFD and multi physic applications.

GOVERNING EQUATIONS

Technique use to analyze the performance and behavior of PCMs is a Computational Fluid Dynamics (CFD) modeling and simulation for phase change materials (PCMs). The CFD models have been successful in studying and analyzing the air quality, natural ventilation and stratified ventilation, air flow initiated by buoyancy forces and temperature space for the systems integrated with PCMs.

Mass Equation

$$\partial p/\partial t + \nabla(\rho u) = S_m$$

Where;
ρ is fluid density,
t is time,
u is the flow velocity vector field
Sm is a Constant.

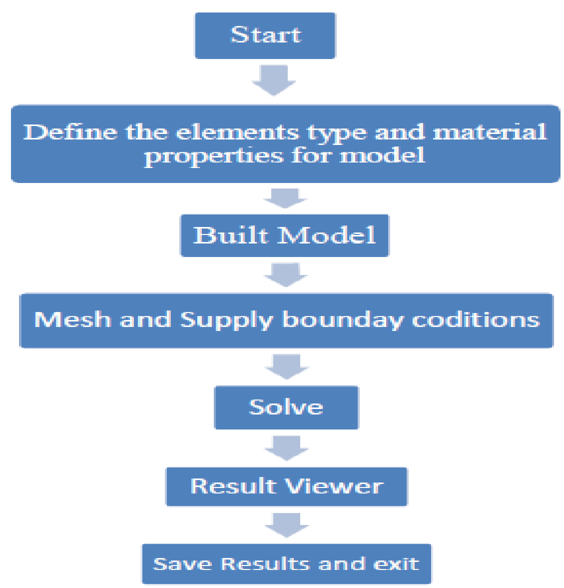

Figure 2: Setup of working

Energy Equation

$$\frac{\partial(\rho H)}{\partial t} + \frac{\partial}{\partial x_j}(\rho * u_j * c_p * T) = \frac{\partial}{\partial x_j}\left(\lambda.\frac{\partial T}{\partial x_j}\right) + S_E$$

where;
ρ is the fluid mass density,
S_E is the source term.

Navier Stokes equation

$$\frac{\partial(\rho H)}{\partial t} + \frac{\partial}{\partial x_j}(\rho * u_j * c_p * T) = \frac{\partial}{\partial x_j}\left(\lambda.\frac{\partial T}{\partial x_j}\right) + S_E$$

Here f represents "other" body forces (per unit volume), such as gravity or centrifugal force. The shear stress term$\nabla.T$ becomes, $\mu\nabla^2 V$ where ∇^2 is the vector Laplacian.

4. CONCLUSION:

In this thesis the thermal characteristics of condenser of a refrigerator is analyzed and compared with and without PCM material. The condenser with Ethylene Glycol as the PCM material showed the best results for compared to other two PCM material i.e. Paraffin wax and Lauric acid.

5. SCOPE OF THE WORK:

1. The results provided in this work can be experimentally verified.
2. Study can be done with compressor off and on condition simultaneously.

RFERENCE:

1. Shiming, Song, Mengjie, Niu, Fuxin, Mao, Ning, Hu, Yanxin, Deng," Review on building energy performance improvement using phase change materials" Elsevier Journals, Energy and Buildings, Volume 158, 1 January 2018, Pages 776-793.
2. Ding-Quan Ng, Yen-Lin Tseng, Yeng-Fong Shih Hong-Yuan Lian,Yi-Hsiuan Yu, "Synthesis of novel phase change material microcapsule and its application" Elsevier Journals, Polymer, Volume 133, 20 December 2017, Pages 250-262.
3. YutaoHuo, ZhonghaoRao, "Lattice Boltzmann investigation on phase change of nanoparticle-enhanced phase change material in a cavity with separate plate" Elsevier Journals, Energy Conversion and Management, Volume 154, 15 December 2017, Pages 420-429
4. A Inés Fernández, CamilaBarreneche, Martin Belusko, MercèSegarra, Frank Bruno, Luisa F.Cabeza, "Considerations for the use of metal alloys as phase change materials for high temperature applications", Elsevier Journals, Solar Energy Materials and Solar Cells, Volume 171, November 2017, Pages 275-28.
5. LeiShao, ArunRaghavan, Gun-Ho Kim, Laurel Emurian, Jeffrey Rosen, Marios C. Papaefthymiou, Thomas F.Wenisch, Milo M.K.Martin, Kevin P.Pipe, "Figure-of-merit for phase-change materials used in thermal management", Elsevier Journals, International Journal of Heat and Mass Transfer, Volume 101, October 2016, Pages 764-771.
6. Aziz Babapoor, Gholamreza Karimi, Samad Sabbaghi, "Thermal characteristic of nanocomposite phase change materials during solidification process", Journal of Energy Storage, Volume 7, August 2016, Pages 74-81.
7. Pierre Noé, Chiara Sabbione, Nicolas Bernier, Niccolo Castellani, FrédéricFillot, Françoise Hippert," Impact of interfaces on scenario of crystallization of phase change materials", ActaMaterialia, Volume 110, 15 May 2016, Pages 142-148.
8. Marco Casini, "5 – Phase-change materials", WoodhHead Publishing, Advanced Materials and Nanotechnology to Improve Energy-Efficiency and Environmental Performance, 2016, Pages 179–218.
9. KingaPielichowska, Krzysztof Pielichowski, "Phase change materials for thermal energy storage", Progress in Materials Science, Volume 65, August 2014, Pages 67-123.
10. Yanping Yuan, Nan Zhang, Wenquan Tao, Xiaoling Cao, Yaling He, "Fatty acids as phase change materials", Elsevier Journals, Renewable and Sustainable Energy Reviews, Volume 29, January 2014, Pages 482-498.
11. Joseph Stalin, Barath, Gokulamanikandan, "Air Conditioning Using Waste Heat and Solar Energy with Phase Change Materials", Energy Procedia, Volume 52, 2014, Pages 579-587.
12. Weihuan Zhao, Sudhakar Neti, Alparslan Oztekin, "Heat transfer analysis of encapsulated phase change materials" Elsevier Journals, Applied Thermal Engineering, Volume 50, Issue 1, 10 January 2013, Pages 143-151.
13. Min Li, "A nano-graphite/paraffin phase change material with high thermal conductivity", Elsevier Journals, Applied Energy, Volume 106, June 2013, Pages 25-30.
14. Yuefeng Li, Yang Zhang, Mingguang Li, Dong Zhang, "Testing method of phase change temperature and heat of inorganic high temperature phase change materials", Elsevier Journals, Experimental Thermal and Fluid Science, Volume 44, January 2013, Pages 697-707.
15. X.H.Yang, T.J.Lu, T.Kim, "Temperature effects on the effective thermal conductivity of phase change materials with two distinctive phases" International Communications in Heat and Mass Transfer, Volume 38, Issue 10, December 2011, Pages 1344-1348.
16. Yifen QIU, Nan JIANG, Wei WU, Guangwei ZHANG, Baoliang XIAO, "Heat Transfer of Heat Sinking Vest with Phase- change Material", Chinese Journal of Aeronautics, Volume 24, Issue 6, December 2011, Pages 720-725.

17. Omar Sanusi, Ronald Warzoha, Amy S. Fleischer, “Energy storage and solidification of paraffin phase change material embedded with graphite nanofibers”, International Journal of Heat and Mass Transfer, Volume 54, Issues 19–20, September 2011, Pages 4429-4436.
18. Bogdan M.Diaconu, SzabolcsVarga, Armando C.Oliveira, “Experimental assessment of heat storage properties and heat transfer characteristics of a phase change material slurry for air conditioning applications”, Applied Energy, Volume 87, Issue 2, February 2010, Pages 620-628.
19. C.Muriset, P.W.Egolf, D.Vuarnoz, P.Haas, “Lowering and phase shifting of temperature profiles with phase change materials” International Journal of Refrigeration, Volume 33, Issue 8, December 2010, Pages 1670-1675.
20. Guobing Zhou, Yongping Yang, Xin Wang, Jinming Cheng, “Thermal characteristics of shape-stabilized phase change material wallboard with periodical outside temperature waves” Applied Energy, Volume 87, Issue 8, August 2010, Pages 2666-2672.
21. L .Xia, P.Zhang, R.Z.Wang, “Preparation and thermal characterization of expanded graphite/ paraffin composite phase change material” Carbon, Volume 48, Issue 9, August 2010, Pages 2538-2548.