International Journal of
Emerging Research in Management &Technology
ISSN: 2278-9359 (Volume-6, Issue-4)

Research Article | **April 2017**

Various Applications of Phase Change Materials: Thermal Energy Storing Materials

M. A. Boda[1*], R. V. Phand[2], A. C. Kotali[3]
[1]Assistant Professor, [2 & 3]U.G. Students
[1, 2 & 3]Department of Mechanical Engineering, V.V.P.I.E.T., Solapur, Maharashtra, India

Abstract—

PCMs provides the ability of latent thermal energy change their state with a certain temperature. This paper gives reviews of previous work on the latent heat storage and provides an insight to recent efforts to develop new classes of phase change materials (PCMs) for use in energy storage. Largely there are more numbers of phase changing materials that will melt and solidified at a wide range of temperatures, making them attractive in a number of applications and uses. The results show the relevance of an integral design in which the thermal resistance of the building shell, the sensible heat capacity of the building and the latent heat capacity of the PCMs are considered simultaneously. PCM in solar thermal energy storage systems for various types like sensible heat storage, latent heat storage and thermo-chemical storage etc. In sensible heat storage system the thermal energy is stored by raising the temperature of a solid or liquid. Thermal energy storage (TES) systems using PCM have been recognized as one of the most advanced energy technologies in enhancing the energy efficiency and sustainability of buildings. Microencapsulation is a best and advanced technology for better utilization of PCMs with building parts, such as, wall, roof and floor besides, within the building materials. Phase change materials based microencapsulation for latent heat thermal storage (LHTS) systems for building application offers a challenging option to be employed as effective thermal energy storage and a retrieval device. Insulation effect reached by the PCM is known and it depends on temperature and time. Therefore it is an attempt which has been taken to review the working principle of PCM and their applications for smart temperature regulated textiles. A latent heat thermal energy storage system using a PCM is an efficient way of storing and releasing a large amount of heat during melting or solidification. It has been determined that the shell-and-tube type heat exchanger is the most promising device as a latent heat system that requires high efficiency for a minimum volume. Latent heat thermal energy storage is one of the best efficient ways to store thermal energy for heating water by energy received from sun. This paper showed the investigation and analysis of thermal energy storage incorporating with and without PCM for use in solar water heaters. Phase change material are one of the latent heat materials having low range of temperature and high energy density of melting and solidification compared to the sensible heat storage. The use of PCMs is increasing in buildings because it provides the potential for a better indoor thermal comfort for occupants due to the reduced indoor temperature fluctuations, and lower global energy consumption due to the load reduction shifting.

Keywords— ***PCM, TES, Application, sensible heat storage and latent heat.***

I. INTRODUCTION

Thermal energy storage plays an important role an effective use of thermal energy and has applicable in diverse areas, such as building heating or cooling systems, solar energy collectors, power and industrial waste heat recovery [1]. The term "Latent Heat Storage", as we generally The "Latent Heat Storage", applies to the storage of heat as the latent heat of fusion in suitable substances that undergo melting or freezing at a desired temperature level [2]. Solar energy is available during the day only, and its application requires efficient thermal energy storage so that the excess heat collected during sunshine hours may be stored for later use during the night [6].

The continuous increase in level of greenhouse emissions gas and the climb in fuel prices are the main driving forces behind efforts more effectively utilize various sources of renewable energy. In many parts of the world, direct solar radiation is considered by the most prospective sources of energy [7].

In moderate climates we imagine that concrete floors having PCMs can be store thermal energy provided by solar irradiation that directly enters by the windows during the day. Storing this solar energy during daytime and releasing in the evening to reducing the energy that need for thermal comfort during the relatively cold night [8]. The method of heat energy storage provides much higher energy storage density with a smaller temperature swing when compared with the sensible heat storage method. In practice for difficulties in applying the latent heat method due to low thermal conductivity, density change or stability of properties under extended cycling [9]. Introduction to the total energy consumption, particularly for a space conditioning and domestic hot water. Energy use and emissions result from both direct and indirect sources. Pérez-Lombard, Ortiz, and Pout reported that primary energy has grown by 48% and CO_2 emissions by 44%, with an average annual increase of 2.1% and 1.7%, respectively. Based on the International Energy Agency (IEA) reports on energy consumption trends and promoting energy efficiency investments, it is estimated that building sector in developed countries is a consuming over the 40% of the global energy with 25% of greenhouse emissions gas [11].

Phase change materials possess that the ability to change their state with certain temperature range. This energy can be transferred to the environment in the phase change range during a reverse cooling process [15]. Designing a latent heat storage unit, the melting and solidification periods of a certain phase material. The predict heat transfer coefficients during the phase change processes; one must be the operating conditions and the storage configuration. The two types of configurations have been essentially studied. One of them is the shell or tube type of heat exchanger with the phase change material placed in the shell, and the heat transfer fluid flowing through the tubes [16]. These systems are not a commercial use like sensible heat storage (SHS) systems because of poor heat transfer rate during the charging and discharging processes [18]. Studies of phase change systems have been design fundamentals, system and process optimization, transient behaviour, and field performance. The research and development has been broad based on productive, concentrating on both the resolution of specific phase change materials and the study of the characteristics of new materials [22]. Over the past two decades, many scientists, international and communities environmentalists have devoted considerable efforts on promoting energy efficiency and sustainability the buildings, which have resulted in a number of the energy technologies and green strategies with different degrees of promise available in literature [25].

II. LITERATURE REVIEW

Z. Zhengguo and F. Xiaoming[1] The prepare expanded graphite had a wide pore size distribution, which mainly consists of mesopores and macropores. It is known to organic compounds are easily absorbed into mesopores and macropores of expanded graphite's .Therefore, the prepared expanded graphite had a large sorption capacity and can be used as a good matrix for expanded graphite based composites. **A. Kurklo [3]** The results of this study revealed that due to cold weather conditions, it was not possible to utilise the full energy storage capacity of the PCM, and that the target inside air temperature of 7ºC could not be achieved for more than half a day. **Lavinia Gabriela [5]** The PCM can be used as natural heat and cold sources or manmade heat or cold sources. In any case, storage of heat or cold is necessary to match availability and demand with respect to time. There are mostly three different ways to use PCMs for heating and cooling purpose of buildings exist: PCMs in building walls; PCMs in building components other than walls that is in ceilings and floors; and PCMs in separate heat or cold stores. **Revankar** has devised a new method for the satellite power testing using PCMs. Central to the solar power system are in series of metal cells contain a PCM that is liquid under high temperature, which is freezes during hours of cold darkness, it releasing its latent heat. The heat released can then be used to generate electricity by driving thermoelectric units. **A. G. Entrop et.al. [8]** The experimental setup was developed to offer opportunity to gain more insights on how PCMs can be used concrete floors in buildings to heat living rooms during the early evening and even night in order to avoid auxiliary heating. **D. N. Nkwetta and F. Haghighat[11]** The applications in which PCMs can be used are many and thus needing different PCMs to be critical analysis. This paper presents different configurations, modelling, simulation and experimental studies conducted for the PCMs – hot water tanks and TSC with PCMs storage. It is helps to clarity the factors and most important selection criteria to be taken into account when selecting or using different PCMs. PCMs usage has the potential to improve the storage capacity, serve energy , shifting and smoothing peak power demand when integrated for use in hot water tanks and space heating.**V. V. Tyagi et. al. [13]** The new results demonstrate to the good behaviour, energy savings and technical viability of using macro-encapsulated PCM in typical Mediterranean constructive solutions. Moreover, about 1–1.5 kg/year/m^2 of CO_2 emissions could be reduced in the PCM cubicles due to the reduction of power consumption. **M. A. Boda and C. V. Papade [17]**The storing of energy in latent heat storing material is very useful because it stores maximum amount energy as compared to sensible heat storing materials at equal quantity of material. The PCM's are convenient to store the solar energy. By observing results convergent section is revives one, because inlet velocity of air is same for both cases but in convergent section the outlet velocity is observed as nearly doubled that of the inlet velocity and in divergent section it is nearly reduced by one third. **R. M. Reddy [18]**The temperature distributions of phase change materials in the storage tank for various mass flow rates and different diameters of capsules are recorded during the charging and discharging processes. **A. Shukla, D. Buddhi and R. L. Sawhney [20]**Whenever solar energy is available, it is collected and transferred to the energy storage tank for example that is filled by 1500 kg encapsulated PCM. It consisted mostly of a vessel packed in the horizontal direction with cylindrical tubes. The energy storage material inside the tubes made of poly vinyl chloride plastic and heat transfer fluid flow parallel to them. **P. Tatsidjodoung et. al. [23]** Consider latent heat storage, numerous PCMs have been developed 0–80ºC temperature range, which is suitable for the building eating needs. The advantages of the latent heat storage materials on sensible heat storage materials is well established with their high storage energy density and various melting point temperatures that allow different levels of use. **Na Zhu et. al. [25]** This paper provided a comprehensive overview on the previous studies related to the investigation or evaluation of dynamic characteristics and energy performance of buildings due to the integration of phase change materials.

III. PHASE CHANGE MATERIALS

Phase change materials (PCM) are latent heat storage materials. While changing its phase from solid to liquid and liquid to solid a thermal (Heat) energy transfer occurs, this is called a change in state, or phase. First, these solid-liquid PCMs acts like conventional storage materials and their temperature rises up to what they absorb heat energy. Unlikely conventional storage materials, PCM absorbs and release heat at nearly to a constant temperature. PCMs stores five to fourteen times heat (energy) per unit volume more than sensible heat storage materials such as rock, sand, gravel, water, or masonry etc. A large number of phase change materials are to melt with a heat of fusion in any required range.

Depending on the applications, the PCMs should first be select on the bases of their melting point temperature. Much type of materials that melt between14ºC and 91ºC temperatures is to be applied during the solar heating and for heat load levelling applications purpose. These materials represent the class of materials that are,

- The time delay and available of power between production and availability of energy and its consumption in receiving systems from solar energy.
- Security of energy supply to the hospitals, computer centres, etc.
- Thermal inertia and thermal protection from sun.
- Large heat storing capacity in a unit volume.
- The isothermal behaviour oh PCM during the charging or discharging processes

IV. ADVANTAGES

1. The use of the composite PCM as a storage medium can reduce the weight of the thermal storage.
2. The heat transfer rate of the composite PCM was obviously higher than that of the pure paraffin owing to the combination with the expanded graphite that had a high thermal conductivity.
3. PCMs absorb energy during the heating process as phase change takes place and release energy to the environment in the phase change range during a reverse cooling process.
4. Organic PCMs have a more number of characteristics which is render them useful for latent heat storage in certain building elements. They are more chemically stable than inorganic substances, they are corrosion resistance, they have a high latent heat per unit weight, they are recyclable, they melt congruently and they exhibit little or no super cooling that is they don't need to be cooled below their freezing point to initiate crystallization.
5. Inorganic PCMs have very good properties: thermal conductivity is high; speciallynot flammable; lower in cost in comparison to organiccompounds; high water content means that they are inexpensive and readily available.
6. A phase changing materials walls is capable of absorbing the large proportion of the solar radiation incidenton the walls or roof of a building. Due tovery high thermal mass of PCMs walls, they are capable of minimizing the effect of large fluctuations in the ambient temperature on the inside temperature of the building.
7. The main benefit of Phase changing materials encapsulation are providing large heat transfer area, reduction of the PCMs reactivity towards the outside environment and controlling the changes in volume of the storage materials as phase change occurs.
8. Phase change materials (PCM) take benefit of latent heat that can be stored or released from a material over a narrow temperature range. These materials absorb energy during the heating process as phase change takes place and release energy to the environment in the phase change range during a reverse cooling process.
9. A latent heat TES system using a PCM is an efficient way of storing or releasing a large amount of heat during melting or solidification.
10. Phase change materials (PCMs) are given as a possible solution for reducing the energy consumption of buildings. By storing and releasing the heat under a certain temperature range, it raises the building inertia and stabilizes indoor climate.

V. DISADVANTAGES

1. However, their not suitable characteristics have led to the investigation of organic Phase change materials for this purpose. These include: corrosion; instability; improper resolidification; suffer from decomposition and super cooling affects their phase change properties.
2. The initial cost of organic Phase change materials is higher than that of the inorganic type, the installed cost is competitive. Because of these characteristics like: thermal conductivity is low, changes in volume are high during phase change mostly, they are flammable and they may generate harmful fumes on combustion. Other problems, which can arise in a minority of cases, are a reaction with the products of hydration in concrete, thermal oxidative ageing, odour and an appreciable volume change.
3. PCMs not always have resolidified properly, because some Phase change materials get separated and stratify when in their liquid state. When temperature falls, they did not completely solidify, reducing their capacity to store latent heat.
4. Organic PCM have low thermal conductivity in solid state, volumetric latent heat storage capacity can be low, to obtain reliable phase change points, most manufacturers use technical grade paraffins which are essentially paraffin mixtures and are completely refined of oil, resulting in high costs.

VI. APPLICATIONS

1. PCMs have been widely used in latent heat thermal storage systems for heat pumps, solar engineering, and spacecraft thermal control application.
2. Medical applications: Transportation of blood, operating tables, hot-cold therapies,treatment of asphyxia.
3. PCM applications such as in solar cooking, solar power plants, thermal energy storage, cold energy battery and cooling of heat and electrical engines etc.
4. PCMs are also used in textiles i.e. is used in clothing.
5. In the case of a power failure to conventional cooling systems, PCMs minimise use of diesel generators, and this can translate into enormous savings across thousands of telecom sites in tropics.
6. Thermal storage of solar energy.

7. Passive storage in bioclimatic building/architecture (HDPE þ paraffin).
8. Cooling: use of off-peak rates and reduction of installed power, ice bank.
9. Heating and sanitary hot water: using off-peak rate and adapting unloading curves.
10. Safety: temperature maintenance in rooms with computers or electrical appliances.
11. Thermal protection of food: transport, hotel trade, ice-cream, Food agroindustry, wine, milk products (absorbing peaks in demand), greenhouses.
12. Thermal protection of electronic devices (integrated in the appliance)Medical applications: transport of blood, operating tables, hot–cold therapies.
13. Cooling of engines (electric and combustion).
14. Thermal comfort in vehicles.
15. Softening of exothermic temperature peaks in chemical reactions.
16. Spacecraft thermal systems.
17. Solar power plants.

VII. CONCLUSION

Organic and the Inorganic compounds are the two most common groups of phase change materials. Most organic PCMs are chemically stable and non-corrosive, exhibit little or no sub cooling, are compatible with the most building materials and have a high latent heat per unit weight and low vapor pressure. The disadvantages are the low thermal conductivity, high changes in volume and flammability. Inorganic compounds have a high latent heat per unit volume and high thermal conductivity and they are non-flammable and low in cost in comparison to organic compounds they are corroded for the most metals and suffer from decomposition and sub cooling, which can affect the phase change properties. The applications of inorganic PCMs require the use of the nucleating and thickening agents to minimize sub cooling or phase segregation. Significant efforts are continuing to discover agents by commercial companies. The applications in which PCMs can be applied are the vast, ranging from heat and cold storage in buildings to thermal storage in satellites and protective clothing's. A phase change materials with an easily adjustable melting point would be a necessity as the melting point the most important criterion for the selecting a PCM for passive solar applications. Many more applications are to be discovered.

REFERENCES

[1] Zhengguo Zhang and Xiaoming Fang, "Study on paraffin/expanded graphite composite phase change thermal energy storage material", Energy Conversion and Management Vol. 47, pp. 303–310, 2006.
[2] A. Abhat, "Low Temperature Latent Heat Thermal Energy Storage: Heat Storage Materials", Journal of Solar Energy, Vol. 30 No.40, pp. 313-332, 1983.
[3] Ahmet Kurklu, "Energy Storage Applications in Greenhouse by means of Phase Change Materials: Review", Journal of Renewable Energy, Vol. 13, No.1, pp. 89-103, 1998.
[4] Mehmet Esen, Aydin Durmus¸ and Ayla Durmus, "Geometric Design of Solar-Aided Latent Heat Store Depending on Various Parameters and Phase Change Materials", Journal of Solar Energy Vol. 62, No. 1, pp. 19–28, 1998.
[5] Lavinia Gabriela SOCACIU, "Thermal Energy Storage with Phase Change Material", Leonardo Electronic Journal of Practices and Technologies, Issue 20, pp.75-98, 2012.
[6] Mohammed M. Farid et al., "A review on phase change energy storage: materials and applications", Energy Conversion and Management Vol. 45, pp.1597–1615, 2004.
[7] Atul Sharma, V. V. Tyagi, C. R. Chen and D. Buddhi, "Review on thermal energy storage with phase change materials and applications", Renewable and Sustainable Energy Reviews vol. 13, pp.318–345, 2009.
[8] A. G. Entrop, H.J.H. Brouwers, A.H.M.E. Reinders, "Experimental research on the use of micro-encapsulated Phase Change Materials to store solar energy in concrete floors and to save energy in Dutch houses", Journal of Solar Energy Vol. 85, pp.1007–1020, 2011.
[9] P. A. Prabhu, N. N. Shinde, P. S. Patil, "Review of Phase Change Materials For Thermal Energy Storage Applications", International Journal of Engineering Research and Applications, Vol. 2, Issue 3, pp.871-875, 2012.
[10] Belen Zalba et al., "Review on thermal energy storage with phase change: materials, heat transfer analysis and applications", Applied Thermal Engineering vol. 23, pp.251–283, 2003.
[11] D. N. Nkwetta and F. Haghighat, "Thermal energy storage with phase change material-A state-of-the art review. Sustainable Cities and Society, 2013.
[12] Vasishta D. Bhatt, Kuldip Gohil and Arunabh Mishra, "Thermal Energy Storage Capacity of some Phase changing Materials and Ionic Liquids", International Journal of ChemTech Research, Vol.2, No.3, pp.1771-1779, July-Sept 2010.
[13] V.V. Tyagi, S.C. Kaushik, S.K. Tyagi, T. Akiyama, "Development of phase change materials based microencapsulated technology for buildings: A review", Renewable and Sustainable Energy Reviews Vol. 15, pp.1373–1391, 2011.
[14] Amar M. Khudhair and Mohammed M. Farid, "A review on energy conservation in building applications with thermal storage by latent heat using phase change materials", Energy Conversion and Management Vol. 45, pp.263–275, 2004.

[15] S. Mondal, "Phase change materials for smart textiles – An overview", Applied Thermal Engineering Vol. 28, pp.1536–1550, 2008.

[16] Aytun-c Erek, Zafer Illken and Mehmet Ali Acar, "Experimental and numerical investigation of thermal energy storage with a finned tube", International Journal of Energy Research, Vol. 29, pp.283–301, 2005.

[17] C.V.Papade , M.A.Boda, " Design & Development of Indirect Type Solar Dryer with Energy Storing Material", International Journal of Innovative Research in Advanced Engineering ,Vol 1,2014.

[18] R. Meenakshi Reddy, N. Nallusamy and K. Hemachandra Reddy, "Experimental Studies on Phase Change Material-Based Thermal Energy Storage System for SolarWater Heating Applications", Journal of Fundamentals of Renewable Energy and Applications Vol. 2, 2012.

[19] Liwu Fan, J.M. Khodadadi, "Thermal conductivity enhancement of phase change materials for thermal energy storage: A review", Renewable and Sustainable Energy Reviews Vol.15, pp. 24–46, 2011.

[20] Anant Shukla, D. Buddhi, R. L. Sawhney, "Solar water heaters with phase change material thermal energy storage medium: A review", Renewable and Sustainable Energy Reviews, Vol.13, pp.2119–2125, 2009.

[21] Ruben Baetens, Bjørn Petter Jelle andArild Gustavsen, "Phase change materials for building applications: A state-of-the-art review", Energy and Buildings Vol. 42, pp.1361–1368, 2010.

[22] Francis Agyenim, Neil Hewitt, Philip Eames, Mervyn Smyth, "A review of materials, heat transfer and phase change problem formulation for latent heat thermal energy storage systems", Renewable and Sustainable Energy Reviews Vol. 14, pp.615–628, 2010.

[23] Parfait Tatsidjodoung, Nolwenn Le Pierres andLingaiLuo, "A review of potential materials for thermal energy storage in building applications", Renewable and Sustainable Energy Reviews Vol. 18, pp. 327–349, 2013.

[24] Abhay B. Lingayat1, Yogesh R. Suple, "Review On Phase Change Material as Thermal Energy Storage Medium: Materials, Application", International Journal of Engineering Research and Applications, Vol. 3, Issue 4, Jul-Aug 2013, pp.916-921.

[25] Na Zhu, Zhenjun Ma andShengwei Wang, "Dynamic characteristics and energy performance of buildings using phase change materials: A review", Energy Conversion and Management Vol. 50, pp.3169–3181, 2009.

