International Journal of Advance Engineering and Research Development
Scientific Journal of Impact Factor (SJIF): 4.72
Special Issue SIEICON-2017,April -2017
e-ISSN : 2348-4470 p-ISSN : 2348-6406

An Assessment of Phase Change Materials for Domestic Applicatons

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Abstract-*Thermal Energy storage has been the significant area of research over the last many decades. Various methods and materials are developed for storing heat energy. Yet a main obstacle to modern methods is its lack of thermal mass. Phase change materials are one of the optimized alternate to various energy storing methods and materials. They have high energy storage capacity. In any case, despite the fact that the data is quantitatively tremendous, it is moreover spread generally in the writing, and hard to discover. This report contrasts on the properties of phase change materials and also reveals their significant applications. Furthermore, the discussion includes main benefits and drawbacks of phase change materials over the different renewable energy sources. It also carries various types of PCMs and performance analysis of PCMs for selecting the best required PCM for the purpose of heating and cooling of building.*

Keywords **-** *Thermal energy storage; Phase change material; heating and cooling.*

I. NOMENCLATURE

C_p	Specific heat [J/ (kg K)]
H	Enthalpy [J/ kg]
Δh_m	Latent heat [J/ kg]
M	Mass [kg]
Q	Heat [J]
T	Temperature [K]
T_i	Initial temperature [K]
T_f	Final temperature [K]
T_m	Melting temperature [K]

II. INTRODUCTION

In current period, inexhaustible energies and their increasing performance towards the energy development is on high notes. This is leading to weakens the climatic change and, notably for regions without or with lesser source of nonrenewable resources, an opportunity to be more free from nonrenewable resources.

The access to inexhaustible energy is limited to the availability of their raw material. Hydro power units for example only produce power when there is availability of water, and solar equipment produces energy only in the presence of sunlight. Usually, production and demand do not synchronize. Infrequently there is higher energy production than required and vice versa. And to overcome this obstacle energy storing will be most effective option. When the conditions meet the requirement for energy generation, energy is produced. The needless energy can be collected and released whenever the demand is high.

On the point for thermal energy storage, an advance form of material has been brought in demand. Phase Change Materials (PCMs). PCM is efficient of storing and releasing abundant amount of energy. The system relies on the variation in phase of the material for storing and releasing the energy. For example, processes like melting and solidifying requires energy and it is gained by the phase change of the material. Thus, PCMs effortlessly and certainly change their phase with a specific input of energy and release this energy whenever required. The current report briefly takes up the PCM technology. Later focusing the conception of PCM, it benefits, drawbacks and issues related to its applications. Lastly the selection criterion of PCM for heating and cooling of building room will be discussed.

III. PCM CHARACTERISTICS

The PCMs has melting point within the active temperature range. This makes essential difference with the conventional thermal energy storage means like water. Basically, the first PCM was water and probably it was used for instance in food refrigeration with ice. Still, the water was not considered as an energy storing medium, as it has melting point at 0°C and the working temperature of PCM is beyond the 0°C. Once, it is an excellent example to demonstrate how much thermal energy can be absorbed in phase change: almost same amount of energy is required for both heating water from 0°C to 82°C and melting ice to water [3].

During the process of melting and solidification of material a fixed amount of heat is absorbed and released. This is called as Latent heat (h_m). The additional heat storing capacity generates, if the melting point lies in the active temperature range. The melting and solidification processes are basically carried out at fixed temperature, illustrated in figure 1.

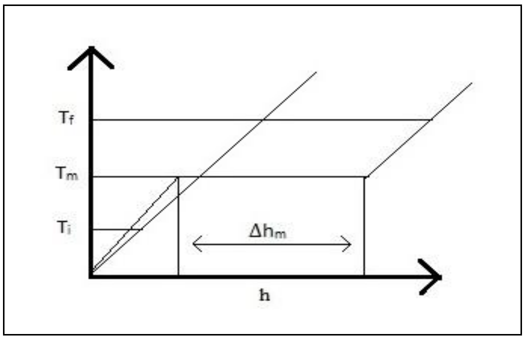

Figure 1 Temperature Vs Enthalpy diagram for Melting of PCM

The equation for heat store process without phase change is given by as

$$Q = \int_{T_i}^{T_f} mC_p\,dT \quad \ldots\ldots\ldots\ldots\ldots (1)$$

And the equation for heat store process with PCM from the melting point T_m below temperature T_i to the temperature T_f above T_m is given as

$$Q = \int_{T_i}^{T_m} mC_p\,dT + m\Delta h_m + \int_{T_m}^{T_f} mC_p\,dT \quad \ldots\ldots\ldots\ldots\ldots (2)$$

Here, the latent heat is given by the term $m\Delta h_m$. This generated latent heat tends to increase the energy storing capacity when the material is heated from T_i to T_f significantly. Contingent upon the medium also, the temperature range, the energy can be stored between 5 – 15 times in a latent heat storing process just as in sensible heat storing process [1].

Phase changes are of various types. Equivalently solid-solid phase change has low latent heat and low volume change. In solid-liquid phase change, latent heat is high and there is almost 10% change in volume. There is great volume change and highest latent heat in both phase changes solid-gas and liquid-gas [1]. Amongst all phase change, solid-liquid phase change is utilized in numerous applications. The latent heat produced under this phase change increases the energy storage capacity and the heavy volume change can be easily conducted.

IV. PCM APPLICATION

PCMs have numerous applications. Conditioning of the building is one of the significant areas: PCMs can be encapsulated in walls, ceiling boards, floor warming system hence, increase heat storage limit and helps to maintain the temperature. PCMs are also utilized in water and air based heating systems. It provides effective storage capacity for heating and cooling, respectively. For instance, use of PCM greatly reduces the energy utilization of greenhouses, where higher amount of energy is consumed overheating. Still there are many other applications of PCMs, like temperature regulation in transport containers for example for storing frozen foods, medicines etc. PCMs are also utilized in practical wear [1, 3].

V. SALT HYDRATES AND PARAFFIN

Paraffin and salt hydrates are most significant class of PCM with a solid-liquid phase change. Researchers differ in the interim on which class is most favorable. Sharma et al. [1] prefers salt hydrates as most vital where as Kim and Drzal [2] feel that paraffin are more favorable.

Usually, salt hydrates have great fusion energy than paraffin. However, an incongruent melting of material tends to decrease the reversibility of the phase change and hence decrease the thermal storage limit of the salt hydrate. The issue of incongruent melting can be solved by using various chemical and physical solutions, contingent upon the utilization.

Paraffin is safe from incongruent melting as this phenomenon does not happen. Still, paraffin has a noteworthy drawback contrasted with salt hydrates: low heat conductivity. The heat conductivity of a general paraffin utilized as PCM is marginally over 0.21 W/mK [2] and accordingly, about a variable two lower than the heat conductivity of nearly all salt hydrates [1].

Likewise, water or different fluids utilized as a thermal storage medium, PCMs with solid-liquid phase can't be utilized as thermal energy transfer medium. Consequently, water is used in many thermal storage applications where it is utilized to transfer heat from the heat sources, for example heat from sunlight to the thermal collector that carries PCM. When the liquid PCM blend with water, it spread over the whole circulation framework and required to be drawn out from the water. Thus, those storage systems are used which are made up of material that remains chemically stable when comes in contact with both water and PCM, ensuring better heat transfer between them. Figure 2 illustrate PCM product with aluminum casing.

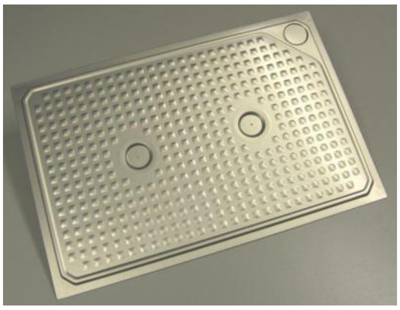

Figure 2 Aluminum casing with PCM element [8]

Figure 3 Shell and tube configuration [9]

VI. PERFORMANCE ENHANCEMENT OF PARAFFIN PCMS

Putting light on the major difficulty related to paraffin utilized as PCM, their low heat diffusivity. The time consumed by the PCM for melting and solidifying reduces the action of the latent heat storage system. Due to the less heat diffusion of paraffin, the heat transfer inside the PCM is moderate and therefore limits the speed of melting process. Thus the heat storing phenomenon takes equivalently much time. Similarly, the solidification process is affected by low rate of heat discharge.

Great attempt has been taken on analyzing and fixing this issue. Necessarily there are two ways to raise the action of paraffin-based PCM heat storage systems: altering the geometric design of heat storage container and developing different paraffin compounds with expanded heat diffusivity. A couple of possible methods have been examined to improve this issue are likely in the following.

The shell and tube setup is most considered design for PCM heat collector [4]. This setup can be depicted from figure 3 which is united with solar accumulator. Esen et al. [6] have emulated the melting action of few PCMs utilized to collect energy from basic solar equipments, altering design specification of shell and tube setup. They found that the time taken for melting process can be minimized if the PCM is placed in the shell and heat transfer liquid run through tubes. Furthermore, they suggested relevant design specification for a given melting time, inlet conditions and mass flow rate of heat carrying fluid and the PCM volume for few PCMs.

Aghbalou et al. [4] analyzed the solar collector with PCM by directing different analysis. For this situation, the capacity tank is rectangular and carries PCM packets arranged parallel in the direction of the flow of the fluid utilized as heat transport means. According to PCM melting temperature, the size factors (length and thickness) of PCM packets are given.

As specified over, other ways to raise the action of paraffin in thermal storing operations is to boost the heat conductivity. Mettawee and Assassa [7] ingrained aluminum powder in paraffin. The molecule size of aluminum powder was 80µm and mass fraction of 0.5%. As a result, the charging time was decreased by around 60%.

Kim and Drzal [2] tried a unique kind of graphite nanoparticles, formed by a composite paraffin PCM and xGNP. That results in the linear increment of heat conductivity directly with the xGNP weight division inside the tried limits from 0 to 7%. Adding 7% of xGNP also raise the heat carrying capacity of the paraffin from 0.27 to 0.9 W/mK. Notwithstanding this extensive mass fraction, neither the thermal stability nor the latent heat limit of the material was influenced.

The action of paraffin PCMs was upgraded by adopting both, the design specification of heat reservoir and altering thermo physical parameters of paraffin. In mean time, merging of these two approaches will give the best output.

VII. CONCLUSION

Phase change materials have two significant characteristics. They contain immense heat storage density and they collect and discharge an extensive amount of heat at a steady temperature. Hence, the PCM can be used a great intrigue to other thermal storage means. However, there is a great progress in PCM utility but it still requires advancement to the performance, specifically in the temperature limit 5-26, which is important for building related utilization [3]. The requirement for energy saving is constantly rising and PCMs might be the great alternate for engineers to develop energy-efficient projects in future.

REFERENCES

[1] A. Sharma, V.V. Tyagi, C.R. Chen, D. Buddhi. Review on thermal energy storage with phase change materials and applications. Renewable and Sustainable Energy Reviews, vol. 13, 2009, pp. 318-345.
[2] S. Kim, L.T. Drzal. High latent heat storage and high thermal conductive phase change materials using exfoliated graphite nanoplatelets. Solar Energy Materials & Solar Cells, vol. 93, 2009, pp. 136-142.
[3] H. Mehling. Latent warm espeicher. Fachinformationszentrum Karlsruhe, Gesellschaft für wissenschaftlichtechnische Information mbH, ISSN 1610-8302, 2002 BINE themeninfo IV/02.
[4] F. Aghbalou, Mohamadhosein Sadafi, Javad Rezapour, Hamed Safikhani. Exegetic optimization of solar collector and thermal energy storage system. International Journal of Heat and Mass Transfer, vol. 49, 2006, pp. 1255-1263.
[5] H. El Qarnia. Numerical analysis of a coupled solar collector latent heat storage unit using various phase change materials for heating the water. Energy Conversion and Management, vol. 50, 2009, pp. 247-254.
[6] E.-B. S. Mettawee, G. M. R. Assassa. Geometric design of solar-aided latent heat store depending on various parameters and phase change materials. Solar Energy, vol. 62 (1), 1998, pp. 19-28.
[7] M. Esen. Thermal conductivity enhancement in a latent heat storage system. Solar Energy, vol. 81 (7), 2007, pp. 839-845.
[8] German Aerospace Center (DLR) http://spie.org/x8476.xml?pf=true-&ArticleID=x8476.
[9] Rubitherm Technologies GmbH www.rubitherm.de

