PHASE CHANGE MATERIAL REVIEW

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Abstract: Thermal energy storage has gained increasing interest in past decade. While the storage of heat as sensible heat is established in many applications, the storage of heat as latent heat is not yet as wide spread. The storage of heat as latent heat using the phase change solid-liquid promises high storage density in small temperature range around the melting point. Due to its low cost, high storage capacity, and suitable melting temperature for applications, water is by far the most commonly used PCM for cooling applications. They range from cooling food and beverages to space cooling and process cooling. As a short survey shows, the globally installed storage capacity in large ice storage is quite significant. Application of other PCM have by far not reached a comparative market penetration. However, they promise better efficiency in many cooling as well as heating applications. To develop this potential, current R&D focuses, among other things, on improving the technical properties and performance of these PCM.

Keywords: thermal energy storage, phase change materials (PCM), organic PCM, inorganic PCM, advantages, eutectics applications

Introduction:

Energy storage is a key issue to be addressed to allow intermittent energy sources, typically renewable sources, to match energy supply with demand. There are numerous storage technologies that are capable of storing energy in various forms including kinetic energy, chemical solutions, magnetic fields, or other novel approaches. PCM is substance with a high heat of fusion which, melting and solidifying at certain temperature, is capable of storing and releasing large amounts of energy. Heat is absorbed or released when the material changes from solid to liquid and vice versa. Phase change material or PCM have the capacity to store and release large amount of energy that energy is called latent heat. Each PCM has specific melting and crystallisation temperature and a specific latent heat storage capacity.

PHASE CHANGE MATERIAL (PCM):

Phase change materials are a class of material that use a phase transition to store energy. A phase transition occurs when a material changes from one state of matter to another without changing it chemical composition, for example from liquid to solid or from solid to gas. Although transitions involving gas have very large enthalpies of transition, containing a large mass of gas is very difficult, requiring expensive and potentially dangerous pressure vessels. Therefore almost all practical PCMs will have solid-liquid transition [1]. There are some materials that exhibit solid-solid transitions; these have a much lower enthalpy of transition. Solid-solid transition involve a change in the crystal structure of the material, for example iron changes from body-centred cubic to face-centred cubic at 1185K[2]. Solid-solid transitions are advantageous from the perspective that they do not require containment the way solid-solid material do [3] [4].

SELECTION CRITERIA OF PCM

A good PCM must meet certain criteria and possess certain material characteristics. These have been listed in a number of reviews by various authors and they are summarised below:-[1] [5] [6] [7] [8] [9]

A. Thermodynamic criteria:-
1. The material should have a large enthalpy of transition, i.e. latent heat ΔH.
2. Material should have a high heat capacity in both the liquid and solid phase.
3. The PCMs should have an appropriate melting point.
4. High thermal conductivity

B. Kinetic criteria:-
1. PCM should exhibits a small amount of super cooling, which occurs when a material fails to crystallize at its melting temperature.
2. The crystal growth rate of the material must also be high.

C. Other criteria:-
3. PCM must have long term chemical stability.
4. PCM should have be non-
5. Corrosive.
6. PCM should have be non-flammable and non-toxic.
7. Cost of PCM must be low.
8. PCM should not contain any rare element.
9. Material should be eco-friendly.

No single material can possibly fulfil all of these stringent requirements, and engineering solutions must be made to accommodate any shortfalls.

TYPES OF PCM:-

Largely through the work of Lane a few broad categories of potential PCMs were delineated [10] [11]. Lane sorted through tens of thousands of materials to find candidates that could be good PCMs. There are two main type that naturally form, inorganic and organic, which are broken up into several major subtypes. In the organic group there are metals, salts hydrates, water, and salts. Organic PCMs includes paraffin waxes, which are long chain hydrocarbons; fatty acids and esters; sugar alcohols; and other miscellaneous organic compounds. Additionally there are mixture of the above categories both in eutectic and non-eutectic mixture.

ORGANIC PCMs:

1. Paraffin

Paraffin of type C_nH_{2n+2} are a group of saturated hydrocarbons with very similar properties. Paraffin between C_5 and C_{15} are liquids and the rest are waxy solids. Paraffin wax is one of the most popular organic heat storage PCM for commercial applications. It consists of a straight chain hydrocarbons having melting temperature between 23ºC and 67ºC [12]. Paraffin are available in large temperature range, Paraffin have no tendencies to super cool. Paraffin are chemically stable. Paraffin waxes show high heats of fusion. Paraffin waxes don’t segregate. Paraffin waxes are safe. Paraffin are non-corrosive. [12][13] Paraffin has Low thermal conductivity. High volume change between the solid and liquid phases. Commercial paraffin do not sharp exact melting point Paraffin are flammable. Pure paraffin are expensive. [12][13]

2. Non-Paraffin:

The non-paraffin organic are most numerous of the PCMs with highly varied properties. Non-paraffin organic PCMs are characterised by their varied properties. Each of these materials will have its own properties unlike the paraffin's, which have very similar properties. Abhat et al [14], Buddhi and Sawhney [15] have conducted an extensive survey and recognised a number of esters, fatty acids, alcohols, and glycols suitable for thermal energy storage. These organic materials are subdivided into fatty acids and other non-paraffin organic [13]. These materials are flammable and should not be exposed to excessively high temperature, flames or oxidizing agents. Following are some features of non-paraffin [13].Non-paraffin has High heat of fusion. Non-paraffin has Low thermal conductivity, Low flash points. Non-paraffin are Inflammable. Non-paraffin has Instability at high temperature. Varying level of toxicity.

- Fatty acids

General formula for all the fatty acid is given by $CH_3\ (CH_2)_{2n}$ x COOH. Fatty acids have the same characteristic as paraffin and have high values of latent heat of fusion compared to paraffin. Fatty acids have the ability of many cycling of melting and freezing with no super cooling, and they are characterised by sharper phase temperature than technical grade paraffin. The major drawback of fatty acids is their high cost that is 2-2.5 times greater than that of the technical grade paraffin. Additionally they are mild corrosive. [13]

INORGANIC PCMs:

Inorganic phase change materials are classified as salt hydrates and metallic. These phase change materials do not supercool appreciably and their heats of fusion do not degrade with cycling.

1) Salt hydrates

Salt hydrates consist of a salt and water that combine in crystalline matrix when the material solidifies. There are many different salt hydrates having melting temperature ranges between 15ºC-117ºC. Salt hydrate are considered as the most important group of PCMs that have been studied for application in latent thermal energy storage system. [12] Salt hydrates has High latent heat of fusion per unit mass of volume (higher than paraffin) It has High thermal conductivity (compared to paraffin) And Have sharp phase change temperature. Salt hydrates has Small volume changes during melting. It has High availability And Low cost. Segregation is the formation of other hydrates or dehydrated salts that settle and reduce the volume that is available for thermal energy storage. Salt hydrate show super cooling because they are unable to start crystallization at the freezing temperature. This problem can be avoided by using nucleating agents. Salt hydrates causes corrosion in metal container, whereas metal containers are common containers used in thermal energy storage system.

2) Metallic

Metallic include the low melting metals and metal eutectics. Metallic have not been strongly studied as PCM for latent heat storage because of their heavy weights. For the applications that weight is not important issue while volume is an important parameter, metallic are attractive because of their high heat of fusion per unit volume. [13] Some features of these materials are: It has Low heat of fusion per unit weight, High heat of fusion per unit volume and High thermal conductivity. Metallic has Low specific heat and relatively low vapour pressure.

3) Eutectics

The eutectic consist of two or more components where each of them melts and freezes congruently forming mixture of a component that crystals during crystallization process. Usually eutectic melt and freeze without segregation. During melting process, both components liquefy at the same without possibility of separation.

ENERGY STORAGE:

Thermal energy storage can have a positive impact in the form if increasing the reliability of the system, improving the functioning of the power plants and energy system, reducing energy purchase costs by shifting energy surplus from period of lower to period of higher demand. During day time when solar energy collection takes place and terminates with complete melting of the PCM, charging of the store does not terminate with complete melting of the PCM if the inlet fluid temperature is above the melt temperature, charging of sensible heat continues. Heat transfer fluid exit temperature is time dependent because the rate of the solidification of the PCM varies with time. This mode terminates with complete solidification of the PCM. Latent heat storage system have many advantages like large hear storage capacity in a unit volume and their isothermal behaviour during the charging and discharging process. Al-Jandal and Sayigh [16] studied the thermal performance characteristics of a solar tube collector (STC) system with phase change storage analytically and experimentally. STC performance during charging is studied and it is concluded that fin structure are strongly affecting the melting process. Mehling et sl [17] concluded that placing PCM module at the top the water tank in TES (thermal energy storage) has given higher storage density and compensated the heat loss at the top surface by doing both numerical and experimental investigation.

APPLICATIONS OF PHASE CHANGE MATERIALS INCLUDE, BUT ARE NOT LIMITED TO:

1. Thermal energy storage
2. Conditioning of buildings, such as 'ice-storage'
3. Cooling of heat and electrical engines
4. Cooling: food, beverages, coffee, wine, milk products, green houses
5. Medical applications: transportation of blood, operating tables, hot-cold therapies, treatment of birth asphyxia
6. Human body cooling under bulky clothing or costumes.
7. Waste heat recovery
8. Off-peak power utilization: Heating hot water and Cooling
9. Heat pump systems
10. Passive storage in bioclimatic building/architecture (HDPE, paraffin)
11. Smoothing exothermic temperature peaks in chemical reactions
12. Solar power plants
13. Spacecraft thermal systems
14. Thermal comfort in vehicles
15. Thermal protection of electronic devices
16. Thermal protection of food: transport, hotel trade, ice-cream, etc.

17. Textiles used in clothing
18. Computer cooling
19. Turbine Inlet Chilling with thermal energy storage

Telecom shelters in tropical regions. They protect the high-value equipment in the shelter by keeping the indoor air temperature below the maximum permissible by absorbing heat generated by power-hungry equipment such as a Base Station Subsystem. In case of a power failure to conventional cooling systems, PCMs minimize use of diesel generators, and this can translate into enormous savings across thousands of telecom sites in tropics.

CONCLUSION:

1. From the review it is seen that the energy stored time can be reduce with the use of phase change material
2. It provide greater advantage towards meeting of energy storing needs, compactness and energy supply at constant temperature.
3. The use of PCM is beneficial towards storing the waste heat with its low cost advantages.

REFERENCES:

1. Belton, G. and Ajami, F. Thermochemistry of salt hydrates Technical Report NSF/RANN/SE/GI27976/TR/73/4 University of Pennsylvania (1973).
2. Haynes, W., Lide, D., and Bruno, T. (2012) CRC Handbook of Chemistry and Physics, CRC Press, Cleveland, Ohio http://hbcpnetbase.com/.
3. Hong, Y. and Xin-shi, G. (2000) Solar Energy Materials and Solar Cells 64(1), 37 – 44.
4. Zhang, L.-J., Di, Y.-Y., Tan, Z.-C., and Dou, J.-M. (2012) Solar Energy Materials and Solar Cells 101(0), 79 – 86.
5. Zalba, B., Mar´ın, J. M., Cabeza, L. F., and Mehling, H. (2003) Applied Thermal Engineering 23(3), 251 – 283.
6. Sharma, A., Tyagi, V., Chen, C., and Buddhi, D. (2009) Renewable and Sustainable Energy Reviews 13(2), 318 – 345.
7. Abhat, A. (1983) Solar Energy 30(4), 313–332.
8. Agyenim, F., Hewitt, N., Eames, P., and Smyth, M. (2010) Renewable and Sustainable Energy Reviews 14(2), 615 – 628.
9. Tyagi, V. V. and Buddhi, D. (2007) Renewable and Sustainable Energy Reviews 11(6), 1146 – 1166.
10. Lane, G. A. (1983) Solar Heat Storage: Background and Scientific Principles, CRC Press, Boca Baton, Florida.
11. Lane, G. A. (1986) solar heat storage: Latent Heat Materials, CRC Press, Boca Baton, Florida.
12. Sharma Someshower Dutt, Kitano Hiroaki, and Sagara Kazunobu, "Phase Change Materials for Low Temperature Solar Thermal Applications'', Res. Rep. Fac. Eng. Mie Univ., Vol. 29, pp. 31-64, 2004.
13. Sharma Atul, Tyagi V.V., Chen C.R., and BuddhiD., "Review on Thermal Energy Storage with Phase Change Materials and Applications'', Renewable and Sustainable Energy Reviews, Vol. 13, pp. 318–345, 2009.
14. Abhat A, et al., "Development of a Modular heat Exchanger with an Integrated Latent heat Storage", Report no. BMFT FBT 8 -050, German Ministry of Science and Technology, Bonn, 1981
15. Farid Mohammed M., Khudhair Amar M., Razack Siddique Ali K., and Al-Hallaj Said, "A Review on Phase Change Energy Storage: Materials and Applications'', Energy Conversion and Management, Vol. 45, pp. 1597–1615, 2004.

16. S. Al-Jandal and A. A. M. Sayigh, Thermal performance Characteristics of STC system with phase change storage, Renewable Energy, 5 (1994), 390–399. S. S. Al-Jandal and A. A. M. Sayigh, Thermal performance Characteristics of STC system with phase change storage, Renewable Energy, 5 (1994), 390–399.
17. H. Mehling, L. F. Cabeza, S. Hippeli, and S. Hiebler, PCMmodule To improve hot water heat stores with stratification, Renewable Energy, 28 (2003), 699–711