Utilization of Solar Thermal Energy Storage using Phase Change Materials (PCM): A Review

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Abstract— Now a day's reduction in the fossil fuels availability leads to the energy crisis. Renewable sources like solar energy being a major replacement for the fossil fuels deficiency, utilization of such renewable energy effectively without any energy losses is a major challenge since the energy requirement is rising day by day. This paper is about utilizing the solar thermal energy using Phase Change Materials (PCMs). Thermal Energy Storage (TES) System serves as alternatives for the conservation of energy efficiently. PCMs have the capability of storing large amount of energy for lateral purpose. A good PCMs should have high heat of fusion, high thermal conductivity, high specific heat and density, long term reliability, and dependable freezing behavior. However high level of utilization is possible only if the effective technology for its storage can be developed with acceptable costs. PCMs for TES should be encapsulated, because they are generally solid-liquid phase change materials. This paper reviews about Thermal Energy Storage systems and PCMs characteristics and their behavior.

Key words: Fossil Fuels, Solar Energy, PCM, TES System

I. INTRODUCTION

Now a days non-renewable resources like fossil fuels, coal, and these sources are continuously reducing. Therefore new type of methods has to be implemented. That method should be a renewable type of energy. In many industries the energy resource will be a major defect. So we have to store the energy sources for future purposes. In that storing method the (PCMs) will be very helpful for us so we have choose the paraffin as a (PCMs). For energy storage purpose we have use the (TES) for gathering and store the thermal energy for our daily purposes. In our future condition everyone has to save the energy sources for future purposes. For that we have chosen the (PCMs) for utilizing the solar thermal energy. One of the best type of renewable energy storage method is Thermal Energy Storage system (TES). Solar energy is an important sources of renewable sources. We can utilize it most of the time without any shortage. Thermal energy storage (TES) is about temporary holding of thermal energy in the form of hot or cold substances for lateral purpose. TES is a noteworthy technology in systems involving renewable energies as well as other energy resources as it can make their operation more efficient, by bridging the period between periods when energy is harvested and periods when it is needed [1]. Effective and widespread utilization of solar energy for low temperature and thermal applications are possible by efficient and economic heat storage [2]. An ideal PCM to be used for latent heat storage system must meet following requirements: high sensitive heat capacity and heat of fusion; stable composition; high density and heat conductivity; chemical inert; non-toxic and non-inflammable; reasonable and inexpensive [17]. In the nature, the salt hydrates, paraffin and paraffin waxes, fatty acids and some other compounds have high latent heat of fusion in the temperature range from 30ºCto 80ºCthat is interesting for solar applications [17].PCM materials undergo reversible transition of phase depending on their temperature. The hypothesis driving the research is simple: when the solar panels' temperature rises, the excess heat must be absorbed until the PCM has completely melted. When the solar panel's temperature decreases, the solidification of the PCM should provide additional heat for the operating liquid in solar thermal panels, provide heat to the building or act as an insulation material [5]. Integrated approach for evaluating the performance of all system components should be used during the design process and determination of system control strategies [15].This paper reviews on Thermal Energy Storage (TES) using PCMs.

II. CLASSIFICATION OF TES

The main types of TESs are sensible thermal energy storage and latent thermal energy storage. By changing the temperature of the storage medium, sensible TES systems stores energy, which can be water, brine, rock, soil, etc. Latent TESs stores energy by phase change, e.g., cold storage water/ice and heat storage by melting paraffin waxes. Latent TES units are generally smaller than sensible storage units [1].

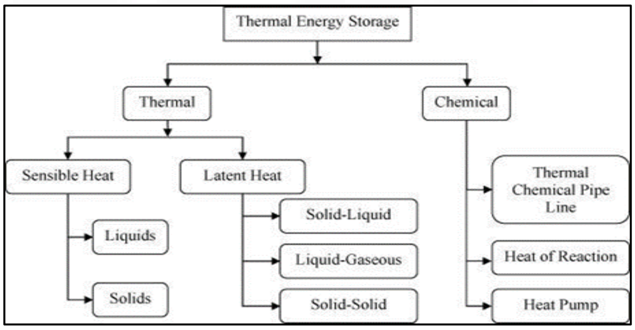


Fig. 2.1: Classification of TES

Latent heat storage (LHS) system in TES is one of the effective ways of storing energy in large quantities due to its high energy storage density. Due to their good thermo physical properties, Phase change materials are used for storing energy in latent heat storage system and also reduced storage volumes compare to sensible heat storage systems 7, 8. Without medium PCMs cannot absorb or release heat. They require heat transfer fluid sand need of a heat exchanger [12]. In sensible heat storage, the thermal energy is stored due to increase in temperature of stored energy stored depends on the specific heat, the change in temperature and mass of the material. In sensible heat storage, the thermal energy is stored due tostored medium. The amount of energy stored depends on the specific heat, the change in temperature and mass of the material [16].

III. SELECTION OF PCM

The two major categories of PCM are inorganic compounds and organic compounds. Inorganic PCMs include salt hydrates, salts, metals and alloys, whereas organic PCMs are comprised of paraffin, fatty acids, alcohols and glycols [14].The phase change thermal energy storage materials must have a large latent heat and high thermal conductivity. They PCM should have a melting temperature lying in the practical range of operation, melt congruently with minimum sub cooling and be chemically stable, low in cost, nontoxic and non-corrosive. Materials that have been studied during the last 40 years are salt hydrates, paraffin waxes, fatty acids and eutectics of organic and non-organic compounds [18]. Some natural substances, such as salt hydrates, paraffin and paraffin waxes, fatty acids and other compounds, have the required high latent heat of fusion in the temperature range from 0 to 1501C and these materials could be used for solar applications, though have certain shortcomings. Salt hydrates has a main limitation that their chemical instability when they are heated, as at elevated temperatures they degrade, losing some water content every heating cycle. Furthermore, some salts are chemically aggressive towards structural materials and they have low heat conductivity. Finally, salt hydrates have a relatively high degree of super cooling [9]. One of the best suited PCM for low temperature applications is paraffin wax. Paraffin has moderate energy storage density and is cheap. Other PCM like palmitic acid is also an organic but non-paraffin group material suited for low temperature applications ranging from 16 to 65oC. It has better latent heat capacity and sharp melting point [12].

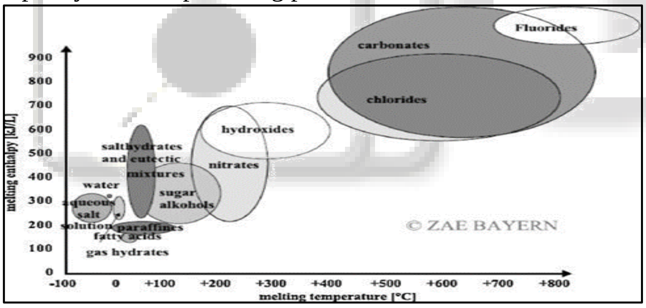


Fig. 3.1: Materials used as PCM with Melting Temperature and Melting Enthalpy

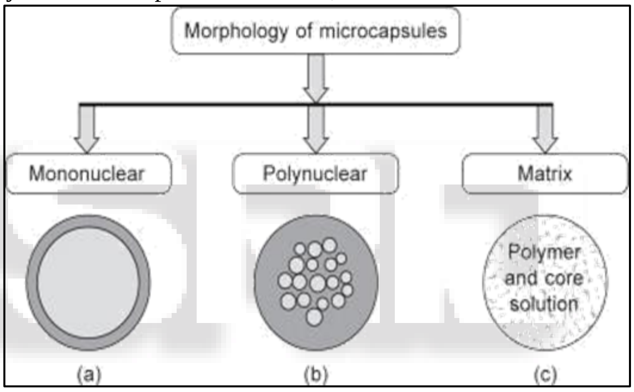
Paraffin is chosen as the promising phase change material because it possesses desirable properties such as high latent heat, chemical inertness, no phase segregation, and commercial availability. The microstructure and thermal property of the paraffin PCM was characterized by means of scanning electron microscope (SEM), X-ray diffraction (XRD) and differential scanning calorimeter (DSC). Moreover, the thermal energy storage property of the paraffin PCM was studied in a LTES system as compared with those of paraffin. Transients ofaxial and radial temperature profiles were obtained in the LTES system for paraffin [14].

IV. ENCAPSULATION OF PCM

PCMs have a relatively low thermal conductivity and there are two ways of solving this problem. On one way the distances for heat transfer by conduction in the PC Mcan be shortened. This method can be done by encapsulating the material into relatively small capsules or by highly dispersed heat exchangers with low distances between fins or pipes. Onthe other way the thermal conductivity can be enhanced by embedding structures of materials with high conductivity into the PCM [1].

Basically there are two principal means of encapsulation: micro and macro encapsulation.

Micro-encapsulation helps to handle the PCMs independently of being solid or liquid. The microcapsules (figure 5) are tiny particles of solid, liquid or gas with diameters smaller than 1 mm and larger than 1µm (ussualy5–10µm in diameter), which surround the paraffinic PCM core material with a individual hard polymeric shell. The particles coated that can then be incorporated in any matrix that is compatible with the encapsulating film. It says that the film must be compatible with both the PCM and the matrix. Because of the small diameter the ratio of surface area to volume isvery high and the low thermal conductivity is not a problem. If these microcapsules are dispersed in water, they form pump able slurry that can be used as an energy transport- and storage medium, as so-called PCM slurry. Because of the microcapsules have small diameter; the slurry can be treated like a homogenous fluid. A microencapsulation of salt hydrates is not possible at all [1, 9].



The second method is macro-encapsulation, which comprises the inclusion of PCM in some form of package such as tubes, pouches, spheres, panels or other receptacle. These containers will serve directly as heat exchangers or they can be incorporated in building products. The PCM should be encapsulated to avoid adversely affect the function of the construction material. Previous experiments with large volume containment or macro-encapsulation failed because of poor conductivity of the PCM. When it was time to regain the heat from the liquid phase, the PCM solidified around the edges and prevented effective heat transfer [1].

V. RESULT & DISCUSSION

The temperature distribution of the phase change material, during charging and discharging was taken at two different mass flow rates at 15, 11kg/min. For each mass flow rate, curve was plotted for variation of temperature at each point in the wax against time elapsed, to get melting curve in case of charging and solidification curve in case of discharging.

A. Case 1: At Mass Flow Rate of 15 kg/min

In this case, the mass flow rate of the heat transfer fluid was taken as 15 kg/min. The melting and solidification curve for the phase change material was obtained and are shown in Figure 5.1 and 5.1 respectively. The variation of temperature in the wax during charging and discharging is shown in Table 5.1 and 5.2 respectively.

1) Melting Curve

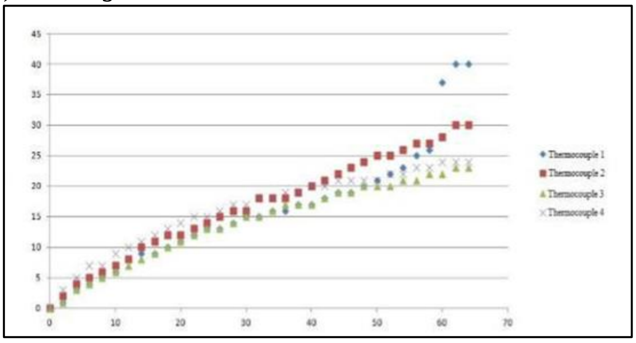


Figure 5.1: melting curve case 1

2) Solidification Curve:

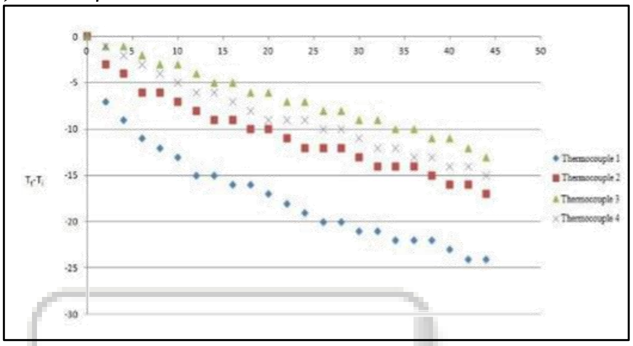


Fig. 5.2: Solidification Curve (Time Elapsed)

Thermocouple 1 represents curve of temperature variation at point 2, Thermocouple 2 represents curve of temperature variation at point 3, Thermocouple 3 represents curve of temperature variation at point 4 and Thermocouple 4 represents curve of temperature variation at point 5, where points 2 to 5 are according to it.

B. Case 2: At Mass Flow Rate of 11 kg/min

In this case, the mass flow rate of the heat transfer fluid was taken as 11 kg/min. The melting and solidification curve for the phase change material was obtained and are shown in Figure 5.3 and 5.4respectively. The variation of temperature in the wax during charging and discharging is shown in Table 5.3 and 5.4 respectively.

1) Melting Curve

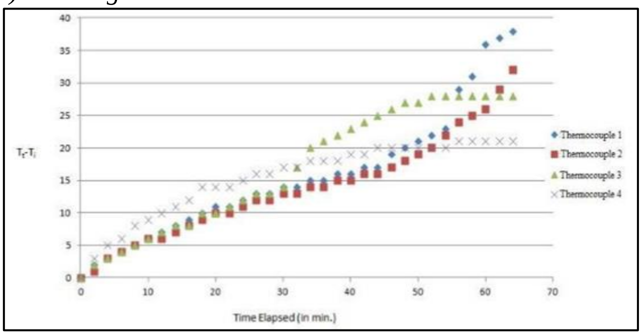


Fig. 1.3: Melting Curve (Case 2)

2) Solidification Curve

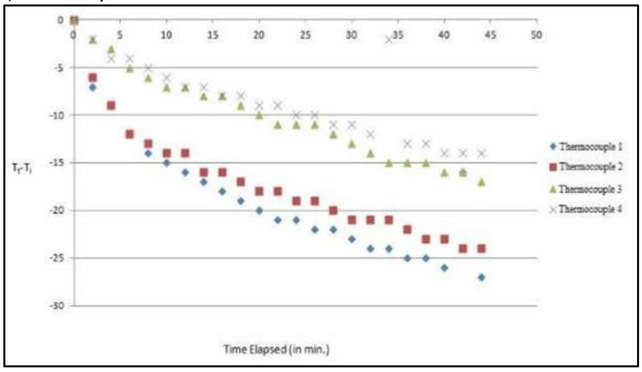


Fig. 5.4: Solidification Curve (case 2)

Thermocouple 1 represents curve of temperature variation at point 2, Thermocouple 2 represents curve of temperature variation at point 3, Thermocouple 3 represents curve of temperature variation at point 4 and Thermocouple 4 represents curve of temperature variation at point 5, where points 2 to 5.

VI. CONCLUSIONS

From the literature survey, it is observed that very few experimental studies are done on thermal enhancement techniques with phase change materials (PCMs). Mostly paraffin is used as PCM for low temperature application (<100ºC). Hence there is need to do more research in PCM storage with thermal enhancement in the temperature range of 150ºC to 200ºC.These thermal storage applications used as a part of solar water-heating systems, solar air heating systems, solar cooking, solar green house, space heating and cooling application for buildings, off-peak electricity storage systems, waste heat recovery systems. Nevertheless, research is still needed to find new more efficient and cheap materials, and to give better solutions to technical problems such as sub cooling, segregation and materials compatibility.

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