Performance Investigation Of A New Latent Thermal Energy Storage System Under Discharging Mode

Pardeep Singh, PhD Research Scholar, I. K. Gujral Punjab Technical University, Jalandhar, India
Harmeet Singh, Professor, Mechanical Engineering Department, G.N.D.E.C, Ludhiana, India

Abstract
There are different ways of energy storage such as sensible warmth, latent heat, reaction heat, or amalgamation of all. One of the best methods to store heat used in the latent heat systems (LHS) system is the phase change materials (PCMs) because of its high heat storage thickness, small framework size and little change in the temperature. Energy is captured in the latent heat storage framework at the time of melting while it is recuperated during the solidifying procedure. Although, phase change material used in this latent heat system as a medium of storage is not good in commercial usage because of the bad quality of transfer of heat rate at the time of storage and release process. In this experimental work, different flow rates (6 liter/min, 4 liter/min and 2 liter/min) with their impact on the discharging process of the system was studied. Batch wise discharging method was adopted in the study.

Keywords: Thermal Energy Storage (TES), Phase change material (PCM), Latent heat, Heat Transfer Fluid (HTF)

Introduction
One of the effective utilization of renewable energy source is the solar energy, but it is intermittent in nature. This way the above method of storage of energy plays an important role in adjusting the time-inconsistency between the supply of energy and its demand. In this way, solar energy can be captured in different forms such as heat, latent heat, reaction heat, or combination of all [1, 2]. The system used in this framework have the quality of limited temperature change as well as is small in size, so with the benefit of this the phase change materials (PCMs) are very good heat storage materials due to the benefits of high heat storage density used in this system [3]. In this method of energy storage, during the process of melting energy is captured and improved at the time of solidification. While on the other side, phase change material used in this latent heat system as a medium of storage is not good in commercial usage because of the bad quality of transfer of heat rate at the time of storage and release process [4].

Different procedures have been produced and different exemplifications have been utilized as a part of LTES frameworks which include bulk storage, macro-encapsulation and micro-encapsulation. As a tradeoff between the heat storage thickness and the heat transfer rate, the large scale encapsulation is the overwhelming structure the phase change material (PCM) it might be exemplified in cans, spheres and other commercially accessible geometries. Specifically, the spherical geometry is a standout amongst the most favored encapsulations since it can make the capacity tank have a higher packing density as well as a larger range for heat exchange.

In the recent years, the latent heat storage method when it is compared with the process of sensible heat storage has magnetized an immensely colossal number of techniques due to its high thickness of storage of energy with a more diminutive temperature swing [1–4]. Techniques should be considered which includes low thermal conductivity in its most phase change materials, heat transfer extent. Different procedures are suggested for upgrading the transfer of heat in latent heat thermal store. To modify the PCM metallic fillers thermal conductivity, metal matrix structures, finned tubes are mundane methods. The PCMs are divided into the following types: Inorganic and organic PCMs, and eutectic PCMs. Each one is then divided into the subgroups as appeared in Fig. 1. The inorganic one consist of salt hydrates and metals, while the organic group contains paraffin’s and non-paraffin of PCMs. Eutectics are made up of the combination of inorganic and/or organics. Everyone have its own range of melting temperature and enthalpy.
Lei yang et al. [1] introduce a numerical study which consist of (PCM) a type of a new packed bed which further consist of stratified material of phase change. In this process, the PCM are used as phase change capsules which are inserted into polycarbonate spheres. At the time of charging and discharging the thermal energy to the PCM, for the heat transfer fluid (HTF) water is used. Numerous samples were picking up to use as PCMs which are classified into two groups, organic and inorganic PCMs. The hydrated salts have the quality of more immensely colossal energy storage density as well as higher thermal conductivity but on the other hand it will experience super-cooling and phase segregation. For rectangular and cylindrical container CaCl2•6H2O were used as PCM [5, 6]. But the organic materials have the ability to melt as well as freeze perpetually without change in the phase segregation and consequent degradation of their latent heat of fusion, with small or no supercooling and conventionally non-corrosiveness when compared to inorganic material.

The utilization of phase change material (PCM) is one of the great selections as a medium of capacity especially for refrigeration frameworks, the principle supporter of the monstrous request amid crest summer days. PCMs are one of the substances in which the warmth at the strong fluid stage change point is utilized as a part of specialized applications for putting away a lot of warm vitality at known temperature. The extensive vitality stockpiling thickness in respect to sensible vitality stockpiling with shake is one of the guideline points of interest of PCMs [4, 5].

The PCM warm capacity framework or called thermal energy storage (TES) framework involves at least three fundamental segments: (an) a PCM with reasonable liquefying point; (b) a compartment to hold the PCM and (c) and a surface for exchange of heat from the warmth source and then to PCM and further from PCM to a warmth sink [6]. Exchange of heat is taking place between the heat transfer fluid and phase change material.

Some paraffin’s have frugal and medium capacity of storing the thermal energy density was employed as PCM. A number of studies were presented in the past. Regin et al. [7] made study consist of experimental and numerical work of paraffin wax to find out the melting component as PCM which is enclosed in a capsule of cylindrical in shape. Results showed that the process of melting was regulated by the following which includes magnitude of the Stefan number, phase change temperature range and the capsule radius. Qarnia [8] introduced a theoretical model predicated equations of energy to prognosticate the implanted in the PCM.

Different numerical simulations were conducted for the optimum design and withal made to study the impact of flow rate during the discharging mode on its out- let...
temperature using three types of PCM (n-octadecane, paraffin wax and stearic acid). Additionally promising PCMs are used such as Adipose acid such as stearic acid, palmitic acid, myristic acid and lauric acid for latent heat storage. Sharma et al. [9] study the adipose acids (capric acid, lauric acid, myristic acid, palmitic acid and stearic acid) thermal performance for the storage of the energy in the system as PCM through the two dimensional simulation models. The results made us clear that the astronomical immense value of thermal conductivity did not develop any consequential contribution on the melt fraction of heat exchanger materials.

Sari and Kaygusuz studied the thermal performance of different acids such as palmitic acid [10], stearic acid [11], amalgamation of palmitic and stearic acids [12] and capric acid/palmitic acid [13] as heat storage materials. Also, Singh et al. [14] did a comprehensive reassessment of various packed bed storage system including design construction of packed beds, different materials used for heat storage, heat transmit properties, and flow phenomenon and pressure drop via packed beds.

**Experimental Set Up:**
The major elements were insulated such as hot water storage tank, water pump, electric heater, flow meter and corrugated PCM enclosure for the experimental work. The elements were gathered as shown in figure Fig 2 and 3. An electric heater heats the water and water pump helped to circulate through the circuit. For the experimental work, suitable piping and fittings were used as shown in Fig. 3.

In this experimental work three different PCMs were used as a phase change material. The properties of different phase change materials are shown in table 1. A stainless steel tank of height 1 m and diameter of 0.40 meter was used as thermal energy storage (TES) tank.

### Table 1. Thermo physical properties of PCMs

<table>
<thead>
<tr>
<th>Sr No.</th>
<th>PCM</th>
<th>Melting Point (°C)</th>
<th>Latent Heat (KJ/Kg)</th>
<th>Density (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Paraffin wax</td>
<td>50</td>
<td>213</td>
<td>788</td>
</tr>
<tr>
<td>2</td>
<td>Hybrid wax</td>
<td>60</td>
<td>270</td>
<td>1450</td>
</tr>
<tr>
<td>3</td>
<td>Bee wax</td>
<td>70</td>
<td>177</td>
<td>970</td>
</tr>
</tbody>
</table>

The schematic of an experimental is shown in figure 2. Phase change material was encapsulated in the stainless steel spheres of diameter 55mm and the tank are filled and then encapsulated with the PCM spheres in 180 randomly set spheres. Another water storage tank was used to supply the hot water continuously. Two automated heaters were used to get the desired hot water. Rotameter was used for the flow rate of the heat transfer fluid to regulate. For the heat transfer fluid throughout the medium, water was used. Centrifugal pump is used to transfer the HTF continuously.

Every three layer have one kind of PCM. The PCM capsules filled with different PCMs are made up of steel spheres and are placed in series in the tank. PCMs with higher melting points will be placed in higher positions and are close near to the HTF inlet PCMs with high melting point are placed in the higher position. During the process of charging, hot water flows from the top to down and used as HTF to melt the PCM while the cold water from top to down during discharge process. There are two methods of producing hot water which includes solar energy and other heat resources. And during off-peak hours, hot water can be made by using electrical energy and heat energy is then transferred to PCM and stored as latent thermal energy.
Various J type thermocouples were used to measure the temperature inside the packed bed. A Total of 14 thermocouples were used in the experiment. All the thermocouples were connected to the computer with National Instruments cDAQ 9174. LABVIEW express software was used to collect the temperature readings per minute. The complete experimental setup is shown in figure 3.
Experimental Trial
Firstly the PCM was estimated in the tank to be totally solidified, as the mass temperature in tank was kept up beneath the stage change temperature in TES. The warmed room was kept up at temperature up high preceding the start of the test. Heat was presented by the streaming HTF through PCM embodiment consequently softening the strong PCM.

The experiment was conducted in two parts. One is charging mode and the other is discharging mode. In this research work the mass flow rate effect on the discharging time was studied. The packed bed is charged until the whole temperature of the bed reaches the melting temperature of the each PCM which was around 70-75 °C. Once the desired temperature is achieved then the system was stopped. In this stage the heat is transferred from hot water to the phase change material. In order to accumulate heat, the PCM changes its phase from solid to liquid. The results obtained from the experimental investigation of performance analysis of the heat transfer characteristics of the latent heat storage system during discharging process with different encapsulation materials are discussed in detail.

Discharging experiment was conducted using open bottom inlet by withdrawing water in batch wise process. By the above process, water was withdrawn for every 20 min time intervals so that heat transfer could take place.

Results And Discussion
Once the warming procedure was finished, the cooling procedure was done until the normal best four temperature of HTF achieved. At the point when temperature of HTF start began dipping under temperature of PCMs, TES began to discharge the put away heat storage. Along these lines the warmth exchange occurred from the PCM to the HTF subsequently keeping up the temperature of HTF. In the discharging process, water at ambient temperature was used to circulate in the TES tank. Actually the discharging process is of two types: continuous discharging and batch wise discharging. Batch wise discharging process was carried out in this experiment trial because it is more efficient. One batch of 35 liter is put into the tank and allowed it for 20 minutes so that heat transfer could take place. This process was repeated until the ambient temperature was achieved from the last batch which was around 30°C. The temperature distributions of HTF and the different PCM for different mass flow rates during discharging processes are recorded in the storage tank as shown in figure 3.

![Figure 3: Temperature distribution during discharging process at different flow rates](image)

Conclusion
Impact of LTES with spherical layering on electric powered water warmer with one outlet location was examined by persistent and batch wise releasing of high temp water at 30 °C with different mass stream rates. Subsequently LTES, the water accessibility of heated water has managed for longer span.

As it can be seen in the figure 3 those temperature behaviors during various flow rates are almost same. During the discharging process there is not so much difference found in the amount of heat recovered at different flow rates (2, 4, and 6 lit/min). This is because of the 6lit/ min flow rate, the mean temperature is high and the low quantity, and for other flow rates, the average temperature is low, and the quantity is high. Therefore it is concluded that there is not so much influence on the heat recovered at different flow rates during the discharging phase. For the better result of transfer of heat further investigations are needed. So for this, correlations on total heat resistances between PCM encapsulated spheres and a liquid based HTF need to be studied further. Also, the consideration of the effect of outlet locations on stratification is left for future work.

References