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Performance of Thermal Energy Storage System with Finned Spherical Capsules

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ABSTRACT

Due to past depletion of conventional energy sources and ever increasing the demand of energy, many researchers started paying attention to renewable energy sources. Thermal energy storage is one key of technologies for energy conservation and has recently developed to a point where it can have a significant impact on modern technologies. The present work deals with the study of finned spherical capsules, the finned sphere is filled with the stearic acid as phase change material. Water used as the heat transfer fluid.HTF occupying space left between the finned spherical containers in thermal energy storage tank. Simulations of the charging and discharging process are performed and obtained results are compared with the previous theoretical results.

***KEYWORDS**: Heat transfer fluid, PCM, Thermal energy storage, Latent heat, Charging process, Discharging process, TES tank.*

I. Introduction

In recent years, due to problem of past depletion of conventional energy sources and increasing the demand of energy, as well as increasing attention towards the usage renewable energy resources, Thermal energy storage is one of the important measures in energy conversion systems. Thermal energy storage is the method to be used in conventional energy resources. In this case thermal energy storage is important to improve thermal energy efficiency. Energy storage is combining with the solar collectors and photo voltaic systems. The thermal energy storage utilized at various industrial purposes. Thermal energy stored in three types. These are sensible heat storage, latent heat storage, thermo chemical cold and heat storage. The thermal energy storage methods most commonly used as sensible heat storage, latent heat storage methods. The sensible heat storage method having disadvantages also i.e. unit volume heat storage capacity is low at storage medium and during charging and discharging process sensible heat storage behaves like a non isothermal. In latent heat storage the small volume storing large amount of energy with the solid liquid phase change has received considerable attention. High storage density and heat charging and discharging process at constant temperature. Latent heat storage system plays an important role in energy conservation of environmental conditions. Latent heat storage having high comparison with the sensible heat storage. In which the material undergoes to phase change due to present of latent heat of fusion. A lot of research work has been carried out on sensible heat storage materials and systems in the past and present technology for their utilization and also well developed. Cool thermal energy storage using by the latent heat storage and it offers good option why because it is having high storage density at constant temperature. The principle of latent heat system is change of state. One of the most popular systems is latent heat storage system. The latent heat system is stored energy in the process of encapsulated phase change material. These are uses cylindrical geometries with fins and without fins, cans, plates or spherical capsules. The method of encapsulation is one of the attractive methods. It seems offers number of advantages.

In spherical capsules on energy storage very limited no of studies are found. Saitosh and hirose (1986) investigated experimental and theoretical of thermal characteristics in phase change thermal energy storage by using spherical capsules. The variation of HTF the inlet and outlet temperature difference, The capsule material, the thermal performance of energy storage unit were studied compared with the experimental results of a prototype LHS unit with the capacity of 300L. A very number of studies are found thermal performance of latent heat storage systems means PCM in various geometries. Siva Gowthami et.al studied the charging and discharging process of a finned spherical LHS capsule with stearic acid as PCM. Her experimental results demonstrated that, compared to charging process and discharging process PCM melts faster and it come to solid state taking long time.

The objective of the present work is to study on the thermal performance of a packed bed latent heat thermal energy storage unit integrated with constant heat source. The packed bed contained spherical capsules these contained with encapsulated PCM. The spherical capsules surrounded by the SHS material. Parametric studies were carried out to examine the effects of porosity and HTF flow rates on the performance of the storage unit for varying inlet fluid temperatures. Discharging is carried out by batch wise processes and both continuous to recover store heat.

II. Experimental investigation and setup

It consists of insulated thermal energy storage tank; PCM encapsulated finned spherical capsules, water heaters, storage tank, flow meter and circulating pump. A photographic view of experimental set up is shown below figure. The 380mm diameter and 500mm height stainless steel TES tank has a capacity of 52L to supply hot water for a family of 4 to 5 persons. The shower plate is provided on the top of the tank is to get uniform flow of HTF. The water tank is kept beside the storage tank.TES tank is supplied by HTF from water tank through pump. Spherical capsule of 70 mm outer diameter and 0.8mm thickness inserted with fins of 0.6mm. Because of these fins temperature will be equilibrium at the middle of the spherical ball. The total number of balls in the storage tank is 92. The spherical balls uniformly packed in five layers each supported by wire mesh. Stearic acid used as PCM with melting temperature of 56±1◦c and water is used as both SHS material and HTF.

A flow meter is having accuracy of ±3% is used to measure the flowrate of HTF. The centrifugal pump is used to circulate the HTF from the top of the storage tank. The TES tank was divided in to four segments along its axial direction, thermo couple wires are placed at the inlet, outlet and four segments of thermal energy storage tank. These are used to measure the inlet and outlet temperature of HTF. Another five thermocouple wires are placed at finned spherical capsules to measure the temperature of PCM. The total numbers of thermo couple wires are eleven. These are connected to a temperature indicator. It provides instantaneous digital outputs.

III. Experimental procedure

The water tank connected with the 2200W capacity heaters. The water is heated with the heaters and the temperature rise up to 80◦c. The hot water is circulating in to the storage tank with the help of centrifugal pump. The hot water passes through the finned spherical balls. The finned spherical balls are immersed in hot water. Several experiments are conducted at the different flow rates of HTF. The inlet temperature is varied at different experiments.

During the charging process the HTF is stored in storage tank after some time the hot water is circulated through the TES tank continuously. The heat energy is transfer in to the finned spherical capsules and at the beginning of the charging process the temperature of the PCM in finned spherical capsules is 32◦c.it is very lower to the melting temperature. Initially the heat energy stored inside the finned spherical capsules then it is started to reach the melting temperature. In TES tank energy storage is achieved by melting the PCM at certain temperature. PCM will be super heated at constant temperature this is the charging process. The sensible heat energy stored in the form of liquid PCM. The variations of PCM temperatures and HTF temperatures are recorded with the interval of 3 minutes. The charging process is continued to reach the PCM temperature 80◦c.

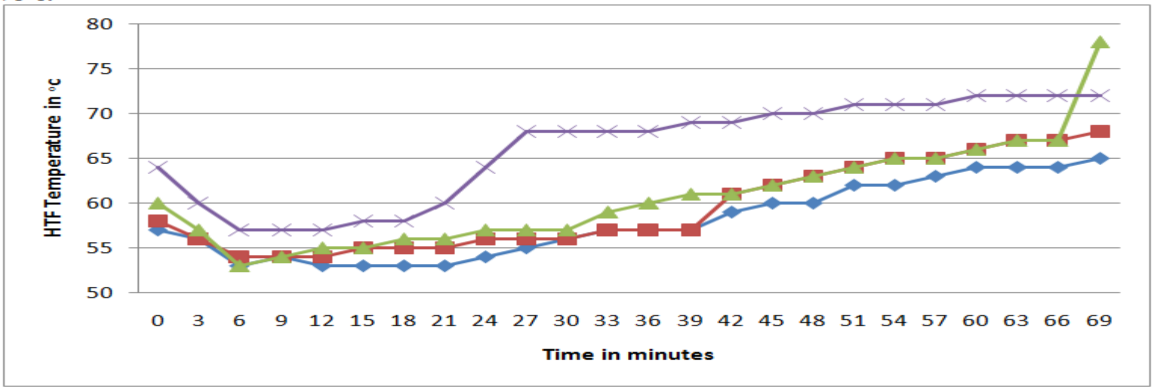
In discharging process the experiments carried out in to two methods. First method is continuous process and second one is the batch wise process. In the first method the cold water is continuously circulated in to the storage tank. The cold water temperature is 28◦c.it is recovered to heat energy. The second method is step by step method. First of all 25lit/min water was withdrawn from TES tank and it is mixed with the cold water at 28◦c.Recorded the PCM temperatures at the time interval 10mins, this discharging process is continued until the temperature of PCM reaches 45◦c.

IV. Results and discussions

The temperature variations of PCM and HTF are recorded in thermal energy storage tank for different positions. And the mass flow rates of charging and discharging processes are also recorded. Different mass flow rates are studied in detail.

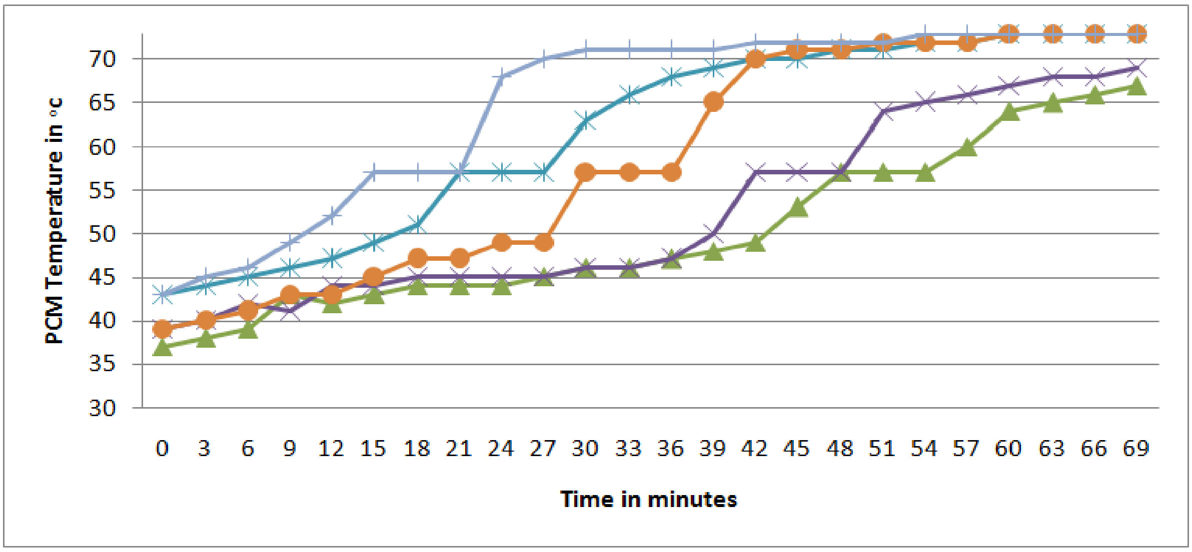
"4.1.Charging process"

The temperature histories of PCM and HTF are taken in four segments of the thermal energy storage tank. These are taking as X/L=0.25,0.50,0.75and 1. Where X is the axial distance from top of the TES tank and L is the length of the TES. The figure A represents the temperature variation of the heat transfer fluid inside the storage tank with the mass flow rate of 2lit/min and observed the temperature of HTF increases gradually and its temperature reaches 73◦c or 74◦c and then remains nearly constant around 78◦c for a period of 2hrs during which the PCM undergoes to phase changes at 56±1◦c.after that the HTF temperature increases up to 76◦c or 78◦c.

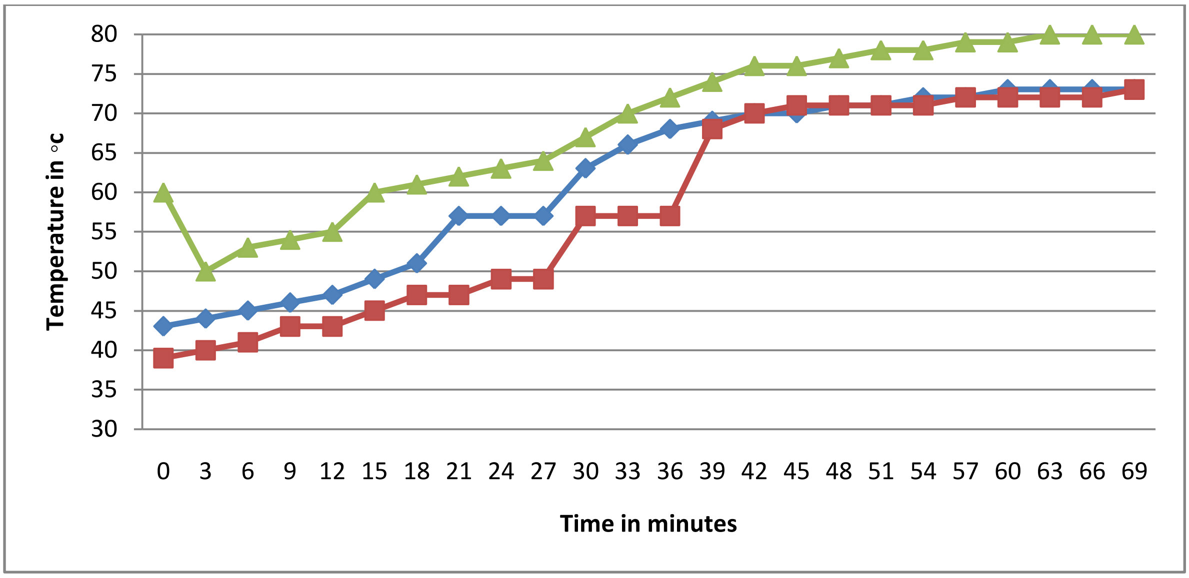


"Figure A.HTF Temperature @ 2 Lit/Min"

Fig B represents the temperature distribution of PCM during the charging process for the mass flow rate of 2lit/min. From the figure it was observed that PCM temperature increased rapidly from 57◦c at which PCM starts melting. During the charging process temperature of all segments reaches up to70◦c. In the above two figures we observed that the inlet temperature and outlet temperatures of TES are equal during the phase change of PCM. Due to this reason the TES tank water temperature increases gradually to the HTF inlet temperature. These are supplied from the hot water tank heated by the heaters. At this stage heat transfer rate from HTF to the PCM is higher than the HTF received from the heaters. Hence it is possible to decreasing the charging time high heating of water.



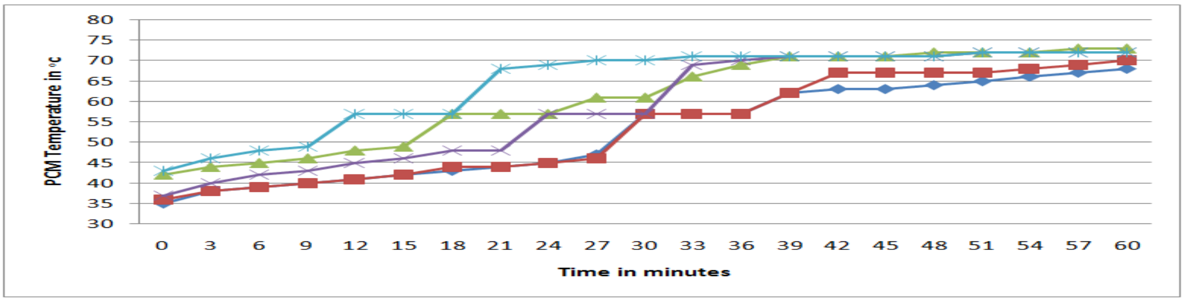
"Figure B.PCM Temperature @ 2 Lit/Min"



"Figure C. Comparison between PCM & HTF Temperatures"

Fig c shows the comparison of PCM temperature and HTF temperatures at segment 2 of thermal energy storage tank. The instantaneous amount of heat transfer to the PCM depends upon the Heat transfer between the HTF and PCM at a given time. During the charging process PCM absorbs more heat from HTF due to higher resistance offered by solid PCM for heat flow. Fig C illustrates temperature comparison between HTF and PCM after completion of 105 min from the initial process for the case with a mass flow rate of 2lit/min. The temperature of HTF and PCM will be increased and the charging process is continued until the PCM attempts 80◦c.

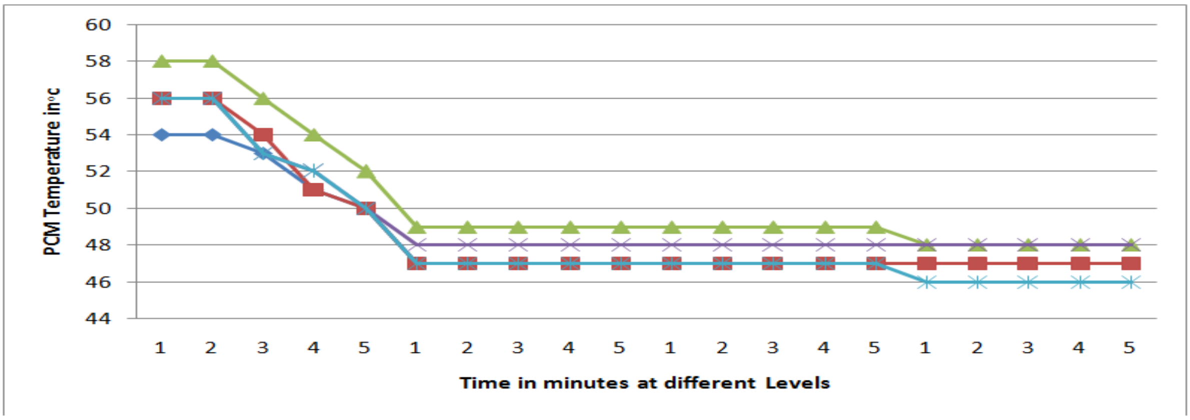
Fig D illustrates the effect of varying the mass flow rate of HTF (2, 4 lit/min) during the charging process of the storage tank. In the phase transition process of PCM, time required will be less when flow rate increases. The figure shows that charging time decreases when the flow rate increases. This is because an increase in fluid flow rates translates in to an increase in heat transfer coefficient between the HTF and PCM finned spherical capsules.



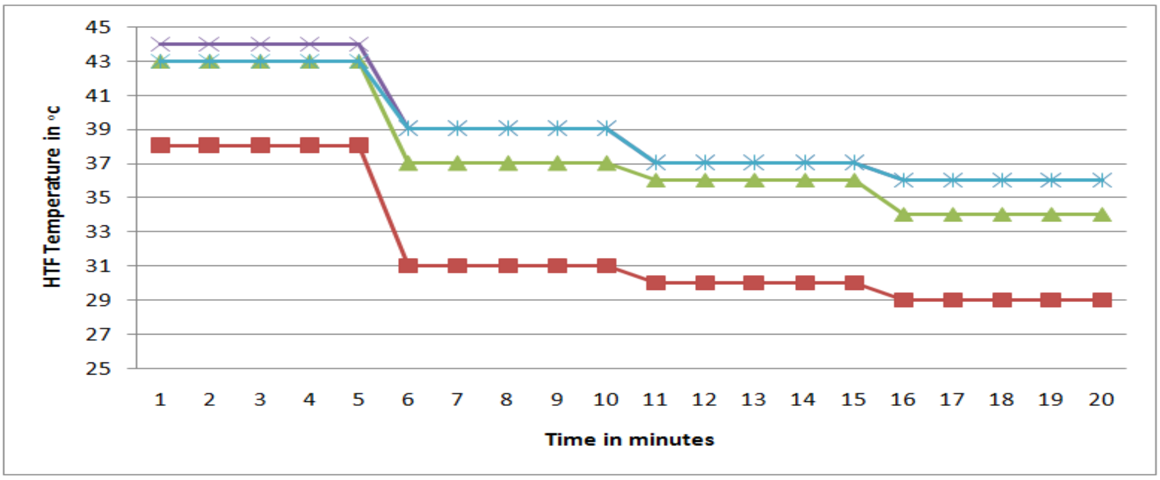
"Figure D. PCM Temperature @ 4 Lit/Min

"4.2.Discharging process"

Fig E represents the temperature distribution of PCM during batch wise in discharging process. It is seen from the figure the temperature drop is large. Until the storage tank losses sensible heat due to mixing of inlet water at a temperature of 32◦c. and observed PCM temperature drop in long duration, as PCM releases its latent heat. During the discharge process the temperature of the finned spherical capsules nearly constant for 25 min and at batch wise process nearly constant temperature occurs over duration of 40 min. The inlet water immediately extracts heat from the storage tank. The temperature decreases after a solidification of PCM. The rate of temperature drop is not high beginning of the discharging process. The temperature difference between the PCM and HTF is low. The solid PCM releases its sensible heat



"Figure E. PCM Temperature during discharging"



"Figure F. HTF Temperature during discharging"

Figure F. shows temperature distributions of HTF during both continuous and batch wise process. At the beginning of the discharge process the rate of heat recovery is very large. Change in thermal resistance of the solidified layer time is decreased. The temperature difference between HTF and solidifying PCM decreases. The HTF outlet temperature is continuously changes with time. This type of process is not suitable for practical applications

In the case of batch wise process 25L/min hot water is drawn from the storage tank and same quantity of cold water at 32◦c enter in to the storage tank at average temperature of 45◦c.entaire storage tank is filled with the cold water. After completion of the filling the storage tank the temperature of HTF is increases. After a retention period of 10mins the tank increases by gaining heat from finned spherical capsules. The variation of HTF is also shown in the graph.

Five batches of 25L of hot water at an average temperature of 45◦c.these are obtained at 60min time interval. Another batch of hot water at a temperature of 43◦c.it is withdrawn after 40min.the heat extraction from the finned spherical capsules is very slow. As the temperature difference between HTF and PCM is small. At this batch large quantity of water is added the time duration is very high. When considering above model of discharging process of the total system approaches equilibrium temperature nearly 43-45◦c.it is best suited method for the thermal energy storage of finned spherical capsules.

"5.Conclusion"

A thermal energy storage system has been developed for the use of hot water at an average temperature of 45◦c for the domestic applications using combined sensible heat storage and latent heat storage concept. The charging process experiments are conducted at the thermal energy storage unit. These are study its performance by integrating with the constant heat source. The temperature histories of HTF and PCM and energy storage characteristics are studied.

In detailed thermal analysis of solid liquid phase changes are performed. The simulations of the charging mode is performed and results are obtained compared against the previous results. The results are compared temperature distribution of HTF and finned spherical capsules temperature. It is concluded that the mass flow rate has been significant effect on the heat extraction rate from the constant heat source, which in turn affects the rate of charge of thermal energy storage tank. Experiment were conducted for continuous and batch wise discharging process.

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