# Experimental Performnce Investigation Of A Thermal Energy Storage System With Spherical Copper Balls

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**Abstract-** The goal of this research is to improve heat transmission in a twin pipe energy storage system. The effective thermal conductivity of the combined media of PCM and copper spherical ball is increased by using a copper spherical ball put inside the phase change material (PCM), which is paraffin wax. The experiments are carried out in accordance with the diameter and quantity of spheres implanted in the phase change material. In addition, the investigations look into the impact of raising the heat transfer fluid's temperature (HTF). The melting Fourier number and the PCM Nusselt number are used to represent the results. The Fourier number decreased by three times, whereas the Nusselt number increased by the same amount. This significant improvement is achieved by replacing 2-volume percent of the wax material with metal spheres.

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## 1 INTRODUCTION

This study focuses on heat transfer enhancement in double pipe energy storage system. Enhancement is achieved by use copper spherical ball placed inside the phase change material (PCM), which is paraffin wax and results in increasing the effective thermal conductivity Of the combined media of PCM and copper spherical ball . The experiments are conducted as a function of the diameter and number of spheres inserted in the phase change material. Also, the experiments investigate the effect of increasing the temperature of the heat transfer fluid (HTF). Results are presented in terms of variations in the PCM Nusselt number and the melting Fourier number. Results indicate three-fold decrease in the Fourier number and similar increase in the Nusselt number. Replacing 2-volume percentage of the wax material by the metal spheres results in this large enhancement.

A hot water storage system is used in many houses for domestic purposes to provide a reliable source of energy and this small step has given a major impact as it can be used as a substitute for manyrenewable resources of energy. Though there are many non-renewable source of energy, there isalways a tendency to look for heated fluid to use as a source of energy . This is because of theeasily available solar energy. The main important feature is that it can function as a storage system inthe morning during the morning by storing the energy and liberating it at off sun times when it isneeded in order to run the system continuously. There is always a misconception that the liquid in the

tank and its temperature is not distributed in a uniform way. In real situations, the cooler, denserfluid is settled at bottom of the tank whereas the hot lighter fluid will go up to the top, provided thatthe water within the tank is not mixed or agitated in any way.

There is also a factor of human comfort that is there in solar energy sources as it is the cheapest sourceof energy . One of the ways to learn the solar energy processes as well as to develop theireffectiveness and performances from the process viewpoint is to pass through the dynamic modelling and numeric simulation especially which consists of strong dynamics such as huge solar tanks andcollectors . Recent studies have proved that usage of molten salts in the tank would increase theefficiency. In recent years powerful commercial computational fluid dynamics (CFD) packagesbecome available allowing it to deal with the complex 3D flows and mixing problems. In this way thelocal structure can be clearly revealed. As compared toward investigational measurements and observations, the CFD technique turns out to be a more efficient diagnosis device thermal energy system design and analysis, a better insight at a reasonable cost, into how these systems operate. The CFD results confirmed the importance of combined effects on the performance of thermal storage tanks and showed that a properly calculated storage tank can provide improved stratification conditions. Moreover, 3D transient CFD simulations can be used as an effectual tool to optimize thermal storage tank parameters at early design stages, therefore it may add to the value of the storage tank presentation and efficiency, by optimizing the whole solar thermal energy storage system design and size [10]. The main use of Therminol-66 is the application of heat transfer fluid. There are many properties that emphasis Therminol-66 as a Heat Transfer Fluid.Therminol-66 is a high stability synthetic heat transfer fluid contribution is extensive life and very low-top up rates resulting in reduced running costs and minimal downtime for operations at downtime at 345oC. The Project aims to study the heat transfer characteristics of solar energy by comparing the results obtained in ANSYS and the results are compared with the experimental ones. In this project we are using balls of different materials i.e., copper dissimilar PCM's such as D-Mannitol, D-Sorbitol and Paraffin wax. The heat transfer rate between Therminol-66 oil, water and PCM is studied and the results are compiled. The purpose of using different balls is to estimate which out of these balls has the maximumenergy (heat) exchange rate.

## 2 EXPERIMENTAL SETUP AND METHODOLOGY

The experimental setup consists of three PCM tanks to store paraffin wax, one heater tank for giving heat to the HTF in charging mode, one process unit to verify the harvest of the cascaded system, one oil pump, one flow meter and 12 thermocouples to sense the HTF temperature.

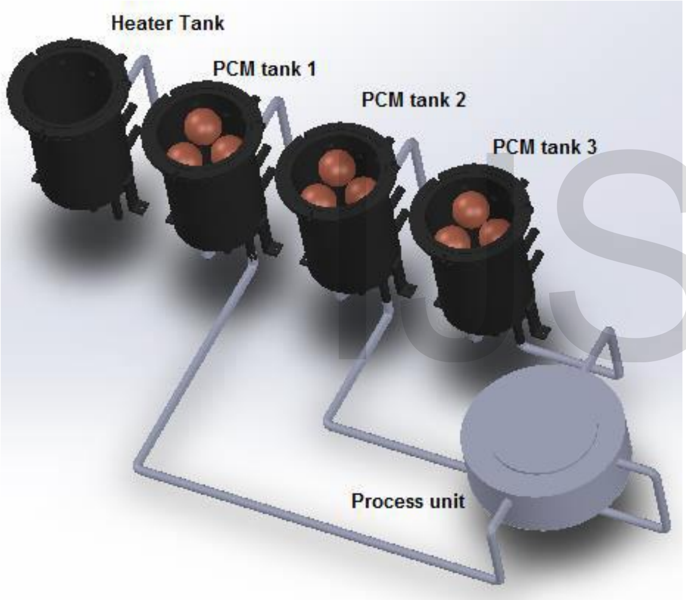

Figure 1. Experimental layout

The heater and pump are turned in to on position. The temperature of HTF in all three tanks is noted after regular intervals of 10 minutes. This is the charging process. After attaining a temperature of about 250oC the heater is switched off. Keeping the flow rate on, the above process is repeated. This is the discharging process. Hence heat is subsequently stored and recovered in these processes. The above process is conducted for all the three types of encapsulations (copper) using therminol-66 as HTF. The figure 1 shows the arrangements of experimental setup, thermocouple of 10 in numbers are used to quantify the temperature of HTF at various locations. Oil circulation rate is maintained by flow meter around 26 LPM. The heat transfer rate in PCM is explained by two staes namely charging and discharging mode.

Charging mode

The HTF has been circulated through the heater source during day time. The oil passing through the heater tank absorbed heat and then sent to phase change material tanks, then it was distributed back to the heater tank. This cyclic process was continued such that PCMs are attained their corresponding melting point. The heat energy thus received by the HTF was given to the PCM encapsulations while passing through the PCMs tank. PCM received the heat from HTF during the charging mode and it gradually changed its phase from solid to liquid and stored the latent heat. This process continued until the PCMs are reached the specific melting point every 5 minutes interval the PCMs temperatures are noted using thermocouple arrangements.

Discharging mode

The circulation of HTF through the heater tank is stopped and by-passed. The temperature of the HTF gradually decreased and so the PCM inside the encapsulations released the heat outside. The oil surrounds the PCM tank gets heated up again by changing its phase from liquid to solid. This process of PCM made the HTF to maintain the temperature again for a longer time. The discharging mode enabled the thermal energy storage system to stock up the energy for a longer time that can be utilized for the evening or late-night applications. This process continued until the oil temperature reaches around atmospheric condition. The time taken by the HTF to attain atmospheric condition was noted at regular intervals of 10 minutes during the Discharging mode. The results obtained from the experimental work is compared with ANSYS output. Initially, the 3-D model of the setup is drawn with Solid Works and then imported to ANSYS window. The

Following inputs are given to perform the analysis.

◎ Input temperature- The input temperature is 90oC and it is applied on the surface of the walls of the heater.

◎ Time- The time mentioned here is 10 minutes which is represented in seconds (600).

◎ Rate of flow- The rate of flow of oil is supposed to be mentioned and it is mentioned as
26 LPM.

◎ Thermal coefficient of oil- The thermal coefficient of oil is 5*10 ^ -6W/m2K. The meshing is generated; divide a particular part into a number of nodes. The advantage of this meshing is that it can give an exact result. The meshed generated multi-temperature thermal energy storage syste-m design is shown in the figure 2.

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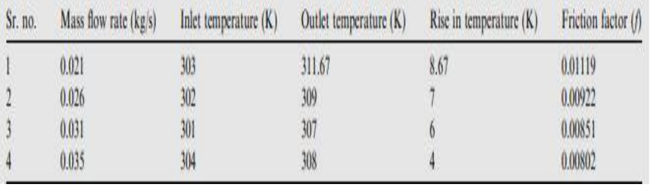
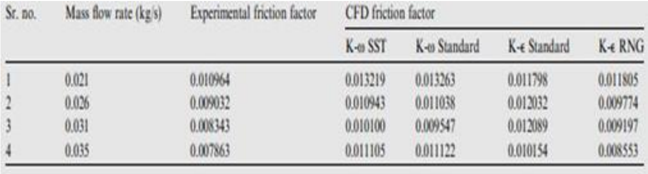
Readings taken on the TESS



| Sr. no. | Mass flow rate (kg/s) | Inlet temperature (K) | Outlet temperature (K) | Rise in temperature (K) | Friction factor ($f$) |
|---|---|---|---|---|---|
| 1 | 0.021 | 303 | 311.67 | 8.67 | 0.01119 |
| 2 | 0.026 | 302 | 309 | 7 | 0.00922 |
| 3 | 0.031 | 301 | 307 | 6 | 0.00851 |
| 4 | 0.035 | 304 | 308 | 4 | 0.00802 |

Table 01

Friction factor from various CFD models



| Sr. no. | Mass flow rate (kg/s) | Experimental friction factor | CFD friction factor | | | |
|---|---|---|---|---|---|---|
| | | | K-ω SST | K-ω Standard | K-ϵ Standard | K-ϵ RNG |
| 1 | 0.021 | 0.010964 | 0.013219 | 0.013263 | 0.011798 | 0.011805 |
| 2 | 0.026 | 0.009032 | 0.010943 | 0.011038 | 0.012032 | 0.009774 |
| 3 | 0.031 | 0.008343 | 0.010100 | 0.009547 | 0.012089 | 0.009197 |
| 4 | 0.035 | 0.007863 | 0.011105 | 0.011122 | 0.010154 | 0.008553 |

**Table 02**

CFD analysis :-

The duct geometry is created using ANSYS ICEM CFD modular software. Geometry shows circular tubes which contains phase change material for energy storage, placed in the path of flow of air just below the absorber plate. This arrangement is shown in Fig. 3(a) and (b). For CFD analysis, structured mesh is created on the computational domain using commercially available ANSYS ICEM CFD code. A structured mesh is shown in Fig. 4. Mesh independence check has been carried out to select a mesh for better result. CFD results of output air temperature and friction factor are obtained using various models such as K-x SST, K-x Standard, K-e Standard, and K-e RNG and then verified with experimental results obtained by performing experimentation on setup. Experimental results for output air temperature are directly noted from the experiment. Similarly, experimental results for friction factor are calculated by taking a note of pressure drop across the test section in experimental setup using a digital micro manometer.

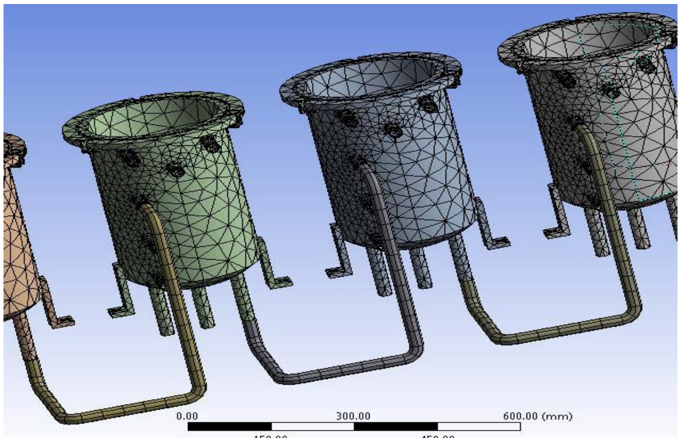


Fig2 Mesh generated TES.

Copper is used as spherical encapsulation material. Finally tank 3 is occupied with 9 spherical copper encapsulations where paraffin wax is used as a PCM

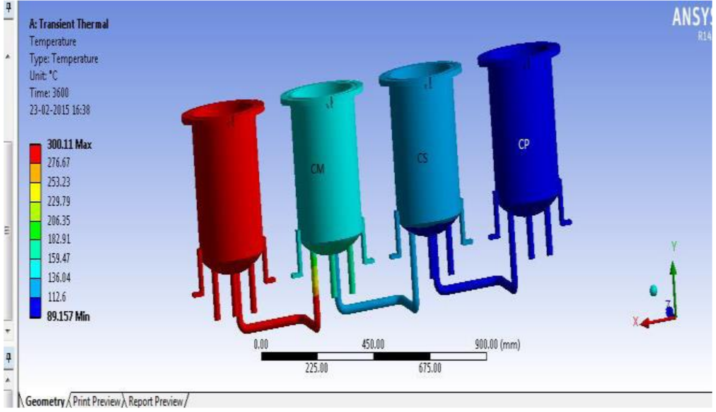


Figure 03. Temperature distribution with copper encapsulation.

The temperature distribution of copper encapsulations with different PCM is shown in the figure 5. It can be an easily concluded that copper would be the ideal material as it possesses the maximum temperature of even more than 150°C in the first tank which consists of D-Mannitol under same conditions. This tank is represented as CM, copper encapsulation with D-Mannitol as PCM. However, there is a slight drop in temperature in the second tank which possesses a temperature range from 112°C to 130°C which has D-Sorbitol in it. This tank is represented as CS, copper encapsulation with D-Sorbitol as PCM. The final tank however possesses a healthy 90°C which is still the highest compared to the other two. This tank is represented as CP, copper encapsulation with paraffin wax as PCM.

Comparison between ANSYS solutions and experimental values – Copper encapsulation

The temperature distribution with the use of copper encapsulated balls is shown in the figure 8. The ansys solution temperature is comparatively higher than the end temperature of the brass encapsulation and aluminium encapsulation. The analysis of D-sorbitol shows the both experimental and ansys values are varying parallel. The analysis of paraffin wax shows that the end temperature of around 90oC which is higher than experimental values of 85oC.

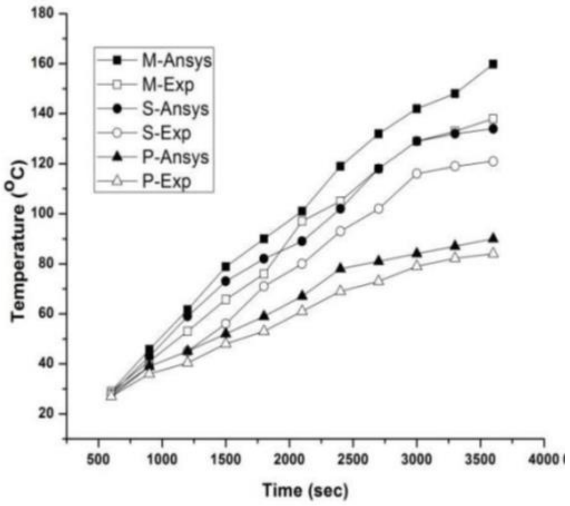


Figure 04 .Comparison in copper encapsulation

Based on the temperatures the overall system efficiency was calculated and the results are showed that the copper encapsulated D-mannitol as PCM has the highest efficiency when compared to other two PCMs namely D-sorbitol and paraffin wax.

Results and Discussions

The results of the heat transfer analysis inside and outside the tubes respectively when using a first set of given conditions., shows the results of the operation of the heat exchanger. For the analysis of the external heat transfer the staggered configuration was used as it allows a higher turbulence in the air increasing the heat transfer in the system. The distances between tube axes (*ST* and *SL*in in Table 3) are initially fixed as two times the diameter of the tube. presents the main dimensions of the tube bank.Methodologybfor the design of a thermal energy storage module for a solar tunnel dryer using phase change material (PCM).

## CONCLUSION

The thermocline storage systems packed with SHM and PCM were individually examined and addressed in this study. The temperature difference for sensible heat storage, temperature profile, total energy storage, and charging time of the PCM system were all investigated in this study. The results indicated that the fluid temperature was higher than that of the solid material, and the maximum temperature difference of the SHM appeared in the middle of the thermocline. The temperature difference peak decreased following an increase in the charging time. The density and conductivity of the SHM and inlet fluid velocity exhibited a considerable effect on the temperature difference between the filler material and the HTF. In the phase-change thermal storage system, the temperature difference between the solid and the fluid phases exhibited two peaks, unlike the thermocline system with sensible heatstorage material. The first temperature difference peak was higher than the second peak. Compared with the system with no PCM, the charging time of the system filled with PCM was significantly increased to improve the overall energy storage. Following an increase in latent heat, the total storage charging time and storage energy rose. The entire storage charge time was reduced due to a fall in the melting point. The final thermal energy storage, however, remained the same..

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