ISSN: 0975-8585

Research Journal of Pharmaceutical, Biological and Chemical Sciences

# Experimental Investigation of PCM based Thermal Energy Storage System using $Al_2O_3$-$H_2O$ nano fluid.

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**ABSTRACT**

The next decade is likely to witness a considerable rise in green house gas emissions and fuel prices. These are the two main driving forces behind the efforts for effective utilization of various sources of renewable energy. Solar energy is one such renewable energy which can be used to various applications such as solar water heating, air heating, solar cooking and kitchen purpose etc. Efficient and reliable Thermal Energy Storage Systems are required for solar applications to overcome their existing discontinuous nature and abrupt change in weather conditions. It has larger heat storage capacity and isothermal nature during charging and discharging process. Nano fluids are becoming a vital factor in thermal sciences which have been suspensions of nano particles in base fluids. In present work, $Al_2O_3$ nanoparticles were added in 0.02% and 0.08% volume concentration into the base fluid (water) to enhance its thermal performance. An experimental set-up is designed, fabricated and commissioned to collect thermal performance data on the thermal energy storage tank using spherical capsule which contains PCM as Paraffin wax. Experiments were carried out with both base fluid and nano mixed base fluid to ensure the enhancement in heat transfer

**Keywords:** Thermal energy storage system (TESS), Phase change material (PCM), Paraffin wax, Nano particles, Charging, Discharging

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ISSN: 0975-8585

## INTRODUCTION

The striking feature of Phase changing material (PCM) is its high storage density with a very small temperature swing [1]. It is a well known fact that these materials can absorb/release high latent heat during solidification process [2]. Thermal energy storage systems are increasingly becoming a crucial factor in energy research due to their vast applications such as air conditioning, heat exchangers and waste heat recovery etc. Few researchers have given a detailed account on thermal energy storage and its scope of applications [3]. Past few years have witnessed the inclusion of nano particles in PCM known to be as Nano enhanced Phase changing material (NEPCM) and Khodadadi, et al have worked on heat transfer of a NEPCM [4]. These researchers have found that the resulting NEPCM exhibited significant enhancement in thermal conductivity when compared to the base materials [5]. A growing body of literature has examined the available TES technologies comparing sensible and latent heat storages [6]. A remarkable feature of nano fluids in PCMs is that they enhance the thermal and heat transfer characteristics of PCM significantly [7, 8]. E.S.Mettawee, et al has found that there was a remarkable heat gain in adding aluminum powder to the wax when compared with pure paraffin as PCM [9]. Few researchers have addressed the high thermal performance ability of $Tio_2$ nano fluid PCMs and their suitability for industrial low temperature energy storage [10]. The coming years are likely to identify the performance of TES coupled with PCM in solar energy applications where some researchers have worked on stearic acid and paraffin wax filled spherical capsules where experimental investigation was done on their charging time [11, 12]. The system has ability to generate hot water for domestic applications. Because of the reason that $Al_2O_3$ nano fluids have better thermal properties, they have been utilized in building up the performance of conventional solar TES [13]. The present work aims at designing, fabricating on experimental setup that incorporates Paraffin wax (PCM) filled spherical capsule where $Al_2O_3$ nano particles in different volume concentrations were considered. This was to study the critical temperature parameters that enhance the thermal performance of the system.

### Experimental setup

Preparation of nanoparticles suspension in water is the first step in applying nanofluid for heat transfer enhancement. In this study, $Al_2O_3$ water Nano fluids were prepared separately by dispersing nano particles into the base liquid, water. Practically some amount of aluminum dispersed into water and observed that the water will not react under room temperature conditions. This is because the aluminum has a thin coherent, adhering layer of aluminum oxide, $Al_2O_3$, on its surface and this alumina layer prevents the reaction. Nano fluids with two different volume concentrations (0.02%, 0.08%) were prepared to measure the time required to transfer the heat in charging process from nanofluid to PCM. $Al_2O_3$ nano particle of mean size, <50 nm were dispersed in distilled water as base fluid in different concentrations. The nano fluid was circulated by means of a pump. The PCM temperatures were measured with the help of thermocouples at flow rate of 2 liter/minute. The amount of $Al_2O_3$ nanoparticles are required to prepare nanofluids of different percentage volume concentrations in 20 liters of base fluid (water) as shown in Table1.

**Table 1: Volume concentration and Weight of Nanoparticles**

| S.No. | Volume concentration (%) | Weight of Nano particles (grams) |
|---|---|---|
| 1 | 0.02 | 15.61 |
| 2 | 0.08 | 62.44 |

An experimental set-up as shown in Figure 1 which is designed fabricated and commissioned to collect thermal performance data on the thermal energy storage tank using spherical capsule. A spherical capsule of 150 mm diameter and containing PCM as paraffin wax as shown in Figure 2. TES tank specifications are shown in Table 2.

**Figure 1: Thermal Energy Storage System**

**Figure 2: Spherical Capsule in TES Tank**

**Table 2: Specifications of TES tank**

| S.No. | Specifications | Units |
|---|---|---|
| 1 | Length | 30 cm |
| 2 | Width | 30 cm |
| 3 | Height | 26 cm |
| 4 | Thickness | 5 cm |

## RESULTS AND DISCUSSIONS

### Charging process

Experiments were carried out with and with out the nano fluid to ensure the enhancement in heat transfer. The nanoparticles were added in 0.02% and 0.08% respectively into the base fluid. The results tabulated below in Table 3 are for 2 liter/minute flow rate and 0.02% volume concentration.

**Table 3: Time vs. PCM temperature for 2 liter/minute flow rate and 0.02% volume concentration**

| S.No. | Time (minutes) | PCM Temperature ( $^{o}C$) | |
|---|---|---|---|
| | | Without Nano fluid | With Nano fluid ($Al_2O_3$) |
| 1 | 0 | 32 | 32 |
| 2 | 10 | 38 | 41 |

| | | | |
|---|---|---|---|
| 3 | 20 | 41 | 43 |
| 4 | 30 | 42 | 45 |
| 5 | 40 | 45 | 47 |
| 6 | 50 | 47 | 52 |
| 7 | 60 | 54 | 58 |
| 8 | 70 | 57 | 60 |
| 9 | 80 | 60 | 62 |
| 10 | 90 | 62 | 65 |
| 11 | 100 | 64 | 68 |
| 12 | 110 | 66 | 70 |
| 13 | 120 | 68 | 74 |
| 14 | 140 | 71 | 76 |
| 15 | 160 | 74 | --- |
| 16 | 180 | 76 | --- |

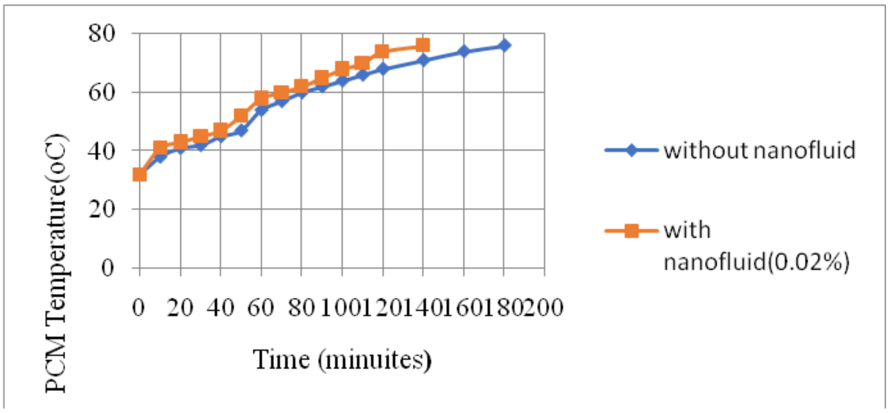


**Figure 3: Variation of PCM charging process temperature with time**

Figure 3 indicates that the charging time decreases with the usage of Nano fluid along with base fluid with a mass flow rate of 2 liter/minute and 0.02% Volume concentration.

The results shown in table 4 are regarding 2 liter/minute flow rate and 0.08% volume concentration.

**Table 4: Time vs. PCM temperature for 2 liter/minute flow rate and 0.08% volume concentration**

| S.No. | Time (minutes) | PCM Temperature ( $^{o}$c) | |
|---|---|---|---|
| | | Without Nano fluid | With Nano fluid ($Al_2O_3$) |
| 1 | 0 | 32 | 32 |
| 2 | 10 | 38 | 43 |
| 3 | 20 | 41 | 45 |
| 4 | 30 | 42 | 48 |
| 5 | 40 | 45 | 50 |
| 6 | 50 | 47 | 54 |
| 7 | 60 | 54 | 58 |
| 8 | 70 | 57 | 64 |
| 9 | 80 | 60 | 68 |
| 10 | 90 | 62 | 73 |

ISSN: 0975-8585

| | | | |
|---|---|---|---|
| 11 | 100 | 64 | 76 |
| 12 | 110 | 66 | --- |
| 13 | 120 | 68 | --- |
| 14 | 140 | 71 | --- |
| 15 | 160 | 74 | --- |
| 16 | 180 | 76 | --- |

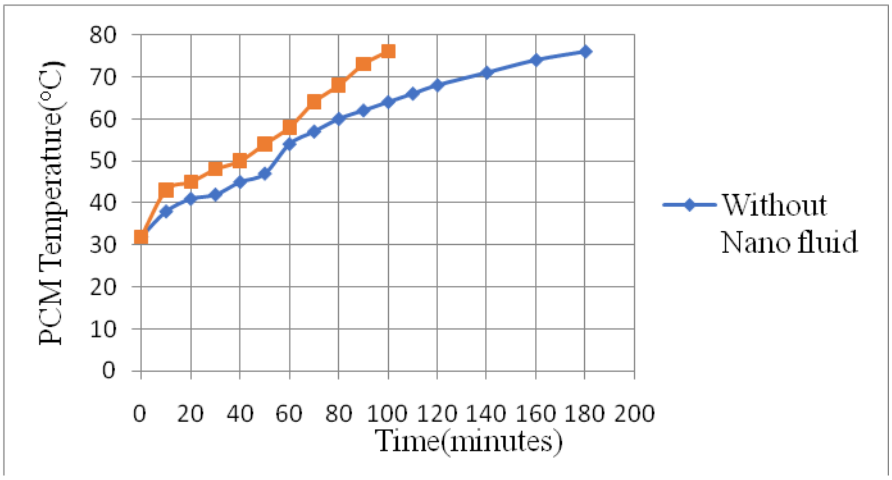


**Figure 4: Variation of PCM charging process temperature with time**

From figure 4 it can be observed that the charging time decreases with the usage of Nano fluid along with base fluid with a mass flow rate of 2 lit/min and 0.08% Volume concentration.

**Discharging Process**

The discharging experiments were carried out in a batch wise process where 20 liters of hot water was discharged from the TES tank in each batch. A thermometer was used to measure the average temperature of the collected discharge water in the bucket. A 20 minuite time difference was allowed between two consequent discharges. The water was supplied into the TES tank at 30°C. The batch wise process of with drawing the hot water was continued till the outlet water reaches the temperature of 45°C.The variations in outlet water temperature with respect to different batches of water is depicted in figure 5.

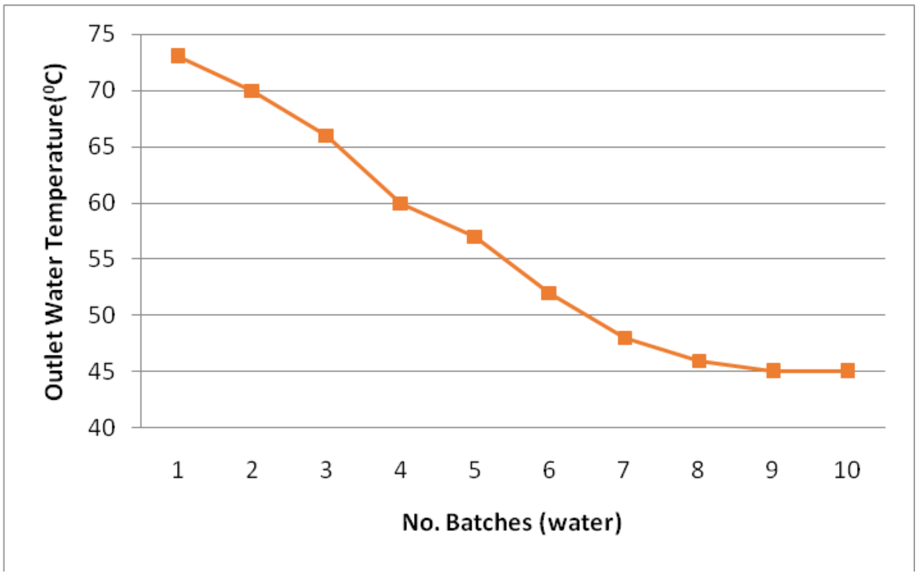


**Figure 5: Variation of outlet water temperature vs batches of water**

ISSN: 0975-8585

## CONCLUSİONS

In this present work a thermal energy storage system was developed which incorporates the concept of integrated sensible and latent heats.This approach has a potential for supplying hot water at an average temperature of 45°C to fulfill the various domestic applications.This include solar water heating, air heating, solar cooking, building applications, printing on the cotton cloths and dying the threads and kitchen purpose etc. Experiments were conducted on the TES unit to study its performance by integrating it with constant heat source. The critical parameter considerd in this process include temperature of PCM with and with out nano fluid for charging of TES system with different volume concentrations (0.02% and 0.08%). It is observed that in the case of base fluid devoid of nanoparticles, the PCM charging time is 180 minutes where it reduced to 140 minuites when nano particles with mass flow rate of 2 liter/minute and 0.02% volume concentration was considered. However it is also observed that the PCM charging time is 100 minutes in the case of base fluid with nanoparticles regarding a mass flow rate of 2 liter/minute and 0.08% volume concentration.The discharging process allowed to collect 200 liters of water at an average temperature of $45^0$C.

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