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Analysis of Thermal Energy Storage Systems by Using Nanoparticles

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Abstract

More usage of the fuel system to acquire heat and usage of the fuels which causes more harmful. Due to this, we go for the effective utilization of various types of renewable energy sources such as solar energy, which can be used for the various applications in different usages, like solar water heating, solar pesticide sprayer, and solar power grass cutter, etc. In nowadays solar heating applications by the usage of the PCM (phase changing Materials) are used to store the energy in the form of heat. An experiment is designed and fabricated, and to enhance the thermal performance in our experiment we use the nanoparticles Al_2O_3 and CuO were added to the base fluid to perform the thermal properties with good results within less time as nanoparticles are having the more thermal conductivity. Thus to heat the water we use the solar flat plate collector, and paraffin wax was stored in spherical capsules to carry the heat in the form of one phase to another phase. An Experiment was conducted with different flow rates as to enhancement with a good heat transfer.

Keywords: solar flat plate collector, Thermal Energy Storage system, Phase Changing Material, nanoparticles, charging, discharging.

I. INTRODUCTION

A renewable energy has a vital role in the future existing applications such as solar energy, geothermal heat. For the bulk usage of energy in the heat transferring applications, thermal conductivity plays a vital role Dincer[1]. There are many forms of storage systems but we use the thermal energy storage system in this experiment.

Thermal Energy storage system:

1. Sensible Heat Storage Systems: It means that no change of state but a transfer of heat takes place. The most common material to store the heat is the water due to low costs.

2. Latent Heat Storage Systems: Latent heat Storage principles states that the there is the change of phase from one form to other form (i.e., solid to liquid and liquid to solid).

These two TES forms of energy are expected to be developed for the various usage purposes. TES was the temporary energy storage of high and low temperature for the lateral uses. The examples of TES are overnight heating, summer heat for winter use and solar energy and fossil fuels which will be not available at all times.

Flat plate collectors is a device which absorbs the incoming solar radiation, converts it into heat, and transfers this heat to a fluid such as air, water or different forms which is flowing through the collectors.D.Prakash[3]. Thus coming solar energy thus collected is carried from the circulating fluid. The solar flat plate collectors are used because they are capable of the transferring of the hot water at the required temperature and absorption of radiations from the sun.

Due to the nanoparticles are having many more advantageous properties in today usage many more nanoparticles are using for the various purposes. Nanoparticles or nanofluids are used in our experiment because to reduce the time for the charging process (i.e to melt the temperature for the PCM within a requirement usage.Holman[2] Many more researches are investigating that Al2O3 is the most nanopowder or nanofluid usag. Nanoparticles are used because they have the more thermal conductivity property, density, melting point, temperature and boiling point.R.Rafee[5].

Thermal conductivity: It states that the rate at which heat passes through a specified material, expressed in the amount of heat flows per unit time through a unit area with a temperature gradient of one degree per unit distance.Buddhi[4]

Copper oxide (Cuo) is also used as the nanofluid in our experiment because the copper is having high thermal conductivity when compared to the other nanoparticles).

PHASE CHANGING MATERIALS (PCM):

Phase changing materials means changing of one phase to the other phase that is from solid to liquid or liquid to solid or liquid to gas. The phase changing materials works under the thermal energy storage energy function. They are many types of PCM’s but we use the paraffin wax. The paraffin wax is the organic phase change material that is characterize of ability to melt and freeze without phase segregation and latent heat of fusion. The paraffin wax is used because the PCM because it is chemically stable, non-corrosive, having high latent heat of fusion.

They are the many types of energy storage systems but the solar energy is renewable and non harmful by the usage of the solar flat plate collector it us more advantage to extract heat from the sun and to transfer of heat to the water so that many usage applications can be used.

The storing process takes by three steps:

1. Charging

2. Storing

3. Discharging

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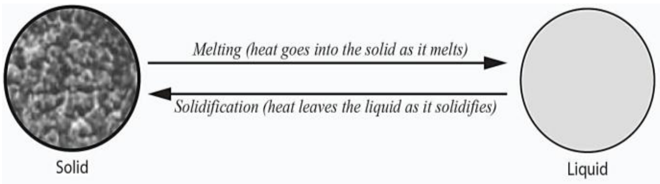

Fig 1: Process of PCM

II. EXPERIMENTAL SETUP

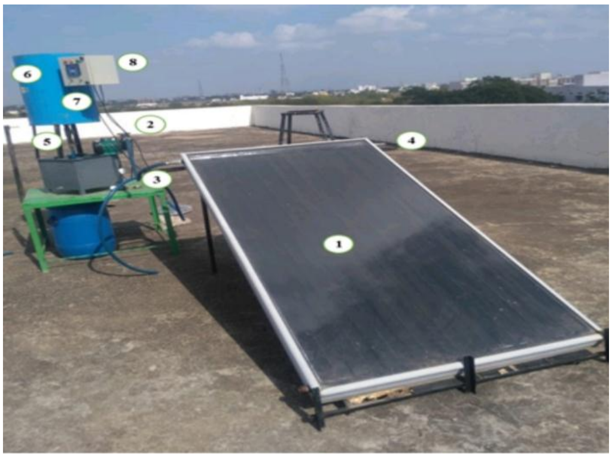

Fig 2: Experimental Set-up

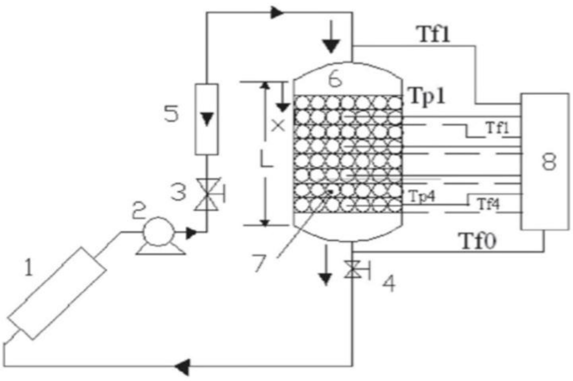

Fig 3: Schematic diagramatic representation of Experimental Set-up

a. Copper oxide

b. aluminum oxide

Fig 4: Nanoparticles

This experiment consists of thermal energy storage tank, solar flat plate collector, water, storage tank, flow meters, PCM encapsulated finned spherical capsules, circulating pump. The TES tank specifications consist of 380mm diameter and 500mm height stainless steel TES tank which has a capacity of 52 litres of water storage. Shower plate is placed in the top of the TEs tank to sprinkle the water distribution uniformly. TES tank and solar flat plate collector is placed side by side. A Spherical capsule of 70mm outer diameter and 0.2mm thickness consists of 80 balls are placed in the tank, thus spherical balls are placed in five layers and each layer supported by their mesh. Paraffin wax is used as a PCM material with melting temperature 59^0C and water is used as both sensible heat storage and latent heat i.e., heat transfer fluid (HTF).

A Flow meter is used to measure the heat flow rate of heat transfer fluid (water) which is coming out from the solar flat plate collector and going in the thermal energy storage tank. Centrifugal pump is used to circulate the HTF from the top of the storage tank. The five thermocouple wires are placed at finned spherical capsules to measure the temperature of PCM. Total numbers of thermocouples are eleven, that is five of the PCM balls and five thermocouples attached to the mesh and one for inlet and one for outlet total thermocouples are 12. These thermocouples are connected to the temperature indicator. It gives digital readings as represented in below.

III. EXPERIMENTAL PROCEDURE:

The experiment consists of flat plate a collector contains of 6 litres of water and TES tank consists of 34 litres of water. Through the pump the water in the solar flat plate collector is sends to the TES. A flow meter is placed after the pump which is used to measure the water flow rate which is sending to the tank coming out from the SFPC (Solar Flat Plate Collector). Continuously the water flow in the SFPC and TES tank circulating and the heat is absorbed through the solar flat plate collector and the water is get heated in the SPFC and in TES tank.

The hot water flows over the spherical balls, these are placed on a mesh, total experiment consists of 5 layers separated by mesh, and each layer consists of 16 balls. The spherical balls are immersed in hot water. Several experiments are conducted at the different flow rates of HTF such as 2litres/min, 4litres/min, and 6litres/min.

During the charging process, the heat transfer fluid 34 litres of water is stored in the thermal energy storage tank, and inlet and outlet flow rates remain constant while HTF will be circulating. At the beginning the PCM temperature was 34^0C and paraffin wax melting temperature was 59^0 C. The heat energy is transferred from the HTF containing of the solar flat plate collector to the spherical capsules containing paraffin wax to melt. Firstly the heat is stored in the spherical capsule which contains PCM then it is started to melting of paraffin wax that comes to the 680C because to reach the steady temperature. In TES tank energy stored in the melting form of the PCM at a certain temperature. PCM will be superheated at a constant temperature in 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 every 15mins. The charging process is done till the PCM temperature reaches to the 70^0C i.e., Steady state temperature (till the water and PCM reaches to the same temperature).

Filling of paraffin wax in spherical Capsules :

Volume of sphere $= 4/3*3.14*(r)^3$

$= 4/3*93.14*(3.3)^3$

$=150.53\ cm^3$

The above calculated is for the single ball volume, after leaving the clearance thus the 75% filling of the PCM is $113.53cm^3$

$= 113.53cm^3$

$=113.53*1*10^{-6}$

=0.00011353

Density of paraffin wax = 861 kg/m^3

Mass of PCM in single ball = Density*volume of sphere in grams

=861*0.00011353

=0.0972kg =0.0972*1000 = 97.29 grams

Formulation of Nanoparticle :

%Volume concentration = weight of nanoparticle in grams/density of nanoparticle to the weight of nanoparticle/density of nano particle+weight of base fluid (water)/density of the fluid (water)

Where,

The Weight of nanoparticle in Grams

Density of nanoparticle i.e, Al2O3 = 3970 kg/m3, CuO = 6310 kg/m3

The Weight of base fluid (water) in grams

Density of base fluid (water) = 995kg/m3

Table 1: Charging Process With Plane Water With Different Flow Rates

HTF	TIME IN MINS	PCM TEMPERATURE		
		2LITERS/MIN	4LITERS/MIN	6LITERS/MIN
WATER	0	27	28	27
	120	49	46	51
	210	51	47	62
	300	60	56	68
	330	64	68	
	360	68		

Table 2: Charging Process Time with Al_2O_3 with 0.05 CONC with Different Flow Rates

HTF	TIME IN MINS	PCM TEMPERATURE		
		2LITERS/MIN	4LITERS/MIN	6LITERS/MIN
Al_2O_3 + water	0	28	27	28
	90	51	55	59
	180	54	58	64
	260	59	64	69
	280	65	68	
	300	68		

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Table 3: Charging Process Time with CuO with 0.05 CONC and Different Flow Rates

HTF	TIME IN MINS	PCM TEMPERATURE		
		2LITERS/MIN	4LITERS/MIN	6LITERS/MIN
CuO + water	0	28	27	28
	90	53	58	60
	150	54	60	66
	250	60	65	69
	270	64	69	
	290	68		

TABLE 4: Temperature of Water When Discharging Process:

BATCHING PROCESS/ TIME IN MINS	BATCH I	BATCH II	BATCH III
0	28	28	28
10	37	33	30
20	43	40	38
30	45	42	40
35		45	42
40			44

GRAPHS :

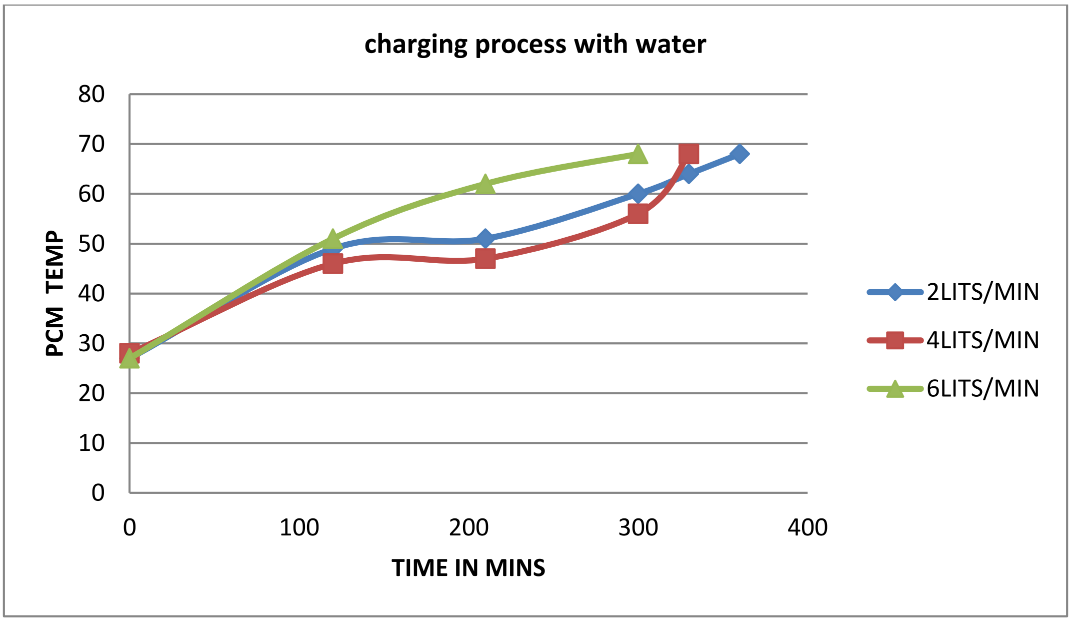

Fig 5: Charging process only with HTF (water)

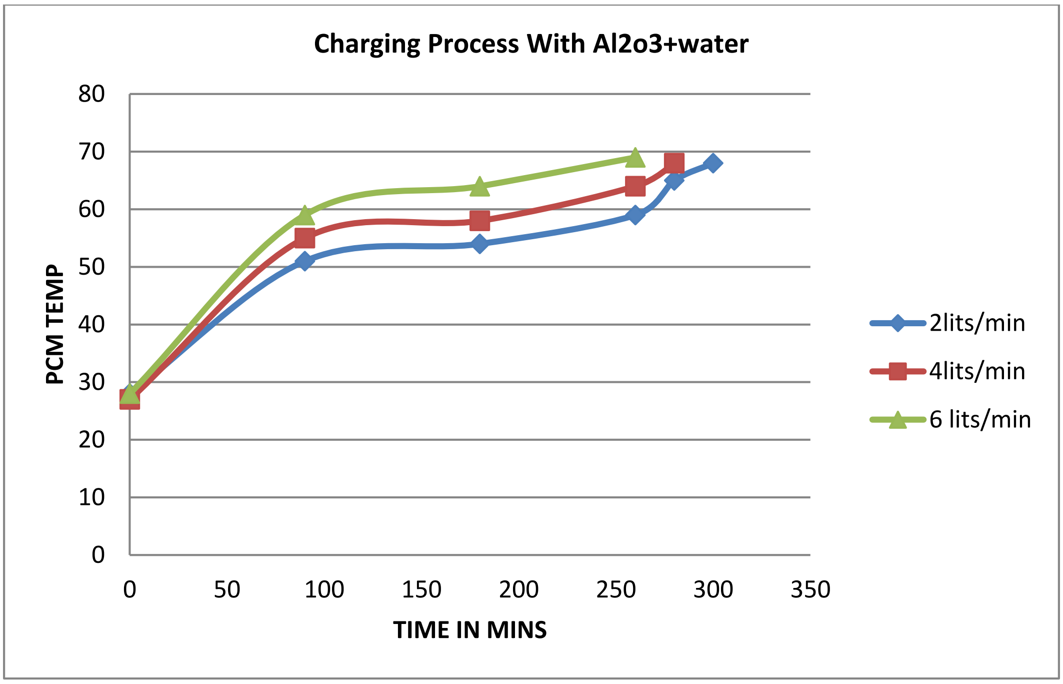

Fig 6: Charging process with Al_2O_3+HTF

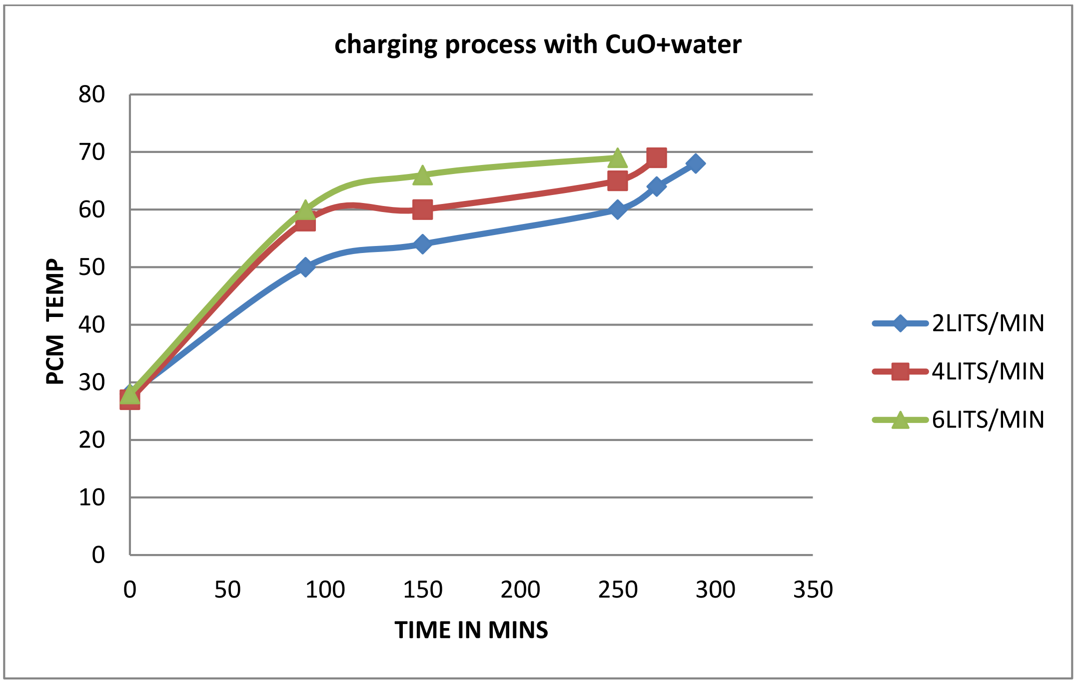

Fig 7: Charging process with CuO+HTF

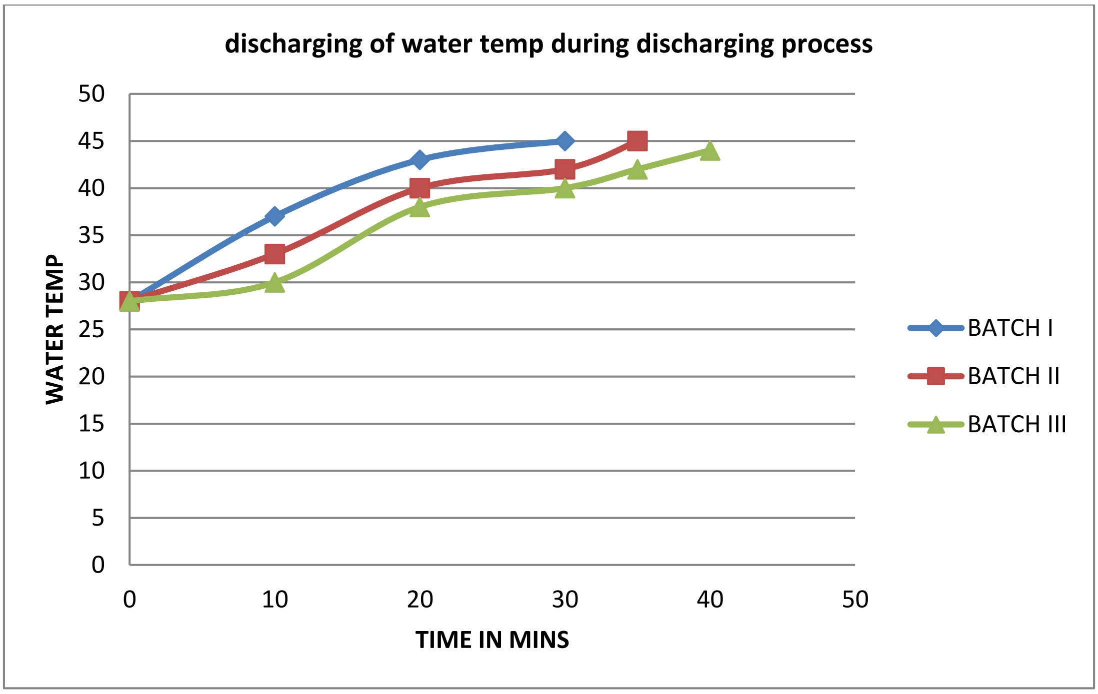

Fig 8: Discharging process

IV. RESULTS AND DISCUSSIONS

The Experiment was conducted with different flow rates of HTF 2,4,6 with a nanoparticles usage of Al2O3 and CuO with a 0.05 concentration. In this experiment, Fig.5 shows that the charging time to be taken for the plane water is 360,330,300 mins

With the nanofluid (Al_2O_3)the time taken for the charging process is 300,280,260 thus by comparison we show that the time taken is reduced when compared with the charging process done only with the HTF,when we conducted.

An experiment on CuO nanoparticle the time is taken for the charging process is 290,270,250 and by this experiment, we can know that CuO took the less time for the charging process, and the time taken for the charging process is reduced when compared with the HTF and (Al_2O_3) nanofluid and CuO.

V. CONCLUSIONS

In conclusion, the work above led us to sum up the following:

Nanofluids are the new method to transfer the heat for various purposes thus the effect of melting the PCM by the usage of the nanoparticles with the base fluids thus gives the good heat transfer of the system so that it will be more useful as it is the renewable energy sources. Thus the nanofluids give the effective utilization for the heating of the PCM melting.. High specific surface area and therefore more heat transfer surface between particles and fluids. The High dispersion stability predominant Brownian motion of particles. Reduced pumping power as compared to pure liquid to achieve equivalent heat transfer intensification. Reduced particle clogging as compared to conventional slurries, thus promoting system miniaturization. Thermal energy storage offers the option to improve output control for some energy technologies as to storage of heat.

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