© 2018 IJSRSET | Volume 4 | Issue 8 | Print ISSN: 2395-1990 | Online ISSN : 2394-4099
Themed Section : Engineering and Technology

Renewable Energy for PCM Based Thermal Energy Storage System by Using Nanoparticles

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ABSTRACT

Day by day the use of fossil fuels increase in greenhouse gas emissions and rise in fuel prices. These are the main driving forces behind efforts for the effective utilization of various types of renewable energy resources. Thermal energy storage is an effective method of storing thermal energy. The use of phases change materials in the solar system would improve the performance of the system due to its high energy storage density and isothermal operations. Nowadays for solar heating applications, phase change materials (PCM) are used to store the energy in the form of latent heat because the large quantity of thermal energy is stored in the small volume. In present work, nanofluids namely Al2O3 and CuO were used in 0.02%, 0.05%, and 0.08% volume concentration into the base fluid (water) and also different flow rates 2lit/min, 4lit/min and 6lit/min 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. In these experiment spherical capsules is used with a circular fin which contains phase change materials (PCM) of stearic acid charging and discharging. Experiments were carried out with the base fluid to study the heat transfer rates.

Keywords : Thermal energy storage systems (TESS). The phase change material (PCM), Nanoparticles, charging and discharging.

I. INTRODUCTION

The renewable energies available in the environment should be used to meet the growing power demand for sustained future. These renewable energy systems play a vital role in energy savings and reducing global gas emissions to have a pollution free environment for future generations. Thermal energy storage system is one of the renewable energy sources. Thermal energy storage system is one of the renewable energy sources.

II. METHODS AND MATERIAL

Thermal Energy Storage Systems

Thermal Energy Storage Systems are conserving thermal energy in the form of sensible heat and latent heat that can be utilized later for many industrial and domestic applications. Sensible heat storage system is high efficiency but constrained with storage capacity. Latent heat storage system is using PCM most preferred thermal heat devices. Because of their less volume with good storage capacity and quick charging/discharging process.

Phase change material

In the experiment, the phase change material is used stearic acid. The stearic acid is a saturated fatty acid with an 18 carbon chain and has the IUPAC name octadecanoic acid. It is a waxy solid and its chemical formula is C17H35CO2H.

Table : 1 Stearic acid properties

Appearance		White
Melting Temperature ^0C		69.4
Latent heat of fusion (KJ/Kg)		198.91
Density (Kg/m^3)	Solid	960
	Liquid	840
Specific heat (J/Kg^0C)	Solid	1600
	Liquid	2300
Thermal conductivity(W/m)	Solid	0.3
	Liquid	0.172

Nanoparticles

In present investigation base fluid (water) and nanoparticles are mixed. The nanoparticles are used Al2O3 and CuO.

Table : 2 Properties of nanoparticles

Properties	Al_2O_3	CuO
Thermal conductivity(w/mk)	39	17.5
Density(Kg/m^3)	3970	6500
Specific heat (KJ/Kgk)	0.775	0.525

The purpose of the present work is to study the thermal performance of the latent heat storage unit investigated with a constant heat source. In these experiment spherical capsules is used with a circular fin which contains phase change materials(PCM) of stearic acid charging and discharging. Different experiments were carried out with the base fluid to study the heat transfer rates.

Experimental setup and investigation

Two water heaters 1000w capacity,100lits capacity of water storage tank, 0.5 Hp of circulating pump, flow meter based on adjusting, 40mm diameter of PVC pipe, three-foot al ball valves, 380mm diameter and 500mm height of stainless steel TES tank has the 52L capacity and also insulated. The shower plate is arranged at the top of the tank is to get the uniform flow of HTF. The water tank is placed beside the storage tank.PCM is encapsulated finned spherical capsules with stearic acid. TES tank supplied by HTF from water tank by using a centrifugal pump. The spherical capsule of 70mm outer diameter and 0.8mm thickness and inserted with circular fins of 0.6mm.These circular fins temperatures will be equilibrium at the middle of the spherical capsule ball. The capacity of the TES tank is 80 balls. The spherical balls are each layers supported by wire mesh. The PCM are used stearic acid with melting temperature is 69^0C and base fluid (water) is used as SHF material and nanopartical is used Al_2O_3. The HTF is water+Al_2O_3. The flow meter is used different flow rates of HTF. The centrifugal pump is used to circulate the HTF from the top of the TES tank. The TES tank is divided in to five layers. Each layer placed 16 spherical PCM balls with one thermo couple is inserted to any one PCM ball. The thermo couple wires placed at inlet, outlet and five layers of the mesh in TES tank. These are used to measure the inlet and outlet temperatures of HTF. The total numbers of thermo couple wires are twelve. These thermo couple wires are connected to a temperature indicator. The experimental set up is shown in below fig.

Experimental Procedure

The water tank is taken and it is filled with water up to 80 lits. The water tank is connected to the heaters. The water is heated by using heaters and the temperature rise up to 80^0C. The hot water is circulating to the TES tank by using centrifugal pump.

Figure 1. Schematic diagram of TESS System

Figure 2. Nanoparticles CuO and Al_2O_3

Formulation of Nano particle

% volume concentration = $\frac{Wp/\dot{\rho}p}{\frac{Wp}{\dot{\rho}p}+\frac{Wf}{\dot{\rho}f}}$

Where

W_P = Weight of the nano particles in grams

W_f = Weight of base fluid (water) in grams

$\dot{\rho}_P$ = Density of Al_2O_3 is 3970 kg/m^3 and CuO is 6310 kg/m^3

$\dot{\rho}_f$ = Density of base fluid (water) is 995kg/m^3

Table : 3 Different concentration of Nano particle Weight

% of concentration	Weight of nano particles in grams
0.02	61.52
0.05	187.32
0.08	249.72

Table : 4 Charging process Time only with water 2lit/min

Time in mins/PCM temperature	0	60	100	120	130
T_2	33	54	64	69	73
T_4	34	55	65	69	74
T_6	35	57	66	70	74
T_8	35	58	66	70	75
T_{10}	34	58	67	70	75

Table : 5 Charging process Time only with water 4lit/min

Time in mins /PCM Temperatures	0	30	60	90	100
T_2	34	46	54	64	69
T_4	35	45	53	65	69
T_6	34	46	54	65	68
T_8	35	47	54	66	69
T_{10}	35	45	55	67	70

Table: 6 Charging process Time only with water 6lit/min

Time in mins/PCM Temperatures	0	20	40	60	80	90
T_2	35	43	52	64	68	73
T_4	35	42	53	63	69	72
T_6	34	44	54	64	67	74
T_8	35	44	55	64	69	74
T_{10}	35	44	55	63	68	74

Table: 8 charging process Time with 0.05% concentration of Al_2O_3

Nano particle 0.05%	Time in mins	2 lit/mins	4 lit/mins	6 lit/mins
Al_2O_3 + water	10	47	53	55
	20	50	56	58
	30	52	58	60
	40	55	59	65
	50	60	62	67
	60	62	65	72
	70	65	68	73
	80	66	73	
	90	68		
	100	72		

Table : 9 charging process Time with 0.08% concentration of Al_2O_3

Nano particle 0.08%	Time in mins	2 lit/mins	4 lit/mins	6 lit/mins
Al_2O_3 + Water	10	50	52	54
	20	54	54	55
	30	55	59	60
	40	62	62	71
	50	64	66	75
	60	67	70	
	70	69	71	
	80	71	73	
	90	72		

Table : 10 Charging process Time with 0.02% concentration of CuO and different mass flow rates

Nano particle 0.02%	Time in mins	2 lit/mins	4 lit/mins	6 lit/mins
CuO + Water	10	42	54	56
	20	48	57	58
	30	50	59	60
	40	53	63	65
	50	57	66	67
	60	58	68	70
	70	65	70	73
	80	70	72	
	90	71		
	100	72		

Table : 11 Charging process Time with 0.05% concentration of CuO and different mass flow rates

Nano particle 0.05%	Time in mins	2 lit/mins	4 lit/mins	6 lit/mis
CuO + Water	10	43	50	54
	20	47	54	60
	30	50	58	63
	40	55	67	66
	50	62	69	69
	60	67	70	72
	70	69	72	
	80	71		
	90	73		

Table : 12 Charging process Time with 0.08% concentration of CuO and different mass flow rates

Nano particle 0.08%	Time in mins	2 lit/mins	4 lit/mins	6 lit/mins
CuO + Water	10	41	52	53
	20	50	57	59
	30	55	63	64
	40	60	67	70
	50	63	70	72
	60	66	73	
	70	69		
	80	71		

GRAPHS

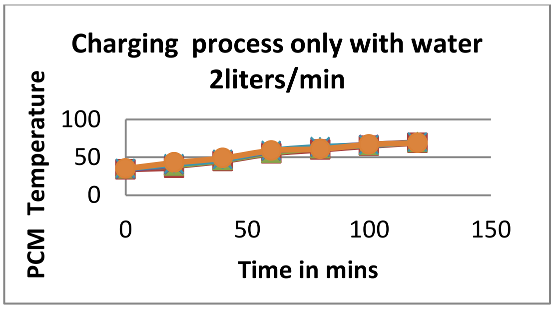

Figure 3. Charging process only with the water

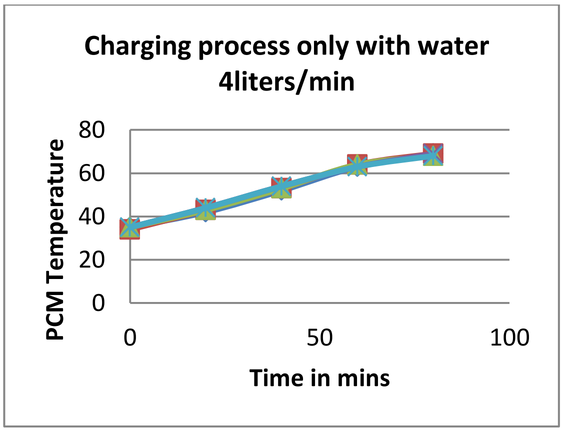

Figure 4. Charging process with water 4 litres/min and the time taken for the charging process is less when compared to the 2 litres/min

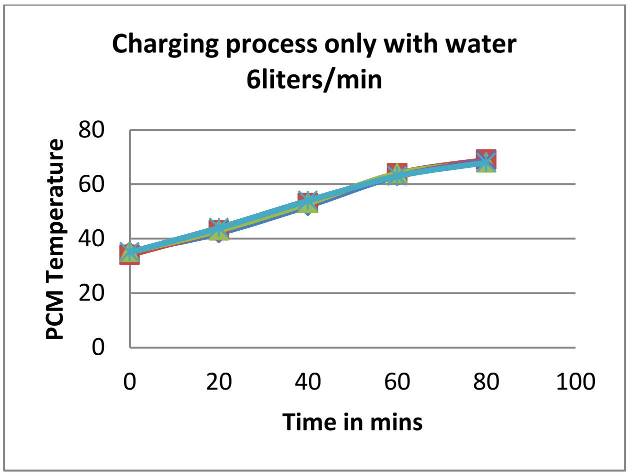

Figure 5. Charging process with water 4 litres/min and time taken for the charging process is more less compared with the water 2,4 litres/min

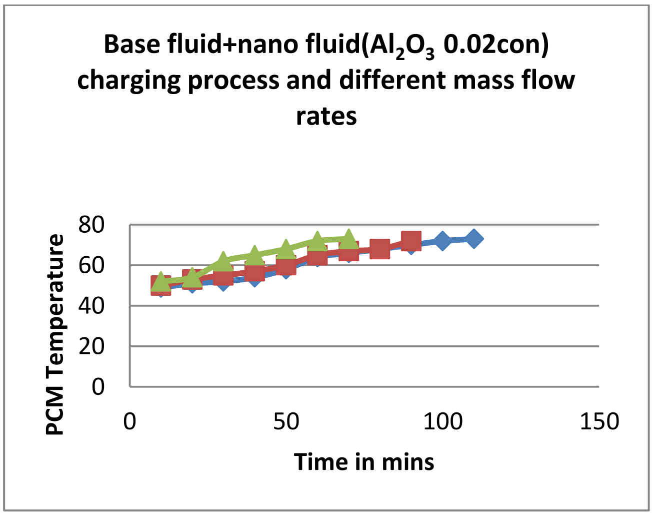

Figure 6. Charging process with the nanoparticle with the 0.02 Conc with the different flow rates

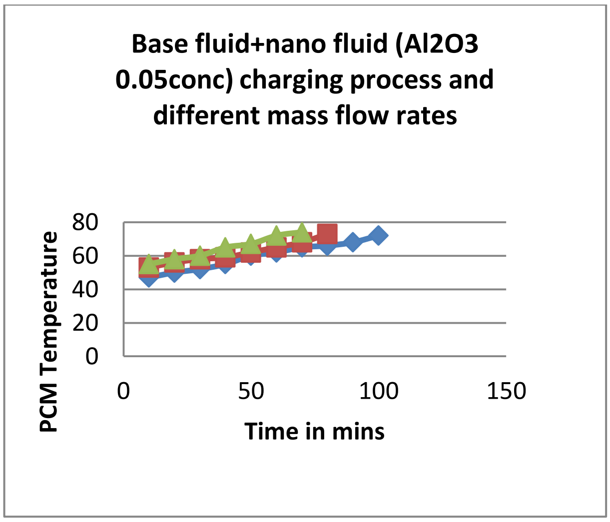

Figure 7. Charging process with the nanoparticle with the 0.02 Conc with the different flow rates and the time taken is less when compared with the 0.02 Conc

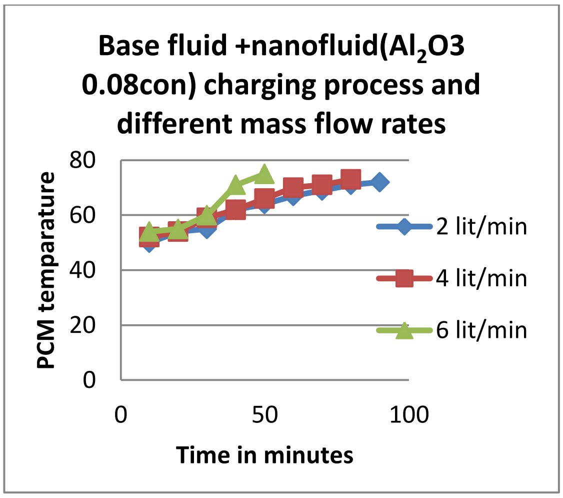

Figure 8. Charging process with the nanoparticle with the 0.02 Conc with the different flow rates and the time taken is less when compared with the 0.02, 0.06 Conc

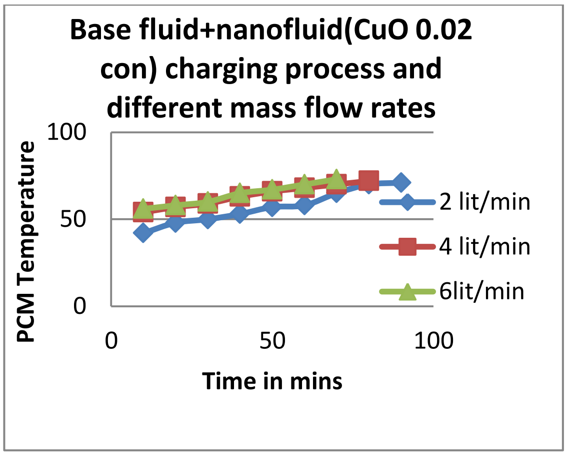

Figure 9. Charging process with the nanoparticle with the 0.02 Conc with the different flow rates

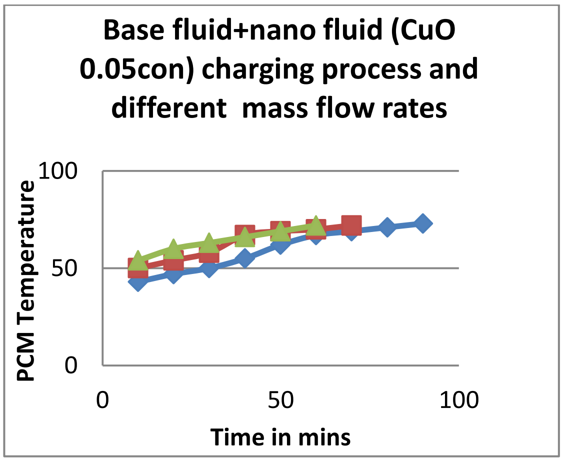

Figure 10. Charging process with the nanoparticle with the 0.05 Conc with the different flow rates and the time taken for the charging process for the CuO nanoparticle, the time is less when compared with the 0.02 Conc

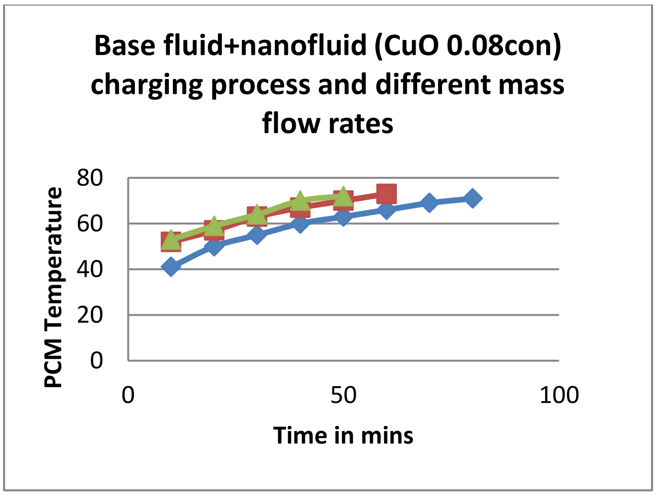

Figure 11. Charging process with the nanoparticle with the 0.08 Conc with the different flow rates and the time taken for the charging process for the CuO nanoparticle, the time is less when compared with the 0.02, 0.05 Conc

III. RESULTS AND DISCUSSIONS

By using the PCM the thermal energy storage for the total systems was compared with the plane water and by using the nanoparticles. The charging process required for the TESS system when compared with water the time taken for the charging process with the nanoparticles was less. So for the charging process required to raise the temperature was additionally increased the flow rates for the time reduction, in this experiment the different flow rates are 2,4 and 6. For the above flow rates the time reduction is 6 litres/min. As the thermal conductivity of the CuO is more the charging process for the TESS system with the high flow rates gives the good result within a short period of time for the many more usage applications, and the different nanoparticles with different concentrations with the different flow rates are explained in the table with the reference to the time and the temperature for melting of the PCM.

IV. CONCLUSION

In Thermal Energy storage System is developed for the supply of at the average temperature 45^{0}C for different applications. There are building applications, air heating, water heating, printing on the cotton cloths and also dying the threads etc. In this paper the charging process different experiments are conducted such as H_2O, $H_2O+Al_2O_3$, H_2O+CuO different concentrations of nano particles, different mass flow rates. From the experimental results it is concluded that less times taking of charging process is H_2O+CuO when compared to only with water and $H_2O+Al_2O_3$. Hence, it is concluded that by charging process times can be reduced by using nanoparticles.

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