EXPERIMENTAL INVESTIGATION OF THERMAL ENERGY STORAGE SYSTEM USING NANOFLUIDS (Al_2O_3, CuO)

M. Siva Nagendraiah[1], R. Meenakshi Reddy[2], K. Krishna Reddy[3]
[1,2]Department of Mechanical Engg., G.P.R College of Engineering, Andhra Pradesh, India.
[2]Dept. of Mechanical Engg. Brindavan Institute of Technology and Science, Kurnool, Andhra Pradesh, India.)

Abstract : ***Research avenues found not only that the fossil fuels upturn critical factors- greenhouse gas emissions and fuel prices-but also that these are the main driving forces behind efforts for the effective utilization of various types of renewable energy resources. Of these, solar energy is one of the types of renewable energy resources, which can be used to various applications like solar water heating, solar cooking, solar pesticide sprayer, and solar power grass cutter etc. Nowadays solar heating applications are gathering much market attention, and phase change materials (PCM) are used to store the energy in the form of latent heat is increased, because a large quantity of thermal energy is stored in the small volume. In present work, Al_2O_3 and CuO were added in 0.02% and 0.05% 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. In this experiment spherical capsule is used which contains phase change materials (PCM) as Paraffin wax. Experiments were carried out with base fluid and nanomixed base fluid to ensure the enhancement in heat transfer.***

IndexTerms - Thermal energy storage systems (TESS), phase change material (PCM), Nanoparticles, charging, discharge.

I. INTRODUCTION

A renewable energy source plays a vital role in the future existing applications such as solar energy, geothermal heat. In the development of the energy in the heat transferring applications, the thermal conductivity plays a vital role. For the development of the energy efficient usages, the convection heat transfer can be preferred by changing the flow geometry. More attention has been focussed for the utilization of the thermal energy storage. The energy storage is of the three types that are latent heat, sensible heat, and thermo chemical heat.
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: It is used the storage capacity of a material's phase change.
The performance of different types of heat exchangers and heat storages used as latent heat thermal energy storage units has investigated by many researches. zalba [1],[2] have reviewed various kinds of PCMS, Phase change materials (PCMs) with their phenomenal phase changing behaviour hold a key for many developments in renewable energy and engineering systems for sustainable future. PCM which can store and release heat energy over a temperature range has become an eminent candidate for many engineering applications that includes thermal, civil, electronics and textile[3], Nanofluids are suspensions of nanoparticles in base fluids, a new challenge for thermal sciences provided by nanotechnology. Nanofluids have unique features different from conventional solid-liquid mixtures in which mm or μm sized particles of metals and non-metals are dispersed. It has been shown that nanoparticles with higher thermal conductivity than their surrounding liquid can increase the effective thermal conductivity of suspension[4], since the thermal conductivity of the solids are typically higher than that of liquids, by suspending nano-or larged sized particles in fluids, the thermal conductivity is increased[5].
A lot of research has been going on the thermal energy storage such as sensible heat and latent heat. Of this latent heat storage systems have more advantageous so the materials containing latent heat principle was used for the heat energy storage applications. Thermal energy storage system was used to store the heat in the PCM for the charging process. Phase Changing Materials(PCM) with their heat storage and releasing behaviour have found suitable for latent heat storage systems that can be operated at wide range of temperatures. PCM's are Latent heat storage system place an important role in energy conservation of environmental conditions. Latent heat storage system having a high thermal conductivity when compared with the sensible heat storage system. Phases changing materials are those which is used to observe heat and release heat even to the surroundings temperature High storage density and heat charging process at constant temperature. These systems are preferable to store the high energy in terms of latent heat and sensible heat. Nanofluids are a fluid containing nanometer size called nanoparticles. As the nanoparticles having the more thermal conductivity, nanoparticles are used to increase the heat transfer rate for the PCM within the less period of time so that more heat usage producing can apply for the various energy usages. Nanoparticles are suspended in the base fluid with water to increase the thermal conductivity. These fluids are engineered colloidal suspensions of nanoparticles in a base fluid. The nanoparticles used in nanofluids are typically made of metals, oxides etc. The thermal conductivity of the liquid in nanofluid was to be higher than that of the base fluid. Even small quantity of nanoparticles used in the base fluid tends to the more developing improvements in the heat transfer applications. The heat transfer fluids are water, oil etc. Phase changing materials such as paraffin wax, stearic acid are used because of their latent heat storage capacity which allows to high heat storage capacity even though a small amount of energy in small temperatures rises to great increase in the thermal energy storage systems. Latent heat systems have great advantages over sensible heat systems. The latent heat systems are stored energy in the process of encapsulated phase changing materials. This encapsulated spherical capsule is the best method to usage of the more no. of advantageous applications. Nanoparticles used are Al_2O_3, CuO. Pressure drop developing during the flow of the nanofluids is one of the important factor considerations. Pressure drop and pumping power are the mainly associated with each other usages. The physical properties that can influence the flow pressure droop are the nanofluids

density and viscosity. It is estimated that the nanofluids with higher density and viscosity experience higher pressure drop. In this we can know that the viscosity of the nanofluids is more than the base fluid.

II.EXPERIMENTAL INVESTIGATION & SET UP

This experiment consists of thermal energy storage tank, water, storage tank, heaters, 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 water storage tank is placed side by side. A Spherical capsule of 70mm outer diameter and 0.8mm thickness of 80 balls and with 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 heat transfer fluid(HTF).

A Flow meter is used to measure the heat flow rate of heat transfer fluid (water). 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 figure no.1

Fig.1 Schematic diagram of TESS System

Fig.2 Nanoparticles CuO and Al_2O_3

III.EXPERIMENTAL PROCEDURE

The base fluid 80 litres of water was heated up to 70^0C by 2 heaters, each heater containing 1000W capacity, the base fluid water is stirred to get the uniform temperature in the tank. The hot water is circulated into the storage tank with the help of a centrifugal pump. 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, 6litres/min.

During the charging process, the heat transfer fluid 30 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 59^0C . The heat energy is transferred from the HTF to the spherical capsules containing paraffin wax to melt. Firstly the heat is stored in the spherical capsule then it is started to reach the paraffin wax that comes to the 68^0C 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 10mins. The charging process is done till the PCM temperature reaches to the approximately 70^0C.

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, Al_2O_3 = 3970 kg/m^3 , CuO = 6310 kg/m^3

The Weight of base fluid (water) in grams

Density of base fluid (water) = 995kg/m^3

TABLE 1. DIFFERENT CONCENTRATION OF NANOPARTICLE WEIGHT

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

TABLE 2. CHARGING PROCESS TIME ONLY WITH WATER 2LITERS/MIN

Time in mins/ PCM Temperatures	0	60	100	120
T2	34	55	65	69
T4	35	56	66	69
T6	34	58	67	70
T8	35	59	66	69
T10	34	59	67	69

TABLE 3. CHARGING PROCESS TIME ONLY WITH WATER 4 LITERS/MIN

Time in mins/PCM Temperature	0	30	60	90	100
T2	35	45	53	65	69
T4	34	46	54	64	68
T6	35	45	54	66	69
T8	34	44	55	65	68
T10	35	45	54	65	69

TABLE 4. CHARGING PROCESS TIME ONLY WITH WATER 6 LITERS/MIN

Time in mins/ PCM Temperatures	0	20	40	60	80
T2	35	42	52	63	69
T4	34	43	53	64	69
T6	35	43	53	64	68
T8	35	44	54	63	69
T10	35	44	54	64	69

TABLE 5. CHARGING PROCESS TIME WITH Al_2O_3 WITH 0.02 CONC AND DIFFERENT FLOW RATES

Nano particle0 .02con+ water	Time in mins	PCM temper-ature 2liters/ min	4 liters/ min	6 liters/ min
Al_2O_3 + Water	10	42	43	43
	30	52	53	56
	40	54	55	58
	50	55	56	64
	60	58	61	69
	80	60	69	
	100	69		

TABLE 6. CHARGING PROCESS TIME WITH Al_2O_3 WITH 0.05 CONC AND DIFFERENT FLOW RATES

Nanoparticle(0.05con)+ water	Time in mins	PCM Temperature 2lits/min	4 lits/min	6 lits/min
Al_2O_3+water	10	48	50	51
	20	53	54	56
	30	62	63	66
	40	64	64	69
	50	67	69	
	60	69		

TABLE 7. CHARGING PROCESS TIME WITH Al_2O_3 WITH 0.08 CONC AND DIFFERENT FLOW RATES

Nanoparticle (0.08 con)+ water	Time in mins	PCM Tempe-rature 2lits/ Min	4 lits/ min	6 lits/ min
Al_2O_3+ Water	10	51	52	57
	20	55	58	64
	30	59	65	67
	35	65	67	69
	40	67	69	
	50	69		

TABLE 8. CHARGING PROCESS TIME WITH CuO WITH 0.02 CONC AND DIFFERENT FLOW RATES

Nano particle (0.02 con)+water	Time In mins	PCM Temp-erature 2lits/ min	4 lits/ min	6 lits/ min
Cuo+water	10	47	48	49
	20	51	52	50
	30	59	55	58
	40	61	60	65
	50	64	64	69
	65	69		
	69			

TABLE 9. CHARGING PROCESS TIME WITH CuO WITH 0.05 CONC. AND DIFFERENT FLOW RATES

Nanoparticle (0.05con)+ Water	Time in mins	PCM Temp-erature 2 lits/min	4 Lits/min	6 Lits/min
CuO(0.05) +water	10	46	47	48
	20	49	51	53
	30	55	57	65
	40	59	61	69
	50	65	69	
	60	69		

TABLE 10. CHARGING PROCESS TIME WITH CuO WITH 0.08 CONC AND DIFFERENT FLOW RATES

Nano particle(0.08con) +water	Time in mins	PCM Temp-erature 2 lits/min	4 lits / min	6 Lits/ min
Cuo(0.08 Con)+ Water	10	45	47	49
	20	50	55	57
	30	55	60	62
	40	61	68	69
	50	69		

GRAPHS

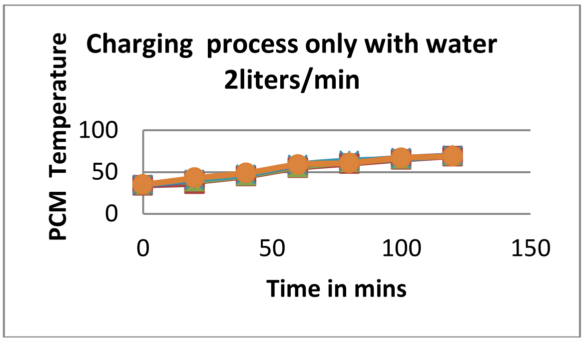

Fig.3 Charging process with water 2lits/min

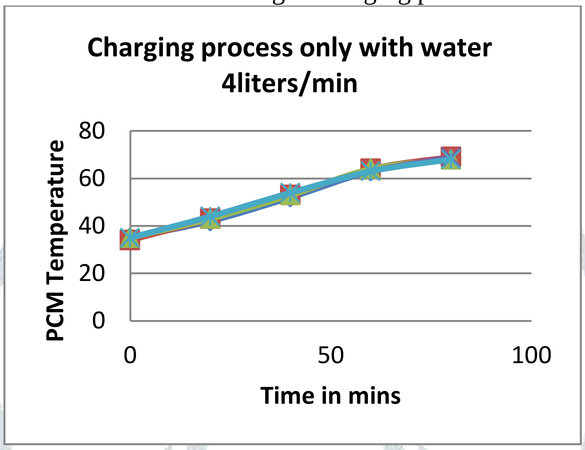

Fig.4 Charging process with water 4lits/min

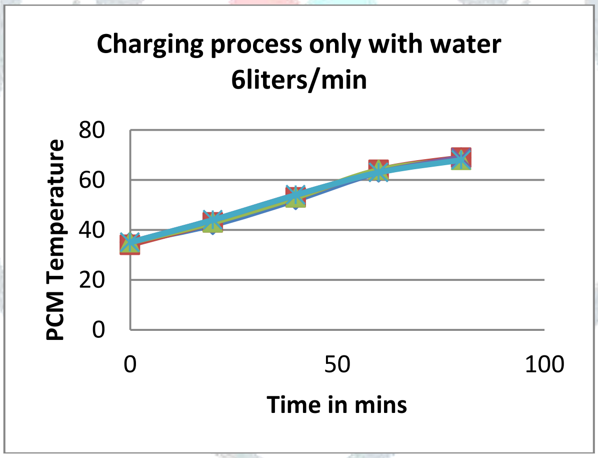

Fig.5 Charging process with water 6 lits/min

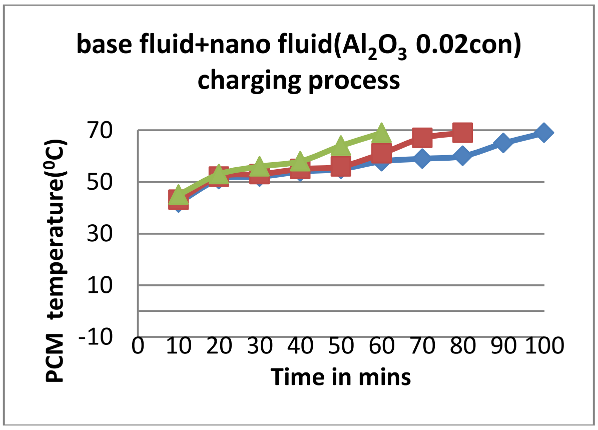

Fig.6 Charging process with base fluid and nanofluid(Al_2O_3 0.02 con) with 2,4,6 lits/min

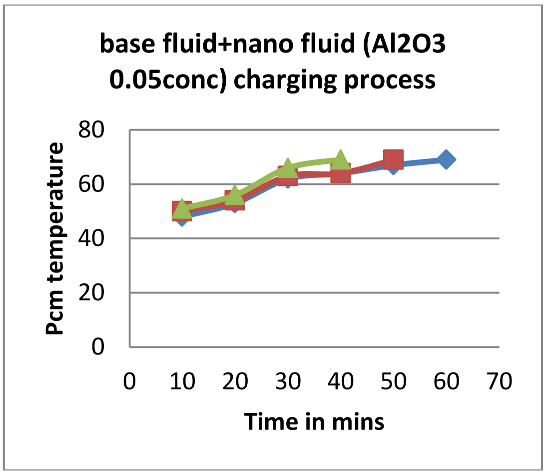

Fig.7 Charging process with base fluid and nanofluid(Al_2O_3 0.05 con) with 2,4,6 lits/min

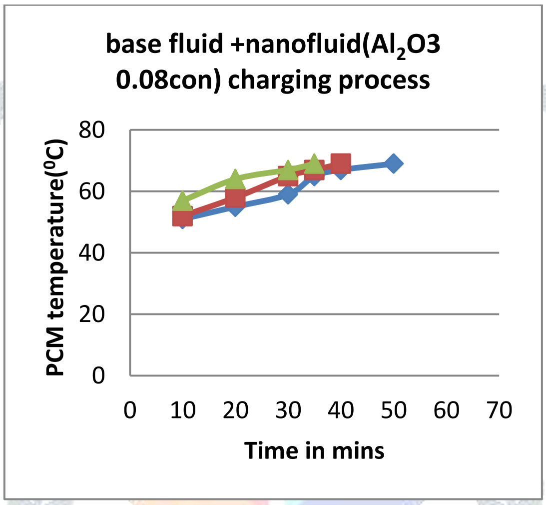

Fig.8 Charging process with base fluid and nanofluid(Al_2O_3 0.08 con) with 2,4,6 lits/min

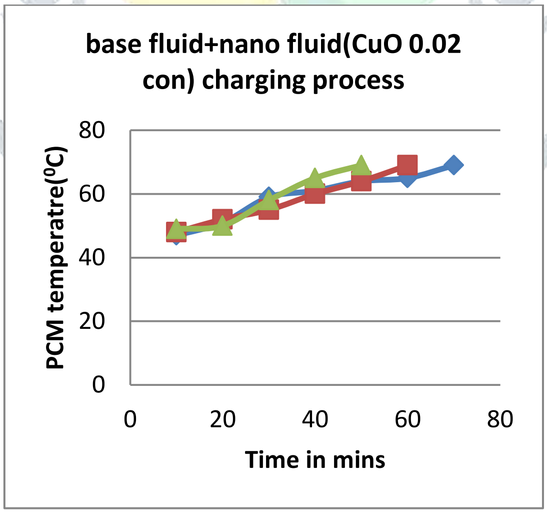

Fig.9 Charging process with base fluid and nanofluid(CuO 0.02con) with 2,4,6 lits/min

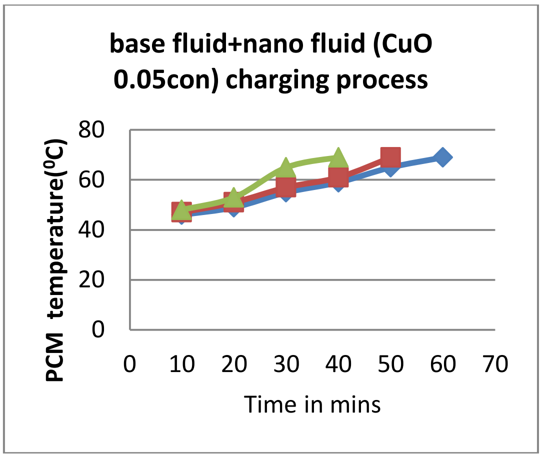

Fig.10 Charging process with base fluid and nanofluid(CuO 0.05con) with 2,4,6 lits/min

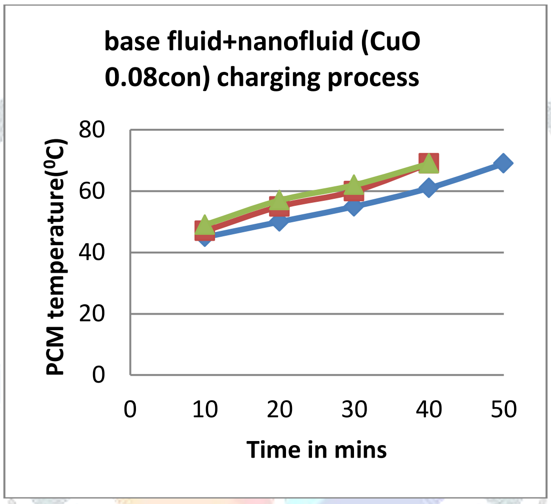

Fig.11 Charging process with base fluid and nanofluid(CuO 0.09con) with 2,4,6 lits/min

IV. RESULTS AND DISCUSSIONS

The figure3,4 and 5 shows the charging process with respect to time with the flow rates of 2,4,6 litres/min only with water, but the charging process with respect to the fig.5 represents the maximum flow rate of HTF so that the charging process.

Fig 6,7&8 shows the charging process with the nanoparticle(Al_2O_3) With the different flow rates and fig 8 represents the time reducing for the charging process because the nanoparticle has added and due to the maximum flow rate.

Fig.9,10& 11 represnts the charging process with the nanoparticle(CuO) with the different concentrations witht the different flow rates and the charging process for the CuO with the highest concentration of 0.08 and the maximum flow rate 6 litres/min, represents the time reducing for the charging process.

The different concentrations of nanoparticles with the different flow rates are pumped to the TESS system. The HTF is pumped to the spherical capsules until PCM reaches to 70^0C. Heat transfer rate increases with a less period of time for the maximum flow rates. Different flow rates values are recorded in the table, among them CuO with the maximum flow rate with high Concentration reduces the heat transfer time.

V.CONCLUSIONS

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

1. 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.
2. High specific surface area and therefore more heat transfer surface between particles and fluids.
3. The High dispersion stability predominant Brownian motion of particles.
4. Reduced pumping power as compared to pure liquid to achieve equivalent heat transfer intensification.
5. Reduced particle clogging as compared to conventional slurries, thus promoting system miniaturization.
6. Thermal energy storage offers the option to improve output control for some energy technologies.

VI.REFERENCES

1. Dincer, I., and Marc A.R., 2000. Thermal Energy Storage: Systems and Applications, John Wiley & Sons, Chichester.
2. Holman, J.P., 2004. Experimental methods for engineers, seventh ed, Tata Mcgraw-Hill Publishing Company Limited, New Delhi.
3. C.kavirasu and D.prakash, Review of phase change materials with Nanoparticles/Journal of engineering science and Technology Review 9 (4) (2016) 26-36.
4. Hani Najim Obaid, Majeed Ali Habeeb, Thermal Energy Storage by Nanofluids, Journal of Engineering Technology and Policy Vol.3, No5, 2013.

5. R.rafee, Entropy Generation Calculation for Laminar Fully Developed forced flow and Heat transfer of nanofluids inside annuli.
6. Stephen U.-S. Choi, nanofluid technology: current status and future research.
7. Wang X.Q., Mujumdar A.S. (2007), "Heat transfer characteristics of nanofluids a review", International journal of thermal sciences, 46,1-19.
8. Das S.K., Putra N., Peter T., Roetzel w., (2003), "Temperature dependence of thermal conductivity enhancement for nanofluids", journal of Heat Transfer, Vol. 125, 567-574.
9. Khodadai, J.m., and Hosseinizadeh, S.F.,(2007), "nanoparticle enchanced phase change materials (NEPCM) with great potential for improved thermal energy storage," International Communicatioin in Heat Mass Transfer, 34,534-543.
10. Sharma A., Tyagi V.V., Chen C.R., Buddhi D. (2009), "Review on thermal energy storage with PCM and applications", Renewable and sustainable Energy Reviews, 13,318-345.
11. Zalba b., Marin J.M., Cabeza L.F., Mehling H. (2003), "Review on thermal energy storage with PCMs, heat transfer analysis and applications", Applied Thermal Engg.,23, 251-283.
12. Choi SUS. Enhancing thermal conductivity of fluids with nanoparticles. ASME FED-Vol. 231/MD. 66 1995:99-103.