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USE OF CuO NANO-MATERIAL FOR THE IMPROVEMENT OF THERMAL CONDUCTIVITY AND PERFORMANCE OF LOW TEMPERATURE ENERGY STORAGE SYSTEM OF SOLAR POND

K KARUNAMURTHY[a*], K MURUGUMOHANKUMAR[b], S SURESH[c]
[a]*CARE School of Engineering, Trichy 620 009, India*
[b]*Pavendar Bharathidasan College of Engineering and Technology, Trichy,620 024, India*
[c]*National Institute of Technology, Trichy 620 015, India*

Solar Ponds collects the solar energy and the collected solar energy will be carried by a flowing fluid. Low Temperature Energy Storage System (LTES) stores the thermal energy from solar pond and increases the period of operation of the solar pond. In this paper, the solar energy collected by the simulated solar pond was stored in a LTES and the medium adopted was paraffin phase change material (PCM). PCM is preferred because of its higher storage density, with less volume. However the disadvantage of PCM for using as LTES is its poor thermal conductivity and requires more time period and more surface area for charging and discharging of thermal energy. To overcome this problem, an attempt was made by dispersing CuO nano particles within the PCM. The thermal conductivity of LTES is determined both analytically and experimentally. From the experimental investigation carried out, it was observed that, the thermal conductivity of PCM and the charging and discharging time of LTES has also been reduced significantly by introducing CuO nano-particles.

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1. Introduction

Solar energy is available abundantly among the other renewable sources of energy. The availability of solar energy is not constant and continuous, whereas the demand for energy is almost constant and continuous. To bridge the gap between the energy demand and availability it is mandatory to have thermal energy storage system. It is also preferred to have thermal energy storage system which can work for an extended period of operation, even after the sun sets. The storage of thermal energy is achieved by increasing the internal energy of a material as *sensible heat, latent heat, and thermo-chemical heat, or combination of these*. Sensible heat storage system uses the specific heat capacity of the substance and the temperature of a material (in solid or liquid state). Temperature of the substance increases during charging and decreases during discharging. Latent heat storage (LHS) is based on absorption or release of heat when a storage material undergoes a phase change. Thermo-chemical systems rely on the energy absorbed and released in breaking and reforming molecular bonds in a completely reversible chemical reaction. In this case, the stored heat depends on the amount of storage material, the endothermic heat of reaction, and the extent of conversion. A.Abhat. (1993) suggests that, amongst various thermal energy storage techniques, latent heat energy storage is attractive and paraffin have been predominantly used as PCM because of the following reasons, easy availability, large latent heat per unit volume, low melting temperature, low vapour pressure, small volume changes on phase transformation, the

[*]Corresponding author: karunamurthy.k@gmail.com

properties remain unaltered even after multiple cycles of charging and retrieving the stored energy during discharging. Zalba.B et al (2003) specified the problem of paraffin for using as PCM; it is its low thermal conductivity, also during charging the PCM melts and the solid-liquid interface moves away from the heat transfer surface. The surface heat flux decreases due to the increasing thermal resistance of the growing thickness of the molten paraffin. In the case of solidification, conduction is the only transport mechanism, and in most cases, it is very poor. In the case of melting, natural convection can occur in the molten layer and this generally increases the heat transfer rate compared to the solidification process (if the layer is thick enough to allow natural convection to occur). However, low rate of heat transfer can be increased considerably by using a suitable heat transfer enhancement technique. Ahmed Sari et al (2007) studied the thermal conductivity and thermal energy storage characteristics of paraffin with expanded graphite. Jose' M. Marin et al (2005) improved the thermal energy storage using plates with paraffin-graphite composite. Zeng J.L et al(2007) improved the thermal conductivity of PCM based thermal energy storage system by dispersing AgO nano particles. I Dincer (2002), discussed the necessity and the need for thermal energy storage system with reference to conservation of thermal energy. Zhang.Y et al (1996) improved The heat transfer of Latent Heat Thermal Energy Storage System by providing finned tube. L.F. Cabeza et al (2002) studied about the heat transfer enhancement in water when used as PCM. In this experimental study CuO nano particles are dispersed in paraffin and the thermal conductivity and thermal energy charging and discharging performance of PCM were studied.

2. Experimental investigation

2.1. Materials

Paraffin (N-docosane) of melting point of 52-55ºC, latent heat of fusion of 190kJ/kg, specific heat capacity 1.94 kJ/kg K(solid) and 2.4 kJ/kg K(liquid), density 785kg/m^3, thermal conductivity of 0.214 W/mK was received from Wax Chem India manufactured by Shell.

2.2 Dispersing nano particles with paraffin

Ultra sonic stirrer was used for dispersing nano particles with PCM. Ultrasonic stirring is an advanced mixing technology providing higher shear and stirring energy without scale-up limitations. The ultrasonic cavitation induces intense micro mixing and dissipates high power locally. Copper oxide is mixed with paraffin wax in ultrasonic frequency generated from the ultrasonic stirrer of 5- 10 MHz The stirrer was run for 8 hours for stable suspension of nano particles with no precipitation. Nano particle is mixed with various proportions. The various concentrations of mixing are

Table 1. Various Samples

SAMPLE No	*VOLUME CONCENTRATION*
Sample 1	*0.01*
Sample 2	*0.02*
Sample 3	*0.03*
Sample 4	*0.04*
Sample 5	*0.05*
Sample 6	*0.10*
Sample 7	*0.15*

3. Determination of Thermal Conductivity

3.1. Analytical Method

Maxwell Garnett Equation is used to determine the thermal conductivity of PCM for Low Temperature Energy Storage. The Maxwell – Garnett equation is

$$K_{composite} = \frac{K_p + 2K_1 + 2(K_p - K_1)\phi}{K_p + 2K_1 - (K_p - K_1)\phi} K_1$$

Where

K_p -is the thermal conductivity of the dispersed particles.

Thermal conductivity of CuO= 6540 W/mK.

K_l -is the thermal conductivity of the dispersion medium,

Thermal conductivity of paraffin = 0.214 W/mK

Φ -is the particle volume concentration of the suspension.

3.2. Experimental Method

Transient Hotwire Thermal Conductivity Measuring apparatus is used to determine the thermal conductivity of PCM blended with nano particles in various proportions.

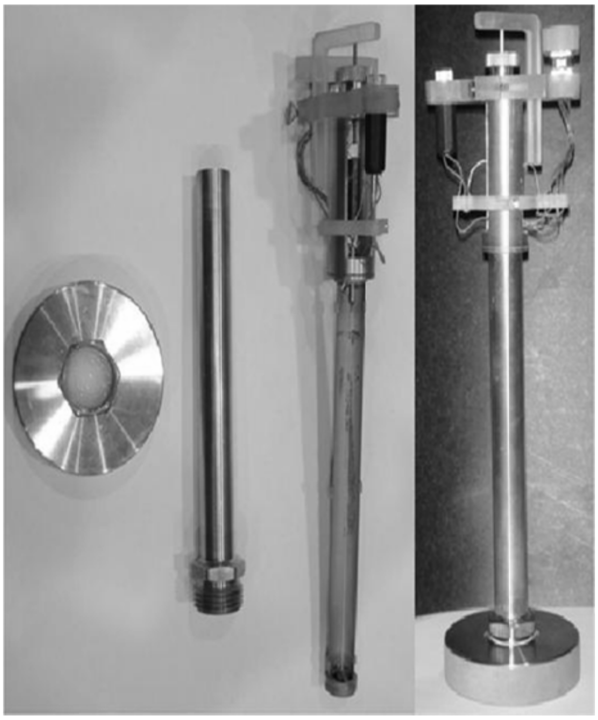

Fig.1 Transient Hotwire Thermal Conductivity Measuring Apparatus

3.3. Determination of Performance (Charging and Discharging Time) of LTES

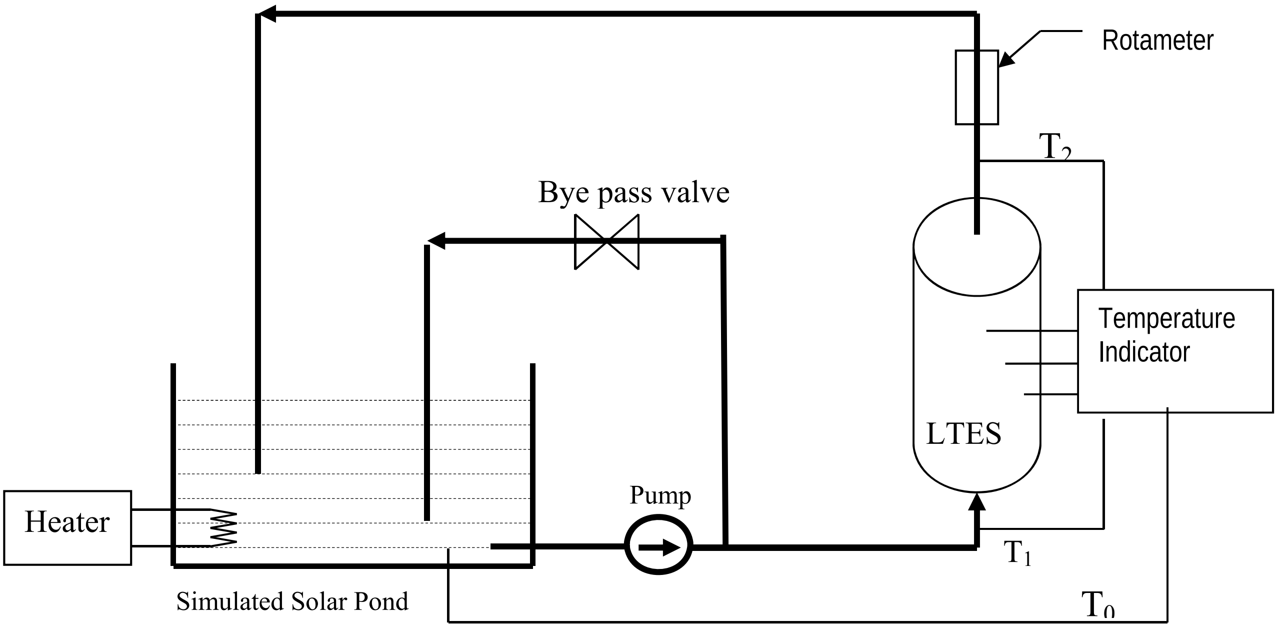

Fig.2 Schematic sketch of experimental set up.

A simulated solar pond of 500mmX500mmX250mm depth was fabricated using GI sheet of 1.5 mm thick. In the solar pond an electrical resistance heater of 2000W was provided for heating the salt water, the heater was also fitted with a thermostat which can maintain constant temperature of salt water. The heater acts as a simulator to provide heat energy to the solar pond. The temperature of the salt water was maintained at 65ºC. The hot salt water from the solar pond was pumped using a centrifugal pump (of 2 kg/s capacity) to the PCM store and then to the collecting tank. The PCM store is made of mild steel of 105 mm (ID) and 1000 mm height, the water line of 12.5mm (OD) passes through the PCM store concentrically. The annulus of the PCM store was filled with 2kg of paraffin. A bye pass line for the PCM store was also provided with a valve to adjust the flow of water through the circuit. The flow of salt water through the PCM store was measured using a rotameter fitted immediately after the PCM store. The temperatures of salt water in the solar pond (T_0), inlet to the PCM store(T_1), outlet from the PCM store (T_2)and temperature of the PCM at three different positions(T_3,T_4,T_5) radially were monitored using a digital temperature indicator fitted with 'K' type thermocouples. The time taken for charging and discharging the PCM were observed for various concentration of CuO nano particles dispersed with paraffin. The flow rates of salt water through the PCM store were maintained as 0.25 kg/s, 0.5kg/s and 0.75 kg/s. The heating of PCM was carried out using hot salt water, until the PCM melts completely. While charging, the temperatures T_0. T_1, T_2, T_3, T_4, T_5 were observed for the system with paraffin (without dispersing nano particle) and the time taken for melting was also noted. The same set of readings was also noted while discharging (after switching off the heater). The above said procedure was repeated again for the paraffin (PCM) dispersed with CuO nano particle with various concentrations.

4. Results and discussion

4.1. Thermal Conductivity

The thermal conductivity of the raw paraffin was 0.214 W/mK, the value of thermal conductivity was determined using transient hot wire thermal conductivity apparatus. After dispersing the nano particle with the paraffin the thermal conductivity of the PCM has increased. The increase in thermal conductivity of the PCM is observed with increasing concentrations of CuO nanoparticle. For a concentration of 0.15% of CuO in paraffin resulted with a thermal conductivity of 0.3802 W/mK and 0.3222 W/mK as per experimentally and analytically.

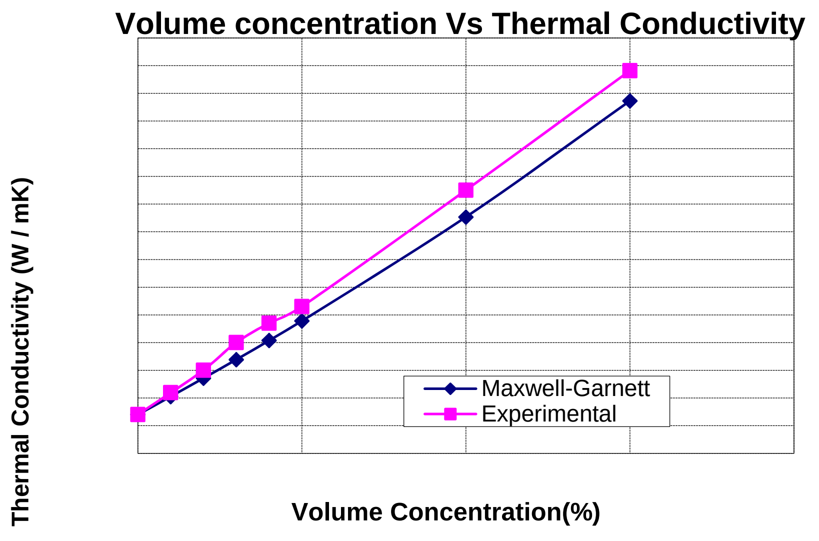

Fig.3. Thermal Conductivity Vs Volume Concentration of CuO nanoparticle in PCM.

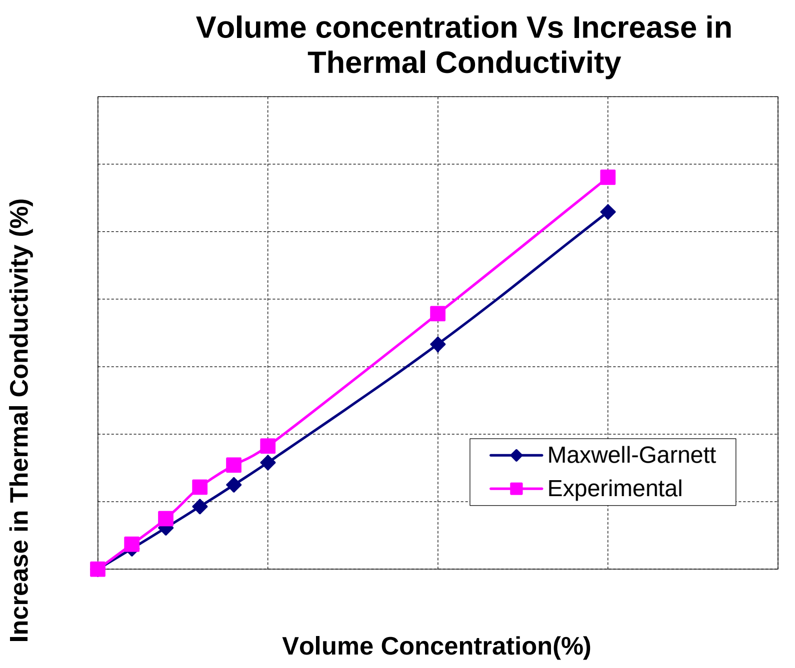

Fig.4 Volume Concentration Vs Increase in Thermal Conductivity of PCM after dispersing nano particle.

4.2. The Performance of PCM Containing CuO Nano-particle.

4.2.1. During Charging of LTES

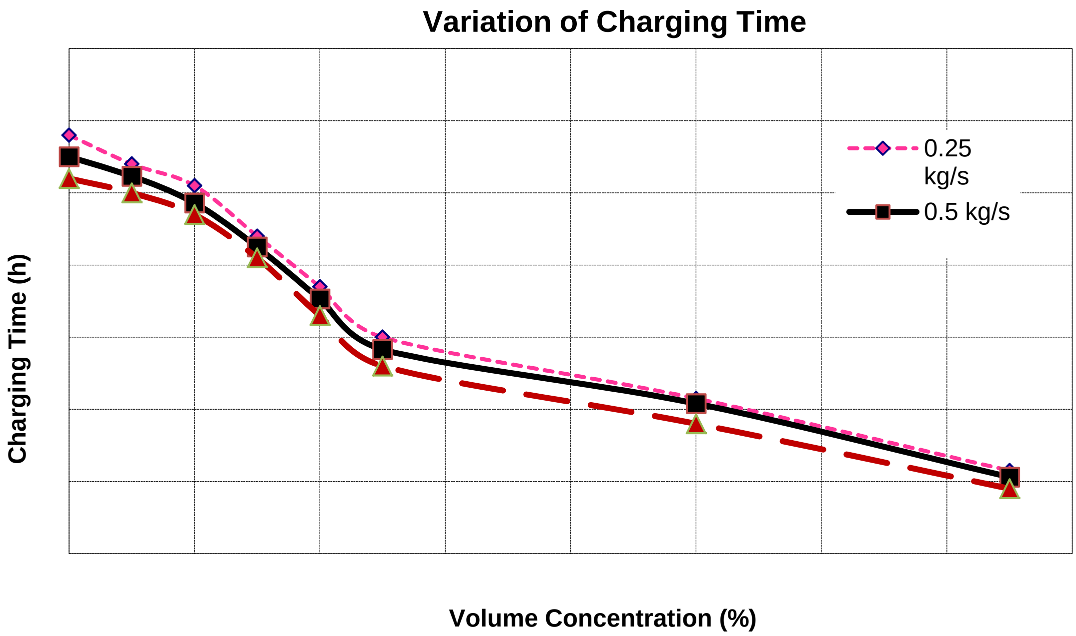

Fig.5. Charging time of LTES containing nano-particle.

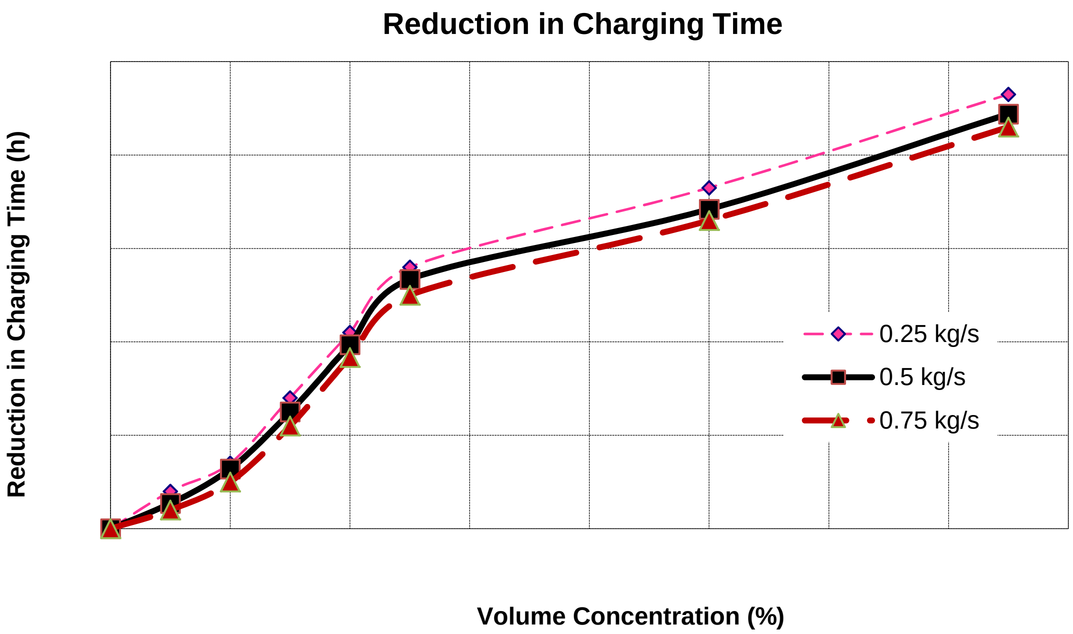

Fig.6. Reduction in Charging time of LTES containing CuO nano particle.

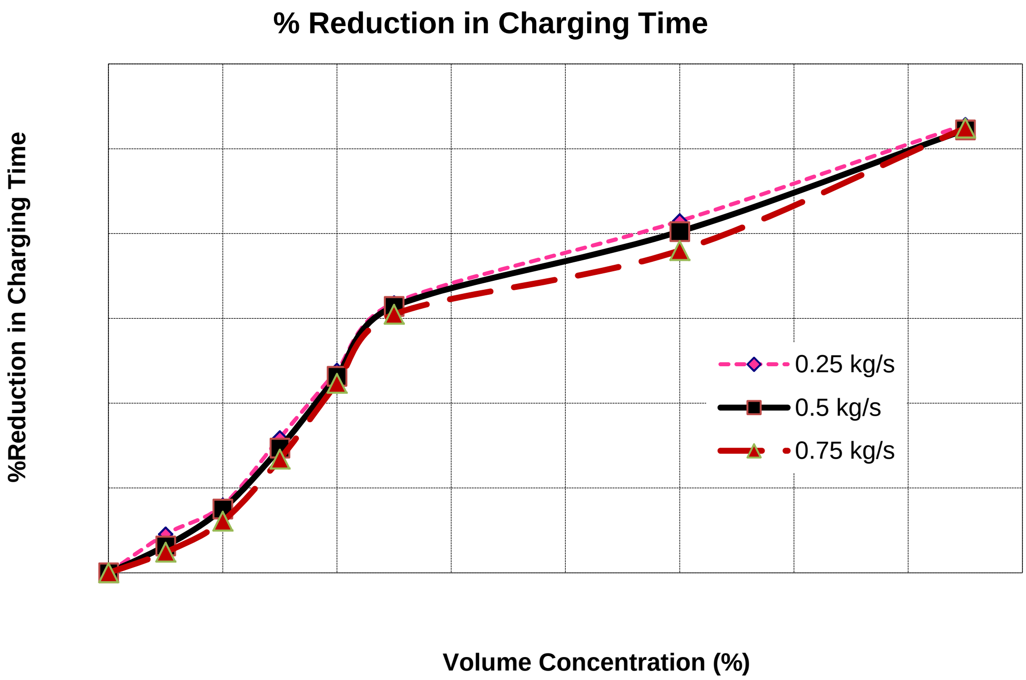

Fig.7. Percentage Reduction in charging time of LTES containing CuO nano-particle.

From the Fig.5, 6 and 7 it is observed that the charging time of the LTES has decreased with increasing concentration of CuO nano particle in the PCM, for constant (flow rate of hot water) heat flux, also as the flow rate of the hot water supplying heat is increased the charging time of the LTES is decreased for the same concentration of CuO nano particle in the PCM. The slope of the charging curve is more till 0.05% concentration of CuO nano particle, beyond this concentration, the slope of the charging curve is less.

4.2.2. During Discharging of LTES.

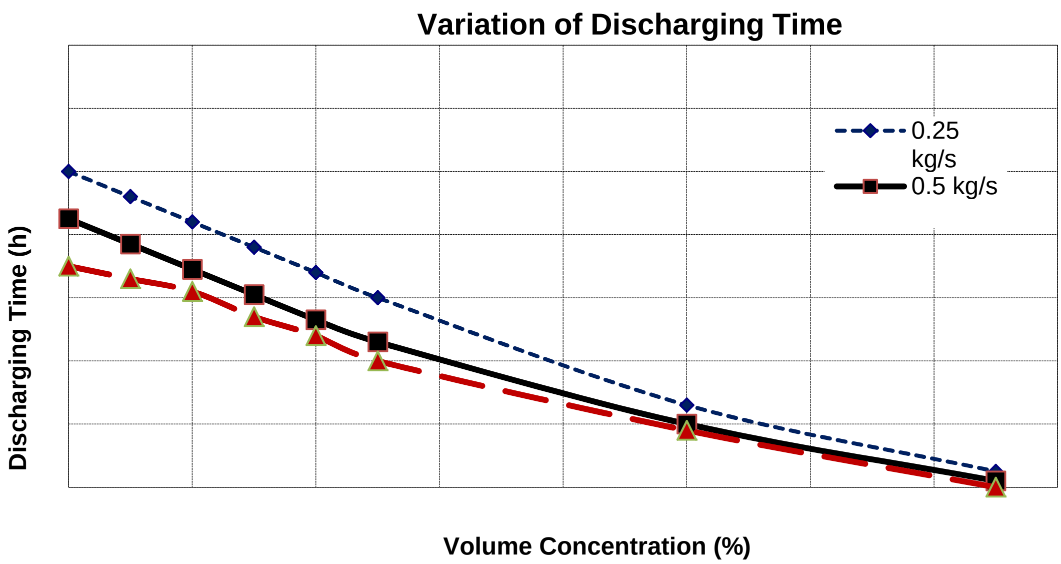

Fig.8. Discharging time of LTES containing CuO nano-particle.

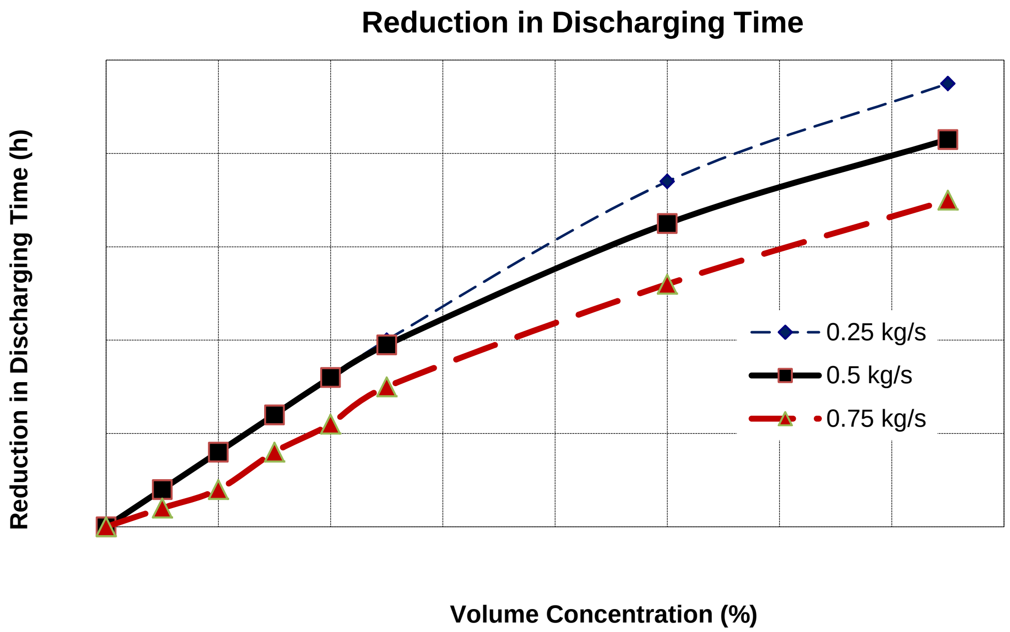

Fig.9. Reduction in discharging time of LTES containing CuO nano-particle.

From the Fig.8, 9 and 10 it is observed that there is a substantial decrease in the discharging time of the LTES with increasing concentration of nano particle and the decrease in the discharging time of LTES is comparatively minimum for variation in the heat flux (flow rate of hot water) for a particular concentration of CuO nano-particle in the LTES. Also for all the heat flux (flow rates of hot water) supplied the behaviour of the LTES is almost similar with respect to the increasing concentration on nano particles.

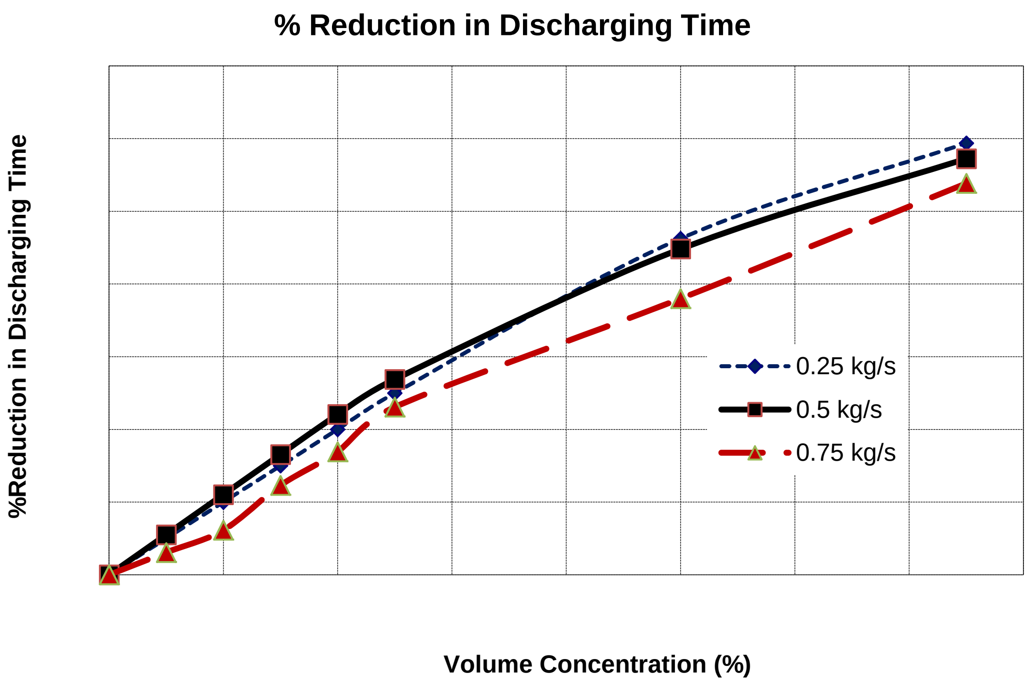

Fig.10. Percentage reduction in discharging time of LTES containing CuO nano-particle.

5. Conclusion

Solar Ponds are used to collect the solar energy and to provide the collected energy for process heating or for generating electric power by operating organic rankine cycle. The performance and period of operation of the solar can be improved by providing a thermal energy storage system. PCM are used as thermal energy storage system, the problem with the most commonly used PCM (paraffin) is its poor thermal conductivity. From the above experiment performed it is evident that dispersing CuO nano particles with paraffin had resulted in the improved thermal conductivity of the PCM. This improved thermal conductivity of PCM overcomes the poor rate of heat transfer in the thermal energy storage system. Also the performance of the PCM like charging and discharging time and the melting process are improved. Higher the concentration of CuO nano particle dispersed in the PCM, the performance is better. It is also observed that there is almost 50% reduction in charging time and discharging time of the PCM for a volume concentration of 0.16% and for all the three constant heat flux (flow rate of hot water). Further, there is a scope to determine the correct proportion of mixing the nano particle to the PCM and also there is scope to determine the better nano particle that can be dispersed with a particular type of PCM.

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