PERFORMANCE ANALYSIS OF PCM BASED THERMAL ENERGY STORAGE SYSTEM CONTAINING NANOPARTICLES

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Abstract - *Reviews of current experimental studies on improve thermal conductivity of phase change material due to dispersion of nano particles. Phase change material has strong ability to store energy and constant temperature in course of absorbing and releasing energy. The main disadvantage of phase change material is low thermal conductivity to improve thermal conductivity NiO nanoparticle was added with phase change material. A series of numerical and experimental testes were carried to know the effects of parameters such as the volume concentration of nanoparticle and the mass flow rate of the heat transfer fluid. The experimental setup has made and experiments were carried out with pure phase change material and nanoparticle mixed phase change material. From these readings are tabulated and ensure the enhancement in heat transfer.*

Key Words: Phase change material, nanoparticle, thermal conductivity, mass flow rate, store energy.

1. INTRODUCTION

Energy storage is a most important one. Now a day increasing its usage so save energy and store it a proper way is more essential. Energy storage used in later time. This will lead to a reduction in the overall energy demand. The renewable energy is an expanding field of innovation. Renewable energy sources try to reduce the CO_2 emissions from the combustion of fossil fuels. Thermal energy is an ancient and widely used energy. Thermal energy storage is one of the ways to energy recovery from solar energy, industrial waste heat recovery and off-peak electricity. Thermal energy is store as a change in the internal energy of some materials as sensible heat, latent heat [8].Hence thermal energy storage system used as a renewable energy for example solar heat energy largely available during day time but night time solar energy not available to solve this problem thermal energy storage system used also it can be used as a waste heat recovery system.

Thermal energy storage system have divided as long term storage and short term storage depending on its storage time short term storage is only a few hours is essential however long term storage is a few days is essential. In another way it is divided as sensible heat storage and latent heat storage. From their sensible heat storage system used normally water as storage medium. In latent heat storage system using phase change material. Fatty acids and paraffin wax are best organic PCMs because of their desirable properties such as high latent heat of fusion, low vapor pressure during the melting, negligible super cooling and thermally stable. The low thermal conductivity of paraffin is main drawback so it decreases the rates of heat storage. Hence low thermal conductivity limits their utility capabilities [2]. Many researchers have been conducted on this topic high conductive metal like fins, wool, and brush, to enhance the thermal conductivity of PCM. However the metal fillers, fins, fibers increase the weight and cost of the storage systems. Difficult to determine the proper configurations of these fixed enhancers and their interactions with conduction or convection heat transfer involved in solid-liquid phase. On the other part many advantages in the nanotechnology field. A new concept of using nano sized particles which usually possess a nominal diameter of 10–100 nm, have become commercially available in various metals and metal oxides The heat transfer of Nanoparticles is increased when size decreases because the ratio of Surface to volume increased. By Increasing the Thermal conductivity of paraffin the heat transfer rate increased so loading and unloading time for the paraffin is also increased. Hence nanoparticles are added with pcm and improve its thermal conductivity.

1.1 Thermal energy storage

There are four type of energy storage methods are available they are electrical storage method, chemical storage method, mechanical storage method and thermal storage method. From those I have used thermal energy storage. Thermal energy can be stored as a change in internal energy of a material. It is divided in three type's sensible heat, latent heat, and thermo-chemical heat, or combination of these. Sensible heat storage is increasing its temperature without changing its phase. In this type amount of energy stored equal to temperature change of the material. In thermo chemical storage gives some chemical reactions. This energy absorbed and released by breaking and reforming molecular bonds in a completely reversible chemical reaction so storage capacity depends on amount of storage material. When the energy needed the products are recombined by exothermic reaction. Latent heat is store the heat without any temperature change but it changes its phase during charging and discharging. So in this paper takes latent heat storage as storage method.

1.2 Phase change materials

Phase change material (PCM) which melting and solidifying at a certain temperature. It is capable of store energy during melting and releasing large amount of energy during solidifying so PCMs are classified as latent heat storage. It has many advantages like it stores large heat energy with only small temperature changes.

The latent heat storage can be achieved through following phase change solid-solid, solid-gas, solid-liquid and liquid-gas. There is only solid-liquid phase change used in PCM because liquid-gas phase change is not practically used and it requires large volume and high pressure created during gas phase change. Solid-gas transition requires higher heat. Solid - solid phase change are typically very slow. The desirable properties of PCM material used for latent thermal energy system are type of phase change material, latent heat, thermal conductivity. Phase change materials are divided in to three types and its heat storage capacities are Organics paraffin 125-350 kJ, Inorganic 250 -400 kJ, and Eutectics 100-250 kJ.

1.3 Thermal energy storage using phase change material

Phase change material stores the energy with minimum temperature or maximum temperature for later use. It will reduce the gap between demand and supply of thermal energy. The storage cycle is varies (daily, weekly and seasonal) depends on requirement and design. Their input and output are thermal energy so there is no another energy transaction are takes place and energy losses are minimized. Reason for useing PCM as thermal energy storage medium is non corrosive, green solution, used as spare, reduced running cost, stability, increased capacity and cost effective. Hence the phase change material is selected as energy storage medium.

1.4 Paraffin

Generally paraffin wax is used as a thermal energy storage medium. It absorb heat at small temperature can be observed. The normal paraffin C_nH_{2n+2} are a family of saturated hydrocarbons with same properties. Paraffin between C_5 and C_{15} are liquids. It consists of mainly straight chain hydrocarbons that have melting temperatures from 23 to 67 ºC. Commercial-grade paraffin wax is making from petroleum distillation and is not a pure material but a combination of different hydrocarbons. In general the longer the average length of the hydrocarbon chain higher melts temperature and heat of fusion. In this project paraffin properties are melting temperature of paraffin n-Tricosane is 47.5ºC, Latent heat of fusion is 235 kJ/ kg, Specific heat 1.7kJ/kg K (solid at -10 ºC) 2.7kJ/kg K (liquid at 50 ºC), Thermal conductivity is 0.214W/mK, Density is 764 kg/m^3.

1.5 Enhancement of paraffin thermal conductivity

Most of the research works were conducted on improvement of thermal properties of PCM such as paraffins and fatty acids. Paraffin have a great attraction to researchers. For its many advantages like good heat storage density, melting and solidification are easy, no sub cooling, non reactive and low cost. Fatty acids have the similar properties as paraffin. Main disadvantage of these PCM's is their low thermal conductivity. By mixing high conductive nano particles is the solution to improve the thermal conductivity of these PCM's.

1.6 Nano materials

Nano technology is the learning of tinny structures like the size of blew 100nm. Develop materials with dimension on the nano size. Nano technology studies material with those special properties at their nano scale dimensions. The heat transfer rate of nanoparticle is increased when size of nano particle decreased because ratio of surface to volume increased. From our literature survey we have chosen nickel oxide as a nano material to enhance the thermal conductivity of paraffin. By using NiO nano particles thermal conductivity of paraffin increased so charging and discharging time is reduced.

2. BLENDING OF NANOPARTICLE WITH PCM

Initially take paraffin wax and nanoparticle with required proportions. Melt the paraffin in water bath. Water bath is equipment have container filled with heated water. It is used to increase temperature of samples in water at a constant temperature over a long period of time. All water baths have a digital or an analogue indicator to allow users to set the desired temperature. It is used to allow particular chemical reactions to occur at high temperature. Water bath is recommended for heating flammable chemicals instead of an open flame to prevent fire accidents. Different types of water baths are available depending on application. Water baths can be used up to 99 °C. When temperature is above 100 °C, alternative methods such as oil bath, sand bath may be used. In this experiment we have use water batch method of melting. When the paraffin melted compleatly then add the requied propotion of NiO nanoparticle.To find the volume concentration the below formula used.

$$\text{Volume concentration} = \frac{v_s}{v_s + v_p}$$

Where V_s is the volume of the dispersed particles, v_p is the volume of the dispersion liquid. By using this equation volume concentration of nano particle is determined.

Table -1: Volume concentration of nano particles

Volume of concentration	Amount of nano materials used in gm
.01	5
.02	10
.03	15
.04	20
.05	25
.10	50
.15	100

Nano particles can be settled down in liquids by means of precipitation. In order to reduce the precipitation particle size, ultrasonic stirring is essential to control it. Ultrasonication is latest mixing technology providing higher shear and stirring energy without any scale-up limitations. Nickel oxide is mixed with paraffin wax in ultrasonic frequency generated from the ultrasonic stirrer is 5-10 MHz. The stirrer is run for 1 hour for stable suspension of Nano particles with no precipitation. To determine the thermal conductivity of new composition of PCM and nano particle Maxwell Garnett equation is used when the two different phases of materials are mixed.

$$K_{maxwell} = \frac{K_p + 2K_1 + 2(K_p - K_1)\emptyset}{K_p + 2K_1 - (K_p - K_1)\emptyset} K_1$$

Where k_p is the thermal conductivity of the dispersed particles, k_l is the thermal conductivity of the dispersion liquid, φ is the particle volume concentration of the suspension. To determine the proportions of nano particles for blending with paraffin FESEM image are taken they are given below.

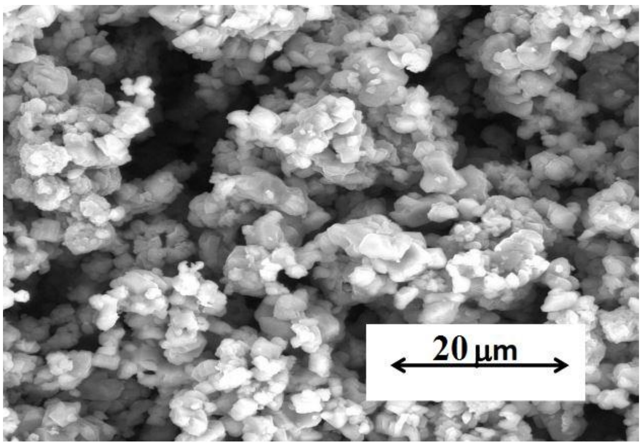

Fig -1: FESEM image of NiO nano particles

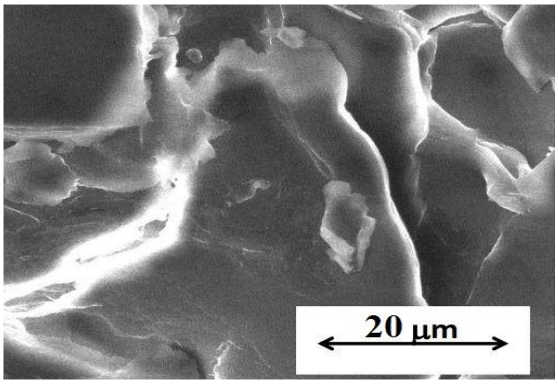

Fig -2: FESEM Image of 0.01% NiO blended with Paraffin

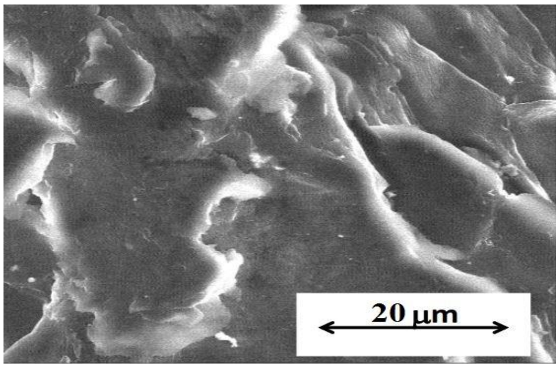

Fig -3: FESEM Image of 0.02% NiO blended with Paraffin

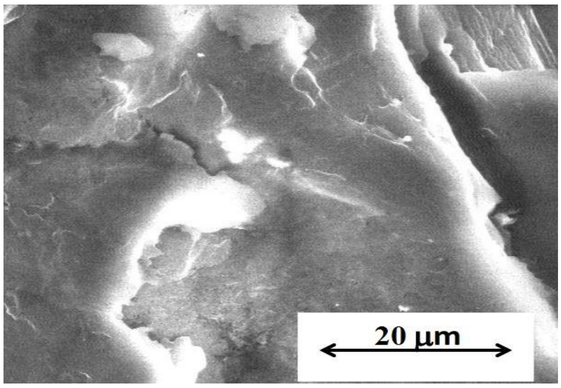

Fig -4: FESEM Image of 0.03% NiO blended with Paraffin

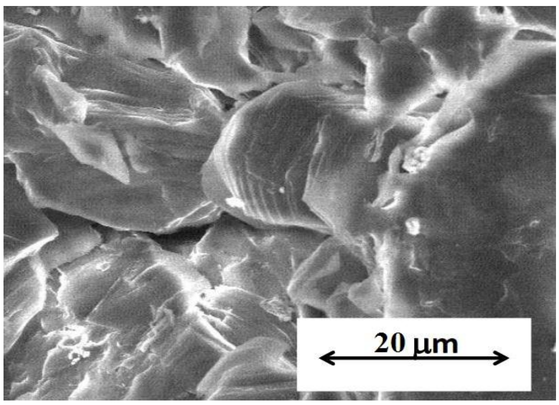

Fig -5: FESEM Image of 0.1% NiO blended with Paraffin

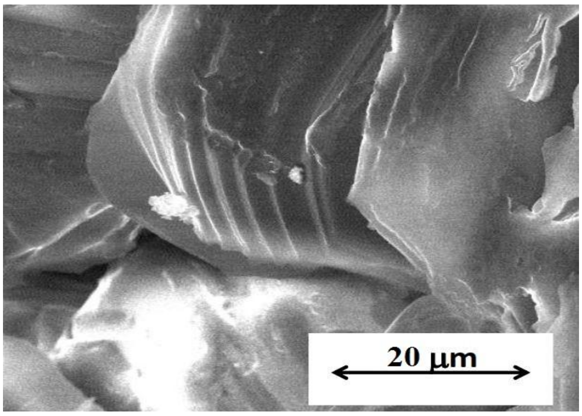

Fig -6: FESEM Image of 0.15% NiO blended with Paraffin

3. EXPERIMENTAL SETUP

Initially PCM tank and water storage tank are made with dimension of the water storage tank length is 60 cm, width is 60 cm, depth is 25 cm and volume of tank is 90000cm^3.pipe connections are made between water circulation pump and storage tanks. pcm storage tank made with diameter of 11 cm and height of 25 cm. The flow rate of water is 7.5 lit/min, kinematic viscosity is 5.2275E^{-7} m^2/s. calculated velocity of water through pipe line is 0.98 m/s, the Reynolds number is 23886>2300 so it is turbulent flow. The k type thermocouples are inserted to the inlet, outlet of PCM tank and also to the inside of PCM tank. The insulation of pcm tank is also made. The 2000 w water heater is fixed into water storage tank.

3.1 Experimentation

Water storage tank temperature maintained to 70°C. Then after reach required temperature the water is starting to circulate through the pipes to the PCM tank. The flow of water was controlled by the control valves and constant flow is maintained thought the experiment.

Fig -7: Experimental setup

Time at which experiment is started, initial reading of thermocouples and rate of flow are noted down. The volume of water reduced due to evaporation and other losses are controlled by adding of water at proper interval. The thermocouple readings are noted for the interval of every 30 min and time taken for paraffin to reach the complete melting point are noted down .When the temperature of the pcm tank reaches 63 °C. The experiment is reversed by supplying fresh water into it and time taken for discharge of paraffin is determine.The experiment is repeated for different flow rate of water. The paraffin containing Nanoparticle was placed in the PCM store tank and the experiment was carried out once again and the temperatures were observed .The results from both experiments are compared.

4. RESULTS AND DISCUSSION

The experiment was conducted in various water flow rates. Loading and unloading time of raw paraffin and NiO nano particle mixed paraffin are tabulated and a graph has drawn between them.

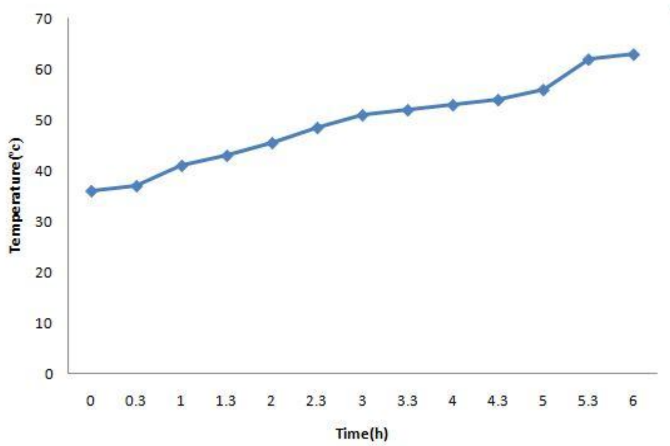

Chart -1: Loading of pcm without nano composite at mass flow rate of 7.5 L/min

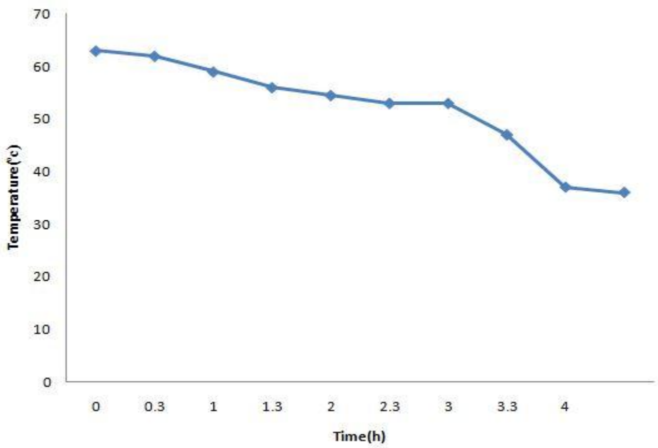

Chart -2: Unloading of pcm without nano composite at mass flow rate of 7.5 L/min

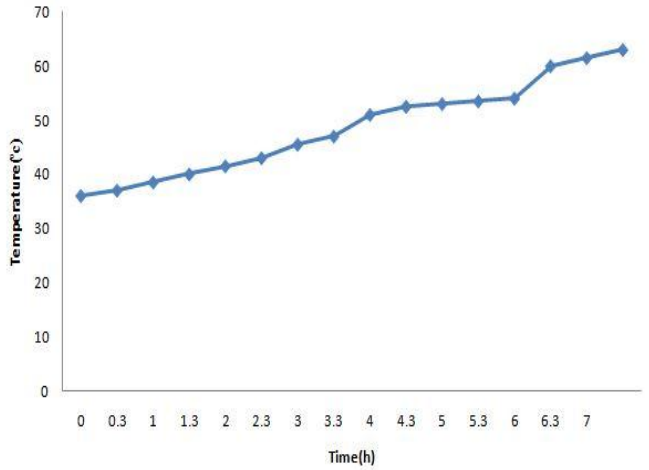

Chart -3: Loading of pcm without nano composite at mass flow rate of 5 L/min

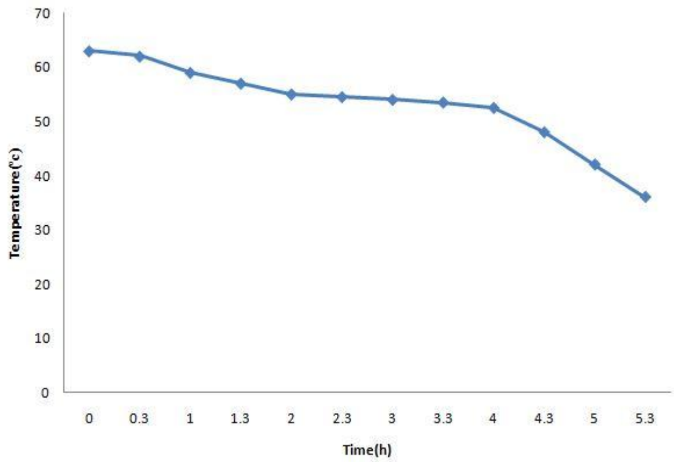

Chart -4: Unloading of pcm without nano composite at mass flow rate of 5 L/min

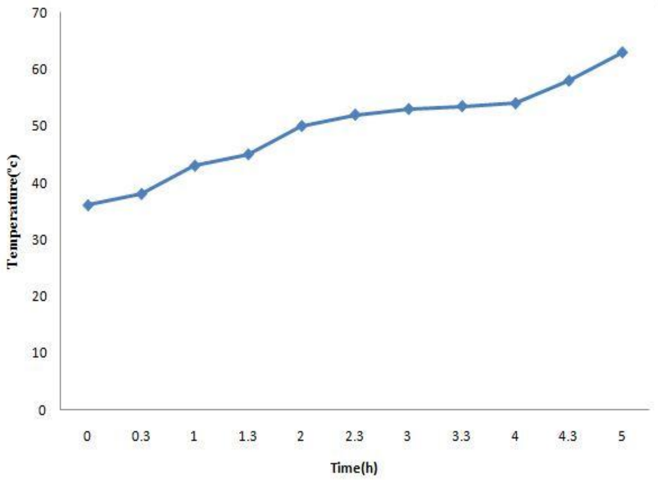

Chart -5: Loading of pcm with nano composite at mass flow rate of 7.5 L/min

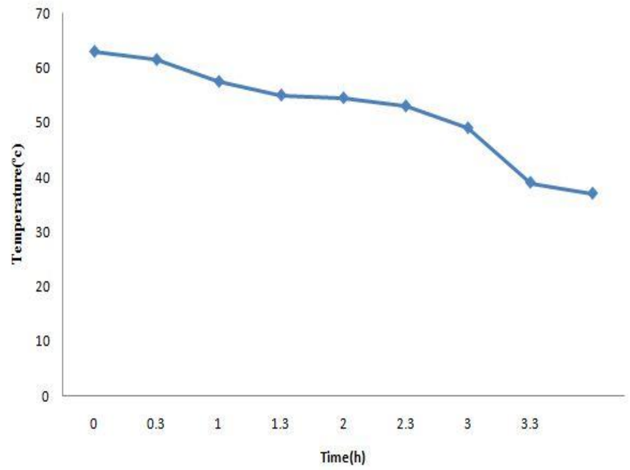

Chart -6: Unloading of pcm with nano composite at mass flow rate of 7.5 L/min

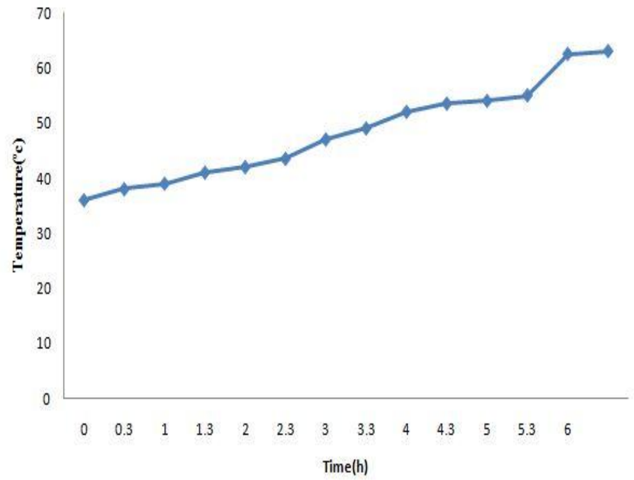

Chart -7: Loading of pcm with nano composite at mass flow rate of 5 L/min

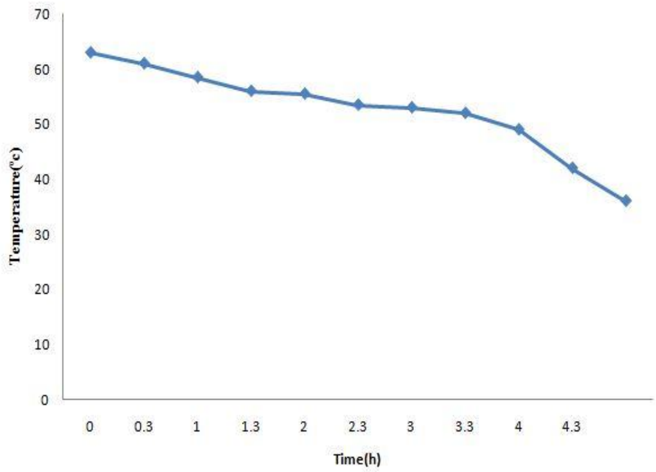

Chart -8: Unloading of pcm with nano composite at mass flow rate of 5 L/min

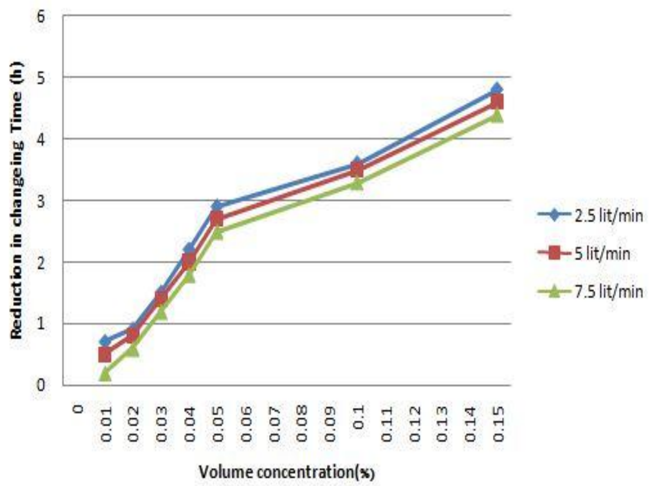

Chart -9: Reduction in charging time

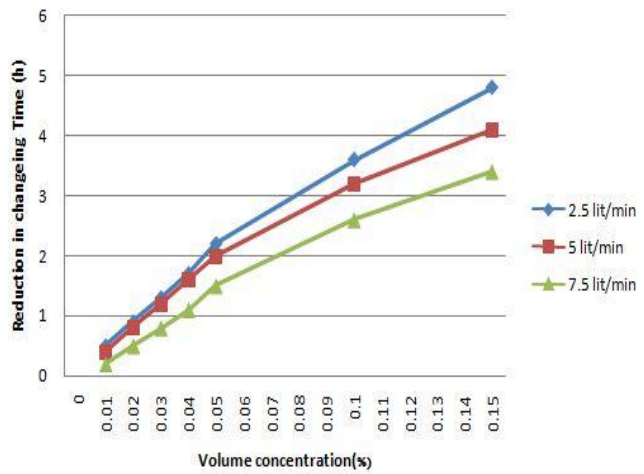

Chart -10: Reduction in discharging time

4. CONCLUSION

In this project different cases of thermal energy storage have been studied. The Paraffin is considered as a PCM and the thermal conductivity of phase change material was improved by adding NiO nano particle with paraffin wax. An experimental setup was made to conduct the tests on pcm. When adding the nano material of 2% to the paraffin then the thermal conductivity of the paraffin is increased to 5% so the loading time is reduced to 12% and unloading time reduced to 11.5%. The improved thermal conductivity is reducing the loading and unloading time of the pcm.

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