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THERMAL STABILITY AND THERMAL PROPERTIES OF NANO-ENHANCED SOLID-SOLID PCM AS ENERGY STORAGE MATERIALS

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ABSTRACT

With the rapid technological developments taking place in an expeditious manner, PCM (phase change materials) holds an immense importance in thermal energy storage. Due to the low thermal conductivity of PCM it is enhanced with Nano particles. Neopentyl glycol(NPG) [2,2-dimethylpropane-1,3-diol] is enhanced with alumina Nano particles in concentrations of 0.5% and 1% by weight. Tests are conducted to ascertain the thermal properties and thermal stability of the PCM. The thermal properties of the PCM are determined using the T-history test and its thermal stability by DSC test subjected to 300 cycles. From the T- history test it can be concluded that the thermal conductivity and specific heat of the sample decreases with the number of thermal cycles conducted. With the increase in concentration of alumina the thermal conductivity is found to be increasing and the specific heat is found to be decreasing. DSC test shown that the samples are thermally stable with minimum degradation after 300 cycles.

KEYWORDS: PCM, Nano-enhanced PCM, Alumina, DSC, T-history.

1. INTRODUCTION

During phase change process, phase change materials (PCM's) can absorb, store and release a large amount of thermal energy and it has higher thermal energy density than sensible thermal storage materials. Large amounts of energy can be stored in relatively small volumes, that makes phase change materials one of the lowest storage media costs of any storage concepts [1, 2, and 3]. The organic materials are found to be more chemically stable than inorganic substances, and for organic substances sub-cooling does not create a significant problem[4].As the material changes phase from solid to liquid, the reaction being endothermic, the PCM absorbs heat energy and gets released as the temperature decreases. The solid – liquid PCM are having high mass loss occurring during the transition which is thus replaced by solid-solid PCM which has high latent heats as far as the latent heats of solid – liquid PCM are concerned. Solid-solid transition occurs at a well-defined temperature where the physical and chemical properties of PCM changes when its crystalline structure gets changed. P.Hu et.al [5] has experimentally investigated solid–solid phase change properties of pentaerythritol (PE)/nano-AlN composite for thermal storage. It is found that the addition of nano-AlN can accelerate the crystallization rate and reduce the super cooling of PCM. By adding Nanoparticles, the low thermal conductivity of the PCM is improved which acts as nucleating agent and improves the thermal conductivity of the mixture [6-9].In comparison to a reference sample, DSC measures the amount of heat absorbed or released by a sample. From DSC measurements, heating and cooling curves of PCM is obtained. By analyzing these results, the thermal properties and latent heat capacity of PCM can be determined [10].In TGA technique the amount and rate of change in the weight of a material is measured as a function of temperature or time in a controlled atmosphere. Fourier transform infrared spectrophotometer (FTIR) was used to identify chemical stability of PCMs. FTIR spectrum of PCM sample before and after thermal cycling was taken. The obtained spectra were compared with that of pure to determine whether a change occurred in chemical structures of PCM [11]. For measuring the specific heats and thermal conductivities, a simple method called *T*-history method, is used for determining the thermal properties of several PCM samples simultaneously[12,13].

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2. MATERIALS AND METHODS

2.1Materials Used

The materials were purchased from Alfa Asear with purities of 98% for Neopentyl Glycol (NPG, $C_5H_{12}O_2$)which is an organic solid-solid phase change materials, where the transition takes place at 40-48^{0}C and Aluminum Oxide (Al_2O_3) nanoparticles having 99.5% purity with 40-50nm powder size is used to improve the thermal conductivity of the materials were also purchased from Alfa Asear.

2.2 Sample Preparation

The Nanoparticle (Al_2O_3) were added to Neopentyl Glycol in 0.5% and 1% mass fraction. Proper mixing of Nano additive in PCM was ensured with the aid of the low energy lab ball mill (0.5HP/230V/50Hz/300rpm, Make: VB Ceramics) operated at 200rpm for 120 minutes.

2.3 Methods

2.3.1 Thermal Cycling Test

A thermal cycling test was done to determine the cycling stability of the PCMs. The samples were subjectedto repeated charging and discharging in the thermal cycling unit. The schematic diagram of the thermalcycling experiment setup is shown is the figure 1. The test unit consists of a hot plate. The PCM sample temperature and hotplate temperatures are recorded with the help of thermocouples connected to a computer-controlled data logger

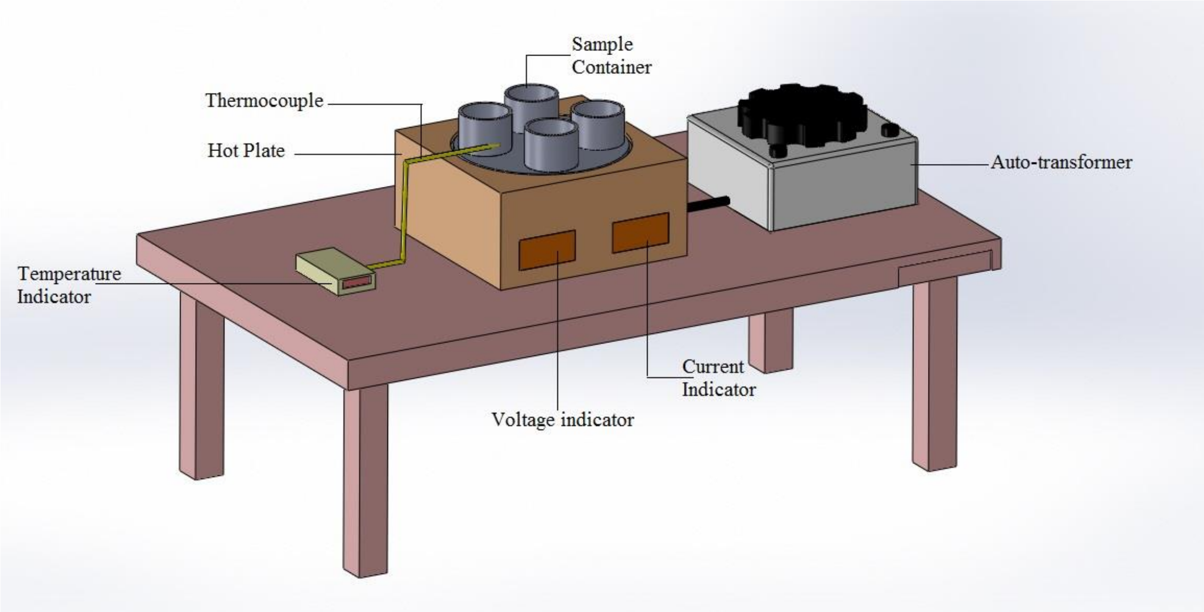

***Figure 2.1.Thermal Cycling Setup*[14]**

2.3.2 T-History Method

In order to simultaneously measure heat capacity and thermal conductivity of several samples in a single experiment T-history method was used . This is a process which is based on the derivation of a model for the concern where the test tube containing the material is at a uniform temperature and then slowly exposed to a low atmospheric temperature; it is considered that atmospheric temperature is time dependent.

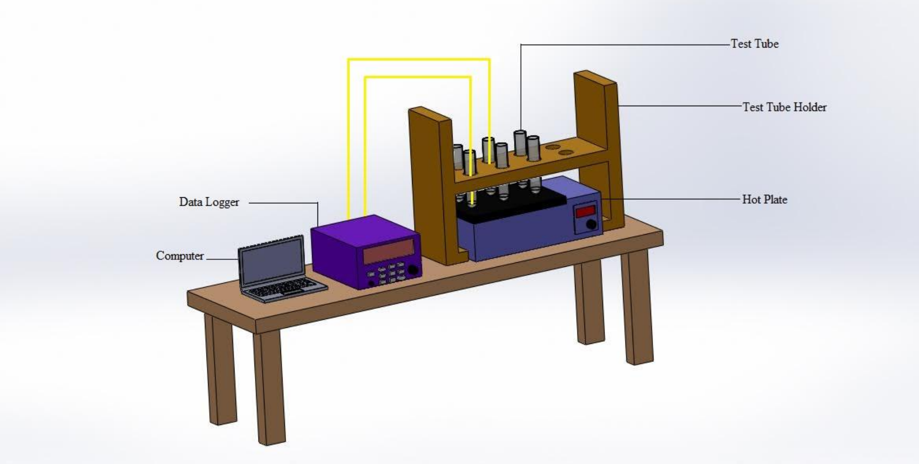

***Figure 2.2.T-History Setup*[14]**

Initially the required mass of the PCM, the mass of glycerin and the mass of the test tubes are measured with the help of a weighing machine. The weighed PCM along with the test tube are placed on the experimental rig. Thermocouples connected to the data logger are kept in contact with the PCM. The setup is placed over the hot plate and heat is provided at a constant rate. The corresponding data are recorded in the PC with the help of the data logger. The graph is plotted and the calculations of the specific heat and thermal conductivity are made.

The specific heat can be calculated using the following equation;

$$c_p=\frac{m_g c_{p,g} + m_t\ c_{p,t}}{m_p}\frac{Ap}{Ag} - \frac{m_t}{m_p}c_{p,t} \quad \ldots\ldots\ldots\ldots\ldots(1)$$

where,
m_g=mass of glycerin(kg); m_t=mass of test tube(kg); m_p=mass of PCM(kg); $C_{p,w}$=specific heat of glycerin(2.43J/KgK); $C_{p,w}$=specific heat of test tube(0.84J/KgK); A_p=area of PCM under the curve; A_g=area of glycerin under the curve.

$$k=\frac{1+\frac{c_p(T_m-T_\alpha)}{H_m}}{4[\frac{t_f(T_m-T_\alpha)}{\rho_p R^2 H_m}]} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where,
c_p=specific heat at constant pressure(J/KgK); H_m=enthalpy of melting point(J/kg); T_m=melting temperature PCM(^{0}C); $T_\propto$=room temperature(^{0}C); t_f=time for steady state considering graph;ρ_p=density of particle(kg/m^3); R=radius of test tube.

2.3.3 DSC Method

DSC measures the temperature and heat flows associated with transitions in materials as a function of time and temperature in a controlled atmosphere. DSC is used for determining transition temperature and latent heat associated with the transition. The samples are heated at a particular rate say 10ºC/min. The heat flow v/s temperature graph is plotted. At a particular point there is a sudden increase in heat flow. Area corresponding to this peak in DSC curve gives the enthalpy of phase change. The temperature corresponding to the peak in DSC curve gives the transition temperature.

3. RESULTS AND DISCUSSION

For characterizing the heat transfer properties of a material, thermal conductivity and specific heat are the most important thermal properties. The method that is executed to find the thermal conductivity is T-history analysis. DSC test is used to find the phase transition temperature and latent heat of PCM.

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3.1 T history test

The Thermal properties such as thermal conductivity and specific heat are tabulated in the table 1.

Table 1. Thermal Property values of NPG

Sample	Specific Heat(kJ/KgK)		Thermal Conductivity(W/mK.)	
	Before Cycling	After Cycling	Before Cycling	After cycling
Pure NPG	2.6575	2.6168	0.1091	0.103336
NPG + 0.5% Al_2O_3	2.6063	2.5769	0.1106	0.108614
NPG + 1% Al_2O_3	2.5868	2.560	0.1199	0.113232

From the test results it is found that the addition of the nanoparticles to the PCM increases its effective thermal conductivity at the expense of its latent storage capacity. The results after thermal cycling show that there is a slight decrease in thermal conductivity and specific heat values. Variations in specific heat and thermal conductivity of samples before and after cycling is represented in figure 3(a) and (b).

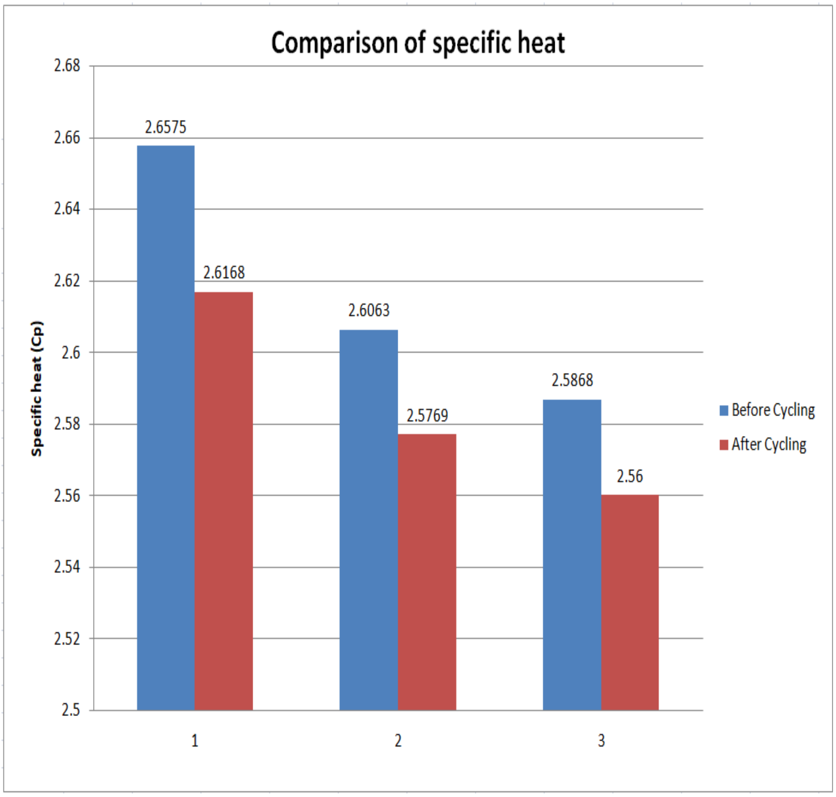

Figure.3(a). Specific Heat of NPG

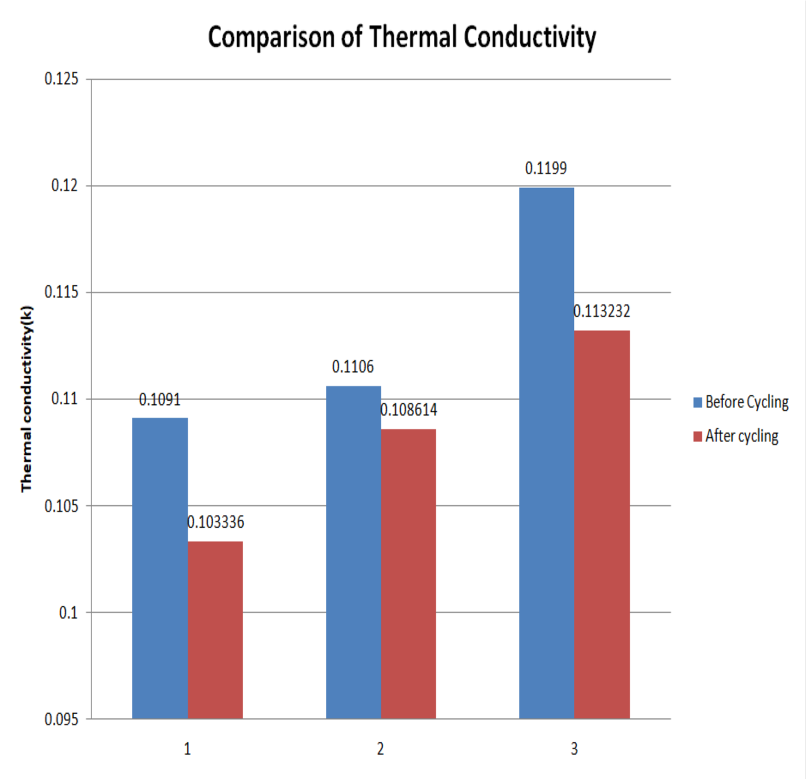

Figure.3(a). Thermal Conductivity of NPG

The percentage increases in the thermal conductivities and decreases in specific heat of the samples due to the addition of nanoparticles and thermal cycling are tabulated in table 2 and table 3. The results show that the enhancement in thermal conductivity is greater in the case 1% Al2O3 mixed PCM as compare to pure PCM.

Table 2 Effect Of Addition Of Alumina On Specific Heat Capacity And Thermal Conductivity

Samples	%Decrease in specific heat	% Increase in thermal conductivity
NPG+0.5% Alumina	1.92	1.375
NPG+1% Alumina	2.66	9.899

Table 3 Effect Of Thermal Cycling On Specific Heat Capacity And Thermal Conductivity

Samples after 200 thermal cycles	%Decrease in specific heat	% decrease in thermal conductivity
Pure NPG	1.531	5.288
NPG + 0.5% Alumina	1.128	1.79
NPG + 1% Alumina	1.03	5.56

3.2 DSC Test

Phase transition temperature and latent heat associated with the phase transition obtained from DSC test are tabulated in table 4

Table 4

Sample	Transition Temperature (^{0}C)		Latent Heat of Transition (J/g)	
	Before Cycling	After Cycling	Before Cycling	After cycling
Pure NPG	49.86	48.02	124.884	122.21
NPG + 0.5% Al_2O_3	46.68	45.53	120.6	118.42
NPG + 1% Al_2O_3	46.32	44.85	114.23	104.4

Table 4 shows the transition temperature latent heat associated with heat flow of samples before and after thermal cycling.

The results show that the addition of nanoparticles tend to slightly decrease the transition temperature and latent heat of transition. On comparing the samples before and after thermal cycles there was a reduce in transition temperature and latent heat. Since the changes are slight and not much significant, the samples are said to be thermally stable.

4. CONCLUSION

The specific heat and thermal conductivity for the samples were obtained from the T-History method and an enhancement in thermal conductivity using alumina nanoparticle was observed. On comparing the samples before and after thermal cycles it was seen that there was a reduction in thermal conductivity and specific heat. Among the Nano-enhanced samples, it can be concluded that 1% alumina Nano-enhanced has the highest percentage increases in thermal conductivity of 9.899%. Using DSC method latent heat of transition and transition temperature of the samples are obtained. It is found that the transition temperature and latent heat are decreased on addition of nanoparticles and thermal cycling. The samples are said to be thermally stable since the changes are not significant.

5. ACKNOWLEDGEMENTS

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