



ENHANCEMENT OF THERMAL CONDUCTIVITIES OF CAPRIC ACID, LAURIC ACID AND GRAPHENE COMPOSITES.

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Abstract : Phase change materials are frequently & widely used in latent thermal energy storage system and thermal management system due to their large latent heats and capabilities of maintaining nearly constant temperature. However the performance of PCM's in latent thermal energy storage & thermal management systems are seriously limited by their low thermal conductivities and poor heat transfer performance. In this project we are developed composite PCM (Capric acid – 450grams, Lauric acid – 450grams, Graphene – 15grams). The three different CPCM sample 1. Grapheme 40% wt + Lauric acid 45% wt, sample 2. Capric acid 15% wt + Graphene 35% wt + Lauric acid 30% wt, sample 3. Capric acid 10% wt + Graphene 25% wt + Lauric acid 25% wt was developed and their thermal conductivities are measured in experimental approach. The results are indicated the thermal conductivities of composite PCM were higher compared to PCM. Sample 2 having high thermal conductivity compared to other two samples.

Index Terms – Organic PCM, Graphene, CPCM, and Thermal conductivity.

I. INTRODUCTION

Thermal energy storage is a key process which has been widely applied in various energy transportation and utilization system. Three major technologies currently being considered for heat storage include: sensible heat-, latent heat- and thermo-chemical-heat storage. Among the three technologies, latent heat thermal energy storage (LHTES) is most promising for heat storage due to the consistent temperature and large thermal capacity [1]. Latent heat thermal energy storage (LHTES) is becoming an attractive technique to overcome the energy crisis and environment problem. In a LHTES system, heat energy can be stored/ released during melting/freezing process of phase change materials (PCMs). Unlike other energy storage techniques, LHTES can provide high energy storage density and has the advantage of storing latent heat at a nearly constant temperature corresponding to the phase change temperature of PCMs. These features make PCMs widely used in various applications such as energy buildings, clothing manufacture and condensation heat recovery [2].

Qianjun Mao [3] was investigated the thermal energy storage performance of a three-PCM cascade tank in a high-temperature packed bed system the results was indicated that heat storage capacity and utilization rate of 3-PCM energy storage tanks are relatively high. And that increase from 86.07% to 86.65% and 86.07% to 86.67%, respectively, when the porosity is reduced from 0.6 to 0.1. This results in an increase in the total storage energy of 5.2×10^{12} Wh to 1.3×10^{13} Wh. Similarly, when the particle diameter decreases from 0.6 to 0.1, the storage capacity ratio and utilization rate increase from 85.8% to 87.3% and 85.6% to 87.4%, respectively. Mustafa S. Mahdi et.al [4] was presented Improved PCM melting in a thermal energy storage system of double-pipe helical-coil tube Results reveal that the thermal performance of the double-pipe helical-coil LHTES during the PCM melting phase is spurious compared with that of others. Moreover, results show that the coil pitch has a remarkably impact on the total PCM melting time in the double-pipe helical-coiled tube, however the optimum coil pitch is 2 OD. The analysis also reveals that the initial temperature and Reynolds number (Re) of heat transfer fluid (HTF) are other factors that significantly affect the PCM melting process. Yong Tae Lee et.al [5]

Numerical analysis in a full-scale thermal energy storage tank with dual PCM capsules the results are indicated the range of the ratio of cooling-PCM and heating-PCM was found to satisfy both the required energy storage densities in heating and cooling demand. For the required energy storage densities of heating mode, 25 kwh/m³, and cooling mode, 30 kwh/m³, the results suggest the combined ratio in the dual PCM tank is within a 50/50-90/10 mixing zone ratio, of the cooling-PCM/heating-PCM respectively. Xian Wan et.al [6] Thermal characterization of net-like and form-stable ML/SiO₂ composite as novel PCM for cold energy storage The DSC results showed that the net-like PCMs melted at 6.71 °C with a latent heat of 151.3 J/g and solidified at -5.43 °C with a latent heat of 148.9 J/g. Besides, the PCMs composite exhibited outstanding chemical compatibility, thermal reliability and complete micro morphology. Sepehr Mousavi et.al [7] Battery thermal management with thermal energy storage composites of PCM, metal foam, fin and nano particle the results indicated that the porous-PCM composition performs more efficiently than the nano-PCM and the fin-PCM ones. In addition, ΔT_{avg} , battery parameter is introduced and its variations are analyzed to judge about the effect of each technique to reduce the battery mean temperature. Using the porous-PCM led to 4–6 K reduction in the battery mean temperature with respect to the pure PCM. Moreover, for the porous-PCM composition a delay is observed in the PCM melting initiation time that can adversely affect the performance of battery TMS.

II. EXPERIMENTAL

2.1 Statement of Problem

Performance of PCM in thermal energy storage system & thermal management system are seriously limited by their low thermal conductivities and poor heat transfer performance. So we are developed composite phase change material for improving their thermal conductivity and their heat transfer rate

2.2. Materials

Table 2.1 Materials and their thermo physical properties.

Materials	Melting temperature °C	Thermal conductivity W/MK	Density Kg/M ³	Latent heat KJ/Kg
Lauric Acid	43.2	0.442	880	
Capric Acid	31.6	0.372	893	
Graphene	3652 – 3697	2000	150	

2.3 Preparation of PCM Composites

Cold compression method has adopted to prepare the PCM Composites. Table 2.2 shows the three different samples and their weight percentage.

Table 2.2 CPCM samples and their weight percentage.

Materials	Sample 1	Sample 2	Sample 3
Lauric Acid	45% wt	30% wt	25% wt
Capric Acid	-	15% wt	10% wt
Graphene	40% wt	35% wt	25% wt

Capric acid and Lauric acid are heated up to 80°C and maximum 3 hours, capric acid was melted in 28°C and lauric acid was melted in 48°C, then the graphene was added into the molten CPCM and continuously stirred by a magnetic stirrer at 1200 rpm. After completeing

the preparation process the composites was cooled at below 10°C for 8 hours. Figure 2.1 (a) shows the melting process of lauric acid and capric acid, (b) shows the graphene powder added in to molten PCM, (c) shows final sample of CPCM.



(a)

(b)

(c)

Figure 2.1 (a) Melted PCM. (b) Added Graphene into molten PCM. (c) CPCM sample 1

2.4 Measuring method of thermal conductivity of composite PCM's

One dimensional steady state heat conduction approach, which is based on the Fourier's law to determine the effective thermal conductivity under the steady state. Where experimental setup in combination of heat sink, thick aluminum block, thin aluminum block, CPCM samples and it was thermally insulated to minimize the heat loss. The heat flux from the heater to the heat sink could be determined by the thermal conductivity of aluminum, temperature difference and distance between the measuring of the aluminum block. Then the thermal conductivity of CPCM was calculated based on corresponding measured temperature and distance.

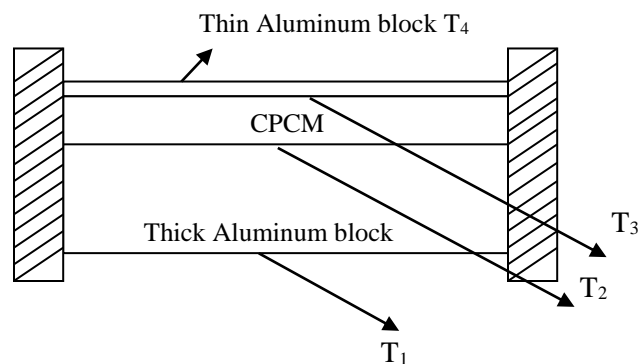


Figure 2.2 Typical experimental setup of effective thermal conductivity measurement by one dimensional steady state heat conduction method.

$$Q = K_{Al} + A \frac{T_4 - T_1}{dx} \quad (1)$$

Where, Q – Heat transfer of test rig in KJ/Kg, K_{Al} – Thermal conductivity of aluminum in W/m²K, A – Area of test rig in m², dx – Distance between the heater and heat sink in m, T_4 –Temperature of thin aluminum block in K, T_1 – Temperature of thick aluminum block in K.

$$Q = 2\pi K_{CPCM} L \frac{(T_2 - T_3)}{\ln r_o / r_i} \quad (2)$$

Where, Q – Heat transfer of test rig in KJ/Kg, K_{Al} – Thermal conductivity of CPCM in W/m²K, r_o – radius of outer pipe in m, r_i – radius of inner pipe in m, T_3 – Lower temperature of CPCM in K, T_2 – Higher temperature of CPCM in K. Temperature was measured many times in each samples and take the high temperature difference range to calculate the heat transfer and thermal conductivities.

III. RESULTS AND DISCUSSION

Thermal conductivities are measured in experimental approach for three CPCM samples. The temperatures are started to record after 120 minutes of heating process. Initially the temperatures are recorded the outside of thick Al block and outside of thin Al block and the heat transfer was calculated using Fourier's law of heat conduction equation and then CPCM temperatures are recorded inside and outside surface of the CPCM pipe. Then the thermal conductivity of CPCM was calculated. The temperatures are measured using a temperature sensor. Table 3.1 shows the measured temperatures of three CPCM samples. The three samples are measured the same time sample 2 was starting to melt at 62 to 64°C and other two samples are starting to melt at 54 to 56°C.

Table 3.1 Measured temperatures of three CPCM samples.

Samples	Bottom side of Thick Al block (°C)	Bottom side of CPCM pipe (°C)	Top side of CPCM pipe (°C)	Top side of Thin Al block (°C)
Sample 1	66.42	56.54	54.28	59.42
Sample 2	77.21	65.61	63.28	71.91
Sample 3	76.4	58.41	54.82	71.22

Table 3.2 shows the calculated thermal conductivities of three samples. The composite PCM samples thermal conductivity was increased compared to Capric acid and Lauric acid. Lauric acid thermal conductivity is 0.442 W/mK and capric acid thermal conductivity is 0.372 W/mK. Thermal conductivity of Grapheme 40% wt + Lauric acid 45% wt mixture is 8.05 W/mK, Thermal conductivity of Capric acid 15% wt + Graphene 35% wt + Lauric acid 30% wt is 9.09 W/mK, Thermal conductivity of Capric acid 10% wt + Graphene 25% wt + Lauric acid 25% wt is 5.05 W/mK.

Table 3.2 Calculated Thermal conductivities of three samples.

Samples	Thermal conductivity W/mK
Sample 1	8.05
Sample 2	9.09
Sample 3	5.05

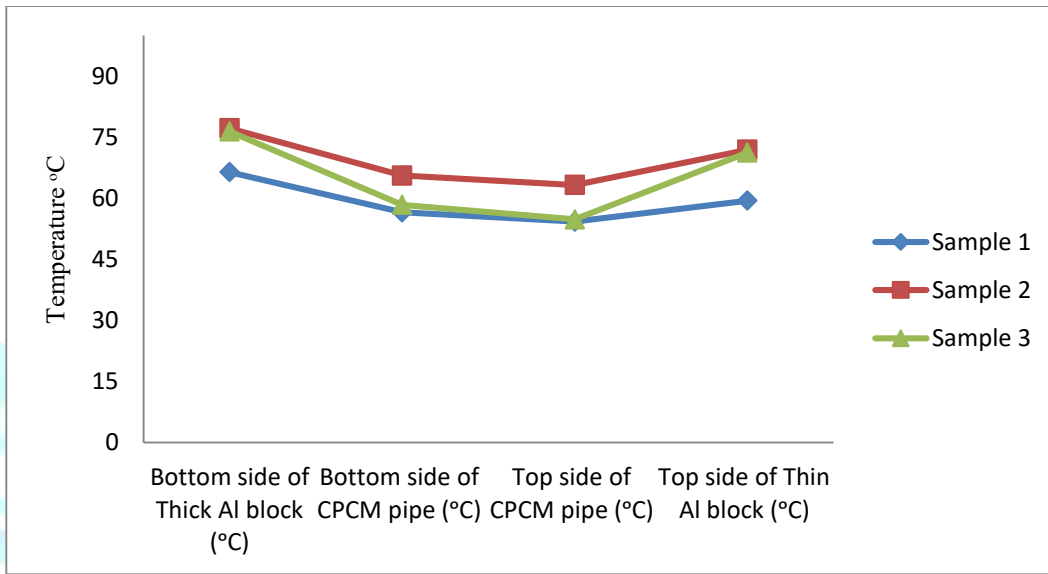


Figure 3.1 Variation in measured temperatures

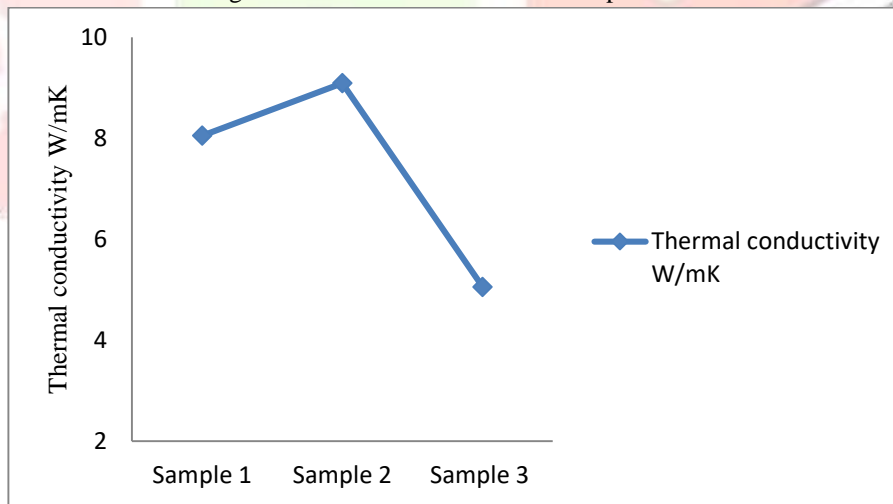


Figure 3.2 Variation in calculated thermal conductivities.

Figure 3.1 represents the variation in measured temperatures at various point with respect to bottom side of Thick Al block, bottom side of CPCM side, top side of CPM side, top side of Thin Al block. Figure 3.2 represents the variation in calculated thermal conductivities, high thermal conductivity compared to other two CPCM samples is Capric acid 15% wt + Graphene 35% wt + Lauric acid 30% wt mixture was found 9.09 W/mK.

IV CONCLUSIONS

The experimental studies on the thermal conductivities of the composite PCM samples, the following conclusions can be drawn.

- ✓ Composite PCM can increase the thermal conductivity maximum 8.648 W/mK.
- ✓ Capric acid 15% wt + Graphene 35% wt + Lauric acid 30% wt mixture having high thermal conductivity compared to other to composite PCM samples.

The similar analysis may be considering to SEM images of CPCM samples and to obtain the thermal conductivity of the same samples as scope for the future research.

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