ISSN (Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

IJIRSET

International Journal of Innovative Research in Science, Engineering and Technology

An ISO 3297: 2007 Certified Organization | Volume 4, Special Issue 2, February 2015

5th International Conference in Magna on Emerging Engineering Trends 2015 [ICMEET 2015]

On 27th & 28th February, 2015

Organized by

Department of Mechanical Engineering, Magna College of Engineering, Chennai-600055, India.

Studies on Paraffin-Graphite-Cu PCM Composites for Solar Thermal Storage Applications

Kavitha. K[1,] Arumugam. S[2]

Solar Energy Division, Department of Physics, Gandhigram Rural Institute-Deemed University, Gandhigram, Tamilnadu, India[1, 2].

ABSTRACT: In this paper an experimental investigation on the thermal storage capacity for a typical composite mixture of paraffin- Graphite- Cu PCM composite has been studied. Paraffin wax was used as the base phase change material (PCM) and the paraffin has been mixed with Cu turnings in different ratios 10, 50, 70 and 90 weight percentages and considered as a composite. The thermal charge and discharge capacities of the paraffin- copper composite were tested and reported. The Paraffin copper PCM composite was found to have higher heat transfer capacity when compared to pure paraffin as PCM material. The heat charge and discharge performance of the Paraffin was found to be high, when the Cu turnings were mixed with paraffin in a smaller ratio of 10 weight percentage when compared with other weight percentage mixtures of copper. The shiny black colour nature of graphite has been considered to provide a better absorption. The paraffin-Cu composite mixture was studied for different weight percentage 10, 20, and 30 mixture of Graphite powder. It was found that 20 weight percentage mixture of the graphite with paraffin-Cu had considerable better heat energy storage potential because of its expected good heat transfer property and the results have been presented. These composite (paraffin- Graphite- Cu) sample were encapsulated in heat exchanger pipe of .02m diameter sealed at both ends of length 0.3m were subjected to thermal charging and discharging capabilities. From the observation it is noted that heat exchanger pipes with the PCM composites have higher rate of rise of temperature of 14.7 X 10^{-3} 8C/s, while charging the PCM composite. When compared with the charging performance of pure paraffin, the rate of rise of temperature for the pure paraffin is known to be 6.389 X 10^{-3} 8C/s. So the thermal charging time gets enhanced to more than double while using the PCM-composite as the PCM material for thermal energy storage instead of pure paraffin alone. The rate of fall of temperature of the pure paraffin while discharging was 1.94X10^{-3}8C/s which was less than the rate of fall of temperature of the best composite 4.167X10^{-3}8C/s. A best composition of PCM composite has been identified from the present study. The thermophysical properties of the paraffin and paraffin-Graphite-Cu composite are determined through the differential scanning calorimeter (DSC) analysis. Further study is in process to use the PCM-composite in solar water heating application in solar thermal storage utilities.

KEYWORDS: PCMs, Copper turnings, Latent thermal energy storage, Heat transfer, Graphite powder, DSC

I. INTRODUCTION

The quest for new technologies to avert the growing concern about environmental problems, the imminent energy shortage and the high cost of energy and new power plants has been a scientific concern over the last three decades. Central to the problem is the need to store excess energy that would otherwise be wasted and also to bridge the gap between energy generation and consumption. Latent heat thermal energy storage is particularly attractive technique because it provides a high-energy storage density. When compared to conventional sensible heat energy storage systems, latent heat energy storage system requires a smaller weight and volume of material for a given amount of energy. In addition latent heat storage has the capacity to store heat of fusion at a constant or near constant temperature which correspond to the phase transition temperature of the phase change material (PCM) [1]. The use of paraffin wax as a phase change material in small aluminum containers packed in conventional water storage tanks represents an

ISSN (Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

An ISO 3297: 2007 Certified Organization *Volume 4, Special Issue 2, February 2015*

5th International Conference in Magna on Emerging Engineering Trends 2015 [ICMEET 2015]

On 27th & 28th February, 2015

Organized by

Department of Mechanical Engineering, Magna College of Engineering, Chennai-600055, India.

approach for simple and inexpensive thermal energy storage. Such storage can be reliably used with conventional and existing solar water heating systems. The suitability of the melting temperature of paraffin wax enables the storage of excess energy available in daytime hours as latent heat, and then the release of this stored heat to maintain the water temperature in an acceptable range for most domestic applications [2]. It is found that phase change process of the binary mixture takes place over a temperature range and the temperature range depends on both the heating rate and the mixture composition [3].Soft computing techniques can be used to model of a solar collector with PCM [4]. Different metals are also used with PCMs to improve the thermal storage performance [5]. Graphite was also used to increase thermal diffusivity of the Paraffin [6], [7], [8], [9], [10]. The progress in latent heat storage energy systems depends on the development of efficient heat exchangers for energy transfer between a PCM and a working fluid during charging and discharging [11]. The Palmatic acid was confined in maximum percentage of 80 wt% without leakage of melted PCM from porous structure of the EG and therefore, the composite was described as form-stable PCM [12]. Adding expanded graphite into paraffin to form paraffin graphite composite also proves to be a feasible method for heat transfer enhancement [13].When compared to the pure PCM with PCM/CENG composites, the composites shows high and stable thermal power and it easily defined the phase change duration. The thermal storage processes using such composite materials are designed and managed much more easily [14]. Adding expanded Graphite into paraffin to form paraffin-graphite composite improves the heat transfer enhancement. Metal foams also provide better heat transfer performance due to its continuous inter-connected structure. Adding metal foams and Graphite into PCMs can enhance the heat storage capabilities. Metal foam continuous structure enhances the heat transfer capacity of the paraffin wax more than the Graphite [15]. The thermal conductivity of the heat exchanger container material doesn't have any effect on the thickness of the heat exchanger container material. The boundary wall temperature plays an important role during the melting process and has a strong effect on the melt fraction [16].

II. MATERIALS AND METHODS

Commercial grade paraffin wax was used in the experiment. Copper, graphite is used to make the PCM composite. Electric heater was used to heat the samples. A Solar Paraffin Wax melting chamber (figure 12) of area 0.22 m^2 was constructed to study the melting /solidification characteristics of Paraffin wax. Copper Constantan monojunction thermocouples were used to measure the temperature. Polyurethane foam was used for thermal insulation purposes. Galvanized iron (GI) pipes are of diameter 0.019 m and length 0.30 m were chosen as the heat exchangers (pipe). Each pipe was filled with 115 grams of paraffin wax. A monojunction thermocouple was fixed on the outer surface of the GI pipe arrangement to study the pipe temperatures. Similarly another thermocouple was inserted inside the GI pipe and well sealed to study the Paraffin wax temperature in the pipe during charging/discharging process. The heat collection cum storage unit was covered with two glass layers.

III. RESULT AND DISCUSSION

A. Differential scanning calorimetry (DSC Analysis):

The Melting characteristics of paraffin and PCM-Composite samples were measured using a DSC instrument. The thermophysical changes of the samples were recorded in the temperature intervals from 30 °C and 500 °C when subjected to application of heat at a uniform heating rate of 20 °C/min.

ISSN (Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

An ISO 3297: 2007 Certified Organization *Volume 4, Special Issue 2, February 2015*

5th International Conference in Magna on Emerging Engineering Trends 2015 [ICMEET 2015]

On 27th & 28th February, 2015

Organized by

Department of Mechanical Engineering, Magna College of Engineering, Chennai-600055, India.

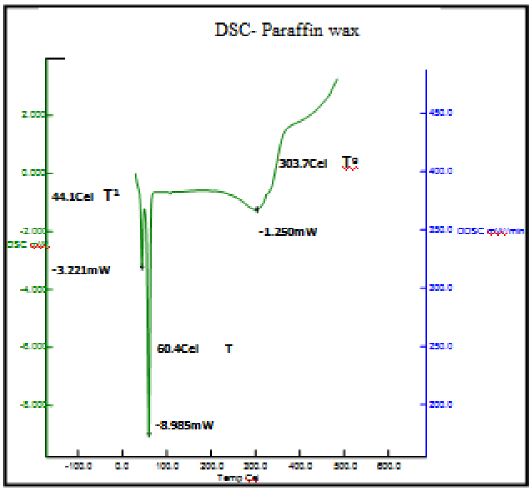


Fig 1: DSC of paraffin

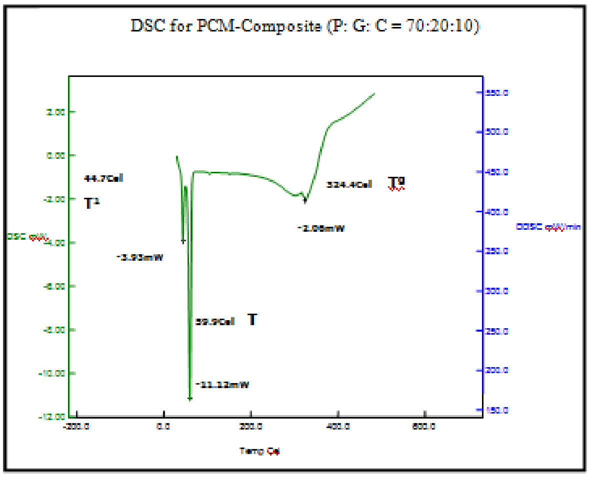


Fig 2: DSC for PCM-Composite (P: G: C = 70:20:10 Wt %)

A 3 mg of sample was taken and sealed in an aluminum pan. The melting temperature range of the sample was taken as peak temperature of DSC curve. The enthalpy has been determined from the area under the peak which represents solid melting to liquid phase and converting all solid wax into liquid and from liquid to gaseous phase change. The thermophysical properties of the paraffin and the PCM-Composite used in the study are given in Table 1. Figure 1, 2 shows the result of DSC analysis for paraffin and composite. Three dips were noted in the Figure 1. The first dip T^1 represents a temperature of 44.1 °C with the beginning of the melting of solid paraffin into liquid with the energy absorption of thermal absorption of -3.221mW. The second dip T represents a temperature of 60.4 °C the complete melting with the energy absorption of -8.985mW represents the complete melting of the paraffin wax into paraffin oil. At T^g of 303.7 °C the paraffin attains the flash temperature of oil and it begins to get converted into vapour. Similarly figure 9 represents the temperature curve of the composite. Three dips were noted in the Figure 2. The first dip T^1 represents a temperature of 44.7 °C with the beginning of the melting of solid paraffin-composite into liquid with the energy absorption of thermal absorption of -3.93mW.

The second dip T represents a temperature of 59.9 °C with the energy absorption of -11.12mW which represents the complete melting of the solid paraffin wax into paraffin oil phase. At the third dip T^g, it absorbs the energy of -2.06mW and attains a flash temperature of 324.4 °C, which represents the oil get converted into vapour phase.

(d h/ d t) X (˚C) / (d T / d t) = Enthalpy J/g [17] __________ (1)

From the enthalpy values, it was studied that composites absorbs more energy to change from one state to another state and the Paraffin-Graphite-Copper composite absorbs more energy during the heat charging process and discharges the absorbed heat during the discharging process, when compared with the pure paraffin. The PCM-Composites stores and discharges more heat. The temperatures and the enthalpy values of the pure paraffin and paraffin-graphite-copper composites in different phases are shown in table 2. The enthalpy value was calculated using the equation 1 .

ISSN (Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

An ISO 3297: 2007 Certified Organization *Volume 4, Special Issue 2, February 2015*

5th International Conference in Magna on Emerging Engineering Trends 2015 [ICMEET 2015]

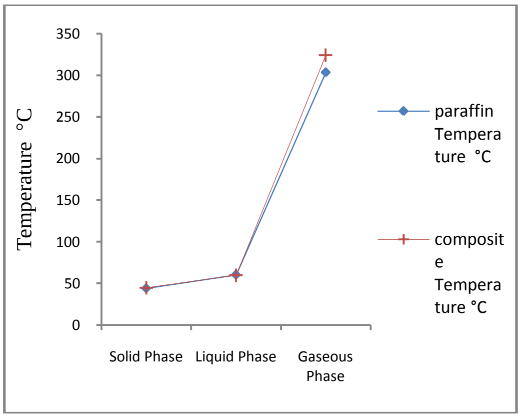
On 27th & 28th February, 2015

Organized by

Department of Mechanical Engineering, Magna College of Engineering, Chennai-600055, India.

Table 2: Temperatures and Enthalpy values of pure paraffin and paraffin-graphite-copper composite in different phases

Phases	Paraffin Temperatures (^{0}C)	Composite Temperature (^{0} C)	Enthalpy of the Paraffin (J/g)	Enthalpy of the Composite (J/g)
T^1(^{0}C) Solid to Liquid	44.1	44.7	0.243	0.261
T(^{0}C) Liquid to Liquid	60.4	59.9	0.161	0.160
T^g (^{0}C) Liquid to Vapour	303.7	324.4	1.873	2.227



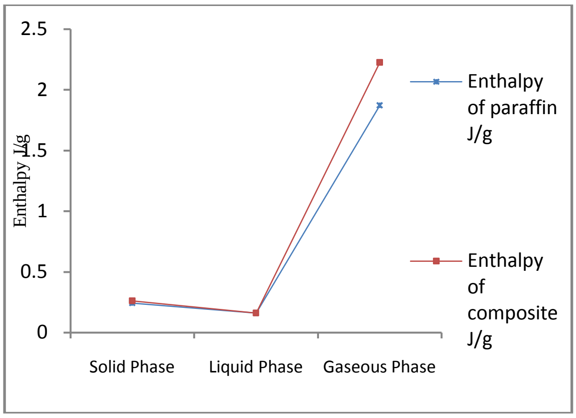


Fig 3: Temperature curves of the pure paraffin and PCM-Composite (P: G: C = 70:20:10)

Fig 4: Enthalpy curves of the pure paraffin and PCM-Composite (P: G: C = 70:20:10) in different phases

From the figure 3 and 4 it was observed that paraffin-graphite-copper composite absorbs more heat then the pure paraffin during the heat charging process. So from the DSC analysis it is understood that using the Paraffin-graphite-copper composite as PCM materials is found to be more suitable for thermal storage of solar energy.

B. Charging and discharging characteristics of the PCM-Composite:

Pure Paraffin was mixed with copper powder in four different weight percentages 50, 10, 70, and 90. The mixture was heated, until the whole paraffin copper powder mixture was melted to the solid-liquid, copper particle state. Pure paraffin was also taken in a separate beaker and heated simultaneously by using electric heater until the whole paraffin was converted to the liquid state. The system was allowed to cool until the paraffin was solidified under normal atmospheric condition. From the study the best composite ratio has been identified 10 weight percentage of Cu with paraffin alone as shown in the figure 5.

ISSN (Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

An ISO 3297: 2007 Certified Organization Volume 4, Special Issue 2, February 2015

5th International Conference in Magna on Emerging Engineering Trends 2015 [ICMEET 2015]

On 27th & 28th February, 2015

Organized by

Department of Mechanical Engineering, Magna College of Engineering, Chennai-600055, India.

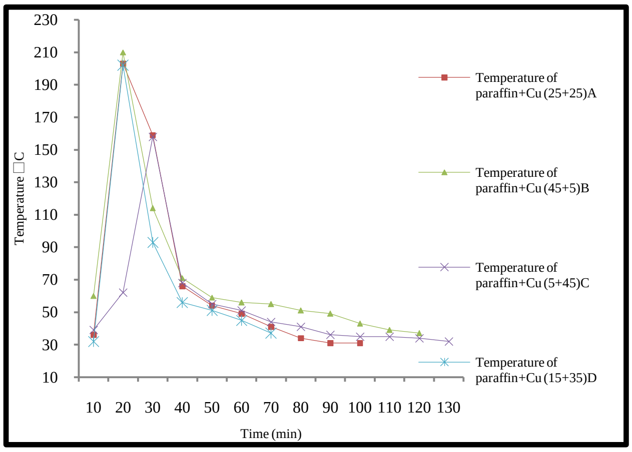


Fig 5: Temperature curves of the Paraffin-copper Composite for the Different weight percentages

Fig 12: Wax melting chamber

Similarly an another study was made with pure paraffin was being mixed with different weight percentages of graphite powder of 10, 20 and 30 weight of graphite powder has been represented in figure . Among the three 20% of Graphite composite was chosen for PCM composite. The charging and discharging characteristics of the paraffin-Graphite composite have been studied and reported in figures 6, 7. The Paraffin wax, Graphite powder and copper powder of 35, 10 and 5 grams was chosen respectively and the mixture was heated by using electric heater, until the whole Paraffin-Graphite-copper powder composite was converted to the solid and oil state and then the system was allowed to cool to get solidified under normal atmospheric condition. The rate of rise of temperature for the pure paraffin is known to be 0.1533 8C/s, which was less than the charging rate of the composite (P, 70: G, 20: C, 10) 0.2788C/s. The rate of fall of temperature of the pure paraffin while discharging was 0.1167 8C/s which was less than the rate of fall of temperature of the best composite 0.113 8C/s. The investigation shows that adding graphite powder and copper powder with the pure paraffin provides to be a feasible method for heat transfer enhancement. From figure 8 and 9 it was absorbed that paraffin (70):graphite(20):copper(10) composite reaches the peak temperature faster than the other mixtures, it also discharges the heat fastly so it was considered as best composite and loaded as PCM in the heat exchanger and subjected to study in a chamber**.**

PCM-Composite encapsulated in iron pipes were placed in the wax melting chamber. In the wax melting chamber, 4 liters of water was used as the heat transfer fluid. An electrical heater was used to perform the charging process of encapsulated PCM composite enclosed in the wax melting chamber and the temperature of the PCM composite has been reported in figure 10. Similarly, the charging process of encapsulated pure paraffin (PCM) enclosed in the wax melting chamber and the temperature of the pure paraffin (PCM) has been reported in figure 11.

ISSN (Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

An ISO 3297: 2007 Certified Organization *Volume 4, Special Issue 2, February 2015*

5th International Conference in Magna on Emerging Engineering Trends 2015 [ICMEET 2015]

On 27th & 28th February, 2015

Organized by

Department of Mechanical Engineering, Magna College of Engineering, Chennai-600055, India.

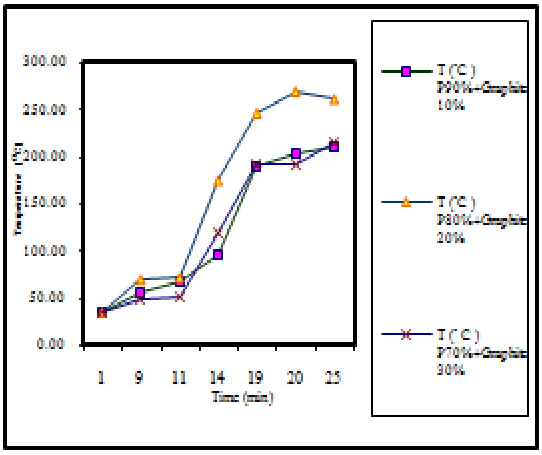


Fig 6: Charging curves of the paraffin-Graphite Composite for different wt% of Graphite powder

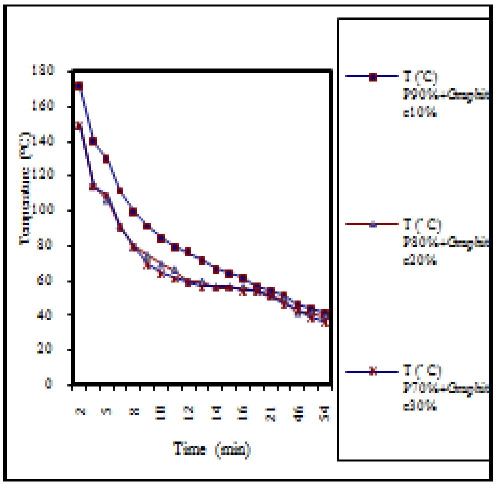


Fig 7: Discharging curves of the temperature of the paraffin-Graphite composite for different wt% of Graphite powder

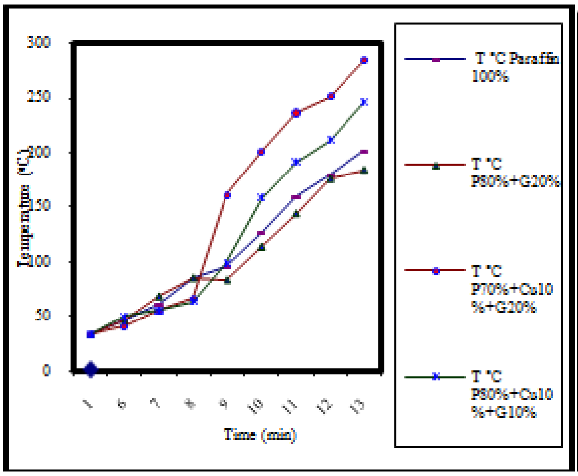


Fig 8: Charging curve of the paraffin-Graphite -Copper (P: G: C) composite

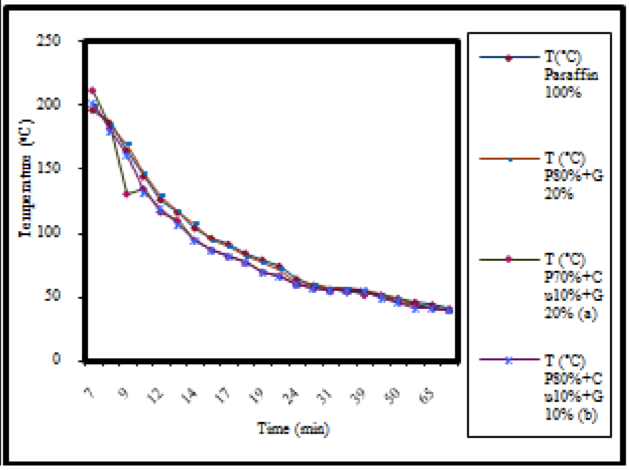


Fig 9: Discharging curves of the temperature of the Paraffin-Graphite-Copper (P: G: C) composite

The paraffin-graphite-Copper composite with 70:20:10 wt% was encapsulated in the 0.3m length of iron heat exchanger pipes. From the observation it is noted that heat exchanger pipes with the PCM composites have higher rate of rise of temperature of 14.7 X 10^{-3} 8C/s, while charging the PCM composite. When compared with the charging performance of pure paraffin, the rate of rise of temperature for the pure paraffin is known to be 6.389 X 10^{-3} 8C/s. So the thermal charging time gets enhanced to more than double while using the PCM-composite as the PCM material for thermal energy storage instead of pure paraffin alone. The rate of fall of temperature of the pure paraffin while discharging was 1.94X10^{-3}8C/s which was less than the rate of fall of temperature of the best composite 4.167X10^{-3}8C/s.

ISSN (Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

An ISO 3297: 2007 Certified Organization *Volume 4, Special Issue 2, February 2015*

5th International Conference in Magna on Emerging Engineering Trends 2015 [ICMEET 2015]

On 27th & 28th February, 2015

Organized by

Department of Mechanical Engineering, Magna College of Engineering, Chennai-600055, India.

IV. CONCLUSION

An experimental investigation has been carried out in order to study the charging (melting) and discharging (solidification) characteristics of the paraffin composites made of copper and Graphite powders. This PCM composite assembly has been tested for heat exchanging property with stored volume of water which could be used as a heat returning material due to its PCM characteristic property.

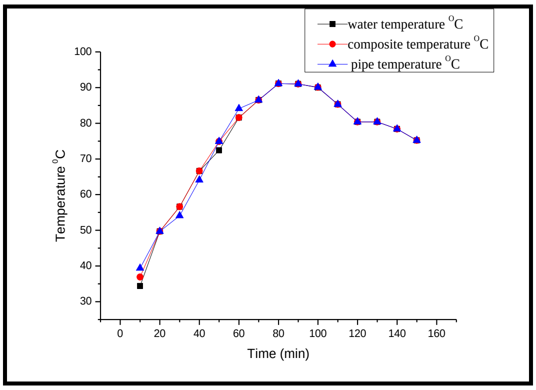


Fig 10: Charging and discharging characteristics of PCM composite encapsulated in iron tubes.

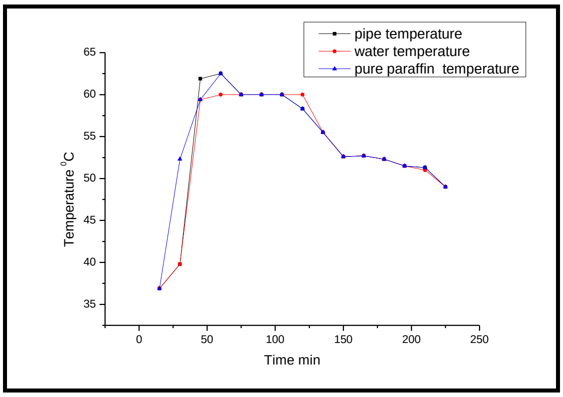


Fig 11: Charging and discharging characteristics of Pure paraffin encapsulated in iron pipes.

Nomenclature

T^1	Temperature of phase of paraffin solid
T	Temperature of phase of paraffin as oil
T^g	Temperature of paraffin oil converted to gaseous phase
DSC	Differential scanning calorimetry
PCM	phase change material
P	pure paraffin
Cu	copper powder
G	graphite powder
dh/dt	rate of heat flow
dT/dt	rate of rise of temperature

REFERENCES

[1] Yunus A. Cengel, Afshin J. Ghajar, "Natural Convection in Heat and Mass Transfer", McGraw Hill Education (India), pp 526-530.
[2] Al-Hinti, A. Al-Ghandoor, A. Maaly, I. Abu Naqeera, Z. Al-Khateeb, O. Al-Sheikh, "Experimental investigation on the use of water-phase change material storage in conventional solar water heating systems", Energy Conversion and Management vol. 51 pp. 1735–1740, (2010) .
[3] T.Kousksou A.Jamil, Etal "Paraffin Wax mixture as phase change materials", Solar energy materials & Solar cells, vol. 94, pp. 2158-2165, (2010).
[4] Yasin Varol , Ahmet Koca, Etal, "Forecasting of thermal energy storage performance of phase change material in a solar collector using soft computing techniques", Expert system with applications vol. 37, pp. 2724-2732, (2010).
[5] C.Y.Zhao, W. Lu, Y. Tian, "Heat transfer enhancement for thermal energy storage using metal foams embedded within phase change materials (PCMs)", Solar Energy, vol. 84, pp. 1402-1412, (2010) .
[6] Sumin Kim, Lawrence T.Drzal, " High latent heat storage and high thermal conductive phase change materials using exfoliated graphite nonoplatelets", Solar Energy Materials NA Solar Cells vol. 93 pp. 136-142, (2009) .
[7] Yajuan Zhong, Quanqui Guo , Jingli Shi, Etal, " Heat transfer enhancement of paraffin wax using graphite foam for thermal energy storage", Solar Energy Materials &Solar Cells vol. 94 pp. 1011-1014, (2010).
[8] Mehling, S.Hiebler, F. Ziegler Latent heat storage using a PCM-graphite composite material (2000) A-070

ISSN (Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

An ISO 3297: 2007 Certified Organization *Volume 4, Special Issue 2, February 2015*

5th International Conference in Magna on Emerging Engineering Trends 2015 [ICMEET 2015]

On 27th & 28th February, 2015

Organized by

Department of Mechanical Engineering, Magna College of Engineering, Chennai-600055, India.

[9] YanxiangLi [a,b], MinWu [a], RuigangLiu [a], YongHuang [a,c], "Cellulose-based solid–solid phase change materials synthesized in ionic liquid", Solar Energy Materials & Solar Cells vol. 93, pp.1321–1328, (2009).

[10] Min Xiao, Bo Feng, Kecheng Gong, "Thermal performance of high conductive shape-stabilized thermal storage material", Solar Energy Material & Solar Cells, pp. 293-296, (2001).

[11]J. Banaszek, R.Domananski, M. Rebow, etal, "Experimental study of solid-liquid phase change in a spiral thermal energy storage unit", Applied Thermal Engineering, vol. 19, pp. 1253-1277, (1999) .

[12] Ahmet Sari, Ali Karaipekli, "Preparation, thermal properties and thermal reliability of palmitic acid/expanded graphite composite as form-stable PCM for thermal energy storage", Materials & Solar Cells, vol. 93, pp. 571–576, (2009) .

[13] D. Zhou, C.Y.Zhao, "Experimental investigations on heat transfer in phase change materials (PCMs) embedded in porous materials", Applied Thermal Engineering vol. 31, pp. 970-977, (2011).

[14] Xavier Py, Regis Olives, Sylvain Mauran, "Paraffin/porous-graphite-matrix composite as a high and constant power thermal storage material", International Journal of Heat and Mass Transfer vol. 44, pp. 2727-2737, (2001).

[15] D. ZHOU, C.Y. Zhao. "Experimental investigations on heat transfer in phase change material (PCMs) embedded in porous materials", Applied Thermal Engineering vol no. 31 pp. 970-977, (2011).

[16]Chang Ren Chen, Atul Sharma.s "Numerical Investigation of melt Fraction of PCMs in a Latent Heat Storage System", Journal of Engineering and Applied Sciences, vol. 1 (4), pp. 437-444, 2006.

[17] www.Research Gate.com