Experimental Investigation of Acetamide as PCM with Metal Matrix

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Abstract— In this study concept of increasing the heat transfer rate in the Phase Change Material during the charging and discharging has been presented. An experimental investigation has been made to see the effect of the metallic fins inside the PCM on improvement in thermal conductivity. One PCM acetamide is selected for the experimental investigation and their charging characteristics and thermo physical properties are studied by using different configurations of the fins. It is observed during the experimental investigation that there is significant effect of the fin on the charging characteristics, discharging characteristics of the PCM.

Key word: PCM, The Teflon tube

I. Introduction

The energy demand of our country is increasing at a rapid rate and energy resources are limited in nature. In India, households generally use a combination of energy sources for cooking that can be categorized as :

- traditional (such as dung cakes, agricultural residues and fuel wood),
- intermediate (such as charcoal and kerosene) or
- Modern (such as LPG, biogas and electricity).

Disadvantages associated with these cooking methods are pollution, health problems, and deforestation. Solar energy is beneficial for cooking as it is economical, eco-friendly and excess in nature i.e. solar energy has 3E’s.

Renewable energy, particularly the solar energy, is gaining more importance worldwide for its clean, non-polluting, inexhaustible and cost free nature.

Though there are many applications possible, an important factor is that solar energy is time dependant in nature.

Hence the commercial acceptance and the economics of solar thermal utilities or devices are dependent on the design of an efficient thermal storage system to meet the time-dependant supply and end use requirements.

Energy is curial input in the process of economic, social and industrial development. The degree of development and civilization of a country is measured by the utilization of energy by human beings for their needs. The energy demand of our country is increasing at a rapid rate and energy resources are limited in nature. Energy requirement for cooking accounts for 36% of total primary energy consumption in India. In India, maximum population lives in rural areas, which generally uses the conventional energy sources for cooking, such as dung cakes, agricultural residues, wood, charcoal, kerosene, electricity etc. Charcoal is usually produced from forest resources and its production is often inefficient so it can lead to localized deforestation and land degradation. The conventional energy sources are exhaustible, polluting and responsible for global warming. Also it is a crime against nature and future generation to use our irreplaceable fossil fuels for low temperature heating. These should be reserved for high temperature heating and manufacturing of commercial commodities like rubber, plastics and fertilizers etc. Due to this reason the people around the world are switching to renewable energy sources. Renewable energy sources have the capacity to replace the use of wood, animal dung etc. for cooking. So it is necessary to harvest the available solar energy for the domestic uses. Solar cooking has the following advantages:

- Solar cooking is absolutely free. Cost of solar cooker can be recovered through saving on conventional fuels.
- Solar cooked food is easily digestible. It gradually relieves stomach disorder, constipation, gastric trouble and acidity.
- Solar cooked food preserves most of the vitamins, minerals and antioxidants
- In villages, women have to travel less often to forage for firewood, thus keeping them closer to home and safe as a result.
- There are no chances of explosion or fire while using Solar Cooker. It is very dangerous for household families with infants to use LPG which is highly explosive.
- It helps in preserving our environment.
- It is durable and simple to operate.

II. Literature review

Velraj et al. [2012] studied the performance of a solar parabolic trough collector with a thermal energy storage system and took therminol-55 as heat transfer fluid. Various performance parameters like useful heat gain and thermal efficiency of individual components were evaluated.

Chaudhary et al. [2013] investigated a solar cooker based on parabolic dish collector with phase change material. It was observed that solar cooker with phase change material having outer surface painted black along with glazing stores 32.3% more heat as compared to PCM in ordinary solar cooker.

Lecuona et al. [2013] simulated a portable solar cooker of parabolic type using 1-D finite difference method. A numerical model was used to study its transient behaviour with two different types of PCMs: Paraffin and Erythritol. High melting heat and conductivity of a PCM like erythritol is an advantage for fast cooking.

Farooqui Suhail [2013] presented a solar cooker based on Fresnel lens type collector. The proposed cooker consists of rectangular glass mirror strips mounted on wooden frame and requires one dimensional solar tracking. The maximum temperature attained in the experiment was 250°C. Heat absorption capacity of this collector was five times more than conventional box type solar cooker.

Mussard and Nydal [2013] used two different types of heat storage units with solar parabolic trough. The latent heat storage unit contained nitrate mixtures (salt) and oil was used as the heat transfer fluid which self circulates in the loop connecting the collector and storage unit. A storage based on thermal oil is much more efficient than aluminium based storage unit as it reduces thermal losses in the pipe and absorber.

III. EXPERIMENTAL SETUP

This section outlines the sample fabrication, The setup consist of cylindrical Teflon tube at the centre brass tube which supplies constant heat with the help of heating element as shown in the figure.

The whole test system consists of the following component:

1) The Teflon tube.
2) The brass tube.
3) The thermocouples(8 nos)
4) The digital display for temperature reading.
5) The heating element.
6) The sun flower oil
7) The acrylic plate
8) The voltage controlling unit.
9) The temperature controlling unit.
10) The voltmeter and ammeter.
11) Metallic fins
12) Acetamide and paraffin wax are used as PCM

Fig. 1: Teflon Tube and Brass tube

The Teflon tube consist of inner diameter 112mm, outer diameter 150mm and height 102mm. Teflon tube is having very good heat resisting properties .The value of thermal conductivity is very low and can withstand temperature up to 260′C.

Properties	Teflon Tube
Density	2200 kg/m^3
Melting point	327 °C
Working Temperature	260 °C
Young's modulus	0.5 GPa
Thermal expansion	112-125 · 10^{-6} K^{-1}
Thermal conductivity	0.25 W/(m·K)

The brass tube consists of 34 mm inner diameter and 38 mm outer diameter and is installed at the centre of brass tube. The brass tube contained sun floor oil and heating element. The space between heating element and brass tube is filled with oil to eliminate the air space so that conductivity can be increased and it can act as more uniform cylindrical heat source.

These are temperature measuring devices which are installed at various positions in Teflon tube. There are total 8 number of thermocouples 4 of which are installed along the length and three are installed along the circumference. The thermocouples used are j-type which can tell temperature up to 450′C. The locations of the different thermocouples are as shown in the figure:

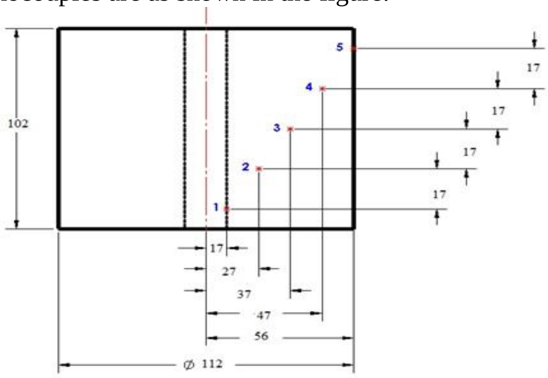

Fig. 2: locations of the different thermocouples
All dimensions are in mm.

IV. METHODOLOGY

The required amount of PCM is filled in the annular space between brass tube and Teflon tube after measuring the weight. The brass tube is filled with sun floor oil and then fitted with heating element. The heating element is then turned on at particular input through controller say 100 watt. The time is recorded for heating element from starting to the point at which phase transition started and then till the point when all the mixture is melted in order to find out the sensible heat as well as latent heat, at the same time the reading of the thermocouple number 3 and thermocouple 1 is recorded at the interval of 30 second in order to find out charging characteristics of the different PCMs.

Three cases are studied for each PCM as given below:

1) Case 1 PCM without fins
2) Case 2 PCM with 4 fins placed at uniform gap along the circumference of Teflon Tube.
3) Case 3 PCM with 12 fins placed at uniform gap along the circumference of Teflon Tube.

The following thermo physical properties can be obtained with the help experimental set up:

1) Charging characteristics.
2) Thermal conductivity of PCM.
3) The sensible heat of the PCM.
4) The latent heat of the hybrid PCM.

Schematic of the experimental set up has been shown in the figure:

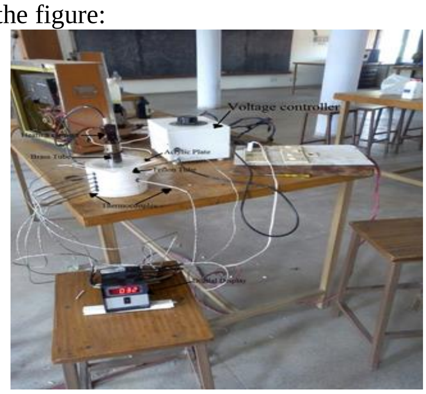

Fig. 3: Schematic of the experimental set up

Heat stored by the PCM is given by

$$Q_{PCM} = m_{PCM}[C_{PCM}(T_m - T_i) + L + C_{PCM}(T_{max} - T_m)]$$

It is assumed that the specific heat for solid and liquid phase of PCM is same.

V. RESULTS AND DISCUSSION

The main objective of this experimental set up was to obtain the charging characteristics and different thermo physical properties of the acetamide, paraffin wax and hybrid mixture of these two components at different mixing ratio. The total charging time was noted at constant heat supply of 100 watt, temperature reading corresponding to thermocouple number 3 is recorded at fix time interval of 30 second until whole the sample is fully charged (melted). Temperature at starting point t=0sec and temperature at point when phase transition started and temperature at point when mixture is fully charged is noticed because these temperature are helpful in carrying out the calculation for sensible heat, latent heat and total heat required by the PCM during the charging period.

A. Case 1 Experiment With Acetamide(750gm) As A PCM Without Fin:

Data of the PCM (acetamide) temperature in centigrade, heat input(watt) is recorded for the 750 gm of acetamide sample.

The temperature v/s time variation of the acetamide is given in the figure 6

B. Case 2 When 4 Metallic Fins Are Used:

The 4 metallic fins are used in between the brass tube and Teflon tube at a location as shown in figure. The temperature v/s time variation of the acetamide is given in the figure 7

Fig. 4: Four fins

C. Case 3 When 12 Metallic Fins Used:

The 12 metallic fins are used in between the brass tube and Teflon tube at a location as shown in figure.

The temperature v/s time variation of the acetamide is given in the figure 6

Fig. 5: Twelve fins

The results of the experiments are represented graphically in the following figure.

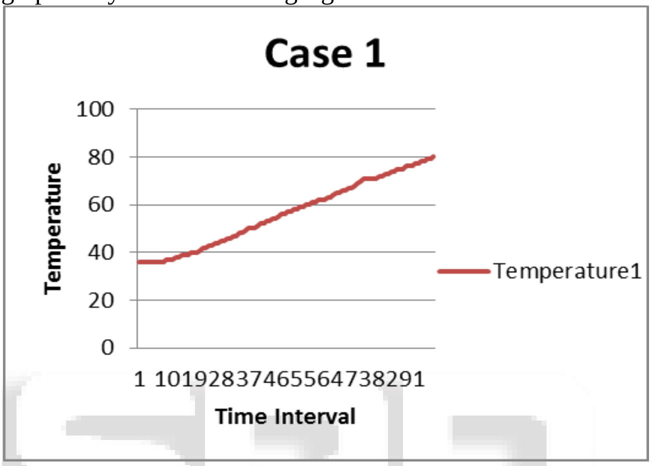

Fig. 6: temperature v/s time variation of case1

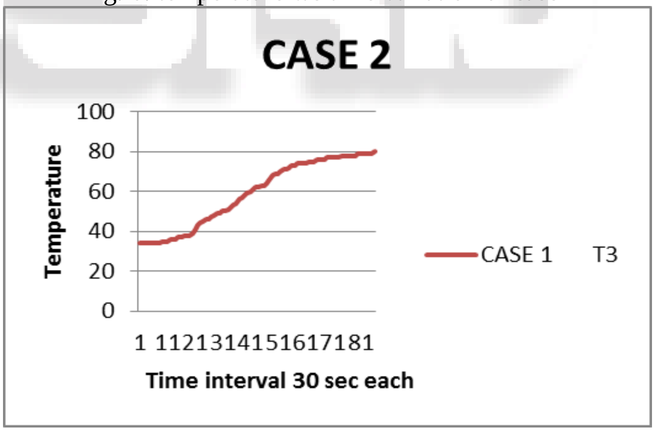

Fig. 7: temperature v/s time variation of case2

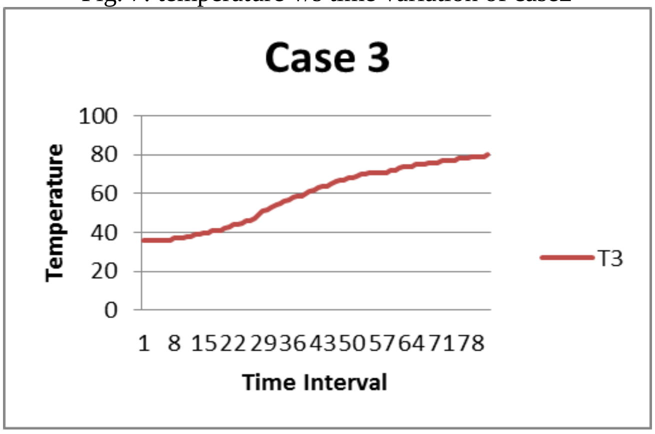

Fig. 8: temperature v/s time variation of case3

VI. CONCLUSION

The various thermo physical properties of the acetamide which are obtained from the given set up using the above equation are given in the table:

Acetamide	Properties
Sensible Heat	51 KJ/kg
Latent Heat	262 KJ/kg
Thermal conductivity	.592 W/mK
Specific Heat	2 KJ/kg/k

Table 2: Properties of Acetamide

There was significant decrease in the charging period using the fins, further with increase in the number of fins charging period further decreases. So we can enhance the heat transfer in the PCM using fins. The comparison of the above three cases is shown in the figure:

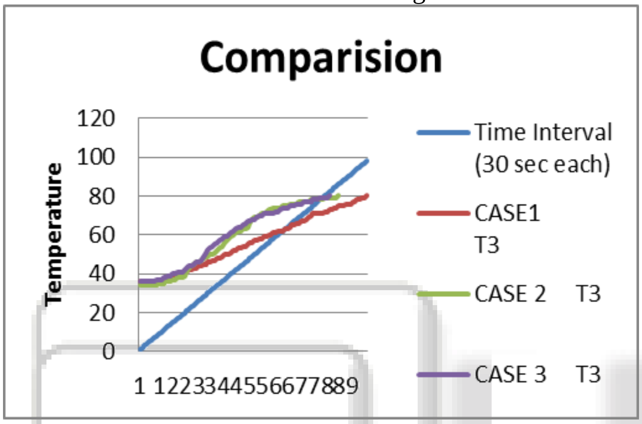

Fig. 9: Comparison of three temperature v/s time variation in three cases

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