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Performance Analysis of Palmitic Acid Coated PCM Storage Container

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ABSTRACT

The phase change material is considered as the best source of latent heat energy storage units. The usages of phase change material for advanced engineering applications are increased significantly. The major application of the phase change material is food storage containers. The capability of storing heat energy would help the stored food container to withstand sufficient temperature for a reasonable extended time. The organic and inorganic pcm's are experimented by many researchers to unleash the maximum thermal efficiency available with it. In this study organic pcm called palmitic acid is selected for the experimentation. A closed insulation chamber of soft wood coated with mica sheet is fabricated. The aluminium container is placed inside the insulation chamber and connected with a polyurethane coated heating coil arrangement. The experiments are performed with the pure distilled water and high salt water to observe the difference in time period of the latent heat energy storage capability. The experiments are also repeated with and without pcm in between the insulation box and the container. The software called ANSYS fluent is used to simulate the real heat transfer between the container and box. The performances of the experimental setup with and without the pcm material are compared. The results indicate that comparing to high salt water content distilled water exposed improved heat energy storage performance. The overall thermal efficiency is improved for the container with palmitic acid pcm for almost upto 25% when comparing to the setup without pcm.

Keywords: Phase Change Material; Palmitic Acid; Softwood Insulation Chamber; Aluminium Container; Latent Heat Energy Storage; Pure Distilled Water; High Salt Water.

INTRODUCTION

Thermal energy storage is an unavoidable in any kind of engineering applications. The need for the thermal energy storage spread out in various advanced engineering applications especially in food storage applications. [1, 2] The convenient and improved storage density along with the minimum temperature variation from storage to extraction made latent heat storage as a best method for thermal energy storage. [3, 4] The energy is enhanced into the phase change material and extracted back as by freezing the corresponding material. [5, 6] As part of many latent heat thermal energy storage applications the various organic and inorganic phase change materials like hydrates, paraffin and non-paraffin etc. were experimented by many researchers in the literature. [7, 8] The selection and utilization of a particular pcm material for certain application is decided by the temperature range needed for that specific application. The transition temperature range needed for the pcm selected for a normal water storage container should be around 40-70°C. [9] Palmitic acid provides a great flexibility in this range because of its inherent properties of the fatty acid family. The fatty acid

family of chemicals contains a great potential for to be used in heat energy storage applications. [10] Palmitic acid pcm was used in solar heater and the efficiency of the heater was improved significantly. [11] The palmitic acid provides a very good latent heat capability of 200 KJ/Kg which includes another advantage of low reaction to sub cooling property. The objective of this study is to perform an experimental investigation to analyze the melting and solidification behaviour of the palmitic acid phase change material for the application of storage container.

EXPERIMENTATION

The type of phase change material selected for this study is palmitic acid. The molecular formula is $CH_3(CH_2)14CO_2H$.It was extracted from the palm tree oil so that it was called as organic phase change material. In our study the palmitic acid pcm was purchased in the form of white powder as shown in figure1.

Figure.1 Palmitic acid pcm powder.

The selected pcm is diluted with a solvent called ethyl alcohol. The chemical formula of the ethyl alcohol used in this study is CH_3CH_2OH. The palmitic acid powder was diluted in the ratio of 1:3. The ethyl alcohol used in this study for the dilution purpose is shown in figure 2 as follows

Figure 2. Ethyl Alcohol

A closed insulation chamber of soft wood coated with mica sheet is fabricated. The aluminium container is placed inside the insulation chamber and connected with a polyurethane coated heating coil arrangement. The experiments are performed with the pure distilled water and high salt water to observe the difference in time period of the latent heat energy storage capability. The experiments are also repeated with and without pcm in between the insulation box and the container. The 3d model of the insulation chamber setup and the container setup is shown in figure 3.

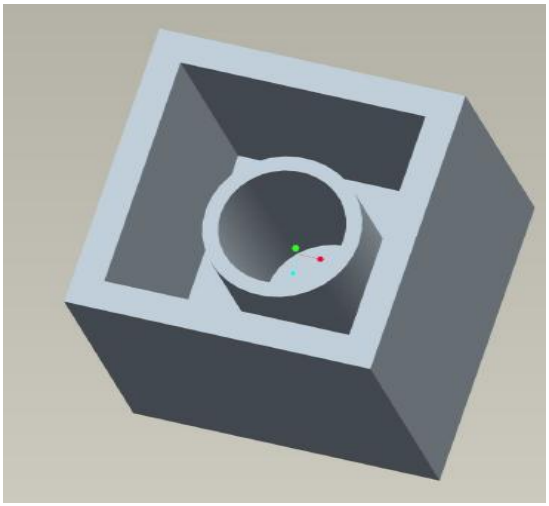

Figure.3. 3D Model of the insulation chamber and container setup.

The open top view of the fabricated container with pcm material is shown in figure 4. Similarly the closed top view of the container with the heating coil attached is shown in figure 5 as follows.

Figure.4 Open top view of the fabricated container.

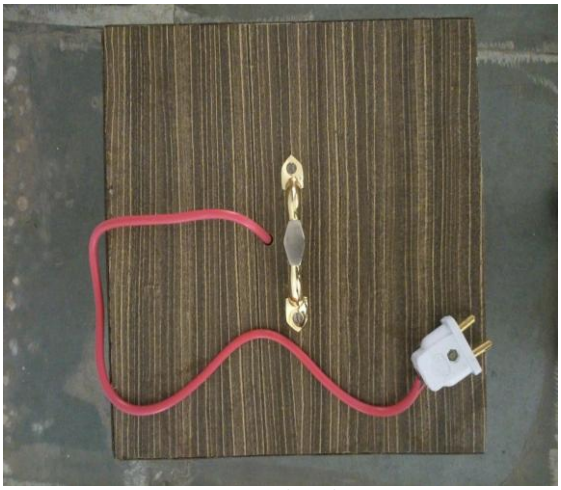

Figure.5 Closed top view of the fabricated container.

The fluid medium considered in our study pure distilled water and highly concentrated salt water is shown in figure 6 for the understanding purpose.

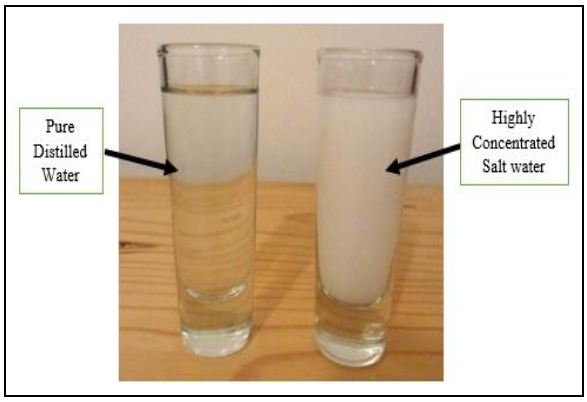

Figure. 6. Pure distilled water and salt water.

The various components used in this study are listed in the table 1. The experiments were performed with respect to time and a maximum time interval of 60 minutes with a mean gap of 5 minutes is considered for this study. The stop watch is used to measure the values. The different time horizon used for the measurement of values is shown in table 2.

Table.1. Components used in this study

S.No	Component	Quantity	Material
1.	Container	1	Aluminium
2.	Insulation Chamber	1	Soft wood coated with Mica sheet
3.	PCM	5 Kg	Palmitic acid
4.	Solvent	15 litre	Ethanol
5.	Heating Coil	1	Poly urethane coated

Table.2. Time Parameters used in this study

S.no	Time (minutes)
1.	0
2.	5
3.	10
4.	15
5.	20
6.	25
7.	30
8.	35
9.	40
10.	45
11.	50
12.	55
13.	60

The dimensions of the insulation chamber and the container vessel are shown in table 3 as follows.

Table.3. Dimensions of the components

S.no	Component	Dimensions(mm)
1	Container	200 x 200 x 600
2	Insulation Chamber	100 (dia) x 300 (height)

Boiling of water generally takes place at 100 degree Celsius so we used the phase change materials which have the phase change temperature of 75 degree celsius. Now the water is heated by the current supplied through the heating coil. The heating coil is attached at the top of the experimental setup. The phase change material here palmitic acid is poured around the aluminium vessel upon which contains the water. At the temperature of 75 degree Celsius the phase change material which is liquid in phase at initially starts to change its phase to gaseous state. The phase change temperature of the material is constant after 75 degree Celsius and it absorbs to absorb heat continuously until the gaseous phase is reached completely. The major principle behind this phase change concept is latent

heat storage and the heat transmits from the high temperature concentration area to low concentration area. After sometime when the current supplied to the heating source is unavailable now as per the above said principle of transmission of heat from high concentration area to lower concentration area takes place and now the phase change material begins to retain its phase from gaseous state to liquid state by releasing its heat energy stored in it. It takes place continuously until the gaseous state is completely transmitted to liquid state. We have measured the corresponding temperature at various intervals with the help of temperature measuring device.

RESULTS AND DISCUSSION

Table.4. Results of the experimental setup without PCM for pure distilled water

S.no	Time (minutes)	Measured Temperature (Degree Celsius)
1.	0	100
2.	5	96
3.	10	90
4.	15	88
5.	20	82
6.	25	76
7.	30	65
8.	35	59
9.	40	54
10.	45	50
11.	50	47
12.	55	42
13.	60	38

Table.5. Results of the experimental setup with PCM for pure distilled water.

S.no	Time (minutes)	Measured Temperature (Degree Celsius)
1.	0	100
2.	5	95
3.	10	91
4.	15	89
5.	20	81
6.	25	78
7.	30	72
8.	35	65
9.	40	62
10.	45	58
11.	50	54
12.	55	50
13.	60	45

The measured corresponding values are plotted in graph and finally we have compared the graph with pcm and without pcm. It showed the positive signs in improving thermal efficiency and the thermal energy storage is improved to the maximum extent of 25 to 35 percentage than the normal vessel without pcm. We also made thermal analysis for our phase change material coated container by measuring its dimensions and the temperature of pcm. The thermal analysis graph also witnessed the improvements in heat energy storage than the normal vessel which have normal convection. The measured corresponding values with and without phase change material were shown in table 4, 5, 6 and 7 for the pure distilled water and salt water respectively. The heat transfer flow of the experimental setup with and without PCM is analyzed with ANSYS fluent as shown in figures 7 and 8 respectively. The comparison graphs were shown in figure 9 and 10 respectively. The analysis results clearly show that the energy conservation is happened in the experimental setup with phase change material than the experimental setup without phase change material.

Table.6. Results of the experimental setup without PCM for Salt water.

S.no	Time (minutes)	Measured Temperature (Degree Celsius)
1.	0	100
2.	5	98
3.	10	96
4.	15	90
5.	20	87
6.	25	85
7.	30	82
8.	35	79
9.	40	74
10.	45	71
11.	50	68
12.	55	65
13.	60	61

Table.7. Results of the experimental setup with pcm for Salt water.

S.no	Time (minutes)	Measured Temperature (Degree Celsius)
1.	0	100
2.	5	99
3.	10	97
4.	15	95
5.	20	89
6.	25	87
7.	30	85
8.	35	80
9.	40	76
10.	45	73
11.	50	70
12.	55	68
13.	60	65

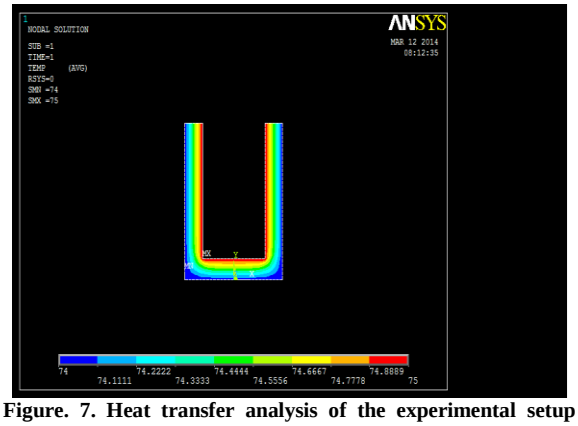

Figure. 7. Heat transfer analysis of the experimental setup without PCM by ANSYS fluent.

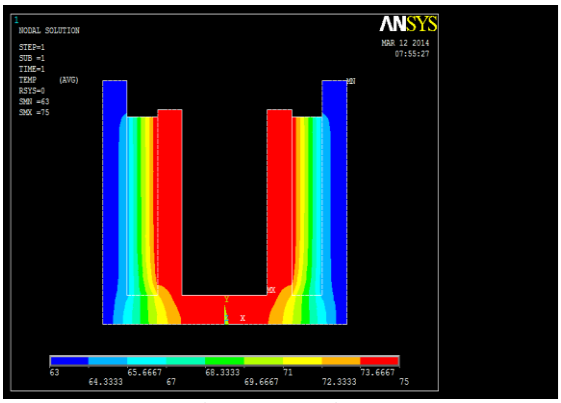

Figure. 8. Heat transfer analysis of the experimental setup with PCM by ANSYS fluent.

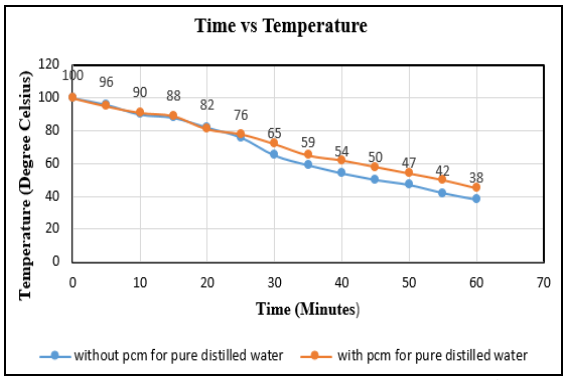

Figure.9. Time vs Temperature comparison graph for with and without pcm.

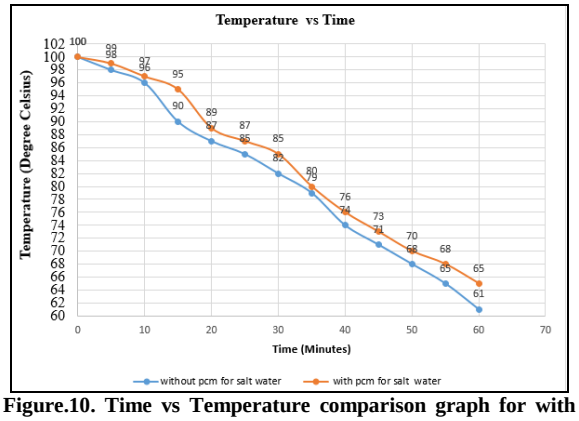

Figure.10. Time vs Temperature comparison graph for with and without pcm.

CONCLUSION

Based on the results and discussion the following points are concluded as

- The usage of palmitic acid as phase change material for the water storage container application significantly improved the thermal energy storage efficiency when comparing to non pcm coated container.
- The latent heat energy storage percentage is improved approximately upto 35% in pcm coated container than non-pcm coated container.
- Two types of water source is used say pure distilled water and high salt water. Comparing to pure distilled water the salt water has high melting point and subsequently took more time at the time of reverse cycle effect in latent heat storage.
- The selection of pcm material should be according to the size and volume of the targeted application.
- The outcomes of this study could be further extended for many large applications like boiling feeder pipes to maintain superheated steam etc…
- Even though the aluminium is good resistor to corrosion and other volatile chemical reactions we should also add some amount of suitable inhibitor as a preventive measure.

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