EXPERIMENTAL INVESTIGATION OF PHASE CHANGING MATERIAL (PCM) FOR THE HOT FOOD STORAGE APPLICATION

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Abstract - *The Objective of the study is to analyze the thermodynamic behaviour of the Phase Changing Material (PCM) and apply the concept of PCM into the hot food storage purpose. An experimental study is carried out in a food storage vessel; Paraffin wax is used as PCM. From experimental study, PCM is a substance with a high heat of fusion in which melting and solidifying at a certain temperature, is capable of storing and releasing large amount of energy. The results confirm that, the proposed concept of hot food storage system is cheap and effective. This application can be used in hotels, home, and where there is a need to keep food warm.*

Key Words: Latent heat of fusion, Paraffin wax, Phase changing materials, Thermal conductivity, natural convection.

1.INTRODUCTION

Thermal energy can be stored in the form of sensible heat in which the temperature of the storage material varies with the amount of energy stored. Water is the best example. Alternatively thermal energy can be stored as latent heat in which energy is stored when a substance change from one phase to another by melting or freezing.

In general people choose to have hot food in hotels, or at home. Once it is provided, its hotness is reduced because of the outside temperature. We use hot boxes to reduce the heat loss but it is less efficient to reduce the heat loss of the food for a longer time and it should be kept closed to retain the heat. In order to tackle this problem and improve the efficiency of hot box, we thought of phase changing material in which heat is absorbed or released when the PCM material changes its state.

In this study, PCM is utilized, which is capable of storing and releasing large amount of energy. Since the thermodynamic properties of the PCM are favor for this particular application, it should be efficient and effective also cost effective one for waste heat utilization and hot food storage.

1.1. Phase Changing Material (PCM):

The PCMs proposed for low temperature application mostly are both organic and inorganic substance such as paraffin hydrocarbons, paraffin wax and salt hydrates. PCM is a substance with a high heat of fusion in which melting and solidifying at a certain temperature, is capable of storage, and releasing large amount of energy. Latent heat is thermal energy released or absorbed by a body or a thermodynamic system during a constant temperature process – usually a first order phase transition.

PCMs usually have low thermal conductivity, allow only a small heat transfer rate when a melted and solidified layer of PCM have been formed on the heat exchanger surfaces during heat absorption and heat extraction. This means that while these materials store or extract thermal energy, it takes a long time or large temperature between the heating/coolant fluids and melting temperature to get the heat to transfer through the phase change materials. Figure 1 describes the nature of PCM. Figure '1.A' represents the heat absorption, 'B' represents the heat storage and 'C' represents the heat release.

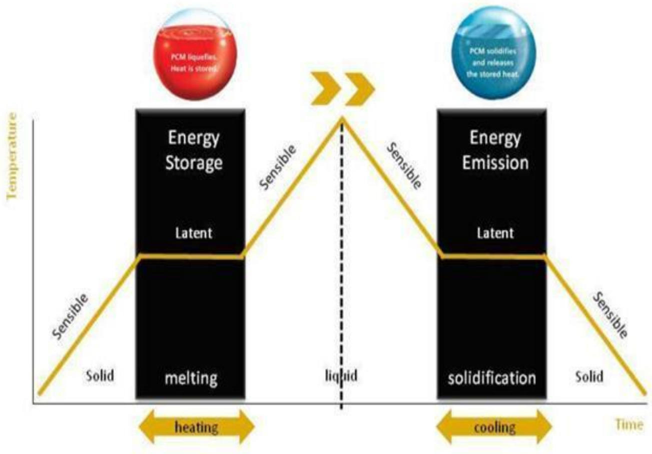


Figure: 1 Property of PCM

In the proposed concept Paraffin wax (PCM) have the following thermodynamic properties;

1. High latent heat of fusion per unit volume.
2. Melting temperature in the desired operating temperature range.
3. High specific heat, high density and high thermal conductivity.
4. Chemical stability
5. Non corrosiveness, non toxic, non flammable and non explosive materials.
6. Low cost, availability
7. Retain its property and do not loss its efficiency till the entire life cycle of the product.

Paraffin wax is a white colorless of solid derivable from petroleum products that consist of a mixture of hydrogen molecules containing between 20 and 50 carbon atoms. Its melting point is 46-48·C and density is 900kg/m^3. It is insoluble in water, but soluble in ether, benzene, and certain ester. Its heat of combustion is 42kJ/kg. Figure 2 represents the chemical structure of paraffin wax.

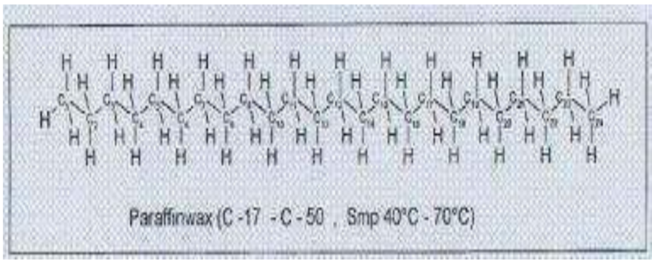


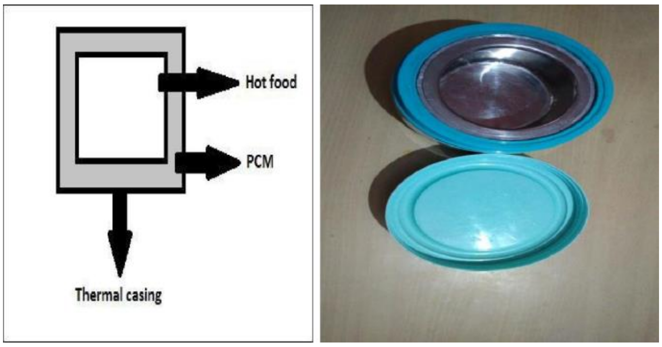
Figure: 2 Chemical structure of paraffin wax

The following table 1 represents the thermo- physical properties of commercial grade paraffin wax.

Table 1: Thermo- physical properties of commercial grade paraffin wax.

Specific heat of the PCM (Solid phase)	2.38kJ/kg·C
Thermal conductivity	0.15 W/m·K
Thermal expansion co-efficient	0.007/·C
Specific heat of the PCM (Liquid phase)	2.44kJ/kg·C
Melting temperature of the PCM	40-60·C
Latent eat of fusion	184.48 kJ/kg

The proposed study consists of the following components. These are paraffin wax, hot food storage vessel, thermal casing, food sample, thermometer and stop watch.



(A) (B)

Figure: 3 [A] Schematic diagram of Experiment on paraffin wax and hot food storage vessel
Figure: 3 [B] Original proposed product of PCM hot food storage vessel

The above schematic diagram represents the working of hot food storage vessels in the proposed work. In the experiment, we used a thermal casing to prevent the heat loss of PCM. When hot food is placed in the container which placed inside the PCM, the PCM absorb the heat from the food, by utilizing the absorbed heat and in a way of storing the energy PCM changes from solid to liquid form. After some time once the food temperature drops below the PCMs then the PCM supply the absorbed heat back to the food and gets cool down. The cycle gets repeated again and again till the temperature is being equalized to room temperature. Experiment readings are given in the table 2. The reading in the table is graphically represented in the graph 1.

Table: 2 An Experimental readings of paraffin wax and hot food storage vessel

Combination	**Time**	**Food Temperature**	**Wax Temperature**
Hot wax & Cold food	0 s	308.2 K	335 K
	300 s	311.3 K	329.1 K
	600 s	316 K	323.7 K
Hot food & Cold wax	0 s	338.9 K	300.3 K
	300 s	323.9 K	313.1 K
	600 s	319.6 K	317 K
Hot wax & Hot food	0 s	315.8 K	348.3 K
	300 s	320.2 K	341.4 K
	600 s	330.7 K	336.8 K
Hot food without wax	0 s	338.5 K	Not Applicable
	300 s	330.9 K	Not Applicable
	600 s	315.5 K	Not Applicable

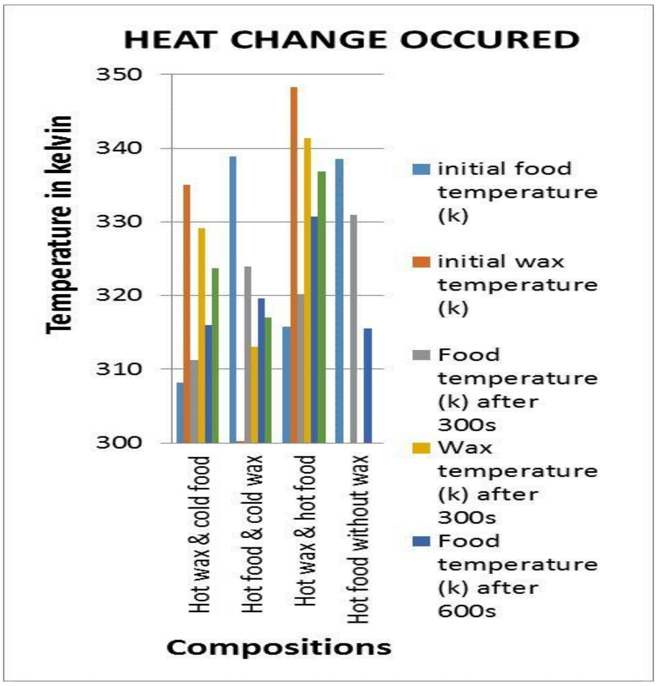
The Basic Equations for heat transfer and the efficiency are,

Efficiency, $\eta = Q_S/Q_A$

$Q_S = m_w * Cp_w * \Delta T$
$Q_A = m_{pcm} * Cp_{pcm} * \Delta T + m_{pcm} L_{pcm}$

Where,

Q_S = Heat stored Q_A = Heat available
m_w = mass of heat transfer of hot food Mpcm = mass of PCM
Cp_w = Specific heat of hot food Cppcm = Specific heat of PCM
L_{pcm} = Latent heat of PCM



Graph 1: Represents the Variation of Temperature in PCM hot food storage vessel

Conclusion:

The experimental results proved the feasibility of using PCM as thermal storage media in heat recovery systems. Latent heat storage system with PCM can be successfully used for reuse of waste heat. Hot box should be kept closed to maintain the temperature and keeping it close results in water precipitation inside the hot box which lead to change in the taste of food proves difficult to maintain the quality of the food but this proposed hot food storing vessel can be kept open and have no chance of water precipitation, will not have any change in taste and quality. Hot box hold heat, keep the food warm for a short period only; but this proposed hot food storage vessel can hold the temperature for a very long time because of the PCMs low thermal conductivity property.

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