

A RESEARCH PAPER ON EXPERIMENTAL ANALYSIS OF FORCED CIRCULATION SOLAR AIR HEATING SYSTEM WITH PHASE CHANGE MATERIALS (PARAFFIN WAX) ENERGY STORAGE

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Abstract

Latent heat thermal energy storage is one among the most economical ways that to store the thermal energy for heating air by energy received from the sun. This project is investigation and analysis of thermal energy storage incorporating with phase change materials (PCM) and integrated solar dish plate to be used in solar air heater. During this project reflector plate with stand and paraffin is employed. The heat storage capability of paraffin is additional. So the number of heat energy is increased with the assistance of this reflector. Because of this additional quantity of heat energy the difference of water air temperature and outlet air temperature is additional, so high temperature of hot air is obtained and efficiency of collector plate is enhanced. This improved collector efficiency by reducing heat loss to the atmosphere, and facilitate reach an overall efficiency, that accosts of pumping loss for moving air through the collector.

Keyword: Solar air heater, Thermal storage, Paraffin wax, Experimental analysis

I. INTRODUCTION

The analysis and development has been broad primarily based and productive,

concentrating on each the resolution of specific phase change material and also the study of the characteristics of recent materials. As reported by several researchers the key disadvantage has been the low thermal conductivity possessed by PCM that results in low charging and discharging rates particularly for organic primarily based materials).The development of a heat of transformation thermal energy storage system there for involves the Understanding of heat transfers/ exchanges within the PCMs after they endure solid-to-liquid phase change within the needed in operation temperature vary, the planning of the container for holding the PCM and drawback raised because of formulation of the phase transition.

II. DIFFERENT TYPES OF THERMAL STORAGE OF SOLAR ENERGY

Amongst All thermal heat storage techniques, heat of transformation thermal energy storage significantly attractive because of its ability to supply high-energy storage density and its characteristics to store heat at constant temperature like the phase-transition temperature of phase change material (PCM). Phase change is within the following form: solid–solid, solid–liquid, solid–gas, and liquid–gas and vice versa.

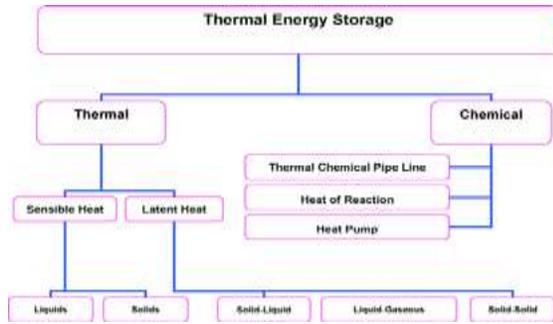


Fig. 1 Different types of Thermal Energy Storage

In solid–solid transitions, heat is kept because the material is transformed from one crystalline to a different. These transitions typically have little latent heat and tiny volume changes than solid–liquid transitions. Solid–solid PCMs supply the benefits of less stringent instrumentation needs and larger style flexibility. Most promising materials are organic solution of pentaerythritol (m.p.188°C, latent heat of fusion 323kJ/kg), pentaglycerine (m.p.81°C, heat of transformation of fusion 216kJ/kg), Li_2SO_4 (m.p.578, latent heat of fusion 214kJ/kg) and KHF_2 (m.p.196°C, latent heat of fusion 135kJ/kg). Trombe wall with these materials may offer higher performance than a plain concrete Trombe wall. Solid–gas and liquid–gas transition through have higher latent heat of action however their giant volume changes on action are related to the containment issues and rule out their potential utility in thermal- storage systems. Large changes in volume build the system complicated and impractical.

III. CLASSIFICATION OF PCMs

A large variety of phase changes materials (organic, inorganic and eutectic) are on the market in any needed temperature vary. A

classification of PCMs is given in Fig. 2. There are a large variety of organic and inorganic chemical materials, which may be known as PCM from the purpose of read melting temperature and latent heat of fusion. However, except for the melting point within the in operation vary; majority of phase change materials doesn't satisfy the factors needed for an adequate storage media as mentioned earlier.

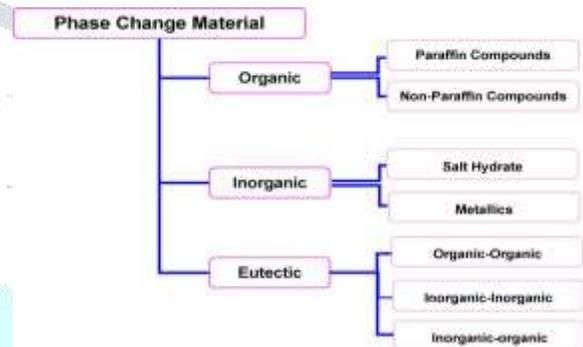


Fig.2 Different Types of PCM

Paraffins

Paraffin wax consists of a combination of largely straight chain n- alkenes $\text{CH}_3\text{-(CH}_2\text{)-CH}_3$. The crystallization of the $\text{(CH}_3\text{)-}$ chain release an outsized quantity of latent heat. Each the melting point and latent heat of fusion increase with chain length. Paraffin qualifies as heat of fusion storage materials because of their handiness during a massive temperature vary. Because of value thought, however, only technical grade paraffins is also used as PCMs in heat of transformation storage systems. Paraffin is safe, reliable, certain, less costly and non-corrosive. They with chemicals inert and stable below 500°C, show very little volume changes on melting and have low pressure level within the melt kind. For these properties of the paraffins, system using

paraffins typically have very long freeze–melt cycle. Table lists thermal properties of some technical grade paraffins, that are primarily, paraffin mixtures and aren't fully refined oil. The melting point of alkane will increase with the increasing variety of carbon atoms. Except some many favorable characteristic of paraffins, like congruent melting and smart nucleating properties. They show some undesirable properties such as: (i) low thermal conduction, (ii) non compatible with the plastic container and (iii) moderately flammable. of these undesirable effects may be part eliminated by slightly modifying the wax and also the storage unit.

Table 1: Physical Properties of some paraffin

No. of carbon atom	Melting Temperature (°C)	Latent heat of fusion (kJ/kg)
20	36.7	246
21	40.2	200
22	44.0	249
23	47.5	232
24	50.6	255
25	49.4	238
26	56.3	256
27	58.8	236
28	61.6	253
29	63.4	240
30	65.4	251

Paraffin wax could be a white or colorless soft solid derived from petroleum, coal or shale that consists of a mix of hydrocarbon molecules containing between twenty and forty carbon atoms. it's solid at temperature

and begins to melt on top of some 37 °C (99 °F) its boiling purpose is >370 °C (698 °F).Common applications for wax embrace lubrication, electrical insulation and candles dyed wax will be created into crayons. It's distinct from kerosene another fossil oil product that's generally referred to as paraffin.

IV. SAMPLE CALCULATION

We considered second set of reading only first day

The reading absorbed from experiment $T_{amb} = 25^{\circ}C$

$$I = 5.95 \text{ mv} = (3.95 \times 129.31) = 511.25 \text{ W/m}^2$$

$$T_{avg_i} = 25^{\circ}C$$

$$V = 1.5 \text{ m/s}$$

$$T_{avg_o} = 30^{\circ}C$$

$$\rho_{27.5} = 1.175 \text{ Kg/m}^3$$

$$T_{mf} = 27.5^{\circ}C$$

Data obtained from hand-book (Data Hand book by Domkundwar & Domkundwar)

$$\rho_{20} = 1.205 \text{ Kg/m}^3$$

$$\rho_{30} = 1.165 \text{ Kg/m}^3$$

$$\rho_{29.5} = 1.167 \text{ Kg/ m}^3$$

$$\rho_{42} = 1.120 \text{ Kg/m}^3$$

$$\vartheta_{29.5} = 1.5953 \times 10^{-5} \text{ m}^2/\text{s}$$

$$K_{29.5} = 0.02634 \text{ W/m K}$$

$$Pr = 0.699$$

$C_p = 1005 \text{ J/Kg K}$

Geometrical Data: Cross-section

Area of duct (A) = ($w \times d$) = (0.30×0.03) = 0.009 m^2

Perimeter of duct (p) = $2(0.30 + 0.03) = 0.66 \text{ m}$

Panel Area (A_p) = ($1 \times w$) = (2×0.30) = 0.6 m^2

Equivalent Diameter (D_e) = $\frac{4A_c}{p} = 0.05454 \text{ m}$

Hydraulic Radius (R_h) = $\frac{A_c}{p} = 0.013636 \text{ m}$

Calculation:

1. Mass flow rate (\dot{m}_1) = 0.015 Kg/s

2. Mass flow rate (\dot{m}_2) = 0.020 Kg/s

3. Mass flow rate (\dot{m}_3) = 0.025 Kg/s

4. Reynolds number (R_e) = $\frac{4R_h V}{\nu} = 5189.724$

5. Friction Factor (f) = $\frac{1}{(1.82 \log R_e - 1.64)^2} = 0.038124$

6. Nusselt Number (Nu) = $\frac{(f/8)(R_e - 1000)Pr}{1 + 12.7\sqrt{f/8}(\sqrt[3]{Pr^2} - 1)}$ = 17.14

7. Convective Heat Transfer Coefficient (h) = $\frac{Nu \times k}{D_e} = 8.2366 \text{ W/m}^2\text{k}$

8. Efficiency (η) = $\frac{\dot{m} C_p (T_{avg_o} - T_{avg_i})}{I A_c} = 24.57\%$

V. RESULTS

Local measured information of global solar radiation incident on inclined surface and meteorologic information (Temperature) on testing days are obtained by direct measure. The hourly variation of star intensity-I and close temperature-Ta for the testing days are shown in figures 3 and 4 severally.

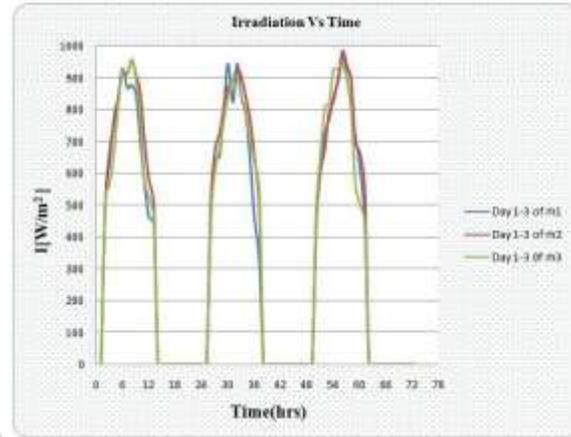


Fig.3 Hourly variation of solar radiation in all run days

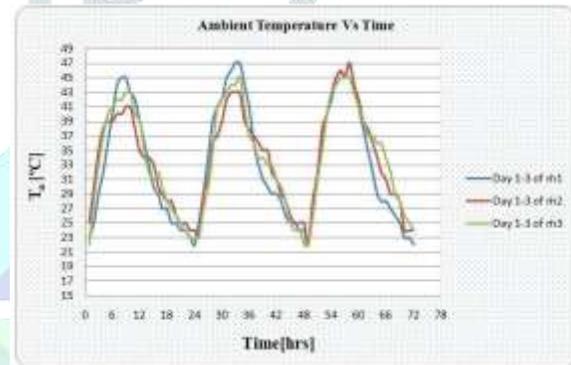


Fig.4 Ambient air temperature in all run days.

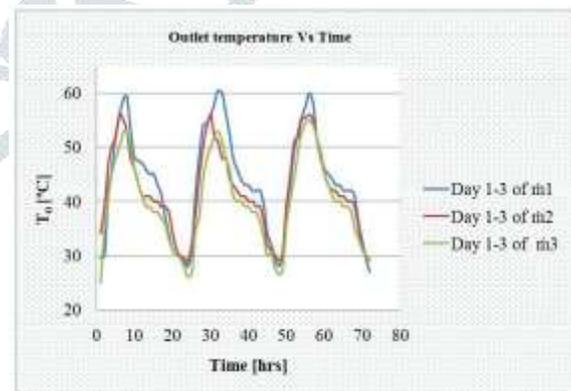


Fig.5 Outlet temperature Vs Time for run days

VI. CONCLUSION

On the premise of the experimental results obtained for 9 run days on 3 totally different mass rate of air, for force convection solar air utility with phase change material (Paraffin wax) energy storage, manufactured and tested. Increasing the mass rate causes a consequent increase of the time average instant collector efficiency. Average efficiency of the collector are 35.85 %, 36.97 %, and 38.66%, on 3 totally different mass rate (i.e. $\dot{m}_1 = 0.015$ Kg/s, $\dot{m}_2 = 0.020$ Kg/s, and $\dot{m}_3 = 0.025$ Kg/s) of air severally. Air and plate temperature normally will increase on the air heater. air mass rate and radiation are predominant issue that affect the performance of air heater. Increasing the mass rate causes a consequent decrease of air and plate temperatures.

REFERENCES

- [1] Abhat A. Low temperature latent heat thermal energy storage. In: Beghi C, editor. Thermal energy storage. Dordrecht, Holland: D. Reidel Publication Co.; 1981.
- [2] Abhat A, et al., Development of a modular heat exchanger with an integrated latent heat storage. Report no. BMFT FBT 81-050. Germany Ministry of Science and Technology Bonn; 1981.
- [3] Aissa, W., et al. —An Experimental Investigation of Forced Convection Flat Plate —THERMAL SCIENCE: Year 2012, Vol. 16, No. 4, pp. 1105-1116
- [4] Alkilani Mahmud
M.Kamaruzzamansopian and Sohif
- mat — Fabrication and Experimental Investigation of PCM Capsules Integrated in Solar Air Heater, American Journal of Environmental Sciences, . vol.7 (6).
- [5] A.Mohamad, High efficiency solar air heater, Solar Energy, vol. 60, no. 2, pp. 71-76, February 1997.
- [6] A.Severson and et. al., Solar air heater, U.S. Patent 4085730, 1978.
- [7] A.Shukla, D.Buddhi, and R.Sawhney, Solar water heater with phase change material thermal energy storage medium: A review, Renewable and sustainable energy Reviews, vol. 13, no. 8, pp. 2119-2125, October 2009.
- [8] A.Whillier, —Plastic cover for solar collector, solar energy vol. 7, no.3, pp.148-151, July-September 1963.
- [9] B.Kumar, Design, development and performance evaluation of a latent heat storage unit for evening and morning hot water using a box type solar collector, M.Tech, Devi Ahilya University School of Energy and Environment studies Indore, India, 2001.
- [10] B.S.Romdhane, —The air solar collector: Comparative study, introduction of baffels to favor the heat transfer, Solar Energy, vol 81, no. 1, pp. 139-149, January 2007.