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Research Article

STUDY ON THERMAL PERFORMANCE OF PCM INTEGRATED CONCENTRATED SOLAR ABSORBER

RAMALINGAM SENTHIL*, MANISH KUMAR AND AVINASH VAISHYA

Department of Mechanical Engineering, SRM University, Kattankulathur-603 203, Chennai, India

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ABSTRACT

In this study,a cylindrical solar absorber is investigated with integrated phase change material (PCM). The objective of this work is to store the heat energy at the focal point using thermal masses. A eutectic mixture of NaNO3 and KNO3 in 60:40 ratio is used as the phase change material. The absorber is placed at the focus of Scheffler reflector of 16 m2 aperture area. The receiver is heated to different upper temperature limits and the heat energy stored is determined based on the temperature measurements.

INTRODUCTION

Concentrated solar collectors are cavity absorber has the advantage of maximum heat absorption through the total internal reflection of concentrated solar rays. The construction and testing of Scheffler type solar water heater wereinvestigated (Rupesh, *et al.*, 2011). The solar air receiver was investigatedwith foam (Wu and Wang, 2013).

Analysis of a latent heat thermocline storage system with encapsulated PCMfor the solar thermal plant was investigated (Nithyanandam, *et al.*, 2014).

The encapsulated PCM was investigated during both energy storage and retrieval processes (Elmozughi, *et al.*, 2014).

The thermal characteristics of a volumetric solar absorption system were examinedand the void increased the melting time of PCM (Siddiqui and Yilbas, 2015; Zhao, *et al.*, 2014; Yilbas and Kaleem, 2015).

The effect of recirculated fluid flow through the concentrated solar receiver based on the temperature distribution and incorporation of PCM were reported with thermal enhancement of the solar receiver (Senthil and Cheralathan, 2015; Senthil and Cheralathan, 2016; Senthil and Cheralathan, 2015).

The selective coatings of the solar absorber were investigated and the effective coating was proposed (Sundaram and Senthil, 2016). The coating is important to capture more incident energy to convert the radiation to heat energy of fluid.

In this work, the charging of PCM integrated solar absorber in investigated at the parabolic dish collector and the energy stored based on the operating temperature are reported.

EXPERIMENTAL PROCEDURE

The 16 m^2 parabolic dish collector is built by Thermax Ltd, Pune, India. The absorber is kept at a focal distance of 2.75 m. The concentrated direct radiation on the absorber surface is transferred to HTF through the attached mild steel fins. (Fig. 1) illustrates the various stages of fabrication of the solar absorber (Table 1).

(Fig. 2) illustrates the photographic view and schematic layout of the experimentalsetup. Thermal performance of the PDC can be characterized by an estimation of the stagnation temperature and performance test at constant solar energy input with the equal periods.

A eutectic mixture of $NaNO_3$ and KNO_3 in 60:40

***Corresponding authors email: rsenthilsrm@gmail.com**

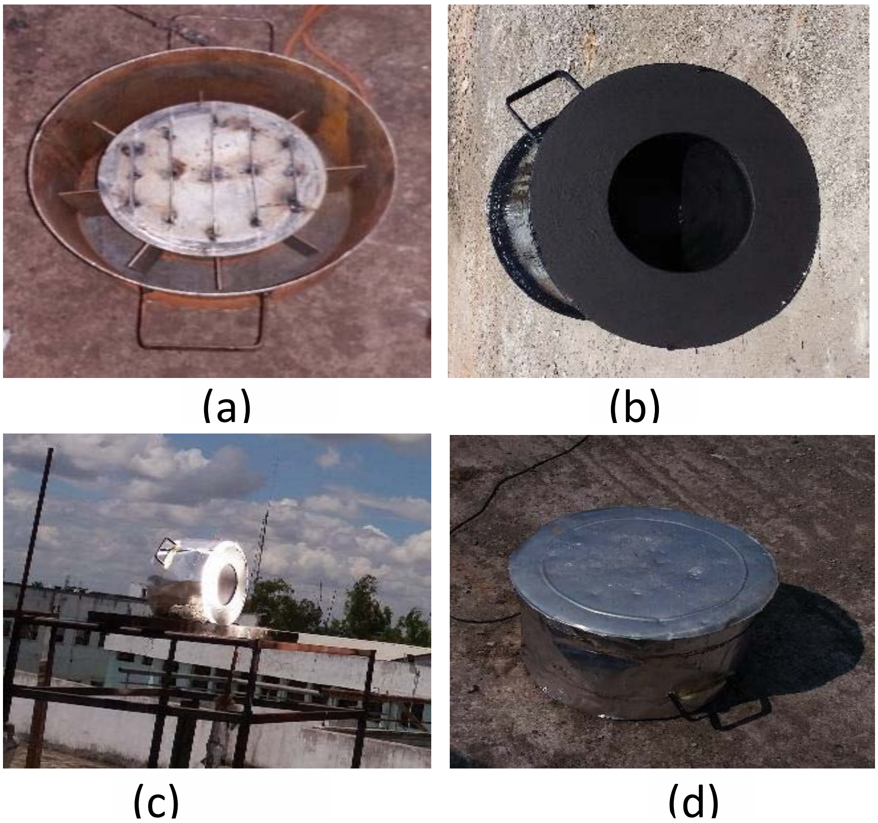

Fig. 1 Solar cavity absorber: (a) Absorber with fins (b) black coated absorber (c) Absorber at the test bed (d) Insulated solar absorber after charging

Table 1. Specifications of cavity absorber

Outer diameter	360 mm
Inner diameter	220 mm
Plate thickness	2.5 mm
Wall thickness	5 mm
Fin thickness	2 mm
Material	Mild steel

ratio has melting temperature and enthalpy of 220°C and 121 kJ/kg respectively. The solar radiation, wind speed and ambient temperature are observed using pyranometer, anemometer and K-type thermocouples respectively (Fig. 2).

Heat absorbed by heat transfer fluid is given by

$$Q_u = mC_p\,(Ta\text{-}Ti\,) \tag{1}$$

Where Q_u -heat gain, m – mass of PCM, Ta - ambient temperature, T_i– initial temperature,Cp- Specific heat.

The thermal efficiency of absorber given by the following relation.

$$\eta_i = \frac{m_f C_p (T_o - T_i)}{I_b A_a} \tag{2}$$

Where C_p is the mass flow rate of water (kg s^{-1}), C_p is the specific heat of water (J kg^{-1} k^{-1}), (To - Ti) is the temperature difference of HTF in the absorber inlet and outlet. The overall efficiency of the system is evaluated by the given expression as,

$$\eta_o = \frac{Q_u}{Q_{in}} = \frac{m_f C_p (T_o - T_i)}{I_b A_a t \eta_{op}} \tag{3}$$

RESULT AND DISCUSSION

Experimental performance of 16 square-meter solar PDC with cylindrical absorber. The absorber is heated in various operating condition at different temperature and found the energy store by the PCM in theabsorber. The graphs are plotted between time, PCM temperature, ambient temperature and radiation. The temperature of PCM depends upon the solar radiation.

(Fig. 3-5) shows the operating conditions of the charging process of PCM integrated solar absorbers. The solar radiation, PCM temperature and ambient temperature are depicted graphically. The PCM temperatures are 275, 290 and 295°C. The experiment is started at 11:00 am that PCM temperature increased with solar radiation in one and half hour to 275°C.

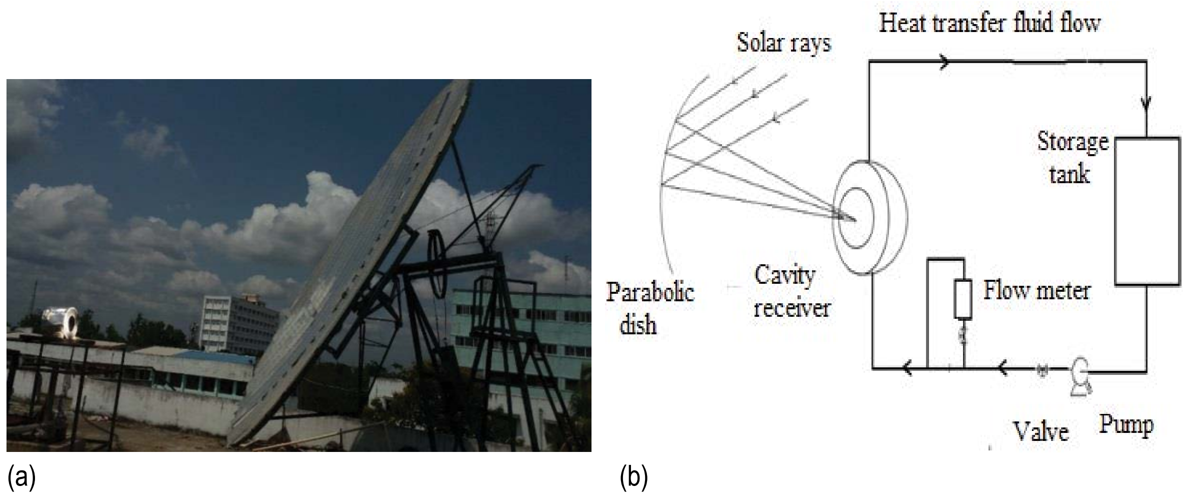

Fig. 2 Parabolic dish collector (a) Photographic view; (b) Schematic layout.

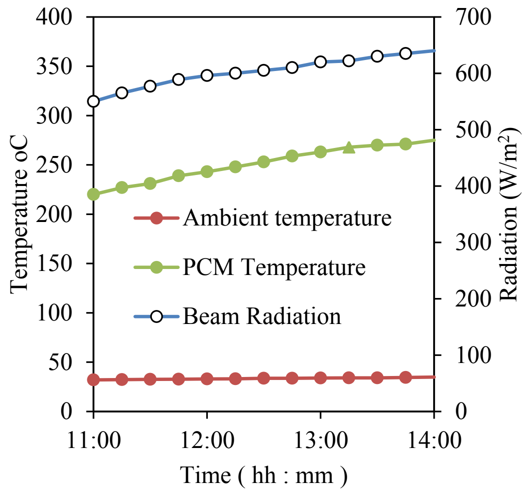

Fig. 3 PCM temperature versus solar radiation.

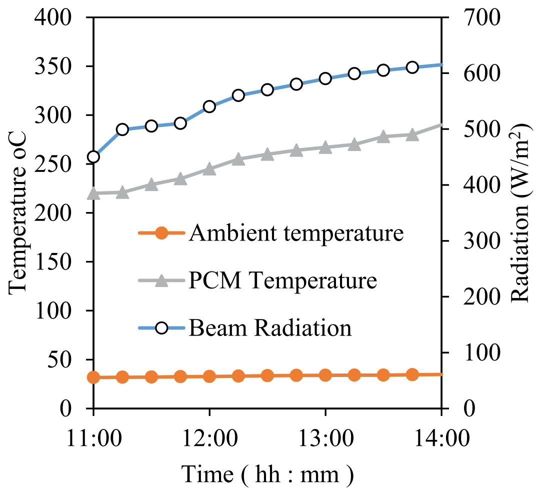

Fig. 4 PCM temperature versus solar radiation.

All the charging experiments are conducted with similar radiation conditions and clock hours. The test standards of solar collector are (ASHRAE, 1991).

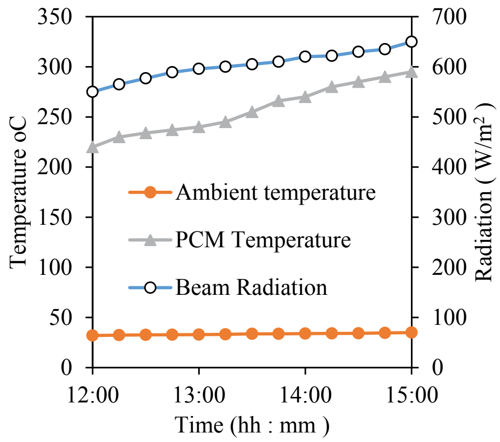

Fig. 5 PCM temperature versus solar radiation.

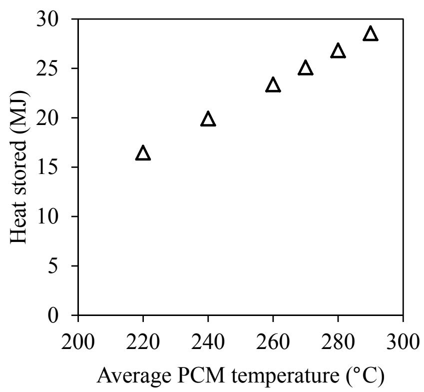

Fig. 6 Heat stored by the absorber at different operating temperatures.

The experiment is carried out in high radiation within two hours it gives the 300°C temperature. Hence, the charging time depends upon the solar radiation. When radiation level is maximum the time require by the absorber for charging is minimum (Fig. 5).

(Fig. 6) shows the quantity of heat stored based on the PCM temperatures. The increase in temperature increases the energy stored by the absorber. At maximum temperature, the amount of energy stored by absorber is maximum due to the sensible heat of absorber and latent heat of PCM. Around 30 kJ is stored in 1.5 hours of operation with 20 kg of salt nitrates.

The selection of PCM and a suitable heat retrieval mechanism to be devised to extract the stored energy effectively for any particular application.

CONCLUSION

A cylindrical cavity absorber using fins has been investigated at various operating temperatures. Fins are used to increase the thermal performance of absorber. The heat energy stored in the absorber itself reduces the heat transport losses in piping. The upper critical temperature of the energy storage material defines the maximum energy of the absorber.

The charging of the PCM integrated solar absorber depends upon the solar beam radiation, wind velocity and ambient temperature. With the selected PCM, around 30 MJ of heat energy is stored. The energy stored by the absorber can be utilized in the different heating application such as space heating, cooking application, water heating application.

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