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"Performance Analysis of PCM Filled Absorber Plate in Double Pass Solar Air Heater"

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Abstract: The solar air heater is widely used for food drying and printing industries. But due to the solar time its utilization is for limited time period. The conventional solar air heater has lower heat transfer coefficient as compared to the double pass solar air heater and for that the double pass solar air heater has been selected to enhancement of performance. The Phase Change Material (PCM) is used to enhance the time period for air heating by storing the energy with Latent heat of material. Selection of material is based on the temperature application. Finned type absorber plate is enhancing the heat transfer with high heat transfer area.

Keywords: PCM, Solar Air Heater, DPSAH, Solar Radiation, Heat transfer

Introduction

The supply and demand of energy determine the course of global development in every sphere of human activity. Sufficient supplies of clean energy are intimately linked to global stability, economic prosperity, and quality of life. Finding energy sources to satisfy the world's growing demand is one of society's foremost challenges for the next half-century. The importance of this pervasive problem and the perplexing technical difficulty of solving it requires a concerted national effort marshalling our most advanced scientific and technological capabilities. The world now uses energy at a rate of approximately 4.1 × 1020 joules/yr, equivalent to a continuous power consumption of 13 trillion watts, or 13 terawatts (TW). Even with aggressive conservation and energy efficiency measures, an increase of the Earth's population to 9 billion people, accompanied by rapid technology development and economic growth world-wide, is projected to produce more than double the demand for energy (to 30 TW) by 2050, and more than triple the demands (to 46 TW) by the end of the century. The reserves of fossil fuels that currently power society will fall short of this demand over the long term, and their continued use produces harmful side effects such as pollution that threatens human health and greenhouse gases associated with climate change. Alternative renewable fuels are at present far from competitive with fossil fuels in cost and production capacity. Without viable options for supplying double or triple today's energy use, the world's economic, technological, and political horizons will be severely limited.

Problem Statement

Solar air heater lower heat transfer co-efficient and working period is only an in solar hour which is required to enhance for the industrial application.

Objective of Work

- To enhance the Performance of the Solar Air Heater.
- Reduction in the area required for the same.

- Increase the working time of Solar Air Heater by storing Energy.

To observe the effect of PCM based Absorber Plate in the double pass Solar Air Heater.

Literature Survey

Baig, W. and Ali, H.M., (2019) worked to enhance the DPSAH experimentally with four different conditions. The scope of present study encompasses the use of Thermal Storage Medium (paraffin wax) integrated with porous/foam metal (aluminum) during the winter season. In the first phase of experimentation, first formation consisted of flat plate whereas foam aluminum embedded with paraffin wax was placed inside two copper ducts in the second configuration. In1 the third configuration, four copper ducts were used. During the second phase of experiment, similar configurations were used as in the first phase but with pre-heat. No melting of wax was accomplished when the outside air temperature ranged between 12-24°C, however increased thermal conductivity was attained for configuration two and three. Melting of wax was achieved when the outside air temperature ranged between 15-29°C, using pre-heat. The increase in thermal conductivity was achieved using foam aluminum but at the expense of slight decrease in storage capacity of the paraffin wax. In the last configuration no fan was used during the day time, and melting of wax achieved under similar conditions. Fourth configuration provided beneficial heat for 2.5 hours after the sunset while the second and third configurations provided expedient heat for 1.5 hours after the sunset. [1]

Singh, S et al. , (2019) investigated double pass converging finned wire mesh packed bed solar air heater design is experimentally. Double (Counter) pass of air is provided by forcing the air first through an upper channel which is formed between the lower glass cover and the absorber plate, then through the lower channel created between the absorber and the back plates. Whereas, solar air heater design consists of two glass covers on the top and converging fins in the lower channel. Periodic converging sections are provided in the lower channel by utilizing sixteen numbers of fins attached at an angle of about 11° to the bottom and top of the absorber and back plates, respectively. In addition to the finned channel, ten layers of wire mesh screens confer 96% channel porosity in the second channel. Moreover, wire mesh offers high heat transfer area to the exiting jet of the air from the converging region as well as provides thermal energy storage. The maximum thermal and thermo hydraulic efficiencies of the solar air heater are obtained as 93% and 80%, respectively, at a mass flow rate of 0.03 kg/s and about 0.023 kg/s, respectively. The best output of the solar air heater is the hot air at a temperature of 55 °C corresponding to the mass flow rate of 0.01 kg/s and solar radiation of about 823W/m^2. [2]

Murali, G et al., (2019) investigated experimentally on solar air heater with a double pass configuration and rectangular longitudinal fins on one side of the absorber plate. Performance parameters outlet temperature, absorber plate temperature, output power of the air heater with fins placed in lower channel and fins placed in upper channel were presented. The effect of mass flow rate of air on the efficiency of air heater with fins in lower and upper channel were also investigated. The result shows that air heater with fins placed in lower channel is more efficient than the air heater with fins placed in upper channel. [3]

Fan, W., Kokogiannakis, G. and Ma, Z., (2019) integrated double pass photovoltaic thermal-solar air heater (PVT-SAH) system with heat pipes was developed for high-temperature air requirement. The PVT-SAH systems with heat pipes had higher capital construction costs than the benchmark designs but can still offer an annualized life cycle saving that ranged from A$925 to A$4606 and a payback time between 5.7 and 16.8 years. The PVT-SAH system with heat pipes was also found to deliver more efficient cooling effect to the PV panel and improve the temperature uniformity of the PV panel. The temperature variation along the length of the PV panel for the proposed system and for the benchmark design was 9.4 ºC and 21 ºC respectively. In addition, the maximum thermal efficiency of the PVT-SAH with heat pipes was 69.2% compared to 61.7% for benchmark design. [4]

Salih, S.M et al., (2019) aims to investigate and analyze the thermal performance of a double-pass solar air heater using multiple rectangular capsules filled with paraffin wax-based on a phase change material PCM. An indoor projector simulator was used to test a new system during the charge/discharge process. The computational results were in reasonable agreement with the experimental readings. The investigations were carried out at various airflow speed of (0.6, 0.9, 1.2, 1.5, and 1.8) kg/min and three solar irradiance intensities of 625, 725, and 825 W/m2. The results showed that the increased airflow rate leads to delay in the melting period and decrease melting temperature of the paraffin during the melting period. Furthermore, it can be detected that the optimal discharging period and the air temperature rise of the heater were reached of: 3hr with (17.95e3) ˚C, 2 h with (14e3) ˚C, and 1.25 h with (11e2.5) ˚C, for various solar intensity of 825, 725, and 625 W/m2 at the same airflow speed of 0.6 kg/min, respectively. [5]

Methodology

Double pass solar air heater used for drying and space heating. This device has lower efficiency. So that lots of research work has been carried out by researchers to enhance the efficiency of the solar air heater. To increase the heat transfer rate researchers perform solar air heater with different type of absorber plate such as perforated, wired mesh type, grooved type, with fins type, etc.

In this case study, double cover double pass solar air heater can be performed with PCM based finned type absorber plate. Absorber plate will be fitted at the middle of the collector. 4mm glass cover will attached at the top of the collector. Glass cover has a negligible thermal conductivity and it cannot allow low frequency (low grad energy) rays to outside. Inner surface of the collector and absorber plate will coated black to absorb the maximum solar radiation. 23° inclination to the horizontal is providing to the collector. Inlet outlet channel has equal holes to distribute the air equally. Blower attached at the outlet to blow air from the all around the system and circulate it into a recycle channel. Control valve is providing to control the amount of air added in the recycle. Anemometer will provided to measure the flow rate of air threw the outlet of blower or Solar air heater. Temperature at the different points is required to measure with the help of J- Type thermocouple and value has been checked on J-type temperature indicator. Air velocity and wind velocity will measured by anemometer and solar radiation measuring by pyranometer bulb type digital solar meter. Variac has been given to varying load of blower. This experiment will carried out with simple absorber plate and Modified absorber plate. Resultant temperature, pressure, solar radiation air temperature will measure at different flow rate and compare respectively.

The thermal efficiency of the solar collector (η) is defined as the ratio of energy collected (useful energy) and solar radiation incident on the collector plane (Eq. 6):

$$\eta = \frac{\dot{m}C_p\left(T_{a,out} - T_{a,in}\right)}{I.A_c} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (6)$$

Experimental Process

The experimental setup will be designed to measure the effect of metallic wiry sponge inserted in the double pass solar air heater. The experimental setup has been fabricated from the galvanized iron sheet of 16” gauge (1.6mm), the reduced draft has been provided to the equally air distribution at the inlet and outlet section. The absorber M.S. plate is put at the middle of the solar air heater and all inner surfaces with absorber plate coated black paint to absorb the maximum solar radiation. Adjustable inclination stand has been designed to measure the effect of different inclination angles of solar air heater. For batter comparison there are two set up will fabricated of same dimensions. Absorber plate area is designed to measure the effect is $0.5m^2$. Induced draft fan is placed at the inlet of the DPSAH with reverse side. 4mm clear glass is placed at the top of the air heater to reduce the heat loss. In the experimental setup absorber plate is made up of square pipe in which both the sides are closed. From the two side of pipe one side is welded closed and the other side is made with internal flange type to seal the side with flat plate with screw. The absorber plate is placed at the middle in the solar air heater flow tunnel. The inlet is from the bottom section and the outlet is at the top circular pipe. The inlet and outlet provision is made with standard pipe which is outside threaded and fix flange on it for attaching the induced draft fan. Induced draft fan is configuring reversely to ensure the flow is flow inside the duct. The fan speed is maintaining with dimmer regulator. Before fixing the glass temperature sensors were placed at the desired positions. The temperature sensors are connected with the temperature indicator which is help to record data manually by scanning one by one.

Figure 1 Experimental Setup

Properties of Paraffin Wax

Density(Solid)	810 (kg/m3)
Latent Heat	249 (kJ/kg)
$\mathbf{T_{melt}}$	59 to 66 (°C)
Corrosive	Non-Corrosive
PCM Filled in Single pipe	1.5kg
Total PCM Filled in Pipe	4.5kg
Form of PCM	Powder

Result & Discussion

Results have been calculated by collected data from observation and measurement from the number of experiments. The calculations of the efficiency and heat transfer co-efficient have been calculated in the Software **Microsoft Excel**. As per the equations of the solar air heater and reference of data collected the efficiency of the solar air heater has been calculated and represented as following:

Result Tables

The result tables have been collected from the **Microsoft Excel Sheet.** The number of table shows the calculated results for two different solar air heater with various flow rate the solar air heater.

Result for the Comparative Study

Figure 2 shows the behavior of Solar radiation for the different run during the experiment. From the Figure 2 it has been observed that the solar radiation is increasing during the start of the day gradually. The maximum solar radiation has been observed during the time of 12:00pm to 02:00pm and then it reduced gradually towards the end of the day. The data has been observed for the longer day time because of PCM material store the energy in terms of heat as latent heat.

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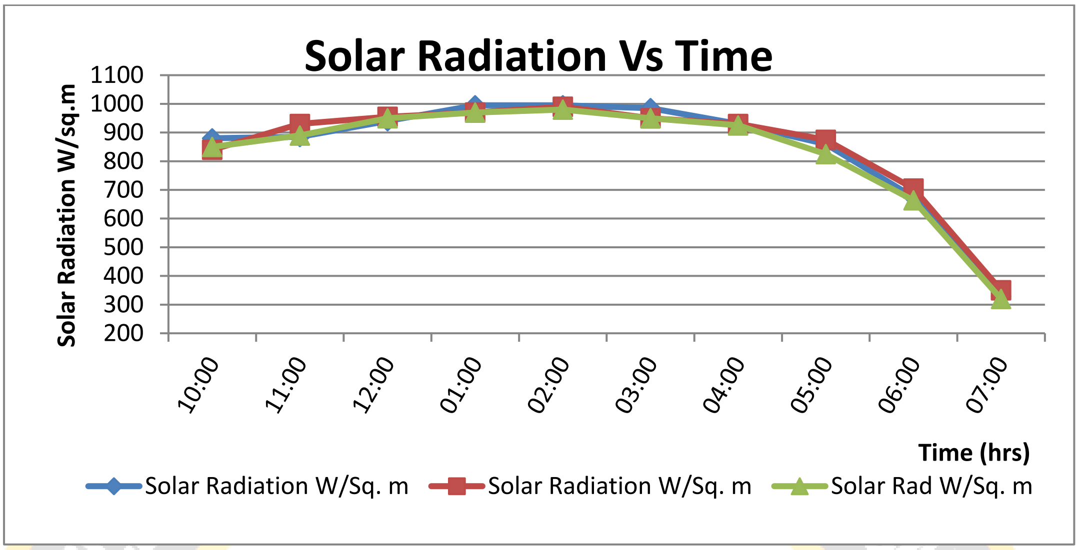

Figure 2 Solar Radiation with respect to Time during the day time

Figure 3 shows the temperature behavior of double pass solar air heater with change in temperature with respect to time. The lowest temperature observed with the ambient air temperature and the highest temperature observed with highest air outlet temperature from the double pass solar air heater during the experiment.

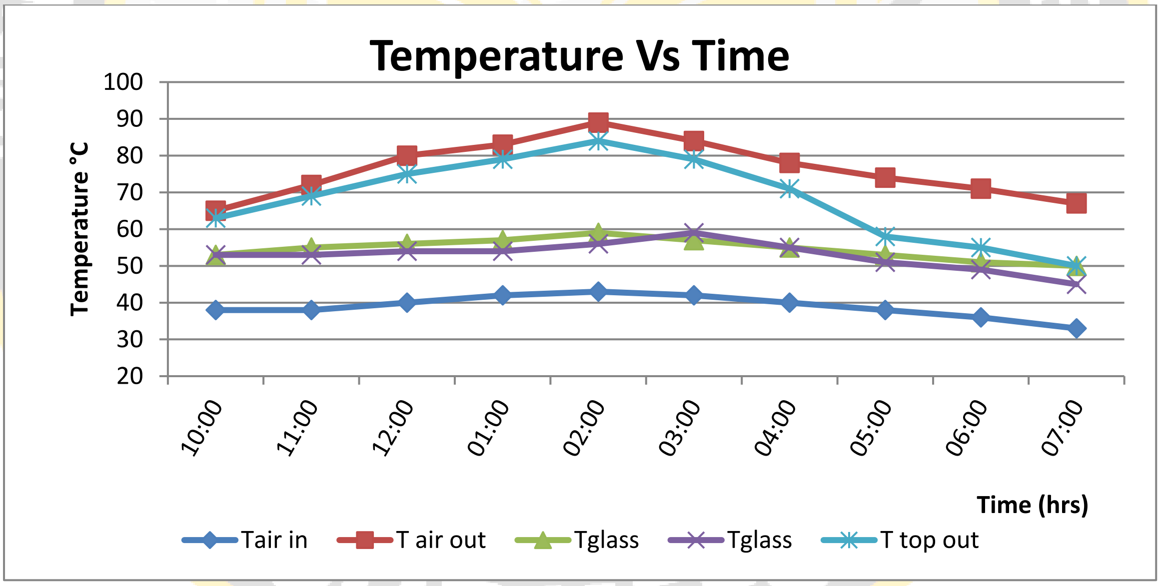

Figure 3 Effect on Temperature behavior with Time for 50CFM Air Flow

Figure 4 shows the daily temperature recorded data during the experiment. From the result it has been observed that the temperature in the modified double pass solar air heater gives the high temperature as compared to the double pass solar air heater with metallic wiry sponge.

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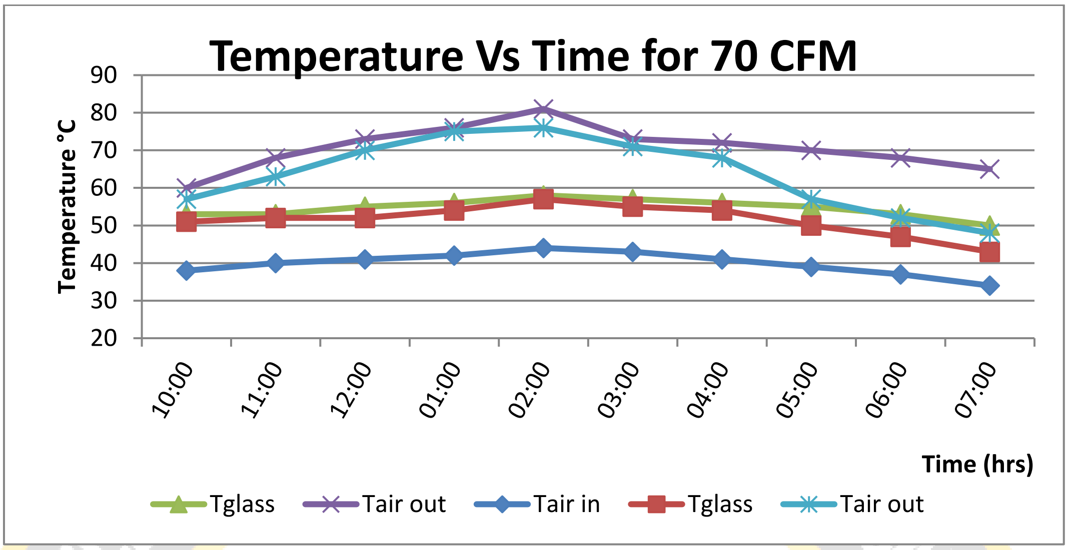

Figure 4 Effect on Temperature behavior with Time for 70CFM Air Flow

From the Figure 5 it has been observed that the temperature of the modified double pass solar air heater is higher as compared to the metallic wiry sponge based absorber plate. And from the result it has been observed that with increase in the flow rate of air the outlet air temperature is reduced.

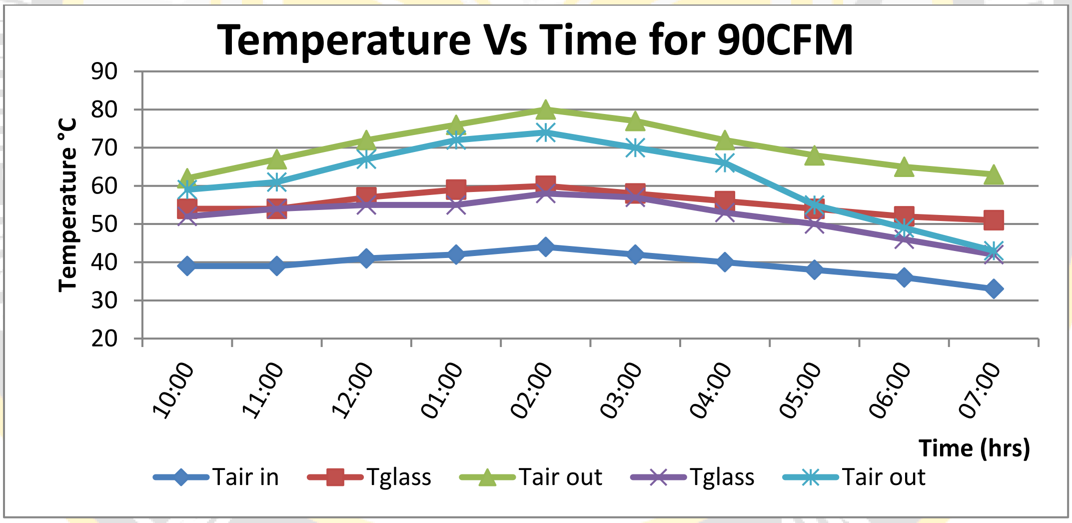

Figure 5 Effect on Temperature behavior with Time for 90CFM Air Flow

From the Figure 6 it has been observed that the efficiency of the system is gradually increasing in both the double pass solar air heater but after 02:00pm the efficiency in the DPSAH with metallic wiry sponge is reduced and the efficiency in the DPSAH with PCM material is increasing drastically because of lower solar radiation and heat convected from stored in the PCM material.

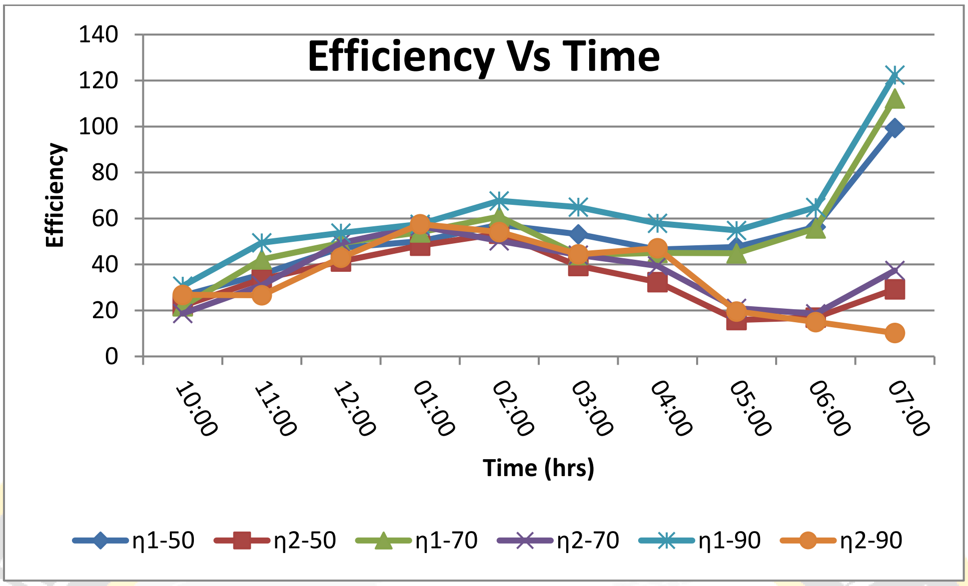

Figure 6 Efficiency of DPSAH with PCM material and with Metallic wiry Sponge Vs Time

Conclusion

The experiment has been carried out to enhance the performance of Double pass solar air heater. For that the comparative study between metallic wiry sponge and PCM based absorber plate has been taken. From the results it has been observed that the PCM based absorber plate has high efficiency and also it give high temperature air in output for a longer time because of energy stored inside the PCM material.

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