Enhancement in efficiency of solar air heating system with thermal energy storage system

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ABSTRACT

In order to produce process heat for drying of agricultural, textile, marine products, heating of buildings and re-generating dehumidify agent, solar energy is one of the promising heat sources for meeting energy demand without putting adverse impact of environment. Hence it plays a key role for sustainable development. Solar energy is intermittent in nature and time dependent energy source. A solar air heater is such a device which is fabricated and integrated with thermal storage system in this paper. A salt hydrate(STL27) is used as a thermal storage medium. The performance of this heater was studied for two configurations and comparison between two configuration is shown in this paper. The solar heater integrated with thermal storage delivered comparatively high temperature. The efficiency of the air heater integrated with thermal storage was also higher than the air heater without thermal storage system. The study concluded that the presence of the thermal storage medium at the absorber plate is the best configuration.

Keyword : - *Double pass solar air heater, thermal storage medium, salt hydrate*

1. Introduction

Energy crisis and global warming lead to find an alternative way to overcome the above worsening situation. Renewable energy plays a major solution and thereby meets our energy demand and reduces the CO2 emission which reduces the greenhouse effect. In the renewable energy side, Sun is the mother for all sources and utilizing the solar energy in proper ways can eliminate the energy crisis of the world. To use the solar energy, collectors are used and for low temperature application side flat plate collectors are used. In solar air heater, solar energy is collected by means of an absorbing plate and the collected heat energy is transferred to heat transferring medium such as air.

Lovemore Kagande, Ignatio Madanhire, Canicius Matsungo [1] in their research study investigated the possibility of solar energy replacing other sources of energy such as thermal and hydro electric energy in domestic water heater. Economic comparative work on its use has been dealt with in air and water heating, and it has been found out that it can be utilized and result in appreciable power savings as well as effectively complementing existing supply sources. Nabila Ihaddadene, Razika Ihaddadene, Azzeddine Mahdi, [2] in their research paper, an attempt has been made to come across the effect of multiple glazing covers on the efficiency of a solar thermal collector. Double glazing decreased the efficiency of the solar collector with 15%. This efficiency was decreased by 29.95% for triple glazing, and by 45.96% for quadruple glazing. Vijaykumar Kalwa, R. Prakash [3] presented air cooling methods are evaporative coolers, air conditioning, fans and dehumidifiers.

Rajesh Thombre, Gajanan Awari, Shashikant Thombre [4] aimed at studying the effect of different systemparameters on the heat transfer on vertical circular tube air heater. D.S.Rawat, Dr.A,R.Jaurker [5] presented in their paper investigated heat transfer enhancement in two pass solar air heater with V-shaped rib. Ribs were attached on absorber plate, having angle of attack. Air enters the upper channel of the air heater and subsequently to the lower channel in the opposite direction. Roughened wall of the duct is uniformly heated with constant heat flux electric heater while the remaining three walls are insulated. The heat transfer results have been compared with those for smooth ducts under similar flow and thermal boundary conditions.

2. Experimental set up

A solar air heater of 750 mm length, 500 mm width and 182 mm height was fabricated using mild steel plate as shown in the Fig 1. To reduce the heat losses to the atmosphere, the collector bottom and lateral sides were insulated with 20 mm thick glass wool and to reduce convective losses, the collector top side was covered with a 4 mm glass plate. To maintain a uniform distributed flow inside the collector, a conical inlet and exit sections were provided. Using a blower, the air was forced through the upper channel in the double pass collector between the top glass cover and the absorber plate and then recirculated in opposite direction through the lower channel between the absorber plate and back plate. The heater was tilted with an angle of **23^0 03'** (local latitude angle) with respect to the horizontal position facing south direction to receive the maximum solar radiation. The detailed technical specification of the collector and the pipes used for thermal storage are listed in the Table 2. To improve the system performance, the thermal storage system i.e. phase change material was integrated with solar air heater. A salt hydrate(STL27) in the four aluminium pipes (each 4 cm diameter and 60 cm length) were used to store the excess thermal energy. The absorber plate and aluminium pipes are painted with black color to absorb maximum solar radiation. The capsules are arranged in different configurations on the absorber plate and on the back plate.

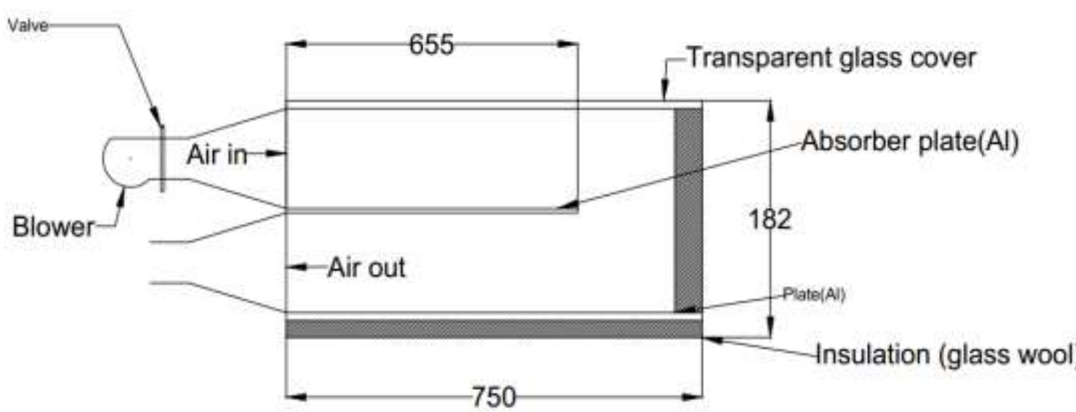

Fig-1 Diagram of solar air heater

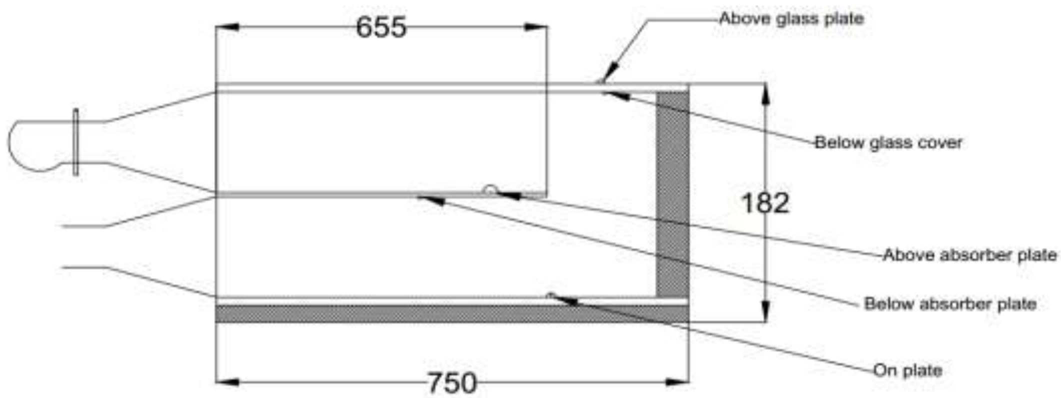

Fig-2 Position of thermocouples

Blower is connected to the inlet of the air heater through a gate valve, orifice meter and U-tube manometer. Gate valve is used to control the mass flow rate of air and U-tube manometer is used to find out the mass flow rate by measuring the head difference across the orifice. To measure the inlet and exit air temperatures, absorber plate temperature and back plate head difference across the orifice. To measure the inlet and exit air temperatures, absorber plate temperature and back plate. temperature, K type thermocouples were placed at different locations as shown in the Fig. 2 and connected to the digital indicator. Sun meter is used to measure the solar radiation intensity (Table 1). The photograph for the solar air heater experimentation setup integrated with thermal storage medium was shown in the Fig-3.

Table-1 : Accuracies and errors for various measuring instruments.

Sr no	**Instrument**	**Accuracy**	**Range**	**% error**
1	Thermometer	±1^{0}C	0–100^{0}C	5
2	Thermocouple	±0.1 ^{0}C	0–100^{0}C	0.5
3	PV type sun meter	±1 W/m^2	0–1500 W/m^2	2.5
4	U-Tube mano meter scale	±1 mm	0–1000	1

Table-2: Physical parameters of solar air heater

Sr no	**Collector components and parameters**	**Specifications**
1	Tilt angle	23^0 03 (due south)
2	Glass area	0.375 m^2
3	Collector glazing	glass with 4 mm thickness
4	Absorber plate	Width: 460 mm, length: 650 mm
5	Bottom plate	Width: 460 mm, length: 725 mm
6	Bottom insulation	20 mm thickness of glass wool
7	Side insulation	20 mm thickness of glass wool
8	Pipe, inner diameter	4 cm
9	Pipe, outer diameter	4.6 cm
10	Pipe length	60 cm
11	Weight salt hydrate(STL27) per pipe	0.55 kg

Fig-3 Photograph of solar air heater.

3. Experimental procedure

Experiments were conducted with solar air heater for four different configurations. In configuration 1(Fig.4), no thermal energy storage system was used, where as in other configurations the capsules were placed above absorber plate. In configuration 2 (Fig.5), the pipes are placed above the absorber plate. Experiments were conducted on different configurations of solar air heater from 6 AM till evening 6 PM during May 2012 at G.I.D.C Vatwa, Ahmedabad ($23^0 03^{'}$N, 72^0 $40^{'}$E), India.

The solar radiation, temperature and manometer readings were observed and recorded for every one hour. For each configuration, the readings were taken for two or three days. The observations on these days of similar radiation conditions were considered for analysis.

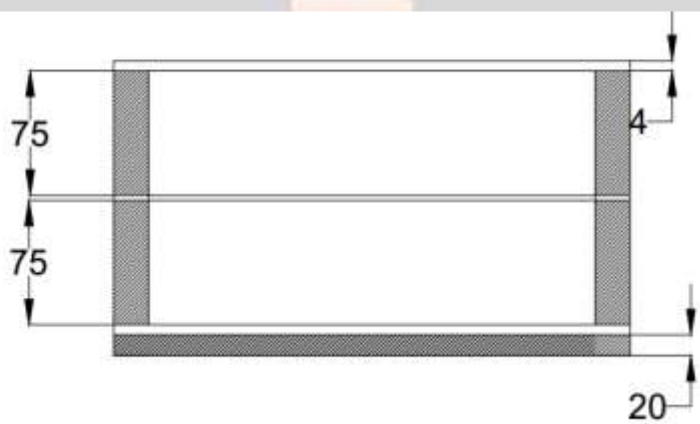

Fig-4 configuration 1**.(without thermal storage system)**

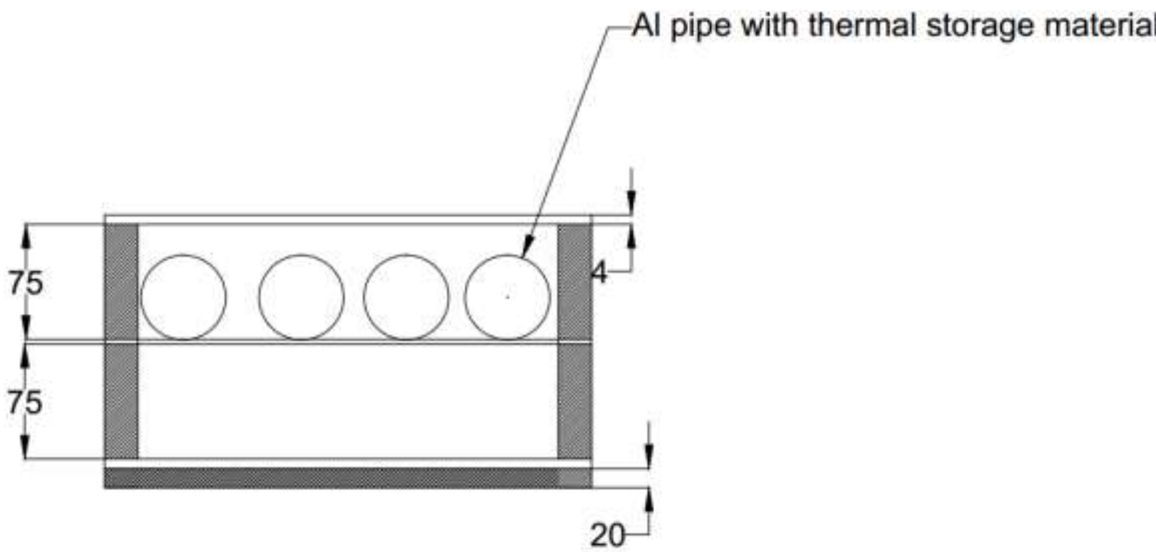

Fig-5 configuration 2.**(With thermal storage system-Pipes are placed above plate)**

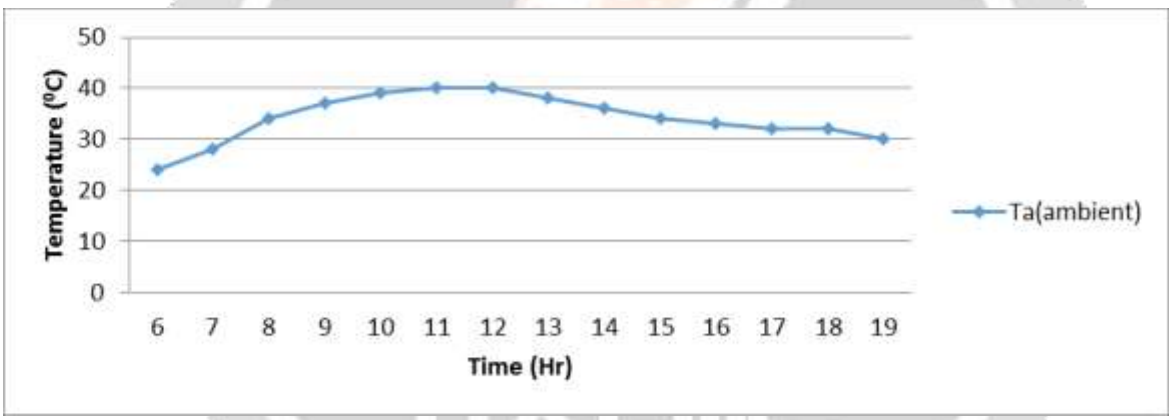

Fig-6 : Ambient temperature data on May 2012

Fig-7 : Irrradiation data

4. Results and Discussion

The average solar radiation intensity and atmospheric temperature variations during the experimental period were as shown in Fig.(6)&(7). The maximum solar radiation intensity recorded was 900 W/m^{2}at 12:30 pm. From the morning till the evening, the ambient temperature was between 30 and 40^{0}C and the mass flow rate was estimated by using U-tube manometer as 0.02 kg/s.

The typical variation of different temperatures of solar air heater with configuration 2 was as given in Fig.(8). The variation pattern was similar for all configurations. All the temperatures were varying with radiation intensity. The absorber plate is the hottest part in the air heater and it reached 70^{0}C around noon. The glass also reached the maximum temperature with absorber plate during noon. The exit air temperature closely varied with capsule surface temperature. The exit air temperatures reached a maximum value of 55^{0}C around noon. Only after 8 AM, there was an appreciable rise in all temperatures and after 5 PM all temperatures reached the low value.

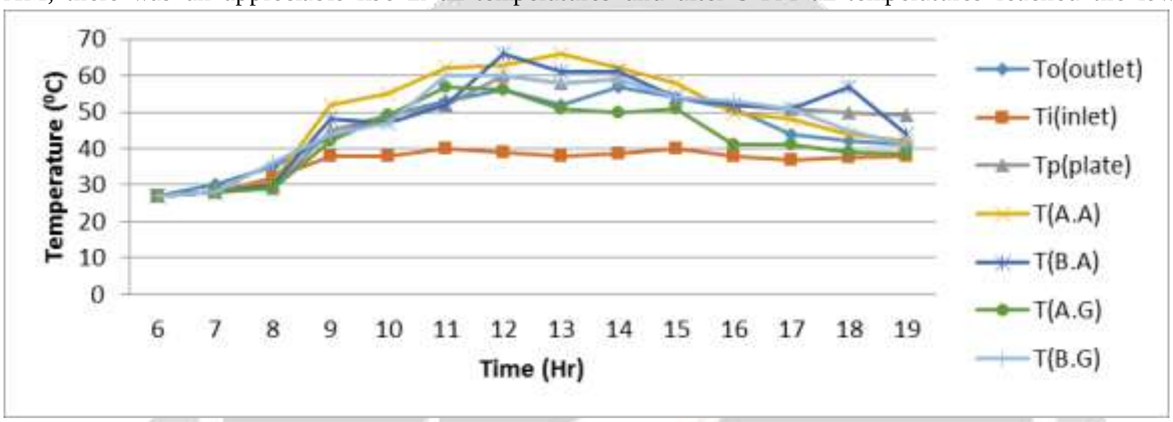

Fig-8 Temperature of different parts of air heater

When there is no energy storing material, the maximum temperature reached by the air is comparatively less and during the evening there was a high fall rate in the temperature.For configuration 2, better performance was observed. The air was maintained maximum from 9 AM to 7 PM.Thermal efficiency of solar air heater is determined from the following equations:

$$\text{Efficiency } \eta = \frac{m\, Cp\, (To - Ti)}{IA}$$

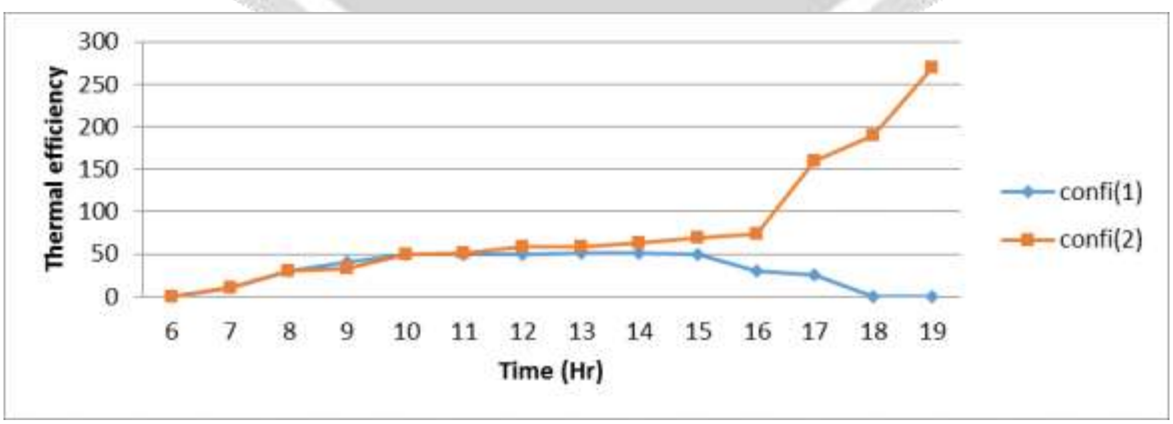

Fig-9 Comparision of Thermal efficiencies.

The efficiency of the solar air heater was calculated using the radiation received by the heater and the enthalpy rise of the air. The variation in efficiency for different configurations is given in Fig(9). When no energy storage system was used, the efficiency was proportional to the radiation received. When energy storage material was used, the excess energy stored in the morning was released during evening. Hence the efficiency of the air heater with energy storage materials is higher and efficiency increased during evening hours. The solar air heater with configuration 2, with pipes on the absorber plate was having better performance.

5. Conclusion

The salt hydrate(STL27) with aluminium pipes was used as phase changing energy storing material. Experiments were conducted to study the performance of the air heater with and without energy storage materials. From the experimental results, it was observed that, the solar air heater with salt hydrate(STL27) as energy storage material delivers comparatively high temperature air throughout the day. The efficiency is also higher during evening hours. The solar air heater with pipes placed on the absorber plate is more efficient.

References

[1] Lovemore Kagande, Ignatio Madanhire, Canicius Matsungo, "Assessment of the Economic Impact of Full Scale use of Domestic Solar Water Heaters in Zimbabwe in Comparison with other Electrical", International Journal of Science and Research (IJSR), India Online ISSN: 2319-7064 (online).

[2] Nabila Ihaddadene, Razika Ihaddadene, Azzeddine Mahdi, "Effect of Glazing Number on the Performance of a Solar Thermal Collector", International Journal of Science and Research (IJSR) ISSN (Online): 2319-7064 (Online).

[3] Vijaykumar Kalwa, R. Prakash, "Design and Development of Solar Powered Air Cooler", International Journal of Science and Research (IJSR), ISSN (Online): 2319-7064 (Online).

[4] Rajesh Thombre, Gajanan Awari, Shashikant Thombre, "Experimental Study of Buoyancy Induced Flow and Heat Transfer Through Uniformly Heated Vertical Tube Air Heater", International Journal of Science and Research (IJSR) ISSN (Online): 2319-7064 (Online).

[5] D.S.Rawat, Dr.A,R.Jaurker, "Performance Evaluations of Two Pass Solar Air Heater using 600 Inclined V-Shaped Ribs on absorber plate", International Journal of Engineering Science Invention ISSN (print) 2319-6726, Volume 3 Issue 8, August 2014, PP 01-10. (Journal)

[6] G.D RAI (1998), non-conventional energy sources, khanna publishers Delhi. (Book).