Experimental Performance Analysis of Solar Air Heaters With and Without Fin

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Abstract: The present study aims to compare two different types of designed and fabricated Performance of air heaters are tested for natural and forced convection. In both convection mode it is found that air heater with fins are more efficient. flat plate solar air heaters, one having fin and the other without fin. Comparisons between the measured outlet temperatures of flowing air, temperature of the absorber plate and output power were also presented. It is found that the solar air heater with fin is 8.5 % more efficient than the solar air heater without fins during natural convection and solar air heater with fins is 10.45 % more efficient than without fins during forced convection for the ambient temperature of 28^0 C.

KEYWORDS: Solar Air Heater, ambient temperature, fins, natural convection, forced convection

1. INTRODUCTION

The increase in the development of the country demands for the use of resources for generation of electricity to run the machines, transportation and to increase the living standards. The fossil fuels are the primary sources of energy used today. The over demand of fossil fuels are depleting the primary resources as the production of fossil fuels takes millions of years whereas it is used at a higher pace than its production. To overcome the situation solar energy is the best alternative available at free of cost as the renewable sources. The Solar Energy is the need of the future for balancing the demands of the increasing population globally. Heating is the most important application of the solar energy.[1] Solar air heaters are the most important and most efficient application. Solar air heater are used to heat the atmospheric air at a higher temperature which is further used for the applications like the drying of agricultural crops, green house heating, space heating and many others.[2]

The solar air heaters consists of the absorber plate , glass covering, metallic fins, wood and the insulated material. These air heaters are economically available in markets. The absorber plate is of a high absorbing metallic material which is painted black to absorb the most of the solar energy. The glass lid is used to cover the solar air heater from the top to allow the solar radiations to pass inside the system. The solar air heater is kept at a tilt angle of 30^o due south because the Sun faces the earth most of the time in this direction only, so to collect most of the solar radiation it has been advised to keep the solar equipment due south .The solar air heater works best when it is insulated properly. Styrofoam, sawdust, glass wool , wood , etc should be used to prevent the heat losses occurring in the Solar air heater. The minimum amount of heat losses will give the most efficient heating to the air entering in the solar air heater. [3]

Among many factors on which the performance of the solar air heater is based, the shape of the absorber plate is also a important area of consideration while designing the system. The increase in the area of the absorber plate increases the thermal efficiency of the system. This is due to the heat transfer coefficient between the absorber plate and the air stream. In most of the solar air heaters the heat transfer coefficient is always low which decreases the thermal efficiency of the solar air heater. This can also lead to the increases in the pressure drop which requires the power consumption by the fan of the solar air heater. To overcome the drawback different modifications are applied to improve the heat transfer coefficient between the absorber plate and air. This will increase the outlet temperature. These modifications include using an absorber with fins attached [4,5 –8,11]. The iron scraps are used to store the heat and increase the efficiency of the solar air heater.[10]

Both the concentrator with and without fins were used for natural and forced convection. The difference efficiency was observed. The natural convection was observed in both the concentrators with and without fins and then the forced convection in the similar manner. Both the system were having same configuration , the only difference was of the fins. One was without fins and the other was with fins.

2. EXPERIMENTAL SETUP AND MEASUREMENT PROCEDURE

2.1 Heat Transfer Coefficient

The efficiency of the solar air heater also depends on the heat transfer coefficient h for air flowing over the top surface of the transparent cover. The wind velocity V_{Wind} is directly proportional to the convective heat transfer coefficient [12]. The experimental results was obtained as:

$h = 5.7 + 3.8\ V_{Wind}$

where the units of h, V_{Wind} are W/m² K and m/s, respectively. The heat transfer coefficient between the absorber plate and the airstream is always a base, resulting in the low thermal efficiency of the solar panel. The heat transfer to the flowing air can be increased by increasing the absorber plate area.

2.2 Collector thermal efficiency

η = solar energy collected / *total solar energy striking collector*

$\eta = Q_u / (I \times A_c)$

Q_u is the useful heat collected , it can be expressed as :

$Q_u = m\ Cp\ (T_{outlet} - T_{inlet})$

2.3 Experiment

Fig. 1. shows a schematic view of the solar air heater. The frame of the solar air collector was made up of the plywood of 0.8cm thickness and it was painted black from inside and outside .Styrofoam was used as the insulator on the sides and the bottom of the collector. The solar air heater has a dimension of 60 cm in length (L), by 80 cm width (W). The Plexiglas of 4 mm thickness was used as glazing. Single transparent cover was used in all the collectors for comparison .[14] Thermal losses occurring in the solar air collector was due to the conduction across the insulation and by the wind. After installation, the two collectors were left operating several days under normal weather conditions of Dehradun for weathering processes. The thermocouples were installed at the inlet, outlet and the top of the glass cover to read the temperature variations in the system due to the climatic conditions. The thermocouples were sensitive with least count of 0.1^{0}C. The readings was taken in degree Celsius. The distance between the absorber plate and the glass was 20cm. The distance should be maintained adequately to allow the air to stay in the system for maximum time for maximum heat transfer.

The fin arrangement was the *straight fins of rectangular profile on the plane wall* .There were four metallic fins of 60 cm length by 4 cm height painted black ,creating five equal sections for air passage .In this way the collector was divided into five equal sections. The copper pipe in the solar air collector gives the inside and outlet air flow with the thermometer at both the ends to note the temperature difference. The copper pipe has a dimension of 2.54 cm (1 inch) diameter placed at the bottom for the cold air to enter and at the upper portion to exit the heated air rising up.

The 12 V battery 150 Ah is used to give a constant supply of electricity to the Fans. The Intel fans of 1500 rpm were used for forced convection in both the solar air heaters with and without fins. The combination of forced convection with fins heated the ambient air to the most with respect to the other combinations.

The observation was taken after every 15 minutes and were recorded throughout the experimental period. The measured variables include inlet and outlet temperatures of the working air circulating through the collectors, ambient temperature, absorber plate temperatures at several selected locations and air flow rates (digital anemometer). All tests began at 9 am and ended at 5:30 pm. The mass flow rate was maintained between the m= 0.012 kg/s to m= 0.016kg/s. The lowest solar radiation and highest solar radiation in the months of February to May was 98W/m^2 to 689 W/m^2 at the temperature range of 22 to 34^{o}C between the 9am to 5:30 pm. The heat transfer is directly proportional to the mass flow rate, solar radiation intensity and the ambient temperature.

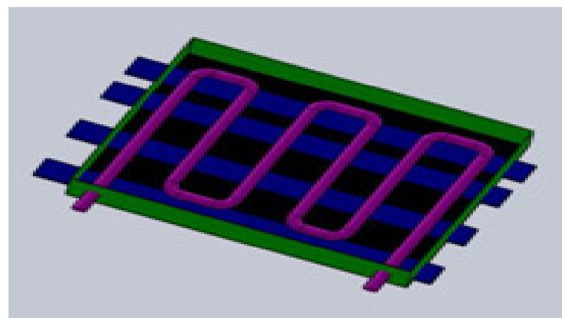

Fig 1: Single Pass Air Collector

3. RESULTS AND DISCUSSIONS

Fig. 2 shows the comparison of the temperature rise and fall throughout the day . The average readings was used to prepare the graph of the experimental period. The comparison was made between the Solar Air Heater having fins during the natural convection. The air was allowed to move in the Single Pass Air Heater naturally. The thermocouple was installed in the inlet and outlet ducts. The thermocouple was having a least count of 0.1 ^{0}C.

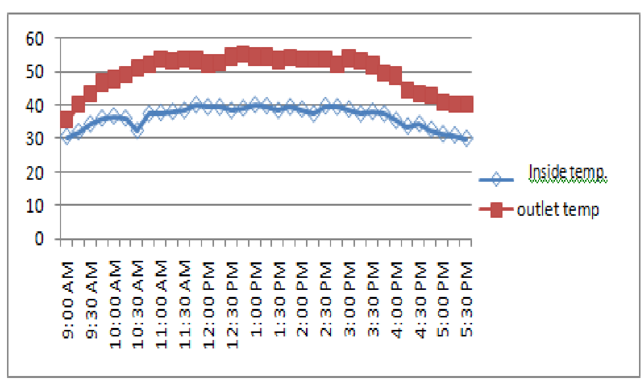

Fig. 2. Time vs temperature with fins during natural convection

The observation was started at 9:00 AM and the inside temperature was around 30^{0}C and the outlet temperature was around 35^{0}C. Inside temperature increased till 10:00 AM and after that it decreased and became 32^{o}C , the outlet temperature increased till 12:00PM and then after that it became constant and there is no greater change in it. After 3:00PM both inside and outlet started decreasing and the observation was stopped at 5:30PM. The reason in the change in temperature throughout the day was due to the variation in the solar radiation falling on the concentrator and the wind speed. Digital Solarimeter having least count of 0.1W/m^{2}was used to measure the solar radiation intensity.

4. TIME OF DAY V INSIDE TEMPERATURE V OUTLET TEMPERATURE (WITHOUT FINS NATURAL CONVECTION)

Fig. 3 shows the comparison of the temperature rise and fall throughout the day in the Solar Air Heater without fins. The average readings was used to prepare the graph of the experimental period. The comparison was made between the Solar Air Heater without fins during the natural convection. The air was allowed to move in the Single Pass Air Heater naturally. The thermocouple was installed in the inlet and outlet ducts. The thermocouple was having a least count of 0.1 ^{0}C.

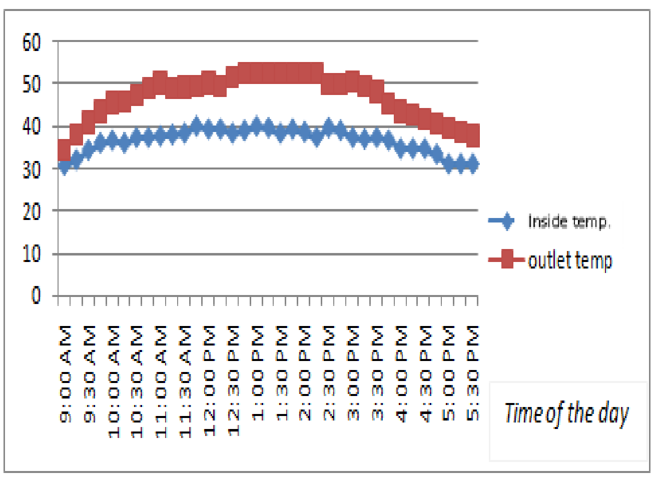

Fig. 3. Time vs temperature without fins during natural convection

The observation was started at 9:00 AM and it was for natural convection without fins and the inside temperature was around 30^{0}C and the outlet temperature was around 35^{0}C. Inside temperature increased till 12:00 PM and after that it became constant and became around 39^{o}C and the outlet temperature increased till 2:00PM and it was above 50^{0}C after that it started decreasing. After 3:00PM both inside and outlet started decreasing and the observation was stopped at 5:30PM. The variations in the ambient temperature, solar radiation intensity and the wind speed throughout the day is seen in the graph because the inlet and outlet temperature is dependent on all of these conditions.

Fig. 4 shows the comparison of the temperature rise and fall throughout the day in the Solar Air Heater with fins. The average readings was used to prepare the graph of the experimental period. The comparison was made between the Solar Air Heater with fins during the forced convection. The air was allowed to move in the Single Pass Air Heater naturally and the fans of 12V were used for forced circulation. The rpm was 1500. The thermocouple was installed in the inlet and outlet ducts. The thermocouple was having a least count of 0.1 ^{0}C.

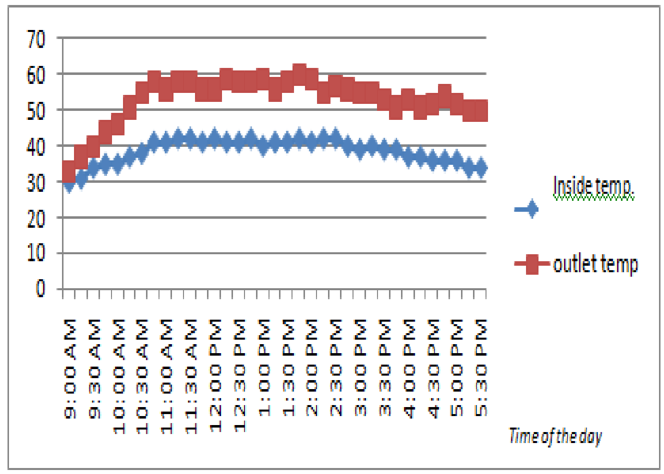

Fig. 4. Time vs temperature with fins during forced convection

The observation was started at 9:00 AM and it was for forced convection with fins and the inside temperature was around 30^{0}C and the outlet temperature was around 32^{0}C. Inside temperature increased till 2:30 PM and after that it started lowering down and became around 39^{o}C and the outlet temperature increased till 2:00PM and it was above 50^{0}C and also reached 60^{0}C after that it started lowering down. After 3:00PM both inside and outlet started decreasing and the observation was stopped at 5:30PM.The variations in the ambient temperature, solar radiation intensity and the wind speed throughout the day is seen in the graph because the inlet and outlet temperature is dependent on all of these conditions.

Fig. 5 shows the comparison of the temperature rise and fall throughout the day in the Solar Air Heater without fins. The average readingswas used to prepare the graph of the experimental period. The comparison was made between the Solar Air Heater without fins during the forced convection. The air was allowed to move in the Single Pass Air Heater naturally and the fans of 12V were used for forced circulation. The rpm was 1500. The thermocouple was installed in the inlet and outlet ducts. The thermocouple was having a least count of 0.1 ^{0}C.

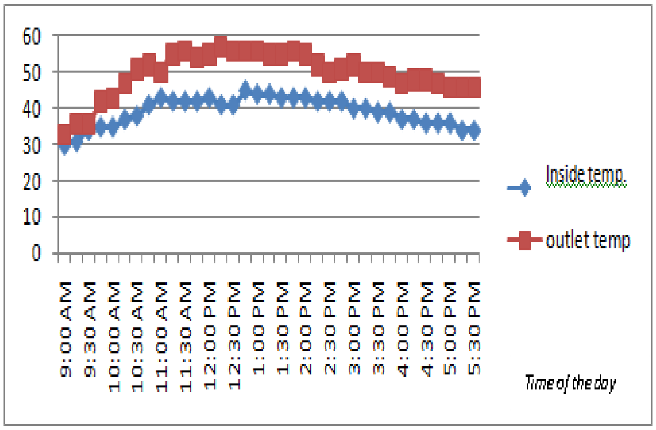

Fig 5. Time vs temperature without fins during forced convection

The observation was started at 9:00 AM and it was for forced convection without fins and the inside temperature was 30^0C and the outlet temperature was around 32^0C. Inside temperature increased till 1:00 PM and after that it started lowering down and became around 39°C and the outlet temperature increased till 2:00PM and it was above 50^0C and also reached 56^0C after that it started lowering down. After 3:00PM both inside and outlet started decreasing and the observation was stopped at 5:30PM. The reason in the change in temperature throughout the day was due to the variation in the solar radiation falling on the concentrator and the wind speed. Digital Solarimeter having least count of 0.1W/$m^2$was used to measure the solar radiation intensity.

Fig. 6 shows the variation of the outlet temperature of the Solar Air Heater with fins during natural convection and the outlet temperature with fins during forced convection throughout the experimental period under the same weather conditions. Both systems were inclined at the same angle of 30^o, the average solar radiation intensity and the wind speed was same for both.

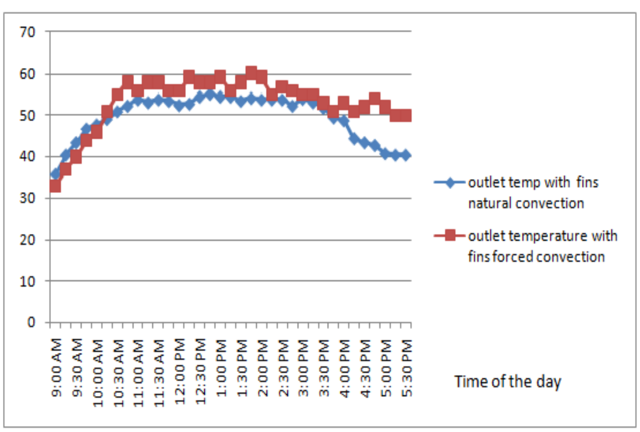

Fig. 6. Variation of the outlet temperature of the Solar Air Heater with fins during natural convection and the outlet temperature with fins during forced convection

The observation was started at 9:00 AM and it was a comparison between outlet temp with fins natural convection Vs outlet temp with fins forced convection. The outlet temperature with fins (natural convection) was 32^0C and the outlet temperature with fins(forced convection) was around 33^0C. The temperature increased till 2:00 PM (forced convection) and after that it started lowering down and became around 50°C to 49^0C and the outlet temperature(natural convection) increased till 3:00PM and it was above 50^0C and also reached 56^0C after that it started lowering down. After 3:00PM both started decreasing and the observation was stopped at 5:30PM. The variation in the graph of the outlet temperature during natural convection and the outlet temperature during the forced convection, with fins, is due to the forced convection which was created by the external fan.

Fig. 7 shows the variation of the outlet temperature of the Solar Air Heater without fins during natural convection and the outlet temperature without fins during forced convection throughout the experimental period under the same weather conditions. Both systems were inclined at the same angle of 30^o, the average solar radiation intensity and the wind speed was same for both.

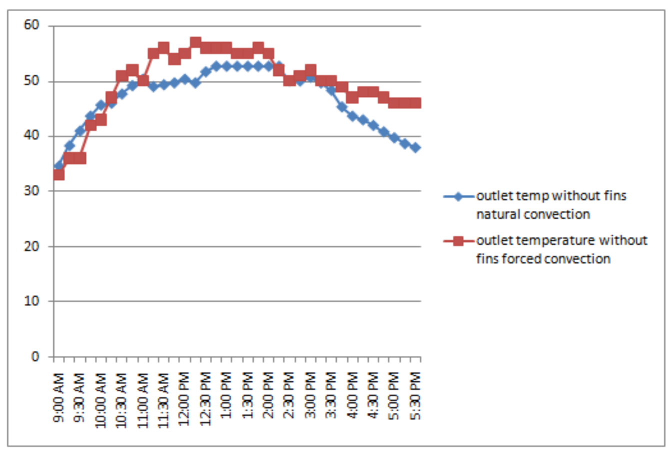

Fig. 7. Variation of the outlet temperature of the Solar Air Heater without fins during natural convection and the outlet temperature without fins during forced convection

The observation was started at 9:00 AM and it was a comparison betweenTime of day V outlet temperature without fins natural convection V outlet temperature without fins forced convection. The outlet temperature without fins(natural convection) was 33^0C and the outlet temperature without fins(forced convection) was around 32^0C. The temperature increased till 1:00 PM (natural convection) and after that it started lowering down and became around 40°C to 38^0C, it also reached 52^0C and the outlet temperature(forced convection) increased till 1:00PM and it was above 50^0C and also reached 58^0C after that it started lowering down. After 3:00PM both started decreasing and the observation was

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stopped at 5:15PM. The variation in the graph of the outlet temperature during natural convection and the outlet temperature during the forced convection, without fins, is due to the forced convection which was created by the external fan.

Fig. 8 gives the average data of the experimental period between the time of 9:00 am to 5: 30 pm along with the variation in the solar radiation intensity and the variation in the ambient temperature throughout the day. The data is plotted. Solar radiation intensity and the ambient temperature is dependent on the wind speed and the climatic conditions of the place at which the experimental place.

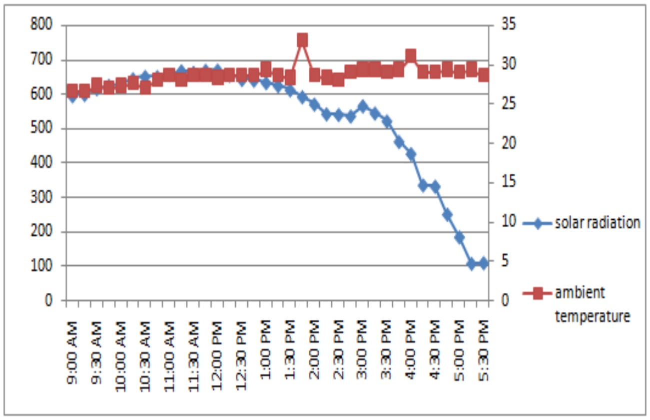

Fig. 8. Solar radiation and ambient temperature vs time

The graph is plotted after taking the average reading of two months of the solar radiation intensity, ambient temperature and the time of the day. The readings are taken continuously for two months between 9:00AM to 5:30 PM. The ambient temperature and the solar radiation is highest in the noon time between 12: 00 PM to 1:30 PM and after that the temperature and the solar radiations decreases gradually. This is due to the change in the climatic conditions.

The single pass solar air heater was investigated experimentally under the prevailing weather conditions of Dehradun. Generally, the sky in Dehradun was clear all through the month of March and April and partially cloudy from time to time through the day depending on the wind speed. The wind speed is always changing its speed and its direction during the day and the month. The performance of the proposed single and double pass solar air heater with and without fin and aluminium as absorber plate was studied and compared with the performance of a conventional solar air heater. The mass flow rate of the air was varied from 0.012 kg/s to 0.038 kg/s. The tilt angle affects the thermal characteristics or the performance of solar air heaters. The temperature is a function of length of solar collector and the temperature of absorber plate depends on the mass flow rates also.

The solar intensity increases from the early hours of day with about 226 W/m2 at 8:00 h to a peak value at noon and then, reduces later on during the day. The highest daily solar radiation obtained with single pass solar air collector, which was 650 W/m2 at 13:00 h and the average solar intensity through that particular day was about 445 W/m2. Calculating the mean solar intensity for each day, there was stability in the solar radiation as all mean averages are within the same range. The mean average solar intensity for all the days of the experiment was 744.8 W/m^2 for single pass solar air collector with and without fins respectively.

The maximum output temperature which we got for the solar air heater with fins was 68^{o}C and the maximum output temperature for solar air without fins was 55^{o}C.

The Efficiency of solar air heater with fins was greater with respect to solar air heater fins. The Efficiency was around 50-65%. The experimented solar air heater gave better results than the conventional solar air heater and was much more efficient than that.

5. CONCLUSION

The performance of solar air collector equipped with fins and fans is discussed. Efficiency up to 85% could be obtained from such configuration. The ambient temperature has a significant effect on the performance of the solar air heater. The lower the ambient temperature, the higher the heat losses and consequently the lower the efficiency. The performance of Solar Air Heater was observed for the several weeks between the months of January to April 2014. The working was based on the natural and forced convection of the Solar Air Heater. The project is completed within the time limit. The solar air heater with fins is 8.5% more efficient than the without fins during the natural convection and the solar air heater with fins is 10.45% more efficient than without fins during the forced convection. The working of the solar air heater is dependent on the solar radiation intensity, wind speed and direction, atmospheric conditions, ambient temperature.

NOMENCLATURE

A_e:- Effective area of receiver
A_t:- total area
P_f:- packing factor
T_{on1}:- average outlet temperature of solar air heater with fins during natural convection
T_{on2}:- average outlet temperature of solar air heater without fins during natural convection
T_{of1}:- avg. outlet temperature of solar air heater with fins during forced convection
T_{of2}:- avg. outlet temperature of solar air heater without fins during forced convection.
η_n:- Percentage increase in efficiency of solar air heater with fins to the without fins during natural convection.

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η_f:- Percentage increase in efficiency of solar air heater with fins to the without fins during forced convection.

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