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EXPERIMENTAL INVESTIGATION OF THERMAL PERFORMANCE OF SOLAR AIR HEATERS WITH AND WITHOUT FINS

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ABSTRACT

This study aims to compare two different types of solar air heaters, simple single pass without fins, and simple single pass with fins. In solar air heater with fins three fins are attached to the absorber plate to increase the surface area of the absorber plate and to increase the time period of air flow. A 4 mm single glass plate used to cover the collector, to reduce convective loses to the atmosphere. The solar air heater is insulated to reduce heat losses. These two types of experimental setup were tested for two different air flow rates and temperature conditions versus time. The collector slope was adjusted to 27° and south faced, which is suitable for the geographical location of Jaipur (26.9260° N, 75.8235° E). Experiment on the solar air heaters was performed and the maximum thermal efficiency was achieved in solar air heater with fins.

KEYWORDS: *Solar Air Heater, Thermal Efficiency, Solar Flux w/m^2 and absorber plate.*

1. INTRODUCTION

SOLAR AIR HEATER

Solar air heater is a device which is used for heating of air. This heated air can be used somewhere else where required such as industrial, process heating, agriculture and industrial product etc.

Solar Air Heater consist of absorber plate with a parallel plate just below the absorber plate so that air can pass to gain energy and raise its temperature. Absorber plate is covered by the transparent glass and the bottom of absorber plate is insulated by the insulator at the bottom side to reduce the heat loss.

The maintenance cost of solar air heater is less as compared to solar liquid heater. Problem of corrosion and leakage are less as compared to other. The thermal efficiency of solar air heater is less because the heat transfer coefficient is less between the air stream and absorber plate.

Some of the factor which can affect the solar air heater efficiency are glass cover plate, wind speed, type of material used for absorber plate etc.. If we increase the surface area of absorber plate it will result in the increase of heat transfer coefficient of air stream flowing through the absorber plate. In solar air heater we use air as a working medium, density of air is low which result larger volume as compared to liquid solar collector.

Some of the advantages of using air type collector are

- No freezing.
- No boiling,
- No pressure drop problem,
- Low construction cost,
- Low weight.

Classification of solar air heaters according to absorber plate

Basically solar air heaters are classified in the following two categories:

(i) Air heaters with non-porous absorbers and
(ii) Air heater with porous absorber

(i) Air heaters with non-porous absorbers

In this type of solar air heaters the air stream does not flow through the absorber plate. Air may flow above and or behind the absorber plate.

A non-porous absorber may be cooled by the air stream flowing over both sides of the plates. Transmittance of the solar radiation through the transparent cover system and its absorption is identical to that of liquid type flat plate collector.

(ii) Air heaters with porous absorbers

This type of solar air heater has porous absorber that include slit and extended metal, transpired honey comb and over-lapped glass plate. Various types of packing elements used for solar air heaters include metal sphere, glass beads, crushed glass, iron turnings, slit and expanded aluminum foils and wire screens. Unless selective coating is used, radiative losses from the absorber plate are excessive. Too many surfaces and too much restriction to air flow will require a larger amount of energy to push the air through. The energy require for this cancels out saving from using solar energy, particularly if the fan is electrical and it the amount of energy which is burned at the power plant to produce the electrical energy is included.

Following are the types of porous solar air heater:

(i) Slit or expended metal air heating collector
(ii) Transpired honey comb air heating collector
(iii) Over-lapped glass plate air heating collector
(iv) Broken bottle absorber
(v) Packed bed solar air heater

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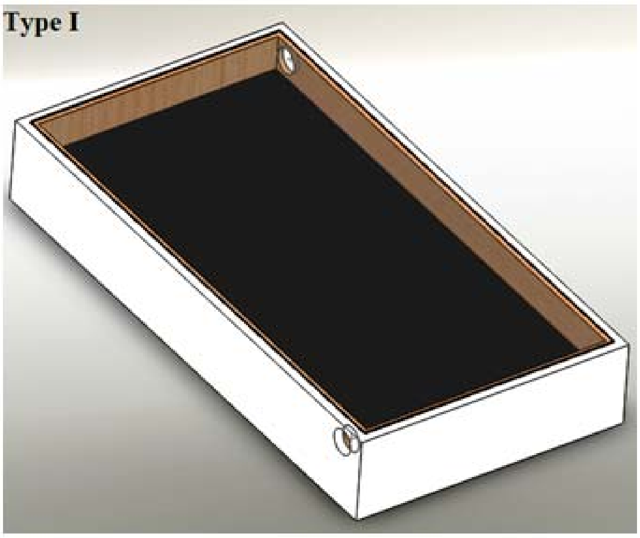

Figure 1: Simple single pass solar air heater without fins

Figure 2: Simple single pass solar air heater with fins

2. EXPERIMENTAL SETUP AND MEASUREMENT PROCEDURE

Solar air heater mainly consist of absorber plate, cover plate, wooden box, fins, insulated material, fan, inlet and exit hole. In this solar air heater wooden box is made from plywood of 12mm thick and insulated with a themacol which is 22mm thick. The internal dimension of box was 1200 x 600 x 170 mm. Wooden box is insulated properly by pasting the themacol on the box. The absorber plate is made up of aluminum sheet which is 30 gauge in thickness. The absorber plate is panted by black color so that it can absorb the maximum radiation from the sun. Normal window glass of 4 mm thickness was used as glazing. To cover the box from the top a glass cover is used which is 4 mm thick so that it can trap the radiation inside and stop the leakage of air from box. The inlet and exit hole of air is made in the wooden box to provide the passage to the air. At the inlet hole a fan of 60 watt is fixed to provide the running air inside so that it can exchange the heat from collector. A special nozzle type arrangement is provide at 57 mm inlet hole. LM-35 temperature sensor is fixed to the solar air heater. LM-35 sensor has five different sensor and fixed to different place to measure the temperature at collector, glass cover, inlet, outlet, temperature of air inside the solar air heater. A digital pyranometer was used to measure the measure the solar lux after every half an hour at 27° and horizontal. . Digital anemometer (METRAVI AVM-05) was used to the air velocity in m/s at the exit of solar air heater as well as surrounding air velocity. Glass cover was sealed with the glass putty to stop the leakage. The collector plate was placed in between of the box to reduce the leakage. It was above 85 mm from the bottom of the wooden box.

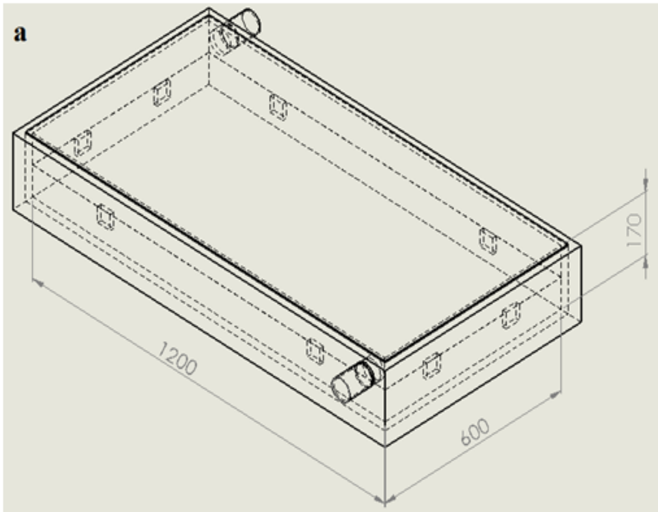

Figure 3: Dimension of solar air heater

Procedure for Measurement

1. Set all the sensors at desired positions (inlet, exit, glass, hang between absorber plate and glass and absorber plate) to measure the temperature.
2. Cover the solar air heater with the glass cover and sealed it with glass putty.
3. To identify the leakage from between the glass cover and glass putty, for this I used to blow an agarbati inside the apparatus and the leakage was detected. Once the leakage was detected it was sealed by applying glass putty at that place.
4. Place the apparatus on the stand at 27° towards the south face, because the latitude of Jaipur is 27° and longitude of Jaipur is 74°. Hence, at this angle apparatus will trap the maximum radiation.
5. Set the thermometer near to the apparatus so that we can measure the temperature of surrounding air at desired interval.
6. Set the fan at the inlet of the apparatus.
7. Switch on the fan and wait for five minutes so that the solar air heater can stabilize..
8. After five minutes take the reading of all those five sensors at (inlet, exit, glass, hang between absorber

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plate and glass and absorber plate) to measure the temperature.

9. Measure the solar radiation.
10. Switch off the fan.
11. Repeat step 7, 8, 9 and 10 after every hour.
12. Repeat the process again on the next day from point 7 to 10.

3. THERMAL PERFORMANCE ANALYSIS

Thermal efficiency (η) of the solar air heater is defined as the ratio of the useful energy gain to the solar radiation incoming to the solar air heater:

$$\eta = Q_u / I\,A_c \quad (1)$$

Where Q_u is the collector useful energy gain (W), **I** is the solar radiation (W/m^2) on the heater surface, A_c is the surface area of the collector (m^2). The useful energy gain (Q_u) can be calculated by following equation:

$$Q_u = \dot{m} C_p (T_{a,out} - T_{a,in}) \quad (2)$$

Where $\dot{m}$ is the mass flow rate (kg/s), C_p is the specific heat of air at constant pressure (kJ/kg K), $T_{a,out}$ is the temperature of air at outlet, $T_{a,in}$ is the temperature of air at inlet.

Putting Q_u from equation (2) in equation (1), we get:

$$\eta = \dot{m} C_p (T_{a,out} - T_{a,in}) / I\,A_c \quad (3)$$

Equation for Mass flow rate ($\dot{m}$) is:

$$\dot{m} = \rho A V \quad (4)$$

Where **ρ** is the density of air (kg/m^3), **A** is the cross section area of pipe at exit (m^2) and **V** is the velocity of air at exit (m/s).

Density of air (**ρ**) can be calculated by following equation:

$$P\nu = RT \quad (5)$$

Where **P** is the pressure (N/m^2), **ν** is the specific volume (m^3/kg), **R** is the specific gas constant (287 J/kgK) and **T** is the temperature.

ν can be written as:

$$\nu = 1/\rho \quad (6)$$

So, equation for **ρ** is:

$$\rho = P/RT \quad (7)$$

4. RESULT AND DISCUSSIONS

The thermal efficiency of solar air heaters with fins, was calculated using equation (3) at different velocity of air (2.0 m/s and 2.2 m/s). Experiment on the solar air heater was performed in the month of July and august in Jaipur, Rajasthan, India (30.nce 07.2014 to 25.08.2014) period. The test was conducted between 10:00 hrs to15:00 hrs solar time.

The thermal performis compare with a solar air heater of another research done by Mr. Afjual Ansari under the guidance of Mr. H K Singh of same dimension and material. The detail of research is published in the research paper bearing ISSN 2348-4098 volume 02 issued 06 July 2014.

It was seen that the during the experiments conducted by Mr. Afjaul Ansari, the hourly variations of temperatures (inlet and exit) of solar air heater without fins at exit air velocity 3 m/s is shown in Fig. 4.The solar flux (W/m2) is also shown in the secondary axis. The highest daily solar flux is obtained as 1253.5 W/m2. As expected, it increases in the morning to a peak value 1253.5 W/m2 at noon and starts decrease in the afternoon. Daily mean temperature on the absorber plate, inlet, exit, inside glass surface, b/w glass and absorber, and surrounding are measured as 94.18, 43.86, 73.13, 76.76, 79.13 and 40.81°C respectively. Daily mean solar flux is measured as 1088.5 W/m2. The mean thermal efficiency is calculated as 28.67%. The difference between the mean daily exit and inlet temperature of SAH without fins at exit air velocity 3 m/s is measured as 29.27 °C. The graph of Thermal efficiency versus time of SAH without fins collector at exit air velocity 3 m/s, during the experiments is shown in fig. 5.

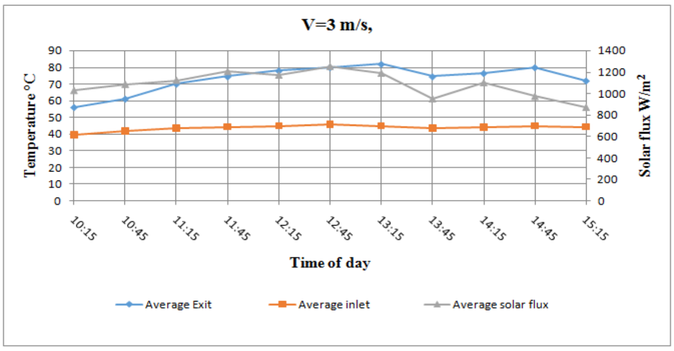

Figure 4: Temperature variation of SAH without fins at 3m/s

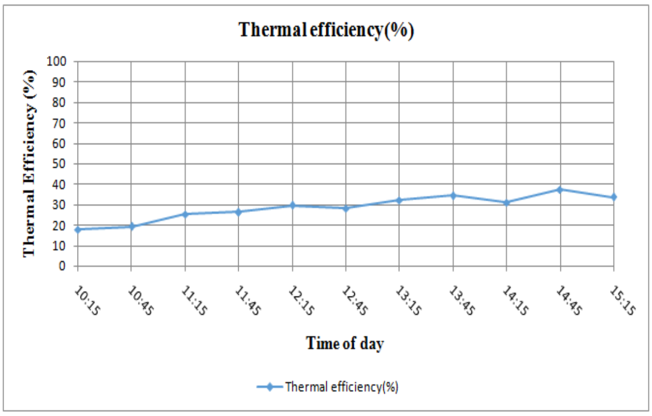

Figure 5: Thermal efficiency (%) versus time of SAH without fins at 3m/s

Fig. 6 shows the hourly temperature variations (inlet and exit) of SAH without fins collector and exit air velocity is 3.25 m/s, during the experiments. The solar flux (W/m^2) is also shown in the secondary axis. The highest daily solar flux is obtained as 1248 W/m^2. As expected, it increases in the morning to a peak value 1248 W/m^2 at noon and starts

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decrease in the afternoon. Daily mean temperature on the absorber plate, inlet, exit, inside glass surface, b/w glass and absorber, and surrounding are measured as 94.45, 37.90, 65.5, 71.26, 74.77 and 36.08°C respectively. Daily mean solar flux is measured as 1119.36 W/m². The mean thermal efficiency is calculated as 29.01%. The difference between the mean daily exit and inlet temperature of type I at exit air velocity 3.25 m/s is measured as 27.6 °C. The graph of Thermal efficiency versus time of SAH without fins at exit air velocity 3.25 m/s, during the experiments is shown in fig. 7

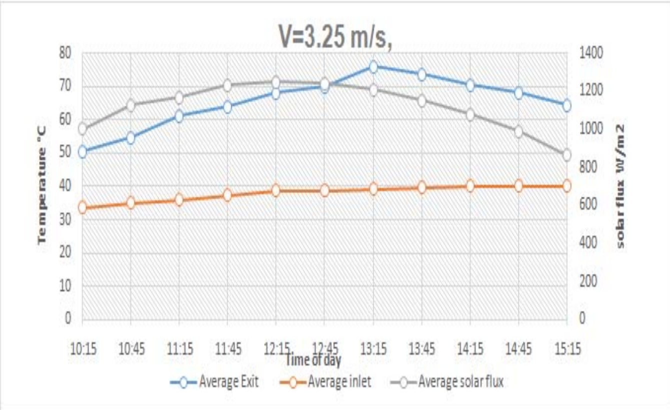

Figure 6: Temperature variation of SAH without fins at 3.25 m/s

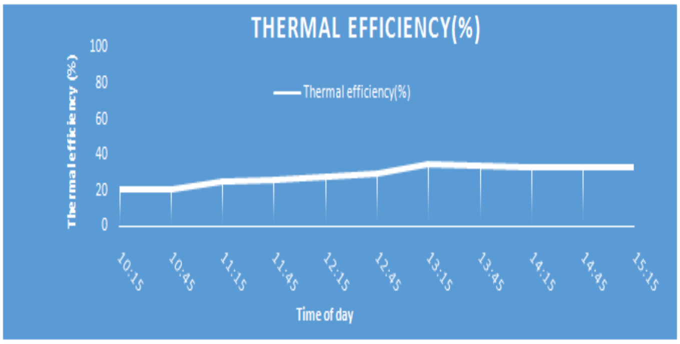

Figure 7: Thermal efficiency (%) versus time of Type I at 3.25 m/s

SOLAR AIR HEATER WITH FINS

The hourly temperatures variations (inlet and exit) of SAH with fins at exit air velocity 2.2 m/s is shown in Fig. 9. The solar flux (W/m²) is also shown in the secondary axis. The highest solar flux is obtained as 1219 W/m² at 27° collector slope angle dated 21.08.2014. As expected; it increases in the morning to a peak value 1219 W/m² and 1170 at horizontal at noon and starts decrease in the afternoon. The mean temperature on the absorber plate, inlet, exit, inside glass surface, b/w glass and absorber, and surrounding are measured as 95.42, 35.72, 82.42, 78.42, 79.42 and 33.72 in °C respectively. The mean solar flux is measured as 996.064 at 27° latitude and 984.93 at horizontal W/m². The mean thermal efficiency is calculated as 36.03%. The difference between the mean daily exit and inlet temperature of SAH with fins at exit air velocity 2.20 m/s is measured as 46.69 °C.The graph of Thermal efficiency versus time of SAH with fins collector at exit air velocity 2.2 m/s, during the experiments is shown in fig.8.

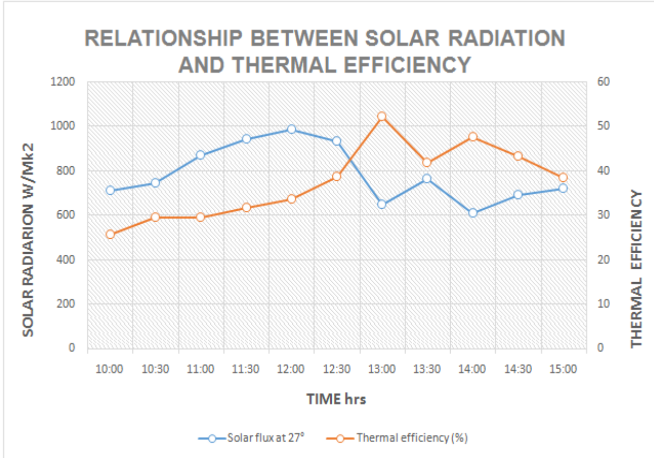

Figure 8: Thermal efficiency (%) versus time with solar radiation at velocity 2.2 m/s

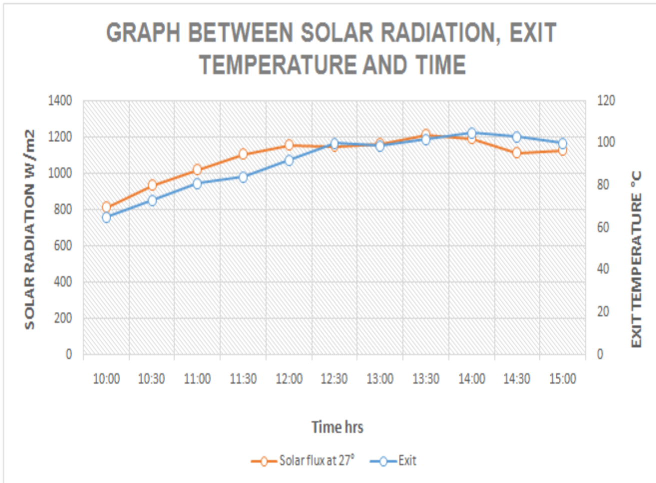

Figure 9: Temperature variation of SAH with fins at 2.2 m/s

The hourly temperatures variations (inlet and exit) of SAH with fins at exit air velocity 2.0 m/s is shown in Fig. 10. The solar flux (W/m²) is also shown in the secondary axis. The highest solar flux is obtained as 1318 W/m² at 27° collector slope angle dated 04.08.2014 as expected; it increases in the morning to a peak value 1318 W/m² and 1372 at horizontal at noon at 12:00 hrs and starts decrease in the afternoon. The mean temperature on the absorber plate, inlet, exit, inside glass surface, b/w glass and absorber, and surrounding are measured as 77.79, 33.53, 65.57, 61.61, 62.84 and 31.53 in °C respectively. The mean solar flux is measured as 854.636at 27° latitude and 851.922 at horizontal W/m². The mean thermal efficiency is calculated as 21.87%. The difference between the mean daily exit and inlet temperature of SAH with fins at exit air velocity 2.20 m/s is measured as 30.03 °C.The graph of Thermal efficiency versus time of SAH with fins collector at exit air velocity 2.2 m/s, during the experiments is shown in fig. 11.

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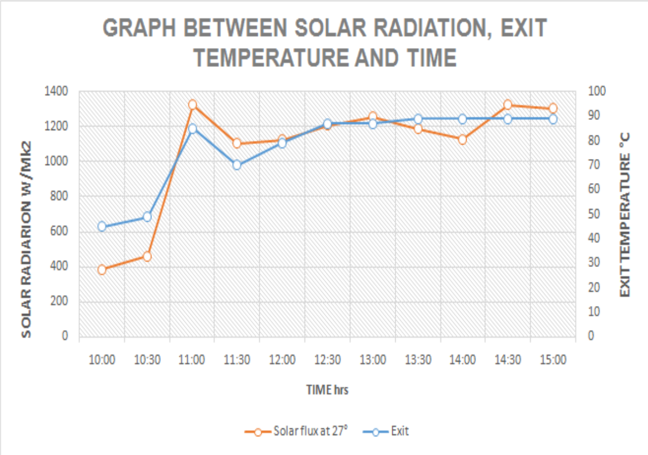

Figure 10: Temperature variation of SAH with fins at 2.0 m/s

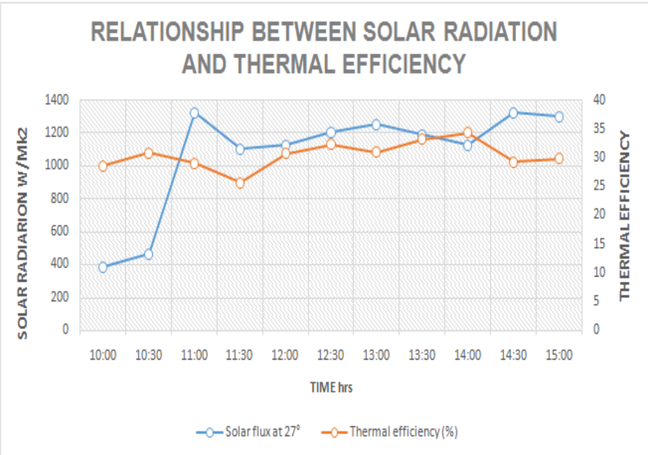

Figure 11: Thermal efficiency (%) versus time with solar radiation at velocity 2.0 m/s

COMPARISON OF THERMAL EFFICIENCY OF SAH WITH AND WITHOUT FINS

Thermal efficiency comparison graph of SAH without fins and SAH with fins is shown in the figure 12. From the figure it can be seen that maximum mean thermal efficiency obtained as 42.37% in SAH with fins at 15:00 hrs at exit air velocity 2.2 m/s. The mean thermal efficiency of SAH with fins is 36.04% and SAH without fins is 29.01.The study show that by including fins in absorber plate it will result in the significant improvement in the efficiency by 7.03%. The graph also show that in morning thermal efficiency was between 29 to 36 % but after 12:30 hrs thermal efficiency increased to 42.37 %. The cost of including fins is very nominal, it is about Rs. 150 to 200.

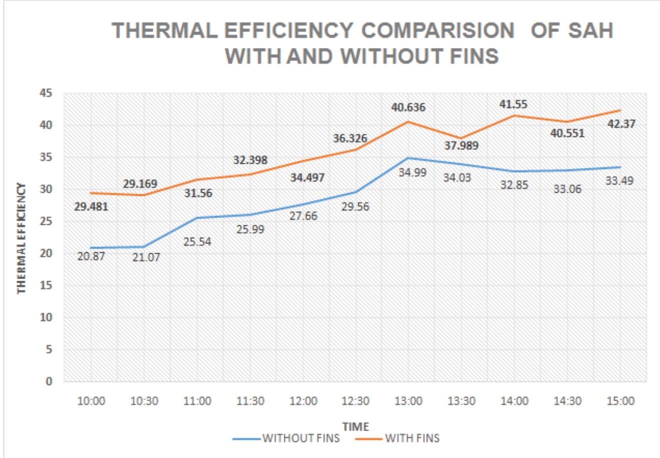

Figure 12: Thermal efficiency (%) comparison of SAH with and without fins

5. CONCLUSIONS

A detailed experimental study was conducted to evaluate the thermal efficiencies of two types, solar air heaters (with and without fins). It was concluded from the above experiment that the SAH having fins have higher thermal efficiency and higher exit temperature. The cost difference is very nominal in both the solar air heater, the cost of fins around Rs.150 to 200. The maximum mean thermal efficiency obtained as 42.37% in SAH with fins at exit air velocity 2.2 m/s.

Abbreviation and Nomenclature used above:-

SAH	Solar air heater
Q_u	Collector useful energy gain (W)
I	Solar radiation (W/m^2)
A_c	Surface area of the collector (m^2)
$\dot{m}$	Mass flow rate (kg/s)
C_p	Specific heat of air at constant pressure (kJ/kg K)
$T_{a,\,out}$	Temperature of air at outlet
$T_{a,\,in}$	Temperature of air at inlet
ρ	Density of air (kg/m^3)
A	Cross section area of pipe at exit (m^2)
V	Velocity of air at exit (m/s)
P	Pressure (N/m^2)
v	Specific volume (m^3/kg)
R	Specific gas constant (J/kgK)

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