Effect of Longitudinal Fins on Thermal Performance of Solar Air Heater: An Experimental Study

Mahesh Jadhav[1], Paramveer Patil[2]

[1-2]Jayawantrao Sawant College of Engineering Hadapsar, Pune – 28.

Abstract - Over the past century, fossil fuels have provided most of our energy because these are much cheaper and more convenient than energy from alternative energy sources, and until recently environmental pollution has been of little concern. Also, sun-drying i.e. hot air usage is still the most common method used to preserve agricultural products in most tropical and subtropical countries. In this paper, primarily solar air heater is studied along with different design considerations and different layouts of solar heater. The development of the model was done along with testing for different conditions. Experiential results were compared along with different conditions. Compare to existing air heater modified heater has 40 % more efficiency.

Key Words: Solar Air heater, improved results, pollution, solar energy.

1. INTRODUCTION

The Solar Air Heating (SAH) system developed by Conserval Engineering is a proven system for heating or preheating air in various applications. The system, commonly known as "Solar wall," is most widely used to heat ventilation air in buildings, but it has also been applied in processes such as crop drying where heated air is an important requirement. It is common knowledge that solar radiation is unevenly distributed and that it varies in intensity from one geographic location to another depending upon the latitude, season, and time of day. This unequal solar radiation distribution throughout the year constitutes the biggest problem when it comes to design a solar collector system in a specific location.

Solar energy systems can be classified as; solar thermal systems and solar PV systems. In solar thermal systems, the function of the solar collector is the conversion of solar radiation on its surface into energy (in the form of sensible or latent heat in a fluid, which is passed through the collecting unit). Numerous types of solar energy collectors have been devised in recent years among which SAH is a commonly used device. In the earlier phase, various types of SAHs have been designed and tested for certain rating parameters. These SAHs are used for crop drying, space heating, and re-generating dehumidifying agents. SAHs offer the possibility of providing cheap, low-grade heat, because of their inherent simplicity. [8]

2. OBJECTIVE

- To develop Solar Air heater set up.
- Experimental testing of Solar Air Heater.
- To Study the effect of air flow rate on output air temperature.
- To Study thermal Efficiency of Solar Air heater with and without Fin.

3. LITERATURE REVIEW

Ravi Kant Ravi et. al. [1] studied various experimental and theoretical investigations have been considered to enhance the performance of double pass solar air heaters (DPSAHs) provided with performance enhancement techniques i.e. using packed bed materials (PBMs), extended surfaces and corrugated/grooved absorbing surfaces.

Abhishek Saxena et. al. [2] reviewed the article focus on the developments that have followed around the globe in various aspects of solar air heating systems since1877 up to now, with a glimpse of some novel patents of SAHs.

Foued Chabane et al. [3] in their study, the thermal performance of a single pass solar air heater with five fins attached was investigated. Experiments were performed for two air mass flow rates of 0.012 and 0.016 kg/s. Moreover, the maximum efficiency values obtained for the 0.012 and 0.016 kg/s with and without fins were 40.02%, 51.50%, and 34.92%, 43.94%, respectively.

A.J. Mahmood et. al. [6], the purpose of this work is to construct and test single-pass and double-pass solar air heaters (SAHs) with four transverse fins. These fins were painted dark black and placed transversely to create four equal-spaced sections. The maximum efficiency obtained using the 7.5-cm high collector was 62.50% for the double-pass SAH and 55% for the single-pass SAH at an airflow rate of 0.032 kg/s.

Foued Chabane et. al. [13] in this paper presents the experimentally investigated thermal performance of a single pass solar air heater with fins attached. Maximum efficiency was obtained by using five longitudinal fins and without using fins. The maximum efficiency levels obtained for the 0.012 kg/s with and without fins were 40.02% and 34.92% respectively.

4. EXPERIMENTAL SET UP

A. Model

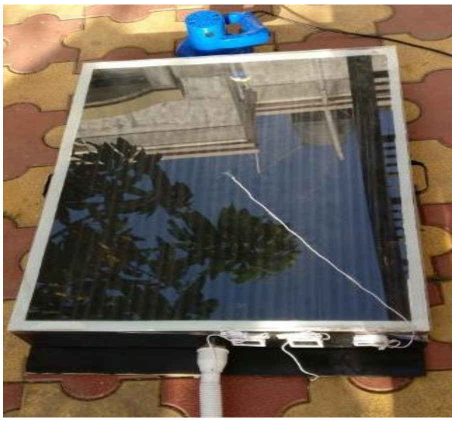


Fig 1: Solar air Heater model

From fig 1 we can see that blower is attached to supply controlled flow of air. Glass is used to cover up the box and trap the heat. Thermocouples are mounted at Inlet and Outlet to measure the air in and out of temperature. We can see that flat and finned profile bottom plate which will be tested for performance effect.

B. Material

Wood is used to made solar pre-heater along with glass for box covering and trapping the heat.

C. Method

Initially, blower will start to force air into the heating chamber where solar energy is used to heat incoming air. It will rise the temperature of air till it is present in the chamber. While getting out temperature is measured of air. The difference between air out temperature and Air in temperature is the rise in air temperature due to solar heater. This test is done for different absorbing materials, different air flow rates, and different orientations of solar heater, and results are discussed in the subsequent section in detail.

5. EXPERIMENTAL RESULT

Readings for Existing design (Plane plate)

Table 1: Reading with existing model at 10:00am

Time	10am	Ta	24^{0}C	Plate angle	20^{0}C	Area (m^2)	0.6
Longitudinal Position of sensor temperature in panel (m)	Temp, ^{0}C	ΔT	Cp of air (J/kg kelvin)	Mass flow rate (m) kg/sec	q= mcp ΔT, KJ	Solar intensity (Io)W/m^2	efficiency
0	Tin = 26	7	1.006	0.005	0.03521	0.56	10.48 %
1.0	Tout = 33						

Sample Calculation for above table:
A = Surface area of solar collector, m^2
C_p=Specific heat of air at constant pressure in KJ/kg^{0}K
ΔT = Temperature Difference between inlet at outlet
q = Heat Transfer Rate in KJ
m = Flow rate of Air, Kg/S
Io = Solar Intensity, W/m^2

$$q = m * C_p * \Delta T$$

$$\text{Efficiency } \eta = \frac{q}{Io * A}$$

By following the above calculation method, the efficiency of the solar air heater was calculated and tabulated for various observed readings as follows,

Table 2: Summary of readings for 1st day using existing system

Reading no	Time of the day	Tin, °C	Tout, °C	Efficiency, %	Solar Intensity, W/m²
1	10:00 am	26	33	10.48	0.56
2	12:00 pm	29	41.5	16.12	0.65
3	2:00 pm	31	46.2	17.70	0.72
4	4:00 pm	29	37.7	12.79	0.57

Similarly readings for different conditions taken and are given below.

Flat plate with black coating with flow 0.0025 kg/s and results are tabulated below:

Table 3: Summary of readings for 2nd day using existing system

Reading no	Time of the day	Tin, °C	Tout, °C	Efficiency, %	Solar Intensity, W/m²
1	10:00 am	26.0	33.4	11.22	0.55
2	12:00 pm	29.9	42.6	16.38	0.65
3	2:00 pm	31.2	45.7	18.10	0.67
4	4:00 pm	29.1	38.42	13.02	0.60

Flat plate with black coating with flow 0.001 kg/s and results are tabulated below:

Table 4: Summary of readings for 3rd day using existing system

Reading no	Time of the day	Tin, °C	Tout, °C	Efficiency, %	Solar Intensity, W/m²
1	10:00 am	26.6	34.6	11.98	0.56
2	12:00 pm	31.0	44.2	16.79	0.66
3	02:00 pm	30.8	45.6	18.80	0.66
4	04:00 pm	28.9	38.8	13.57	0.61

Longitudinal fin plate with black coating and results are tabulated below: (Flow 0.005 kg/s)

Table 5: Summary of readings taken on 27th day

Reading no	Time of the day	Tin, °C	Tout, °C	Efficiency, %	Solar Intensity, W/m²
1	10:00 am	26.6	37	15.29	0.57
2	12:00 pm	28.9	45.1	20.27	0.67
3	02:00 pm	32.1	46.8	20.90	0.71
4	04:00 pm	30.0	39.4	14.07	0.56

Longitudinal fin plate with black coating with flow 0.0025 kg/s and results are tabulated below:

Table 6: Summary of readings taken on 28th day

Reading no	Time of the day	Tin, °C	Tout, °C	Efficiency, %	Solar Intensity, W/m²
1	10:00 am	26.8	38.6	17.06	0.58
2	12:00 pm	29.1	46.9	21.32	0.70
3	2:00 pm	30.7	47.9	21.20	0.68
4	4:00 pm	29.5	40.5	15.37	0.60

Longitudinal fin plate with black coating with flow 0.001 kg/s and results are tabulated below:

Table 7: Summary of readings taken on 30th day

Reading no	Time of the day	Tin, °C	Tout, °C	Efficiency, %	Solar Intensity, W/m²
1	10:00 am	26.4	38.4	17.65	0.57
2	12:00 pm	29.0	47.2	21.80	0.70
3	2:00 pm	30.5	48.4	21.135	0.71
4	4:00 pm	29.8	41.0	15.14	0.62

Different collector orientations with longitudinal fin plate with black coating and results are tabulated below: (Flow 0.005 kg/s)

Table 8: Summary of readings taken on 50th day

Reading no	Time of the day	Orientation, deg	Tin, °C	Tout, °C	Efficiency, %	Solar Intensity, W/m²
1	10:00 am	-21	31.6	45.1	17.68	0.64
2	12:00 pm	0	35.9	53.4	23.224	0.74
3	2:00 pm	+25	34.5	53.2	21.77	0.72
4	4:00 pm	+45	32.4	44.5	16.101	0.63

Different collector orientations with longitudinal fin plate with black coating and results are tabulated below: (Flow 0.0025 kg/s)

Table 9: Summary of readings taken on 52nd day

Reading no	Time of the day	Orientation, deg	Tin, °C	Tout, °C	Efficiency, %	Solar Intensity, W/m²
1	10:00 am	-21	31.5	45.3	18.363	0.63
2	12:00 pm	0	35.1	55.4	23.31	0.73
3	02:00 pm	+25	34.8	54.0	22.05	0.73
4	04:00 pm	+45	32.9	46.1	17.025	0.65

Different collector orientations with longitudinal fin plate with black coating and results are tabulated below: (Flow 0.001 kg/s)

Table 10: Summary of readings taken on 53rd day

Reading no	Time of the day	Orientation, deg	Tin, °C	Tout, °C	Efficiency, %	Solar Intensity, W/m^2
1	10:00 am	-21	31.9	45.9	18.93	0.62
2	12:00 pm	0	35.7	56.5	23.89	0.73
3	02:00 pm	+25	34.7	53.8	22.24	0.72
4	04:00 pm	+45	33.1	45.9	17.30	0.62

Longitudinal fin plate with galvanized coating at different orientations with flow 0.005 kg/s and results are tabulated below:

Table 11: Summary of readings taken on 63rd day

Reading no	Time of the day	Orientation, deg	Tin, °C	Tout, °C	Efficiency, %	Solar Intensity, W/m^2
1	10:00 am	-21	26.9	37.75	15.98	0.57
2	12:00 pm	0	30.0	44.6	18.23	0.67
3	2:00 pm	+25	31.7	45.1	17.55	0.64
4	4:00 pm	+45	28.8	38.9	14.06	0.60

Longitudinal fin plate with galvanized coating at different orientations with flow 0.0025 kg/s and results are tabulated below:

Table 12: Summary of readings taken on 64th day

Reading no	Time of the day	Orientation, deg	Tin, °C	Tout, °C	Efficiency, %	Solar Intensity, W/m^2
1	10:00 am	-21	26.4	38.04	16.83	0.58
2	12:00 pm	0	29.0	43.8	18.86	0.66
3	2:00 pm	+25	30.5	44.8	18.45	0.65
4	4:00 pm	+45	29.8	40.3	14.97	0.59

Longitudinal fin plate with galvanized coating at different orientations with flow 0.001 kg/s and results are tabulated below:

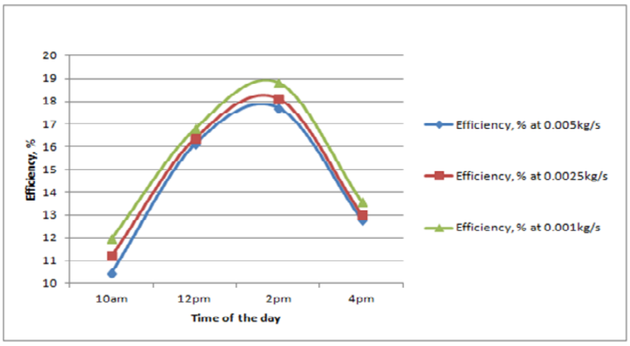
Table 13: Summary of readings taken on 65th day

Reading no	Time of the day	Orientation, deg	Tin, °C	Tout, °C	Efficiency, %	Solar Intensity, W/m^2
1	10:00 am	-21	26.4	37.8	17.09	0.56
2	12:00 pm	0	29.0	45.0	19.74	0.68
3	2:00 pm	+25	30.5	45.8	19.38	0.66
4	4:00 pm	+45	29.8	40.72	15.01	0.61

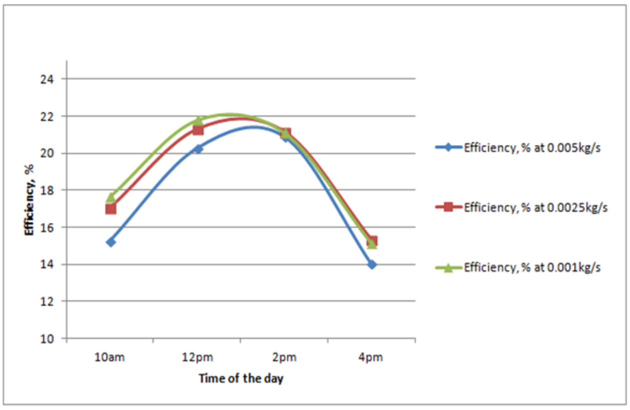
6. RESULT AND DISCUSSION

Results are plotted in graphs below and it can be seen from the result that at low flow rates efficiency is more than a high flow rate for all time of the day. From graph 1 it can be seen that the existing air heater with a flat plate fixed orientation has less efficiency than the suggested model with longitudinal fins and flexible solar orientation. Graph 2 represents Efficiency vs Time of the day for longitudinal fin plate Black Coating with different mass flow rate21.80%. Graph 3 represent Efficiency vs Time of the day at different collector orientations for longitudinal fin plate Black Coating with different mass flow rate has efficiency is maximum from 12 pm -2 pm and in best possible conditions is 23.224%. In the best possible conditions its 40% more.

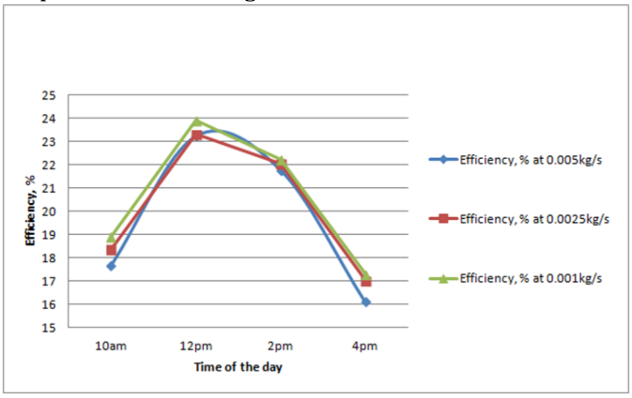
From graph-4 represent Efficiency vs Time of the day at different collector orientations for longitudinal fin plate galvanized coating with different mass flow rate Use of galvanized coating is less effective than black coating.



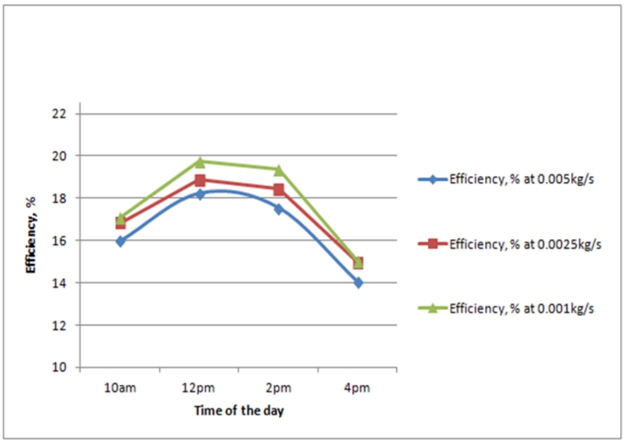
Graph 1: Efficiency vs Time of the day for Flat plate Black Coating with different mass flow rate



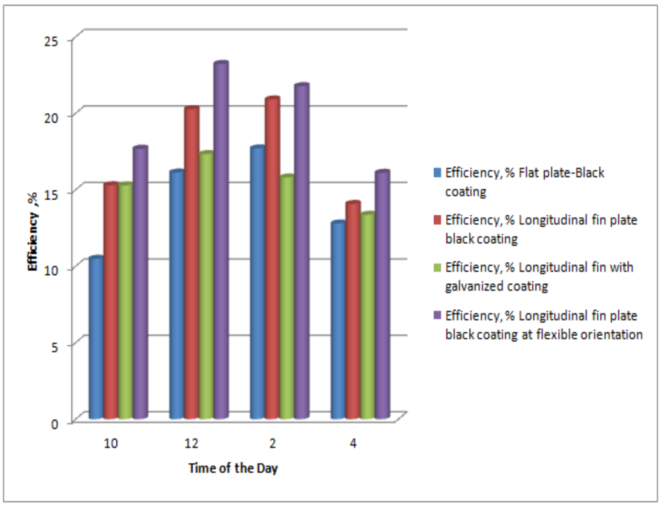
Graph 2: Efficiency vs Time of the day for longitudinal fin plate Black Coating with different mass flow rate



Graph 3: Efficiency vs Time of the day at different collector orientation for longitudinal fin plate Black Coating with different mass flow rate



Graph 4: Efficiency vs Time of the day at different collector orientations for longitudinal fin plate galvanized coating with different mass flow rate.



Graph 5: Efficiency at different conditions

7. CONCLUSIONS

- The Model is developed for solar air heater.
- Efficiency is maximum from 12 pm -2 pm and in the best possible conditions it's 23.224%.
- Longitudinal fins give better results than flat plates.
- Suggested heater model with longitudinal fins and flexible orientations give 40% more efficient than the existing preheater model with flat plate and fixed orientation.

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BIOGRAPHIES

Mahesh Jadhav.
Studying in JSPM College of Engineering Hadapsar, Pune – 28. Working on Energy Solutions projects in Industry.