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Performance Analysis of Solar Collector with Inline and Perforated W Shape RIB Roughened Absorber Plate

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ABSTRACT

Solar air heater is one of the commonly used thermal collection equipment because it is easy to use and maintain. In general, for using smooth surface or plane plate of solar air heater, the energy saving in the form of thermal performance is quite low due to low convective heat transfer coefficient. It can be enhanced by employing passive methods in the form of artificial irregularity on the absorber plate of solar air heaters. This paper presents results of a study of the performance of solar air heaters with W-shaped inline perforated fin as roughness on the air flow side of the absorber plate. Investigations have been carried out by testing the collector under clear sky with available solar radiations intensity with variation in mass flow rate of air passing through collector ranging from 0.01484 kg/sec to 0.01726 kg/sec for three different absorber plates. Collector efficiency has been evaluated for plane absorber plate and compared with the absorber plate having inline W shape perforated rib roughened absorber plate. It is found that instantaneous collector efficiency for staggered W shape perforated fin roughened absorber plate solar collector is 8 % higher as compared with plane absorber plate solar collector for mass flow rate of 0.01726 kg/sec W shape rib roughened absorber plate collector. Enhancement in the collector efficiency is due to the increase in the turbulence of the air for staggered W shape absorber plate solar collector. The instantaneous collector efficiency increases with increase in intensity of solar radiation and mass flow rate of air passing through the collector. The results of the study are presented in the form of plots to show the effect of ambient, design and operating conditions collector efficiency.

1. Introduction

A tremendous amount of effort has been devoted to developing new methods to increase heat transfer from fined surface to the surrounding flowing fluid. Rib turbulators, an array of pin fins, and dimples have been employed for this purpose.

Solar energy is the one most abundant renewable energy source and emits energy at a rate of 3.8×1023 kW, of which, approximately 1.8×1014 kW is intercepted by the earth. The primary forms of solar energy are heat and light. Sunlight and heat are transformed and absorbed by the environment in a multitude of ways. Solar thermal energy is the cheapest and widely available renewable energy that often replaces fossil-fuelled or electrical water heating, reducing utility bills and greenhouse gas emissions. All the developed nations are in the process of promoting the use of solar energy for various applications. India is endowed with a high solar energy potential. India is actively pursuing the development of renewable energy technologies, especially solar based technologies, as high solar radiation is present in major regions, with a majority of days of clear sun.

To improve performance, heat sinks should be designed to have a large surface area since heat transfer takes place at the surface. In addition, flatness of the contact surface is very important because a nominally flat contact area reduces the thermal interface resistance between the heat sink and heat source. A heat sink must be designed to allow the cooling fluid to reach all cooling fins and to allow good heat transfer from the heat source to the fins. Heat sink performance also depends on the type of fluid moving device used because airflow rates have a direct influence on its enhancement characteristics.

To obtain higher performance from a heat sink, more space, less weight, and lower cost are necessary. Thus, efforts to obtain more optimized designs for heat sinks are needed to achieve high thermal performance. One method to increase the convective heat transfer is to manage the growth of the thermal boundary layer. The thermal boundary layer can be made thinner or partially broken by flow disturbance. As it is reduced, by using interrupted and/or patterned extended surfaces, convective heat transfer can be increased. Pin fins, protruding ribs (tabulators), louvered fins, offset-strip fins, slit fins and vortex generators are typical methods. The pattern and placements are suitably chosen based on the required cooling.

Ribbed roughened surface was found to markedly affect the local heat transfer characteristics of the flat plate of the plates when the inter plate distance was relatively small. How the variation in shape of the ribs, Discrimination of ribs and heat input for large fins is going to affect the heat transfer performance is to be studied by conducting the experimentation on the same. And considering these criteria this Study is aimed mainly at examining the extent transfer enhancement from horizontal rectangular W shape ribbed roughened surface under forced convection.

2. Objectives

Following are the research objectives for proposed work:

- To study effect of artificially roughened absorber plate on the rate of heat transfer.
- To find the instantaneous collector efficiency of flat plate solar collector at different mass flow rate of air.

3. Design and development of experimental system

Experimental system has been developed with Flat plate solar collector, blower and flow regulating arrangement with orifice meter to measure the mass flow rate of air and the temperature sensors along with digital temperature indicator to measure the inlet and outlet temperature off the air. A flat-plate collector consists cover (the glazing) and a black coloured absorber plate. Solar radiation is absorbed by the absorber plate and transferred basically through an insulated metal box with a glass or plastic to air that circulates through the collector. The schematic diagram of the experimental set up is as shown in the fig.1 the air taken from the atmosphere pressurises when it passes through the blower, the pressurised air then flows through the flow control valve where flow is regulated. Air then passes through the orifice meter, which is used to calculate the discharge. The air is fed to the solar collector where is absorbs the heat from the absorber plate which receives the heat from incident solar radiations. The heated air then taken out from the outlet of the collector. The temperature sensors (RTD) are mounted at inlet and outlet of the collector to measure the air inlet and outlet temperature.

Fig 1: *Flat Plate Collector*

The experimental set up is developed as shown in following figure:

Proposed experimental system for Performance investigation of temperature variation from flat plate different absorber surface consists of the components like Blower, G. I. Pipe for connection, Flow control valve, Orifice meter with U tube manometer, Acrylic sheet duct, Voltmeter, Ammeter, Dimmerstat, plate type heater, Temperature sensors, Temperature indicator, Insulating materials, air vane anemometer etc.

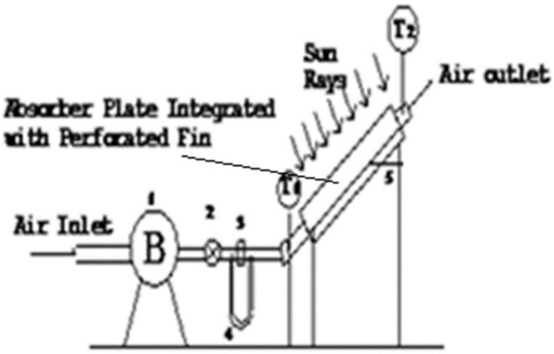


Fig2: Schematic diagram of Experimental setup

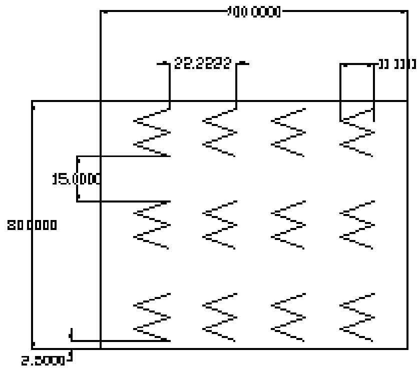


Fig3: Inline W shape perforated rib roughened absorber plate

4. Test Methodology

The experiments were carried out using different test conditions. The mass flow rate of air was varied and the subsequent effects on the temperature rise were calculated. Also studied the effect of using FPC with three different configuration of absorber plate. Initially the experiment was carried out with plane absorber plate and then with inline W shaped perforated fin absorber plate.

The mass flow rate of air was varied from 0.01726 kg/sec to 0.01484 kg/sec. The experiments were conducted throughout the day for given absorber plate and mass flow rate of air. The mass flow rate was measured with the help of orifice meter and temperatures were recorded from Temperature indicator. The Solar radiations are measured with the help of radiation pyranometer. The instantaneous collector efficiency is calculated at a particular instant of time.

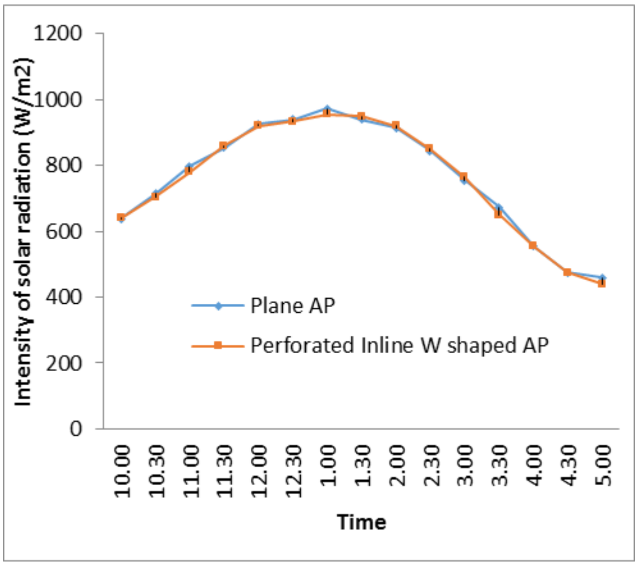
The Different temperature readings are taken at the interval of half hour. And by using the analytical formulae and readings the solar intensity is carried out for different mass flow rate and time intervals. Results obtained are proposed as follows.

5. Results

It is assumed that amount of energy incident on the collector should be constant for all mass flow rates and for all the absorber plates at a given time. Variation in the intensity of solar radiation is recorded during the testing with respect to time and Fig. 4 shows the variation intensity of solar radiation with time for mass flow rate of 0.01484 kg/sec for three absorber plates. It indicates that the variation in intensity of solar radiation with time for all plates for given mass flow rate is same, which indicates variation in intensity of solar radiation is same and same amount of energy is supplied to the all the absorber plates at a given time.

Table1: Variation of intensity of solar radiation for mass flow rate = 0.01484kg/s.

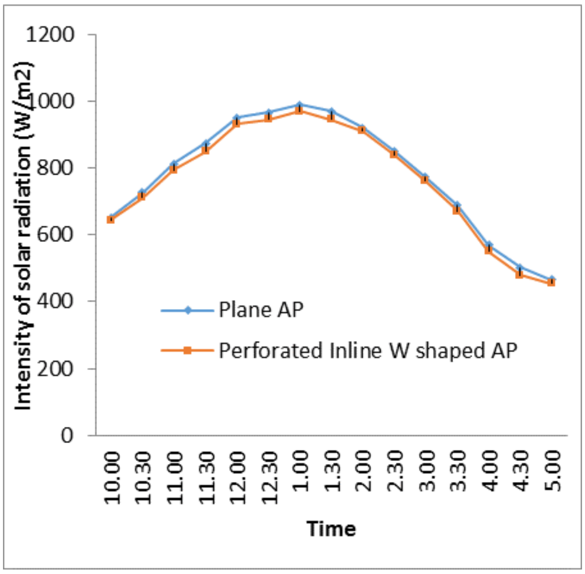
Time am/pm	Solar Radiation Intensity(w/m^2)	
	Plane Absorber Plate	Perforated Inline W shaped Fin Absorber Plate
10.00	638	640
10.30	715	705
11.00	799	780
11.30	854	860
12.00	927	920
12.30	940	935
1.00	974	955
1.30	940	950
2.00	915	920
2.30	845	850
3.00	755	765
3.30	674	650
4.00	554	555
4.30	476	475
5.00	459	440



Graph 1: Variation of Intensity of Solar radiation with time at mass flow rate 0.01484 kg/sec

Table 2: Variation of intensity of solar radiation for mass flow rate = 0.01569 kg/s.

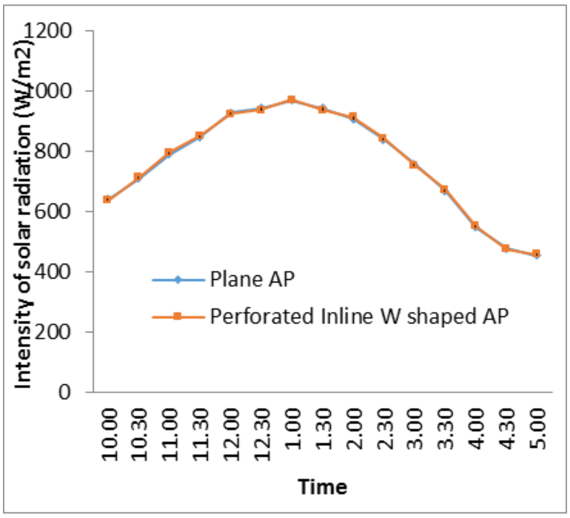
Time am/pm	Solar Radiation Intensity(w/m^2)	
	Plane Absorber Plate	Perforated Inline W shaped Fin Absorber Plate
10.00	653	643
10.30	727	711
11.00	813	793
11.30	873	850
12.00	950	931
12.30	967	945
1.00	990	970
1.30	970	945
2.00	920	910
2.30	852	840
3.00	772	760
3.30	688	670
4.00	568	550
4.30	502	480
5.00	465	455



Graph 2: Variation of Intensity of Solar radiation with time at mass flow rate 0.01569 kg/sec

Table 3: Variation of intensity of solar radiation for mass flow rate = 0.01649 kg/s

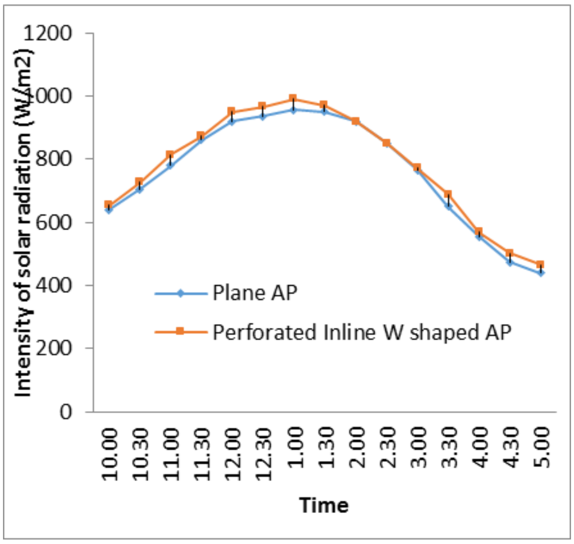
Time am/pm	Solar Radiation Intensity(w/m^2)	
	Plane Absorber Plate	Perforated Inline W shaped Fin Absorber Plate
10.00	643	638
10.30	711	715
11.00	793	799
11.30	850	854
12.00	931	927
12.30	945	940
1.00	970	974
1.30	945	940
2.00	910	915
2.30	840	845
3.00	760	755
3.30	670	674
4.00	550	554
4.30	480	476
5.00	455	459



Graph 3: Variation of Intensity of Solar radiation with time at mass flow rate 0.01649 kg/sec

Table 4: Variation of intensity of solar radiation for mass flow rate = 0.01726kg/s

Time am/pm	Solar Radiation Intensity(w/m^2)	
	Plane Absorber Plate	Perforated Inline W shaped Fin Absorber Plate
10.00	640	653
10.30	705	727
11.00	780	813
11.30	860	873
12.00	920	950
12.30	935	967
1.00	955	990
1.30	950	970
2.00	920	920
2.30	850	852
3.00	765	772
3.30	650	688
4.00	555	568
4.30	475	502
5.00	440	465

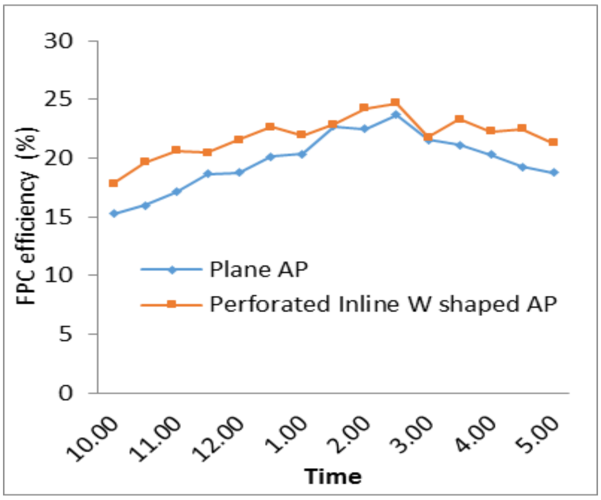


Graph 4: Variation of Intensity of Solar radiation with time at mass flow rate 0.01726 kg/sec

Variation of Flat Plate Collector efficiency when mass flow rate of 0.01484 kg/sec is considered:

Table 5.Variation of intensity of solar radiation for mass flow rate = 0.01484 kg/s

Time am/pm	FPC efficiency (%)	
	Plane Absorber Plate	Perforated Inline W Shaped Fin Absorber Plate
10.00	15.27	17.86
10.30	15.99	19.67
11.00	17.12	20.66
11.30	18.65	20.48
12.00	18.80	21.59
12.30	20.13	22.64
1.00	20.39	21.97
1.30	22.72	22.88
2.00	22.53	24.24
2.30	23.73	24.69
3.00	21.59	21.80
3.30	21.13	23.35
4.00	20.29	22.28
4.30	19.29	22.48
5.00	18.78	21.29

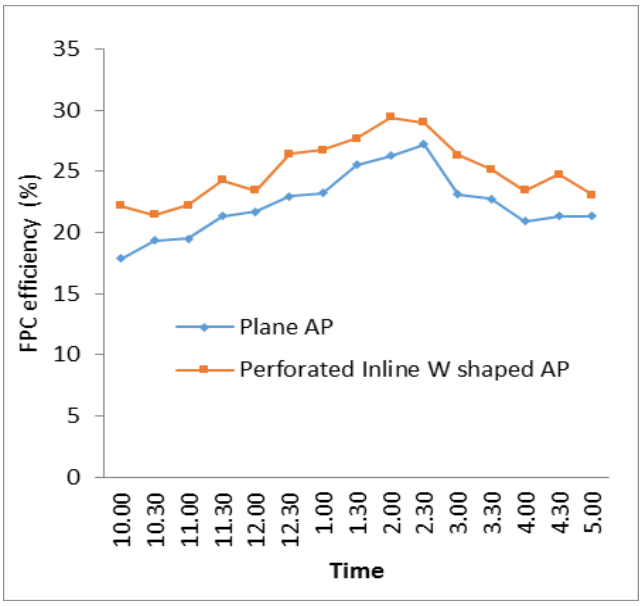


Graph 5: Variation of FPC efficiency with time at mass flow rate 0.01484 kg/sec

Table 6: Variation of intensity of solar radiation for mass flow rate = 0.01569 kg/s

Time am/pm	FPC Efficiency %	
	Plane Absorber Plate	Perforated Inline W Shaped Fin Absorber Plate
10.00	17.89	22.18
10.30	19.35	21.45
11.00	19.48	22.23
11.30	21.32	24.24
12.00	21.69	23.40
12.30	22.95	26.41

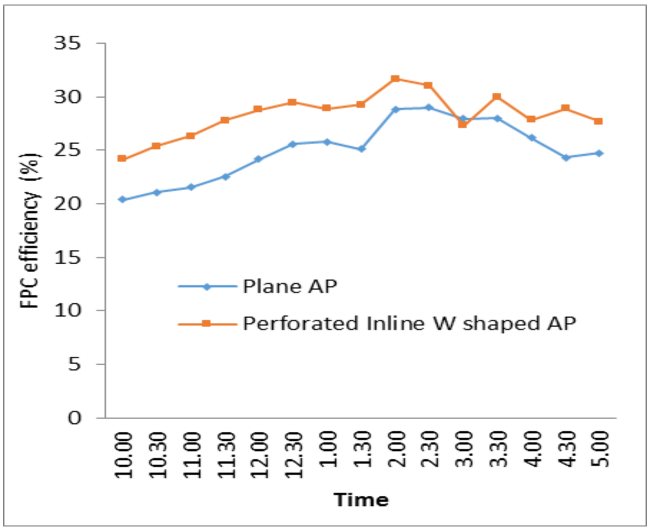
1.00	23.21	26.75
1.30	25.53	27.67
2.00	26.27	29.39
2.30	27.21	29.01
3.00	23.10	26.32
3.30	22.73	25.13
4.00	20.91	23.41
4.30	21.31	24.76
5.00	21.30	23.07



Graph 6: Variation of FPC efficiency with time at mass flow rate 0.01569 kg/sec

Table 7: Variation of intensity of solar radiation for mass flow rate = 0.01649kg/s

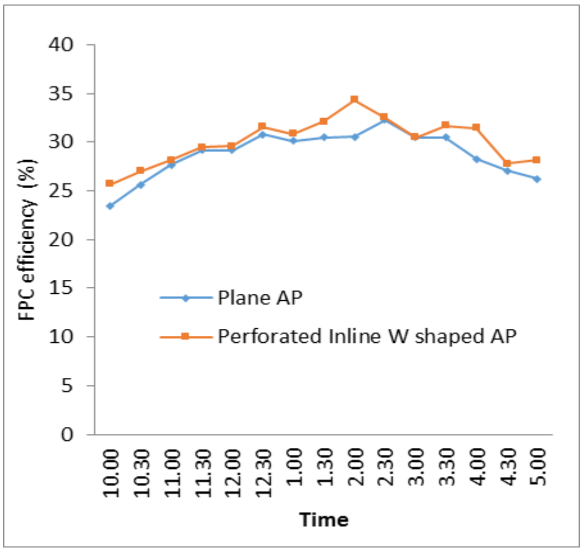
Time am/pm	FPC Efficiency %	
	Plane Absorber Plate	Perforated Inline W shaped Fin Absorber Plate
10.00	20.40	24.15
10.30	21.09	25.34
11.00	21.53	26.32
11.30	22.54	27.80
12.00	24.16	28.76
12.30	25.56	29.47
1.00	25.76	28.86
1.30	25.12	29.24
2.00	28.83	31.64
2.30	29.01	31.05
3.00	27.95	27.31
3.30	27.97	29.97
4.00	26.13	27.82
4.30	24.30	28.88
5.00	24.72	27.68



Graph 7: Variation of FPC efficiency with time at mass flow rate 0.01649 kg/sec

Table 8: Variation of intensity of solar radiation for mass flow rate = 0.01726 kg/s

Time am/pm	FPC Efficiency %	
	Plane Absorber Plate	Perforated Inline W shaped Fin Absorber Plate
10.00	23.50	25.69
10.30	25.66	26.98
11.00	27.66	28.14
11.30	29.14	29.45
12.00	29.14	29.59
12.30	30.77	31.56
1.00	30.12	30.82
1.30	30.51	32.13
2.00	30.56	34.35
2.30	32.31	32.50
3.00	30.48	30.50
3.30	30.51	31.66
4.00	28.27	31.45
4.30	27.07	27.79
5.00	26.25	28.12



Graph 8: Variation of FPC efficiency with time at mass flow rate 0.01726 kg/sec

The variation in the thermal efficiency of the FPC with plane absorber plate, inline W-shaped perforated absorber plate, for the four different mass flow rates of the air throughout the day from 10am to 5 pm. Above graphs shows that the instantaneous flat plate collector efficiency for Inline W shaped perforated absorber plate collector is higher by 8-16 % compared with plane absorber plate collector absorber plate.

6. Conclusion

In this study experimental performance evaluation has been carried to investigate the variation in instantaneous collector efficiency for inline and plane plate absorber plate collector. The effect of variation in mass flow rate of the air on instantaneous collector efficiency has also been evaluated.

The following conclusions were drawn from this study.

- Solar collector with artificially roughened absorber plate enhances the rate of heat transfer from absorber plate to air and thus increases the instantaneous collector efficiency of the solar collector. Thus, results obtained from this study are in line with the findings of previous researcher.
- The instantaneous collector efficiency of flat plate solar collector increases with increase in mass flow rate of air.
- Enhancement obtained in instantaneous collector efficiency with Inline W-shaped perforated absorber plate solar collector ranges from 8-12 % as compared with plane absorber plate solar collector.

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