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Performance Analysis of Vortex Type Flat Plate Collector

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Abstract: *The contemporary solar energy harvesting devices have low efficiency and higher cost which limits its commercial usage. So there is imperative necessity to improve collector performance. This paper presents novel design of flat plate collector (FPC) having spiral channels to permit vortex flow of air in the collector with tangential inlet and an outlet at the center. Comparative study of above design with conventional design shows Vortex type collector has higher heat removal factor or heat transfer coefficient between air and collector plate. Also by increasing number of revolutions of spiral, heat removal factor can be further increased. Thus vortex FPC shows improved thermal efficiency.*

Keywords: *Flat plate air collector, vortex fluid flow, efficiency, drying.*

1. INTRODUCTION

Energy is considered as a prime agent in the generation of wealth and is a significant factor in economic development. The rapidly increasing world population gives rise to a greatly increased demand for energy. In view of this growing global energy needs and concern for environmental degradation, the possibility of running thermal system using the energy from the sun is receiving considerable attention in recent years. Solar energy is clean and most inexhaustible of all known energy sources [1]. There is significant utilization of solar energy, particularly in the areas where low temperature (temperature less than 100C) is involved e.g. drying in agricultural sectors [2]. One of the most potential mean of harnessing solar thermal energy is through air-collector [3]. Therefore, it is important to design an air collector of high efficiency since it is one of the main components and would lead to a better performance of the system [4]. Flat plate air collectors are widely used in solar drying and space heating. Five critical parameters that influence on the thermal performance of a solar air collector with one pass: (1) heat transfer resistance in the airflow channel, (2) height of the stagnant air layer, (3) optical properties of the transparent cover, (4) emittance of the absorber plate and (5) conductive thermal resistance of the back plate Decreasing heat transfer resistance.

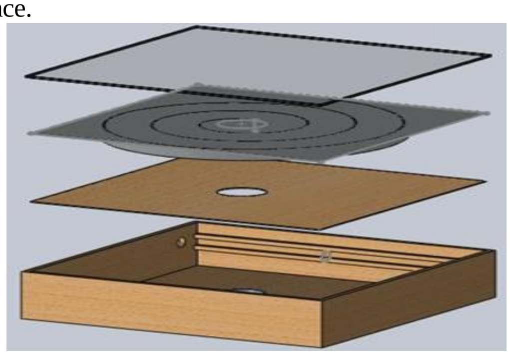

Figure 1: Exploded view of FPC

Airflow channel plays the most significant role in improving thermal efficiency. Increment in efficiency is 14.5% by decreasing the heat transfer resistance in the airflow channel, 5.5% by adjusting the height in the stagnant air layer, and 3.4% by increasing the transmittance of the transparent cover. However, neither increasing the thickness of the thermal insulation board nor decreasing the emittance of the absorber plate, resulted notable improvement [5].

Heat transfer resistance in flow channel of different collectors can be compared by a constant called heat removal factor. Higher heat removal factor of any collector shows it has lesser heat transfer resistance in flow channels. Heat removal factor for given collector can be increased by (1) increasing effective area in contact of collector plate and working fluid, (2) increasing heat transfer coefficient between collector plate and air. Different ways to increase the transfer area are by incorporating internal fins or by designing corrugated surfaces. Heat transfer coefficient can be improved by creating turbulence inside the flow channel using baffles and enhancing the convective transfer rate [6]. Vortex type collector presented in this paper theoretically and experimentally shows higher heat removal factor as compared to conventional collector.

2. VORTEX TYPE FPC

Exploded view of vortex type flat plate collector is shown in figure 1. Vortex type FPC has spiral channels for air flow with tangential inlet and outlet at center. Archimedes spiral with constant pitch is used as flow geometry for designing collector (Fig 2). Above FPC has vortex flow of air between absorber plate and bottom plate. Vortex FPC has higher velocity than conventional collector for given mass flow rate causing higher turbulence.

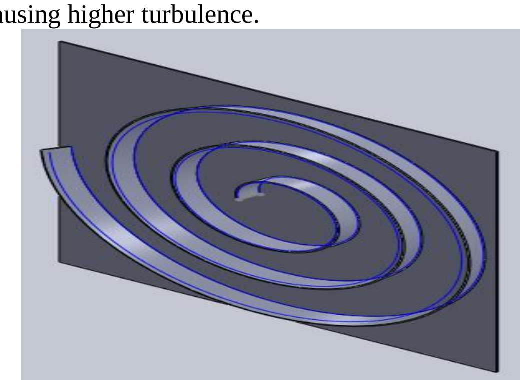

Figure 2: Vortex type collector plate

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3. EXPERIMENTAL SETUP AND PROCEDURE

Schematic diagram of experimental setup for testing conventional flat plate collector and vortex type flat plate collector is shown in figure 5. Solar flat plate collector was fabricated and assembled is such a way that absorber plate cane be removed and replaced. Two absorber plates were fabricated: (a) conventional absorber plate and (b) vortex type absorber plate (figure 2 and 4). All other components and apparatus of experimental setup for collector were kept same. Design considerations and specifications of two collectors were kept same for fair testing.

Figure 3: Experimental setup

Design considerations and specifications of components of collectors are as follows:

(1) The solar collecting area was 50cm (Length) x 50cm (width)

(2) The installation angle of the collector was 00 from horizontal.

(3) The transparent cover was made of a normal polycarbonate panel, with a thickness of 3 mm (4) The height of stagnant air layer was 1cm, while that of the airflow channel was 2cm.

(5) The absorber plate was made of aluminum, which was 2mm thick and black- painted;

(6) Thermal insulation board EPS (expanded polystyrene board), with thermal conductivity 0.046 W/ (m K), was put on the exterior surfaces of the back and side plates, with a thickness of 50 mm.

(7) Values of incident solar radiation were taken from J. P. Sukhatme[7] at particular date and time.

Measuring apparatus used in experiment are shown in table 1. Actual experimental setup is shown in figure 3. Fabricated vortex type absorber plat is shown in figure 4.

We adopted NBS standards to test our FPC. Accordingly 8 tests were conducted symmetrically before and after solar noon and 1 at solar noon with 15 min interval.

Experimental observation obtained is given in table 2 and table 3 for vortex type FPC and conventional FPC respectively.

Figure 4: Vortex type absorber plate

Table 1: Measuring instruments and apparatus used in experiment.

Name of apparatus	Measuring range / specifications	Function
Blower	Power: 28 HP RPM: 2800 Rating: continuous Phase: single phase	To provide mass flow rate of 0.1m^{3}/s for both collectors.
Thermocouple (Type)	200 to 300 ¯C	Measure inlet and outlet air temperatures and surface temperatures
Anemometer	**Accuracy** : Stated accuracy at 23^{0}C ±5^{0}C, <80%relative humidity. **Operating environment** : 0^{0}C to 50^{0}C at <75% relative humidity. **Battery :** Standard 9V battery	To measure velocity at outlet.

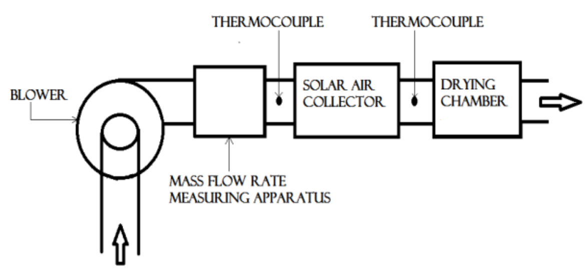

Figure 5: Schematic diagram of experimental setup

Table 2: Testing results of vortex type collector

Test: 1
Collector Type: vortex type collector
Mass flow rate = 0.01 m3/s
Date: 10/03/2015

Sr. no.	IT (w/m^2)	Time	Ambient temperature(^{0}C)	Inlet temperature(^{0}C)	Outlet temperature(^{0}C)	Efficiency (%
1	880	11.50	34.1	37.1	46.9	11.18
2	889	12.05	34.4	38	47.6	10.85
3	892	12.20	35	40	50.1	11.37
4	895	12.35	34.2	38	49.9	13.35
5	898	12.50	34.5	38.8	49.7	12.18
6	895	1.05	34.5	38.3	49.4	12.46
7	878	1.20	35.4	39.4	50.7	12.93
8	860	1.35	34.4	38.7	49.9	13.08
9	843.5	1.50	33	37.6	48.4	12.86

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Table 3: Testing results of conventional collector

Test: 2
Collector Type: Conventional collector
Mass flow rate = 0.01 m3/s
Date: 18/04/2015

Sr. no.	I_T (w/m^2)	Time	Ambient temperature(^{0}C)	Inlet temperature(^{0}C)	Outlet temperature(^{0}C)	Efficiency (%)
1	921	11.50	34.1	37.4	47.5	11.02
2	938	12.05	34.4	37.8	47.2	10.5
3	943	12.20	35	37.4	47.7	10.9
4	947.5	12.35	34.2	38.6	48.7	10.7
5	952	12.50	34.5	39.8	49.5	10.2
6	949.8	1.05	34.5	38.4	49.4	11.64
7	934.3	1.20	35.4	39.4	50	11.4
8	918	1.35	34.4	38.6	49	11.37
9	903	1.50	33	38.4	48.4	11.13

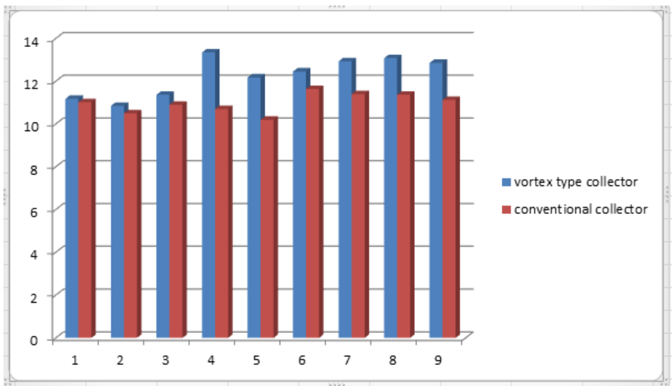

Figure 6: Graphical comparison of efficiencies of vortex type collector and conventional collector.

4. RESULTS AND DISCUSSION

From table 2 and 3, maximum efficiency obtained by vortex collector is 13.35% while that of conventional collector is 11.64%. Also average efficiency of vortex collector and conventional collector over 2 hours span is 12.25% and 10.98%. Figure 6 shows graphical comparison of efficiencies of vortex type collector and conventional collector. From above implications, apparently vortex collector has higher efficiency than conventional collector. Using efficiency as performance parameter for comparing two collectors we can rightly state vortex collector show improved performance than conventional collector.

5. CONCLUSION

In this experimentation performed in accordance to the objectives stated, we arrived at the experimental result which verifies that our novel design gives higher efficiency than the conventional flat plate collector. Efficiency at solar noon for vortex collector was 12.18% and for conventional collector is 10.2%. Testing of both the models according to NBS standards led us to observations which prove improved performance of collector due to vortex type collector plate using efficiency as performance parameter. This states that the ability of vortex collector to transfer heat from absorber plate to air is increased.

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