Development and Testing of a Forced convection Solar Air Heater Integrated with Circular Duct Absorber Plate

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Abstract— This paper presents the study of heat transfer in a solar air heater by using new design of solar collector. The collector efficiency in a single pass of solar air heater with using fins with shapes like circular duct attached under the absorbing plate has been investigated experimentally. Due to adding the fins to the interior of an absorber plate, the desirable effect of increasing the heat transfer coefficient compensates for the undesirable effect of decreasing the driving force (temperature difference) of heat transfer, while the attached fins provide an enlarged heat transfer area. In this study, the absorbing plate of solar collector is attached with fins for further improved performance. The improvements of collector efficiencies in the single pass solar air heaters with fins attached.

Keywords— Solar collector; With fins; Single pass;Circular duct

1. INTRODUCTION

Solar air heaters have been found to have a low thermal efficiency because of the low heat transfer coefficient between the absorber plate and air which leads to a high absorber plate temperature and hence a greater heat loss to the surroundings. The flat plate or non-concentrating type collectors absorb the radiation as it is received on the surface of the collector. There are two types of flat plate solar collectors, water heating solar collector and air heating solar collector. The water heating solar collector is more efficient compared to air heating solar collector. Solar air heater is less complicated as compared to solar water heater because it has free from corrosion and freezing. Solar air heater has no need of heat transfer fluid as air is used directly as the working fluid. Solar air collector can be mounted in variety of ways, depending on the type of building, application, and size of collector.

The pressure inside the solar air collector is not high than less chances to leakage air. It is compact, simple in construction and requires very little or no maintenance. Solar air heater provided free interior heating complement conventional climate control systems. It is important to note that the output from solar heater is reduced when clouds reduce the amount of sunlight. A typical solar heater collector panel would assist in heating of small room. Solar air heating is potentially suitable for any building that requires heating, providing the collector panel can be placed on an appropriate un-shaded south facing (in the northern hemisphere) roof or wall.

2. LITERATURE REVIEW

Fouedchabane et al. The researcher has given their attention to analysis of flat plate solar air heater by experimental method. In this paper analysis is done using smooth plate by varying different mass flow rate. Fouedchabane et al. effect of tilt angle of natural convection in solar collector with longitudinal fins, a series of experimental test carried out on plan and in this study shows that for a single pass solar air heater using internal fin inferior and absorber plate, there is a significant increase in thermal efficiency of the air heater. Choundhury et al. proposed to modify the simple absorber fat plate for a corrugated absorber. Garg et al. introduced the absorber plate with fins attached. Krishnanantsh et al. In this paper the solar heater integrated with thermal storage delivered comparatively high temperature. The efficiency of the air heater integrated with thermal storage was also higher than the air heater without thermal storage system.

3.DESIGN PARAMETERS FOR CIRCULAR DUCT :

A. Frame

- Material: Mild steel (L-angle).
- Dimension:1000*2000*100mm

B. Absorber surface

- Material: Mild steel (20 gauge sheet).
- Dimension: 2000*1000*10mm.

C. Circular duct

- Material: Mild steel
- Diameter:50mm
- No. of duct:10
- Duct spacing:40mm
- Absorber plate:

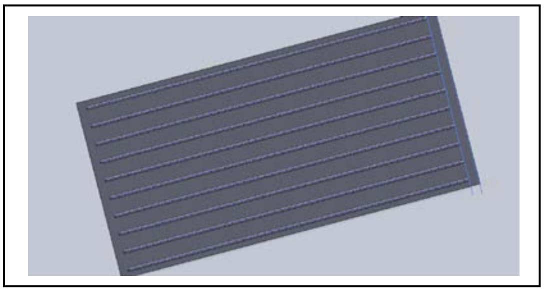

Fig.1. Absorber Plate

4.OPERATIONAL FEATURES

A. Physics Concept Used

Solar air heater based on 'THERMOSIPHON' effect. It refers to a method of passive heat exchange based on natural convection, which circulates a substance (liquid, or gas such as air) without the necessity of a mechanical pump. Thermo siphoning is used for circulation of liquids and volatile gases in heating applications.

B. Working principle

The atmospheric air passed through the gap between the glass and absorber plate from one end of the solar air heater. The air is sucked from the atmosphere, with the help of blower and passed towards the gap. The maximum gap between the glass and absorber plate is 25mm.Glass is act as a good productive wall, which does not allow the passing air to the atmosphere. The passing air gets the heat energy from sun, and the heated air is collected at another end of solar air heater. Some amount of heated air escaped to the atmosphere. And the collected air is used to some engineering applications. The channel on the absorber plate is closed at both the end. The expanded surface absorbs and liberates heat energy which is used to heat the air for few more hours after the sun set.

Fig.2. Experimental Setup

5. Experimental Reading

Date: 31.10.2014

TABLE I. SUMMARIZED TABLE

	Channel Name	MIN	MAX	AVERAGE
T1	INLET AIR TEMP (° C)	20.57	30.17	27.38269
T5	OUTLET AIR TEMP (° C)	25.06	64.3	50.36163
T2	INSIDE FLOOR TEMP (° C)	42.81	120.7	68.51058
T3	INSIDE AIR TEMP (° C)	39.25	101.9	75.04712
CH1	RELATIVE HUMIDITY (%(RH))	18.69	54.16	27.77567
CH2	WIND VELOCITY (m/s)	- 0.00667	4.9222	1.765465
CH3	SOLAR INDENSITY (w/m2)	84.58	1048	558.8181

TABLE II. READINGS

TIME	T1	T4	T2	T3	CH1	CH2	CH3
8:38:34 AM	20.57	25.06	48.91	41.46	54.16	4.1666667	279.4
9:08:34 AM	22.06	40.73	74.09	63.97	37.47	1.6205556	361.9
9:38:34 AM	24.02	44.53	81.25	69.84	36.63	3.7555556	678.9
10:08:34 AM	25.56	47.46	85.9	72.66	31.37	2.7219444	637.7
10:38:34 AM	26.22	53.7	98.88	83.77	24.49	3.4555556	735.1
11:08:34 AM	26.34	58.52	111	92.96	23.42	2.9166667	987.9
11:38:34 AM	27.48	53.37	93.39	79.6	26.47	1.3611111	694.4
12:08:34 PM	28.52	63.24	118.4	99.68	19.4	2.4611111	860
12:38:34 PM	28.22	60.26	105	90.56	19.3	1.7575	269.7
1:08:34 PM	29.25	58.31	100.5	87.39	19.94	1.0383333	314.6
1:38:56 PM	27.99	46.36	72.42	63.42	30.19	1.0838889	390.7
2:08:56 PM	29.3	50.65	84.79	74.69	28.15	0.9788889	891.3
2:38:56 PM	29.38	53.38	87.85	76.36	22.35	0.6827778	290.5
3:08:56 PM	29.95	57.45	95.58	84.77	20.27	0.1997222	603.1
3:38:56 PM	30.14	52.73	87.56	77.69	21.45	2.4294444	430.5
4:08:56 PM	29.11	47.96	74.27	66.74	26.28	1.3027778	341.4
4:38:56 PM	29.03	41.3	59.72	54.77	31.84	1.2458333	218.6
5:08:56 PM	28.92	34.71	45.4	42.61	41.49	1.7161111	101.4

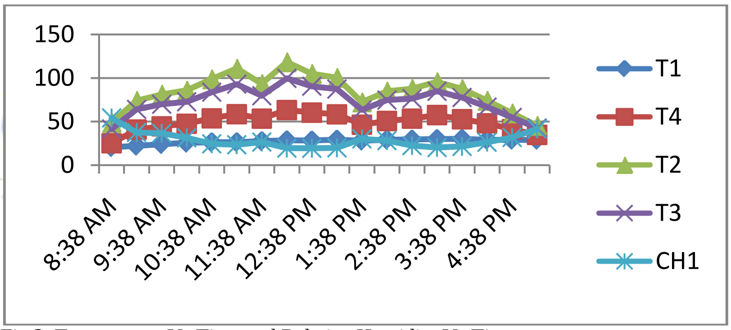

Fig 3. Temperature Vs Time and Relative Humidity Vs Time

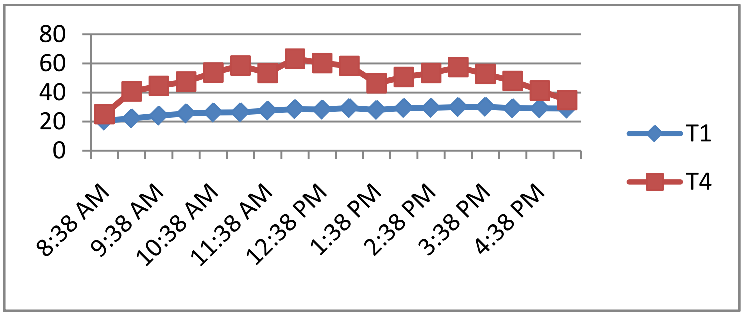

Fig4. Inlet and Outlet Temperature Vs Time

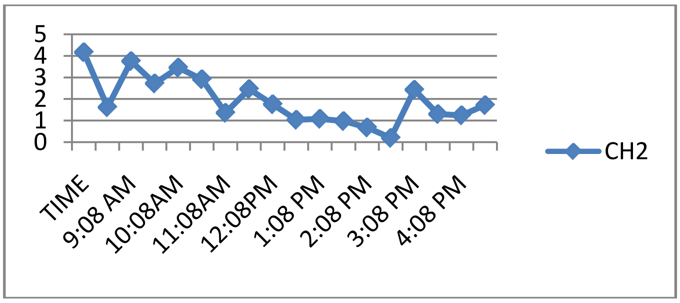

Fig 5. Wind Velocity Vs Time

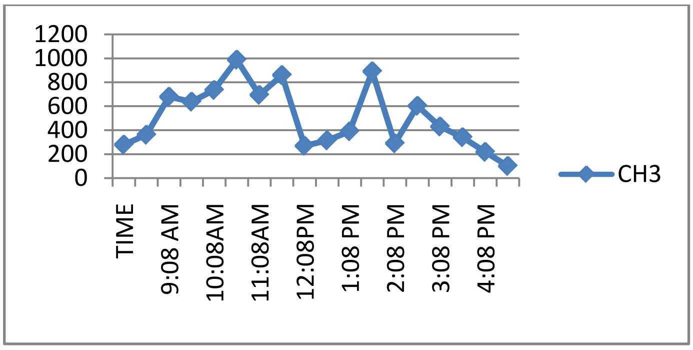

Fig 6. Solar Intensity Vs Time

Date: 01.11.2014

TABLE III. SUMMARIZED READING

	Channel Name	MIN	MAX	AVERAGE
T1	INLET AIR TEMP (° C)	20.57	28.82	25.232
T5	OUTLET AIR TEMP (° C)	28.31	73.36	55.0905
T2	INSIDE FLOOR TEMP 2(° C)	41.16	124.6	84.52
T3	INSIDE AIR TEMP 3 (° C)	37.12	106.4	74.2515
CH1	RELATIVE HUMIDITY (%(RH))	14.03	70.63	25.63
CH2	WIND VELOCITY (m/s)	-0.01167	3.483333	0.820514
CH3	SOLAR INDENSITY (w/m2)	173.8	1149	491.225

TABLE IV. READING

TIME	T1	T4	T2	T3	CH1	CH2	CH3
7:29:48 AM	20.57	28.31	41.16	37.12	70.63	-0.0072222	220.3
7:59:48 AM	21.49	35	52.47	46.5	49.65	-0.0019444	260
8:29:48 AM	22.33	41.22	64.99	57.96	37.49	0.525	449.6
8:59:48 AM	22.65	51.66	85.19	74.67	24.3	0.7811111	515.8
9:29:48 AM	22.68	53.93	81.43	71.29	22.42	-0.0116667	368.1
9:59:48 AM	23.64	52.03	75.31	67.09	24.18	-0.0091667	411.9
10:29:48 AM	23.84	55.73	87.62	77.14	22.16	0.0588889	547.7
10:59:48 AM	24.78	59.05	92.26	81.23	20.43	1.4397222	490.7

11:29:48 AM	24.86	64.89	108.6	95.11	17.23	1.8125	475
11:59:48 AM	24.5	62.74	94.88	83.27	18.86	0.0161111	658.8
12:29:48 PM	26.25	68.11	111.3	95.52	15.55	0.3875	1149
12:59:48 PM	27.38	73.36	124.6	106.4	14.03	0.5580556	704.6
1:29:48 PM	27.75	68.64	107.5	93.02	15.23	1.2855556	719.2
1:59:48 PM	27.92	73.14	121.4	104.4	14.32	1.4022222	890.3
2:29:48 PM	26.48	66.31	99.02	86.49	15.41	0.4358333	455.3
2:59:48 PM	27.34	58.4	83.96	73.99	19.31	3.4833333	367.9
3:29:48 PM	28.82	50.33	69.39	61.45	25.21	1.5594444	345
3:59:48 PM	28.01	48.55	69.95	62.29	27.67	0.2133333	373.1
4:29:42 PM	26.57	47.54	64.12	58.96	26.95	0.5038889	248.4
4:59:42 PM	26.78	42.87	55.25	51.13	31.57	1.9777778	173.8

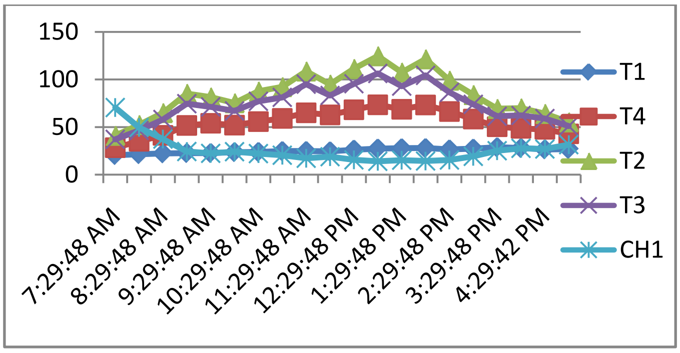

Fig 7. Temperature Vs Time and Relative Humidity Vs Time

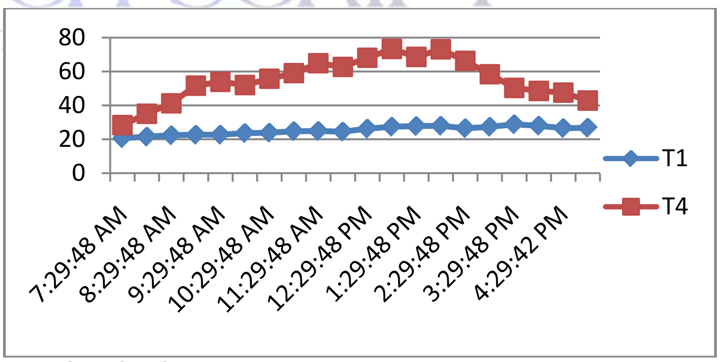

Fig8. Inlet and Outlet Temperature Vs Time

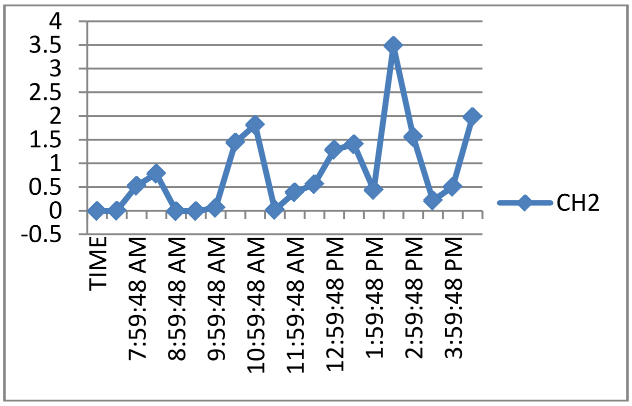

Fig 9. Wind Velocity Vs Time

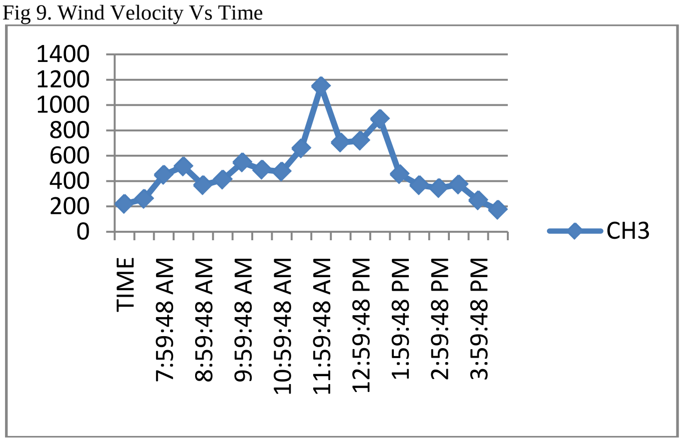

Fig 10. Solar Intensity Vs Time

6. Result

Based on the experimental reading, found that the Outlet temperature of the air depends upon the following characteristics of Relative Humidity, Wind Velocity and Solar Intensity.

TABLE V: Factors Affecting The Outlet temperature

Relative Humidity	Wind Velocity	Solar Intensity	Outlet Temperature
High	Low	High	Medium
Low	High	High	Medium
Medium	Low	Medium	Medium
Low	Medium	Medium	Medium
Low	Low	Medium	High
Low	Low	High	High
Low	Medium	High	High
Medium	Low	High	High

7. Conclusion

Based on the experiment, conclude that the outlet temperature of the solar air heater is improved significantly while comparing with the absorber plate without any extend surface integrated with it. Heating effect can be further increased by using a heat storage material in the absorber plate. In addition to that, it will extend the period of heating effect in the air.

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