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FABRICATION AND ANALYSIS OF V-CORRUGATED WITH TRIANGULAR FINS SINGLE-PASS SOLAR AIR HEATER

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Abstract- *An investigation and experiment of the characteristics of a v-corrugated single-pass solar air heater with triangular fin added on both the upper and lower side of the corrugated surface is shown in this work. A lot of works have been done on the corrugated surface and the finned surface individually but this is a new concept of combining both criterions. It is also found that attaching fins with the corrugated surfaces effectively amplify the outlet air temperature and efficiency in comparison to the conventional devices. In this experiment, the solar intensity, air density, wind velocity, initial and outlet air temperatures were considered. The recorded maximum value of the temperature difference was 42°C. The comparison between free and forced convection was shown where the maximum efficiency was found in force convection and the highest efficiency was 52.12%. Experiments were piloted from 10.00 AM to 4 PM in the premises of CUET, Chittagong, (22.3569º N, 91.7832º E).*

Keywords: V-corrugated, Triangular fins, Free and forced convection, Temperatures, Efficiency.

1. INTRODUCTION

Solar energy is advantageous and efficient over the other energy sources as one of the most significant criterions is that the operating capacity of the systems used to convert solar to thermal. Renewable energy heating technologies help to minimise the space heating heat demand and thus resource depletion and emissions are also reduced. Utilising solar energy, through many devices and in many other ways, is an effective way to diminution of CO_2 emissions and resource ingestion. Solar air heater is one of those that uses solar energy to heat the air [1]. Solar air heaters can be categorised basically on active, hybrid and passive modes. On the basis of the tracking axis, extended surface, numbers of covers and energy storage Tyagia [2] et al. classified the solar heater. Hot air is produced at distinct locations in the active solar air heating systems and guided use at its end. In active solar air heaters, heat storage materials are commonly used to generate hot air during the night when passive solar air heaters are generally used during the day.

From another perspective, Solar air heaters can be classified into single and double passes with or without heat storage in relation to the quantity of air passes [2][3][4]. In the single-pass solar air heater, water currents from air inlet to outlet in one manner either above or below the absorber plate. While in solar heater with double-pass air, air flows in two different passages, which can be either counter or parallel. It can also be classified with different surface geometry, with different energy storage and according to the Hybrid Photovoltaic/Thermal (PV/T) [5] SAH etc. SAHs have been used at a wide range in many countries as space heating, textiles, oceangoing products, solar water distillation and crop dehydrating applications [2][6]. It also has many benefits as compared to liquid heaters from the heat transfer medium to prevent the issues of stagnation or freezing, outflows, destruction and risk of ecological or health risks. By acknowledging the applications of silica gel the humidity and moisture content in air during the rainy season can also be reduced. Some of the significant applications are- space heating, process heat, dampness removal, night cooling and ventilation. H. M. Yeh [7] et al. enhances mass transfer carried out an orthogonal expansion technique and considerably improved the mass transmission in double-pass mass exchangers through counter-current flow. Gupta and Garg [8] studied the performance of four SAH where two of those were corrugated type and the other two were of mesh type. Deb and Sarma [9] experimented on SAH in which the surface plate itself worked as a collector that absorbed the heat by the waste heat recovery process where in the conventional setup, the concentrator made up of thin metallic reflector sheet that causes heat loss through exposed surfaces and supporting structure. Chabane et al. [10] manufactured a single SAH pass where two collectors used with two methods of the absorber plates. Bayrak et al. [11] used baffles made of Closed-cell aluminum foams. He investigated the performance of five collectors by this. He positioned the baffles in both staggered and systematic arrangements and compared it with non-baffle. An experiment for double pass SAH has been constructed by El-Sebaii et al. [12] where the improvement in thermohydraulic efficiency and outlet airflow temperature were by 28.5% and 16.5%. In this experiment, the finned plate SAH and the V-corrugated plate SAH were compared. Their findings showed that the double-pass V-corrugated plate is 9.3–11.9% additionally effective than the double-pass-finned plate. For both, the design settings were the same and the outcomes were taken over a period of one year. Bouadila et al. [13] used a latent storage collector and constructed an experimental test-rig where a packed bed absorber with a black coating has been used which was formed of spherical capsules. The capsule dimensions were chosen according to the encapsulation method.

2.METHODOLOGY

2.1 Design and Fabrication

A 105 cm × 78 cm × 11 cm wooden frame with plywood at the bottom was made and placed the v-corrugated surface with fins attached on the frame and painted matte black. The length of V- corrugated absorber plate was 75 cm long and the bend angle of the absorber plate was 60° with triangular fins which were attached in number of total 117 where 54 fins were on top and 63 were at the bottom of the corrugated surfaces to help the heated air flows in devious pattern, for increasing the area of heat transfer. In the event of inclined or v-pattern ribs, heat transfer improvement was revealed to be greater than the transverse ribs [14] where their inclined angle of 60 degrees is the most preferred one as for low mass flow rates applicable to space heating applications, according to the previous studies [15].

Fig.1: Wooden collector of solar air heater

An accurate design of wooden collector of SAH is shown in Fig.1. It was made of wood. There were 13 circular holes of 4 cm diameter for receiving inlet air and a hole of 8 cm diameter on the upper side of the surface to install a mini exhaust fan. The function of this exhaust fan was to fetch the hot air from solar collector area. The absorber plate design with triangular fins is shown in Fig.2. The fins were placed on both upper and lower surface of the V-corrugated absorber plate. A rectangular transparent glass was installed on top of the collector. The thickness of that glass was 3mm.

Fig.2: V-corrugated absorber plate with fins.

When the sunlight passed into the unit through the glass and struck the 14 individual facets, the metal then got quickly heated, and in turn, this heated the air inside the unit for the turbulence of air where the fins increased the heat transfer area for the air inside. The hot air was brought out by using a small solar powered 12V DC case fan. The fan was connected to an 18V solar panel with a 12V battery and a voltage regulator to fix the fan velocity. The slope angle of both the SAH and the solar panel was 25 °S from horizontal surface and fixed to the south by a wooden stand as the latitude of Chittagong is 22.3569 °N where the experiment was carried on. A duct was fixed from the back of the unit that carries out the inside air to the outside and this is how the warmer air was collected. The anemometer, temperature meter with thermocouple, thermometer, pyrometer and multi-meter were used to calculate the air flow velocity, all the temperatures, solar intensity and battery voltage respectively.

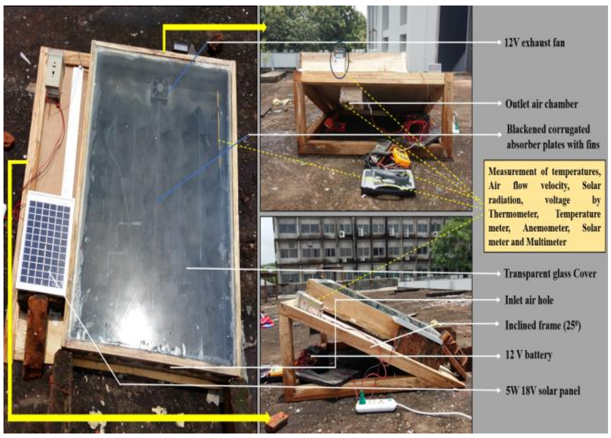

Fig.3: Indication of the isometric view of the experimental setup

2.2 Initial data and parameters

Collector area, Ac = 66 cm × 93 cm = 0.6138 m²
Specific heat capacity of air, C = 1006 J/Kg K
Air density, ρ = 1.146 m³/s (for 30° C air temperature)
T_i = Inlet temperature (°C)
T_o= Outlet temperature (°C)
T_P = Plate temperature (°C)

T_G = Glass temperature (°C)
α = mass flow rate (kg/s)
I = Solar intensity (W/m²)
η = efficiency (%)
Duct diameter, D = 0.08 m
Duct area, $A = \pi D^2/4 = 5.0265\times10^{-3}$ m²

Efficiency, $\eta = \frac{\alpha\times C\times(T_{out} - T_{in})}{I\times A_c}$

3. RESULT AND DISCUSSION

T_{in} or T_{amb}, glass temperature T_G, plate temperature T_P and outlet air temperature T_{out}, the solar intensity I and temperature difference ΔT were recorded from 10:00 am to 4:00 pm for natural draft air circulation on 2/09/19.

Table 1: Natural draft (2/9/19)

Day time	T_{amb} (°C)	T_G (°C)	T_P (°C)	Solar Intensity (W/m²)	Air Velocity (m/s)	T_{out} (°C)	ΔT= T_{out}-T_{amb}
10:00 am	33	58	74	658	0.3	62	29
11:00 am	34	61	80	826	0.4	70	36
12:00 pm	38	71	97	1066	0.5	79	41
01:00 pm	37	66	94	956	0.5	76	39
02:00 pm	35	62	88	884	0.5	72	37
03:00 pm	35	53	81	821	0.4	68	33
04:00 pm	32	49	72	690	0.3	60	28

Solar intensity was gradually increased with the time of day. The highest solar intensity was 1066 W/m^2 during the experiment at 12 pm. All temperature gradients were subjected to change with the changes of the solar intensity. In the glass cover temperature and absorber plate temperature were gradually increased with the increment of solar intensity and the highest temperatures were at 12 pm. Maximum glass cover and absorber plate temperatures were noted 71 °C and 97 °C respectively. That time temperature of outlet air was noted 79 °C. A graph of temperature evolution of solar air heater for natural draft is plotted in Fig.4.

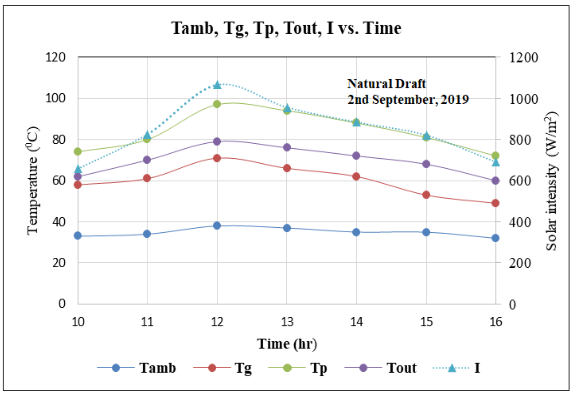

Fig.4: Temperature evolution of solar air heater for natural draft

The efficiency curve for natural draft is at first increased and then decreased with respect to solar intensity. The highest efficiency was 20.12% which was found at 2:00 pm though the highest solar intensity was found at 12:00 pm.

Table 2: Efficiency for natural draft (2/9/19)

Day time	T_{amb} (°C)	Solar Intensity (W/m²)	Air Velocity (m/s)	Tout (°C)	ΔT= T_{out}-T_{amb}	Efficiency (%)
10:00 am	33	658	0.3	62	29	13.33
11:00 am	34	826	0.4	70	36	16.21
12:00 pm	38	1066	0.5	79	41	18.46
01:00 pm	37	956	0.5	76	39	19.26
02:00 pm	35	884	0.5	72	37	20.12
03:00 pm	35	821	0.4	68	33	15.39
04:00 pm	32	690	0.3	60	28	12.49

The graph of efficiency of SAH for natural draft is plotted in Fig.5.

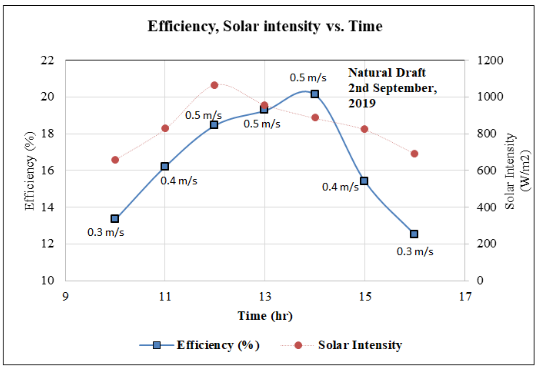

Fig.5: Efficiency of solar air heater for natural draft

T_{in} or T_{amb} , glass temperature T_G, plate temperature T_p and outlet air temperature T_{out}, the solar intensity I and temperature difference ΔT were recorded from 10:00 am to 4:00 pm for forced draft air circulation on 3/09/19.

Table 3: Forced draft (3/9/19)

Day time	T_{amb} (°C)	T_G (°C)	T_P (°C)	Solar Intensity (W/m²)	Solar Intensity (W/m²)	Air Velocity (m/s)	T_{out} (°C)	ΔT= T_{out}-T_{amb}
10:00 am	34	57	72	651	651	1.2	63	29
11:00 am	35	61	79	826	826	1.2	73	38
12:00 pm	39	73	96	1072	1072	1.2	81	42
01:00 pm	37	67	91	995	995	1.2	77	40
02:00 pm	37	62	89	880	880	1.2	73	36
03:00 pm	35	61	77	782	782	1.2	66	31
04:00 pm	33	54	70	676	676	1.2	62	29

Solar intensity is gradually increased with the time of day. The highest solar intensity was recorded 1072 W/m^2 during the experiment at 12 pm. The graph shows that the glass cover temperature and absorber plate temperatures were gradually increased with the increment of the solar intensity and maximum glass cover and absorber plate temperatures were noted 73 $^{\circ}$C and 96 $^{\circ}$C respectively at 12 pm. The data was taken at a fixed 1.2 m/sec speed of that fan which was controlled by a voltage regulator. The fan drags the heat from inside forcefully and thus the efficiency of the SAH got increased. In this forced draft air circulation, the highest temperature difference was found 42 ℃ at 12 pm when the velocity was fixed. At that time, the temperature of the corrugated plate was found 96° C which was the highest where the lowest plate temperature was 70 $^{\circ}$C at 4:00 pm when the lowest outlet temperature (62 $^{\circ}$C) was also found at the same velocity (1.2 m/sec). The temperature evolution of forced draft is plotted in Fig.6.

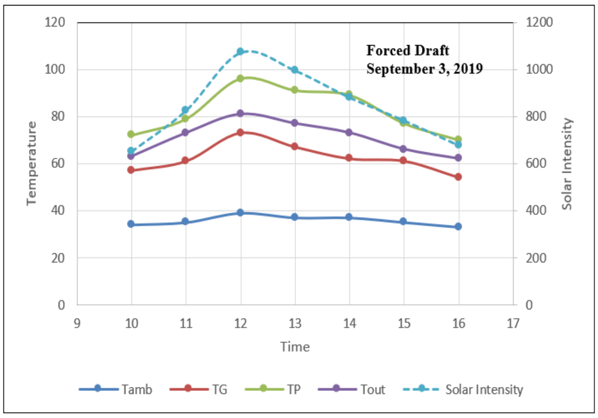

Fig.6: Temperature evolution of solar air heater for forced draft

In the forced draft air circulation, the measured efficiencies are plotted in the table below for the fixed air velocity from 10:00 am to 4:00 pm.

Table 4: Efficiency for forced draft (3/9/19)

Day time	T_{amb} (°C)	Solar Intensity (W/m^2)	Solar Intensity (W/m^2)	Air Velocity (m/s)	T_{out} (°C)	ΔT= T_{out}- T_{amb}	Efficiency (%)
10:00 am	34	651	651	1.2	63	29	50.47
11:00 am	35	826	826	1.2	73	38	52.12
12:00 pm	39	1072	1072	1.2	81	42	44.39
01:00 pm	37	995	995	1.2	77	40	45.55
02:00 pm	37	880	880	1.2	73	36	46.34
03:00 pm	35	782	782	1.2	66	31	44.91
04:00 pm	33	676	676	1.2	62	29	48.60

The lowest efficiency was found 44.39% at 12:00 pm for the velocity (1.2 m/sec). At 12:00 pm, the solar intensity was highest but the temperature difference could not increase in proportion to the intensity, so the efficiency was decreased. The efficiency of solar sir heater for forced draft is plotted in Fig.7.

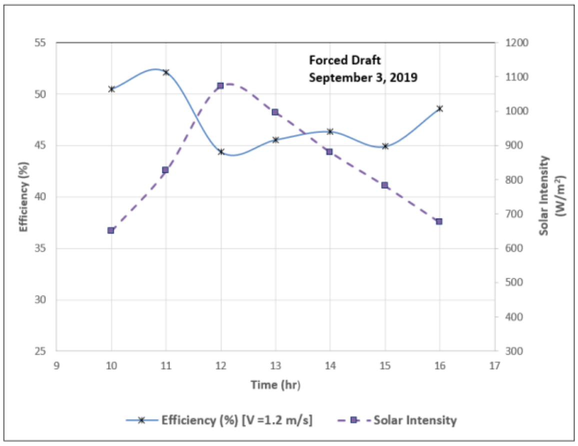

Fig.7: Efficiency of solar air heater for forced draft

The comparison of efficiency for natural draft and forced draft has been graphically represented below. The highest efficiency curve was found for forced draft and the lowest efficiency curve was found for natural draft.

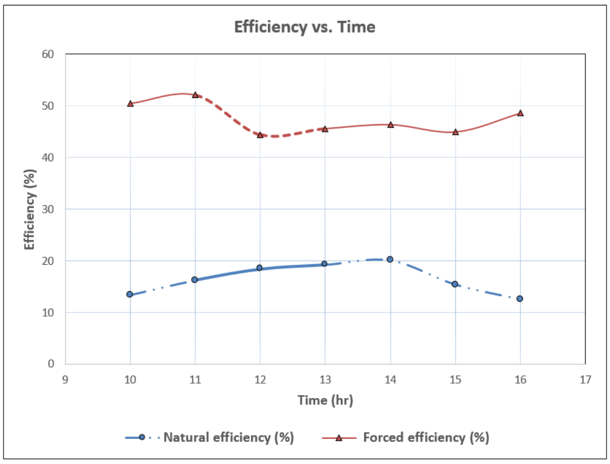

Fig.8: Efficiency comparison curve for solar air heater between natural draft and forced draft

In Fig.8 a comparison of solar air heater efficiency between forced and natural draft is plotted graphically.

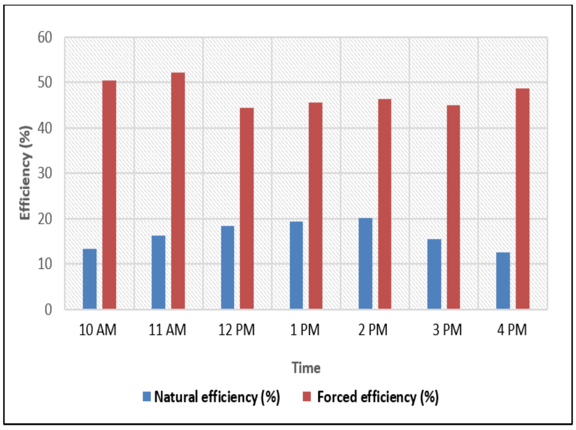

Fig.9: Efficiency of solar air heater in bar chart.

The efficiency of solar air heater for forced draft is shown in bar diagram in Fig.9 for better understanding.

4. CONLUSION

In this experiment, a solar air heater has been fabricated and the analysis of its outcomes has been publicized with a newly emerged technique. The corrugated absorber surface and triangular fins were made of aluminium, which is cost effective and has high thermal conductivity. All the measurements were taken carefully on full sunny day. The temperature and efficiency analysis for natural and forced draft were determined. The highest efficiency was found for forced draft for a fixed velocity. The highest outlet air temperature, plate temperature and efficiency were found 81 °C, 97 °C and 52.12% respectively. This work is less costly and so it can be brought into the mass level as there were a lot of technical methods used in this experiment. The enhancement techniques can be increased by proper using of these technical methods.

5. ACKNOWLEDGEMENT

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7. NOMENCLATURE

Symbol	Meaning	Unit
T_P	Temperature of Absorber Plate	(^{0}C)
T_G	Temperature of Glass Cover	(^{0}C)
T_i	Inlet Temperature	(^{0}C)
T_o	Outlet Temperature	(^{0}C)
SAH	Solar Air Heater	[-]
η	Efficiency	(%)
D	Duct Diameter	(m)
A	Duct Area	(m²)
A_c	Collector Area	(m²)
I	Solar Intensity	(W/m²)
α	Mass Flow Rate	(kg/s)