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Thermal performance Analysis Using V-Shaped Fins in Solar Absorber Plate

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Abstract: In the present work, it is aimed to improve the thermal performance of solar absorber plate by applying v-shaped fins on the collector surface. An experimental analysis has been done to investigate and compare the thermal performance of flat plate and plate with v-shaped fins (α=60°, 45°, 30°) in natural sunlight. The investigation is spread for mass flow rate ranging from 0.007kg/sec to 0.025kg/sec for fixed relative pitch of 15cm. The black coated aluminium absorber plate of area 1.4 m^2 is placed in the mid position of duct covered with acrylic glass. After analysis comparison is made indicating that useful heat gain in v-shaped finned plate is more than the flat plate at the particular day and time. Various losses also accounted during the analysis. There was also noticeable improvement in thermal performance in v finned plates in comparison to flat plate.
Keyword: Thermal Performance, Useful Heat Gain, Solar Air Heater, Fins, Mass Flow Rate.

I. INTRODUCTION

In this present research work it is aimed to experimentally analyse the useful heat gain and thermal performance of solar air heater. Till now many researchers have contributed their work in this field. Various techniques have been applied like artificial roughness; compacts concrete beds etc to improve the thermal performance. In this work 3 types of fin angle in v-shaped fins namely 60°,45°,30° have been used and its performance is compared with and it i introduction of paper contains the nature of research work, flat plate for the Reynolds number range of 10000 to 35000.

Solar air heaters are effective device to harness solar radiation. It has very good applications in space heating, swimming pool water heating and agricultural product drying. During various studies it is found that flat plate solar collectors have poor performance in comparison to finned plates. It is because of low convective heat transfer coefficients between flat plates and flowing air. It results in the increase of temperature of flat plate surfaces leading to heat losses to the environment

Several methods, including the use of fins, artificial roughness and packed beds in the ducts, have been proposed for the enhancement of thermal performance. By applying the fins in the form of different geometries cause the change in fluid flow characteristics. The roughness causes flow separations, reattachments and generations of secondary flows. Thin laminar sub layer formed in the vicinity of flat plate is broken by fins. Various geometries of fins create turbulence results in the better intermixing of air. Thus useful energy gain as well as thermal performance is improved.

Foud chabane investigated experimentally the thermal performance of a single pass solar air heater with five fins attached. Longitudinal fins were used inferior the absorber plate to increase the heat exchange and render the flow fluid in the channel uniform. The effect of mass flow rate of air on the outlet temperature, the heat transfer in the thickness of the solar collector, and the thermal efficiency were studied. 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 comparison of the results of the mass flow rates by solar collector with and without fins shows a substantial enhancement in the thermal efficiency.

Experimental test set up at laboratory scale has been developed by **Santosh vyas** for thermal performance testing of flat plate solar air heater with simulated solar radiation intensity; 600W/m^2. A test cell of size 1m x 0.5m x 0.1m was fabricated. Three designs namely (i) plane absorber (ii) transverse V- porous ribs and (iii) inclined V-porous ribs of absorber are tested. All the experiments are conducted with artificial solar radiation and in natural convection. Performances of these three designs have been compared on the basis of overall thermal efficiency and thermal gradient along normal to the base. Thermal gradient has been determined by laser beam deviation method. PT-100 temperature sensors have also been used to validate the optical results of thermal gradient. The overall thermal efficiencies of these designs have been found as 14.91%, 17.24% and 20.04% respectively. It has also been seen that thermal gradient tends to reduce with increase in efficiency.

A A. EI Sebai investigated theoretically and experimentally the double pass flat and v-corrugated plate solar air heaters. Analytical

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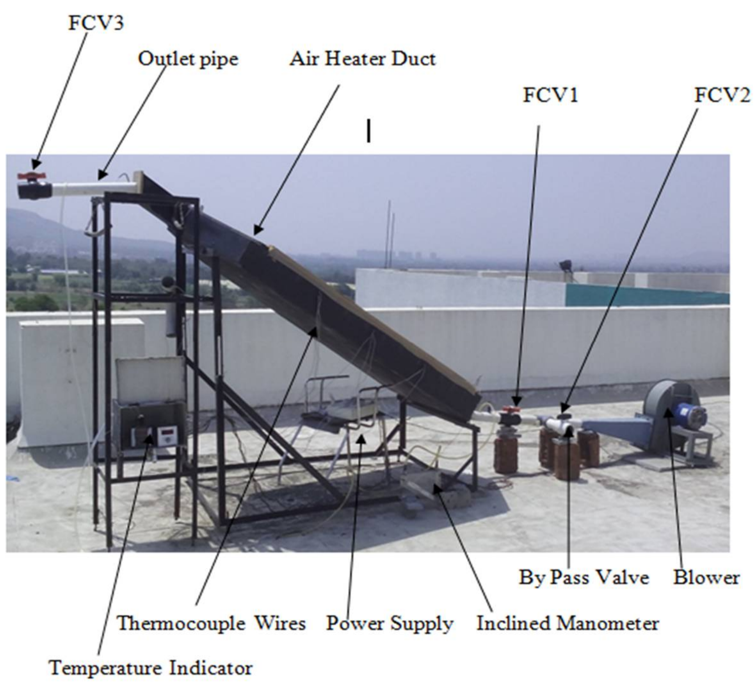
models for the air heater with flat and v corrugated plates are presented. Numerical calculations have been performed under Tanta (latitude, 30°47'N) prevailing weather conditions. The theoretical predictions indicated that the agreement with the measured performance is fairly good. Comparisons between the measured outlet temperatures of flowing air, output power and overall heat losses of the flat and v-corrugated plate solar air heaters are also presented. The effect of mass flow rates of air on pressure drop, thermal and thermo hydraulic efficiencies of the flat and v-corrugated plate solar air heaters are also investigated. The results showed that the double pass v-corrugated plate solar air heater is 11-14% more efficient compared to the double pass flat plate solar air heater. It is also indicated that the peak values of the thermo hydraulic efficiencies of the flat and v-corrugated plate solar air heaters are obtained when the mass flow rate of the flowing air is 0.02 kg/s.

Vishawajeet Singh Hans did the study and found that the conversion, utilization and recovery of energy invariably involve a heat exchange process, which makes it imperative to design more efficient heat exchanger. The use of artificial roughness in different forms, shapes and sizes is the most common and effective way to improve the performance of a solar air heater. Several studies have been carried out to determine the effect of different roughness element geometries on heat transfer and friction in solar air heaters. This study reviews various roughness element geometries employed in solar air heaters for performance enhancement. Based on the correlations of heat transfer and friction factor developed by various investigators, an attempt has been made to compare the thermo hydraulic performance of roughened solar air heaters.

II. EXPERIMENTAL SETUP AND DESCRIPTION



The whole fabrication and experimentation work was conducted in the Indira College of Engineering and Management, Pune. It is located at latitude 18.5204°N, 73.8567°E. A schematic view of the experimental setup has been shown in the above figure. Inclined setup is supported by a firm stand. The inclination angle is kept at 35° to the horizontal for appropriate result. The rectangular duct ends at both sides in taper form. Electric power supply is given to the motor which drives the blower. The motor used is 0.5HP, 1425RPM, 220V. Blower sucks the atmospheric air and directs it to flow through the absorber plate. Solar radiation falls on the acrylic glass plate which transmits almost 90% of the radiation to the absorber plate. Flow control valve has been used for controlling the inlet air. Total numbers of fins are 70 which are uniformly spaced. The pitch of fin (P) is 15 cm and vertical distance between two fins is 14.5cm. Fin height (e) is taken as 1.5cm and thickness (t) is 0.5mm. Pitch to roughness ratio (P/e) is fixed as 10. All the fins are attached over the surface of absorber plate with the fast drying epoxy glue. The material of absorber plate is aluminum and its thickness is taken as 3mm whereas as its surface area is 1.4 m^2.

III. THERMAL PERFORMANCE OF SOLAR AIR HEATER

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It was pointed out earlier that the low thermal efficiency of solar air heaters can be improved by using artificial roughness in the form of different shapes fabricated in various arrangements to create turbulence near the wall or to break the viscous sub layer. As a result, increasing the heat transfer coefficient, thermal efficiency can be increased but at the same time creating turbulence requires additional energy which has to be supplied by fan or blower at the expense of electrical energy.
The collector efficiency, η, is a measure of the collector performance and is defined as the ratio of the useful heat energy gain over a time period to the incident solar radiation over the same time period.

$$\eta_{th} = \frac{Q_u}{IA_c}$$

The following equations have been used for the evaluation of relevant parameters:

The rate of useful energy collected is expressed by considering enthalpy rise of the air as

$$Q = mC_p(T_o - T_i)$$

Heat transfer coefficient of air is calculated by using the formula

$$h = Q/[A_c \times (\overline{t_p} - \overline{t_f})]$$

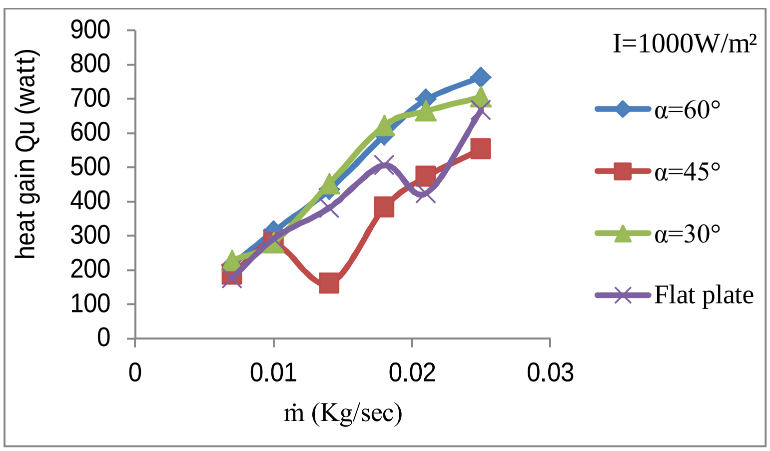
Temperature of plate is taken average of the temperature sensors placed at nine locations

$$T_p = \frac{T_1 + T_2 + T_3 + T_4 + T_5 + T_6 + T_7 + T_8 + T_9}{9}$$

To calculate the temperature of fluid, generally average of inlet and exit temperature of fluid is taken as given below-

$$T_f = \frac{T_i + T_o}{2}$$

IV. RESULTS AND DISCUSSIONS



Graph1: variation of heat gain Vs mass flow rate

The above given figure shows the variation of useful heat gain with respect to mass flow rate for finned plate (α=60°,45°,30°) and flat plate. The heat gain increases with increasing the mass flow rate but slope of increase flattens at mass flow rate of 0.03 kg/sec. The Q for α=60° is higher due better turbulence of air inside the collector. Useful heat gain for (α=45°) is lower than 60°. As per literature survey flat plate should show the least heat gain but plate with (α=45°) shows least heat gain due variation in surrounding condition

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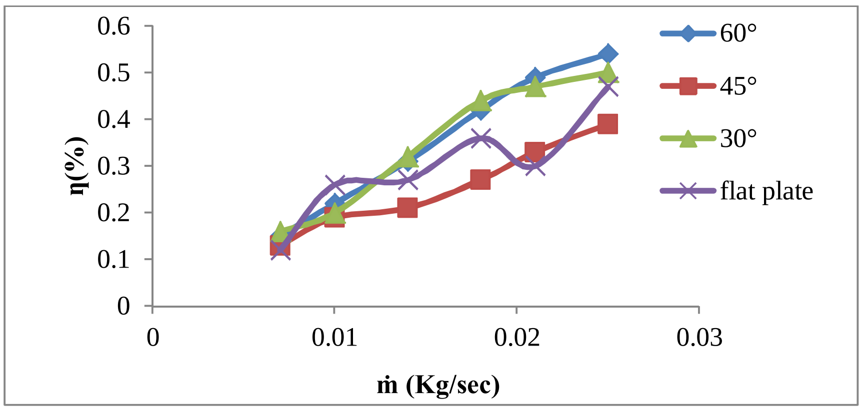
Table: Thermal efficiency data

ṁ	60°	45°	30°	flat plate
0.025	0.54	0.39	0.5	0.47
0.021	0.49	0.33	0.47	0.3
0.018	0.42	0.27	0.44	0.36
0.014	0.31	0.21	0.32	0.27
0.01	0.22	0.19	0.2	0.26
0.007	0.15	0.13	0.16	0.12



Graph2: variation of thermal efficiency Vs mass flow rate

The above given figure shows the variation of thermal efficiency of collector plate (α=60°, 45°, 30° and flat plate) with respect to mass flow rate. The data has been collected at 1:30PM for several days at fixed location. Solar intensity is assumed to be fixed with minute variations. From the previous average data, the value of solar intensity is taken as 1000W/m². It is seen that as mass flow rate increases thermal efficiency also increases. Thermal efficiency obtained by plate (α=60°) is highest followed by the plate (α=30°, flat plate and α=45°) as mass flow rate increases thermal efficiency of the plate also increases. Maximum thermal efficiency is obtained at highest mass flow rate of 0.025Kg/sec. thermal efficiency is 54% for the plate (α=60°) and thermal efficiency is 50% for the plate (α=30°) and it is 47% for flat plate and 39% for plate (α=45°). As per literature survey plate with 45° fin angle should perform better than 30° but due drastic variations in ambient conditions it performs poorer. For flat plate the trends of graph starts lowering only because of the sudden cloudy climate again it starts rising when clouds disappear.

V. CONCLUSIONS

The present study aims to review designs and analyze thermal energy gain of solar air heater. This experimental study compared a solar collector without using fins and with using fins attached at the surface of absorber plate. The thermal energy gain of the solar air collectors depends significantly on the solar radiation, mass flow rate, and surface geometry of the collectors. Thermal energy gain of the collector improves with increasing the day time at mass flow rate of 0.025kg/sec. it is found that maximum thermal energy gain is at 1:30PM.It again starts decreasing with decrease in the solar radiation as well as day time. The highest thermal energy gain and air temperature rise were achieved by the finned collector whereas the lowest values were obtained from the collector without using fins i.e.; (flat plate)

A. Thermal efficiency increases with increase in mass flow rate. It is minimum at 0.005 Kg/sec and maximum at 0.025 Kg/sec.

B. Thermal efficiency is highest for 60° followed by 30° flat plate and 45°.

C. It is seen that thermal performance has been improved for highest degree fins because turbulence generated by highest degree fin is more.

D. Maximum thermal performance for 60° plates at mass flow rate of 0.025Kg/sec is 54% followed by 50% for 30° plate and 47% for flat plate.

E. 45° plate's shows thermal performance of 33% due to data recorded in the cloudy weather conditions.

F. Useful heat gain is clearly dependent on day time and Reynolds number. As day starts increasing useful heat gain collected is also more. It is less when the reading was started to record at 11:30AM. It attains maximum value at 1:30PM and it again starts decreasing and gives least value at 4:30PM when solar intensity is minimum

G. Plate with 60°, 45°, 30° and flat plate shows similar trends .i.e.; heat gain starts decreasing with lowering the Reynolds number.

H. For comparing all the four plate data are taken at fixed time assuming the same solar intensity. The above graph shows the variation of useful heat gain with mass flow rate of air. It is seen that useful heat gain for 60° plate is maximum then 30° and flat plate. Plate with 45° fin shows minimum heat gain due to atmospheric condition. Variation in the results from the conventional trends due to dusty wind and cloudy atmosphere.

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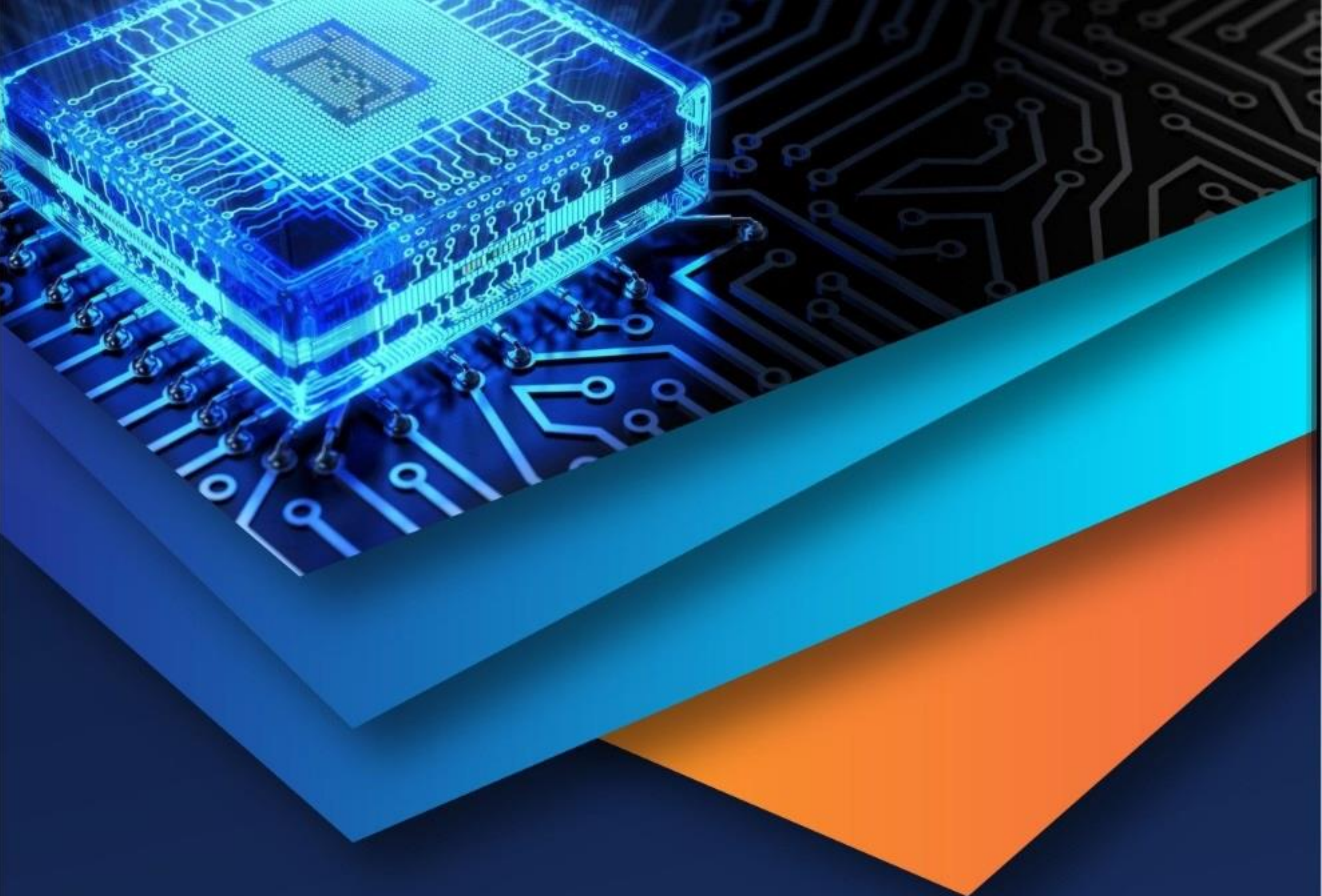

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