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Evaluation of Heat and Efficiency Character of Poly Absorber Plate Solar Air Heater

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ABSTRACT

This paper investigates an experimental study of heat transfer and efficiency of solar heater of air through poly absorber plate. The important of solar heater application gives benefit for space heating and dryer. The increase of surface area in heater plate improves the thermal efficiency and their variable. The forced convection of heat transfer coefficient and rate is studied by various flow characteristics of air via combination of three stage plate surface. The dimensionless character of Reynolds number is formulated to study the laminar and turbulent flow of air through proposed air heater to improve the thermal behavior of heating application. The laminar characteristic is observed in the region of flat plate surface (Stage I) to stabilize the flow at initial. The curved surface plate (Stage II) is now change the flow pattern as turbulent and then passes through the holed flat surface plate (Stage III) to the outlet duct. The observed variable are inlet/ ambient & outlet of air temperature, average of three stage plate surface temperature, velocity of air at outlet and solar radiation. These variables are performed at different Reynolds number using Data Logger Unit (DLU) and C++ coding. The experimental investigation of proposed design gives better thermal efficiency and their variable compare to corrugation plate Solar Air Heater (SAH). The increase in surface area and speed of flow is investigating the better thermal behavior of the system.

Keyword: Thermal behavior, SAH, DLU, heat transfer rate, mass flow rate, and coding.

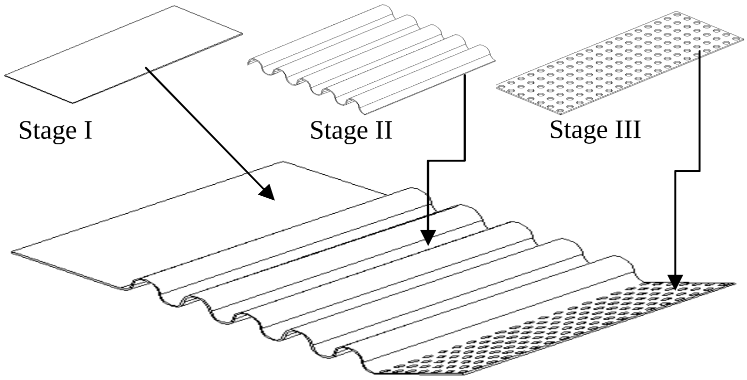
INTRODUCTION

The application of heating has low temperature for non – adiabatic radiative heat exchange of SAHs [4]. The main parts of SAHs are occupying an important place among solar air heating systems because of low heat transfer coefficient and minimal use of material. The higher heat losses is sensed by the high convective heat transfer coefficient of space medium which increase the absorber plate temperature that leads to low efficiency. The heat transfer is improved by changing the flow pattern in this system. There are different factors affecting SAH efficiency. The most important term in the design of SAH for any type is shape/ surface of absorber plate which will increase the thermal variable by the flow pattern. The power is required to pump the air flow crossing the collector is increased by the increase pressure drop in the collector [5].

The literature shows different configuration of SAHs with different dimension and shape of space to be heat in plate type solar air collectors were tested [7-12]. The effect of geometrical parameter on heat transfer and fluid flow characteristic in rectangular duct of SAH was investigated [13]. SAH having free and fixed fins was compared to flat plate SAH as well as each other in term of efficiency and exergy loss ratio [14]. The effective efficiency of roughed and smooth duct solar air heater were analyzed for better result and presented in the form of design plots [15].

The SAH is developed to improve their thermal character and air flow properties. The less heat transfer loss is achieved by applying forced convection to increase heat transfer rate with turbulent character of flow. If the turbulent flow is started at the mouth of the SAH will disturbed the heat transfer rate at low temperature level. So in this investigation, three stage of plate surface is combined to obtain better thermal efficiency for space heating and dryer.

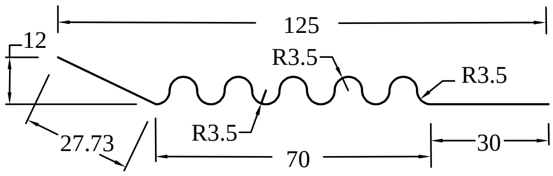
1. DESIGN OF POLY ABSORBER PLATE



The configuration of SAH has an important place among solar heating collectors. The high amount of solar energy is collected through good design of improved performance of SAH. The proposed design of absorber plate is used as isotropic material but surface area is increase by three stage of plate surface. The figure 1 shows the stages of plate surface to predict the good thermal efficiency. The dimension detail of poly absorber plate is tabulated in table 1.

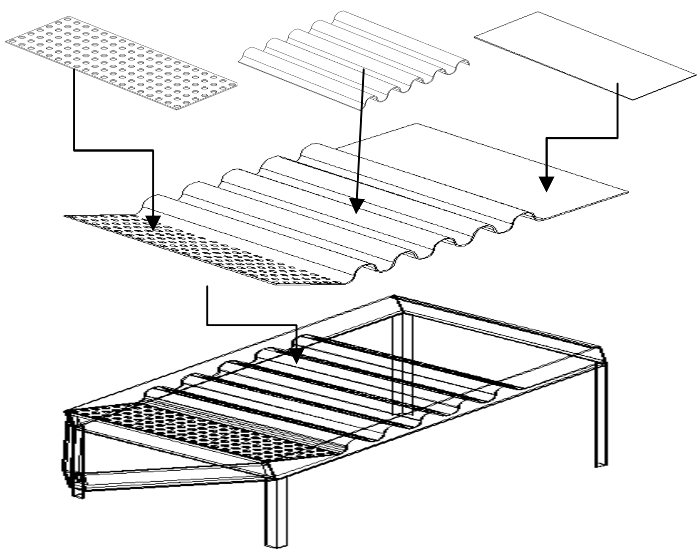
Table .1: Dimensions of Poly Absorber Plate

Dimensions	Stage I	Stage II	Stage III
Surface Length, cm	30	109.96	27.23
Width, cm	75	75	75
Radius of curved surface, cm	---	3.5	---
Inclination, ^{o}	---	---	26



All dimensions are cm

Figure .2: Poly Absorber Plate Dimension Detail



The poly absorber plate means combination of number of plate surface of absorber in the SAH. Stage II of curved surface is modeled at radius 3.5cm to develop turbulent pattern of flow. The figure 2 shows geometry detail of proposed design of poly absorber plate. The SAH has to design 125cm X 76cm (0.938m^2) with poly absorber plate surface area1.258m^2. This modification not only mobilizes the thermal parameter and also changes the flow characterization to prevent much heat loss during heat transfer. The design tree of SAH in wire frame 3D solid modeling is shown in figure 3.

MATERIALS AND METHODS

2. EXPERIMENTAL ANALYSIS

The figure 4 shows experimental setup of poly absorber plate SAH. The observations were picked through electronic system of hardware and software. The sensors were used to sense the field parameter like velocity of air outlet, temperature of ambient/ inlet, plate surface & air outlet, and solar radiation. The sensor signal is transmitted to the converter of analog to digital process electronic system and then transmits to personnel computer (PC) via data cord of serial port communication. These digital data are sequenced from the C++ coding. The code having all details about the heat transfer variable, empirical formula, conversion chart information of milli-volt to degree Celsius and machine language statement to input and output port communication. The sequenced data is finally stored in a separate file using file management of opening and closing statement in normal text format. The photocopy of experiment conducted to compare the proposed work is shown in figure 5 – 6.

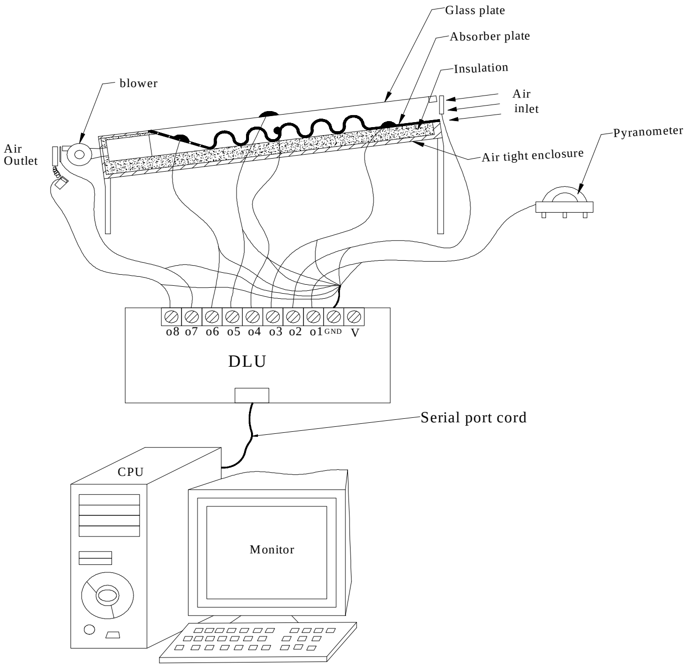


Figure 4: Experimental Setup of Modified SAH

Figure .5: Existing and Modified Model of SAH

Figure .6: DLU Interfacing of SAH

The mass flow rate of air is observed by the experimental value of outlet velocity as

$$\dot{m} = \rho AV$$

The heat gained by the air is

$$Q_{air} = \dot{m} C_P (T_o - T_i)$$

The total heat available in the collector is

$$Q_c = I_{rad} A_c$$

The total heat available by the solar is

$$I_{rad} = \frac{I}{5.56 \times 1000} \times 60 \times 4.187 \times 10^4$$

The efficiency of collector is

$$\eta_c = \frac{Q_{air}}{Q_c}$$

The heat transfer rate and coefficient is more important to prevent heat loss in the application. These parameters are evaluated by the dimensionless relation. The Reynolds number is used to characterize the flow through space providing above the absorber plate surface and then fix other relation to formulate for thermal variable with help of data book [16]. The Reynolds number,

$$\mathrm{Re} = \frac{\rho VL}{\mu},$$

$$\left.\begin{array}{l} Nu = 0.036 \times \mathrm{Re}^{0.8} \times \mathrm{Pr}^{0.333} \\ Nu = 0.664 \times \mathrm{Re}^{1/2} \times \mathrm{Pr}^{1/3} \end{array}\right\} \begin{array}{l} if\ \mathrm{Re} > 5 \times 10^5 \\ if\ \mathrm{Re} < 5 \times 10^5 \end{array},$$

$$h = \frac{Nu \times k}{L},$$

$$Q = hA_c (T_p - T_{mf})$$

The number of thermal relation is applied and is observed the thermal character of proposed design of SAH. These characterizations are discus in the next section.

RESULTS AND DISCUSSION

The thermal variables are measured using DLU and C++ coding to execute the result of their parameter. These results are discussed in this section for the good performance of poly absorber plate SAH. The figure 7 – 8 shows the characteristics of heat gained by the air and heat available by solar radiation in the terms of efficiency for the velocity of air at 5m/s and 11m/s. This variable clearly distinguishes the good efficiency than the corrugation plate.

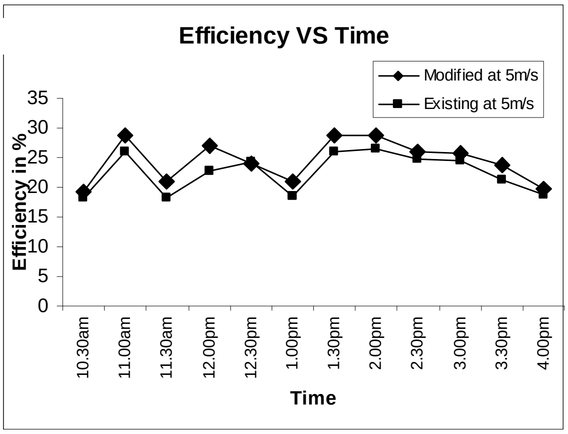


Figure .7: Efficiency of SAH at 5m/s

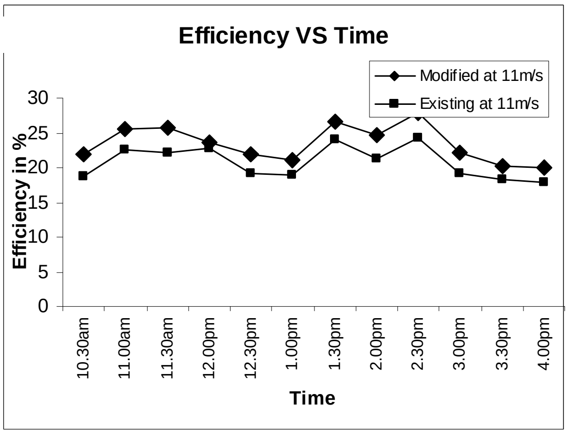


Figure .8: Efficiency of SAH at 11m/s

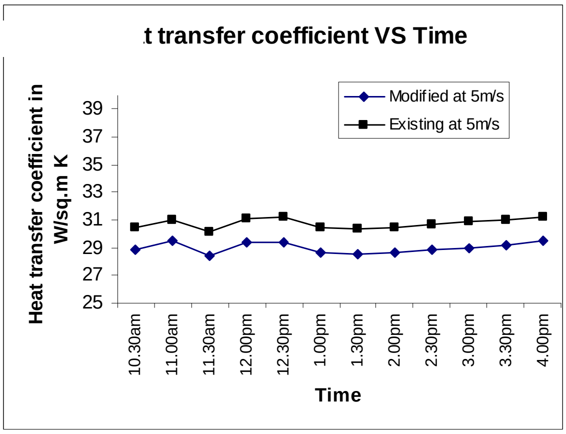


Figure .9: Heat Transfer Coefficient of SAH at 5m/s

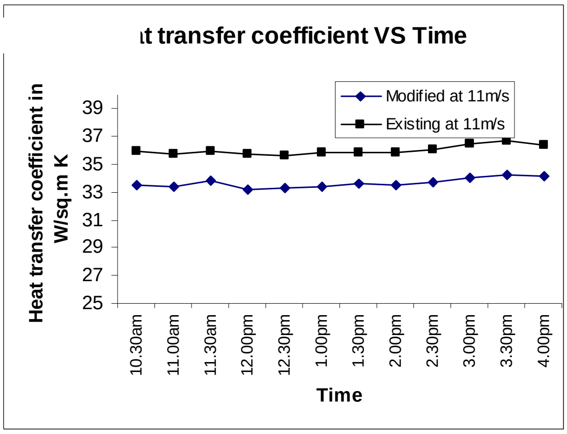


Figure .10: Heat Transfer Coefficient of SAH at 11m/s

The convective heat transfer rate is processed with thermal properties using heat transfer data book [16] for the flow characterization variable. The evidence of good thermal behavior is measure from the characteristics legend of poly absorber plate SAH than corrugation plate as shown in figure 9-12. The suggestion of this paper is to improve the performance of thermal and flow character by increase the surface area of collector with compact surface area of gadgets. Also the velocity of air is increased to gives better turbulent flow for less heat loss and high heat transfer rate.

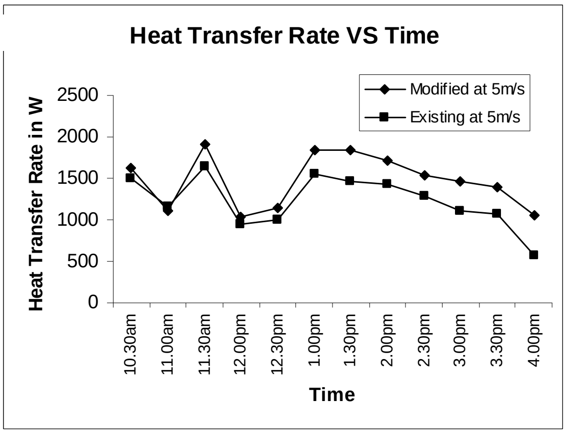


Figure .11: Heat Transfer Rate of SAH at 5m/s

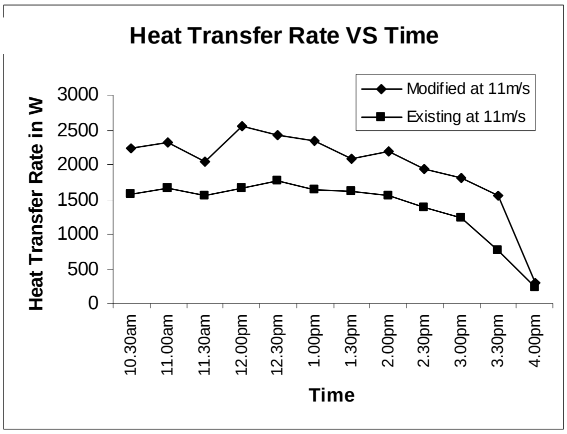


Figure .12: Heat Transfer Rate of SAH at 11m/s

CONCLUSION

It is obvious that the known resources of fossil fuels in the world are depleting very fast and by the turn of the century, man will have to increasingly depend upon renewable resources of energy. Now the possible application of solar air heater are drying or curing of agricultural products, space heating for comfort, regeneration of dehumidifying agents, seasoning of timber, curing industrial products such as plastics. The role of heater is to generate thermal variable for their performance. Many SAHs are available at present to give better thermal aspects, but it not enough to satisfy the need of user. The improvement of efficiency and reducing of heat loss due to pressure drop occurrence of fluid properties are still investigate through increase of surface area of collector instead of gadgets surface area. This paper witnesses the improvement of thermal behavior by change of poly absorber plate instead of corrugation plate. The character behavior of thermal and collector efficiency were determined and indulge the improvement through the characteristic legends. The increase of absorber plate surface area in compact model of SAH gives better result for the quick and high temperature level of application.

Nomenclature:
A - Blower outlet area, m^2
V – Velocity of air, m/s
ρ - Density of air, kg/ m^3
$\dot{m}$ - Mass flow rate of air, kg/s
C_P – Specific heat capacity of air, kJ/kg.K
T_O – Outlet air temperature, K
T_i – Inlet/ ambient air temperature, K
I – Solar radiation, m.v
Q_{air} – Heat gained by the air, W
Q_C – Heat gained by the collector, W
I_{rad} – Heat available in solar, W/m^2
A_C – Collector area, m^2
η_C – Collector efficiency, %
Re – Reynolds number
L – Surface length of collector, m
μ - Dynamic viscosity, $N.s/m^2$
Pr – prandtl number
Nu – Nussult number
h – Convective heat transfer coefficient, $W/m^2.K$
k – Thermal conductive of air, W/m.k
T_P – Absorber plate temperature, K
T_{mf} – Mean film temperature of space, K
Q – Convective heat transfer rate, W

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