EDU Journal of International Affairs and Research (EJIAR), ISSN: 2583-9993
Volume 4, Issue 4, October-December, 2025, Available at: https://edupublications.com/index.php/ejiar

Study of Solar Air collector with A Trapezoidal Corrugated Absorber plate

Himanshu Chaudhary

Assistant Professor, Department of Engineering and Technology, AISECT University, Hazaribagh, Jharkhand

ABSTRACT

Growing global concern about energy security and environmental degradation has stimulated the development of innovative techniques to improve resource efficiency. This study involved the modeling and simulation of a solar air heater (SAH) system. The modeling results showed good agreement with the experimental data, and the validated model was used to investigate the effects of various design parameters on the performance of the SAH. It was observed that the efficiency of the collector increases with an increase in both the collector length and width. The system attains its optimum efficiency values when the collector dimensions are in the range of 1.5 to 2.0 m.

INTRODUCTIONS

Solar energy is the one most aleundant renewable energy source. The primary forms of solar energy are heat and light, sunlight and heat are transformed and absorbed by the environment in a multitude of ways. One of the most potential applications of solar energy is the Supply of not air for the drying of agricultural, tertile, marine products, heating of buildings to maintain a comfortable environment. The SAHS are solar systems that transform solar radiant energy into heat, which is transferred convectively from the absorber to the air flowing in the duct and aroe basically used for drying applications. The main disadvantage of SAHS stem on its low conversion efficiencies as a result of the poor thermal-physical properfies.

Thus, many studies have been done both experimental and theoretical to improve the performance of solar heaters systems [1-7]. Modeling and simulation are considered as fast and simulation are considered as fast and cheap analytical tools by engineers in developing optimal Solar energy systems for a given application poor to their construction. This study involves modeling of a solar air heater system with trapezoidal corrugate absorber plate.

Formulation–

The effective utilization of intermitted and variable energy sources such as solar energy. The collector under consideration consists of a glass cover and absorber plate with a well insulated parallel bottom plate, forming a rectangular duct profile through which the air to be heated flows. The corrugation of the absorber plate is trapezoidal in shape and the air is made to flow along the corrugation. The theoretical solutions of the thermal performance of the SAH system involve the formulation of the energy balance equations that describe the heat transfer mechanisms at each component of the solar air collector. The heat distribution through the air heater is as shown in Fig. 1.

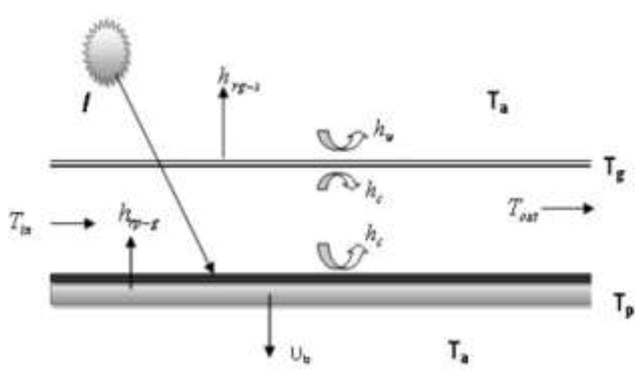

Fig. 1 : Flat plate solar collector with heat transfer parameters

The energy balance equations obtained are as follows:
On the glass cover:

$$h_{rp-g}\left(T_p - T_g\right) + h_c\left(T_g - T_f\right) = U_t\left(T_g - T_a\right) \quad (1)$$

On the absorber plate:

$$(\tau\alpha)AI = Ah_c\left(T_p - T_f\right) + Ah_{r,p-g}\left(T_p - T_g\right) + AU_b\left(T_p - T_a\right) \quad (2)$$

The air flow:

$$\dot{m}C_p\left(T_{out} - T_{in}\right) = Ah_c\left(T_g - T_f\right) + Ah_c\left(T_p - T_f\right) \quad (3)$$

The equations (1) to (3) are used to derive the solutions for the collector components' temperatures, i.e. T_p, T_g, and T_{out} as follows:

$$T_p = \frac{(\tau\alpha)AI + h_{rpg}T_g + h_cT_f + U_bT_a}{h_{rpg} + h_c + U_b} \quad (4)$$

$$T_g = \frac{h_{rpg}T_p + U_tT_a + h_cT_f}{U_t + h_c + h_{rpg}} \quad (5)$$

$$T_{out} = \frac{A_ph_c}{\dot{m}C_p}\left[T_p + T_g - 2T_f\right] + T_{in} \quad (6)$$

It is assumed that there is linear temperature rise in the channel, hence T, is evaluated as the mean of the inlet and the outlet temperatures:

$$T_f = \frac{T_{out} + T_{in}}{2} \quad (7)$$

Heat Transfer Coefficients:
The top heat transfer coefficient U_i, and wind heat transfer coefficient can be obtained by the expressions :

Where, h_W is calculated from the following empirical correlation i.e

$$h_w = 5.7 + 3.8V \quad (9)$$

The radiation heat transfer coefficient ($h_{r\text{-}g\text{-}s}$), from the glass cover to the sky is obtained as

$$h_{r\,g-s} = \sigma\varepsilon_g\left(T_g^2 + T_s^2\right)\left(T_g - T_s\right)\frac{\left(T_g - T_s\right)}{\left(T_g - T_a\right)} \quad (10)$$

Where the sky temperature T_S is estimated as

$$T_s = 0.0552T_a^{1.5} \quad (11)$$

The radiation heat coefficient between the absorber plated and glass cover $h_{r,P\text{-}g}$ is given

EDU Journal of International Affairs and Research (EJIAR), ISSN: 2583-9993
Volume 4, Issue 4, October-December, 2025, Available at: https://edupublications.com/index.php/ejiar

$$h_{r,p-g} = \frac{\sigma\left(T_p^2 + T_g^2\right)\left(T_p - T_g\right)}{\left(\frac{1}{\varepsilon_p} + \frac{1}{\varepsilon_g} - 1\right)} \quad (13)$$

The back heat loss coeficient Ub by conduction through the back insulation is determined by the expression:

$$U_b = \frac{k_i}{d} \quad (13)$$

The natural convection heat transfer coefficient between both the glass cover and the absorber plate and the airflow in the duct is calculated as

$$h_c = Nu\frac{k}{D_h} \quad (14)$$

The hydraulic diameter is given by:

$$D_h = \frac{2WL}{(W+L)} \quad (15)$$

The Nusselt number can be approximated by the following correlation as

Where is the angle of inclination of the collector and Ra is the Rayleigh number

θ

$$Ra = \frac{g\beta' \Delta T L^3}{\nu\alpha} \quad (17)$$

$$Nu = 1 + 1.44\left[1 - \frac{1708(\sin}{Ra\cos\theta}\right]\left[\;\cdot\; Ra\cos\theta\right]\left[\left(\frac{Ra\cos\theta}{5830}\right)^{1/3} - 1\right]^{+} \quad (16)$$

The notation [ ]* in eqn (16) is used to denote that if the quantity in the bracket is negative. It should be set equal to zero Also, the correlation is valid for 0o ≤ θ ≤ 75o.

RESULTS AND DISCUSSIONS

The Graph shows a plot of temperature against time of the day when the measurements were done.

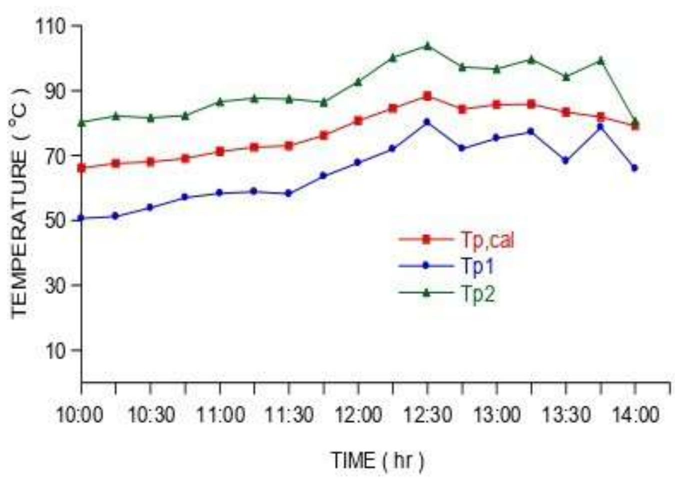

Fig. 2: Comparison between the experimental and theoretical plate temperatures.

Fig. 2 shows the correlation between the theoretical and experimental values of the plate temperature against time. In order to measure the plate temperature, it is recommended to mount temperature sensors at several points on the absorber plate area to enable the average plate temperature to be obtained. This will give the average plate temperature more accurately but such process is cumbersome. Thus, the plate temperature is usually measured at two locations on the plate. One sensor is placed at 1/3 and the other at 2/3 from the inlet of the collector and their average value is used as the plate temperature.

Effect of the collector length and width

The collector dimensions usually define the collector area and influences the mass flow rate and the convective heat Their effect on the transfer of the solar system. was investigated by performance of the collector determining the thermal efficiencies at different values of collector length and width. Figure 3 and 4 presents the results showing the effect of the collector length and collector width on thermal performance respectively.

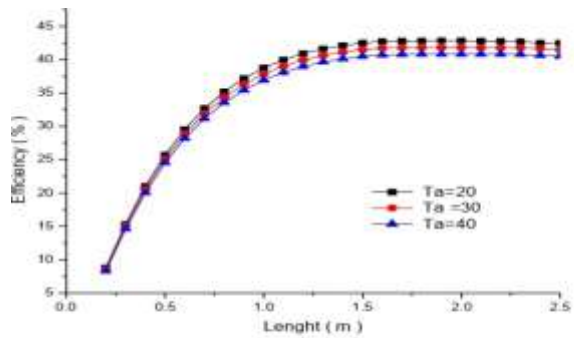

Fig. 3: Effect of collector length on efficiency at different inlet temperatures

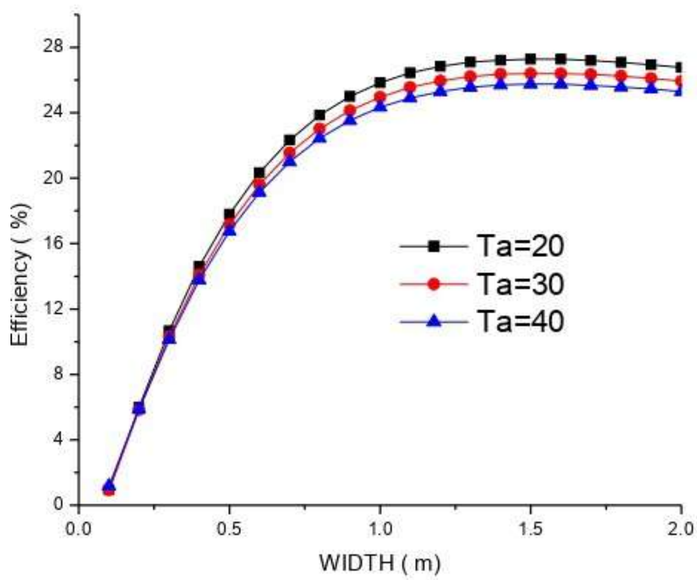

Fig. 4: Effect of collector width on efficiency at different inlet temperatures

It is observed that the efficiency at all ambient temperatures increases with increase in the collector length to about 2.0 m and thereafter decreases with further increase in length.

Similarly, efficiency increases with increase in collector width attains its optimum efficiency when the width is between 1.0-1.5 m. The collector area usually determines the total amount of solar radiation that is intercepted by the SAH system.

Thus, an increase in the collector length and/or collector width intercepting the solar radiation resulting to higher heat production in the SAH system. The length also increases the air residence time inside the solar collector channel and enhances the convective heat transfer rate between the absorber plate and the flowing air. This results to the increase in efficiency as the length increases. Conversely, the increase in collector length results to the increase in pressure drop and thermal losses. The increase in pressure drop is as a result of friction between the air and the channel walls whereas the increase in thermal losses is due to increase in surface area of the collector. This leads to a reduction in efficiency when the length exceeds 2.0 m. Therefore, the optimum collector length of the SAH system for optimum efficiency to be achieved should be between 1.5-2.0 m.

CONCLUSION

It was observed that system's efficiency is high with smaller channel depth and attains the its optimum values of efficiency between 1.5 to 200 m, for both length and width. the validation results showed a good agreement between experimental and modelling results.

REFERENCES

[1]. Quoilin, S., Declaye, S., et al. (2025). Thermo-economic optimization of waste heat recovery organic Rankine cycles. Applied Thermal Engineering, 31, 2885–2893.
[2]. Kapil, A., et al. (2023). Exploitation of low-grade heat in site utility system. Chemical Engineering Transactions, 21, 367–372.
[3]. Charters, W. W. S. (1985). Some aspects of flow duct design for solar air heater applications. Solar Energy, 13, 283–288.
[4]. Garg, H. P., Datta, G., & Bhargava, A. K. (1984). Some studies on the flow passage dimension for solar air heating collectors. Energy Conversion and Management, 24(3), 181–184.
[5]. Yeh, H.-M., Ho, C.-D., & Chen, C.-H. (1999). The effect of collector aspect ratio on the collector efficiency of sheet and tube solar fluid heaters. Tamkang Journal of Science and Engineering, 2, 61–68.
[6]. Bolaji, B. O. (2005). Development and performance evaluation of a box-type absorber solar air heater for drying crops. Journal of Food Technology, 3, 595–600.
[7]. Duffie, J. A., & Beckman, W. A. (2023). Solar engineering of thermal processes (2nd ed.). Wiley.