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Thermal performance comparative analysis of solar air heater with fins addition on the absorber plate

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***Abstract* — A thermal performance comparative analysis of solar air heater with a flat absorber plate and fins addition is carried out. The total area of the absorber plate was increased by adding different geometric shapes: rectangular, triangular and cylindrical fins. Heat transfer was studied by free and forced convection with an air mass flow of 0.033 kg/s. The behavior of the air outlet temperature as a function of time in the flat absorber plate shows that the highest air outlet temperature values correspond to the solar collector cylindrical with fins, the Ts2 value highest was 73°C. The thermal performance of solar air heaters with flat absorber plate and fins, without forced air flow, recorded maximum values with cylindrical fins on the absorber plate, reaching results of η2=35% for solar radiation values of 1203 W/m^2. The thermal performance with the use of triangular fins achieves the lowest results, η3=35%.**

***Keywords* — Thermal performance, solar radiation, free and forced convection, fin, air heater, absorber plate.**

I. INTRODUCTION

Various forms of energy have played a vital role in global industrialization and economic growth. However, with the rapid decline in fossil fuel reserves, which represent the majority of energy sources, it is necessary to look for more sustainable alternatives. In this context, the development of renewable energy sources has become an important option. Renewable energy sources, such as solar energy, offer a promising and sustainable alternative. Solar energy is abundant and comes from an inexhaustible source, the sun. Solar energy can be used to generate thermal and electrical energy in a clean and pollution-free manner. The sun provides a continuous source of energy that can be used through solar collectors. Solar collectors are an efficient way to use solar energy and convert it into thermal energy for various applications, contributing to the creation of a pollution-free fuel reserve.

Solar energy is an infinite and environmentally friendly renewable energy source. One of the most used systems to harness this energy is the solar air heater, which is used to heat the air in different applications. The system is of simple construction and has a cheaper cost, this makes it very interesting for researchers. There are several techniques to increase the performance of solar air heaters. Some of these techniques include the use of rough surfaces, extended surfaces, and porous beds. These techniques have been used to design different types of solar air heaters, [1], [2]. Energy analysis is important to determine the effectiveness of thermal process, but exergetic analysis allows us to examine the real behavior of the irreversibilities of the processes, which involve various energy losses. Exergy analysis is an essential tool for the optimal design of solar air heaters, as it allows efficient utilization of solar energy, [3].

A complete review on the energy and exergy analysis of solar air heaters is carried out in [4]. The authors demonstrate in their research that energetic analysis is of great importance for the study of the process effectiveness, while exergy analysis is another important concept to examine the actual process behavior involving various energy losses and internal irreversibility. Another interesting research is developed by [5], the authors present a review work related to the experimental research procedures and techniques for increasing the thermal performance of solar air heaters.

In the research developed by [6], a study of solar air heaters and various geometric modifications to improve their performance is presented. The effect of these modifications on the Nusselt number, the friction factor and the thermal-hydraulic performance of the solar thermal collector is reported. This article provides researchers working in this field with a summary of the work carried out in relation to solar thermal collectors. The contribution of the researchers in the review of solar air heating systems with low pressure drop and high heat exchange is important, although experimental results that allow a detailed analysis of the systems are not included. The analysis of a solar air heater, with a blackened copper tube is carried out in [7], which is flexible to integrate with any flat plate type thermal system. The results showed an increase in thermal performance, and the total cost of the modified system is much cheaper than the other models studied.

The experimental analysis of air heating in solar collectors by studying heat transfer through natural or forced convection is carried out in [8]. The author analyzes the free convection process, where the air is heated, has a lower density and moves through the interior of the collector, this allows fresh air to enter and the process to be repeated. The author determines several parameters: the Nusselt number, the Rayleigh number, the heat transfer rate and the temperature difference, and found coincidences with the results obtained through various correlations available in the literature.

The comparative analysis of the thermal behavior in flat plate solar collectors for air heating due to incident solar radiation, using two flat plate solar collectors, one with dark glass cover and the other with the use of clear glass is developed by [9]. The experimentation determined that the use of dark glass decreases the thermal performance, the best values are obtained by using clear glass.

The research [10], was done to improve the thermal performance of spiral solar air heaters. In the study, the author used three-dimensional mathematical models of various types of spiral solar air heaters. To analyze the effect of the baffle structure on the microscopic flow and heat transfer characteristics, these models were developed using CFD (Computational Fluid Dynamics). The results indicated that air heaters with right-angle turns and rectangular holes showed the highest efficiency in reducing the pressure loss and heat loss rate.

The use of fins for increasing the thermal performance of air-source solar collectors is widely discussed in the literature, [11]. According to the authors, these heaters are efficient, easy to maintain, and have low energy losses due to vacuum. In the study, the authors built several finned configurations and determined the maximum thermal performance. The aluminum finned system has the largest air temperature difference between inlet and outlet and the highest efficiency as a function of flow rate. In the work developed by Nguyen The energy and exergy analyses of eleven roughness elements in air-source solar heater ducts were reviewed, [12]. Various roughness geometries, such as ribs, twisted taps, and baffles, were examined to determine their effects on heat transfer and friction when the air flow passes over the absorber plate. The evaluation criteria of the absorber plate roughness elements, including the parameters of thermal performance, thermal efficiency, effective efficiency and exergy efficiency, were presented and compared. The results showed that the ribs protruding in an arc shape resulted in the highest Nusselt number.

Another interesting work is developed by [13], in the article the influence of different geometric shapes to improve the thermal performance of air heaters is evaluated. The geometric design considerations, flow conditions and their influence on turbulence, heat transfer rate, absorber plate temperature and thermal enhancement factor on the performance of the solar air heater are analyzed.

The research [14], evaluates a solar air heating system with a new configuration that includes ribs with and without perforations. The authors perform calculations of the Nusselt number, the friction factor and their influence on the thermal performance. The results indicate that the presence of the inserts generates disturbances that amplify the heat exchange, thus increasing the heat transfer rate. A rib distribution with a pitch of 0.1 m proved to be the most efficient configuration for heat transfer. Another similar research is developed by [15], the authors perform an experimental analysis on the thermal performance of a new solar air heater design called tubular solar heater. In this design the flat absorber plate of the solar air heater is replaced by adjacent tubes in the same direction of the air flow. The results reveal that the tubular solar heater has higher efficiency, output power and outlet air temperature and lower heat loss compared to the flat one. A maximum increase of 13.2 °C is achieved for the outlet air temperature and daily heat losses are reduced by 10%.

The analysis of pressure losses and improvement strategies in air-filled solar collectors [16], [17] covers various approaches, such as the use of improved surfaces, optimized absorber materials, airflow reconfiguration, internal components to enhance heat transfer, and integrated energy storage systems. The relative uncertainty associated with the thermal efficiency of these systems is estimated at 7.73%.

Previous research are important to have references in real application conditions, but it is necessary to carry out experimental tests in the conditions of each place. In the present research, the total area of the collector plate of solar collectors is increased by adding rectangular, triangular and cylindrical fins to improve their thermal performance.

Related to the mathematical modeling of thermal systems, it is important to highlight the work developed in [18]. The authors analyze the thermal performance in compressed air systems, through numerical simulation based on experimental data. The results show the tendency to reduce energy consumption with increasing concentration of the transported mixture. In the research [19], the authors establishes the procedure for modeling and simulation of heat exchange systems where heat transfer by conduction, convection and evaporation predominates depending on the cooling zone. The method for adjusting models from experimental data through an experimental design, which analyzes the drying kinetics in an air flow with temperature variation is carried out by [20].

II. METHOD DEVELOPMENT

For the development of the method, the different equations that allow the thermal energy balance in solar collectors with flat absorber plates and with the presence of fins are taken into account. The comparative analysis of the thermal performance is carried out by heating the air due to the incident solar radiation. Fig. 1 shows a diagram of the solar air heaters used in the present investigation and the different parts that comprise it.

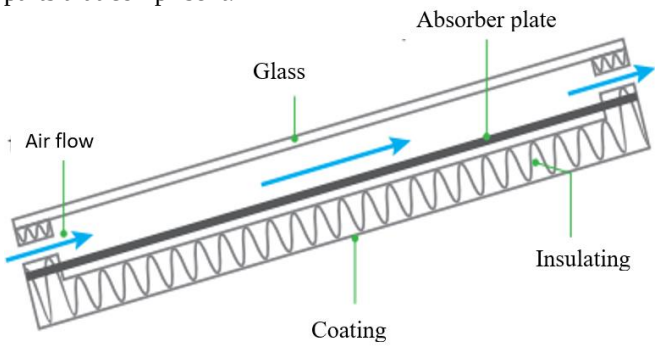

Fig 1. Air circulation between the glass and the absorber plate (source: created by the authors)

The energy balance in air-filled solar collectors is performed on: the glass cover system, the absorber plate and the air inside the heater. The equations governing the thermal performance of air-filled solar collectors are formulated using energy balance expressions of the heater components, making the following assumptions:

- The systems operate under steady-state conditions.
- The air temperature changes only in the direction of flow.
- The air inlet temperature is equal to the ambient temperature.
- Heat transfer through the glass cover, absorber plate and insulator plate is one-dimensional and perpendicular to the air flow.
- Heat losses from the side walls are neglected because they are negligible.
- The thickness of the fins is negligible compared to their length.

Energy balance in glass roof system

For the glass roof system, the energy balance equations in forced convection are expressed in three different ways: Energy entering the roof, energy leaving the roof and accumulated energy (equation 1).

$$\Delta E_c = E_{ec} - E_{sc} \quad (1)$$

The energy entering the cover is obtained through heat transfer by radiation between the cover and the absorber plate (Q_{rc}) and the heat flow gained by convection from the interior air to the cover (Q_{cc}).

$$E_{ec} = Q_{rc} + Q_{cc} \quad (2)$$

The heat flux transferred by radiation between the glass cover and the absorber plate is determined by equation 3.

$$Q_{rc} = h_{rc} \cdot A_c \cdot (T_p - T_c) \quad (3)$$

The radiation heat transfer coefficient between the absorber plate and the glass cover is obtained by equation 4, where the Stefan-Boltzmann constant has a value of $\sigma = 5{,}67 \cdot 10^{-8} W/m^2K^4$, [21].

$$h_{rc} = \frac{\sigma(T_p^2+T_c^2)(T_p-T_c)}{\left(1/\varepsilon_p\right)+\left(1/\varepsilon_c\right)-1} = \frac{4\sigma T_m^3}{\left(1/\varepsilon_p\right)+\left(1/\varepsilon_c\right)-1} \quad (4)$$

The convective heat flux transferred to the cover (equation 5) is determined using Newton's law of cooling which considers the convection coefficient, the area of the glass cover and the temperature difference.

$$Q_{cc} = h_{cc} \cdot A_c(T_{ai} - T_c) \quad (5)$$

The energy leaving the cover (equation 6) takes into account the heat transferred by convection to the outside air and the heat flow by radiation.

$$E_{sc} = Q_{ca} + Q_{ra} \quad (6)$$

The energy stored in the roof is determined by considering the mass of the roof, the heat capacity and the variation in temperature over time.

$$\Delta E_c = M_c \cdot C_{cv} \cdot \frac{dT_c}{dt} \quad (7)$$

Substituting equations 2 to 7 into equation 1, the energy balance of the cover is obtained.

$$M_c \cdot C_{cv} \cdot \frac{dT_c}{dt} = h_{rc} \cdot A_c \cdot \left(T_p - T_c\right) + h_{ci} \cdot A_c(T_{ai} - T_c) - h_e \cdot A_c \cdot (T_c - T_{ae}) - h_{re} \cdot A_c \cdot (T_c - T_{ae}) \quad (8)$$

Energy balance on the absorber plate

The energy balance on the absorber plate is obtained by equation 9.

$$\Delta E_p = E_{ep} - E_{sp} \quad (9)$$

The energy entering the absorber plate (equation 10) is determined by the optical efficiency of the collector, the intensity of the incident radiation and the area of the absorber plate.

$$E_{ep} = (\tau\alpha) \cdot I_r \cdot A_p \quad (10)$$

The energy leaving the absorber plate is determined by equation 11 and has three components: the heat given off by convection to the interior air (Q_{ci}), the heat lost to the environment through the insulation of the bottom of the collector (Q_{ae}), and the heat given off by radiation from the absorber plate to the glass cover of the collector (Q_{rc}).

$$E_{sp} = Q_{ci} + Q_{ae} + Q_{rc} \quad (11)$$

The heat lost to the environment through the insulation of the bottom of the heater is obtained by equation 12.

$$Q_{ae} = U_b \cdot A_p \cdot \left(T_p - T_{ae}\right) \quad (12)$$

The calculation of the overall heat transfer coefficient, between the absorber plate and the outside air (equation 13), is determined by excluding the contact resistance to the passage of heat between the absorber plate and the insulator.

$$U_b = \frac{1}{\frac{1}{h_e}+\frac{\delta}{k_s}} \quad (13)$$

Substituting equations 10 to 13 into equation 9, the energy balance on the absorber plate is obtained.

$$M_p \cdot C_p \cdot \frac{dT_p}{dt} = (\tau\alpha) \cdot I_r \cdot A_p + h_{ci} \cdot A_p \cdot \left(T_p - T_{ai}\right) + U_b \cdot A_p \cdot \left(T_p - T_{ae}\right) + h_{rc} \cdot A_c \cdot (T_p - T_c) \quad (14)$$

Energy balance in the air inside the collector

When the collector plate absorbs energy, the indoor air is heated. However, part of this energy is lost to the heater casing. The energy gained by the indoor air is expressed by the following equation.

$$E_{ea} = M_a \cdot C_{pa} \cdot T_{ae} + h_{ci} \cdot A_p \cdot \left(T_p - T_{ai}\right) \quad (15)$$

The energy leaving the system (inside air) is calculated by adding the energy leaving with the air flow and the energy that the air gives up to the collector cover.

$$E_{sa} = M_a \cdot C_{pa} \cdot T_{se} + h_{cc} \cdot A_p \cdot \left(T_p - T_{ai}\right) \quad (16)$$

The general energy balance equation for the air inside the collector is obtained by considering the energy gained, the energy released and the energy accumulated.

$$M_a \cdot C_{pa} \cdot \frac{dT_a}{dt} = M_a \cdot C_{pa} \cdot T_{ae} + h_{ci} \cdot A_p \cdot \left(T_p - T_{ai}\right) - M_a \cdot C_{pa} \cdot T_{se} - h_{cc} \cdot A_p \cdot \left(T_p - T_{ai}\right) \quad (17)$$

Thermal efficiency of the heater

The useful heat that is transferred to the air during its passage through the heater can be expressed by the following equation:

$$Q_U = \dot{M}_a \cdot C_{pa} \cdot (T_{sa} - T_{ea}) \quad (18)$$

To simplify the evaluation of the system, it is assumed that the indoor air temperature is equal to the average between the air inlet and outlet temperatures. The thermal efficiency of the heater is obtained by considering the useful heat transferred to the air and the heat flux by radiation that reaches the solar collector.

$$\eta = \frac{Q_u}{(\tau\alpha) \cdot I_r \cdot A_p} \quad (19)$$

In flat plate solar heaters, the use of fins improves the heat transfer between the surface and the fluid and therefore the thermal performance of the collector. The thermal energy transferred to the fluid from any point on the fin surface is affected by heat transfer by transverse conduction. However, in practice the fin is thin and the temperature changes in the transverse direction of the fin are small compared to the temperature difference between the fin and the medium. Fig. 2 shows the configuration of the

cylindrical, rectangular and triangular fins used in the solar air heater of the present investigation.

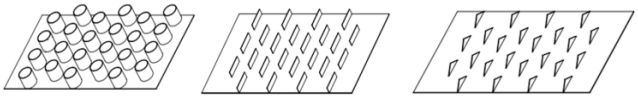

Fig 2. Configuration of cylindrical, rectangular and triangular fins used in solar air heaters (source: created by the authors)

The heat flux transferred for a system of rectangular, triangular and cylindrical fins, which is used in the calculation of thermal efficiency, is obtained by the following equation:

$$Q_t = hA_t\left[1-\frac{NA_f}{A_t}(1-\eta_f)\right](T_p - T_a) \quad (20)$$

For the calculation of the total and surface area of fins, the geometry of rectangular, triangular and cylindrical fins is taken into account. Fins are used to increase heat transfer from a surface by increasing the effective surface area. However, the fin represents a conduction resistance to heat transfer from the original surface. For this reason, there is no guarantee that the heat transfer flux will be increased by using fins, for this it is necessary to calculate the effectiveness of the fins.

$$\varepsilon_f = \frac{q_f}{h\cdot A_{cb}\cdot\theta_b} \quad (21)$$

The design of the fin system on the heater absorber plate was carried out with effectiveness values $\varepsilon_f > 2$.

The comparative thermal efficiency variation between flat plate solar air heater and the addition of fins is determined by equation 23.

$$\Delta\eta = \frac{Q_t - Q_U}{Q_t}\cdot 100\% \quad (23)$$

Using the equations described, a comparative analysis of the thermal performance between solar air heaters is carried out, but the impact of the variability of solar radiation and the behavior of the heat transfer process in an air flow as a function of time must be considered.

III. RESULTS AND DISCUSSION

The experimental installation included four types of heater with different absorber plates: flat, cylindrical finned, rectangular, and triangular. The collectors were equipped with sensors for measuring air temperature, mass flow and incident solar radiation (Fig. 3).

Fig 3. Experimental installation of flat plate solar air heater and different geometric shapes on the absorber plate (source: created by the authors)

Table I shows the configuration of solar air heater modules used in data collection and processing of research results.

Table I. Solar collector configurations

Module	Absorber plate
1	Flat plate without fins
2	Addition of cylindrical fins
3	Addition of triangular fins
4	Addition of rectangular fins

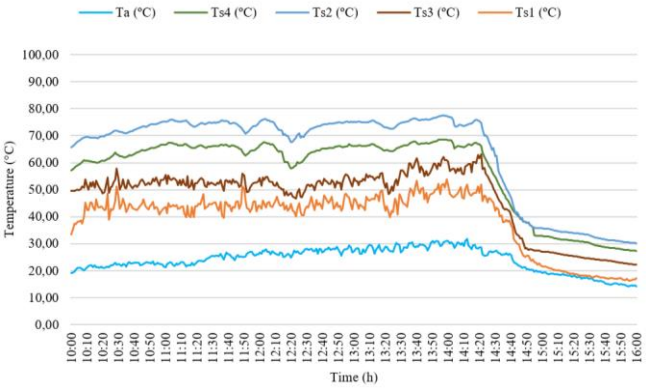

Fig 4. Outlet temperature behavior in solar heater without forced air flow (source: created by the authors)

Fig. 4 shows the behavior of the air outlet temperature as a function of time in solar air heater collectors with flat absorber plates and with the addition of fins, without forced air flow. Measurements were made from 10 AM to 4 PM, taking advantage of the maximum incident solar radiation values. The highest air outlet temperature values correspond to the solar heater with cylindrical fins, where Ts_2 values higher than 73 °C were reached. The use of rectangular fins allowed obtaining maximum Ts_4 temperature values of 64 °C. The lowest values were associated with the triangular fins Ts_3, with average results lower than 61 °C. The heaters with a flat absorber plate Ts_1 reported temperature values lower than 50 °C.

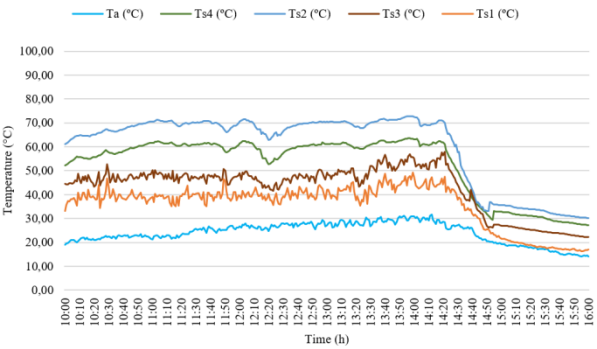

Fig 5. Outlet temperature behavior in solar heater with the addition of fins and air mass flow of 0.033 kg/s (source: created by the authors)

Fig. 5 shows the behaviour of the air outlet temperature for a mass flow of 0.033 kg/s. The experimentation showed that increasing the mass flow reduces the air outlet temperature. The highest air outlet temperature values correspond to the solar heater with cylindrical fins Ts_2, a reduction in temperature to values below 70 °C is observed, in rectangular fins Ts_4 the average values are 60 °C and with triangular fins Ts_3 the average values are 50 °C.

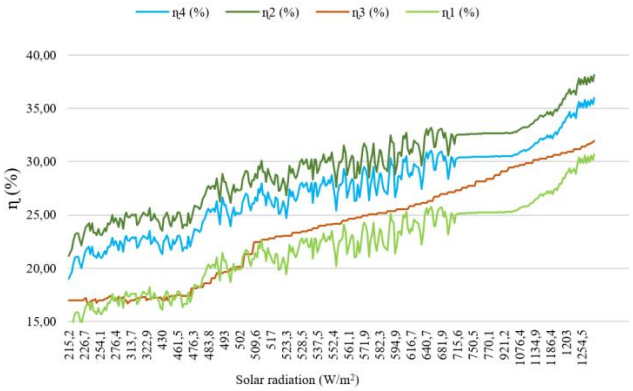

Fig 6. Thermal performance behavior in flat absorber plate solar heater with the addition of fins without forced air flow (source: created by the authors)

Fig. 6 shows the thermal efficiency behaviour of solar heaters with flat absorber plates and fins without forced air flow. Incident solar radiation values from 215.2 W/m^2 to 1254.5 W/m^2 were recorded. In natural convection, without forced air flow, the highest efficiency values were obtained for the solar heater with cylindrical fins on the absorber plate, the highest values reaching results of η_2=35% for solar radiation values of 1203 W/m^2. The thermal efficiency with the use of triangular fins reaches the lowest results with a value of η_3=31, 6 %.

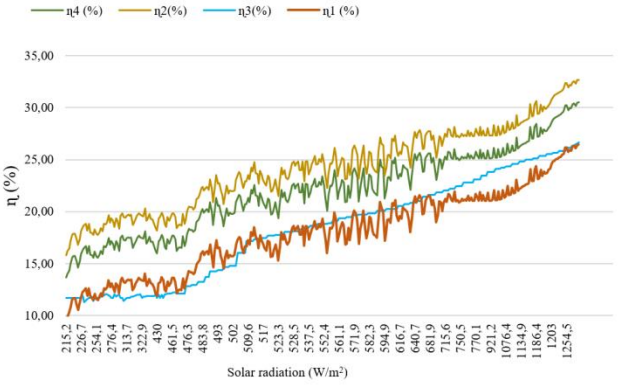

Fig 7. Thermal performance behavior in flat absorber plate solar heaters with the addition of fins for a mass air flow of 0.033 kg/s (source: created by the authors)

Fig. 7 shows the behaviour of thermal efficiency in solar air heaters with a flat absorber plate and with the addition of fins, for an air mass flow of 0.033 kg/s. The thermal efficiency decreases with increasing mass flow, the highest results are obtained with the use of cylindrical fins in the absorber plate, with a value of η_2=32.7 %. The thermal efficiency values with the use of rectangular fins are η_4=31.5 % and with the use of triangular fins η_3=27.4 %. An increase in thermal efficiency is observed compared to the use of flat absorber plates and the increase in incident solar radiation.

A full factorial design was used to develop the experiments. Table II summarizes the main inlet and outlet variables of the air solar collectors under controlled conditions, including the air mass flow rate ($\dot{M}_a$), the inlet (T_{ea}) and outlet ($T\square_a$) air temperatures, as well as the thermal efficiency (η). The results demonstrate that the use of cylindrical fins (Modules 2) generates a significant increase in both the air outlet temperature (up to 70.6 °C in Module 2 with $\dot{M}_a$ = 0.033 kg/s) and the thermal efficiency (34.8 % in the same case), compared to the module without fins (Modules 1). However, a progressive decrease in these parameters is observed with increasing mass flow rate: for example, in Module 2, by raising $\dot{M}_a$ from 0.033 kg/s to 0.061 kg/s, $T\square_a$ decreases from 70.6 °C to 66.7 °C and η from 34.8 % to 32.2 %. This behavior is attributed to the shorter residence time of the air in the collector at higher flow rates, which reduces heat transfer.

Table II. Results of the measurements of the input and output variables of the air solar collectors (source: created by the authors)

Module	$\dot{M}_a(\frac{kg}{s})$	Tea (ºC)	Tsa (ºC)	η (%)
1	0,033	25,7	31,5	25,6
	0,05	26,2	30,4	24,9
	0,061	27,4	29,7	24,2
2	0,033	25,7	70,6	34,8
	0,05	26,2	68,4	33,6
	0,061	27,4	66,7	32,2
3	0,033	25,7	49,9	27,4
	0,05	26,2	47,6	26,5
	0,061	27,4	46,3	26,1
4	0,033	25,7	60,2	31,6
	0,05	26,2	57,8	30,4
	0,061	27,4	55,9	29,7

IV. CONCLUSIONS

- The behavior of the air outlet temperature as a function of time in solar air heater with flat absorber plates and with the addition of fins, without forced air flow, shows that the highest air outlet temperature values correspond to the solar heater with cylindrical fins, where Ts_2 values higher than 73°C were reached. The use of rectangular fins allowed obtaining maximum Ts_4 temperature values of 64°C. The lowest values were associated with the triangular fins Ts_3, with average results below 61°C. The heater with a flat absorber plate Ts1 reported temperature values below 50°C.
- The thermal efficiency of solar air heater with a flat absorber plate and the use of fins without forced air flow recorded maximum values with the use of cylindrical fins on the absorber plate, the highest values reaching results of η_2=35% for solar radiation values of 1203 W/m^2. The thermal efficiency with the use of triangular fins reaches the lowest results with a value of η_3=31.6 %. A reduction in thermal efficiency is observed with the increase in the mass flow of air inside the solar air heater.

Nomenclature

ΔE_c- Energy accumulated in the glass cover, W
E_{ec}- Energy entering the glass cover, W
E_{sc}- Energy leaving from the glass cover, W
E_{ep}- Energy entering the absorber plate, W
E_{sp}- Energy leaving the absorber plate, W
Q_{rc} - Heat transfer by radiation between the cover and the absorber plate, W
Q_{cc} - Heat flux by convection from the indoor air to the cover, W
h_{rc}- Heat transfer coefficient by radiation between the absorber plate and the cover, W/m^{2}K
A_c- Area of glass cover, m^2
T_p - Temperature of absorber plate, K
T_c- Temperature of glass cover, K

ε_p - emissivity of absorber plate
ε_c - emissivity of cover
T_m- Average temperature between absorber plate and glass cover, K
h_{cc}- Convective heat transfer coefficient between indoor air and cover, W/m^{2}K
T_{ai} - Air temperature inside the heater, K
Q_{ca}- Convective heat flux from glass cover to outside air, W
Q_{ra}- Radiative heat flux from cover to outside space, W
h_e- Convective heat transfer coefficient between the cover and the outside air, W/m^{2}K.
T_{ae}- Outer air temperature, K
V_a- Outer air velocity, m/s
h_{re}- Radiative heat transfer coefficient between the cover and the outside space, W/m^{2}K
T_{al}- Temperature of the surroundings, K
C_{cv}- Specific heat at constant volume of the cover, kJ/kgK
M_c- Mass of the glass cover surface, kg
τ - Transmissivity of the glass cover
α- Absorptivity of the absorber plate
$\tau\alpha$- Optical efficiency of the collector
I_r- Intensity of the incident radiation on the heater, W/m^2
A_p- Area of the absorber plate, m^2
Q_{ci}- Heat transferred by convection to the inside air, W
Q_{ae}- Heat lost to the environment through the insulation of the bottom of the heater, W
Q_{rc}- Heat flux by radiation from the absorber plate to the glass cover, W.
h_{ci}- Heat transfer coefficient by convection between the absorber plate and the inside air, W/m^{2}K.
T_p- Temperature of the absorber plate, K.
T_{ai}- Air temperature inside the heater, K.
U_b- Overall heat transfer coefficient between the absorber plate and the outside air, W/m^{2}K.
k_s- Thermal conductivity coefficient of the insulation, W/m.K
δ- Thickness of the insulation, m
M_p- Mass of the glass cover surface, kg.
C_p- Specific heat at constant volume of the cover, kJ/kgK.
Q_U- Useful heat transferred to air in finless solar heaters, kW
Q_t- Useful heat transferred to air in finned solar heaters, kW
$\dot{M}_a$- Air mass flow rate, kg/s
C_{pa}- Heat capacity at constant air pressure, kJ/kg ·K
T_{sa}- Air outlet temperature, K
T_{ea}- Air inlet temperature, K
h- Convection heat transfer coefficient, W/m^2.K
A_t- Total fin area, m^2.
N- Number of fins
A_f- Fin surface area, m^2
T_p- Absorber plate temperature, K.
T_a- Ambient air temperature, K.
ε_f- Fin effectiveness
q_f - Heat flux transferred by the fin, W
h - Convection heat transfer coefficient, W/m^{2}K
A_{cb}- Cross-sectional area at the fin base, m^2.
θ_b- Temperature difference between the absorber plate and the air inside the heater, K.
$\Delta\eta$: Thermal efficiency variation between heaters (%)

Declaration of Generative AI and AI-assisted Technologies in the Writing Process

The authors wrote, reviewed and edited the content as needed and verifies that none utilised artificial intelligence (AI) tools were used. The authors take full responsibility for the content of the publication.

REFERENCES

[1] Varun G., et al (2021). A comprehensive study on the progressive development and applications of solar air heaters. Solar Energy, vol. 229 (1), pp: 112-147, ISSN 0038-092X, https://doi.org/10.1016/j.solener.2021.07.040.
[2] Goel V., et al (2021). A comprehensive study on the progressive development and applications of solar air heaters, Solar Energy, vol. 229 (1), pp. 112-147, ISSN 0038-092X, https://doi.org/10.1016/j.solener.2021.07.040.
[3] Kumar H., et al (2022). A detailed review of various types of solar air heaters performance. Solar Energy, vol. 237(1), pp. 173-195, ISSN 0038-092X. https://doi.org/10.1016/j.solener.2022.03.042.
[4] Ghritlahre, H. K. & Sahu, P. K. (2020). A comprehensive review on energy and exergy analysis of solar air heaters. Archives of Thermodynamics, pp. 183-222.
[5] Chamarthi Subbarao & Satyender Singh (2021). Design and optimization of an air heating solar collector with integrated phase change material energy storage for use in humidification–dehumidification desalination. Solar Energy, vol. 86 (1), pp 3417-3429. https://doi.org/10.1002/er.6255.
[6] Mund Ch., et al (2021). A review of solar air collectors about various modifications for performance enhancement. Solar Energy, vol. 228 (1), pp 140-167, ISSN 0038-092X, https://doi.org/10.1016/j.solener.2021.08.040.
[7] Saxena A. et al (2020). Design and thermal performance evaluation of an air heater with low cost thermal energy storage. Applied Thermal Engineering, vol. 167 (1), 2020, ISSN 1359-4311, https://doi.org/10.1016/j.applthermaleng.2019.114768.
[8] Kumar Shyam (2018). Thermal Analysis of Solar Air Heater in Natural Convection. International Journal of Engineering and Techniques, vol. 4 (1), pp. 36–38. ISSN: 2395-1303.
[9] Albarracín M. D., Torres T. E., Laurencio H. L (2022). Comparative analysis of the thermal efficiency of a flat plate solar collector varying the glass type in the cover. Minería y Geología, vol. 38 (3), pp. 286-298. ISSN: 1993 8012.
[10] Jia B. et al (2021). Optimizing structure of baffles on thermal performance of spiral solar air heaters, Solar Energy, vol. 224 (1), pp: 757-764, ISSN 0038-092X, https://doi.org/10.1016/j.solener.2021.06.043.
[11] Abu H. T. & Salem A (2020). Design and performance analysis of a new evacuated tube solar air heaters equipped with fins and coils. International Journal of Sustainable Energy, vol. 39 (1), pp: 997-1008, doi: 10.1080/14786451.2020.1798446.
[12] Nguyen M. and Nguyen Thanh Luan (2021). A Review of Energy and Exergy Analyses of a Roughened Solar Air Heater. Journal of Advanced Research in Fluid Mechanics and Thermal Sciences, vol. 77 (2), pp. 160–175. ISSN: 2289-7879.
[13] Arunkumar H. et al (2020). Review on the design modifications of a solar air heater for improvement in the thermal performance. Sustainable Energy Technologies and Assessments, vol. 39 (1). ISSN 2213-1388, https://doi.org/10.1016/j.seta.2020.100685.
[14] Jamal E. S. et al (2023). Three-dimensional analysis of a novel solar air heater conception, for an improved heat transfer and energy conversion. Energy Conversion and Management, vol. 19 (1), 2023, ISSN 2590-1745, https://doi.org/10.1016/j.ecmx.2023.100386.
[15] Hassan H. et al (2020). An experimental investigation of the performance of new design of solar air heater (tubular). Renewable Energy, vol. 151 (1), pp: 1055-1066, ISSN 0960-1481, https://doi.org/10.1016/j.renene.2019.11.112.
[16] Zhu T, Diao Y, Zhao Y, Deng Y. (2015) Experimental study on the thermal performance and pressure drop of a solar air collector based on flat micro-heat pipe arrays. Energy Convers Manage 2015;94:447–57. https://doi.org/10.1016/j.
[17] Ji Zhang, Tingting Zhu (2022). Systematic review of solar air collector technologies: Performance evaluation, structure design and application analysis, Sustainable Energy Technologies and

Assessments, Volume 54 (1), 102885, ISSN 2213-1388, https://doi.org/10.1016/j.seta.2022.102885.

[18] Torres T. E., et al (2017). Energy consumption and simulation of pneumatic conveying lateritic mineral in dense and fluid phase. International Journal of Mechanics, vol. 11, pp. 12–17. ISSN: 1998-4448.

[19] Torres T. E.; Morales, J., Albarracín, M. and Laurencio, H. 2021: Cooling temperature and heat transfer coefficients in cylindrical heat exchangers. International Journal of Mechanics, vol. 15(1): 254-259.

[20] Torres T. E., et al (2023). Experimental models of the lateritic minerals drying kinetics at high temperatures, International Journal of Mechanics, vol. 17, pp. 45-50. ISSN: 1998-4448.

[21] Incropera, F. P., & DeWitt, D. P. (2011). Fundamentals of Heat and Mass Transfer. John Wiley & Sons, pp. 1047. 7th Ed. ISBN: 978-0470-50197-9.

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Conflict of Interest

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