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Efficiency Analysis in Solar Air Heaters with Attached Internal Fins

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ABSTRACT

In this study, an original solar air collector model, in which the flow environment was fixed with fins for three different angles at the flow channel's height, was designed. Fixing fins in the flow environment lengthens the flow channel since the fins prevent boundary layer formation in a flow channel. Apart from this, enlarged surface effect exists along with the effects of the fins, the air temperature at the outlet rises. The effects of fixed fins, for 30°, 45° and 60° angles, on the efficiency of collector were investigated. The collectors were made as standard collector sets with measurements 0.93x1.93 m^2 the flow channels of which have been modified. With the help of results obtained from the experiments, efficiency, Nusselt number, Reynolds number values were calculated; and they were compared to each other along with the literature. In the collectors designed for this study, it was observed that the heat transfer increased with the decrease of the fins angles.

1. INTRODUCTION

The systems aiming to increase fluid heat by employing solar energy are called solar collectors. Simply stated, the working principles of these systems can be described as follows: Some portion of solar radiation falling on a surface is absorbed by the collector itself. By means of the absorbed energy, heat transfer is made possible for fluids via convection and transmission. Furthermore, heat transfer occurs from the outer surface to the environment in connection with heat falling on the surface of collectors. The difference between this absorbed radiation and the heat lost to the given off to the environment is useful solar energy; and this energy is used to heat the fluid.
According to the type of fluid used, the collectors can be classified into two categories: fluid and gas collectors. While air is generally used in gas collectors, water (or water with antifreeze) is used in fluid collectors. When compared in terms of efficiency, water collectors are known to be more efficient than air collectors.
By using the passive method, it is aimed to increase collector thermal performance in air collectors that have different surface geometries considered for them. The thermal performance of the collector is known to improve when the flow channel of the heated fluid is lengthened or the turbulence effect in the flow channel is increased to increase the convection coefficient. Due to the physical properties of air, the thermal performance of available solar air collectors is poor. Solar air collectors are widely used for drying agricultural products and forest industry, building heating, and floor heating. A great many studies have been conducted on solar air collectors. In these studies, not only increasing the heat efficiency of the system but also decreasing its costs are taken into consideration.

Nomenclature

A_c	collector surface area (m^2)
c_p	specific heat (J/kg.K)
D_h	hydraulic diameter (m)
F_R	heat gain factor (-)
I	total solar radiation (W/m^2)
Nu	Nusselt number (–)
Q_u	useful heat gain (W)
Re	Reynolds number (–)
T	temperature (K)
T_s	surface temp. of the absorber (K)
U	channel perimeter exposed to air (m)
U_L	total heat loss coeff. of the collec.(-)
V	average velocity of air (m/s)
h	heat convection coefficient (W/m^2.K)
k	heat conduction coefficient (W/m.K)

η	efficiency of air collector (–)
m	mass flow rate of air (kg/s)
v	kinematic viscosity of air (m^2/s)

Subscripts

e	environment
i	inlet
o	outlet

Yeh and Lin (1996) investigated the changes between collector size and collector efficiency experimentally and theoretically in their studies for collectors in which air flow was on the black surface [1]. Parker et al. (1998) carried out experiments for three different collectors where air flow was on the absorber surface, under the absorber surface, or both on and under the absorber surface using V grooved absorber plates. In these studies, the heat performance and efficiency of collectors were examined [2]. In their studies, Yeh et al. (2002) conducted experiments for three different flow-rates and 5 different fin sizes in which there was air-flow under the absorber, and on the absorber; and both under and on the absorber. As a result of the experiments, they found the highest efficiency as 70% [3]. Paisorn and Kontragool (2003) investigated the heat transfer characteristics and thermal performances of 5 different planar collectors experimentally. In empirical results, while normal collectors had the lowest performance, the fifth model, with air inlet on the absorber and air outlet under the entrance, had the highest [4]. In his study, Ammari (2003) conducted experiments on thermal performance of a collector where air flow was from the side surface of the collector. Experiments revealed that the thermal efficiency for 50 lt/sec was 72% for four different flow rates [5]. Tyagi et al. (2007) carried out a study on parameters (exergy, ambient temperature, radiation value), which are effective on efficiency, for different flow-rates using instantaneous radiation values [6]. Karim and Hawlader (2004;2006) determined V grooved collector as the most efficient one in the study they improved and conducted on 3 different collectors, and they performed experiments on drying by means of these collectors [7-8]. Badran et al.(2008) conducted a study of convection coefficient between absorber surfaces and fluid pipes by means of a novel method they developed[9]. Hobbi et al.(2009) carried out experiments adding bent straps, springs, and conical parts to the flow environment to increase heat transfer, and observed significant increases in heat transfer [10]. Ramani et al.(2010) conducted experiments on a double pass air collector where absorber surface had pores [11]. El Sawi et al.(2010) carried out experiments on collectors in which the absorber surface was different. They found out that zigzag designed absorber surface had significant increases on heat efficiency [12]. Kurtbas and Durmus(2004), Akbulut and Durmus(2010), Karakaya and Durmus(2012)performed several experiments on drying by designing different collectors [13-15]. Nematollahi et al.(2014) investigated a dual function solar collector that combines air and water [16]. Akgul (2016) conducted thermal analysis for a novel solar air heater. The results show that conical springs improve thermal effectiveness [17].

Nima et al. (2017) investigated the impact of trying to add porous metal blocks to solar water collector risers in Iraq's climatic conditions. The beneficiary component was lower than the concinnity component for all simulations due to the insertion of the froth blocks, which also caused a significant increase in water pressure loss across the collector to roughly 153 percent [18]. By maintaining the pressure loss steady for various air mass and mass flow rates, Dabra and Yadav (2018) created a precise model in a JAVA simulation software to improve the distance and perimeter of concentric coextensive glass tubes (CCGT). Air flow input levels of 0.0053, 0.0074, 0.0095, and 0.0118 kg/s require more pumping power at high pressure losses [19].
Wenceslas optimized a flat-plate solar collector for thermosyphon solar water heaters (2019). Using the optimization results, a flat-plate solar collector was built using locally accessible materials. Additionally, it has been found that increasing the insulator's thickness to about 0.05 m causes a significant decrease in the heat loss portions and, as a result, an increase in the system's edge. The aluminum absorber plate would perform similarly to the bobby version if its thickness were increased to 0.005 m [20]. Farhan et al. (2022) created in MATLAB terra into predict the thermal and hydraulic efficiency of a V-groove solar air collector (VSAC) merged with transverse wedge-shaped caricatures (TWSR) underneath the absorption plate. When compared to the smooth configuration, the proposed design has a heat gain enhancement of around 9 and a highest rate of heat hydraulic efficiency of 9.6 when the mass in flow rate is 0.084 kg/s [21].

Goel et al. (2022) developed a better, smoother design for a parabolic trough solar collector (PTSC) that can help with a variety of exploration goals, including parametric advancements, energy performance, and enhancement. Furthermore, when compared to estimates from other models, the presented model is more appropriate than numerous other models and capable of thermos precise body. The suggested model is more truthful, comprehensive, less sophisticated, and acceptable over a broad selection than other designs. [22].
In this study, an original solar air collector model was designed whose flow environment was fixed with fins at three different angles and flow channel heights, was designed. The effects of fins fixed at 30°, 45° and 60° angles on efficiency and heat transfer were investigated.

2. EXPERIMENTAL SET

The heating unit, measurement unit, and control unit comprise the experimental set. Solar air collectors are used in the heating unit. The measurement unit is made up of a data collector and heat and speed probes that are linked to it. The control unit includes a fan for mass flowrate, an adjustable AC signal inverter, and a Pentium IV computer. Figure 1 depicts a schematic view of the experimental set as well as details.

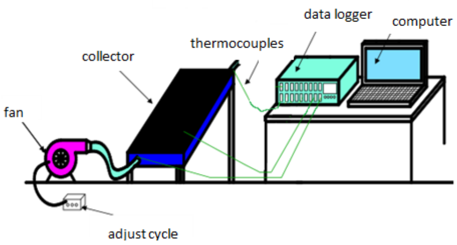

Figure 1. Experimental setup

Solar air collectors were used in the heating unit to heat the drying air. Normal collector measurements (0.93x1.93 m2) of solar air collectors were manufactured. (Figure 2). It was designed with a collector air flow channel height of 10 cm and fins fixed at the same height with 30°, 45°, and 60° angles, respectively.

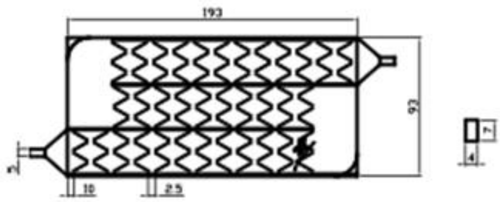

Figure 2. Flow environment and collector dimensions

The fins were separated by 10 cm. The surface of the absorber was made of 0.6 mm thick galvanized sheet. A transparent layer of 4mm in thickness glass was used to reduce the heat from the absorber plate. The sides and bottom of the collector were covered with 10 cm thick fiberglass isolator material. The absorber surface was painted matte black.

Figure 3 shows photos of the solar air collector and flow channel. Furthermore, the positions of angled fins fixed in the flow channel are clearly shown. Solar air collectors were built as standard collectors with 0.93x1.93 m^2 dimensions, but the flow channels were altered. Fins with three different angles at the flow channel's height were fixed in the collector's flow channel. Initially, the effect of fins fixed at 30°, 45°, and 60° angles on collector efficiency was investigated. It is necessary that the instantaneous radiation values belonging to the days when the experiments should be known in order that the collector efficiencies can be calculated. As a result, instant heating values were measured and recorded during the days when experiments were conducted using a Kipp-Zonen solar meter set at an angle of 38°. The temperature values were measured with the help of thermocouples fixed at 5 points in total, 3 of which were on the solar air collector, 1 of which was at the inlet, and 1 at the outlet of the collector. The temperature values were determined using T-type copper-constant thermocouples with a thickness of 0.5 mm.

At one end of the thermocouples, while the copper and constant ends were connected, connecting element ZA9000FST was mounted properly to the other end. The heat values were determined by connecting this element to an ALMEMO 5990-0 model data collector.

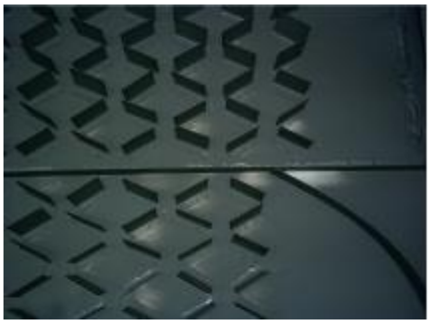

Figure 3. Flow environment and collector image

The heat values, which a data collector connected to a Pentium IV PC measured at 30 minute intervals, were then recorded into the computer. Pressure losses in the solar air collector designed for these experiments were also measured. Employing a FDA612MR model pressure module, pressure losses were obtained. Together with heat values, pressure loss values were determined for each flow rate of air mass.

The air mass flow rate to be heated was measured by adjusting the fan rotation speed. In order to change fan speed to the desired speed, a speed frequency convertor of the Telemecanique Altivar 31(ATV31HU15M2) type, with 1,5 kW power, 220 V entrance voltage, 50/60 Hz entrance frequency, 0.5 Hz and 500 Hz exit frequency intervals, and a nominal output current of 8 A, was used. The fan speed was changed according to the measured air speed using FVA645TH3 Thermo-anemometer flow sensor.

3. ANALYSES

3.1. Analysis of energy and efficiency

To heat the air, solar air collectors were used in the experiment. The air inlet-outlet temperature difference (T) in solar air collectors, which is well known, varies as follows;

$$(\Delta T) = f(V, I, A_c, \tau\alpha, F_R, U_L) \quad (1)$$

The linked and free parameters in equation 1 change in relation to various factors in their own right. The purpose of this research was to enhance collector efficiency using passive methods. In relation to variables, collector efficiency is expressed as follows:

$$\eta = \frac{Q_u}{I\,A_c} = \frac{F_R\, I(\tau\alpha) - F_R U_L (T_i - T_o)}{I} \quad (2)$$

The useful energy used to calculate collector efficiency, Qu, can be determined using the equation below:

$$Q_u = \dot{m} C_p (T_o - T_i) \quad (3)$$

If solar air collectors are regarded as heat convertors, literature comparison can be carried out for heat transfer. For this aim, it is essential that Nusselt number be fixed. As known, Nusselt number is equal to the heat gradient on the surface;

$$Nu = \left.\frac{d\theta}{dy}\right|_{y=collector} = \frac{hD_h}{k} \quad (4)$$

Equation 4 provides the amount of heat gain that it conveys due to the air mass flow rate. In addition, this equation is equal to the heat quantity obtained with regard to the air convection coefficient.

$$Q = hA_c LMTD = \dot{m}\, C_p \Delta T \quad (5)$$

Here, *LOSF* is the logarithmic heat difference. D_h and *LOSF*

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are obtained via the following equations:

$$D_h = \frac{4\,A}{U} \tag{6}$$

$$LMTD = \frac{(T_S-T_i)-(T_S-T_O)}{\ln\left(\frac{(T_S-T_i)}{(T_S-T_O)}\right)} \tag{7}$$

In such systems, flow type has an important effect on heat transfer. Flow type is determined by means of a dimensionless Reynolds number.

$$Re = \frac{V\,D_h}{\nu} \tag{8}$$

The average temperature ((To+Ti)/2) was used to calculate the external properties of air [13, 23-25].

3.2.Error Analysis

It is well known that the errors stem from constant errors, manufacturing errors, and random errors during the measurement of heat, speed, and pressure in the experiments of solar air collectors. In order that the total error of any parameter whose measurement is done can be determined, the total error value can be computed via equation 19 by taking constant errors, manufacturing errors, and random errors into consideration [14].

$$W = \left[(x_1)^2 + (x_2)^2 + \ldots\ldots\ldots\ldots\ldots (x_\infty)^2\right]^{1/2} \tag{19}$$

The following results were calculated using the above equation.

Total error due to temperature measurement: (± 0.173 °C)

Total error due to time measurement:

(±0.141 min.)

Total error from speed measurement:

(± 0.104 m/s)

Total error due to pressure measurement:

(± 0.0025 mbar) [13, 23-25].

4. RESULTS AND DISCUSSIONS

As previously stated, fins are fixed in the flow environment in such a way that they make 30°, 45°, and 60° angles in order to increase the collector's efficiency. As it is well known, fixing fins in the flow environment lengthens the flow channel by preventing the formation of a boundary layer in the flow channel. Aside from that, the enlarged surface effect exists due to the effects of fins, and as a result, the air outlet temperature rises.

Initially, at three different flow-rates, heat transfer experiments were conducted for all three collectors. The heating values belonging to the days, when collector experiments are carried out, are given in Figure 4. It is important to emphasize that experiments were performed for at least three days for each flow rate. On the other hand, comparisons were made for the days that provide approximately the same heating values and they are presented in this study.

As can be seen, between the dates of 8 – 23 August, the heating values in the Elazig region start at 450 W/m^{2}K at morning hours, and reach its peak value between 12-14 with nearly 760 W/m^{2}K. Radiation values begin to fall sharply after 16.00 p.m., and by 18.00, they are approximately 200 W/m2K.

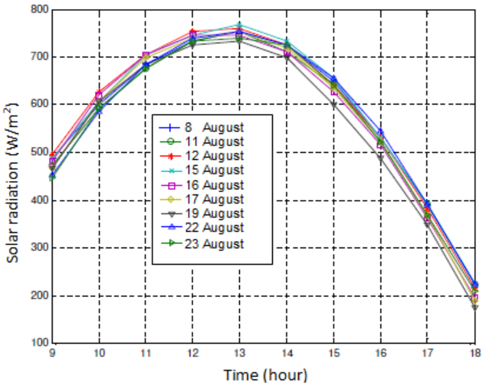

Figure 4. Variations in radiation values from day collector experiments were carried out according to the time of day.

Figure 5 shows the collector efficiency of 0.012 kg/s calculated from the data in Equation 2. As it can be seen, the fins angle and collector efficiency are directly proportional. Depending on the radiation values, the collector's efficiency ranges from 23.5% at 09.00 to 34% at 12.00 for α =60°. This maximum efficiency value obtained for α =30° becomes 42.5% for α =45° and 39% for α =60° becomes 34%, respectively.

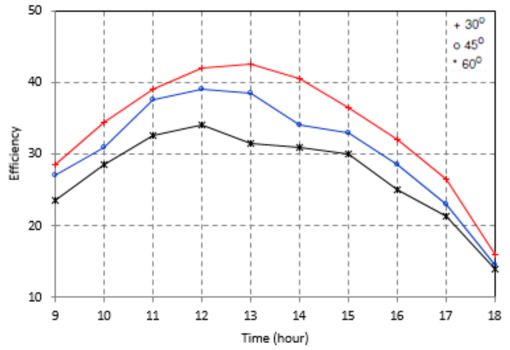

Figure 5. For ṁ = 0.012 kg/s, instant collector efficiency varies with time of day.

Considering the fact that the efficiency values of classical plane-plate solar collectors alternate between 20-25%, it is seen that the efficiency values obtained for collectors were significantly increased. If the mass flow rate is *ṁ = 0.026 kg/s*, maximum efficiency becomes 52% for α =30°, 45% for α =45°and 37% for α =60°, respectively.

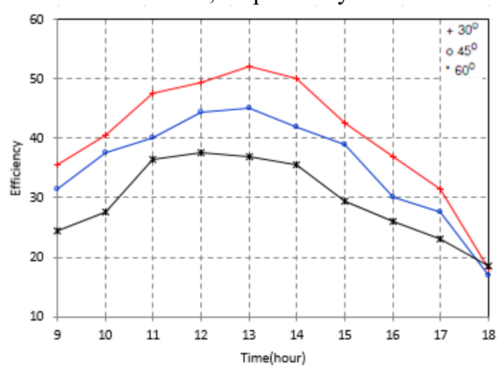

Figure 6. For ṁ = 0.026 kg/s, instant collector efficiency varies with time of day.

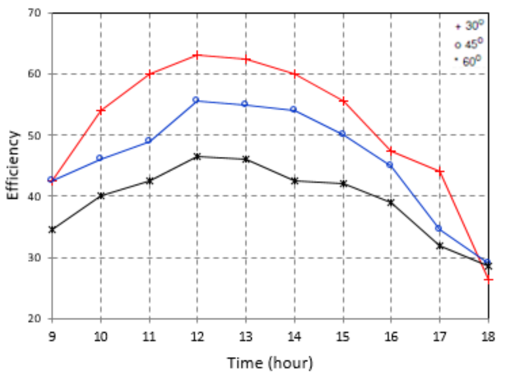

Figure 7. Form = 0.033 kg/s, instant collector efficiency varies with time of day

When Figure 6 and Figure 7 are examined, it will be observed that the efficiency value does not create a full parabola according to the hours of the day, and there are some deviations at some hours. This demonstrates that there are regional clouds on the days when the experiments are carried out. The maximum efficiency value obtained for α =30° becomes 63% for α =45° and 55.5% for α =60° becomes 46.5%, respectively.

This demonstrates the significance of incorporating a specific fin style into the collector flow channel. In other words, as the fin surfaces in the fixed flow environment become upright for flow direction, the collector efficiency increases at the same rate. If the effect of fins in the flow environment on air exit temperature is considered, it will be seen that as the fin angle is lessened, the collector efficiency increases. Figure 8 depicts the air entrance-exit rates and changes in collector surface temperatures throughout the day.

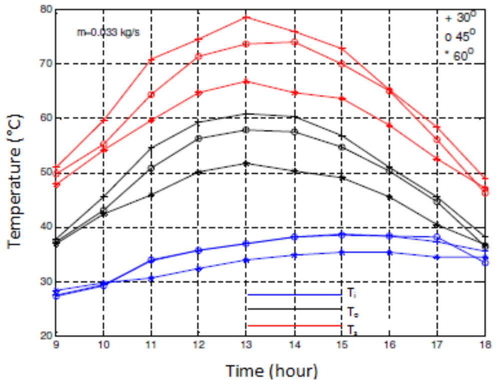

Figure 8. For $\dot{m}$ = *0.033 kg/s*, Temperature alterations according to time of day

When considering the energy balance of solar air collectors, the energy supplied to the system in unit time ($I.A_C$) accumulates on the collector's surface. In this system, with the increase in energy received (Q_u), decrease in the accumulating surface temperature is an anticipated physical behavior.

As previously stated, as the mass flow rate of air increases, so does the energy received from the system. As seen in Figure 9 and 10, there is an inverse relationship between energy gain from the system and collector surface temperature.

In other words, as the heat gain increases, the collector surface temperature decreases. This is valid for approximately equal radiation values. However, there is a direct correlation between heat gain and collector entrance-exit temperature difference (ΔT).

On the other hand, there is an inverse relationship between air mass flow rate and collector entrance-exit temperature.

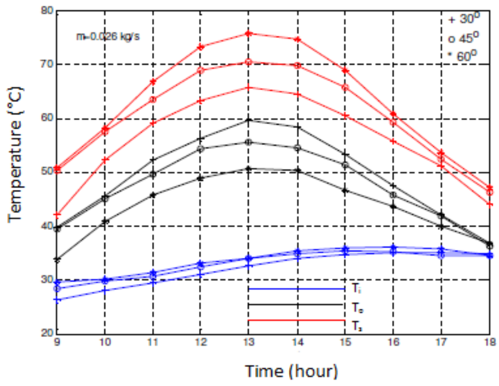

Figure 9. For $\dot{m}$ = *0.026 kg/s*, Temperature changes depending on the time of day

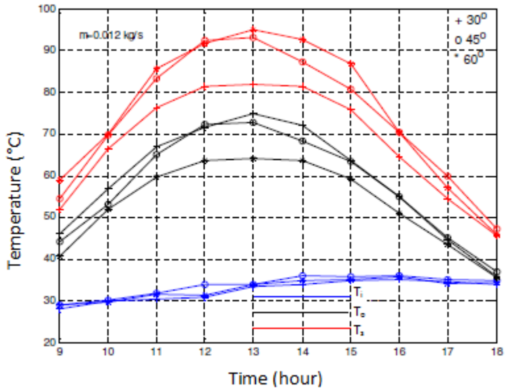

Figure 10. For $\dot{m}$ = *0.012 kg/s*, Temperature changes depending on the time of day

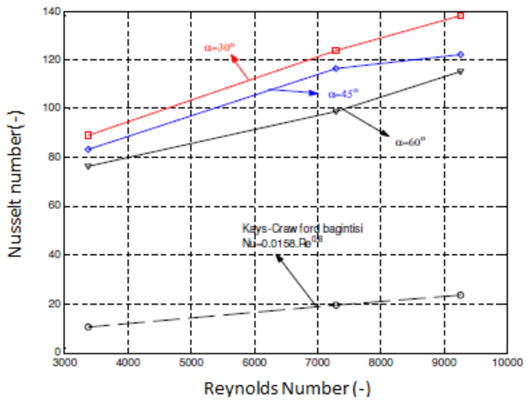

Figure 11. Change of average Nusselt number according to Reynolds number

As shown in Figure 11, the average Nusselt number Kays-Crawford equation is used for a channel with an isolated region on one side and a uniform heat flux on the other. Depending on the mass flow rate, the Reynolds number in the collector varies between 3371 and 9270. Depending on the Reynolds number, the Nusselt number changes between 76 and 115 for α=60° and between 83 and 121 for α=45° and between 89 and 138 for α=30°, respectively. As previously stated, as the Reynolds number increases, so does the effect of the fin angle.

In such systems, heat transfer can be increased at a significant rate by employing passive methods.

As is seen, the average Nusselt number increases approximately 5 times for α =60°, and almost 6 times for α=45°, and nearly 6.5 times for α=30° in comparison to the theoretical Nusselt number.

As a result of the way the fins are placed in the collector, increased collector efficiency has been observed as the angle of the fins decreases. In addition, with the increase in flow rate, increased collector efficiency was observed.

In the experiments performed in the case of fins, the maximum efficiency was obtained as 63% for α =30°, $\dot{m}$ =0.033 kg/s, and the minimum efficiency was 34% for α =60°, $\dot{m}$ =0.012 kg/s.

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REFERENCES

[1] H. Yeh, and T. Lin, "The effect of collector aspect ratio on the collector efficiency of upward- type flat-plate solar air heaters," Energy, vol. 21, no.10, pp. 843-850, 1996.

[2] B.F. Parker et al., "Thermal performance of three solar air heaters," Solar Energy, vol.13, no.7, pp. 543-547, 1998.

[3] H.M. Yeh, C.D. Ho, J.Z. Hou, "Collector efficiency of double-flow solar air heaters with fins attached," Energy, vol. 27, no.8, pp.715-727, 2002.

[4] N. Paisorn, and K. Bancho, "Theoretical study on heat transfer characteristics and performance of the flat-plate solar air heaters," International Comm. Heat Mass Transfer, vol. 30, no. 8, pp.1125-1136, 2003.

[5] H.D. Ammari, "A mathematical model of thermal performance of a solar air heater with slats," Renewable Energy, vol. 28, no.10, pp. 1597-1615, 2003.

[6] S.K. Tyagi et al., "Exergy analysis and parametric study of concentrating type solar collectors," International Journal of Thermal Sciences, vol.46, no.12, pp. 1304-1310, 2007.

[7] M.A. Karim, and M.N.A. Hawlader, "Development of solar air collectors for drying applications," Energy Conversion and Management, vol. 45, no. 3, pp. 329–344, 2004.

[8] M.A. Karim, and M.N.A. Hawlader, "Performance evaluation of a v-groove solar air collector for drying applications," Applied Thermal Engineering," vol.26, no.1, pp. 121–130, 2006.

[9] A.A. Badran et al., "On the measurement of bond conductance in solar collector absorber plate," Energy Conversion and Management," vol.49, no.11, pp.3305–3310, 2008.

[10] A. Hobbi, , and K. Siddiqui, "Experimental study on the effect of heat transfer enhancement devices in flat-plate solar collectors," International Journal of Heat and Mass Transfer," vol.52, no.19-20, pp. 4650–4658, 2009.

[11] B.M. Ramani, A. Gupta, R. Kumar, "Performance of a double pass solar air collector," Solar Energy, vol. 84, no.11, pp.1929–1937, 2010.

[12] A.M. El-Sawi et al., "Application of folded sheet metal in flat bed solar air collectors," Applied Thermal Engineering, vol.30, no.8-9, pp.864–871, 2010.

[13] İ. Kurtbas, and A. Durmus, "Efficiency and exergy analysis of a new solar air heater," Renewable Energy, vol.29, no.9, pp.1489-1501, 2004.

[14] A. Akbulut, and A. Durmus, "Energy and exergy analyses of thin layer drying of mulberry in a forced solar dryer," Energy, vol.35, no.4, pp.1754–1763, 2010.

[15] H. Karakaya, and A. Durmus, "Investigation of efficiency and exergy loss in plate heat exchangers having spiral surface profiles," Energy Educatıon Scıence and Technology, vol.28, no.2, pp.577-590, 2012.

[16] O. Nematollahi, P. Alamdari, M.R.Assari, "Experimental investigation of a dual purpose solar heating system," Energy Conversion and Management, vol.78, pp.359-366, 2014.

[17] M. Abuska, M.B. Akgül, "Experimental Study on Thermal Performance of a Novel Solar Air Collector Having Conical Springs on Absorber Plate" Arab J Sci Eng., vol. 41, pp.4509–4516, 2016.

[18] M.A. Nima, M.A. Ali, "Effect of Metal Foam Insertion on Thermal Performance of Flat-Plate Water Solar Collector Under Iraqi Climate Conditions," Arab J Sci Eng, vol. 42, pp. 4863–4884, 2017.

[19] V. Dabra, A. Yadav, "Effect of Pressure Drop and Air Mass Flow Rate on the Performance of Concentric Coaxial Glass Tube Solar Air Collector: A Theoretical Approach," Arabian Journal for Science and Engineering, vol. 43, pp. 4549–4559, 2018.

[20] K.Y. Wenceslas, T. Ghislain, "Experimental Validation of Exergy Optimization of a Flat-Plate Solar Collector in a Thermosyphon Solar Water Heater," Arabian Journal for Science and Engineering, vol. 44, pp. 2535–2549, 2019.

[21] A.A. Farhan, H.E. Ahmed, M.A. Mussa, "Thermal–Hydraulic Performance of a V-Groove Solar Air Collector with Transverse Wedge-Shaped Ribs," Arabian Journal for Science and Engineering, to be published. https://doi.org/10.1007/s13369-021-06442-5.

[22] A. Goel, G. Manik, , O.P. Verma, "Designing a Robust Analytical Model of a Parabolic Trough Solar Collector Through In-depth Analysis of Convective Heat Transfers," Arabian Journal for Science and Engineering, vol.47, pp.6535–6557, 2022.

[23] F. Gulcimen, "Drying of the mint and sweet basil with new designed air collectors and determining of drying parameters," PhD thesis, Institute of science, Firat University, Elazig, Turkey, 2008.

[24] F. Gülcimen, H. Karakaya, A. Durmus, "Drying of sweet basil with solar air collectors," Renewable Energy, vol. 93, pp. 77-86, 2016.

[25] F.P. Incropera, D.P. DeWitt, Fundamentals of Heat and Mass Transfer, Istanbul, Turkey: Literature Publications, 2001.

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