Heat Transfer Enhancement in Solar Air Heater With Smooth Plate

design procedure of flat plate solar air heaters

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Abstract— **aim and objective of this work is to review and understand the design procedure of flat plate solar air heaters; the heat transfer and thermal performance of a single pass solar air heater a smooth plate was investigated experimentally. In the present paper, heat transfer analysis of a solar air collector with smooth plate, this procedure is used to determine the best thermal performance of flat plate solar air heater by allowing for the different method and operating parameters to gain a maximum thermal performance. Thermal performance is obtained for different mass flow rate changeable in the array 0.0108 to 0.0202 kg/s by five values, solar intensity; tilt angle and ambient temperature. The effects of air mass flow rate, emissivity of channel plates and wind heat transfer coefficient on the accuracy of the criterion are also investigated.**

Keywords-component; solar air heater; temperature; renewable energy.

I. Introduction

In the present paper, energy and heat transfer analysis of a solar air collector with smooth plate, this technique is used to determine the optimal thermal performance of flat plate solar air heater. Solar energy is one of the most useful forms of the renewable energy. Solar collectors (air) are used for the optimal utilization of solar thermal energy. Solar air heaters have a wide range of applications in agricultural, residential and industrial fields, i.e., seasoning of timber, green house heating, etc. Solar air heaters have fewer problems related to corrosion, salt deposits, freezing, boiling, etc.

Thus, the researchers have directed their efforts towards enhancement of heat transfer coefficient by creating turbulence near the heat transferring surface using artificial roughness in various forms, such as solid roughness elements of various shapes and in different arrangements and perforated or detached roughness elements [1–20]. Another work presented the thermal performance of a single pass solar air heater with five fins attached was investigated experimentally; longitudinal fins were used inferior the absorber plate to increase the heat exchange and render the flow fluid in the channel uniform [21−24]. The rapport work aims to review of designed and analysed a thermal efficiency of flat-plate solar air heaters were evaluated for various air flow rates are investigated [25−31].

II. Experimental

A. Thermal Analysis and Uncertainty

Heat transfer coefficients

The convective heat transfer coefficient hw for air flowing over the outside surface of the glass cover depends primarily on the wind velocity V_{wind}. McAdams [32] obtained the experimental result as:

$$h_w = 5.7 + 3.8 V_{wind} \quad (1)$$

where the units of h_w and V_{wind} are W/m²K and m/s, respectively. An empirical equation for the loss coefficient from the top of the solar collector to the ambient was developed by Klein [33].The heat transfer coefficient between the absorber plate and the airstream is always low, resulting in low thermal efficiency of the solar air heater. Increasing the area of the absorber plate shape will increase the heat transferred to the air.

Collector Thermal Efficiency

The efficiency of a solar collector is defined as the ratio of the amount of useful heat collected to the total amount of solar radiation striking the collector surface during any period of time:

$$\eta = \frac{Q_u}{I_0 \times A_C} \quad (2)$$

The equation for mass flow rate (m) is

$$m = \rho \times Q$$

where ρ is the density of air, which depends on the air temperature, and Q is the volume flow rate, which depends on the pressure difference at the orifice as measured from the inclined tube manometer and temperature.

Useful heat collected for an air-type solar collector can be expressed as:

$$Q_u = \dot{m} C_p \left(T_{out} - T_{in}\right) \quad (3)$$

where C_p is the specific heat of the air, Ac is the area of the collector. The fractional uncertainty about the efficiency from Eq. (3) is a function of ΔT, m, and I, considering C_p and A_c as constants.

$$\text{With } \dot{m} = V_f . S$$

So, collector thermal efficiency becomes,

$$\eta = \dot{m} C_p \frac{\left(T_{out} - T_{in}\right)}{I\, A_C} \quad (4)$$

Thermal properties of air are considered to be variables according to the following expressions (Tiwari, 2002), where the fluid temperature is evaluated in Celsius [34]:

$$C_p = 999.2 + 0.1434 T_f + 1.101 \times 10^{-4} T_f^2 - 6.7581 \times 10^{-8} T_f^3 \quad (5)$$

$$\lambda = 0.0244 + 0.6773 \times 10^{-4} T_f \quad (6)$$

$$\mu = 0.0234 \times 10^{-4} + 0.00105 \times 10^{-4} T_f \quad (7)$$

Air density is calculated assuming the fluid is an ideal gas by the expression:

$$\rho = 353.44 / T_f \quad (8)$$

where T_f is the absolute air temperature.

III. DESCRIPTION OF SOLAR AIR HEATER CONSIDERED IN THIS WORK

The experimental results include the performance of the solar collector with a smooth plate under location of Biskra city of Algeria, The solar collector is tested for a fixed air gap thickness of 20 mm. The performance of the solar collector provides the base for comparison with different mass flow rates varying between 0.0108 to 0.0202 kg/s; for difference days.

The photograph of experimental set-up shown in Figs. 1, 2, and the box of the collector is views of the absorber plate in the collector box are shown in Fig. 2. The absorber plate made of galvanized iron sheet with black chrome selective coating. The plate thickness of collector was 0.5 mm. The cover window type a Plexiglas of 3 mm thickness was used as glazing. Single transparent cover was used of collector. Thermal losses through the collector backs are mainly; due to the conduction across the insulation (thickness 4 cm. After installation, the collector was left operating several days under normal weather conditions for weathering processes. Thermocouples were positioned evenly, on the top surface of the absorber plates, at identical positions along the direction of flow, for solar collector. Inlet and outlet air temperature was measured by two well insulated thermocouples. The output from the thermocouples was recorded in degrees Celsius by means of a digital thermocouple thermometer DM6802B: measurement range −50 to 1300 °C (−58 to 1999 °F), resolution: 1°C or 1°F, accuracy: ± 2.2 °C or ± 0.75 % of reading and Non-Contact digital infrared thermometer temperature laser gun model number: TM330: accuracy ±1.5 C/±1.5 %, measurement range −50 to 330 °C (−58 to 626 °F) resolution 0.1 °C or 0.1 °F, emissivity 0.95. The ambient temperature was measured by a digital thermometer with sensor in display LCD CCTV-PM0143 placed in a special container behind the collectors' body. The total solar radiation incident on the surface of the collector was measured with a Kipp and Zonen CMP 3 Pyran-ometer. This meter was placed adjacent to the glazing cover, at the same plane, facing due south. The measured variables were recorded at time intervals of 15 minutes and include: insolation, inlet and outlet temperatures of the working fluid circulating through the collectors, ambient temperature, absorber plate temperatures at several selected locations and air flow rates (Lutron AM-4206M digital anemometer). All tests began at 9 AM and ended at 4 PM.

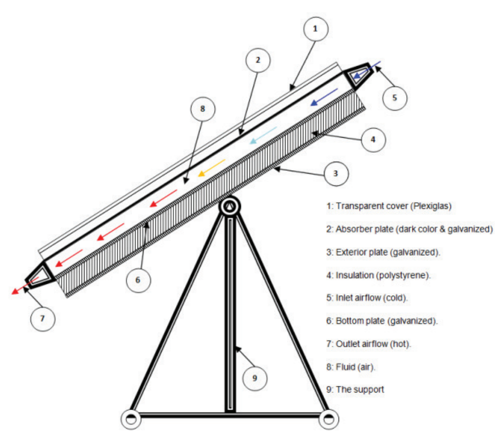

Figure 1. Schematic view of the solar air collector

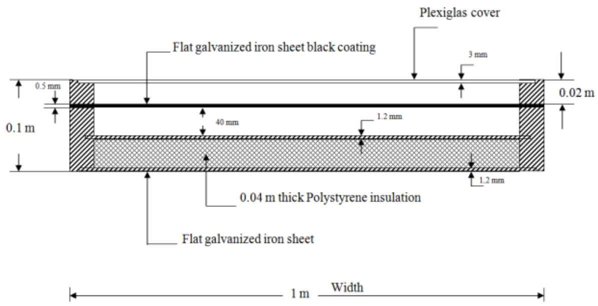

Figure 2. Cross-sectional view of solar air heater

IV. RESULTS

Here, the results of the experimental study on thermal performance of the solar collector with flat plate have been presented; in this part must be energetic analysis of heat transfer; and changes the mass flow rate for increases the thermal efficiency and test new design of solar collector with flat plate. It can be seen when the increases in the mass flow rates are affecting in the temperature of the bottom plate and an absorber plate, the efficiency of the solar collector at mass flow rate equal 0.0202 kg/s found to be higher than the mass flow rates equal of 0.0108 to 0.0161 kg/s. Collector performance tests were conducted on days with clear sky condition. The collector slope was adjusted to 45°, which is considered suitable for the geographical location of Biskra. The collectors were instrumented with T-type thermocouples for measuring temperatures of flowing air at inlet and outlet of the collector, and the ambient temperature.

Figs. 3 & 4 show the variation of the solar intensity and a thermal efficiency, respectively, with air mass flow rate. The thermal efficiency used to evaluate the performance of the solar air heater is calculated; from both figures that the thermal efficiency increases with increasing solar intensity and mass flow rate as a function of the time. The efficiencies of the rate 0.0202 kg/s are higher than inferior of 0.0202 kg/s. Figs. 3 & 4 shows the comparison of the thermal efficiency for the different mass flow rates from 0.0108 kg/s to 0.0202 kg/s.

Evidently the mean highest thermal efficiency (η = 58.02%) at solar intensity I = 898 W/m^2 at air flow rate 0.0161 kg/s and 45° tilt angle at 13:10 h. The mean lowest thermal efficiency (η = 28 %) at solar intensity I = 863 W/m² at 13:00 h was obtained with air flow rate 0.0108 kg/s and 45° tilt angle. Solar air heater were heated the air much more at the lower air rate, because the air had more time to get hot inside the collector, when .

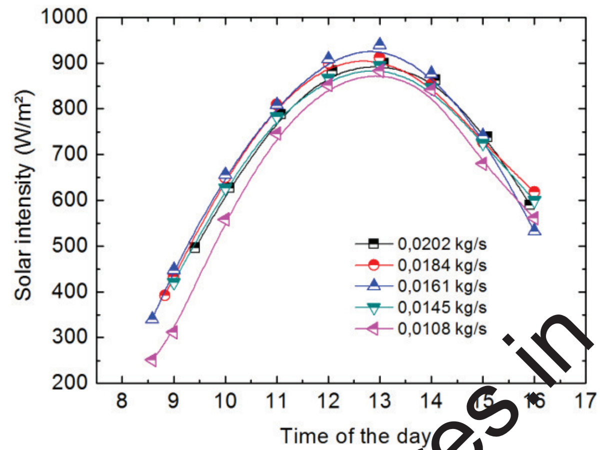

Figure 3. Variation of solar radiation at different days

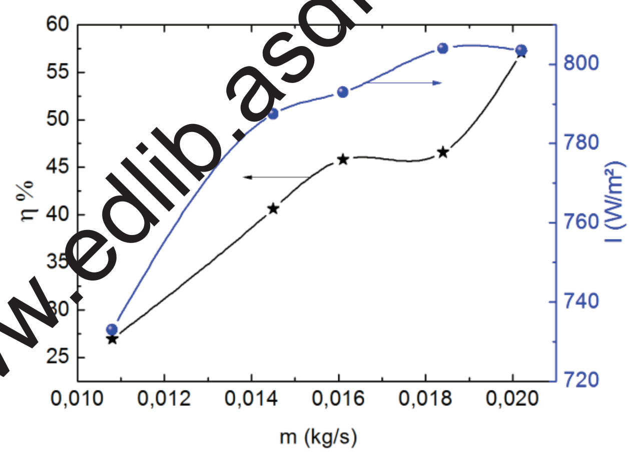

Figure 4. Variation of average solar intensity and thermal efficiency.

The thermal efficiency of the heater improves with increasing air flow rates due to an enhanced heat transfer to the air flow while a temperature difference of fluid decreases at a constant tilt angle β = 45°. Solar intensity is at their highest values at noon (at about 13:30) as is expected. The solar intensity decreases as the time passes through the afternoon. Fig. 6 & 7 it shows overall results of experiments, including the difference of air ambient and outlet temperature and daily instantaneous solar intensity levels. The average ambient temperature was between 18 and 19.95 °C. The inlet temperatures of solar air collectors were measurement to ambient temperature. The temperature differences between the inlet and outlet temperatures can be compared directly when determining the performance of the collectors. The highest daily solar radiation is obtained as 881.38 and 943 W/m² for a Flat-plate.

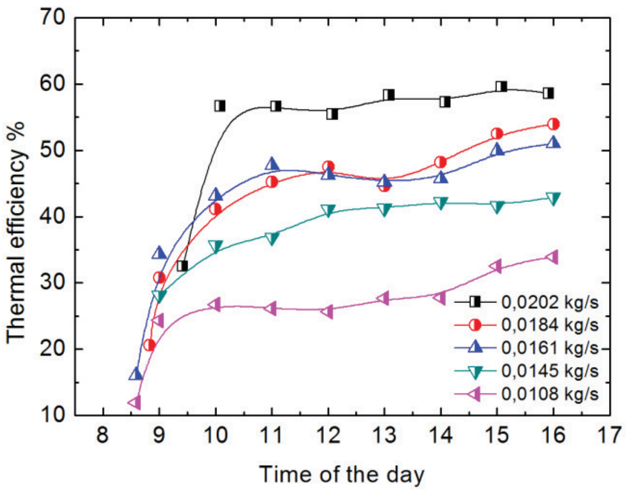

Figure 5. Variation of collector efficiency at different mass flow rates.

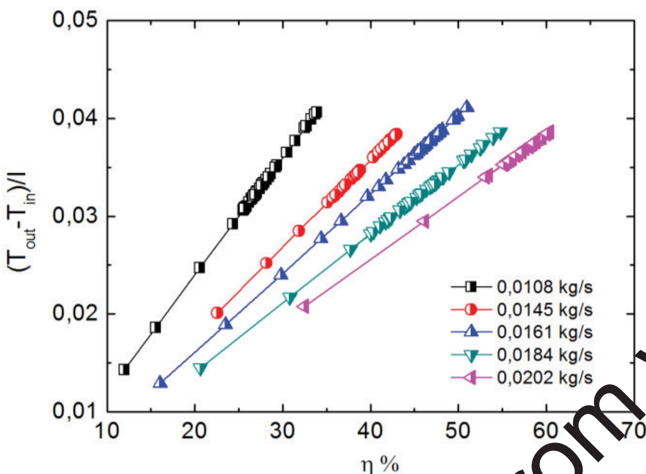

Figure 6. Variation of $\frac{(T_{out}-T_{in})}{I}$ as function of thermal efficiency at different days & mass flow rates

Fig. 5 shows the variation of average temperature $\frac{(T_{out}-T_{in})}{I}$ of the flat plate solar air heater as a function to thermal efficiency depending to mass flow rate. It may be remarked that the temperature $\frac{(T_{out}-T_{in})}{I}$ is varying linearity increases according of thermal efficiency corresponding to mass flow rates of 0.0108 to 0.0202 kg/s. The experimental results indicated by measurement data illustrate that the maximum temperatures $\frac{(T_{out}-T_{in})}{I}$ are obtained when m = 0.0108 kg/s, at thermal efficiency η =33.92% & $\frac{(T_{out}-T_{in})}{I} = 0.0406\left({}^{\circ}C.m^2/W\right)$, this evolution correspondently the minimum values of thermal efficiency, by against when the temperature is taking a minimum values the efficiency as to a maximum values, another way the tangential which to estimated the ratio $\left(\dot{m}\times C_p / A_c\right)$; means that the effect depending the nature of fluid used and the geometrical of solar collector.

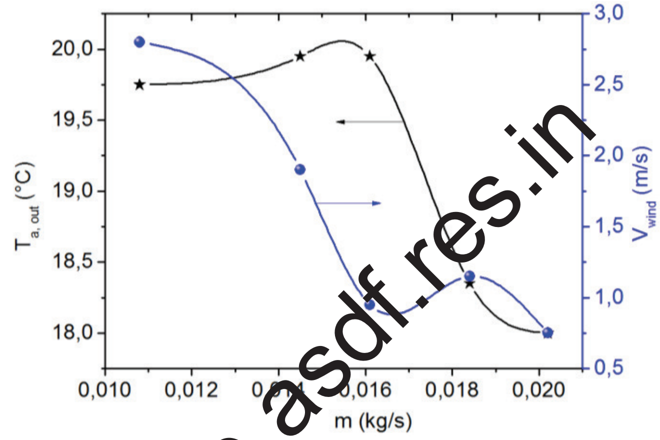

Figure 7. Variation of ambient temperature at different mass flow rates.

Fig. 7 shows the average ambient temperature and the wind speed as function to mass flow rates of the solar collector, respectively, for all the days, the experiment was carried out. The average ambient temperature and wind speed varying from 18 to 19.95 °C & 0.75 to 2.8 m/s, for each mass flow rate are 0.0108, 0.0145, 0.0161, 0.0184 and 0.0202 kg/s, respectively, (Fig. 7). The weather conditions such as wind speed and ambient temperature were affecting in the solar air heater.

V. CONCLUSION

A detailed experimental study was conducted to evaluate the energetic and heat transfer of five days of single-flow solar air collectors under a wide range of operating conditions. According to the results of the experiments, the solar collector type of the SAH has been introduced for increasing the thermal efficiency, leading to improve heat transfer. The optimal value of efficiency is corresponding to mass flow rate equal 0.0202 kg/s is 58.30% at 13:15 pm for all operating conditions. The current researches work an attempt has been made to optimize the thermal performance of flat plate solar collectors by using difference mass flow rate in the location of Biskra city of Algeria. The thermal performance of simple flat plate solar collector is very important, but it is simple in construction, therefore it is necessary to determine the domain of optimum values of operating and system parameters so that the system can be operated with its fullest optimum abilities.

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