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Experimental Study of Heat Transfer and an Effect the Tilt Angle with Variation of the Mass Flow Rates on the Solar Air Heater

Foued Chabane[1], Noureddine Moummi[2], Said Benramache[3], Abdallah Salim Tolba[4]
[1,2,4] Mechanical Energy Department, Faculty of Technology, University of Biskra, Algeria
[3] Material Science Departments, Faculty of Science, University of Biskra, Algeria
([1]fouedchabane@live.fr, [2]n.moummi@hotmail.com, [3]saodzno@yahoo.fr, [4]tsalimdz@hotmail.com)

Abstract- in this study we have been indicated an effect of tilt angle and the mass flow rates onto the thermal performance of a single pass solar air heater will be investigated experimentally. The effects of mass flow rate of air on the outlet temperature, the heat transfer in a solar collector and thermal efficiency were studied. Experiments were performed for range of air mass flow rates from 0.0078 to 0.0166 kg/s., Moreover; the maximum efficiency was obtained at the difference's mass flow rates. The maximum efficiency obtained for the 0.0078, 0.0093, 0.0125 and 0.0166 kg/s were 47.82%, 37.50%, 31% and 26% respectively. Comparison of the results as an effect the mass flow rates by solar collectors and the tilt angle a substantial enhancement in the thermal efficiency. The optimal tilt angles for the outlet temperature were between 20 and 30°.

Keywords- *mass flow rate; tilt angle; thermal efficiency; outlet temperature; inlet temeprature.*

I. INTRODUCTION

Thermal performance and heat exchange of a single pass solar air heater with fins attached back the absorber plate was investigated experimentally. The effects of air mass flow rates range from 0.0078 kg/s to 0.0166 kg/s on the outlet and the difference temperature and thermal efficiency was studied. Result shows that, the efficiency increase with increasing air mass flow, and takes the optimal values of a tilt angles 20° and 30°. The wind speed, and temperature ambient its effect in the evolution of temperature such as the temperature of transparent cover, and temperature of the absorber plate taking account of temperature the fluid under an absorber plate, and the temperature of bottom plate finally the temperature exterior plate in the outside, respectively, in the location of Biskra city of Algeria.

Comparison of results reveals that the thermal efficiency of single pass solar air collector a function of mass flow rates it is higher with a increasing the flow rate. Increasing the absorber area or fluid flow heat-transfer area will increase the heat transfer to the flowing air, on the other hand, will increase the pressure drop in the collector, thereby increasing the required power consumption to pump the air flow crossing the collector [1, 2].

On the other hand several configurations of absorber plates have been designed to improve the heat transfer coefficient. Artificial roughness obstacles and baffles in different shapes and arrangements were employed to increase the area of the absorber plate. As a result the heat transfer coefficient between the absorber plate and the air pass will be improved [3]. Omojaro et al [4], reported a Thermal performance of a single and double pass solar air heater with fins attached and using a steel wire mesh as absorber plate was investigated experimentally. The bed heights were 7 cm and 3 cm for the lower and upper channels respectively. The result of a single or double solar air heater, when compared with a conventional solar air heater shows a much more substantial enhancement in the thermal efficiency.

Studied numerical of the performance and entropy generation of the double-pass flat plate solar air heater with longitudinal fins [5]. The predictions are done at air mass flow rate ranging between 0.02 and 0.1 kg/s. reported used the fins serve as heat transfer augmentation features in solar air heaters however they increase pressure drop in flow channels. Results indicate that high efficiency of the optimized fin improves the heat absorption and dissipation potential of a solar air heater [6]. Designed double flow solar air heater with fins attached over and under the absorbing plate. This resulted in considerable improvement in collector efficiency of double flow solar air heaters with fins compare to single flow operating at the same flow rate [7].

An experimental investigation carried out on the thermal performance of the offset rectangular plate fin absorber plates with various glazing [8]. In this work, the offset rectangular plate fins, which are used in heat exchangers, are experimentally studied. As the offset rectangular plate fins, mounted in staggered pattern and oriented parallel to the fluid flow, high thermal performances are obtained with low-pressure losses. Karim and Hawlader [9] conducted experiments to study the performance of three types of solar air heater, namely flat plate, finned and V-corrugated solar air heaters. The V-corrugated collector was found to be most efficient while the flat plate collector was the least efficient. Lin et al. [10] and Gao et al. [11] used the cross-corrugated absorbing plate and bottom plate to enhance the turbulence and the heat transfer rate inside the air flow channel and tested its thermal performance. Donggen Peng & al. [12], studied a novel solar air collector of pin-fin integrated absorber was designed to increase the thermal efficiency. In the performance analysis of varying flow rate on PZ7-11.25 pin-fin arrays collector, the correlation equation on heat transfer coefficient is obtained and the efficiency variation vs. air flow rate is determined in this work. Other work reported of results is compared with those obtained with a solar air collector without fins, using two types of absorbers selective (in copper sun) or not selective (black-painted aluminum) [13].

II. DESCRIPTION OF SOLAR AIR HEATER CONSIDERED IN THIS WORK

A. Collectors

The layout of the solar air collector studied is shown in (Fig. 1 and 2). In which, collector A served as the baseline one, with the parameters as follows:

- The solar collecting area was 2 m (length) × 1 m (width);
- The installation angle of the collector was 45° from horizontal;
- The transparent cover was made of a Plexiglas panel, with a thickness of 3 mm;
- The height of stagnant air layer was 0.02 m;
- The absorber plate was made of galvanized, which was 0.5 mm thick and black-painted;
- Thermal insulation board EPS (expanded polystyrene board), with thermal conductivity 0.037 W/(m K), was put on the exterior surfaces of the back and side plates, with a thickness of 40 mm.
- The CMP 3 pyranometer is an instrument for measuring the solar irradiance and digital thermometer Model Number: DM6802B.
- The absorber of plate absorption coefficient $\alpha = 0.95$, the transparent cover transmittance $\tau = 0.9$ and absorptive of the glass covers, $\alpha_g = 0.05$;
- 16 Positions of thermocouples connecter to plates and two thermocouples to outlet and inlet flow. Five fins under absorber plate form of semi cylindrical longitudinal was 1.84 m (length) × 0.03 m (Radian); the distance between two adjacent fins and fins t are 120 and mm respectively and 5 mm thickness Figure 2.

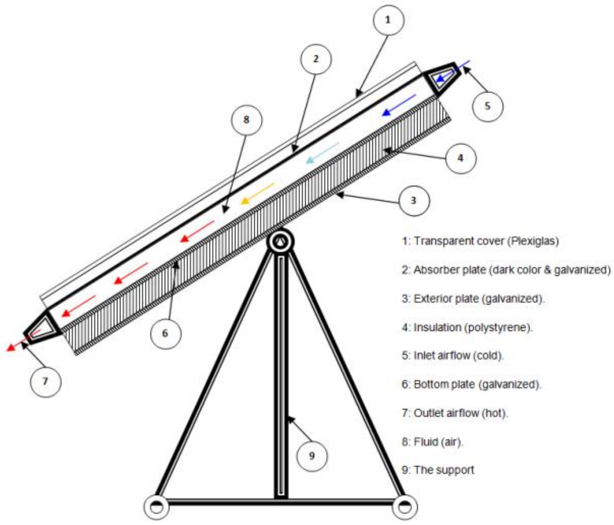

Figure 1. Schematic view of the solar air collector

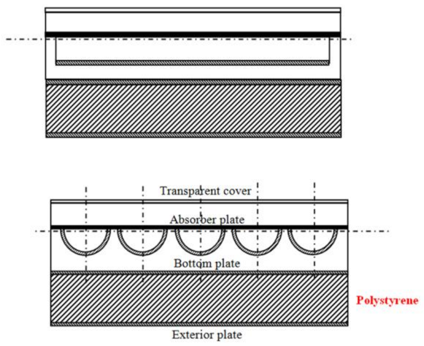

Figure 2. Composition of solar box with and without fins.

III. RESULTS AND DISCUSSION

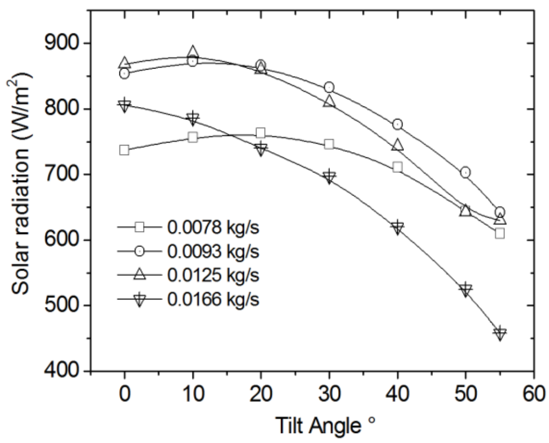

Figure 3. Solar irradiation as a function to tilt angles about every variation of mass flow rates.

Fig.3 shows the hourly variations of the measured solar radiation of different conditions of the days with about flat-plate, correspondent of range from 0.0078 to 0.0166 kg/s, respectively Fig. 3 that the maximum values of solar radiation I are 885 W/m² at m = 0.0125 kg/s about tilt angle β = 10° and 875 W/m² at m = 0.0093 kg/s, correspondent solar collector with about tilt angle β = 10° and I = 760 W/m² at 0.0078 kg/s about β = 20°, finally about a mass flow rates m = 0.0166 kg/s the solar intensity equal to the maximum values I = 800 W/m². The temperatures of the various elements its increase with time as the solar radiation increases to show their maximum values between the tilt angles from β = 0° to β = 20° as seen in Fig. 3, Comparisons between the measured solar intensity of the following the tilt angles with weather conditions.

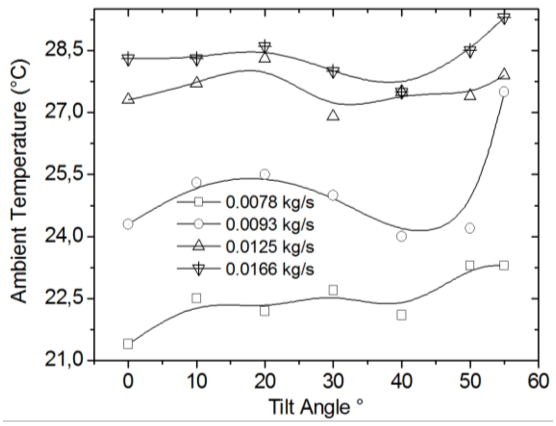

Figure 4. ambient temperature as a function to tilt angles about every variation of mass flow rates.

Fig.4 Presents the ambient temperature; it is as function the tilt angles, this variation dependent upon the weather conditions and the mass flow rates; it's varying by modes of solar collector. The absolute ambient temperature correspondant the range of mass flow rates from 0.0078 to 0.0166 kg/s were 27.5, 29, 31.24 and 31.5 °C,respectively. The ambient temperature it is help, in effect on the thermal performance of the solar collector; this effect shows in Fig. 6 it's estimated by inlet temperature function to tilt angles, this evolution remarkable we can be seen the same evolution with ambient temperature Fig.4. Therefore, prove we can be said the ambient temperature air as an effect directly on the solar panel, and in the thermal properties. this change is enough to affect the solar panel; that is why we have made some adjustments within the solar panel by flat plate.

The wind speed is always changing its speed and its direction during the day and the month, measuring of the average wind speed is 2.2, 2.45, 2 and 2.83 m/s, Fig.5 respectively of the mass flow rates, that the wind speed be alternating in several directions; this affects the values of temperature of transparent cover and exterior plate, and these last is not infected directly on the elements internal of the solar panel but slight, the maximum values of the wind speed for the case of tilt angles are the range from 0 to 55°, by the important of a convection heat loss coefficient .

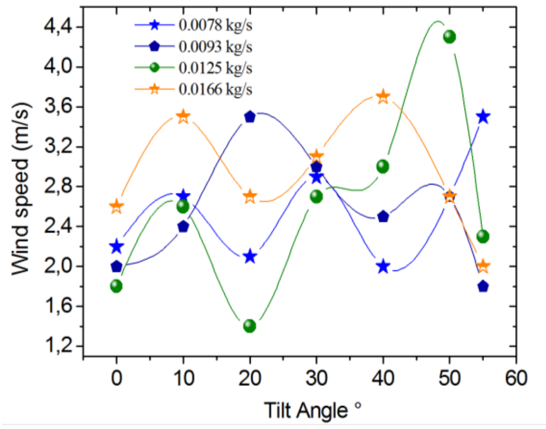

Figure 5. Wind velocity as a function to tilt angles about every variation of mass flow rates.

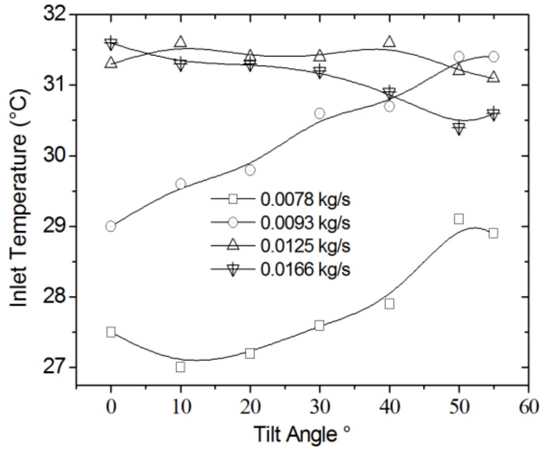

Figure 6. Inlet temperature as a function to tilt angles about every variation of mass flow rates.

As shown from Fig. 6, difference evolution in inlet temperature as function to tilt angles of solar air heater, and the fluid passed between the absorber plate and the bottom plate; it would increase the heat transfer from the first pass to finally. This can account for the efficiency to increase more than 48 % at mass flow rate m = 0.0166 kg/s and the inlet temperature 30.5 °C at tilt angle β = 55°, and lesser air flow rate m = 0.0078 kg/s the inlet temperature was 29 °C when the efficiency η = 26%.

Fig.7 it shows the outlet temperature function to tilt angles, and compared with different mass flow rates the outlet temperature correspondent flat-plate and mass flow rates with the range from 0.0078 to 0.0166 kg/s, T_{out} = 46.5, 56, 59.7 and 56 °C, respectively the range of mass flow rates at tilt angles β = 0°, for β = 10° we have be seen the results T_{out} = 50, 58, 60.2 and 56 °C. About β = 55°, T_{out} = 55.5, 59, 55.5 and 47.5 °C, we can be seen the optimal tilt angles for this range, when the maximum outlet temperature done is 30°. Another report by F. Chabane et al [14], find the maximum outlet temperature with tilt angle equal to 35°.

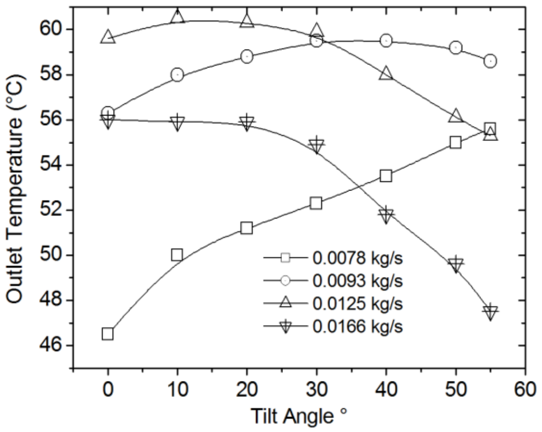

Figure 7. Outlet temperature as a function to tilt angles about every variation of mass flow rates.

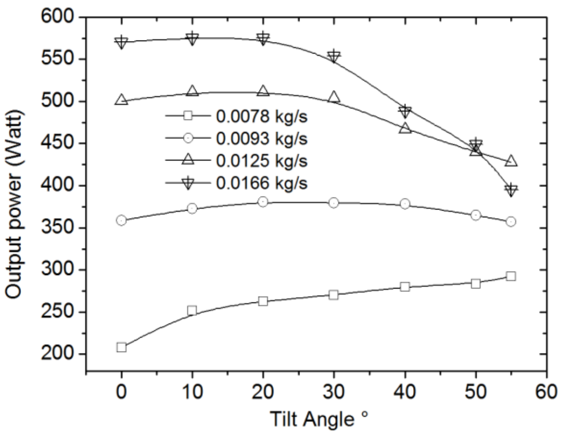

Figure 8. Output power as a function to tilt angles about every variation of mass flow rates.

Figure 8 shows the output power versus standard local time of the day as function to tilt angles and compared by mass flow rates, the experiment was carried out. The useful energy extracted increases from the early hours of the day with about 575 Watt, at β = 0° to reducer a peak value at β = 30° and then, reduces later on tilt angle 55°, The performance of the proposed single pass solar air heater has been studied and investigation the performance and heat exchange in the thickness of a solar air heater by the infect the mass flow rates of the range from 0.0078 to 0.0166 $kg.s^{-1}$. The maximum the accumulated useful energy extracted were 575 Watt at β = 0°, and the minimum takes the values by 400 Watt at β = 55° about 0.0166 $kg.s^{-1}$. For the mass flow rates m = 0.0078 kg/s the output power at β = 0° is 213 Watt and take the more when β = 55° is 286 Watt. We can be improve that the mass flow rate its command in the variation of the power of a solar air collector and the tilt angle, conclude that the efficiency as a relation and as a function to tilt angles.

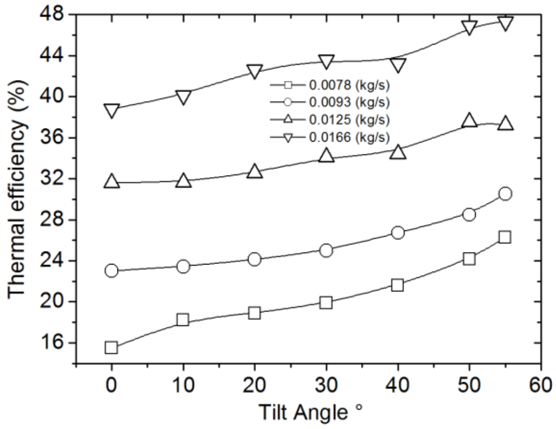

Figure 9. thermal efficiency as a function to tilt angles about every variation of mass flow rates.

Figure 9 shows the variation of the thermal efficiency as function to mass flow rates and tilt angles. The thermal efficiency used to evaluate the performance of the solar air heater is calculated, that the thermal efficiency increases with increasing solar intensity and mass flow rate as a function of the tilt angles. The efficiencies of the finned collectors are higher with β = 60° than that of β = 0°. Fig. 9 shows the comparison of the thermal efficiency for the different mass flow rates. Besides the results data of each solar air heater has been shown in (Fig.3). It can be seen that the mean highest thermal efficiency (η = 47.50%) at solar intensity I = 450 $W.m^2$ at air flow rate of 0.0166 $kg.s^{-1}$ and 60° tilt angle. The mean lowest thermal efficiency (η = 26 %) at solar intensity I = 610 $W.m^2$ at air flow rate of 0.0178 $kg.s^{-1}$ and 0 ° of a tilt angle.

IV. Conclusion

In the present study, two cases of the solar air collectors were tested, and a comparison is made among them Flat plate on the thermal efficiencies. The following conclusions can be derived:

The efficiency of the solar air collectors depends significantly on the solar radiation and surface geometry of the collectors.

The efficiency increases as the increase mass flow rate from 0.0078 to 0.0166 ($kg.s^{-1}$) and tilt angles.

The efficiency of solar air collector is proved to be higher. The highest collector efficiency and air temperature rise were achieved by the tilt angle with an optimal tilt angle at 30°.

The values of thermal efficiency at the mass flow rate 0.0078, 0.0093, 0.0125 and 0.0166 ($kg.s^{-1}$); were 26, 30, 38 and 48 %, respectively.

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