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Performance of an Air Collector Versus the Variation of the Distance between Absorber Plate and the Transparent Cover in the site of Laghouat, Algeria

Djamel Bensahal*, Ahmed Yousfi

Laboratory of Mechanics, Faculty of Technology, University of Laghouat, Algeria
bensahal.dz@gmail.com

The purpose of this study was to investigate the effect of the variation of the distance between the absorber and the transparent cover on the thermal conversion parameters of our solar collector with a single air pass implanted in the site of the University of Laghouat, Algeria. The experimental work with the following conditions such as: volume flow rate (0.012 m^3 / s), an angle of inclination of the collector (80°) and three days selected randomly (clear sky). We used 3 parameters of distances: 20 mm, 27 mm and 34 mm. Then, by comparing the experimental and theoretical results, we show that the ΔT of: Tp-Tab, Tpl-Tab, and Tout-Tab decrease with increasing of the distance. Moreover, It was found that the experimental thermal efficiency generally decreases too with increasing of the distances respectively 23.24%, 20.20% and 13.62% at 15h00. The findings of this study may serve as a tool on the design of the new solar air collectors.

1. Introduction

The sun is one of the main and vital factors in our existence and development. Aissaoui et al. (2016) shows that the solar energy transformed into heat have found many applications in the field of heating, drying, cold production, etc. Solar thermal collectors, which allow the production of thermal energy, convert solar radiations into heat energy extracted by air flow through the collector. The determination of their performance, based on the understanding of flow and heat transfer mechanisms in their different parts, is usually carried out with uniform average heat transfer coefficients.

Therefore, in experimental testing, Chemkhi et al. (2004) suggests the need to have more information about the thermo-physical characteristics of the important components related directly to the heat transfer which conduct an accurate analysis on the thermal performance of the collector with single pass solar air collector. Several applications by using solar air heater or solar water heater are investigated by: Ruozhu et al. (2017) explores to produce split water heater with the conversion of solar energy into thermal energy through chemical methods in the application and design so as to achieve a better integration of solar water heater with the building, thereby making the solar water heater one of the major ways to use new energy in the new or existing buildings. Liang et al. (2017) studies the correlativity of influencing factors of the tunnel length, the ratio of tunnel air inlet to solar chimney area, the height of the solar chimney and soil type through the establishment of tunnel and solar chimney ventilation composite system model.

Kalogirou et al. (2004) shows that when solar radiation passes through a transparent cover and impinges on the blackened absorber surface of high absorptivity, a large portion of this energy is absorbed by the plate and then transferred to the transport medium in the fluid tubes to be carried away for storage or use. The underside of the absorber plate and the side of casing are well insulated to reduce conduction losses. The transparent cover is used to reduce convection losses from the absorber plate through the restraint of the stagnant air layer between the absorber plate and the glass. The collector plates transfer the retained heat to the transport fluid. The absorptance of the collector surface for shortwave solar radiation depends on the nature and colour of the coating and on the incident angle.

Miloştean et al. (2017) and Kalogirou et al. (2004) explained that the glazing has two important functions: first is to reduce the convection losses from the absorber plate and the second is to reduce the radiation losses

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from the collector. Amrutkar et al. (2012) shows in order to choose a good glazing material first we need to check its transmittance. The higher, the more it will allow the passage of a larger amount of energy to the absorber. Several glazing materials used at flat-plate solar collectors construction, and their transmittance are: crystal glass (0.91), window glass (0.85), polyvinyl fluoride (0.93), fluorinated ethylene propylene (0.96), etc. Giovannetti et al. (2014) observes to obtain a good efficiency of collector, the glazing must have low emissivity, in order to reduce the radiative heat loss. O'Hegarty et al. (2015) suggests that the material used for the absorber plate must assure a high conductivity and the selective finish must have a high absorptance. Ehrmann et al. (2012) has increased the efficiency of solar-thermal flat-plate collectors at temperatures above 100 °C or with low solar irradiation; they implemented a double glazing with a low-emitting (low-e) coating on the inner pane to improve the insulation of the transparent cover.

Föste et al. (2016) developed a new thermochromic absorber coating in order to reduce stagnation temperature of solar thermal collectors, while maintaining the collector efficiency. Gorantla et al. (2018) works to find thermal performance of float and tinted window glasses such as grey, green, bronze and clear glasses. Ong K. (1995) and Moummi et al. (2004) have investigated theoretically the different collector designs by applying the heat balance equations in order to compute the temperature distribution.

In the present study, we present the influence of variation of the distance between the absorber plate and the transparent cover of flat plate solar collector on the thermal performance as: absorber temperature, bottom plate temperature, transparent cover temperature, outlet temperature and collector thermal efficiency. We used 3 parameters of distances: 20 mm, 27 mm and 34 mm. Then, by comparing the experimental and theoretical results, we show that the ΔT of: Tp-Tab, Tpl-Tab, Tout-Tab and Tv-Tab can be affected directly by increasing of the distance. The experimental set up was tested in the site of the University of Laghouat, Algeria.

2. Experimental setup

The passage of the air flow between the absorber and the bottom plate is shown in Figure 1 with β angle of inclination.

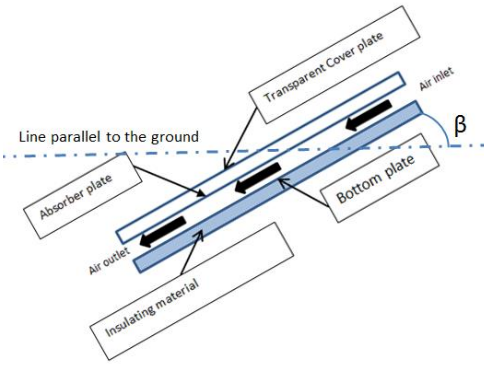

Figure 1: Cross-section of solar air collector with single pass of air

Several thermocouples (model: DC-M02) were placed uniformly on the upper surface of the absorber plate and bottom plate at identical positions along the direction of flow. Two other thermocouples were used to measure inlet and outlet air temperatures. The distribution of the thermocouples as follows: four thermocouples were used to measure the temperatures of absorber and the same number for the bottom plate. All temperatures were measured in degrees Celsius (ºC). Non-contact digital infrared thermometer (model: PCE-777) is used to measure the temperature of the ground and transparent cover.

The solar irradiation incident on the collector surface was measured with a Solarimeter (model: Kimo SL200). This solar collector was oriented towards the south. The measured variables were recorded at a time interval of 30 minutes and included: irradiation, inlet and outlet air temperatures of the fluid circulating in the solar collector, ambient temperature, and temperatures of the absorber surface at several selected locations. The air flows were measured by a digital anemometer (model: Lutron AM-206M). All tests started at 9 am and ended at 4 pm. Table 1 and Table 2 show the experimental conditions, the dimension of the components of the solar air collector and the thermo-physical characteristics of the different constituents. The Figure 2 shows the schematic description of the distance between the absorber and the transparent cover. This distance will be the subject of this study.

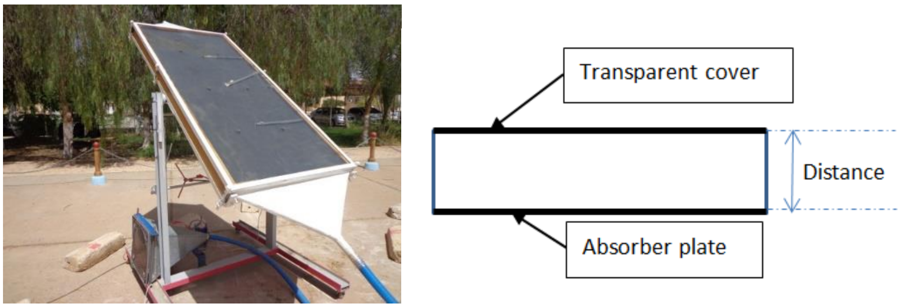

Figure 2: The photograph of experimental set-up and schematic description of the distance between the absorber and the transparent cover

Table 1: The experimental conditions: angle, flow rate, date and sky condition

Thickness (mm)	Angle of inclination (°)	Volume Flow rate	Thickness (mm)	Sky condition
20	80	0.0129402	02.03.2017	clear
27	80	0.0129402	12.04.2017	clear
34	80	0.0129402	08.05.2017	clear

Table 2: Thermo-physical characteristics and the dimension of the different constituents

Component	Materials	density (kg/m3)	Heat capacity (j/kg.°K)	Thermal conductivity (W/m.°K)	Length (m)	Width (m)	Thickness (mm)
Transparent cover	Plexiglass	1.2	1500	1.5	1.94	0.94	4
Absorber, bottom plate	Galvanized iron	7800	473	45	1.94	0.94	1
Insulation	Expanded polystyrene	16	1670	0.037	1.94	0.94	40

3. Theory

3.1 The equation of thermal equilibrium of solar collector

The thermal equilibrium of the transparent cover is:

$$-(T_v - T_{ab}).h_{c\_v} - (T_v - T_c).h_{rv\_c} - (T_v - T_s).h_{rv\_s} + (T_v - T_p).\left\{\frac{h_{c\_nat}}{2} + h_{rp\_v}\right\} + \alpha_v.I_t = 0 \quad (1)$$

The thermal equilibrium of the absorber is:

$$-(T_p - T_v).\left\{\frac{h_{c\_nat}}{2} + h_{rp\_v}\right\} - (T_p - T_f).h_{cp\_f} - (T_p - T_{pl}).h_{rp\_pl} + \tau_v.\alpha_p.I_t = 0 \quad (2)$$

The thermal equilibrium of the heat transfer fluid is:

$$(T_p - T_f).h_{cp\_f} - (T_f - T_{pl}).h_{cpl\_f} - dQu/(l.dx) = 0 \quad (3)$$

The thermal equilibrium of the bottom plate is:

$$(T_f - T_{pl}).h_{cpl\_f} + (T_p - T_{pl}).h_{rp\_pl} - (T_{pl} - T_{is}).h_d = 0 \quad (4)$$

The thermal equilibrium of the external insulating plate is given by Equation (5):

$$(T_{pl} - T_{is}).h_d - (T_{is} - T_{ab}).h_{c\_v} - (T_{is} - T_s).h_{ris\_s} = 0 \quad (5)$$

We have a system of 5 equations for 5 unknowns which represent the temperatures put in the form of a vector Ti (Tv, Tp, Tf, Tpl et Tis) which will be solved by the numerical method. For the resolution, the matrix form is: [Aij] [Ti] = [Ci].

3.2 Heat exchange coefficients

The convective transfer, radiant transfer and front loss coefficients are given by Klein et al., Chabane et al. and Bensahal et al. The average useful heat collected for an air solar collector can be expressed as:

$$Qu = \overset{*}{m} \times Cp \times (Tout - Tin) \tag{6}$$

The efficiency of a solar air collector (%) is defined as:

$$\eta(\%) = Qu \times 100 / I \times Ac \tag{7}$$

Where: the masse flow rate, specific heat and density are defined as:

$$\dot{m} = \rho \, . \, V \tag{8}$$

$$Cp = 999.23 + 0.1434\, T_f + 1.101.10^{-4}\, T_f^2 - 6.7581.10^{-8}\, T_f^3 \tag{9}$$

$$\rho = 1.204 \left(\frac{293}{T_f} \right) \tag{10}$$

With: ṁ is working fluid mass rate, I is incident solar radiation, Ac is the collector surface, Cp is heat capacity of the fluid, Tout and Tin are outlet and inlet temperature of the fluid respectively.

4. Results and discussion

The experimental measurements were carried out in different days for all the distances studied. It is for this reason that we are led to the reference at their ambient temperatures to give more credibility to their comparison.

4.1 Temperature of absorber

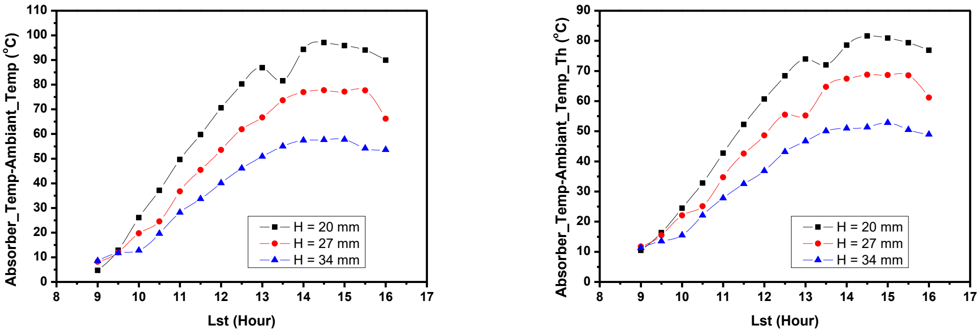

Figure 3: Evolution of the difference of theoretical and experimental temperature of the absorber as a function of time for different distances

The curves show when the distance increases more there is a decrease of this difference temperature as shown in Figure 3.

4.2 Temperature of bottom plate

This variation depends strongly on the incident solar radiation. The curves show when the distance increases, there is a reduction of this difference of temperature as shown in Figure 4.

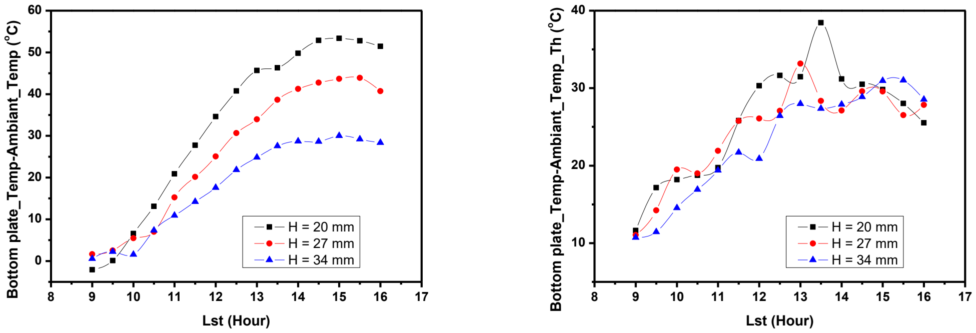

Figure 4: Evolution of the difference of theoretical and experimental temperature of the bottom plate as a function of time for different distances

4.3 Temperature of outlet temperature

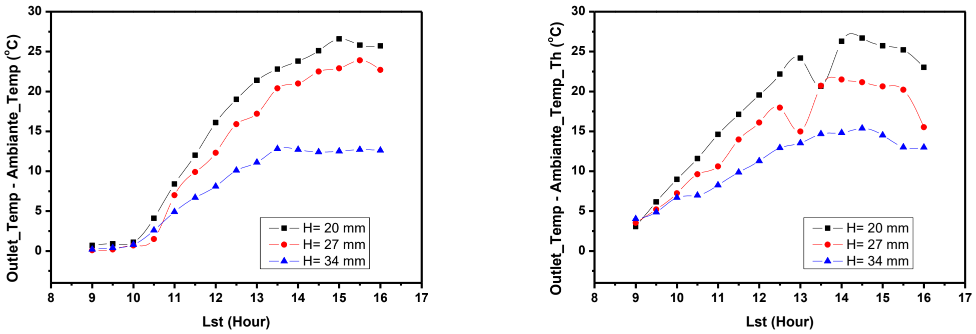

Figure 5: Evolution of the difference of theoretical and experimental outlet temperature as a function of time

The curves show when the distance increases more there is a decrease of this difference of temperature as shown in Figure 5.

4.4 Thermal efficiency of solar collector (η)

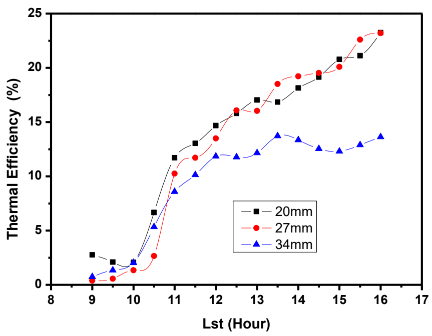

Figure 6: Evolution of thermal efficiency of the collector as a function of time for the three different distances

For the distances 20 mm, 27 mm and 34 mm, the experimental thermal efficiency is respectively 20.77%, 20.09% and 12.29% at 15h00 as shown in Figure 6.

5. Conclusions

This study is based on the evolution of thermal conversion parameters on our flat air solar collector implanted in the site of the University of Laghouat, Algeria. The selected days are clear days and for an angle of inclination of the collector relative to the ground is 80 degrees. The study shows that the difference of temperature between the temperatures of: absorber, bottom plate, and outlet temperature decreases with increasing of distance. For the distances 20 mm, 27 mm and 34 mm, the experimental thermal efficiency generally decreases with the increasing of the distance respectively 23.24%, 20.20% and 13.62% at 15h00.

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