Solar air collectors with doubles glazed by different distances in support of mass flow

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ABSTRACT. *The main objective of this study is to minimize thermal losses forward for improving the thermal performance of a solar collector. The improvement of the thermal performance of the solar collectors, because of the low thermo-physical characteristics of the air used as coolant, is based on several techniques, among them that which consist in conserving the thermal energy by minimizing thermal losses to the heat before. We devoted to a descriptive study of the test bench, the measuring equipment used as well as the configurations of double-glazed solar collector. The test bench consists of an experimental device that has been developed exclusively for on-site measurements. Experimental results show that the addition of second glazed is effective in minimizing forward thermal losses for a solar air collector. Our project is an experimental study of the Biskra site, and the essential goal minimized thermal losses to the front. For this purpose, single-glaze, solar air collector measurements should be compared with the variable-range, dual-pane solar collector measurements for multiple flow rates.*

RÉSUMÉ. *L'objectif principal de cette étude est de minimiser les pertes thermiques afin d'améliorer les performances thermiques d'un capteur solaire. En raison des faibles caractéristiques thermo-physiques de l'air utilisé comme fluide de refroidissement, l'amélioration des performances thermiques des capteurs solaires repose sur plusieurs techniques, notamment celle qui consiste à conserver l'énergie thermique en minimisant les pertes thermiques à la chaleur. Nous nous sommes engagés à effectuer une étude descriptive du banc d'essai, des appareils de mesure utilisés ainsi que des configurations du capteur solaire à double vitrage. Le banc d'essai consiste en un dispositif expérimental développé exclusivement pour des mesures sur site. Les résultats expérimentaux montrent que l'ajout d'un deuxième vitrage réduit efficacement les pertes de chaleur directes du capteur d'air solaire. Notre projet consiste en une étude expérimentale du site de Biskra dans le but fondamental de minimiser les pertes de chaleur à l'avant. À cette fin, il convient de comparer les mesures de capteurs solaires à simple vitrage avec les mesures de capteurs solaires à double vitrage à plage variable pour des débits multiples.*

KEYWORDS: *double-glazed, solar air collector, efficiency, mass flow rate, thermal losses.*

MOTS-CLÉS: Double vitrage, capteur d'air solaire, efficacité, taux du débit massique, pertes thermiques.

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1. Introduction

Renewable energies experienced a first phase of development during the oil shocks in 1973.Among the renewable energies, we quote the solar energy "clean energy". The exploitation techniques of this resource have seen in recent years a remarkable mutation involving a state-of-theart technology, especially its availability over a large part of the globe and the absence of any risk of exhaustion known from fossil sources. The solar air collector date for the first work initiated in this area. The low efficiency of this type of sensor has led researchers to investigate other ways to improve performance and minimize heat loss and increase efficiency. In this article we will have some work done in the field of solar. In order to minimize thermal losses to the front of the absorber, (Benyelles *et al*., 2007) have done work to minimize the forward thermal losses proposed to place a "silica airgel" insulation at Absorber us have choose the silica airgel for its properties, it is a low density solid material ranging from 80 to 270 kg/m3. Transparent, porous (35% to 90% porosity). Its refractive index is between1.2 to 1.5. For a thickness of about 20 mm the normal solar transmission is 90%. Its thermal conductivity is of the order of 0.02 W/m.K. In order to study the influence of some parameters on the loss coefficient thermal forward sensor. Benkhelifa, (1998) conducted a theoretical study in which it presents models which make it possible to calculate these thermal losses. The Balance sheet equations were solved by an iterative method.

The models obtained gave results in agreement with those resulting from the empirical relations encountered in the literature. Njomo, (1998) carried out an experimental study of a solar air collector with an analysis of the influence of various parameters, such as the heat transfer fluid inlet temperature, the flow rate mass of this fluid and the distance between the absorber and the combined system of covers, on the thermal behavior of the collector. El-Sebaii *et al*. (2011) carried out a theoretical and experimental study on an airheater solar collector equipped with flat and corrugated Vshaped absorbers. The theoretical results obtained are compared with the experimental ones. This is the evaluation of the thermal losses from the tests on the outlet temperature for two cases of configurations, manifold with flat absorbers and V- undulated. They concluded a good agreement between the measured and the theoretical performances.

They have also shown that a double passage manifold with a v-corrugated plate is 11-14% more efficient than a doublepass manifold with a flat plate (Kiatsiriroat *et al*., 2007). Experimentally studied the heat transfer enhancement of a flat plate solar air heater using an electric field. The aim of the study was to investigate the effect of electrode spacing and Reynolds number on the performance of the solar air heater. The experiments were conducted with and without electric field under steady state conditions with a solar radiation range between 840-1100 W/m². It was concluded that the electric field enhanced the heat transfer rate significantly at low Reynolds numbers. Othman *et al*. (2006) theoretically and experimentally studied a hybrid photovoltaic-thermal (PV/T) solar air heater. The solar air heater was a double pass system with mono crystalline silicon cells pasted on the absorber plate with fins attached on the other side of the absorber plate in the second channel. The comparisons between theoretical and experimental studies were in a good agreement with each other. Gao *et al*. (2007) Experimentally analyzed the thermal performance of cross-corrugated and flat-plate solar air heaters. Both absorbing and bottom plates of the analyzed solar air heaters were cross-corrugated to enhance the turbulence and consequently the heat transfer rate inside the air flow channel. Three solar air heaters with different designs were investigated in their study.In addition, the effects of selective coatings on the solar air heaters were investigated and it was found that the selective coatings increase thermal performance of the heaters and its use was strongly recommended for practical applications. Enibe, (2002) produced a single pass flat plate solar air heater integrated with phase change material (PCM) heat storage system. He used paraffin type prepared in modules. It was found that for solar collectors with storage, when the cumulative efficiency includes the time integral of energy it was a more useful measure of performance than the instantaneous efficiency. The peak temperature rise of the heated air was about 15K, while peak cumulative useful efficiency was about 50%. Koyuncu, (2006) studied the performance of various designs of solar air heaters for crop drying applications experimentally and theoretically. He aimed to determine a cheap an easily manufactured and a high efficiency solar air collector for low temperature, crop drying applications. Karim *et al*. (2004) conducted an experimental study to evaluate the thermal performances of three types of solar air heaters; a simple flat plate, finned and V-corrugated solar air heaters. The aim of their study was to achieve the most efficient design of solar air collector suitable for solar drying. Three types of collectors were designed, constructed and tested. Kurtbas *et al*. (2004) analyzed the efficiency and exergy of a solar air heater. In order to investigate the effect of flow line dimensions of a solar collector on its performance, an absorber was designed with four different plates. The efficiency of the collector significantly depends on the surface geometry of the collector. The pressure loss and the heat transfer increased as the roughness of the absorbe rsurface increases. Togrul *et al*. (2004) studied the performance of a solar air heater with a cylindrical absorber which is fixed to the center of a conical concentrator.

They aimed to enhance the air outlet temperature of solar air heater when compared to a flat plate collector. It was concluded that, with a conical concentrator, the efficiency and air temperature were increased to 12% and 150°C respectively. This study has been carried out to evaluate the natural convection performance of the proposed concentrating collector in the summer daytimes from July to September in Elazıgˇ (the latitude of Elazıgˇ is 38.4°), Turkey (Chantawong, 2017).This work of the study was compared the thermal performance and indoor heat gain between two small model houses GSC-HWC (Home 1) and SG (Home 2). This work reports the study on the development and thermal performance and of a multi- purpose combined glazed solar chimney and hot water collector assisted with DC fan (GSC-HWC assisted with DC fan) were conducted under the tropical climate conditions of Bangkok, Thailand (Zheng, *et al*., 2016) In this study, the thermal performance of a GTC (glazed transpired solar collector) with perforating corrugated plate was studied.

A mathematical model was developed to predict the thermal characteristics of the GTC and verified by the experimental results. Akhtar *et al*. (2012) was obtained the values of glass cover temperatures from numerical solutions of heat balance equations with and without including the effect of absorption of solar radiation in the glass cover(s) were compared. Cuce, involved an argon filled double glazed windows, which is one the most common fenestration products in the market, is numerically and experimentally analyzed in terms of U-value performance. Shakouri, (2016) was provided the data used in a research project to propose a new simplified windows rating system based on saved annual energy with developing an empirical predictive energy-rating model for windows by using Artificial Neural Network. Arıcı, *et al.* (2010)was consequences show that the optimum air layer thickness varies between about 12 and 15 mm depending on the climate zone, fuel type and base temperature and the optimum air layer thickness was obtained for three different base temperatures which are 18, 20 and 22 °C. Asphaug *et al*. (2016) were found that some double-glazed sealed insulating window panes, with aluminium spacers and Super Spacers, have been subjected to accelerated ageing by climate ageing and elevated temperature ageing. Eryener *et al*. (2017) were showed that transpired solar collector efficiency ranges from 60% to 80% and the maximum temperature rise in the collector area is found to be 16–18 °C on the typical sunny day, were compared to conventional solar tower glazed collectors, three times higher efficiency is obtained. Pérez-Grande *et al*. (2005) were studied in this work the influence of the glass properties on the performance of double-glazed facades to obtain this thermal load into the building it was necessary to solve the fluid field within the channel formed by the two layers of glass. In another work, were presented an experimental study of thin layer solar drying kinetics of Algerian bay leaves, were found the drying rate increases with the increase of air temperature and varies inversely with the drying time (Ouafi *et al*., 2016).The reports were tried to gather information about the previous and current research works in the field of thermal energy storage technology for solar air heater and dryer (Agrawal *et al*., 2016).Reports of study also analysed energy and exergy during solar drying of salted silver jewfish. Energy analysis throughout the solar drying process were estimated on the basis of the first law of thermodynamics, whereas exergy analysis during solar drying was determined on the basis of the second of law of thermodynamics (Fudholi *et al.*,2016).

The objective another work was given the fundamental information that should be known about solar sludge drying, were presented the solar sludge drying process and characteristics (An *et al*., 2017). Some review critically examines existing solar drying technologies in Uganda, highlighting design constraints and plausible solutions for supporting the growing fruit drying industry (Kiggundu *et al*., 2016). Some work reviews the most recent progress in the field of drying of agricultural food products such as new methods, new products and modeling and optimization techniques were presented (Valarmathi *et al*., 2017). The work were presented a comparative study of a solar dryer with and without multiple phase change materials (PCMs) (Sreerag, 2016).

2. Materials and methods

Experimental setup in this study a flat air solar collector with double glazing was realized. Our project is an experimental study of the Biskra site, and the essential goal minimized thermal losses to the front. For this purpose, single-glaze, solar air collector measurements should be compared with the variable-range, dual-pane solar collector measurements for multiple flow rates. Fig. 1 shows the solar collector realizes for the experimental study.

Figure 1. Solar collector realizes for the experimental study

2.1. Characteristic of the measurement site

Tests performed in a period established in the month of February to April 2016, characterized by its Saharan climate. The Biskra site is located at latitude 34 ° 38 'N and longitude 5 ° 44' E. The tests are carried out for clear days free of disturbance.

2.2. Description of the studied solar collector (Effective area)

- Length of the collector: 67 cm
- Width: 46 cm
- Absorber flat galvanized steel, painted mat shipments, equal thickness 0.4 cm
- Inclination of the sensors β= 37
- The gap, absorber - glazed equal 40 mm
- The flow is below the absorber
- The coolant is air
- The insulation is expanded polystyrene at 20 mm thickness.
- A transparent plexiglass cover 3 mm thick.

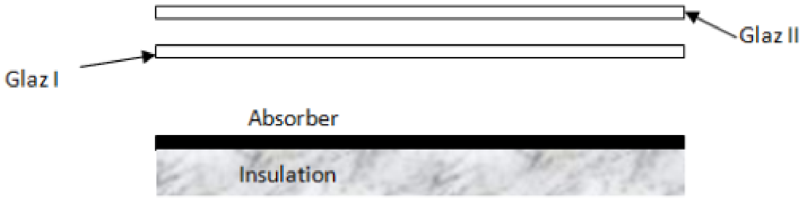

Figure 2. shows the illustration of the double-glazed

The first test uses the collector to a single glass as indicated in Figure 3.

Figure 3. Single-glaze of solar collector

The second test uses the double-glazed collector with a distance of 1cm as it is shown in Figure 4. It shows how placed the second glass of our collector. The separation between the two panes with a wooden frame its height of 1cm.

Figure 4. Solar collector with double glazing at a distance of 1cm

The third test changes the distance between the two windows to 2cm based on Figure 5. The same procedure of flat solar collector has double glass of distance of 1cm but in this case we increased the distance between the two windows to 2 cm.

Figure 5. Solar collector with double glazing at a distance of 2cm

The fourth test increased the distance to 3cm. Figure 6 shows the solar collector with double glazing at a distance of 3 cm. Moreover, Figure 6 shows the solar collector with double glazing at a distance of 3 cm and also, Figure 7 shows the air inlet holes.

Figure 6. Solar collector with double glazing at a distance of 3cm

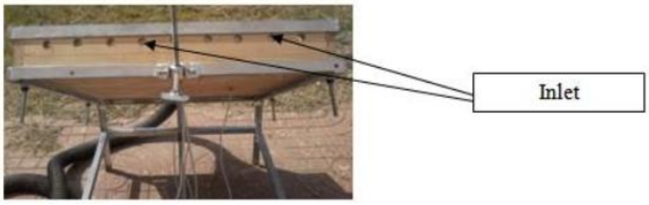

Figure 7. The air inlet holes

It is noted that the air returns to these three uses holes successively to avoid dead zones. Figure 8 represents the output of hot air.

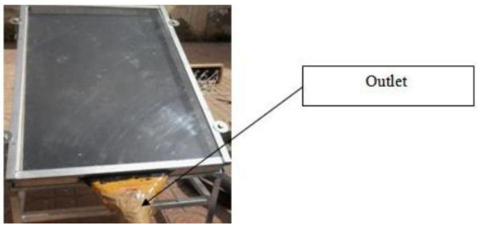

Figure 8. Hot air outlet

Each test the essential parameters are the radiation measurements, the exit and inlet temperatures, the absorber and the window temperatures. The same procedure for other flaws were performed. In addition, the measurement was done successively.

2.3. Measuring instruments

The measurement companion was carried out in the Technological Hall of the Department of Mechanical Engineering of the University of Biskra and at the roof level of our house during 3 months for 3 modes of air circulation (3 flows) in the sensor alone glass and double glass.In order to be able to minimize thermal losses forward, during each measurement day tests are taken between 9am and 4pm. In order to carry out the experiment, ten thermocouples were placed on the system, distributed as follows:

- 2 thermocouples at the sensor inlet and outlet
- 4 thermocouples at the Absorbent plate
- 4 thermocouples on the glass.

2.4. Pyranometer

The instrument used to measure global solar radiation [W/m²] PYRANOMETER type VOLTCRAFT PL-110SM, as it is shown in Figure 9.

Figure 9. Radiation measurement apparatus

2.5. Anemometer with fins

Used to measure the coolant flow rate is made at the air outlet, the anemometer use in our study The thermomagnetometry with propeller PCE -TA 30, as it is shown in Figure 10.

Figure 10. Anemometer with fins

2.6. Temperature measurement

Temperature measurements at the inlet, outlet, the absorber and windows are made using probes such as: digital thermometer TPM-10. The acquisition of temperatures is made through a set of 10 probes, 2 probes for the input and output of the sensor, 4 probes for the absorber and 4 probes for the glass (Figure 11).

Figure 11. Digital thermometer tpm-10

3. Results and discussion

Daily variations in global solar radiation and different temperatures for mass flow m = 0.0025 kg/s. Table 1 shows the measurements of ambient temperature and the wind speed for the measurement days (9h to 17h) correspond to the flow 0.0025 kg/s. The day of 16-03-2016 the wind speed is high compared to the other days.

Table 1. Ambient temperatures and measured wind speed correspond to m = 0.0025 kg/s

15-03-2016			16-03-2016		17-03-2016		19-03-2016	
Temps (h)	T_{amb} (°C)	V_{vent} (km/h)	T_{amb} (°C)	V_{vent} (km/h)	T_{amb} (ºC)	V_{vent} (km/h)	T_{amb} (°C)	V_{vent} (km/h)
9	19	8	25	26	21	2	17	22
10	20.5	9	21.6	33	22.5	0	20.2	37
11	23	9	23	37	23	9	22	33
12	24	7	25	30	25	7	24	37
13	25	19	26	30	25	15	24.5	30
14	27	15	27	33	25	15	26	24
15	28	18	29	37	27	22	27	22
16	27	20	28.5	33	27	26	27	22
17	27	26	28	33	27	26	27	19

Table 2 shows the global solar radiation data and the average temperatures measured correspond to the absorbing plate and the single-pane SAH glass in the day selected from 9:00 am to 3:00 pm, the measurement step is selected at 20 minutes. It is noted that the average temperature of the glass is high almost 33% of the temperature of the absorber.

Table 3 shows the measurement of the solar collector with double glass at a distance of 1cm corresponds to the day of 17-03-2016. It is noted that the values of the radiation are disturbed in each time high and decreases because the type of sky is partial. The average temperature of the absorber is also increased with respect to the temperature of the single pane.

Table 2. Temporal data of temperature and global solar radiation (ONLY GLASS)

Only glass 15/03/2016 m = 0.0025 kg/s					
Temps (h)	G (W/m²)	T_s (°C)	T_e (°C)	T_{ab} (°C)	T_v (°C)
9.28	320	38.5	25,6	58.3	31.95
9.61	359	42.2	32,6	67.85	31.55
9.94	800	45	30,8	71.25	33.925
10.28	774	44.7	32,2	73.42	33.12
10.61	818	46.6	33,3	76.62	33.87
10.94	839	50.8	34,9	79.65	35.97
11.28	858	48.9	35,5	81.17	36.82
11.61	916	54.4	38,3	83.92	34.9
11.94	796	46.2	33,3	74.82	39.2
12.28	701	42.4	32,1	67.92	38.67
12.61	733	39.9	28,1	63.87	39.37
12.94	766	44.1	29,3	60.95	38.82
13.27	735	44.1	32,9	67.85	40.67
13.61	544	46.4	32,3	68.62	42.22
13.94	849	46.3	34,3	67.07	41.7
14.27	935	51.9	37,2	73.65	44.27
14.61	806	45.9	34,5	68.87	43.5

Table 3. The temporal data of the temperature and the global radiation in the double-glazed case correspond to the distance 1 cm

Double glazed (Distance 1 cm) 16/03/2016 m = 0.0025kg/s					
Temps (h)	G (W/m²)	T_s (°C)	T_e (°C)	T_{ab} (°C)	T_v (°C)
9.61	576	42.8	28,7	57.17	32.22
9.95	495	45.5	29,1	61.85	33.75
10.28	677	47.4	30,2	66.95	34.22
10.61	445	47.8	28,2	68.4	36.12
10.95	601	46.2	27,7	65.62	37.25
11.28	780	52.7	31,8	75.97	36.85
11.62	893	52.9	32	76.97	38.45
11.95	554	51.9	30,1	77.87	40.27
12.28	825	58.1	34	86.45	36.87
12.62	683	58.3	35	87.5	34.62
12.95	979	62.2	37,1	92.07	31.65
13.28	560	56.7	32,4	82.9	31.47
13.61	968	59.2	37,4	89.45	34.1
13.94	915	62.2	39	93.95	34.65
14.28	1063	67.6	40,8	103.4	35.75
14.61	1012	66.4	41	104.57	37
14.94	950	69.6	41	104.07	35.45

The data from Table 4 show that the average temperature of the absorber is high when solar radiation increases. It was also noted from the data in Table 3 that the average temperature of the absorber of the solar collector has double glass at a distance of 1cm is lower compared to the solar collector has double glass at a distance of 2cm and also the temperature average of the glass decreases according to the flow 0.0025 kg / s.

Table 4. The temporal data of the temperature and the global radiation, according to the double-glazed case correspond the distance 2 cm

Double glazed (Distance 2 cm) 17/03/2016 m = 0.0025 kg/s					
Temps (h)	G (W/m²)	T_s (°C)	T_e (°C)	T_{ab} (°C)	T_v (°C)
10.28	811	36.9	23,6	60.1	22.92
10.61	569	35.4	25	57.52	23.8
10.94	412	36.7	25,1	61.65	25.02
11.28	807	41.1	28,5	64.7	26.45
11.61	825	42.2	29,6	71.47	28.6
11.94	457	38.4	25,2	61.55	28.85
12.28	685	40.8	27,1	63.77	30.35
12.61	1013	48.1	32,6	76.95	29.55
12.94	1079	53.5	31,9	81	31.2
13.28	991	49.8	31,3	79.37	30.57
13.61	990	52.1	37	89.1	31.97
13.94	1067	54.4	36,4	79.2	33.32
14.28	734	50.1	33,1	77.35	34.37
14.61	663	52.6	35	78.2	34.35
14.94	668	47.9	31,5	72.87	33.3
15.28	332	53.4	34,7	81	33.65
15.61	589	44.3	28,6	67.22	33.52
15.94	476	42.2	29,6	62.85	33.87

It was also noticed that the values of radiation almost remain stable. It is also noted that the average outlet temperature increases successively to about 62.9 ° C, against the average glass temperature decreases also successively reached 21.27 ° C. It has been found that the temperature difference is high and the losses towards the front are minimized (Table 5).

Table 5. The temporal data of the temperature and the global radiation, according to the double-glazed case correspond to the distance 3 cm

Double glazed (Distance 3 cm) 19/03/2016 m = 0.0025 kg/s					
Temps (h)	G (W/m²)	T_s (°C)	T_e (°C)	T_{ab} (°C)	T_v (°C)
9.61	565	31.4	25,9	41.8	21.27
9.95	622	33.4	26,5	46.92	21.92
10.28	608	36.5	27,5	52.92	22.92
10.61	690	39.2	29,1	59.6	23.57
10.94	810	41.5	30,2	65.2	25.07
11.28	846	44.9	31,7	70.67	25.37
11.61	896	49.5	32,4	76.5	27.75
11.94	908	51.3	34	85.17	27.15
12.28	936	53.3	32,4	83.77	28.1
12.61	955	53.1	33,9	85.17	27.15
12.94	978	53.4	34,4	85.02	28.1
13.28	989	56.4	34,7	89.4	29.52
13.61	980	57.1	35,3	90.32	30.8
13.94	979	58.7	37	91.07	30.62
14.28	965	62.9	38	92.05	31.87
14.61	956	61.8	36,9	91.7	32.22
14.94	935	60.2	31,6	90.5	32.32
15.28	872	58.8	36,7	87.7	32.22
15.61	821	58	35,7	85.15	31.6
15.94	794	55.9	32,9	81.27	31.12
16.27	697	51.3	32,1	74.05	30.57
16.60	615	49.8	25,9	69.7	29.55

4. Conclusion

The current study is an experimental contribution to the study of minimizing forward thermal losses on a solar air collector in the Biskra site. To minimize forward thermal losses the experimental model used is based on the addition of second pane and the increase in distance between the two panes. The study was carried out for the comparison between the average absorber temperature, glass and the outlet temperature and the efficiency of the single-window and double-glazed air-cooled solar collector with variable distance (1cm, 2cm and 3cm). Correspond to the three flow rates used. Experimental results show that the addition of second glazes is effective in minimizing forward thermal losses for a solar air collector. The results obtained from the experimental readings show that the minimization of thermal losses forward is a very important factor for improving the performance of a solar collector.

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Abbreviations

Temps	Time of the day (hour)
G	Global solar radiation (W/m²)
Ts	Outlet temperature (°C)
Te	Inlet temperature (°C)
Tab	Temperaure of an absorber plate (°C)
Tv	Temperature of cover plate (°C)
Tamb	Ambient temperature (°C)
Vvent	Wind speed (km/h)
m	Mass flow rate (kg/s)