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# An experimental study of a new solar air heater with a Linear Fresnel Reflector

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***Abstract*—In this experimental study two solar technologies concentration and the flat plate collector were combined in one solar air heater with a Linear Fresnel Reflector (SAHF). A rectangular useful duct with 2.32 [m] length and 0.2 [m] width is equipped with and without artificial roughness. This roughness has wrought of steel galvanized 0.4 [mm] thickness to create a turbulent flow of air and ensure a good heat transfer. An experimental study have started to improve the SAHF collector efficiency especially for the drying and heating process. The measured parameters were the ambient, inlet and outlet temperatures, the absorber plate temperatures, and the solar radiation. All this measured have performed at different values of mass flow rate of air. The results show that we can go to a higher outlet temperature of air about 150 °C.**

***Keywords*— Fresnel, Solar collector with concentration, heat transfer, roughness artificial.***

## INTRODUCTION

In Algeria, eighty percent (80%)of the economics of the country dependent on oil and gas exports that cause a serious economic problems in the future. Therefore, the development of renewable energy become a particular emergency to give solution to the rising energy demand and reduction the $CO_2$ emission.

Heating house and drying agricultural products are tow processes widespread in the Algerian countryside, because the agricultural nature of this desert rural area.

Integrate renewable energy by conversion of the sun energy is very easy and less expensive compared by the cost of the conventional electric and gas connection.

Both flat plate and concentration collector have used to either produce domestic water or generate the electricity combined with conventional process.

Number of researches is going on to improve the performance of flat plate air heater and the linear Fresnel reflector, in order to optimized the performance and the heat transfer in a rectangular useful duct used in Linear Fresnel Reflector. L.S, Panna et al [1] have carried an experiment study about a Linear Fresnel Reflector, with trapezoidal cavity absorbers, was provided with two types of pipe absorber respectively used round and rectangular. In this experimental study, they have studied experimentally at different concentration ratio, the results obtained presence that the thermal efficiency of round pipe has found higher, almost 8% as compared to rectangular pipe absorber. N, Velázquez et al [2], through a numerical simulation of a Linear Fresnel Reflector use as a solar cooling, have tried to understand the effect of design parameters on the thermal performance of the refrigeration system. The analysis of the heat balance in absorber has developed by a theoretical model, then validated by experimental results. H, Esen[3] has been carried an experimental energy and exergy analysis with different values of mass flow rate of air, three different types of absorber two with several obstacles, and one without obstacles, with a double-flow of air over and under of the absorbers, he was fined that for all operating condition the absorber with obstacles batter than that without. The optimal position was find in the middle to get optimal efficiency.

In our experimental study, we investigate the effect of design parameters on the thermal performance of the SAHF considered, including, the outlet temperature of air flowing, and the change in the temperature of the three different types of the absorber in the useful rectangular duct, with a simple flow of air over the absorbers, as well as the thermal efficiency.

Our objective in this study is to combine this tow technology, solar concentration and flat plat collector, in one solar air heater with a linear Fresnel reflector SAHF and compared it with the old technologies.

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Figure 1: Solar air heater with a Linear Fresnel Reflector (SAHF) with rectangular useful duct absorber.

By adopting the method by section and application of the electric analogy on the absorber, in the Figure 2, the conservation equations of energy give us:

$$(h_{r,p-v} + h_{c,f-v} + U_{av})T_v - (h_{r,p-v})T_p - h_{c,f-v}T_f = \alpha_v \rho \gamma I_g \mathrm{CR} + U_{av}T_a \quad (2)$$

$$-(h_{r,p-v})T_v + (h_{c,(p+ch)-f} + h_{r,p-v} + U_{arr})T_p - h_{c,(p+ch)-f}T_f = \tau_v \alpha_p (1{,}01)\rho\gamma\, I_g CR + U_{arr}T_a \quad (3)$$

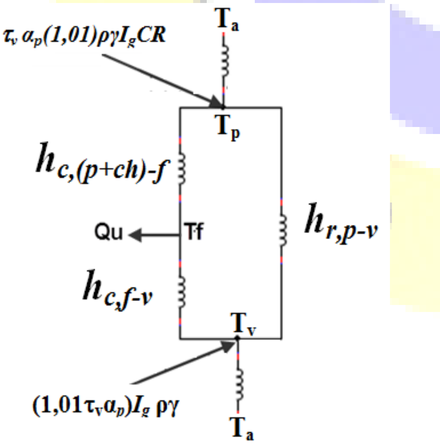


Figure 2 : Electric diagram is equivalent relative to a section of the useful conduit.

$$h_{c,f-v}T_v + h_{c,(p+ch)-f}T_p - \left(h_{c,f-v} + h_{c,(p+ch)-f} + 2\dot{m}\, {Cp}/{A}\right)T_f = \left[2\dot{m}\, {Cp}/{A}\right] \times T_{fe} \quad (4)$$

After mathematical simplifications, the expression of the power output brought by the air will be written as follows [3]:

$$Q_u = AF_R\left[(\tau_V \alpha_P (1{,}01)\rho\, \gamma\, I_g CR) - U_L(T_{fe} - T_a)\right] \quad (5)$$

The temperature [3] of the exit of air whose useful conduit is length L has expressed by

$$\left. T_{fs} - T_a - \frac{\tau_v \alpha_p (1{,}01)\rho\, \gamma\, I_g CR}{U_L} \middle/ T_{fe} - T_a - \frac{\tau_v \alpha_p (1{,}01)\rho\, \gamma\, I_g CR}{U_L} \right. = exp\left(-\frac{l\, F' U_L\, L}{\dot{m}Cp}\right) \quad (6)$$

The heat transfer coefficient $h_{(p+ch)-f}$ resulted in the useful conduit between the absorber and the heat transfer fluid is usually expressed by the average the Nusselt number [3]:

$$h_{(p+ch)-f} = \left[Nu \times \lambda_f\right]/D_H \quad (7)$$

In working conditions considered, we adopted three correlations of the Nusselt number based on the flow regime, which leads useful is equipped with artificial roughness Figure 5.

A. For 1900 ≤ Re ≤2300, we use the correlation of employment RP Saini and JS Saini [4, 5]:

$$Nu = 4 \times 10^{-4} \times Re^{1{,}22}\left[\frac{a_{ch}}{D_H}\right]^{0{,}625}\left[\frac{s}{10.a_{ch}}\right]^{2{,}22}\left[\frac{b_{ch}}{10.a_{ch}}\right]^{2{,}26} exp\left[-1{,}25.\ln\left(\frac{s}{10.a_{ch}}\right)^2\right] exp\left[-0{,}824.\ln\right. \quad (8)$$

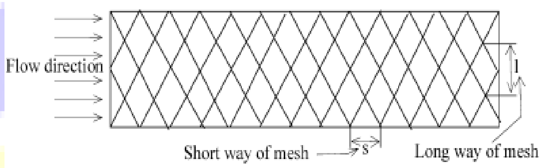


Figure 3 : Grid of artificial roughness [5].

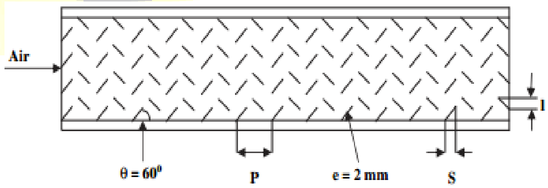


Figure 4 : Roughness in a rectangular channel [6].

B. For 2300 ≤ Re <4000, The correlation of Kays [3] seems more convenient:

$$\mathrm{Nu} = 0,0158\ \mathrm{Re}^{0,8} \text{for } L/D_H > 10 \quad (9)$$

*C.* For 4000 ≤ Re ≤ 17000, we adopt the correlation Karmare and Tikekar (2007) [6], whose arrangement of the fins is similar to the model considered Figure 4.

$$\mathrm{Nu} = 2,4 \times \mathrm{Re}^{1,3} \left[a_{ch}/D_H\right]^{0,42} \left[l/s\right]^{-0,146} \left[p/a_{ch}\right]^{-0,27} \quad (10)$$

With, Re the Reynolds number expressed by:

$$Re = V_f\, D_H/\nu_f \quad (11)$$

Where $D_H$ corresponds to the hydraulic diameter are equivalent of the absorbent useful conduit:

$$D_H = \frac{4.A_f}{P_m} = 2.(l.e - n_{ch}a_{ch}b_{ch}) / \left(l + e + n_{ch}(a_{ch})\right) \quad (12)$$

The thermal efficiency of the sensor has indicated by the ratio of the useful power conveyed by the fluid, solar energy concentrated by the mirrors of the Fresnel concentrator:

$$\eta_{th} = Q_u / \left(\tau_v \alpha_p (1{,}01) \rho \gamma I_g CR\right) \times S_{Cap}$$

EXPERIMENTAL PROTOTYPE

The experimental device appears in **Erreur ! Source du renvoi introuvable.**; was builded in the Laboratoire de GénieMécanique (LGM) of the University of Mohamed Khiader of Biskra, whose dimensions geometrical and constituent elements were shown in Table 1Table 1.

Three configurations of absorbers were study. A rectangular duct was equipped with two different artificial roughness and a plane plate absorber of steel, as three cases of absorbers, were tested in the same operational condition. Thereafter this duct was placed in the linear focal of a Fresnel reflector. Where we have placed, two thermocouples in the inlet and the outlet of the duct to measure the temperature of the air heater. Moreover, four other thermocouples was placed into the absorber to measure the temperature of the absorber in the inlet, outlet and the middle of the absorber as show in Figure 5.

As shown in Figure 5, an illustration of the distribution of the thermocouples, where do we find them as follows: T1 and T2 represent air inlet and outlet temperatures respectively, and T3, T4 and T5 represent the absorber temperatures.

Table 1 : Dimensions of Linear Fresnel reflector.

| Designation | Dimension [m] |
|---|---|
| Length of useful duct absorber [L] | 2.32 |
| Width of the concentrator [Lar] | 1.18 |
| Number of mirrors [n] | 80 |
| Width of e each mirrors | 0.1 |
| Focal distance [f] | 1 |
| Width of the absorber duct [l] | 0.23 |
| Thickness of useful duct absorber [e] | 0.05 |
| Height of artificial roughness [a] | 0.045 |
| Space between artificial roughness [b] | 0.01 |
| Thickness of the walls out of wood isolate | 0.012 |

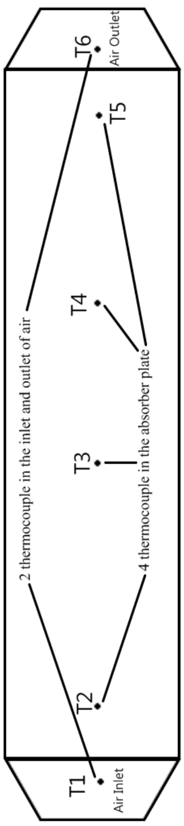


Figure 5: Illustration of the thermocouples position in the duct.

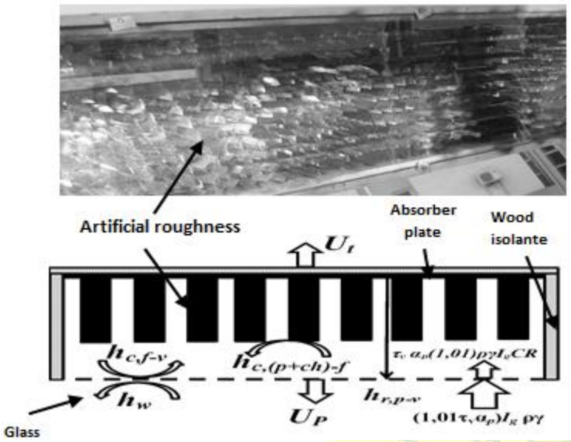

Figure 6: The useful duct absorber with the schema of heat exchange inside it.

The whole of the system, the linear Fresnel reflector and the rectangular duct moving together from EST to the West to tracking the trajectory of the sun with a manual mechanism.

The experimental study presented in this work is carried out in the open air near of the technological hall, of the Laboratory of Mechanical engineering inside the University of Mohamed Kaider of Biskra.

The measurement data are registered at an average interval of 15 min, the experimental protocol need to use the following devices of measurement:

- Electronic pyranometerKipp& standard Zonen CM 11 with 1 % accuracy for the measurement of the solar radiation adaptable on a horizontal and inclined surface.
- Digital k-type thermocouples with an accuracy of (0.01 °C) with range the (0 to 400 °C), for the measurement of the temperature of the air at the inlet and the outlet of the useful duct absorber.
- Pressure transducer accuracy (Kimo CP301) with ±1 Pa and 0.5% of reading.

KIMO Multifunction Anemometer model VT300 with ± 3 % of reading and ±10 $m^3$ for the flow rate measurement and ± 3 % of reading and ± 0.1 m/s accuracy were used.

## RESULTS:

The results resulting from the experiments made it possible to follow the evolution of the thermal performances of the Fresnel concentrator, in particularly the outlet temperature the air heater compared to that measured at the inlet of the useful duct, as well as the thermal efficiency

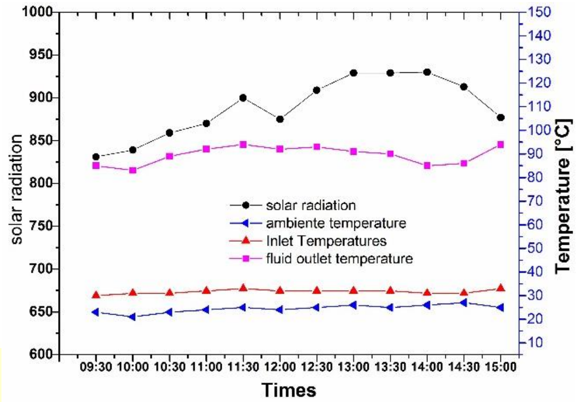

Figure 7 : Evaluation of solar radiation and temperature versus time.

Shawn in Figure 7 the solar radiation, ambient, inlet and outlet temperature versus daytime. It seems that outlet air temperatures is increase with solar radiation and the maximum values is at midday.

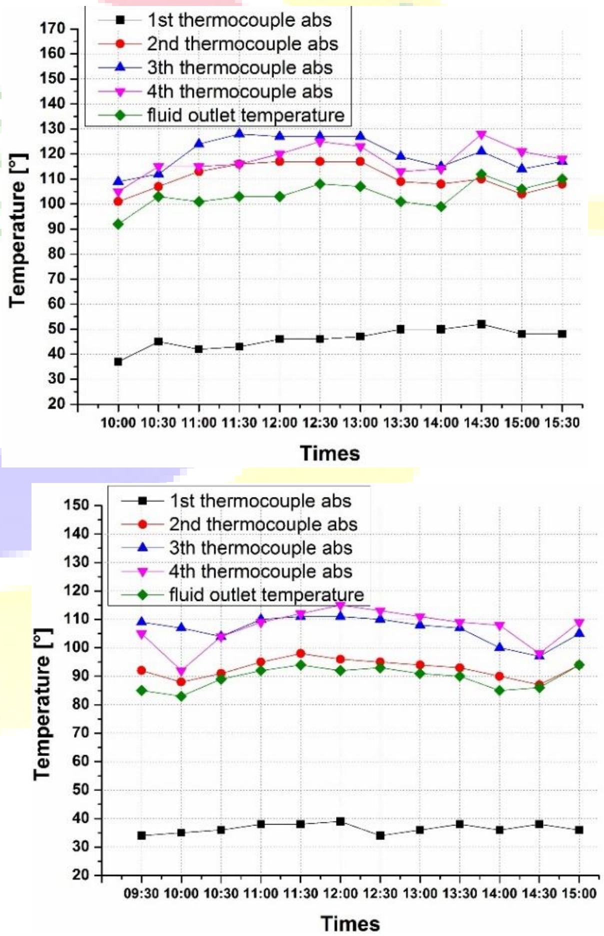

Figure 8 : Evolution of temperatures versus time for 14.05.14 and 15.05.14.

The experimental resultants presented in this section has been shown that the outlet temperature of air heater closer to the 2nd thermocouple placed in the absorber plate, and at hole the evaluation of the temperatures take the same trend and orient.

## CONCLUSION:

Taking into account the temperatures recorded during the operation tests, which were usually between 90 and 100 ° C, this opens up the field for use in drying processes and so are suitable for heating in cold weather in the winter. Moreover, if we compared the SAHF to the solar flat plat, we can find it very effective and do not require considerable space compared to the flat plat collector.

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