IMPROVING THE PERFORMANCES OF A SOLAR CYLINDRICAL PARABOLIC DUAL REFLECTION FRESNEL MIROR (EXPERIMENTAL PART)

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ABSTRACT

The use of solar energy is not only related to its economic benefits, but also for its role in environment protection, for which we have to find solutions to pollution problems (Clean energy). In nature, there are several sources of renewable energy including the solar. Nowadays, thermal Solar is technically reliable and many achievements have been accomplished (solar water heaters, solar homes, solar collectors...etc.). For the realisation of a solar thermal concentrator, we have tried to minimise losses in order to increase performance. The work done focuses on an experimental study, which consists of converting solar radiation into thermal energy using a cylindrical parabolic solar concentrator. The experiment has been conducted on a sample prototype for concentration with an opening of $4m^2$. This prototype is set up in the laboratory of mechanics using local means. In the first experiment, we have tested the focal line of two cylindrically shaped iron receivers of 1.8 cm in diameter and 1m in length, located in the focal line the collector to accumulate concentrated solar power. The first receiver is covered by an auxiliary reflector (2nd reflector), the second with a free opening. The development of a simple theoretical model can estimate the global solar irradiance at the reflector. To measure the wind speed, we have used an anemometer. The other parameters have been measured, including the temperatures (thermocouple). The overall system is the subject of a numerical computer simulation. The software (myPCLab) is designed for this purpose. It controls the whole device and ensures the acquisition of certain parameters by means of a recorder communicating with a computer. In the second experiment, we have focused on the temperature differences (input - output) of water and oil (SAE 15W40 Total quartz), the temperature variation obtained is of the order of 75C°. The developed theoretical model involves a number of parameters such as the average monthly solar radiation that allows us to estimate the direct radiation at the reflector, the geometrical concentration and exchange of heat between the opening of the collector and the the receiver, allows the evaluation of the temperature at the latter. This model of concentration leads to levels of temperatures between 70C° to 200C°.

Keywords: solar energy - cylindrical parabolic concentrator double reflection - Thermal solar

1. INTRODUCTION

Solar heat capturing is one of the valuation techniques of direct solar irradiation mostly used. This technology is conceived to concentrate solar radiation in order to heat a working fluid to a high-temperature to feed industrial processes. The solar thermal power plants cover wide variety of available systems, since the concentration of radiation systems to the choice of coolant or storage mode.
In a solar insulator, the conversion of energy (solar / thermal) at the absorber may constitute a significant contribution to a wide variety of industrial heating applications, thermo-mechanical and thermo-chemical provided that the conversion efficiency can reach maximum values. This is relatively a wide range of temperatures which can be summarized in four categories of applications depending on the temperature [1] : Applications at low temperatures (T < 60°C) such as domestic hot water. Applications at medium temperatures (60°C < T < 150°C), applications at high temperatures (150°C < T < 800°C) and applications at very high temperatures (T > 800°C) .

Currently, most solar power plants under construction are either based on collecting through a cylindrical parabolic or other innovative competitors with potential concentrators based on linear Fresnel mirrors. It is the association of both technologies that constructs a new solar concentrator that we are studying experimentally here. This method applies to a wide range of powers from kW to GW. It is simpler and more robust than the method based on the use of cylindrical parabolic which allows reduced costs. The cylindrical parabolic concentrator is the most used receiver to work on well brought up temperatures, where it is necessary to pick up at the farthest the incidental flux which could be accomplished by concentration of the solar radiation with the elimination of thermal losses at the level of the absorber, which is the objective of our study. This study is accomplished at the level of the laboratory of mechanics started with the realisation of a small experimental installation of a cylindrical parabolic receiver composed of a main reflector and another assistant helper which has as function to recover the solar radiation sent by the main reflector and not recovered by the absorber which is appealed 'double cogitation '. The accomplished auxiliary in-situ reflector is a concentrator with Fresnel mirrors under cylindrical parabolic form, disposed around the absorber to recover, not absorbed radiance with an implement which will be aimed at assessing thermal parameters (radiance, different stocks of temperature), which allows to calculate the stocks of thermal outputs of the installation in different conditions and to make comparisons and to draw conclusions.

2. OPERATION OF A SOLAR COLLECTOR PARABOLIC

In the comprehension of a collector with effect of concentration, one has to call upon techniques more or less complex principle which consists in focalizing incidental radiance on an absorber, of which the very small surface in comparison with the surface of opening of the collector, to augment the concentration of radiance at the level of the absorber. Flat collectors use the diffused radiance coming from the sky and from the soil, by concentrators uses only direct radiance. The following figure shows the principle of capture by both types of thermal conversion of solar energy [2].

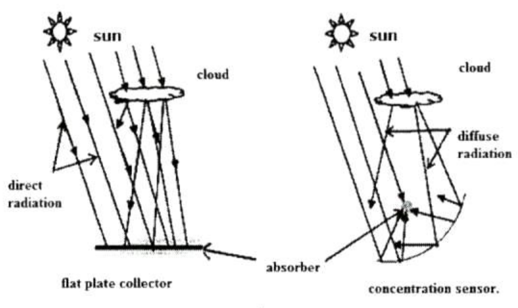

Figure 1, Schematization principle of solar radiation collection.

2.2 Operating principle

The cylindrical parabolic receiver turns to the sun by dint of an implement which concentrates the solar radiation at the level of the absorber (bar, tube).The heat transfer fluid (water or oil in this case) circulates in the tubes of the absorber, while capturing the maximum energy.

Figure 2 : Operating principle of the hub.

The cylindrical parabolic concentrator is the best for its production of water steam at high temperatures which can be acquired without impairment of output. It is made of a reflector (mirror or reflective material) in cylindrical parabolic form .This geometry allows to focalize incidental solar energy to a linear generator where is put a tube in which a coolant circulates that absorbs heat. To augment the quantity of picked up energy and favor the process of the transfer of warmth by radiance, to reduce the losses of radiance, we make appeal in general to selective surfaces or an often glassy transparent plate put above the absorber to reduce thermal losses by radiance and by convection towards the outside. For a (CPR),the geometric general equation, in Cartesian coordinates, is written

$$y = a^0 . x^2 = \frac{1}{4.F} .x^2 \qquad (1)$$

And polar coordinates, is written :

$$r = \frac{F}{\cos^2\left(\frac{\Theta}{2}\right)} \qquad (2)$$

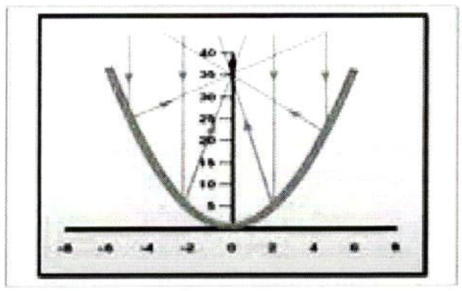

Figure 3 : Position of the focus of a parabolic trough concentrator.

The opening of the concentrator according to the opening angle (Θ) is given by the equation

$$a = 2.r.\sin(\Theta) = 4.F \tan(\frac{\Theta}{2}) \qquad (3)$$

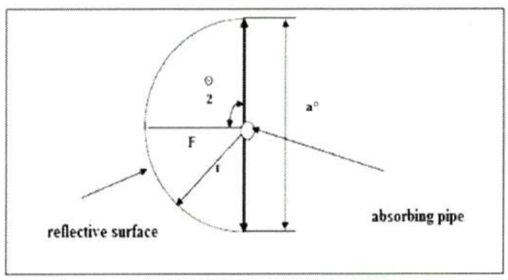

Figure.4: Sizing a parabolic sensor

2.3 Geometric concentration factor [4]

The most common definition of the rate of concentration is based on the concept of surface. It is given as the ratio of opening area to the receiver area.

$$C = \frac{A_{ref}}{A_{abs}}$$

3. EXPERIMENTAL STUDY

In this section, we introduce the description of the elements which compose the cylindrical parabolic concentrator with double cogitation, as well as different stages of realization.

The realization of this installation has been made at the level of the workshop of the Department of Mechanical Engineering at the University of Amar Telidji Laghouat.

Effect of scale and efficiency.For a given radiation, the potency of the receiver is a function of the effective surface of the mirror, but for small sizes, it is necessary to take into account a reduction of efficiency due to a prejudicial effect of scale, noted in particular in the case of small receiver 2m2. In the bottom, there is a minimum critical size (common phenomenon in thermal) and the model with a few dm2 mirror, has no thermal power.

Scale effect and temperature level.The scale effect is also sensitive to the temperature level achieved (Whereas in a first time, we would tend to consider only the dual concentration-temperature). Thus, the temperature level of the mod model is insignificant. The major problem of solar collectors is not reclaiming solar energy, but also to avoid losses.

The width / length of the mirror. From the design of the receiver, it must consider ratios such as that between the total hot surfaces (that is to say all surfaces lose heat, whether insulated or not), and mirror surface supplying heat.
However, the ratio between the width and length of the mirror, directly affects the previous ratio: a receiver in long narrow mirror will have as many losses as production.

3.1 Installation of main and auxiliary reflectors

To have very well brought up temperatures, we use in general The cylindrical parabolic receiver which can be introduced as a module having a reflector of parabolic form of cylindrical disposition sized according to following "Equation.(4)".

$$C = \frac{A_{ref}}{A_{abs}} \tag{4}$$

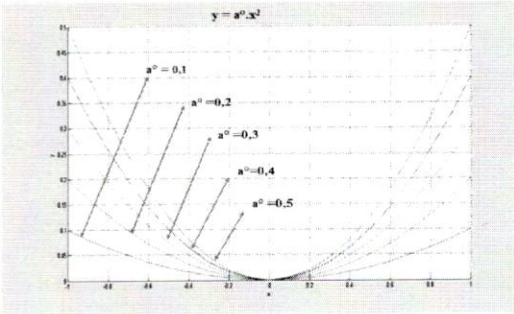

Figure 5: several choices of parabolic curves

Once geometric parameters are undertaken, the realization of the main and auxiliary reflectors is possible.

3.2 Realization of the auxiliary reflector

To be able to make a comparative study, the absorber is a compound of two parts one is covered by the auxiliary reflector and the other is left free. Each of the two parts is 1 m in length, and 18 mm in diameter.

The auxiliary reflector is a parabolic cylindrical reflector which was made following the same steps as the main reflector with a difference in height. As the internal covering of the auxiliary reflector is made with blades of mirrors (mirrors Fresnel) on the contrary, the main reflector is covered by a coat of aluminum

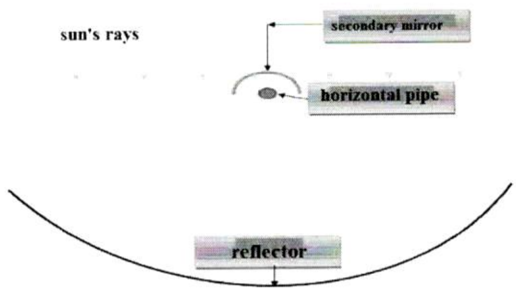

Figure 6: study of the auxiliary reflector

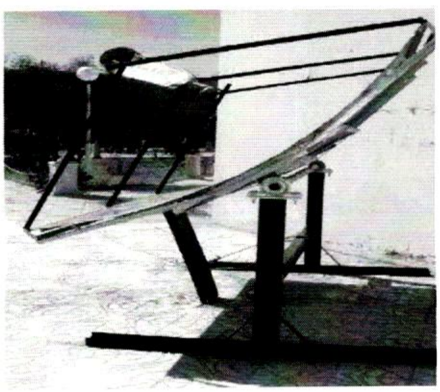

Figure.7: The complete installation in the experimental site

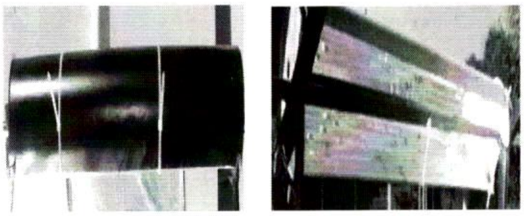

Figure.8: The inner and outer faces of the auxiliary reflector

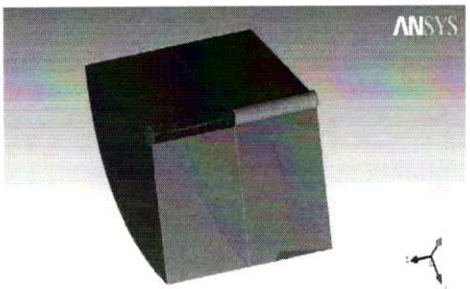

Figure 9: geometric model of the prototype

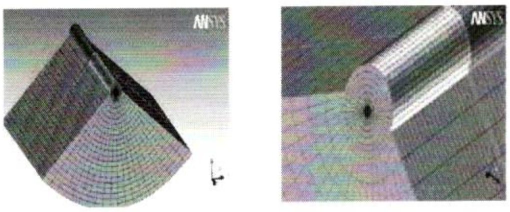

Figure.10 : mesh geometry (overview) and Mesh geometry vertical view

For the first measurements, the absorber is a cylindrical iron bar of 1,8cm diameter and of 1 m length and for the others, the absorber is a brass cylindrical tube of form U, of 3m of complete length, and 10mm of diameter Where circulates a working fluid (water) [5] which a priori is a fluid of ideal transfer. It gives a very good coefficient of exchange and has a strong thermal capacity. Besides, it can be directly used as a working fluid for the thermodynamics cycle of Rankine. However its use implicates to work on very well brought up pressures in receivers, owing to high attained temperatures, what poses problem for cylindrical parabolic technologies.
The absorber is painted in black to augment the quantity of recovered warmth. The acquisition of data is made with the aid of a software mypclab which shows measurements numerically directly on a PC

3.3 Performance

The effectiveness of this prototype is calculated as follows [5]:

$$\eta = \frac{Q_u}{G.A_{ref}} \tag{5}$$

For the Storage system

$$Q_P = M_P.C_P.\frac{dt_p}{dt} \tag{6}$$

$$M_P = V_P.\rho_P = l.\pi.\frac{D_p^2}{dt}.\rho_p \tag{7}$$

To the recovery system

$$Q_f = M_f.C_f.\frac{dt_f}{dt} \tag{8}$$

$$Q_{u\,f} = \dot{m}_f.C_f.(T_S - T_e) \tag{9}$$

4 EXPERIMENTAL PROCEDURE

The installation of a cylindral parabolic concentrator with double cogitation demands an optimum incline, in general equal to the degree of latitude of the place and oriented southward. This type of installation is called stationary concentrator [6].
The climate is the only parameter influencing the choice of test day, because we have conducted several tries in type days [3]

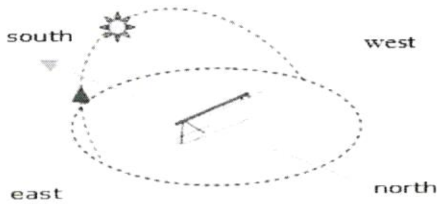

Figure 11: Stationary concentrator facing south

Solar coverage .By being based on the characteristics of elements constituting the system and on meteorological data, we can determine the surface of the receiver according to the given solar power. Receivers under are orientated to the south with an incline of 30 °.

Figure 11 represents the variation of the solar coverage rate for 12 months of seasons according to the number of receivers[3]. By the use of a solarimeter fixed on the surface of the receiver we acquired. Figure 12 represents the variation of the solar coverage rate of seasons along the year.

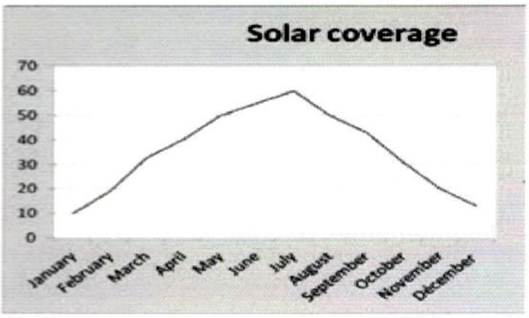

Figure 12: Solar coverage in Laghouat region

Effect of moisture on the transfer at the absorber.The solar cylindrical parabolic receiver (CPR) is the best option at present for the industrial applications working in a range of temperature going from 150 to 400 °C [8]. Numerous studies are performed to ameliorate the performances of the CPR particularly the minimization of thermal losses at the level of the receiver and its envelope. CPR in vacuum or in weak pressures in the annular space receiver envelope gives the best thermal output certainly. However, the expense of manufacture and service is well brought up. So, the most part of the CPR works in climatic conditions where they are installed. The study of the effect of moisture shows that this one affects the performances of a CPR by the increase of thermal losses. This is explained by the participation of moist air to radiative transfer. Numerical results also showed that at low temperatures the thermal losses are greater than at high temperatures [9].

4.1 Experimental results

Under the effect of climatic conditions. In normal conditions and without special dispositions, to test the functioning of this new installation, we compare results acquired by double reflection installation with another one simple, both with an iron bar of 1 m of length as absorber. Bars that have being subjected to the solar radiation for 10 h at 15 h under the direct effect of climatic condition especially the wind each 15 minutes. For a typical day (sunny day), we have recorded the following results.

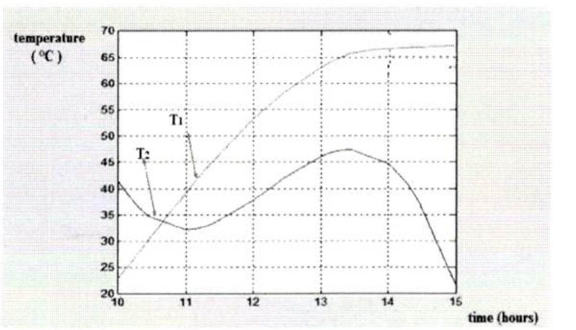

Figure 13: Variation of the temperature T1 of the absorber (bar housed) and the absorber T2 (the unsheltered bar) versus time for type windy day.

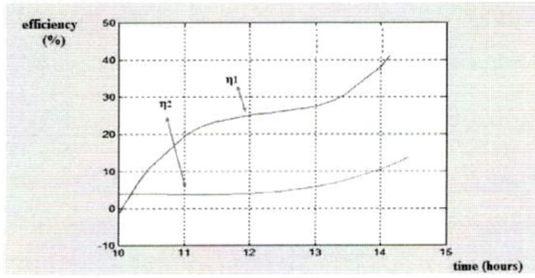

Figure 14: Comparison of temperatures collected in both bars with and without the auxiliary reflector for day portrays ineffectual of the wind.

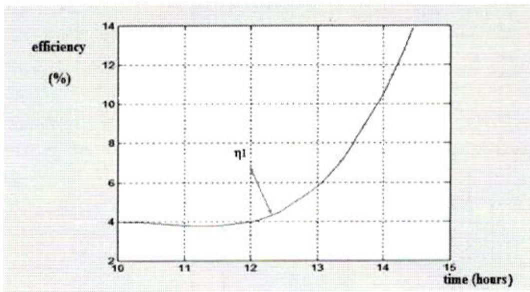

Figure 15: Variation of output according to time for day: In 21/02/2013

Without the effect of climatic conditions.To augment the output, it is necessary to benefit from greenhouse effect and reduce the effect of the wind by covering the auxiliary concentrator. Recorded results are compared with those acquired by another implement without secondary reflector showed by the curve in figure 14. And efficiency in figure 15 where T1 is the temperature of the bar not subjected to the effect of the auxiliary reflector. T2 of the other one subjected to the effect of auxiliary concentrator [8].

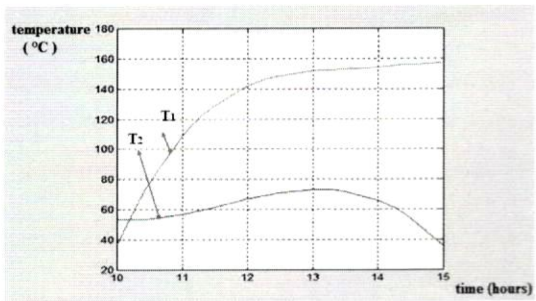

Figure 16: Variation of the temperatures T1 and T2 with time.

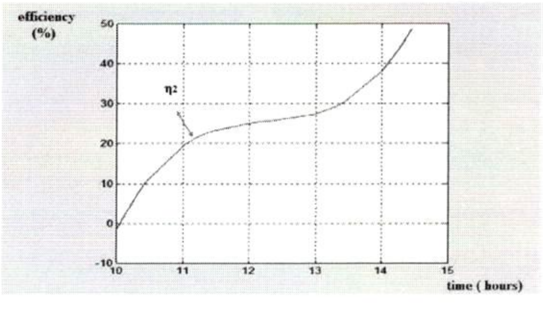

Figure 17: Variation of efficiency 2 according to time

Effect of the auxiliary reflector only (Case of the bar)

To compare results acquired from two absorbers (bar) under the auxiliary reflector. The one subjected to both reflectors (the principal and the assistant helper) and the other one with the auxiliary reflector only, because we have put at the bottom of the absorber a wooden bar to eliminate the expulsions of the main reflector bars being subjected to the solar radiation for 10 h to15 h with an interval of 15 minutes. For a winter day (12/02/2013).

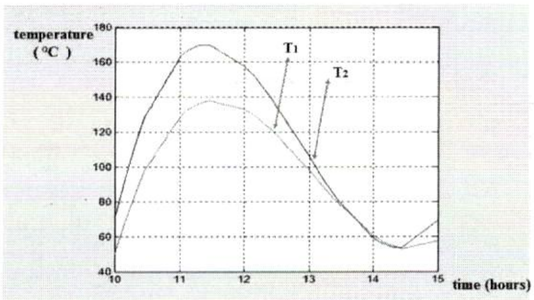

Figure 18: Comparison of the temperatures of both bars the one subjected to both reflectors T2 with other one reflected only to the auxiliary reflector T1 for day 12/04/2013

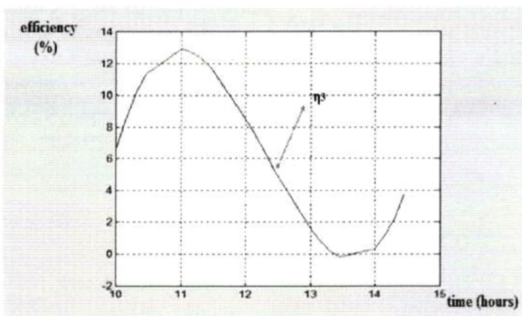

Figure 19: Variation of efficiency with time for 12 / 04 / 2013

To compare the results, same experience were conducted as above for different weather conditions

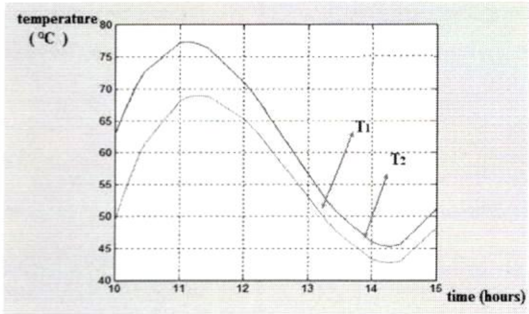

Figure 20: Comparison of temperatures collected in both bars with and without the auxiliary reflector for type day

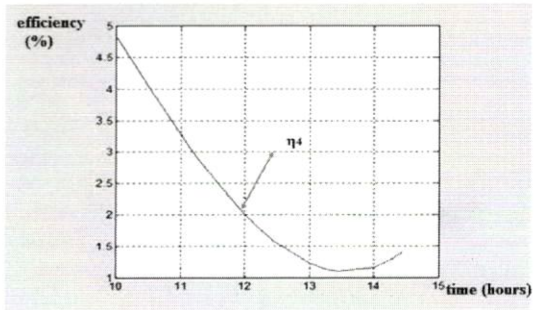

Figure 21: variation of efficiency with time for 14 / 04 / 2013

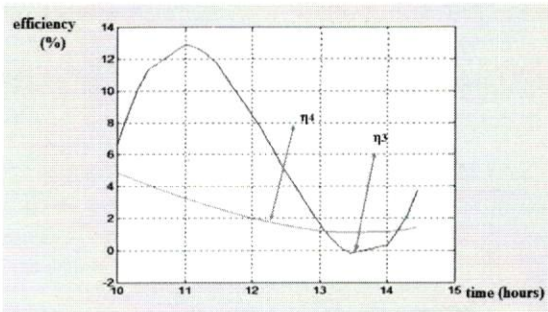

Figure 22: comparison between the efficiency of both implements of two days 14-12/04/2013 .This comparison is made to show the behavior of our installation in different climates.

Absorber with coolant. To measure the amount of heat recovered by our installation for different dispositions, we have put into circulation a heat transfer fluid (water, oil) and we have performed measurements of temperatures at the inlet and at the exit of the exchanger with a constant flow rate for day. The thermal exchanger (the absorber) is put under the auxiliary reflector where temperature measurement is made during 03 hours from 11a.m to 14 p.m with an interval of 15 minute. The following results are obtained.

the coolant water used:

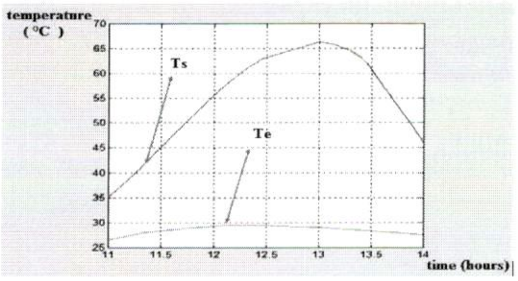

Figure 23: variation of the inlet and outlet temperatures with time

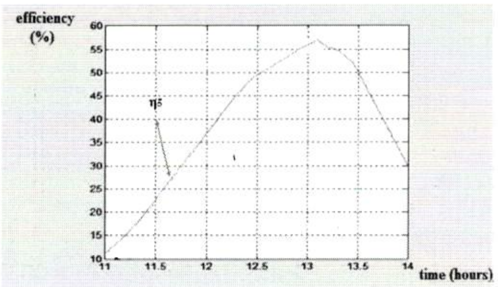

Figure 24: thermal efficiency variation for a type day.

The coolant oïl used.

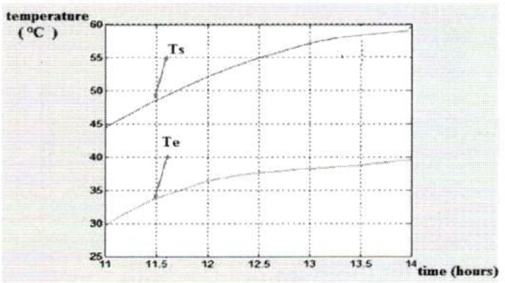

Figure 25: Variation of the temperature of the inlet and outlet of the cooling fluid (oil) as a function of time for the day 06/05/2013.

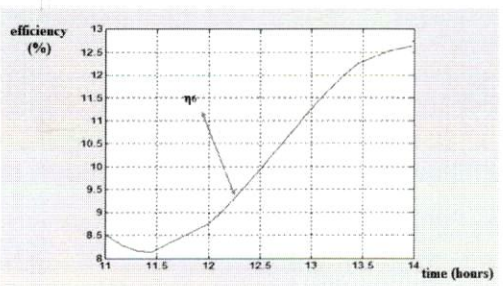

Figure 26: efficiency variation with time for the day: 06/05/2013.

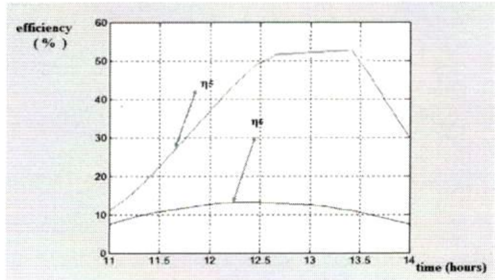

Figure 27: efficiency comparison between the two devices for both coolants

Influence of auxiliary absorber. To quantify energy recovered by the auxiliary absorber only, the lower absorber has been partially isolated, eliminating the main influence of the main receiver. Temperatures were measured at the inlet and outlet of the heat exchanger with water as coolant at constant flow rate.

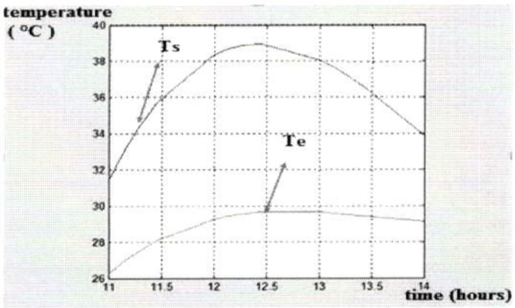

Figure 28: Variation of the temperature of the coolant for a single day for the type absorber.

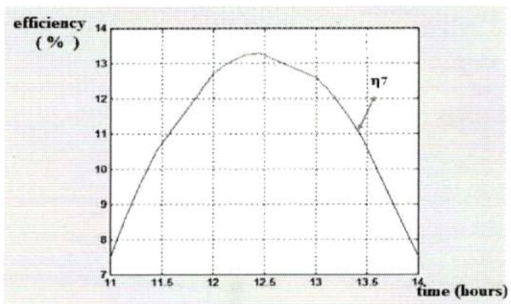

Figure 29 : Variation of performance of the system with the absorber isolated

5. NUMERICAL SIMULATION ON LANSYS [10]

To give more consistency to our study we have made a numerical simulation under LANSYS of our geometric model.

A full mesh size of both reflectors is presented with the heat distribution around the bar (absorber) for case with auxiliary reflector and for case without.

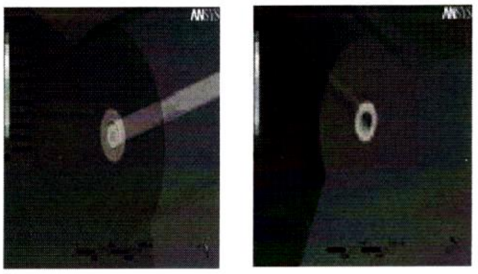

Figure 30: Distribution of energy (isothermal) in the two bars.

This simulation shows the isothermal contours around the two bars where it is clearly seen that the thermal field is very important around the bar under the effect of auxiliary hub in comparison with those around a simple reflector or it is clear that the ratio is very important, which can be more general if we take into account all the physical data, geometric, thermal and climatic.

6. CONCLUSION

To avoid losses of radiation at the absorber and to recover maximum energy, we have installed an auxiliary reflector at the level of the absorber which has been tested in different climatic conditions and especially under the effect of the wind and moisture. It was noted that this method with insulation intended to eliminate the effect of wind on the absorber and increases the efficiency of the system over 50% regardless the level of precision in the positioning of the focus, because any unabsorbed radiation is initially shifted by the auxiliary reflector and converted into thermal energy by the absorber. It should be noted that the various measurements show that we are improving the efficiency of the installation to more than 15% for a normal day and to 25 to 30% for a sunny day. This study is being done by the heat transfer team at the mechanics laboratory to improve performances of this system by adding a sun position tracking device or by increasing the length and / or the surface of the absorber and the reduction of environmental effects on the heat transfer at the absorber such as moisture, wind, Natural barriers and human influence. While maintaining the clearness of the reflective surface by a continuous intervention to remove dust, which can significantly affect and reduce the reflection of radiation.

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8. NOMENCLATURE

A_{ref}	Surface of the parabolic-cylindrical reflector [m^2]
A_{abs}	Surface receptor [m^2]
m	Mass flow rate [kg / s]
D_P	diameter of the absorber (bar)
D_{PI}	inner diameter of the absorber (tube)
a	Opening the hub [m]
r:	Radius of parabolic [m]
MP	Mass of barre [kg]
a°	geometric coefficient
QU	Output power [W]
Mf	the mass of fluid in the absorber [kg]
G	flux of the incident solar energy on the sensor surface [W / m^2]
η	thermal efficiency [%]
ρp	Density of the absorber (bar) [kg/m3]
ρf	Density of absorbing fluid (water, oil)
Cf	Specific heat of the fluid (water, oil) [J / kgK]
Cp	Specific heat absorber (bar) [J / kgK]