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Theoretical study of the thermal behavior of new solar collector

Bellel Nedire
Laboratory of physics energy, department of physics
University of Constantine
Constantine Algeria
E-Mail:bellelnadir@yahoo.fr

Tabet Ismail
Laboratory of physics energy, department of physics
University of Constantine
Constantine Algeria
E-Mail: tabet21@yahoo.fr

Abstract- **In this paper we made a numerical modeling of a new solar collector with cylindro-parabolic concentrator, the different between this collector with the other traditional collector , we introduce mirrors cylindro- parabolic at the bottom of the collector which makes it possible to concentrate the solar irradiation on the focal line that the absorber placed , the advantage is to be able to reach high temperatures on surface absorbing compared to the other system, we can integrate this new collector on the buildings for the heating of water or can used for production cold at low temperature.**

I. INTRODUCTION

Solar thermal is one of the most cost-effective renewable energy technologies and has presented significant global market prospect. Many researchers have investigated the concentrating systems of different sizes, scale and application type. These systems are capable to achieve big outlet temperatures at low cost prices, which imply high enthalpy. It is possible to use them in thermal power plants, hot water production for heating, and also solar air conditioning. Particular interest is shown for roof integrated Parabolic Collectors and especially for mini parabolic collectors in order to remain the aesthetic of buildings unaffected [6].

A new collector design, based on evacuated tubular collectors with cylindro-parabolic concentrator can be utilize solar radiation coming from all directions for any time.

II. DYNAMIC DESCRIPTION OF THE COLLECTOR MODE

The model developed corresponds to direct flow collector. It is not appropriated to vacuum tube with parabolic concentrator used specific fluid in heat pipes to heat the collector inlet fluid by an exchanger. The type of solar collector modeled consists of seven vacuum tubes with mini parabolic concentrator. The heat transfer fluid flows in a copper U-tube which is welded to a narrow flat absorber. Thus, the inlet and the outlet are at the same end of the evacuated tube.

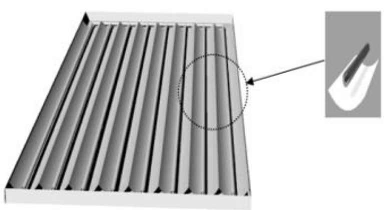


Fig.1 solar collector

III. COLLECTOR DIFFERENTIAL EQUATION SYSTEM

The Model consists of four nodes corresponding to the Fluid flow, the receiver, the envelope glass and the transparent cover. It is considered that the temperature of the fluid is a function of x. The fluid is moving in a Single channel with the velocity, along x-axis.

It results a 4-node collector model given by the Following differential equation system.

- Energy balance of transparent cover

$$M_c c_{pc}\frac{dT_c}{dt} = q_c(t) + q_{c-e}^{c} + q_{c-e}^{r} - q_{c-a}^{c} - q_{c-a}^{r} \quad (1)$$

- Energy balance of envelope

$$M_e c_{pe}\frac{dT_e}{dt} = q_e(t) + q_{c-e}^{c} - q_{c-e}^{r} + q_{e-r}^{c} + q_{e-r}^{r} \quad (2)$$

- Energy balance of receiver

$$M_r c_{pe}\frac{dT_r}{dt} = q_r(t) - q_{e-r}^{c} - q_{e-r}^{r} - q_{r-f}^{c} \quad (3)$$

- Energy balance of fluid flow

$$M_f c_{pf}\frac{dt_f}{dt} = -\dot{m}\frac{dt_f}{dx} + q_{r-f}^{c} \quad (4)$$

Where $q_c(t)$, $q_e(t)$, $q_r(t)$ are ,respectively ,the solar radiation incident on the cover and absorbed by it, the solar radiation absorbed by the receiver envelope and the beam radiation absorbed by the receiver .

$$q_c(t) = I_g(t)\alpha_c \quad (5)$$

$$q_r(t) = I_b(t)\tau_c\rho_m\gamma(\alpha_r\tau_e) \quad (6)$$

$$q_e(t) = I_b(t)\tau_c\gamma\rho_m\alpha_e \quad (7)$$

In the practical the variation of the enthalpy of the components of the collector are small we neglect them the terms in $mc_p\frac{dT}{dt}$ can be neglected We can thus reasonably make the assumption of a quasi-stationary operation of the collector .This assumption results in to simplify' the equations without however masking the temporary evolution of the phenomena which remain related to solar flow I variable in time .en eliminating Tc, Tr, Te of the simplified equations thus obtained, it comes [2],[3]

$$c_{pf}\dot{m}\frac{dt_f}{dx} = 2\pi R_r[S' - U_L(T_f - T_{a)}]F' \quad (8)$$

$$S' = q_r(t) + \frac{(h_{e-c}^{r}+h_{e-c}^{c}+h_{c-a}^{r}+h_{c-a}^{c})U_L}{(h_{e-c}^{r}+h_{e-c}^{c})(h_{c-a}^{r}+h_{c-a}^{c})}q_e(t) + \frac{U_L q_c(t)}{h_{c-a}^{r}+h_{c-a}^{c}} - \frac{6h_{c-a}^{r}U_L}{h_{c-a}^{r}+h_{c-a}^{c}} \quad (9)$$

Where U_L Is overall heat loss coefficient [1], [2]

The differential equation of first order (8) is subjected to the boundary condition.

$$T_f(x=0) = T_{fi} \quad (10)$$

$$\frac{T_f - Ta - (S'/U_L)}{T_{fe} - Ta - (S'/U_L)} = \exp(-\frac{2\pi R_r F' U_L}{C_{pf}\dot{m}}x) \quad (11)$$

If the collector has length L in the direction of flow, the outlet fluid is found by substituting L for x in equation (11) so that

$$\frac{T_{fs} - Ta - (S'/U_L)}{T_{fe} - Ta - (S'/U_L)} = \exp(-\frac{A_r F' U_L}{C_{pf}\dot{m}}) \quad (12)$$

On the basis of unit receiver area U_f can now be formulated as flows [1]

$$U_f = \left[\frac{R_e}{\lambda_f}\ln\left(\frac{R_e}{R_r}\right) + \frac{R_r}{h_f R_e}\right]^{-1} \quad (13)$$

The daily thermal efficiency η of collector is calculated from the relationship:

$$\eta = \frac{\int_{tr}^{ts}\dot{m}c_{pf}(T_{fs} - T_{fe})dt}{A\int_{tr}^{ts} I dt} \quad (14)$$

IV. HEAT TRANSFER COEFFICIENTS

- Convective heat transfer between the glass cover to an ambient

$$h_{c-a}^{c} = 5.7 + 3.8v \quad (15)$$

- Radiative heat transfer between the glass cover to an ambient

$$h_{c-a}^{r} = \varepsilon_c\sigma A_e(Tc^2 + Ts^2)(Tc + Ts) \quad (16)$$

- Convective heat transfer between the glass cover and envelope.

$$h_{c-e}^{c} = \left[3.25 + 0.0085\left(\frac{Te - Tc}{4R_r}\right)\right]\frac{A_e}{A_r} \quad (17)$$

- Radiative heat transfer between the glass cover and envelope.

$$h_{c-e}^{r} = \frac{\sigma\,(Te^2+Tc^2)(Te+Tc)A_e}{\frac{1}{\varepsilon_c}+Ae/Ac\left(\frac{1}{\varepsilon_c}-1\right)Ar} \tag{18}$$

- Convective heat transfer between the envelope and the receiver

$$h_{e-r}^{c} = \frac{2\Pi K_{eff,air}}{\ln(De/Dr)} \tag{19}$$

$$\frac{k_{eff,air}}{K_{air}} = 0.386\left(\frac{P_{r,air}}{0.861+P_{r,air}}\right)^{\frac{1}{4}}(R_{ac}^{*})^{\,1/4} \tag{20}$$

$$R_{ac}^{*} = \frac{[\ln(De/Dr]}{L^3\left(D_r^{-3/5}+D_r^{-3/5}\right)^5}R_{aL} \tag{21}$$

$$R_{aL} = \frac{g\beta_{air}(Tr-Te)L^3}{a_{air}} \tag{22}$$

$$L=0.5\,(D_e\text{-}D_r),\ \ a_{air} = \frac{\lambda_{air}}{\rho_{air}Cp_{air}} \tag{23}$$

$$\nu_{air} = \frac{\mu_{air}}{\rho_{air}} \tag{24}$$

The properties thermo physical of the air depend on the average temperature T_m

$$T_m=0.5\,(T_r+T_e) \tag{25}$$

- Radiative heat transfer between the envelope and the receiver

$$h_{e-r}^{r} = \frac{\sigma(Te^2+Tr^2)(Tr+Te)}{1/\varepsilon_r+A_r/A_e(1/\varepsilon_e-1)} \tag{26}$$

- Convective heat transfer between the receiver and the fluid.

$$h_{r-f}^{c} = \frac{Nuf\lambda_f}{Dr} \tag{27}$$

$$Nuf = 0.023Ref^{4/5}Prf^{n} \tag{28}$$

Avec : n= 0.4 pour Tr> Tf et n= 0.3 pour Tr<Tf

$$Ref = \frac{4\rho_f\dot{V}f}{\pi Dr\mu_f n_{collectors}} \tag{29}$$

$$Pr_f = \frac{\nu_f}{a_f} \tag{30}$$

$$a_f = \frac{\lambda_f}{\rho_f c p_f} \tag{31}$$

V. NUMERICAL PROCEDURE

In numerical calculations, an iterative procedure is adopted to incorporate the effect of the temperature dependence of various heat transfer coefficients .For certain temperature, they are first calculated by using **Gauss -Seidel** methods. The equations are solved by assuming the heat transfer coefficients constant and then new solutions are used to generate all the heat transfer coefficients again till the values converge.

Calculation was carried out for a place or can about it collect all the solar radiation with the 18 out in east Algeria (Constantine). The characteristics of site and other parameters used for calculation are shown in the following table.

Table Input parameter of simulation

Paramètre	*Value*
Day/year	230/2012
Zénith angle	0°
Latitude	37°.17
Longitude	6°.62
Collector Type	6-trought parabolic collecter
Collector inclination	30°
Collector Disposition	Est –ouest
Speed of the Wind	1.5 m/s
Length of collector	1.5m
Aperture of channel parabola	0.1m
Total aperture	0.15
Diameter of receiver tube	0.022m
Diameter envelope tube	0.026m
Parabola reflectance	0.90
receiver absorptivity	0.90
Receiver emissivity	0.80
envelope absorptance	0.023
envelope transmittance	0.9

VI. RESULTS AND DISCUSSIONS

Figure1 illustrate the evolution respectively temperature of the fluid, absorber, glass envelope and cover. It is noticed that the curved quads have the same pace and that temperature of the receiver is higher than that of the fluid and the latter is higher than that of glass envelope and the temperature of the higher envelope has those of the cover and this off with the solar irradiation absorbing by each component of collector.

Figures 2-4 illustrates the effect of the mass flow of the fluid at midday t_m (12) on the time variations of the local temperature of the fluid and on the efficiency of the collector. We see that the temperature of the fluid decrease with the mass flow increase (figure 2). This is explained simply by the fact when the mass flow of the fluid increases, the solar irradiation being maintained constant the quantity of water to heat increase, involving a reduction in its temperature outlet. These results are similar to those obtained by **R. Tchinda** and others [1]. In the same time since the mass flow of the fluid was increasing, heat is carried much more quickly. This explains the increase in the efficiency of the collector which observed on the figure.4.

The outlet temperature of fluid decrease when the mass flow increase (figure 3).

Figure.5 shown the diurnal variation of the thermal efficiency of the collector, we remark for usual mass flow of the fluid. The thermal efficiency of the solar collector reaches values maximum between Ten hour and fourteen hours and that due to solar irradiation, we can say that the figure-5 which the collector works with a nearly constant thermal efficiency.

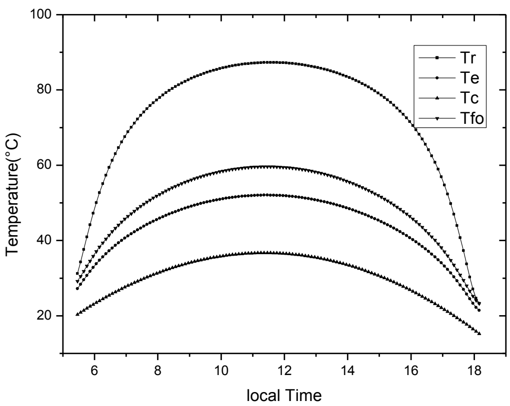


Figure.2 diurnal variation of the temperatures components of the collector (T_{fi}=T_a, $\dot{m}$=0.04 kg/s)

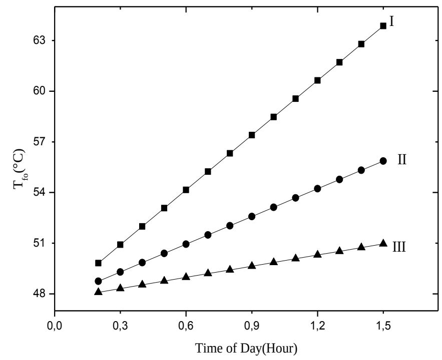
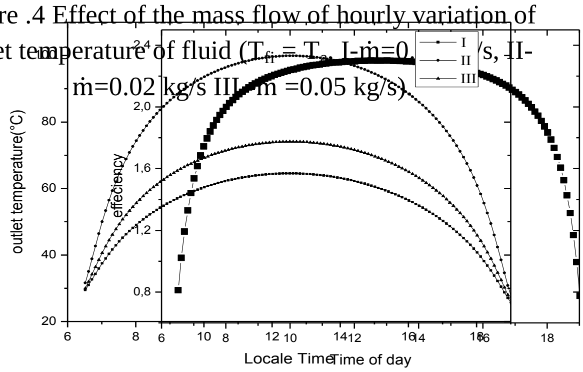


Figure.3 effect of mass flow of the fluid on the local temperature of the fluid in the direction of the flow (T_{fi} = T_a I-ṁ=0.01 kg/s, II-ṁ=0.02 kg/s III -ṁ =0.05 kg/

Figure .4 Effect of the mass flow of hourly variation of outlet temperature of fluid (T_{fi} = T_a, I-ṁ=0.01 kg/s, II-ṁ=0.02 kg/s III -ṁ =0.05 kg/s)



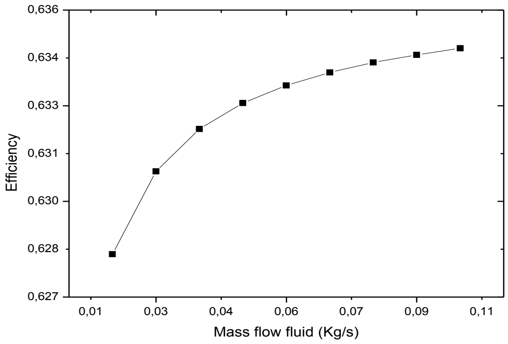


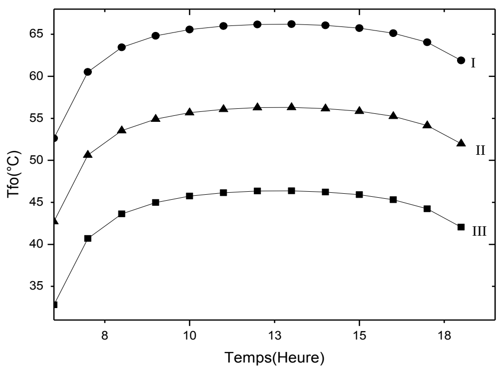
Figure.5 Effect of the mass flow of the fluid on the efficiency of the collector ($T_{fi} = T_a$)

Figure.6 diurnal efficiency of collector

($T_{fi} = T_a$, ṁ=0.04 kg/s)

We represented on the figures (6-7) the effect of the inlet temperature T_{fi} of the fluid on the local temperature of the fluid T_f (X, tm) at the midday tm=12h on the diurnal variations of the outlet temperature of fluid

It appears that for a constant mass flow the outlet temperature of the fluid does not believe significantly with the increase of inlet temperature (figure .6) because the thermal losses of the collector increase quickly when the inlet temperature of the fluid, so that the increase in the



enthalpy of the fluid on the outlet side of the collector is less important than at the inlet.

Figure . 7 effect of the inlet temperature of fluid on the diurnal variation of the outlet temperature of fluid (ṁ=0.01 kg/s, I-T_{fi}=50°C, II-T_{fi}=40°C, III- T_{fi} =50°C).

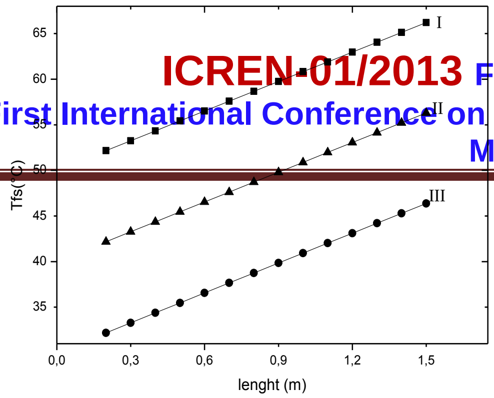
Figure.8 effect of inlet temperature of fluid on the local temperature of the fluid in the direction of the flow (ṁ=0.01kg/s, I- T_{fi} =50°C, II- T_{fi}=40°C, III- T_{fi} =30°C)

VII. CONCLUSION

This study will have made it possible to show that the assumption of a quasi-stationary operation, the equation of heat balances of the components of the solar collector with mirrors cylindro- parabolic at the bottom of the collector in ordinary differential equation, which with only governs the thermal behavior of the collector. We showed in this study the influence of some inlet parameter on the thermal efficiency of the collector and the outlet temperature of the collector such as the mass flow of the fluid, the inlet temperature of the fluid.

VIII. REFERENCE BIBLIOGRAPHIE

[1] R. tchinda, E. kaptouom and D. njomo study of the c.p.c. collector thermal behavior, Energy Convers. Mgmt Vol. 39, No. 13, pp. 1395-1406, 1998
[2] Du • e, J. A. and Beckman, W. A., Solar Energy Thermal Processes. Wiley, New York, 1974, p. 83.
[3] Jean Philippe Praene,François Garde, Franck Lucas, dynamic modelling and elements of validation of solar Evacuated tube collectors,Ninth International IBPSA conference Montréal,Canada ,August 15-18,2005.



[4] Gang Pe, Guiqiang Li , Xi Zhou Jie Ji and Yuehong Su , Comparative Experimental Analysis of the Thermal Performance of Evacuated Tube Solar Water Heater Systems With and Without a Mini-Compound Parabolic Concentrating (CPC) Reflector(C<1),Energies2012,5,911-924; doi:10.3390/en5040911.

[5] THORSTEN A. STUETZLE, Automatic Control of the 30 MWe SEGS VI Parabolic Trough Plant, thesis master of science (mechanical engineering), university of wisconsin-madison,2002.

[6] M,pertrakis,G.barakos and S.kaplanis, Rooof Integrated Mini-Parabolic Solar Collectors .Comparison between simulation and experimental Results,the open fuels &energy sciences journal,2,17-81,2009.