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Influence of the Debit and the Orientation of a Solar Converter

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Abstract: The work presented in this paper is the numerical study of a thermal converter. The main objective of the work is to study the effect of certain parameters on a flat solar collector. We are particularly interested in determining the influence of water flow on the operating characteristics of the solar collector and the effect of the orientation of a surface on the energy received. We have realized a mathematical model simulating the thermal behavior of collectors, to solve the mathematical model using an iterative method of Gauss-Seidel. According to the results obtained on this device, we note that: The inclination between 30 and 37 ° gives the best performances. The outlet temperature is higher for low flow. The overall efficiency increases with the flow of water.

Key words: the solar power, debit, solar converter, performance of the converter

1. Introduction

The thermal solar is mainly the production of the hot water using a solar water heater, is one of the most promising applications of the renewable energy, several research has been conducted in this field.

[1] have carried out a numerical study on the determination of the optimum surfaces of solar water heating systems. The optimization criterion is laminimisation of the total cost of the installation, [2] have studied the theoretical and experimental performances of a flat solar collector. This is mainly to study the effect of the geometric shape of the fluid passages on the sensor efficiency in the case of a direct water-absorption plate contact. A mathematical model has been developed and validated by comparison with tests to determine the thermal performance of the sensor whose absorption plate on the basis of certain geometric parameters with the theoretical results. In another device studied by Melih Tan [3], solar energy recovered in a south-facing sensor is transferred to a north sensor. The advantage of this system is not to directly heat the interior space but rather to reduce heat loss to the outside, [4-7]. The works presented in this article correspond also to improve the energy performance of a solar collector different internal and external parameters influence on the operating characteristics of a solar collector.

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In this work we present the effect of the orientation of a surface on the received energy and the influence of water flow on the operating characteristics of the collector.

2. Description

The studied collector is showed by the diagram in the figure 1 below. This collector allows the conversion of energy from the electromagnetic radiation emitted by the sun into heat energy.

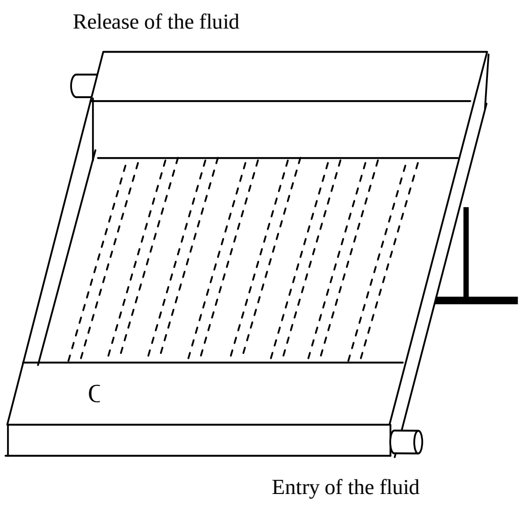

Fig. 1 Diagram of the system of a solar collector plan

3. Exterritorial global radiation

H_0: Extraterrestrial global radiation on a horizontal plane is calculated by the following equation [8-9]:

$$H_0 = \frac{86400.1367}{\pi}\left(1+0.033\cos\left(\frac{360}{365}n\right)\right)\times \left(\cos\Phi\cos\delta\sin w_s + w_s\sin\Phi\sin\delta\right) \quad (1)$$

Where [2]

Φ: latitude of location;

δ: Declination Solar;

n: number of the day in the year**.**

$$\delta = 23.45\sin\left(\frac{320}{365}(284+n)\right) \approx 23.45\sin\left(\frac{360}{365}(n-81)\right) \quad (2)$$

The clarity index [3]

$$\overline{K_T} = \frac{\overline{H}}{\overline{\overline{H_0}}} \quad (3)$$

$\overline{H}$: The average solar flux monthly measured on a horizontal surface by w/m^2.

$\overline{H_0}$ The average solar flux monthly outside of the atmosphere by w/m^2.

$$\frac{\overline{H_d}}{\overline{H}} = 1.391 - 3.560\overline{K_T} + 4.189\overline{K_T^2} - 2.137\overline{K_T^3} \quad [4] \quad (4)$$

With [5]:

$$\overline{H_b} = \overline{H} - \overline{H_d} \quad (5)$$

$\overline{H_b}$: The aaverage flow monthly direct on a horizontal surface w/m^2.

$\overline{H_d}$: The average flow, monthly diffuse on a horizontal surface w/m^2.

$$r_t = \frac{I^*}{\overline{\overline{H}}} \quad [6] \quad (6)$$

$$r_t = \frac{\pi}{24}(a + b\cos w)\frac{(\cos w - \cos w_s)}{\left(\sin w_s - \frac{\pi}{180}w_s\cos w_s\right)} \quad (7)$$

$$r_d = \frac{I_d^*}{\overline{\overline{H}}_d} \quad (8)$$

$$r_d = \frac{\pi}{24}\left(\frac{\cos w - \cos w_s}{\sin w_s - \frac{\pi}{180}w_s\cos w_s}\right) \quad (9)$$

The global power on an inclined surface [7].

$$p_t = I_b R_b + I_d\,\frac{1+\cos\beta}{2} + (I_b + I_d)\rho\,\frac{1\quad\cos\beta}{2} \quad (10)$$

4. Simulation of the collector

The density of heat flow exchanged between two points their temperatures T_1 and T_2 can be written as [10-11].

$$Q_{21} = h_{21}.S(T_2 - T_1) \quad (11)$$

This expression is similar to Ohm's Law.

We crave the solar collector in fictitious slices in the direction of flow.

The thermal balance at node *i* gives:

$$m_i Cp_i \frac{\partial T_i}{\partial t} = \sum_{j=1}^{n}\frac{1}{R_{ij}}(T_j - T_i) + P_i \quad (12)$$

T_j is a potential connected to T_i and P_i is the source term in wells.

The mass flow per unit plane of collector [8]:

$$\frac{T_{fs} - T_a - \frac{P_P}{u}}{T_{fe} - T_a - \frac{P_P}{u}} = \exp\left(-\frac{F.u}{\dot{M}\,C_P}\right) \quad (13)$$

This expression allows determine the outlet temperature T_{fs} of coolant in function to the inlet temperature T_{fe}, so the power supplied to the fluid per square meter of collector is written [12-14] :

$$P_u = \dot{M}\,C_P(T_{fs} - T_{fe}) \quad (14)$$

$$F_t = \frac{\dot{M}\,C_P}{u}\left[1 - \exp\left(-\frac{F.u}{\dot{M}\,C_P}\right)\right] \quad (15)$$

F_t: Thermic transfer factor.

So:

$$P_u = F_t\left(P_P - u(T_{fe} - T_a)\right) \quad (16)$$

Indeed, the instantaneous efficiency of solar collector plan is equal to the ratio between the energical power recovered by the fluid and the solar gain [6].

$$\eta = F_t\left(\eta_0^{\bullet} - u\,\frac{T_{fe} - T_a}{P_T}\right) \qquad (17)$$

To determine the characteristics of the solar collector, a digital simulation on determining of the yield of collector in permanent regime has been performed.

5. Discretization of the equations

Exchange in the outside of the glass:

$$\frac{m_v Cp_v}{Surf_v \Delta t}\left(T_{ve}^{t+\Delta t}(j+1) - T_{ve}^{t}(j+1)\right)$$
$$= P_v + h_{rvc}\left(T_c - T_{ve}^{t+\Delta t}(j+1)\right) +$$
$$h_{v.om}\left(T_{om} - T_{ve}^{t+\Delta t}(j+1)\right) + K_v\left(T_{vi}^{t+\Delta t}(j+1) - T_{ve}^{t+\Delta t}(j+1)\right) \qquad (18)$$

Exchange inside the glass:

$$\frac{m_v Cp_v}{Surf_v \Delta t}\left(T_{vi}^{t+\Delta t}(j+1) - T_{vi}^{t}(j+1)\right) = h_{r.nv}\left(T_n^{t+\Delta t}(j+1) - T_{vi}^{t+\Delta t}(j+1)\right)$$
$$+ h_{vvn}\left(T_n^{t+\Delta t}(j+1) - T_{vi}^{t+\Delta t}(j+1)\right)$$
$$+ K_v\left(T_{ve}^{t+\Delta t}(j+1) - T_{vi}^{t+\Delta t}(j+1)\right) \qquad (19)$$

Exchange in the absorber :

$$\frac{m_n Cp_n}{Surf_n \Delta t}\left(T_n^{t+\Delta t} - T_n^{t}\right) = P_n + h_{rnv}\left(T_{vi}^{t+\Delta t}(j+1) - T_n^{t+\Delta t}(j+1)\right) +$$
$$h_{vvn}\left(T_{vi}^{t+\Delta t}(j+1) - T_n^{t+\Delta t}(j+1)\right) + h_{van}\left(T_F^{t+\Delta t}(j) - T_n^{t+\Delta t}(j+1)\right) +$$
$$h_{rni}\left(T_{ii}^{t+\Delta t}(j+1) - T_n^{t+\Delta t}(j+1)\right) \qquad (20)$$

Exchange in heat transfer fluid :

$$\overset{\bullet}{m}_F\, Cp_F\left(T_F^{t+\Delta t}(j+1) - T_F^{t+\Delta t}(j)\right) =$$
$$h_{van}\left(T_n^{t+\Delta t}(j+1) - T_F^{t+\Delta t}(j)\right) +$$
$$h_{vac}\left(T_{ii}^{t+\Delta t}(j+1) - T_F^{t+\Delta t}(j)\right) \qquad (21)$$

Exchange in the surface of the insulation:

$$\frac{m_i Cp_i}{Surf_i \Delta t}\left(T_{ii}^{t+\Delta t}(j+1) - T_{ii}^{t}(j+1)\right) =$$
$$h_{voi}\left(T_F^{t+\Delta t}(j) - T_{ii}^{t+\Delta t}(j+1)\right) + K_{ii}\left(T_{ie}^{t+\Delta t}(j+1) - T_{ii}^{t+\Delta t}(j+1)\right)$$
$$+ h_{rni}\left(T_n^{t+\Delta t}(j+1) - T_{ii}^{t+\Delta t}(j+1)\right) \qquad (22)$$

Exchange outer wall of the ground insulation:

$$m_i Cp_i\left(T_{ie}^{T+\Delta t}(j+1) - T_{ie}^{t}(j+1)\right) =$$
$$K_{ci}\left(T_{ii}^{t+\Delta t}(j+1) - T_{ie}^{t+\Delta t}(j+1)\right) +$$
$$h_{ris}\left(T_{sol} - T_{ie}^{t+\Delta t}(j+1)\right) +$$
$$h_{vs}\left(T_{om} - T_{ie}^{t+\Delta t}(j+1)\right) \qquad (23)$$

6. Resultants and discussion

6.1 Hypothesis

The ambient temperatures were given by the formula [11]:

$$T_a(t) = \frac{(T_{a\max} - T_{a\min})}{2}.\sin\frac{\pi}{12}(t-8) + \frac{(T_{a\max} + T_{a\min})}{2} \qquad (24)$$

The inlet temperature of water coolant is equal to 35 °.

With a zone of the normal condition for an albedo ρ =0.2.

Since the thickness of the absorber is small, so we put the temperature of the face of plate of the absorber is the same, and we neglect the thermic exchange between the plate and the insulation because the coefficients of thermic exchange between the plate and insulation is negligible compared to the coefficients of thermic exchange between the plate and the fluid.

The solar declination δ varies throughout the year; using the relation $\delta = 23{,}45\sin\frac{320}{365}(284+n)$ [15] we obtain the declination in function of the number of the day n of the year; the graph of this declination variation is shown in Figure 2.

We remark that the declination varies from $+23.44^0$ à -23.44^0, it is null at the equinoxes of spring and autumn, maximum at summer solstice and minimum at winter solstice, and we note also that the allure is sinusoidal [16].

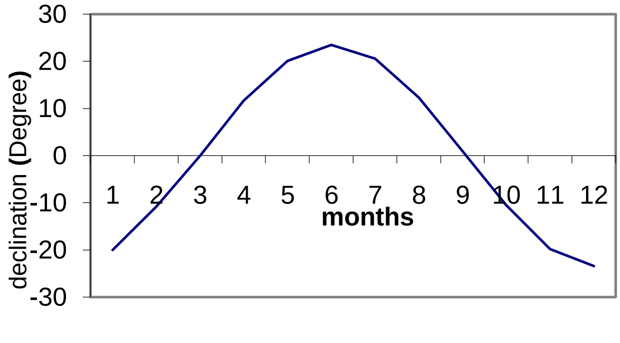

Fig. 2 Declination of the sun throughout the year

6.2 Daily radiation Extra - Terrestrial:

The Figure 3 represents the variation of extra - terrestrial daily radiation in Constantine (Algeria) during the year.

The daily radiation outside the atmosphere passes through a maximum for a maximum declination (δ = +23.44^0) and through a minimum for a minimum declination (δ = -23.44^0).

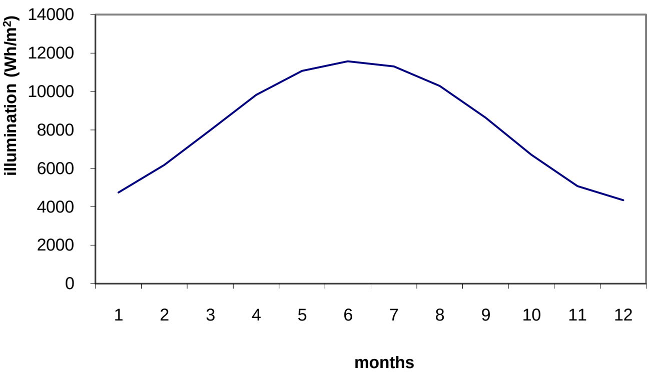

Fig.3 The radiation outside the atmosphere throughout the year

6.3 The effect of the orientation of a surface on the received energy

The Figure 4 represents the global change in flux at solar noon o'clock during the year, for a plane surface oriented verse south and for various values of tilt β = 0, 30, 37.60 degrees.

The South orientation gives the best performances, especially with a tilt of 30 to 37 °. However, a tilt of 37° degrees in the city of Constantine provides better results in summer and excellent performances at annual average.

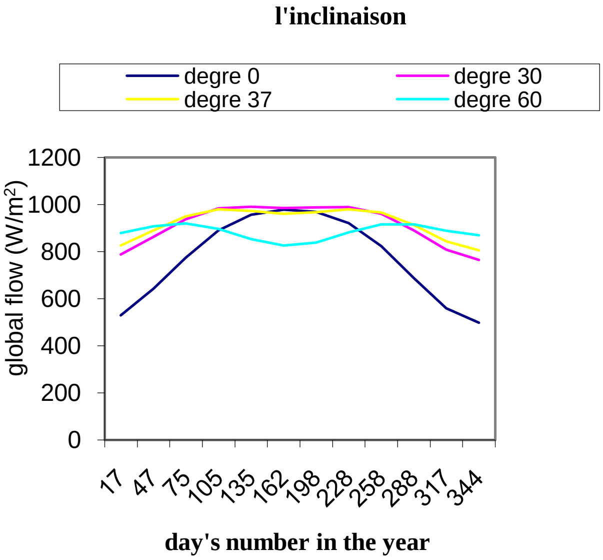

Fig. 4 The global absorbed solar radiation for different tilts of the surface plane

6.4 The influence of water flow

The Figure 5 represents the outlet temperature of water in function of the change in water flow. We observe that the outlet temperature is more important for a low flow .Note that there is symmetry after 12 noon.

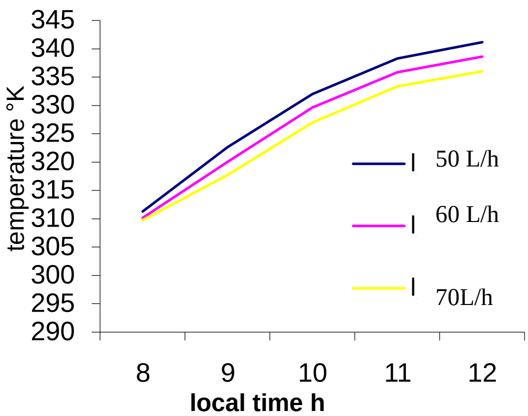

Fig. 5 The influence of flow on the outlet temperature of water

6.5 The influence of water flow on the global yield

The effect of flow is represented in the figure.6; we remark that the global yield increases with the water flow, so efficiency of solar collector depends relatively on the change in water flow.

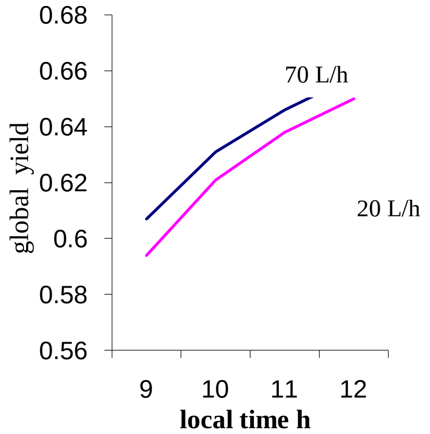

Fig. 6 The influence of water flow on the global yield

7. Conclusion

This study allowed us to evaluate through a model representing the effect of the augmentation of the water flow and orientation of a plane surface on a solar thermal converter for production of sanitary water.

We achieved a mathematical model simulating the thermal behavior of collectors, for the solving the mathematical model in using a Gauss-Seidel's iterative method [9].

According to the results obtained on this device, we remark that:

- The incline between 30 and 37 ° gives the best performance.
- The outlet temperature is more important for a low flow.
- The global yield increases in function of the water flow.

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