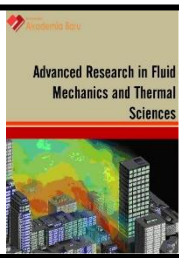
Penerbit Akademia Baru

Journal of Advanced Research in Fluid Mechanics and Thermal Sciences

Journal homepage: www.akademiabaru.com/arfmts.html
ISSN: 2289-7879



Study of the Influence of External Parameters on Thermal Performance of a Solar Water Collector

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ARTICLE INFO

Article history:
Received 14 October 2018
Received in revised form 31 October 2018
Accepted 1 January 2019
Available online 11 January 2019

ABSTRACT

The purpose of this work is to show the effect of external parameters: albedo and wind speed) on a solar collector inclined plane. The method used consists in cutting the collector into fictitious slices (05 meshes) of length Δx in the direction of the flow of the heat transfer fluid and writing the balance sheets of the exchanges which intervene at the levels of the 06 nodes: from the outside of the glass, the inside of the glass, the absorber, in the peddler fluid as well as the inside and the outside of the insulation. It is convenient for this to use the analogies that exist between the transfer of heat and electricity, the results obtained are the temperatures at the nodes.

Keywords:
albedo, wind speed, solar collector, exchanges.

1. Introduction

Solar energy is one of the forms of primary renewable energies (Sun, water, oceans, wind, biomass) that can be converted into final energies, solar energy still occupies a more important place than other renewable energies [1] such as wind energy, geothermal energy, biomass energy etc.

Its applications are numerous and varied, namely, heating homes [2], Meteorological Data [3], swimming pools, greenhouses, hot water production, water distillation, cooking, water pumping and production of electricity [4], nanoparticles [5].

The conversion of solar energy [6], which is submitted in the form of electromagnetic radiation, can be considered according to different physical principles. We distinguish essentially photoelectric and photochemical conversions, as well as photothermal conversion, which is the degradation of solar energy into heat.

In the field of photothermal conversion, many applications have been highlighted; the work presented here is part of the contribution of the design and simulation of thermal converters.

Because of the relative simplicity of implementation and the importance of energy requirements in the form of heat, photothermal conversion is still currently the most common. With regard to the

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production of heat at low temperature, it is nowadays possible to consider that by means of so-called active collector devices, the problems are only of an economic nature. For example, the heating of pools by planar collector has become conventional.

Hossain *et al.* [7] studied the effect of the thermal conductivity of the absorber plate of a solar collector on the performance of a thermosiphon solar water heater, the simulation and reciprocating system. Niccolò Aste *et al.* [8] performed a comparison between covered and uncovered PVT water collectors made with different photovoltaic cells coupled to two roller-connected aluminum absorbers also characterized by different channel arrangements. The analysis of the performance is based on two mathematical models validated by experimental data Aouès *et al*. [9] studied the influence of cylindrically shaped obstacles on the thermal performance of a flat-air solar collector. Touafek *et al.* [10] studied the effect of the distance between two successive tubes on the operation of the thermal photovoltaic hybrid system (PVT) as well as its instantaneous electrical and thermal power. Garg *et al.* [11] studied the PV / T system using air for heating in single and double glazing.

In this work we present the effect of the albedo and wind speed on an inclined solar collector (as shown in Figure 1) operating in forced circulation with a single pane.

Theoretical study consists in putting into equation the energetic exchanges intervening at the level of the sensor which one slices in mesh, before the resolution of this system by a numerical approach based on the iterative method of Gauss Seidel we placed nodes within the mesh with ρ: is the albedo of the soil

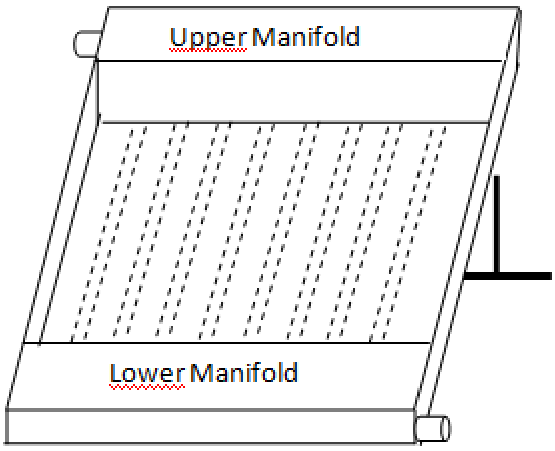

Fig. 1. The schematic diagram of a flat solar collector

2. Solar Collector Simulation

The heat flux density exchanged between a temperature point T_1 and another temperature point T_2 can be written in the form: $Q_{21} = h_{21}.S(T_2 - T_1)$ [12-13]. This expression is similar to Ohm's law. We can apply the laws of Ohm and Kirchhoff consider a spatial section.

Any of the system at the instant t, ie (i) one of the media represented in this section (m_i) Its mass (Kg), Cp_i its specific heat $\left(J/ Kg.^oK \right)$ and Ti its temperature (°k).

The thermal balance or node i gives: $m_i Cp_i \dfrac{\partial T_i}{\partial t} = \sum_{j=1}^{n} \dfrac{1}{R_{ij}} (T_j - T_i) + P_i$

n: set of j for which Tj is a potential connected to Ti

Pi: source term at the well

3. Discretization of the Equations

Discretization of the equations Exchange in the outside of the glass

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

Exchange in the inside of the glass

$$\frac{m_v Cp_v}{Surf_v \Delta t}\left(T_{vi}^{t+\Delta t}(j+1)-T_{vi}^{t}(j+1)\right)=h_{r.nv}\left(T_{n}^{t+\Delta t}(j+1)-T_{vi}^{t+\Delta t}(j+1)\right)+h_{vvn}\left(T_{n}^{t+\Delta t}(j+1)-T_{vi}^{t+\Delta t}(j+1)\right) +K_v\left(T_{ve}^{t+\Delta t}(j+1)-T_{vi}^{t+\Delta t}(j+1)\right) \quad (2)$$

Exchange in the absorber

$$\frac{m_n Cp_n}{Surf_n \Delta t}\left(T_{n}^{t+\Delta t}-T_{n}^{t}\right)=P_n+h_{rnv}\left(T_{vi}^{t+\Delta t}(j+1)-T_{n}^{t+\Delta t}(j+1)\right)+h_{vvn}\left(T_{vi}^{t+\Delta t}(j+1)-T_{n}^{t+\Delta t}(j+1)\right)+h_{van}\left(T_{F}^{t+\Delta t}(j)-T_{n}^{t+\Delta t}(j+1)\right)+ h_{rni}\left(T_{ii}^{t+\Delta t}(j+1)-T_{n}^{t+\Delta t}(j+1)\right) \quad (3)$$

Exchange in heat transfer fluid

$$\dot{m}_F\, Cp_F\left(T_{F}^{t+\Delta t}(j+1)-T_{F}^{t+\Delta t}(j)\right)=h_{van}\left(T_{n}^{t+\Delta t}(j+1)-T_{F}^{t+\Delta t}(j)\right)+ h_{vac}\left(T_{ii}^{t+\Delta t}(j+1)-T_{F}^{t+\Delta t}(j)\right) \quad (4)$$

Exchange in the surface of the insulation

$$\frac{m_i Cp_i}{Surf_i \Delta t}\left(T_{ii}^{t+\Delta t}(j+1)-T_{ii}^{t}(j+1)\right)=h_{voi}\left(T_{F}^{t+\Delta t}(j)-T_{ii}^{t+\Delta t}(j+1)\right)+K_{ii}\left(T_{ie}^{t+\Delta t}(j+1)-T_{ii}^{t+\Delta t}(j+1)\right) +h_{rni}\left(T_{n}^{t+\Delta t}(j+1)-T_{ii}^{t+\Delta t}(j+1)\right) \quad (5)$$

Exchange outer wall of the ground insulation

$$m_i Cp_i\left(T_{ie}^{T+\Delta t}(j+1)-T_{ie}^{t}(j+1)\right)=K_{ci}\left(T_{ii}^{t+\Delta t}(j+1)-T_{ie}^{t+\Delta t}(j+1)\right)+ h_{ris}\left(T_{sol}-T_{ie}^{t+\Delta t}(j+1)\right)+h_{vs}\left(T_{om}-T_{ie}^{t+\Delta t}(j+1)\right)2) \quad (6)$$

For calculation the flow absorbed by the absorber and the glass

$$P_n=I_{bi}\frac{\tau\alpha_P}{1-\rho_d(1-\alpha_P)}+I_{di}\frac{\tau_d\alpha_P}{1-\rho_d(1-\alpha_P)}; \qquad P_V=I_{bi}\alpha_V+I_{di}\alpha_d$$

On obtient un système d'équation de six inconnus

With: P_n flux absorbed by the absorber, P_v flux absorbed by the glass

τ: transmission factor of glazing, τ_d: hemispheric transmittance
ρ_d: hemispheric reflection coefficient, α_d: hemispheric absorption coefficient
α_b: absorption coefficient of the absorber for wavelengths λ, we obtain an equation system of six unknowns

$$B_{ij} \bullet T_i = F_c \tag{7}$$

with j=1…6, i=1…6

For the resolution of this system we apply the iterative method of Gauss Seidel.

4. Results

The temporal evolution of the global solar radiation received per unit of flat surface of the solar collector for the production of hot water for different albedo is illustrated by Figures 2, 3, 4 and 5. It appears clearly in these figures that the solar power is maximum at 12.00, for the two direct and diffuse flux which can be explained by the height of the sun and the atmospheric mass.

Indeed, the lower the sun is on the horizon (its small height) plus the atmospheric mass traveled by solar radiation is important, the latter will therefore undergo significant attenuations following its interaction with the Earth's atmosphere. On the other hand, when the sun moves away from the horizon, its height increases and consequently the atmospheric mass traversed by the solar radiation decreases, it results in a less important attenuation.

4.1 The water

Figure 2 shows the variations of the direct, diffuse and global solar radiation received per unit of flat surface of the solar collector in an area surrounded by water, from the figures we observe that: the maximum flow at solar noon, the maximum value of the global flow is equal to 1003 w / m^2, the direct flow is equal to 779 and the diffuse flux is equal to 223w / m^2.

4.2 The Sahara

The Figure 3 represents the variations of the direct, diffuse and global solar radiation received per unit of flat surface of the solar collector in a desert zone, according to the figures we observe that: the maximum sound flow at solar noon, the maximum value the overall flow is equal to 1036w/m^2, the direct flow is equal to 779 and the diffuse flux is equal to 256w/m^2.

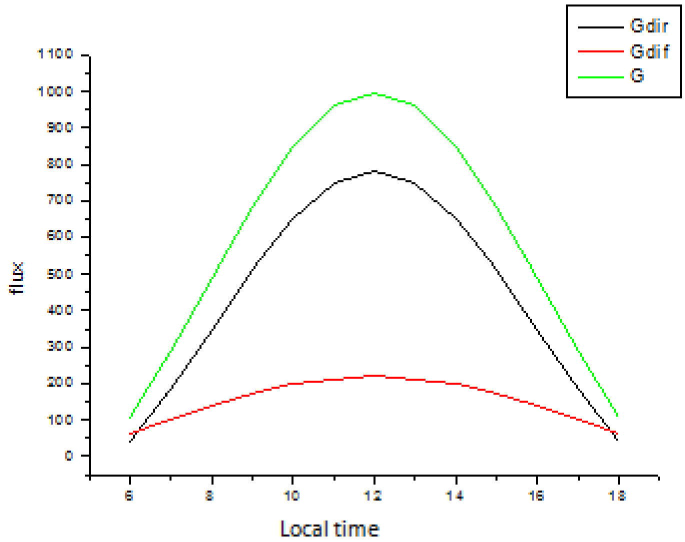

Fig. 2. Variation of solar radiation for the albedo of the water during the day

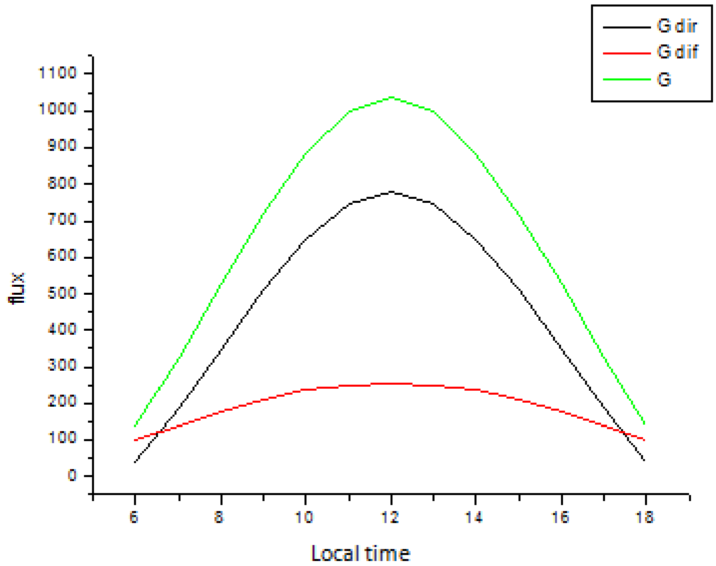

Fig. 3. Variation of solar radiation for the albedo of the Sahara during the day

4.3 The Concrete

Figure 4 shows the variations of direct, diffuse and global solar radiation received per unit of flat surface of the solar collector in a zone surrounded by concrete, from the figures we observe that: the maximum value of the global flux is equal to 1004w /m^2, the direct flux is equal to 779 and the diffuse flux is equal to 224w/m^2.

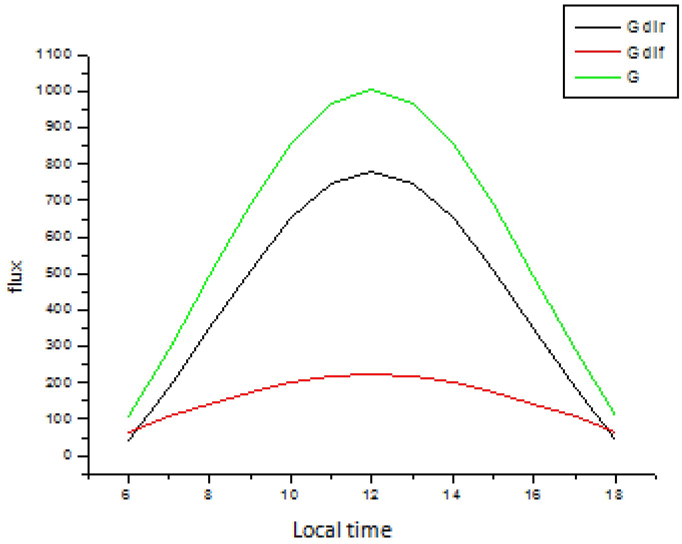

Fig. 4. Variation of the solar radiation for albedo of the biton during the day

4.4 Effect of Albedo on Diffuse Solar Radiation

Figure 5 shows that diffuse solar radiation has optimal values in the desert zone. Since the albedo is the ratio of the light energy reflected to the incident light energy, because the albedo in the desert zone is larger compared to the other zone.

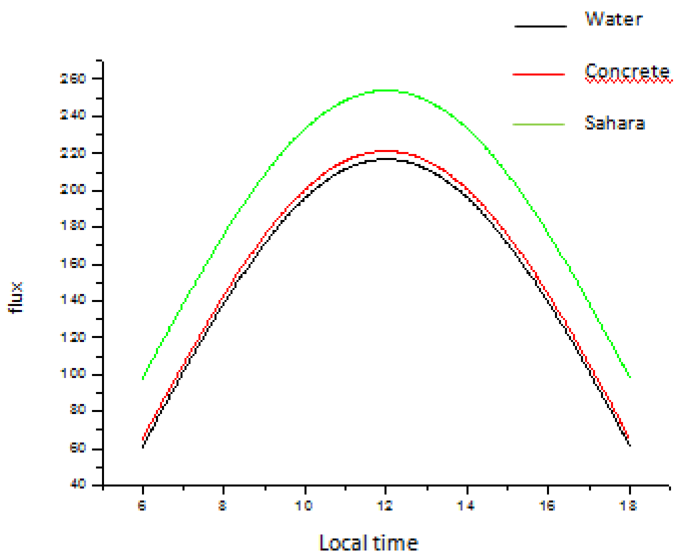

Fig. 5. Effect of albedo on diffuse solar radiation during the day

4.5 Effect of Albedo on Direct Solar Radiation

Figure 6 shows the influence of albedo on direct solar radiation, we notice that the three curves are identical (Sahara, concrete and water), so the albedo does not affect the direct solar radiation.

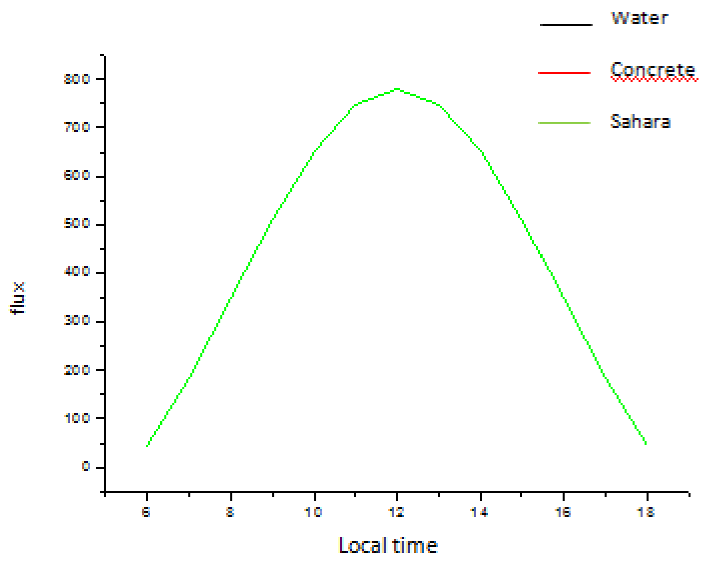

Fig. 6. Effect of albedo on direct solar radiation during the day

4.6 Effect of Albedo on Global Solar Radiation

Figure 7 represents the evolution of the global solar radiation as a function of time for different albedo, allows to notice that the global solar radiation presents optimal values the desert zones the overall flow is equal to 1008w/m^2. Therefore, the best areas are desert areas.

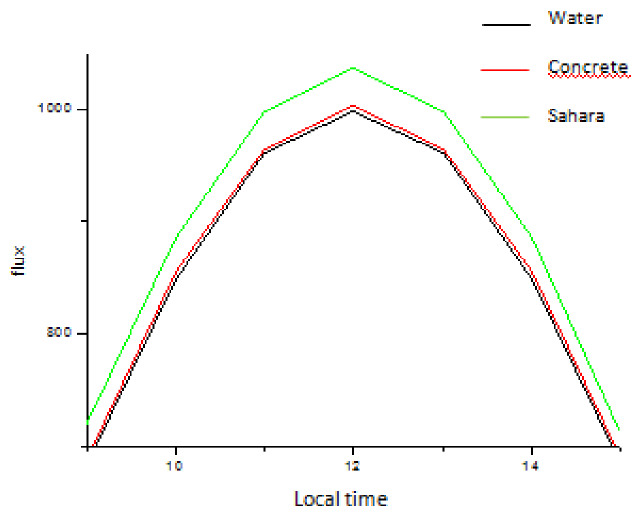

Fig. 7. Effect of albedo on global solar radiation during the day

4.7 The Effect of Wind Speed
4.7.1. The effect of wind speed on the outside of the glass

The wind speed causes a cooling effect on the outer surface of the glass, and Figure 8 shows that the wind speed has a relative effect on the temperature of the outer panes.

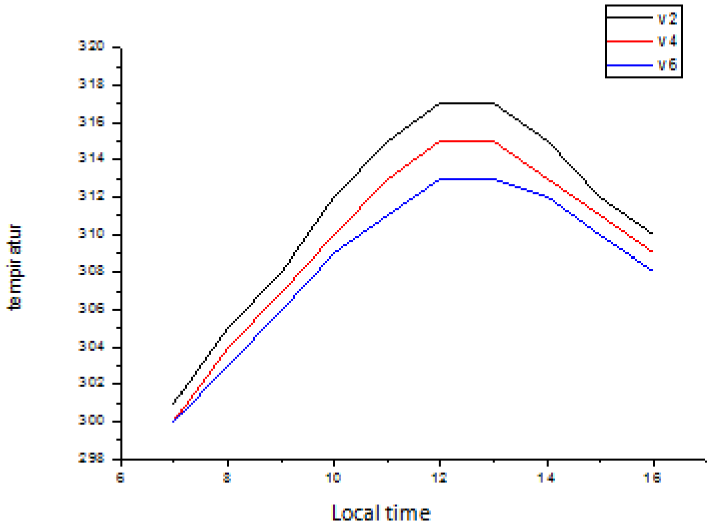

Fig. 8. Effect of wind speed on the outer pane

4.7.2. The influence of wind speed on the inner pane

Figures 9, 10 and 11 show the influence of the wind speed on the internal temperatures of glass, absorber and heat transfer fluid, it is found that the increase in wind speed causes a decrease in temperatures of the sensor elements therefore an increase in thermal losses towards the front of the collector.

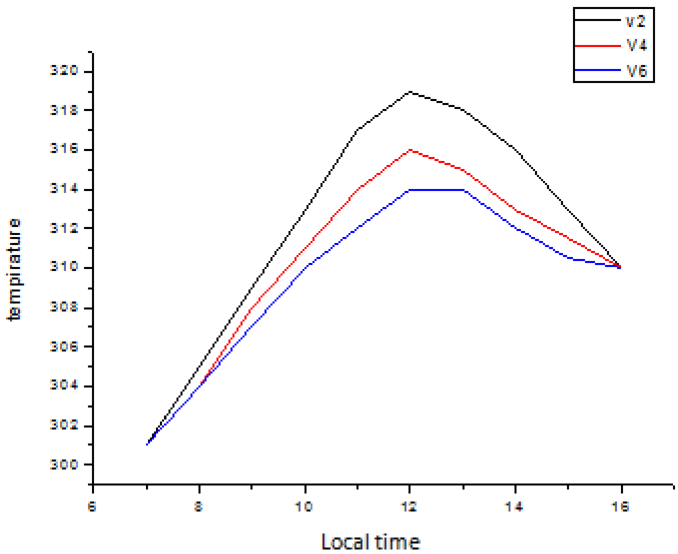

Fig. 9. Effect of wind speed on the inner pane

4.8 The Effect of Wind Speed on Yield

The influence of the wind speed on the efficiency of the sensor is illustrated in Figure 12. It can be seen that the low speeds are more favorable. The increase in wind speed causes an increase in thermal losses towards the front of the sensor which leads to a lower yield.

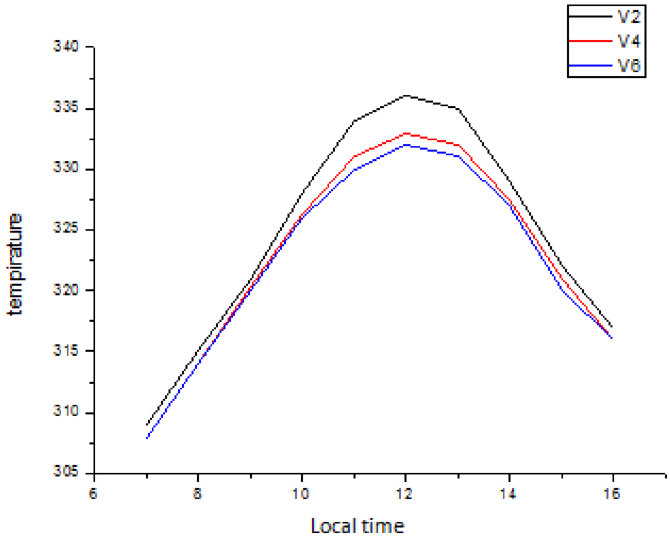

Fig. 10. Effect of wind speed on the absorber temperature

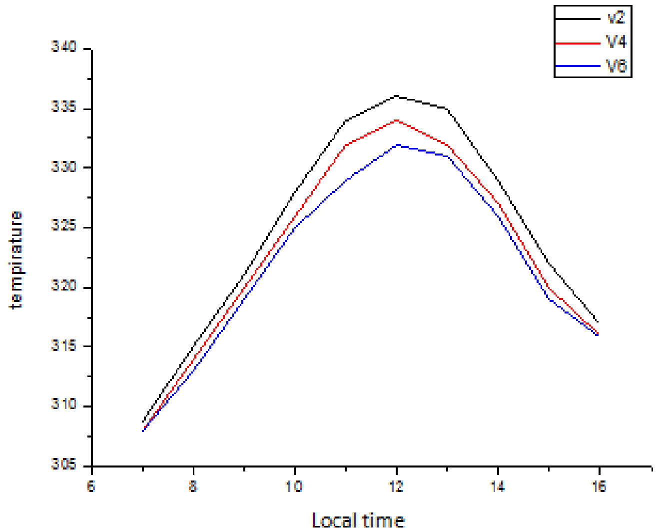

Fig. 11. Effect of wind speed on heat transfer fluid temperature

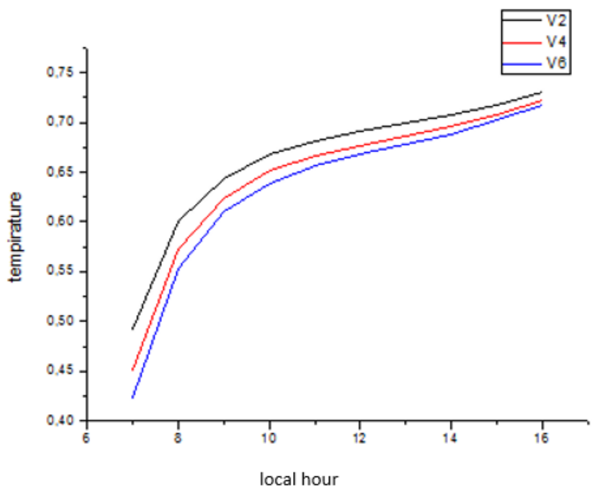

Fig. 12. Effect of wind speed on the efficiency of the collector

5. Conclusion

The solar collector is the essential element for the exploitation of solar energy, it captures solar radiation and transforms it in the form of greenhouse heat by materials that have high absorption coefficients. This heat can be used in the heating of sanitary water or for the air conditioning of buildings. It can also transform solar radiation into current using semiconductor materials called solar cells.

Several factors affect the performance of the sensor. It depends on their type of operation, the improvement of the percentage of solar radiation capture.

This work allowed presenting firstly a descriptive study on the different zones, we found that the global solar radiation Achieves optimal values in the desert zones with an overall flow equal to 1008w/m^2. So the best zones are the desert areas.

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