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Simulation of the Outlet Temperature using Meteorology of the City of El Jadida-Morocco

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Abstract- This article is a continuation of the previous article" Modeling of a parabolic trough using two heat transfer fluids and an economic estimation in the Moroccan dairy industry," presenting new parameters and results. Its objective is to simulate the temperature of the chosen fluid, which is water by using the meteorology of the city of El Jadida, city of the dairy industry.

We presented the energy balance of the parabolic trough then the thermophysical properties of the water, as well as the meteorology of El Jadida by taking the maximum, minimum temperature of the year plus the range of the wind speed influenced the glass cover of the absorber. We finished with a visualization of water velocity within the absorber.

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Simulation of the Outlet Temperature using Meteorology of the City of El Jadida-Morocco

Meryem El Badaoui [α] & Abdelatif Touzani [σ]

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I. Introduction

According to the recent article "Modeling of a parabolic trough using two heat transfer fluids and an economic estimation in the Moroccan dairy industry"[1], We made a comparison between two heat transfer fluids based on several parameters including the heat exchange coefficient, the Grashof number as well as their environmental and economic impact.

This comparison made it possible to choose water as the heat transfer fluid within the industry. It is in this context, and based on the metrology of the city of el Jadida-Morocco, the simulation proposed below was established under Comsol in transient mode using water as heat transfer fluid.

II. Thermal Balance of Parabolic Trough

Accordant with the previous article, we focused on the description of the parabolic trough as well as we presented its thermal balance. Below we will briefly introduce it. [2][3]

a) Description of parabolic through

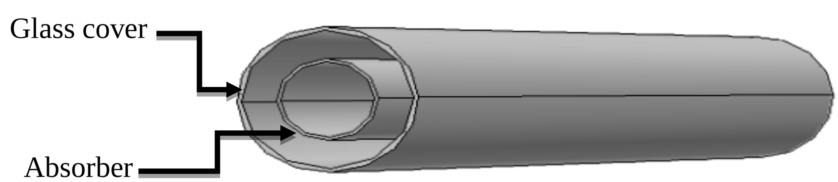

Figure 1: Description of absorber pipe

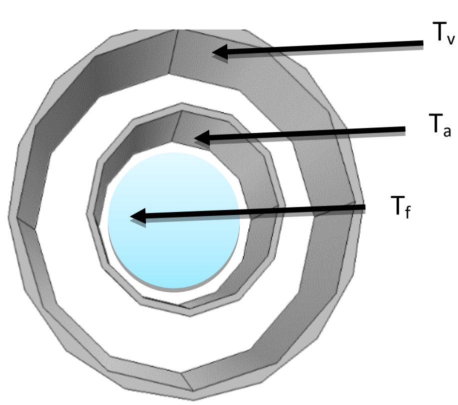

Figure 2: Temperatures inside the pipe

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b) Thermal balance

The characteristic equation using water

$$\rho_f C_p \pi D_{ai} \frac{\partial T_f(x,t)}{\partial t} = \rho_f C_p D_f \frac{\partial T_f(x,t)}{\partial x} + q_u(x,t)$$

$$q_u(x,t) = h_{af} \pi D_{ai} (T_a(x,t) - T_f(x,t))$$

$$T_{fi} = \frac{1}{1 + \frac{\Delta t D_f}{\Delta x \pi D_{ai}}} [T_{f(i-1)} \left(1 + \frac{\Delta t \rho_{f(i-1)} C_{p(i-1)} D_f}{\rho_{fi} C_{fi} D_{ai} \pi \Delta x}\right) + \frac{\Delta t}{\rho_{fi} C_{pi} D_{ai} \pi \Delta x} q_u(T_{ai}, T_{fi})]$$

Using the constants for simplifications, we have the equations below:

$$T_{fi}^{t+1} = A T_{fi}^t + B_{f(i-1)} + C$$

$$A = [1 - \frac{D_f \Delta t}{\Delta x \pi D_{ai}}] \qquad B = \frac{\rho_{f(i-1)} C_{p(i-1)} D_f \Delta t}{\rho_{fi} C_{pi} D_{ai} \pi \Delta x} C = \frac{q_u}{\rho_{fi} C_{pi} D_{ai} \pi}$$

The characteristic equation of the glass cover

$$\frac{\partial T_a(t)}{\partial t} = \frac{1}{\rho_a C_{pa} A} [q_{ab}(t) - q_{a,v}(t) - q_u(t)]$$

$$q_{ab} = \rho_{sel} \alpha_{ab} \tau_v S G q_{a,v} = \frac{2\pi K_{aireff}}{ln \frac{D_{vi}}{D_{ae}}} (T_a - T_v) + \frac{\sigma \pi D_{ae} (T_a^4 - T_v^4)}{\frac{1}{\varepsilon_a} + \frac{1-\varepsilon_v}{\varepsilon_v} (\frac{D_{ae}}{D_{vi}})}$$

$$T_a^{t+1} = T_a^t + \frac{\Delta t}{\rho_a C_{pa} A} [q_{ab}(t) - q_{a,v}(t) - q_u(t)]$$

$$T_a^{t+1} = T_a^t + D \qquad \text{with: } D = \frac{\Delta t}{\rho_a C_{pa} A} [q_{ab}(t) - q_{a,v}(t) - q_u(t)]$$

Water thermophysical proprieties

$$\frac{\partial T_v(t)}{\partial t} = \frac{1}{\rho_v C_{pv} A_v} [q_{a,v}(t) - q_{v,amb}(t)]$$

$$q_{v,amb}(t) = h_{v,amb} S_{ve} (T_v - T_{amb}) + \varepsilon_v \sigma S_{ve} (T_v^4 - T_{amb}^4)$$

$$T_v^{t+1} = T_v^t + \frac{\Delta t}{\rho_v C_{pv} A_v} [q_{a,v}(t) - q_{v,amb}(t)]$$

$$T_v^{t+1} = T_v^t + E \qquad \text{with: } E = \frac{\Delta t}{\rho_v C_{pv} A_v} [q_{a,v}(t) - q_{v,amb}(t)]$$

Since we chose to work with water as heat transfer fluid, this implies to present its thermophysical properties below.
Volumic mass (Kg/m^3):

$$-0.0032T^2 - 1.6126T + 799.26;$$

Heat capacity (J/Kg.K):

$$(276370 - 2090{,}1T + 8.125T^2 - 0.014116T^3 + 9.3701.10^{-6}T^4)/_{18.051}$$

Thermal conductivity (W/m.K):

$$-0.432 + 0.0057255T - 8.078.10^{-6}T^2 + 1.86.10^{-9}T^3 + 1.861.10^{-9}$$

Dynamic viscosity (Pa. s):

$$\exp(-52.843 + \frac{3703.6}{T} + 5.866 \ln(T) - 5.87910^{-29} T^{10})$$

III. DNI of EL Jadida during the Year

According to Solar Atlas Masen [4][5], we were able to generate the following results

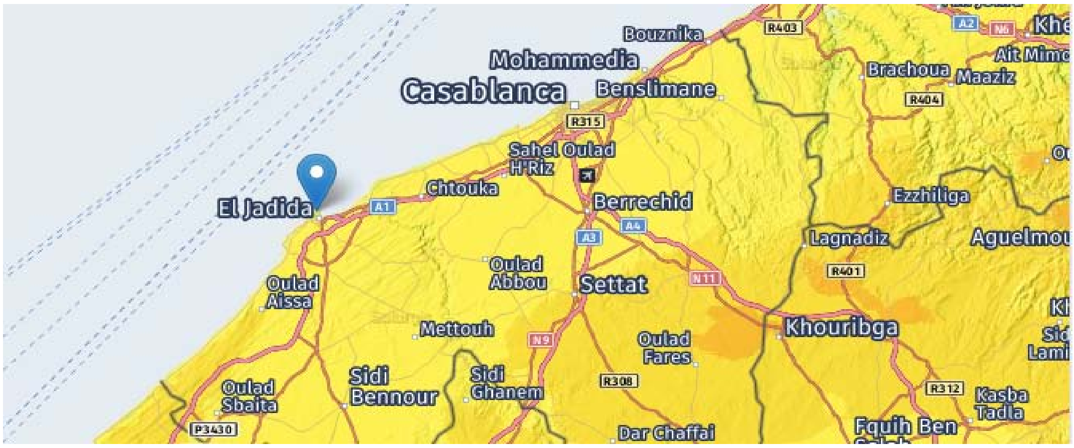


Figure 3: DNI of EL Jadida from March to September

	March	April	May	June	July	August	September
DNI (Kwh/m^2)	151	172	183	171	158	151	156

Figure 4: DNI of EL Jadida from October to February

	October	November	December	January	February
DNI (Kwh/m^2)	130	117	116	120	122

IV. Meteorology of EL Jadida-Morocco

In this paragraph, we will look at the meteorology of El Jadida during the year 2019 by presenting the maximum and minimum temperatures and the wind speed.[6][7]

a) Temperatures of EL jadida in 2019

According to the Accu Weather website [8], we were able to take the meteorological history of the city in 2019 to identify the maximum and minimum temperatures of the year to use them in our simulation.

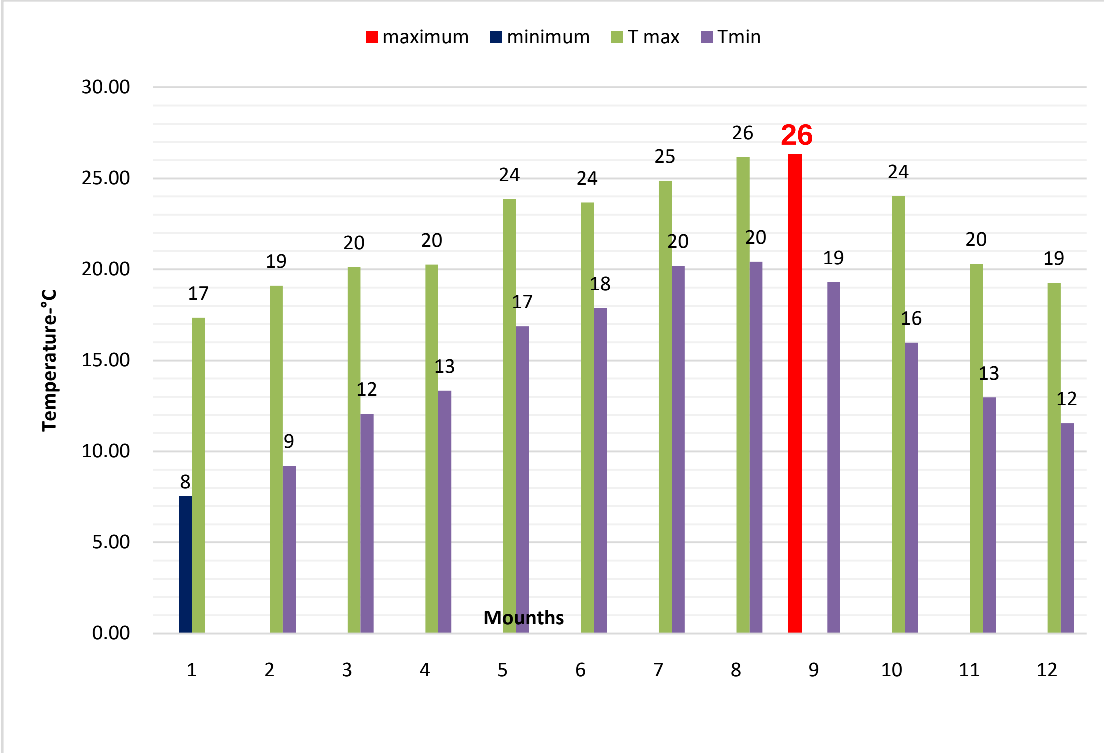


Figure 5: Maximum and minimum average temperature for the year 2019

The figure above shows, on the one hand, the daily average maximum and minimum temperatures of the year. On the other hand, the months with high and low temperatures are September at 26°C and January with 8°C.

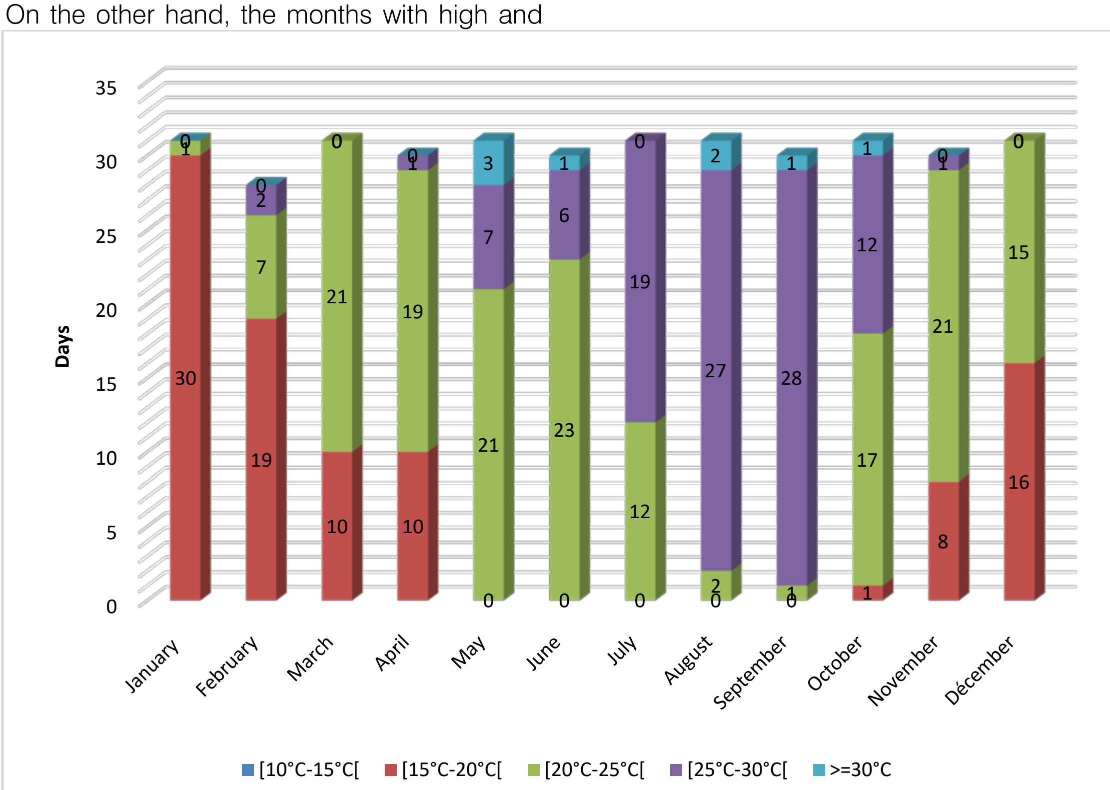


Figure 6: Average Maximum temperature in 2019

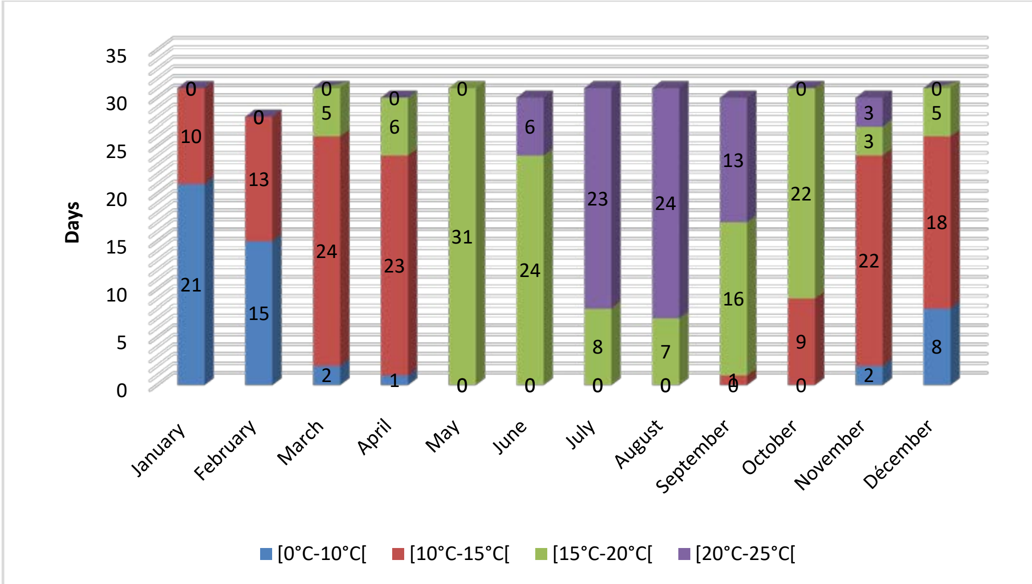
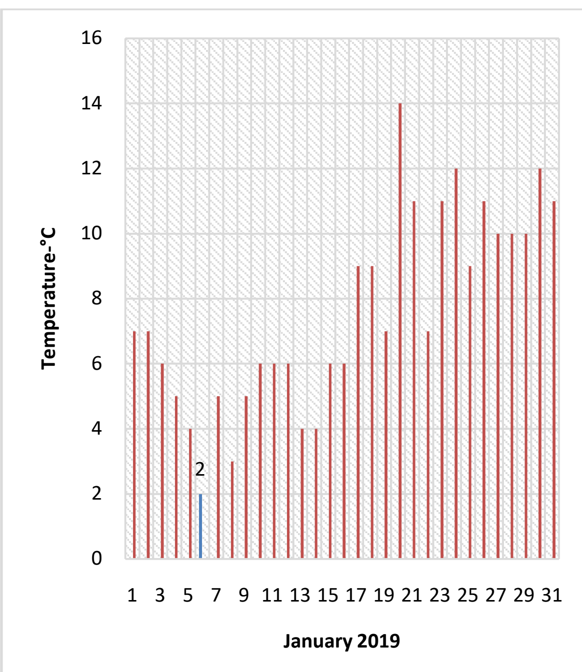


Figure 7: Average Minimum temperature in 2019

The figures beyond show the number of days per month, reaching peak temperatures for the first diagram, while the second presents the days with the lowest temperatures.



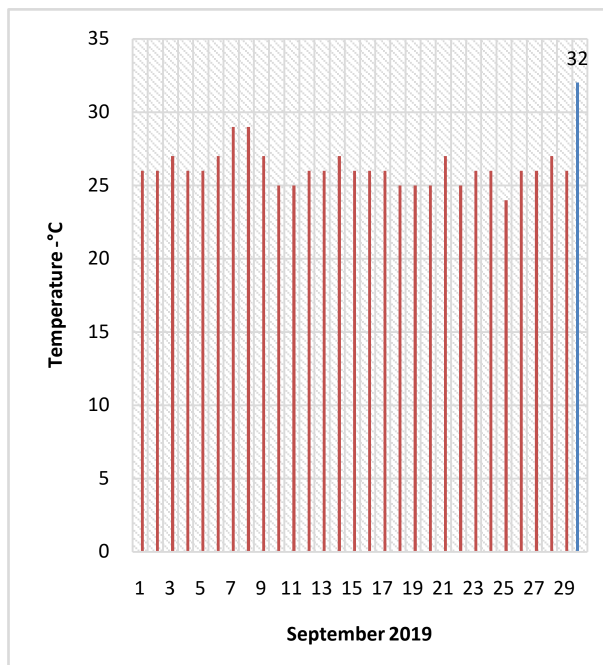


Figure 8: The minimal temperature in January 2019

Figure 9: The maximal temperature in September 2019

Figures 8 and 9 present the months having the maximum and minimum temperature of the year, recording on January 6, the lowest temperature of the year: 2 °C as for September 30 marks the highest temperature of the year: 32 °C.

b) Wind speed during 2019

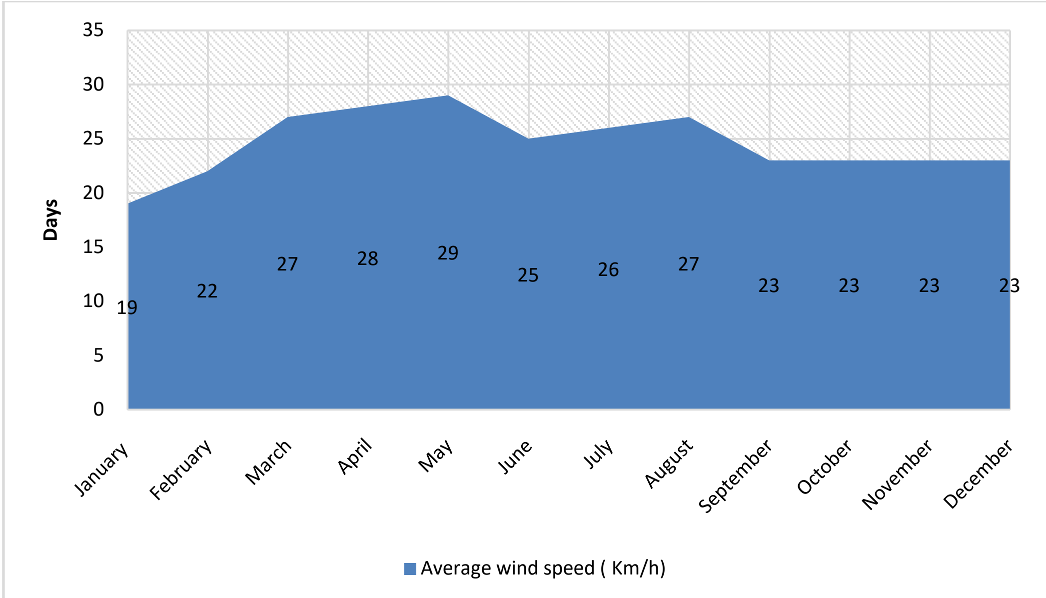


Figure 10: Average wind speed in 2019

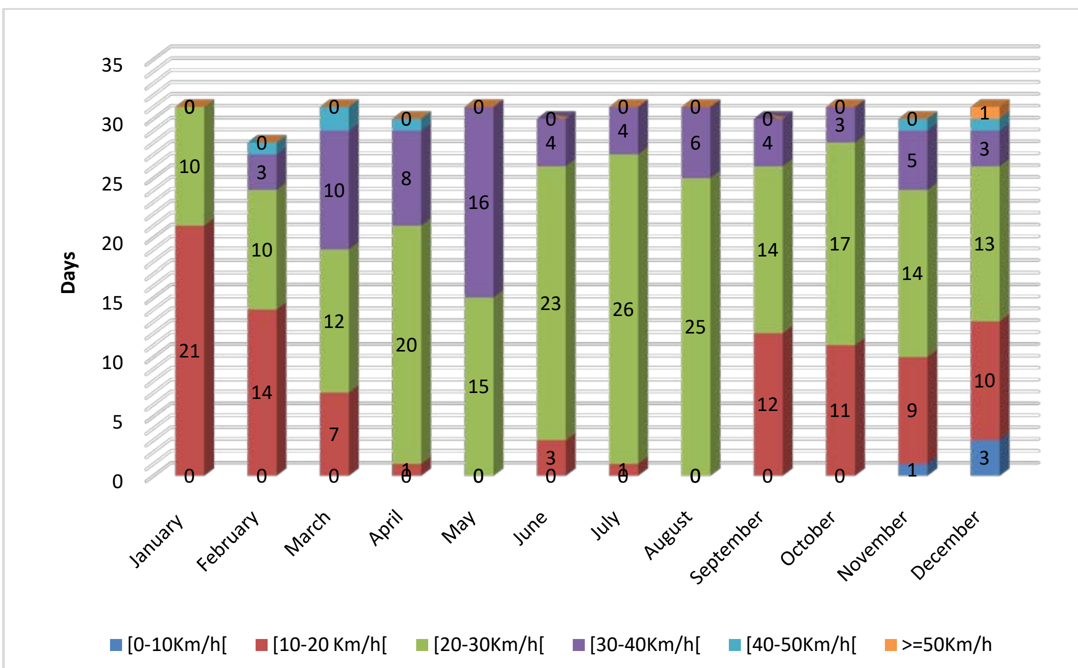


Figure 11: Daily Wind speed in 2019

The figures above show the evolution of wind speed in 2019, varying from 8km/h to 73Km/h. We notice in the second diagram a variation of the wind speed compared to the days of each month of the year.

V. Results and Discussions

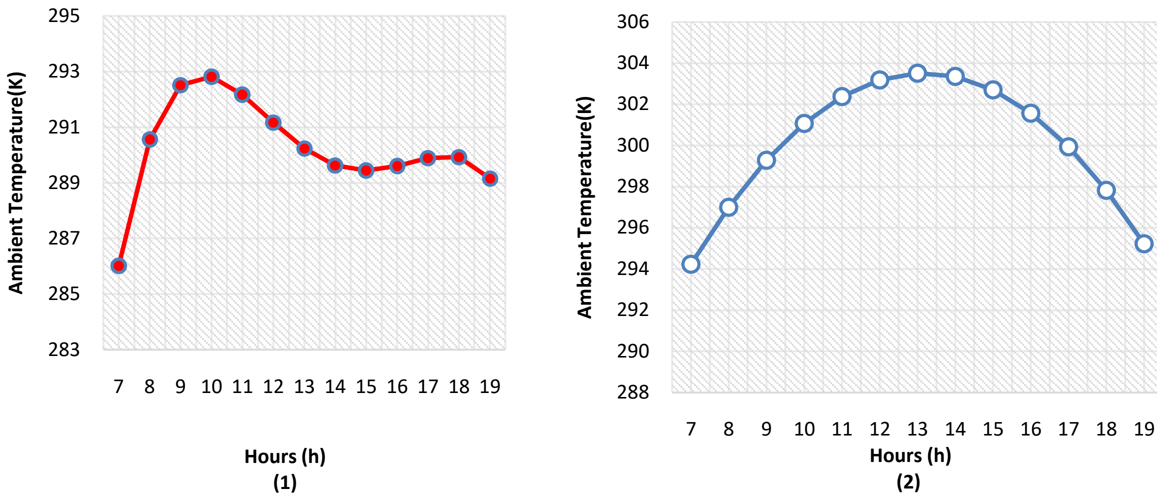


Figure 12: Ambient temperature on 6 January (1) and on 30 September (2)

The figure above shows us the variation of the ambient temperature during the day, starting from 7h to 19h. We observe on 6 January (1), marked the minimal temperature of the year, reaching a maximum of 293K at 10 a.m.

On the one hand and on the other hand, we notice that a higher temperature: 304K at 1p.m was noticeable on 30 September.

☞ Outlet water temperature on January 6 and September 30

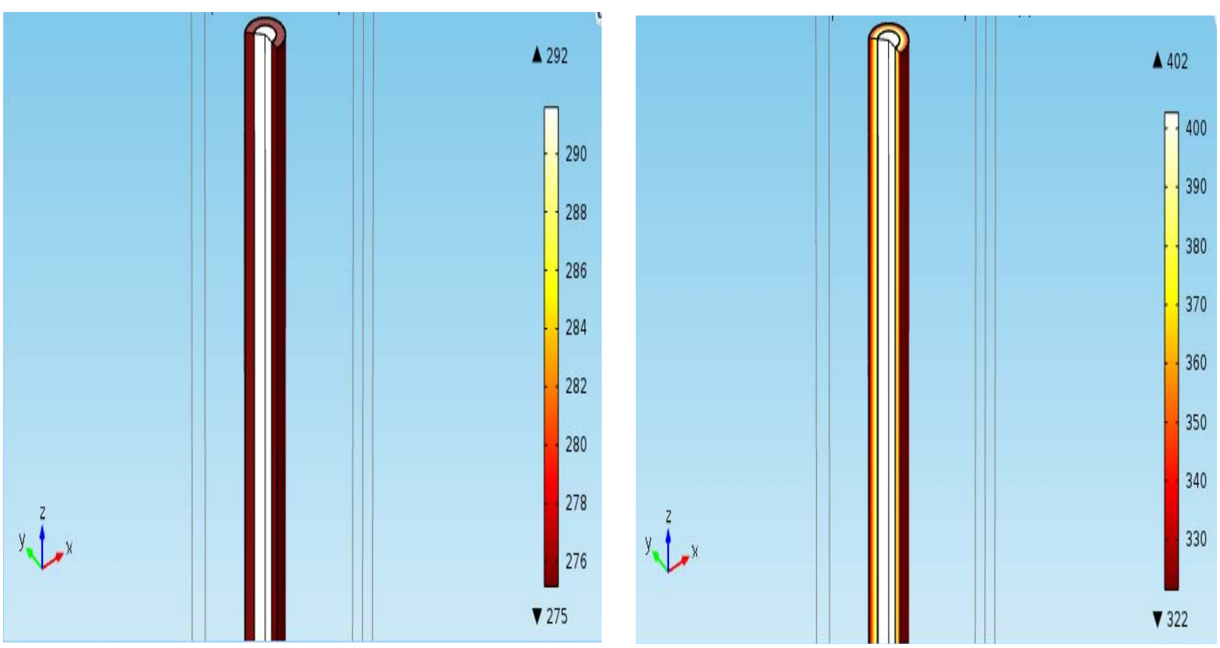


Figure 13: Outlet water temperature on January 6 (1) and September 30 (2) using Comsol Multiphysics

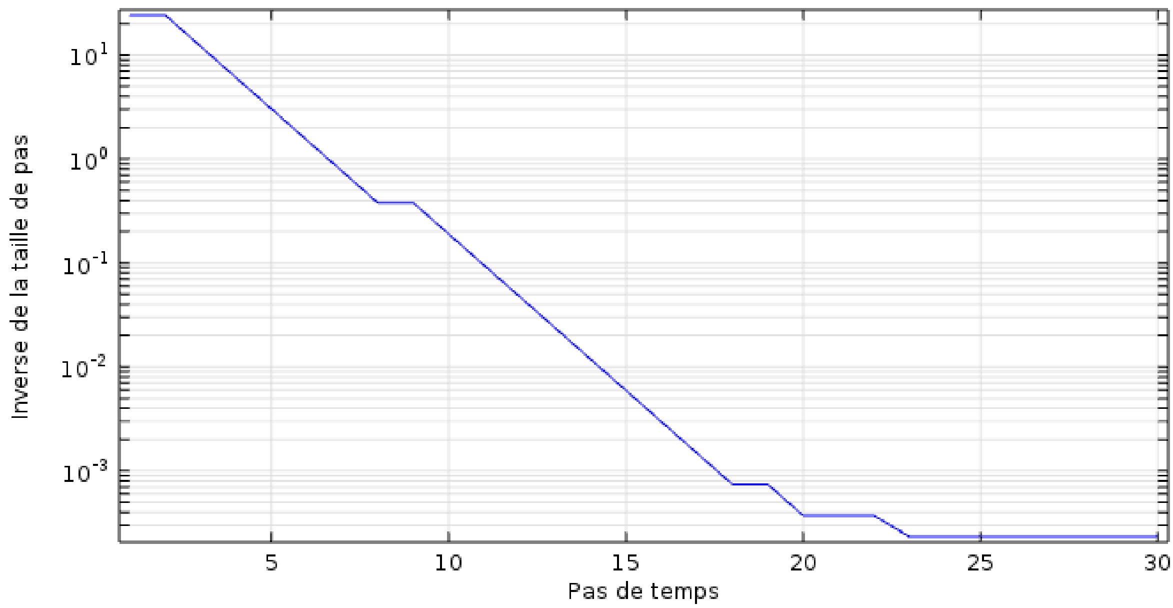


Figure 14: Simulation convergence curve

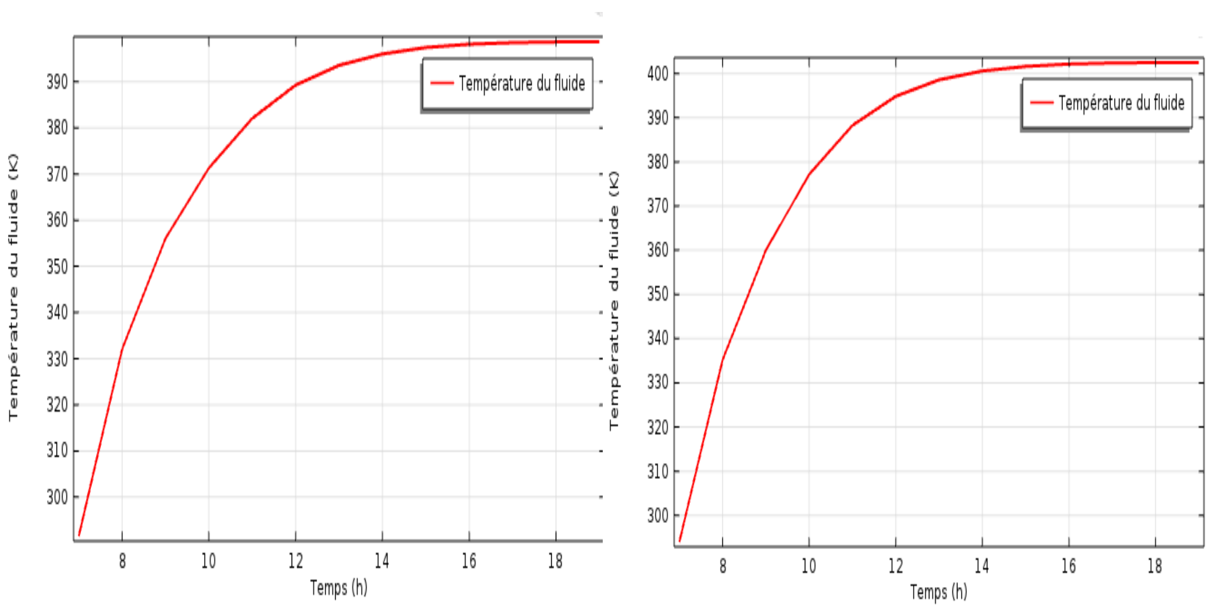


Figure 15: Variation of the outlet temperature according to time on January 6 (1) and September 30 (2)

Figure 13 shows the simulation under Comsol Multiphysics of the water temperature at the outlet on January 6 and September 30. Take an outlet temperature exceeding 290K for January 6, while September 30 marks a temperature exceeding 400k.

For figure 14 of the convergence curve of the simulation converges quickly. This convergence shows us the validity of our simulation.

The figure 15presents the temperature evolution from 7h to 19h of the two days mentioned above.

☞ Variation of Glass cover temperature depending on wind speed

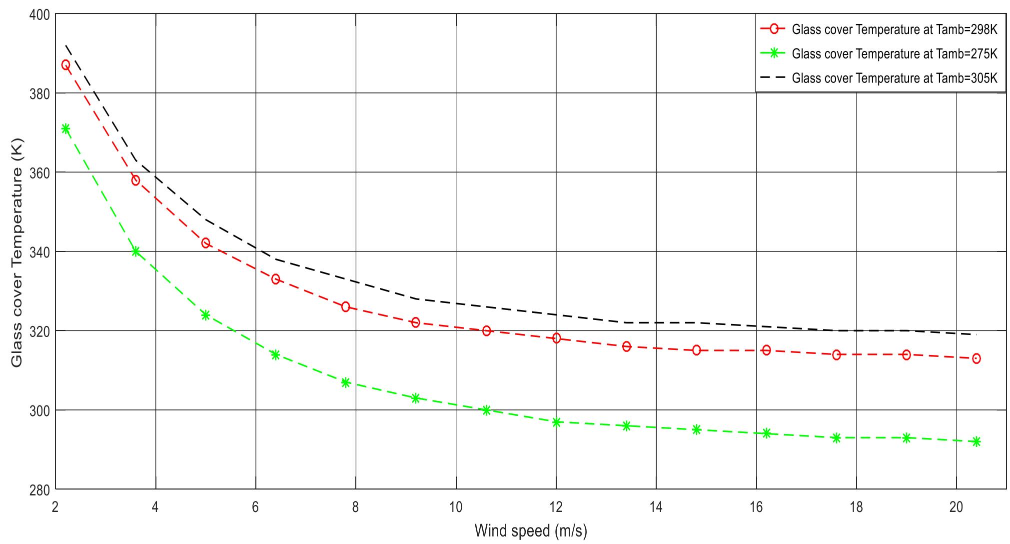


Figure 16: Variation of Glass cover temperature depending on wind speed

In figure 16, we notice a decreasing effect of the wind speed on the glass cover temperature for the three ambient temperatures.

☞ Water speed in the parabolic trough

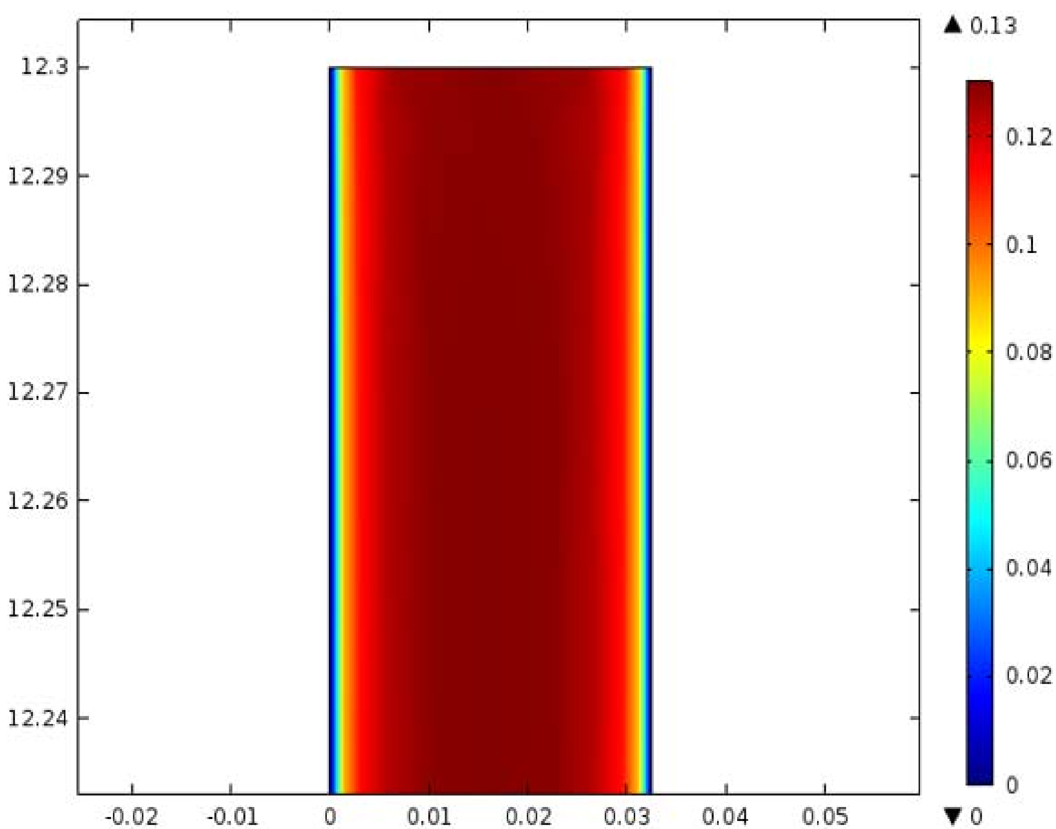


Figure 17: Vertical section of parabolic trough

This figure allowed us to visualize the interior of the parabolic by presenting the speed of the water in the absorber by reaching a speed of 0.13m/s at the parabolic through the outlet.

Variation of temperatures depending on solar irradiation

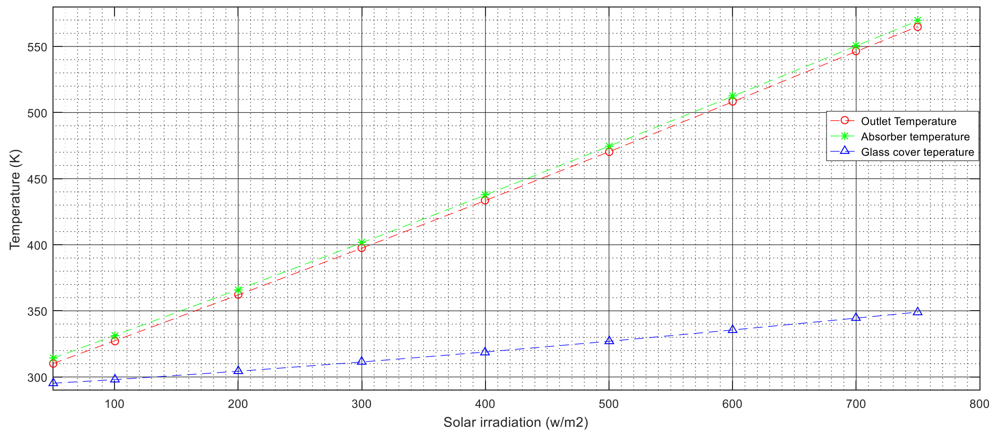


Fig. 18: Temperature variation according to solar irradiation during January 6

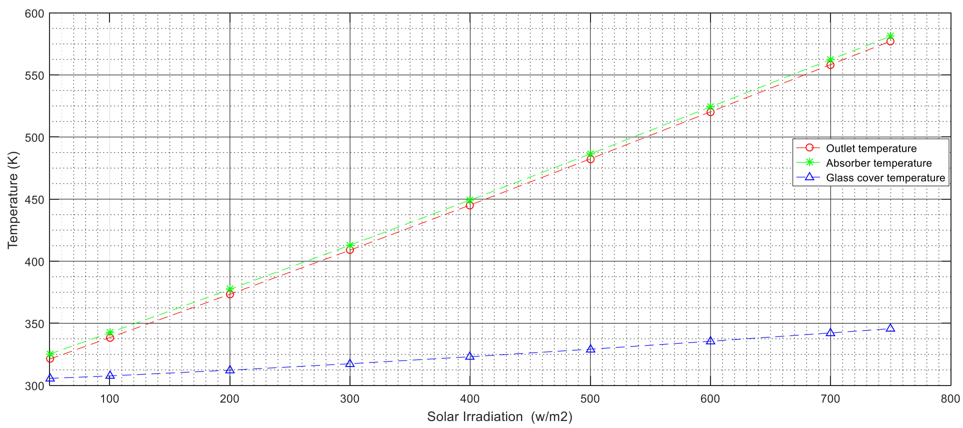


Fig. 19: Temperature variation according to solar irradiation during September 30

The figures above show the variations of the three temperatures during January 6 and September 30 depending on solar irradiation.

It can be seen that solar irradiation has an effect on the three temperatures, more precisely the absorber temperature, its increase implies an increase intemperatures, recording increases in the temperatures of the fluid, the absorber and the glass respectively: 470K, 474K and 327K for a maximum irradiation of 500w / m2 during January 6, moreon September 30 and for a maximum irradiation of 750w / m2 at temperatures of 577K, 581K and 346K.

VI. Conclusion

This labor made it possible to work with the water chosen at the end of the previous work by simulating its temperature at the outlet.

This study, first of all, made it possible to visualize the meteorology of the city by identifying January 6 as the day with minimum temperature and September 30 having a maximum temperature, as well as the variation of the temperature at the exit during these two days.

Also, we exposed the variant wind speed from 8km / h to 73Km / h in 2019, as well as its influence on the glass cover temperature.

Acknowledgment

This work was done in the laboratory "Applied Thermodynamics and Solid Combustibles (ATSC)", Mohammedia School of Engineers (EMI), Rabat-Morocco, under the direction of professor Doctor Abdellatif TOUZANI.

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