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# Computational analysis of heat transfer exchange in two geometrical configuration of greenhouse ,application case study

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***Abstract*—this computational work exploited in a greenhouse heated at the bottom to determine the effect of different forms of heat evacuation wall, i.e. triangular (chappel) and elliptic (tunnel) shape on the cooling by natural convection. The lateral wall supposed like adiabatic walls for the first case. The mass, momentum and energy equations are solved by a finite volume method based on the SIMPLE algorithm. The obtained results for the two different types of wall with the Rayleigh number ($10^5$-$10^7$). From the investigation, it found that the heat transfer rate increased for the triangular and elliptical form walls with the increase of the Rayleigh number, but the maximum rate of heat transfer obtained for the form of the tunnel greenhouse without radiation.**

***Keywords—component Greenhouse, storage system, Nusselt and Rayleigh Number.***

## I. INTRODUCTION

As can be considered an essential captor of solar energy, greenhouse at Algeria has achieved great success with using in agricultural. It can increase outputs of corps and prolong growth period [1].
Greenhouse is usually structured with steel skeletons, walls and roof covered by transparent material, and its covering area is about 50–200 m$^2$. In south Algeria, the polyethylene greenhouse is mostly of tunnel or mono chapel type without walls. Energy inside it (greenhouse) mainly comes from solar radiation [2].
In the daytime, the temperatures of soil and the air inside greenhouse increase as the energy from solar radiation accumulated and stored [3].
With thermal curtain storage system helps greenhouse is able to maintain proper temperature at night. Through insulation and ventilation conditions greenhouse can keep favorable growing in autumn, springer and summer [4].
The temperature inside greenhouse can reach over 50 °C in high temperature season during day, therefore it be required the proper ventilation[5-6].It's (ventilation) also needed to evacuate harmful gas in cold season. The temperature inside greenhouse is too low for corps to grow in winter. To maintain favorable growing conditions; some heating measures are used such as oil (gasoil) furnace.
Many researchers have developed different mathematical models descripting the mass and heat transfer process in greenhouse and including exterior parameters like as solar radiation ,temperature and wind speed and so on Boulard et al .
Some researchers have investigated to develop the mathematical models descripting the mass and heat transfer process in greenhouse [7-8].
Greenhouse combined with earth tube heating, movable thermal curtain, phase change and solar collector is the min few researches found at now.
In this work, two greenhouses configuration tunnel and chapel simulated numerically. The main objective of this study is to improve the most form to evacuate the thermal exchange. We used storage tubes filled with stones to store energy absorbed by greenhouse at a semi-arid climate case Ghardaïa.

## II. GEOMETRICAL CONFIGURATION

Geometrical configuration with all boundaries condition considered in this study showed in the Fig.6.

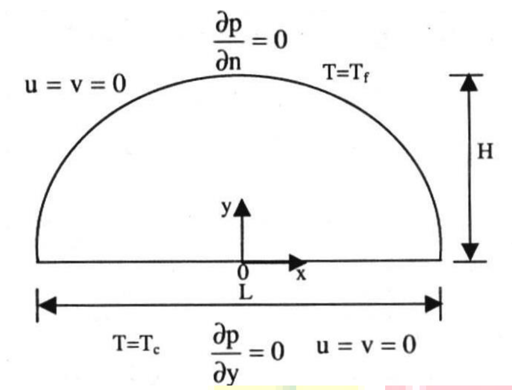



Figure.1. Problem Position and boundary condition for tunnel greenhouse

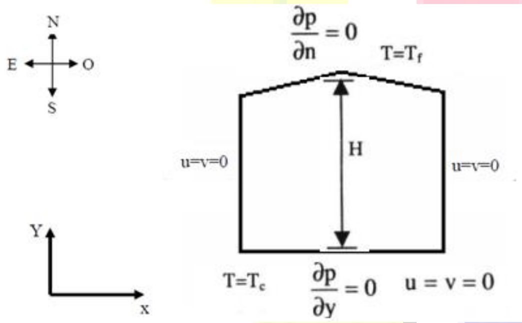



Figure.2. Problem Position and boundary condition for chappel greenhouse

## III. NUMERICAL SIMULATION

### *A. Mathematical Resolution*

The aim of this investigation is to study the natural convection in laminar regime of the air of a tunnel and chapel greenhouse without vegetal cover. The Ansys software 14.0 code used. Flow is considered to be in two-dimensional along x and y. The simulations were obtained by solving the Navier–Stokes equations for a steady flow written as:

$$\frac{\partial U}{\partial x}+\frac{\partial U}{\partial z}=0 \qquad (1)$$

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+w\frac{\partial u}{\partial z}=-\frac{\partial P}{\partial x_i}+\nu\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial z^2}\right) \qquad (1)$$

$$\frac{\partial w}{\partial t}+u\frac{\partial w}{\partial x}+w\frac{\partial w}{\partial z}=-\frac{\partial P}{\partial x_i}+\nu\left(\frac{\partial^2 w}{\partial x^2}+\frac{\partial^2 w}{\partial z^2}\right)+g\beta(T-T_0)$$

(3)

$$u\frac{\partial T}{\partial x}+w\frac{\partial T}{\partial z}=\alpha\left(\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial z^2}\right) \qquad (4)$$

Physical properties of the air confined within the two greenhouses assumed constant, except its density ρ whose variation given by the Boussinesq approximation [5-6-13]:

$$\rho=\rho_0(1-\beta(T-T_0)) \qquad (5)$$

Velocities considered Low (negligible) and the flow is laminar.

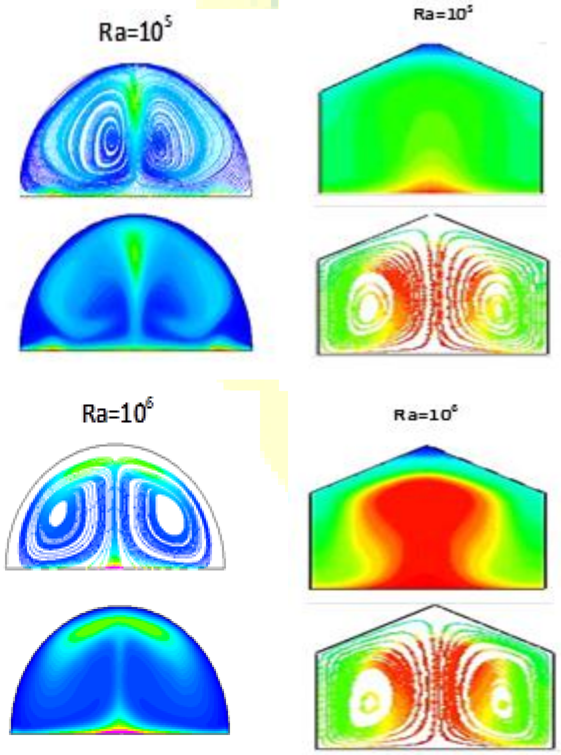
## IV. RESULTS

The stream function and isothermals for different Rayleigh numbers shown in Figu.3.

The flow of the fluid intensifies and the natural convection increases and predominates over the conduction in both cases. The air particles heated at ground level rise along the wall, then, they cooled in contact with roof flow near the other wall. The influence of the Rayleigh number on the traces of the stream function (top of the figure) and the isotherms (bottom figure) is illustrated. For different Rayleigh numbers the flow characterized by two air circulation loops in the two configurations.

For small Rayleigh numbers ($Ra = 10^5$), isotherms are parallel, so the heat transfer was dominated by the conduction. As the Rayleigh number increases, the isotherms become increasingly undulating and the heat, transfer becomes more pronounced. Thus, the flow of the fluid intensifies and the natural convection increases and predominates over conduction. The air particles heated at ground level rise along the wall. Then, the particles cooled in contact with the roof flow in vicinity of a median plane. The exchange of heat transfer in the two simulating greenhouse with different Rayleigh numbers, represented by the Nusselt number is given in Fig.4 .Therefore, the logic is respected as long as there is a concentration of isotherms at (Ground), which explains a large number of Nusselt. In order to analyze the influence of the Rayleigh number on the exchange rate, the variation of the local and mean Nusselt number as function of the Rayleigh number are presented in both cases .It can be seen that for a Rayleigh number ranging from 105 to 106, the Nusselt number is small and conduction dominates. With the increase of the

Rayleigh number, the exchange rate increases indicated by the important values of the Nusselt Number in a tunnel form and smaller than in the chapel form. For the local Nusselt In both cases is increase with the Rayleigh number increase but the mean Nusselt number evolution indicate that the heat transfer exchange is great in the tunnel greenhouse form than the chapel form .From these results, the good connection between the literature and the present work is observed for different Rayleigh numbers. Our objective was to study geometrical effect on the heat transfer exchange of greenhouse. We used a code that allowed us to determine the spatiotemporal distributions of Isolignes and isothermal of two geometrical configuration of greenhouse heated on bottom. We have also shown that for the flow imposed conditions (heating of the rollers) and for low temperature differences between floor and roof, the air circulation characterized by two recirculation cells rotating in the opposite direction. Therefore, this study should make it possible to improve the thermal design of greenhouses as well as the positioning of heating systems with thermal storage.



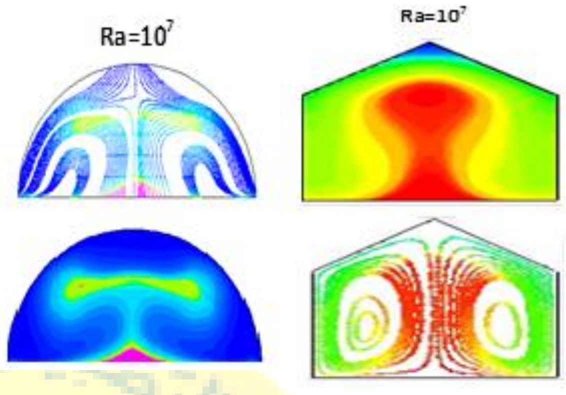




Figure 3. Isolignes and isothermal in both cases

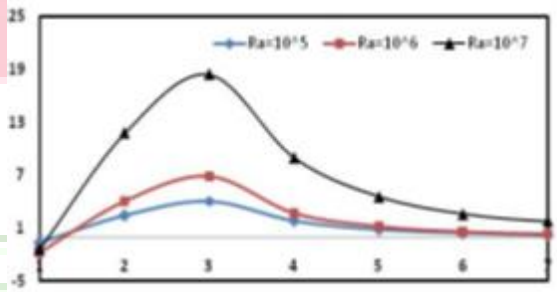


Figure 4. Local Nusselt number tunnel case

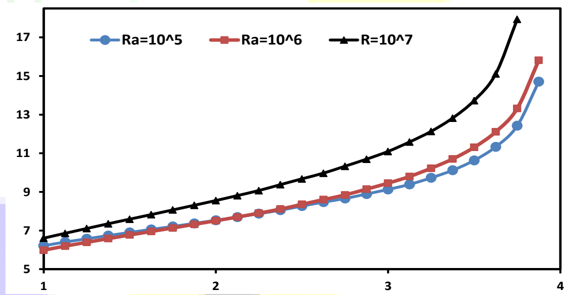



Figure5. Local Nusselt number chapel case

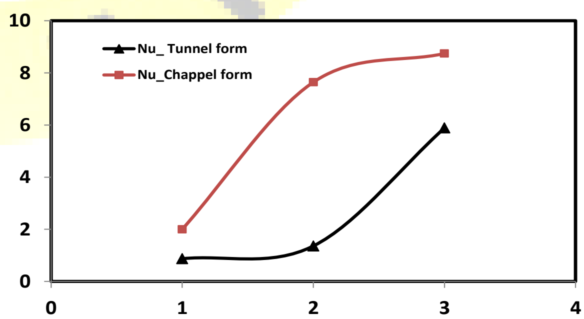
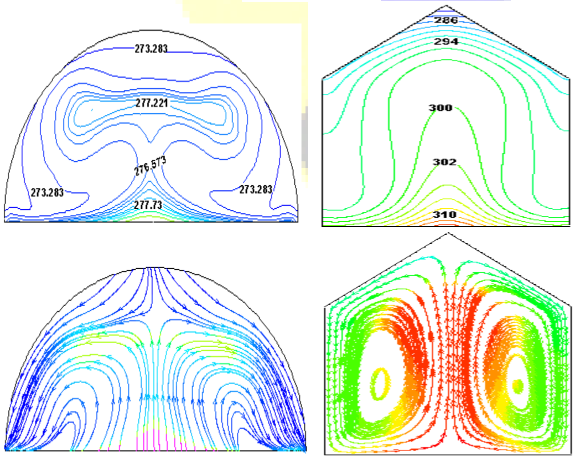


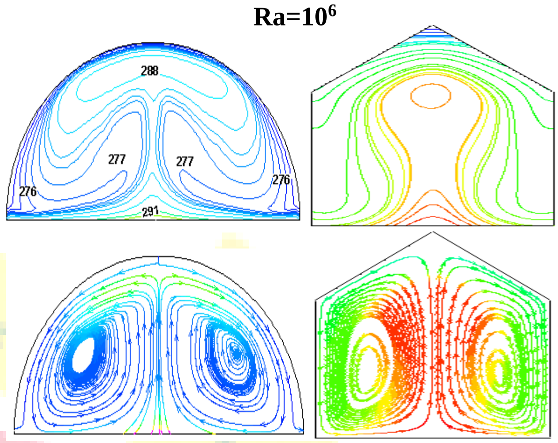

Figure 6.Mean nusselt number of both daces

For the second case, we presented the isotherms and isolines of the stream function corresponding to the natural convection coupled with thermal radiation. In both cases, the air circulation characterized by two recirculation cells located symmetrically with respect to the vertical median of the greenhouse. This structure explained by the fact that the cold air that heats up near the heating system rises to the top of the greenhouse and flows along the roof, where it cools. Therefore, one portion goes down along the left wall and the other along the right wall for the chapel case and at the roof level for the tunnel case. Thus, the symmetrical structure of the roof and the median position of the storage system are responsible for the bicellular structure of the current lines. It is found that the air circulation increases with the Rayleigh number and under the influence of radiation. With regard to the isotherms, the effect of thermal radiation is remarkable just near the adiabatic walls for the chapel case. This is because air is considered perfectly transparent vis-à-vis radiative exchanges, and therefore only solid surfaces participate in radiative exchanges. In pure natural convection, the isotherms are perpendicular to the adiabatic and roof walls, while they tilt in combined mode because of radiative fluxes. It is noted that the increase in the number of Rayleigh promotes heat transfer near the heating system. Indeed, the greater the Rayleigh number, the faster the fluid velocity accelerates and allows the extraction of a greater amount of heat [3-4]. As a result, the isotherms are more dense near the storage system when the Rayleigh number is large. Therefore, for large numbers of Rayleigh the temperature is almost constant in the majority of the interior volume, with the exception of the areas near the storage system and roof figure (8-9).

**Ra=$10^5$**



**Ra=$10^6$**



**Ra=$10^7$**

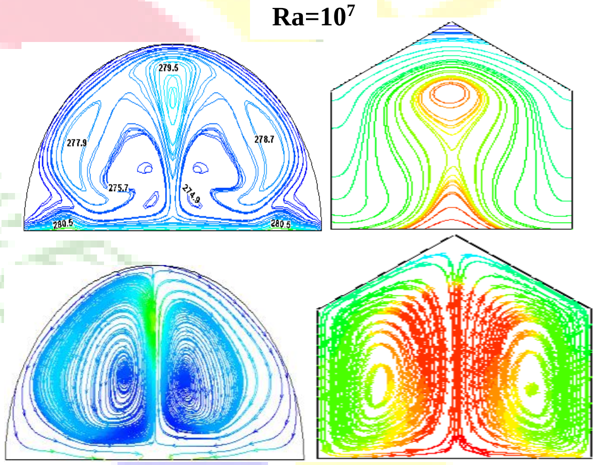


Figure 8 isothermes eand isolines for Ra =$10^5$, Ra =$10^6$ Ra =$10^7$ in both cases tunnel and chappel

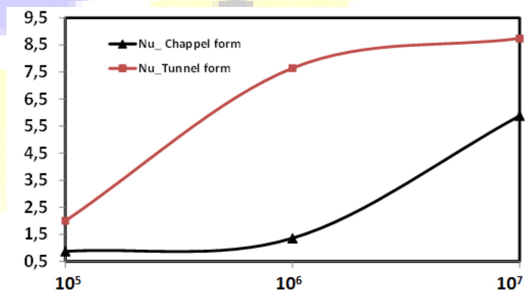



Figure 9 Mean Nusselt number Evolution Ra =$10^5$, Ra =$10^6$ Ra =$10^7$ in both cases tunnel and chappel

## V. CONCLUSION

In conclusion, careful numerical simulation of heat transfer exchange in both geometrical greenhouse configurations was investigated. The obtained results corroborate with the literature (benchmark) with Isolignes and isothermals. The transfer exchange in both cases was predicted with a Nusselt number evolution. The tunnel geometrical configuration was more evacuation than the chapel geometrical configuration but when we considerate radiation we found that the chappel configuration was the more evacuation. This study should make it possible to improve the thermal design of greenhouses as well as the positioning of heating systems with thermal storage.

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