IMPACT: International Journal of Research in Engineering & Technology (IMPACT: IJRET)
ISSN (P): 2347-4599; ISSN (E): 2321-8843
Vol. 5, Issue 7, Jul 2017, 45-50

STUDY OF THE NATURAL CONVECTION IN A CAVITY EQUIPPED WITH A HEATING PLATE INSIDE

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ABSTRACT

The transfer of heat into a square cavity due to a thin heated plate, was studied numerically for hot plate placed vertically / horizontally. The movement of the flow in the cavity depends on the heating plate itself. The effect of position and aspect ratio of hot plate on heat transfer and circulation was addressed.

KEYWORDS: Fortran, Heat Transfer, Hotplate, Natural convection

INTRODUCTION

The study of heat transfer plays an important role in the design and improvement of engineering systems in the field of engineering. In recent years, natural convection in cavities has been the subject of numerous studies due to its involvement in many natural phenomena and industrial applications, such as the cooling of electronic components, nuclear reactors, insulation buildings, semiconductor industries and natural convection cooling is desirable because, it does not require any energy source, such as a forced air fan and is maintenance-free and safe. The objective of this work was, to study the natural convection in a cavity, with a plate heated in different vertical and horizontal positions.

PHYSICAL MODEL AND MATHEMATICAL FORMULATION

We consider a closed square cavity, of languor L which contains a thin heating plate. The right wall and the left wall of the cavity have a temperature below the temperature of the plate, that maintained a uniform cold temperature (Tf). The flow is assumed to be two-dimensional, the horizontal walls are adiabatic and the interface between the two solid and fluid zones is assumed impermeable. All borders are rigid. The study was carried out for different values of the Rayleigh number, ranging from 10^3 to 10^5 for the various aspect ratios and the position of the heating plate. The air was chosen as the working fluid (PR = 0.71).

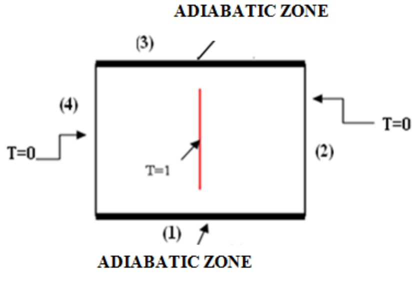

Figure 1: Geometry and Boundary Conditions

Simplifying Assumptions

- Fluid is Newtonian
- Incompressible fluid
- The viscous dissipation flux is negligible
- Transient regime and flow is two-dimensional.

EQUATIONS

The mathematical model describing the present problem has been developed based on the famous equations that manage the indoor air flow and heat transfers are:

- The continuity equation

$$\frac{\partial \rho}{\partial t} + \left(\vec{\nabla}\left(\rho\,\vec{V}\right)\right) = 0 \qquad \textbf{(1)}$$

- The Navier-Stokes equation

$$\rho\left(\frac{d\vec{V}}{dt}\right) = -\vec{\nabla}\,\rho + \mu\,\Delta\vec{V} + \rho\,\vec{g} \qquad \textbf{(2)}$$

$$\text{avec } \Delta\vec{V} = \vec{\nabla}\left(\vec{\nabla}\,\vec{V}\right)$$

- The energy equation

$$\frac{\partial T}{\partial t} + \frac{u\partial T}{\partial x} + \frac{v\partial T}{\partial y} = \frac{\lambda}{\rho C_P}\left[\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2}\right] \qquad \textbf{(3)}$$

$$avec\ \Delta \mathrm{T} = \vec{\nabla}\left(\vec{\nabla}\,\mathrm{T}\right)$$

From these equations we have developed a mathematical model which has been solved numerically using a calculation code based on the finite volume method in FORTRAN.

The elaborated model makes it possible to determine the current lines, the velocities along the x and y axes, and the temperature profiles as well as the whole field studied.

In this study we studied the influence of (02) parameters which are the Rayleigh number (Ra) for the values (10^3, 10^4, 10^5), the position of the heating plate (vertical, horizontal) in the cavity.

INITIAL CONDITIONS AND LIMITS

- Initial conditions: At time t = 0, you = 0, v = 0
- Boundary conditions:
- The function of the current on the walls $\Psi = cte = 0$

THE VORTICITY

- $\frac{\partial \Psi}{\partial x} = 0 \Rightarrow \frac{\partial^2 \Psi}{\partial x^2} = 0 \Rightarrow \omega = -\frac{\partial^2 \Psi}{\partial y^2}$
- $\frac{\partial \Psi}{\partial y} = 0 \Rightarrow \frac{\partial^2 \Psi}{\partial y^2} = 0 \Rightarrow \omega = -\frac{\partial^2 \Psi}{\partial x^2}$
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THE TEMPERATURE

- $\frac{\partial T}{\partial y} = 0$; Null flow or adiabatic.
- $T = T_f$; Temperature imposed.
- $\frac{\partial T}{\partial y} = 0$; Adiabatic.
- $T = T_f$; Temperature imposed.
- T=Tc ; Temperature imposed on the heating plate.

NUMERICAL RESOLUTIONS

The numerical model used to solve our system of equations is based on the finite volume method developed by Patankar.

RESULTS

For this square cavity subjected to the conditions at the following limits of the temperatures imposed on the vertical walls (Tc, Tf) and the two horizontal wells are kept adiabatic for this purpose we have elaborated a program in Fortran. Therefore, the results obtained are comparable with the literature, such as the Bench-Marck, which proves the reliability of the established code.

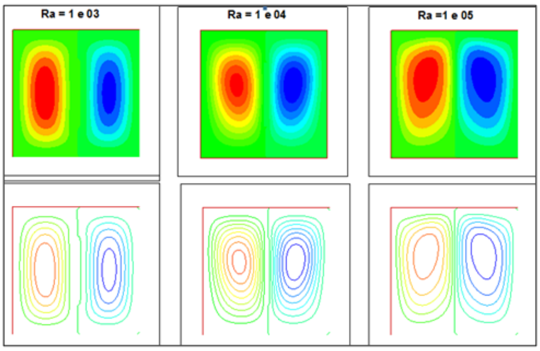

Figure 2: Temperature Field For Ra = 10^3 To Ra = 10^5

with Vertical Plate in the Center

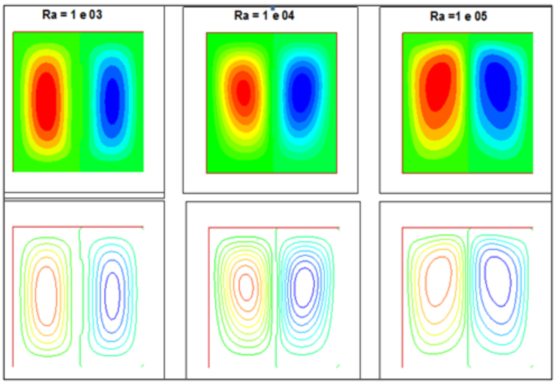

Figure 3: Current Lines For Ra = 10^3 To Ra = 10^5 with Vertical Plate with Center

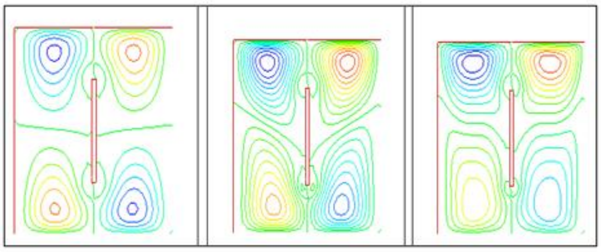

Figure 4: Velocity Field Following X For Ra = 10^3 To Ra = 10^5 with Vertical Plate in the Center

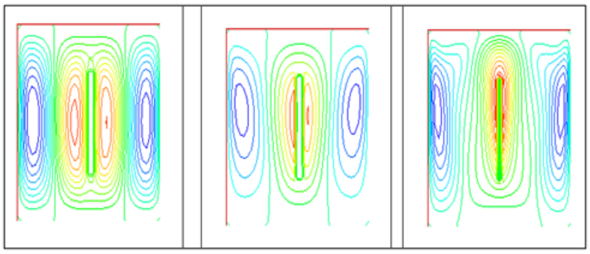

Figure 5: Velocity Field Following X For Ra = 10^3 To Ra = 10^5 with Vertical Plate in the Center

DISCUSSION OF RESULTS OBTAINED

- In the case where the plate varies horizontally from bottom to top with a Ra = 10^5, the convection increases with the displacement of the plate from bottom to top.
- In the case of a plate held vertically in the center of the cavity with different Ra.
- For a Ra = 10^3 the isotherms generally of straight form, but approaching the plate the latter are deformed. By raising the value of Ra the isotherms take the form (S), That is to say convection becomes more and more dominant.

CONCLUSIONS

The work we have presented concerns the study of the thermal influence of a heating plate placed in a square cavity with horizontal adiabatic walls and vertical subjected to a constant temperature. The mathematical model describing the present problem has been developed based on the famous equations that manage the indoor air flow and heat transfer are:

The equation of continuity, The equation of Navier-Stokes, The equation of energy.

From the results obtained it can be concluded that:

The transfer of heat into a square cavity due to a heating plate depends on the plate itself, in order to increase the transfer of heat, it is necessary to increase the temperature of the heating plate.

The heat flux is proportional to the value of Ra, that is to say by increasing the Ra the transfer increases.

The following velocity Y (V) is greater than the velocity following X (U).

In addition, the heat flux is reinforced for the vertical position of the plate as in the horizontal position, because in the latter case the plate acts as an obstacle which prevents the movement of air inside the cavity.

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