Numerical Simulation of Natural convection for thermo-dependent fluids in a square cavity with localized heating from bottom and isothermal cooling from sides

H.Daghab*, M.Kaddiri*, I. Arroub**

* Industrial Engineering Laboratory, Sultan Moulay Slimane University, Béni-Mellal, Morocco

** Team of Applied Physics and New Technologies, Sultan Moulay Slimane University, Béni-Mellal, Morocco

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1- Problem Description :

The present study reports numerical simulation of natural convection cooling of a heat source (representing power-dissipating semiconductor devices in electronics /MEMS applications) embedded on the lower wall of a square cavity filled with thermo-dependent fluids. The heat source produces a constant heat flux. The rest of the bottom wall and the top wall are adiabatic while the vertical ones are kept at a relatively low temperature (figure1).

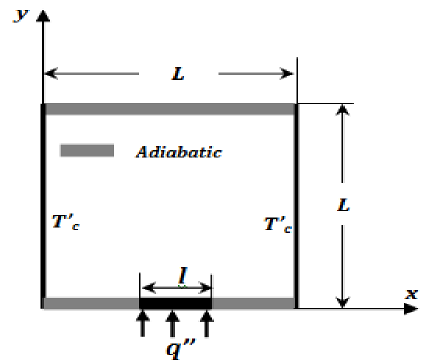

Figure 1: Sketch of the Cavity

The problem satisfies the following conditions:

➢ The fluid is "almost" incompressible and satisfies the Boussinesq approximation.

➢ All other thermodynamic and transport properties of the fluid, except for viscosity, are constant with respect to temperature.

➢ The *Z* dimension is much greater than the *X* and *Y* dimensions and thus the problem can be considered as essentially two-dimensional.

2- Governing equations :

The dimensionless governing equations written in terms of velocity vector components, (*U*, *V*), pressure, *P*, and temperature, *T*, in Cartesian coordinate system (*X*, *Y*), are:

$$\frac{\partial U}{\partial X}+\frac{\partial V}{\partial Y}=0$$

$$U\frac{\partial U}{\partial X}+V\frac{\partial U}{\partial Y}=-\frac{\partial P}{\partial X}+Pr\left[\mu\left(\frac{\partial^2 U}{\partial X^2}+\frac{\partial^2 U}{\partial Y^2}\right)+2\frac{\partial \mu}{\partial X}\frac{\partial U}{\partial X}+\frac{\partial \mu}{\partial Y}\left(\frac{\partial U}{\partial Y}+\frac{\partial V}{\partial X}\right)\right]$$

$$U\frac{\partial V}{\partial X}+V\frac{\partial V}{\partial Y}=-\frac{\partial P}{\partial Y}+Pr\left[\mu\left(\frac{\partial^2 V}{\partial X^2}+\frac{\partial^2 V}{\partial Y^2}\right)+2\frac{\partial \mu}{\partial Y}\frac{\partial V}{\partial Y}+\frac{\partial \mu}{\partial X}\left(\frac{\partial U}{\partial Y}+\frac{\partial V}{\partial X}\right)+RaT\right]$$

$$U\frac{\partial T}{\partial X}+V\frac{\partial T}{\partial Y}=\frac{\partial^2 T}{\partial X^2}+\frac{\partial^2 T}{\partial Y^2}$$

$$\mu=\exp\left(-mT\right)$$

3- Objective and method used to solve the problem :

the main purpose of the present work is to examine the effects of control parameters, which are Rayleigh (Ra) and Pearson (m) numbers on the fluid flow and the resulting heat transfer. In this study finite volume method is used method in a staggered grid system to solve The governing partial differential equations through iterative Semi Implicit Method for Pressure Linked Equation (SIMPLE) algorithm.

4- Results :

Figure 2 displays the average Nusselt number at the heated surface , for different values of Rayleigh (*Ra*) and Pearson (*m*) numbers.

It is clear that the increase in Rayleigh number causes the average Nusselt number to decrease because of the strengthening of buoyancy forces in comparison to viscous forces. Moreover, The increase in m leads to the enhancement of the convection process, which is reflected in the rise of the average Nusselt due to the weakening of apparent viscosity as *m* increases.

Since a poor convection is formed inside the enclosure at $Ra = 10^3$, the Pearson has only a negligible effect on average Nusselt number.

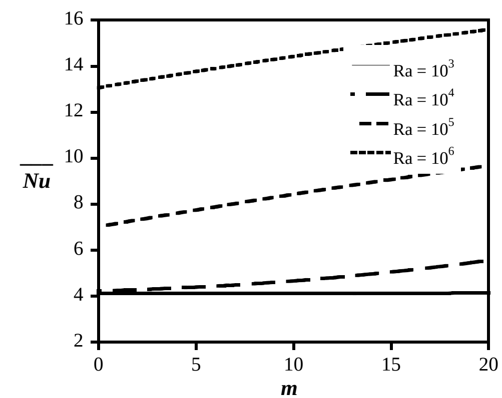

Figure 2: average Nusselt number for different values of Rayleigh and Pearson number

5- Conclusion :

➢the average Nusselt number increases with increasing Rayleigh number due to the strengthening of convective transport.

➢The rise of *m* reduces the apparent viscosity of the fluid, which leads to an enhancement in convection transport due to weakening of resistance to the fluid motion offered by the fluid viscosity.