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NATURAL VENTILATION IN A ROOM BY A COMPOSITE WALL

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ABSTRACT

In recent years, a considerable research effort has been devoted to the study of heat transfer induced by natural convection within a cavity.

The interest in these phenomena of natural convection is due to the numerous potential applications in engineering. These applications include the extraction of geothermal energy, dispersion of pollutants in aquifers, safety problems in the core of nuclear reactors, and thermal building. In recent years, natural ventilation, similar to the phenomenon of the natural convection of living quarters, is approached numerically using primarily the CFD code. It is in this context that our study is located and wants an additional contribution and which is centered around the modeling and the simulation by finite volumes of a system of natural ventilation of a room in a region arid by a composite wall Used in the ventilation system or the passive heating of buildings (analysis of the natural convection phenomena).

The results are presented in the form of temperature fields and current lines for Rayleigh number 10^5, air flow mass and local and average Nusselt numbers.

KEYWORDS: Air Quality, Finite Volume Method, Natural Convection, Natural, Simulation

MODELING OF NATUREL CONVECTION

Convection in two-dimensional cavities (rectangular or square), differentially heated by their vertical faces (Window Problem or Double Glazing) has been studied extensively over the past twenty years.

Modeling Assumptions

Our modeling is based on the following simplifying assumptions:

- The fluid is Newtonian;
- The fluid is incompressible;
- The regime is laminar;
- Heat transfer is two-dimensional;
- The thermo-physical properties of the fluid are constant;
- The dissipation of energy in viscous form is neglected.
- The fluid satisfying the Bossiness approximation.

$$\rho(T) = \rho_0 \left[1 - \beta_T \left(T - T_0\right)\right]$$

The decomposition of conservation equations into Cartesian coordinates gives the following system of differential equations:

Conservation of the Mass

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0$$

Conservation of the Quantity of Movement

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=-\frac{1}{\rho}\frac{\partial P}{\partial x}+\nu\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right)$$

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}=-\frac{1}{\rho}\frac{\partial P}{\partial y}+\nu\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}\right)+g\,\beta_T\left(T-T_0\right)$$

Conservation of Energy

$$\frac{\partial T}{\partial t}+u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}=a\left(\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}\right)$$

In these equations, *u* and *v* are the components of the velocity, *P* the pressure, *T* the temperature, *to* the time, *g* the acceleration component of gravity, the thermal diffusivity and the density

By choosing characteristic scales for each of the variables of the problem, these equations can be dimensioned, which gives dimensionless numbers characteristic of natural convection (*Ra, PR...).*

The system of equations governing the flow of the fluid is then written in the non-dimensional form:

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

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

$$\frac{\partial V^*}{\partial t^*}+U^*\frac{\partial V^*}{\partial X^*}+V^*\frac{\partial V^*}{\partial Y^*}=-\frac{\partial P^*}{\partial Y^*}+\Pr\left(\frac{\partial^2 V^*}{\partial X^{*2}}+\frac{\partial^2 V^*}{\partial Y^{*2}}\right)+Ra.\Pr T^*$$

$$\frac{\partial T^*}{\partial t^*}+U^*\frac{\partial T^*}{\partial X^*}+V^*\frac{\partial T^*}{\partial Y^*}=\left(\frac{\partial^2 T^*}{\partial X^{*2}}+\frac{\partial^2 T^*}{\partial Y^{*2}}\right)$$

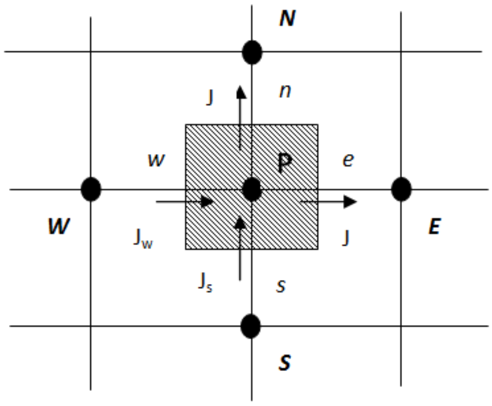
All the equations that govern our problem can be written in the following conservative form:

$$\left[R\frac{\partial\phi}{\partial t}+\left(\vec{V}.\vec{\nabla}\right)\phi\right]=\vec{\nabla}\left(\Gamma_{\phi}\,\vec{\nabla}\,\phi\right)+S_{\phi}$$

Where ϕ the variables of the problem represent $\left(U^{*},V^{*},T^{*}\right),\Gamma_{\phi}$ *and* S_{ϕ} Are the diffusion coefficient and the source term, respectively.

CHOICE OF THE MESH

Le maillage utilize est. un maillage uniform de 61*61 nudes, suivant les directions x et y.



$$\frac{\partial T}{\partial y}=0\,,\,u=v=0$$

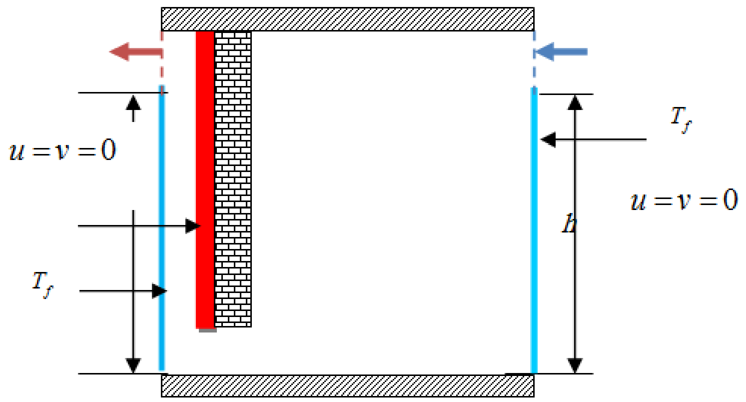


Figure 1: Geometry and Boundary Conditions

CONDITIONS TO THE LIMITS IN THE OPENINGS OF THE ENTRY AND THE EXIT

In the pressure inlet boundary state, Fluent used to define the fluid pressure at the inlet flow all other scalar properties of the flow.

When the inlet pressure is known, but the flow rate or speed is not known. Fluent uses a technique to define a free boundary condition; this situation can arise in many practical situations.

In the incompressible flow, the total inlet pressure P_0 and the static pressure P_S, are related to the rate of admission by the Bernoulli equation

$$P_0 = P_S + \frac{1}{2}\rho V^2$$

For incompressible flows, the boundary pressure is calculated as an average between the external pressure and the internal pressure:

$$P_f = 0.5(P_C + P_e)$$

METHOD OF RESOLUTION

Numerical resolution of partial differential equations has developed considerably since 1940 with the development of computers that are increasingly fast and have a larger memory size.

A large majority of commercial computation codes solves the conservation equations in primitive variables and use the finite volume or control volume method.

In this method, the domain under consideration is divided into finite volumes; a single volume surrounds a mesh node. The conservation equations are integrated on each finite volume. The model thus discretized, will be solved under the CFD (Fluent) code.

The simulation was carried out in transitional regimes in order to study the natural ventilation in a cavity with a composite wall.

The parameters of the simulation are as follows: PR = 0.71 (air), Ra = 10^5

The initial temperature in the cavity T0 = 0 (see FIG. 2).

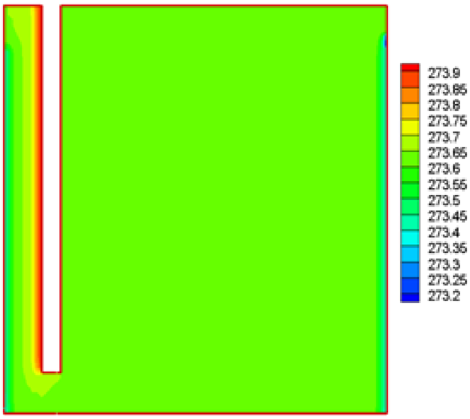


Figure 2: Initial Temperature At (T = 0s)

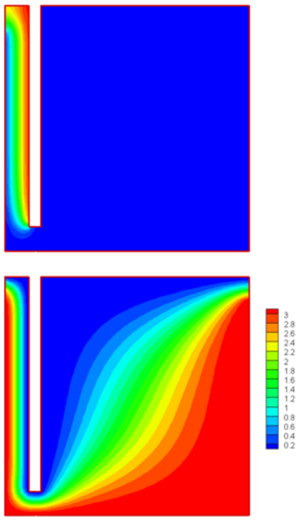


Figure 3: Current Lines and Temperature for Number of Rayleigh=10^5

Temperature Profiles

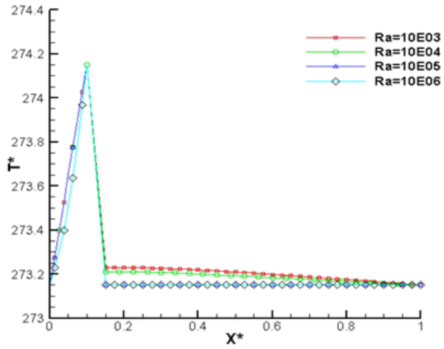


Figure 4: Profiles of Temperature T in the Horizontal Median Plane for Different Numbers of Ra

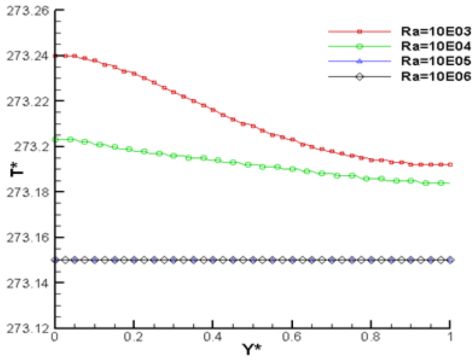


Figure 5: Profiles of Temperature T in the Vertical Median Plane for Different Numbers of Ra

Variation of air flow at Entrance

For the basic situation, we present the mass of airflow as a function of the Rayleigh number in Figure 6; we see that the mass of air entered with the increase of the Rayleigh number.

These values show that the air suction increases with the increase of Rayleigh number, so the mass of air flow tends to a maximum value.

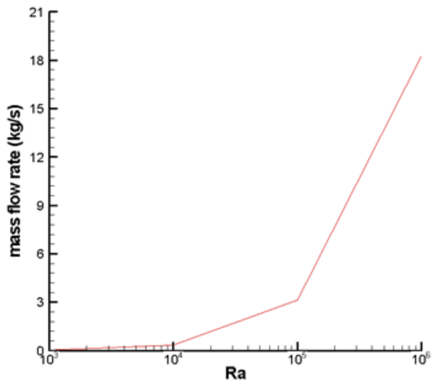


Figure 6: Variation of the Mass of Air Flow at the Entrance for Different Numbers of Ra

Variation in Local Nusselt Number

La figure 7 shows the evolution of the heat transfer (local Nusselt number) as a function of y * at the hot wall of the wall for different Rayleigh numbers Ra.

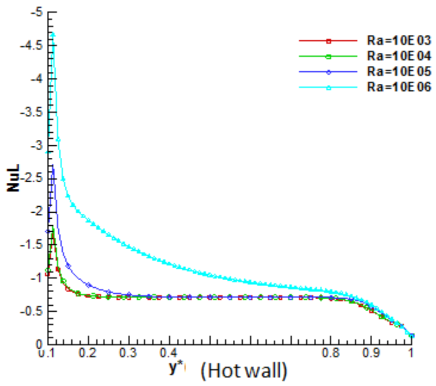


Figure 7: Local Nusselt Number for Different Number of *Ra*

Variation in Number of Medium Nusselt

Figure 8 shows the average Nusselt number as a function of Rayleigh number, these values show that the average Nusselt number increases with the increasing Rayleigh number, and tends to a maximum value. Heat transfer by natural convection becomes more dominant, so the average Nusselt number is small forward

Low Rayleigh number (10^3 - 10^4 - 10^5), for higher Rayleigh numbers 10^6 the average Nusselt number becomes higher.

These observations are expected the fireplace system to become perform better when the Rayleigh number increases, which indicated heat transfer and ventilation

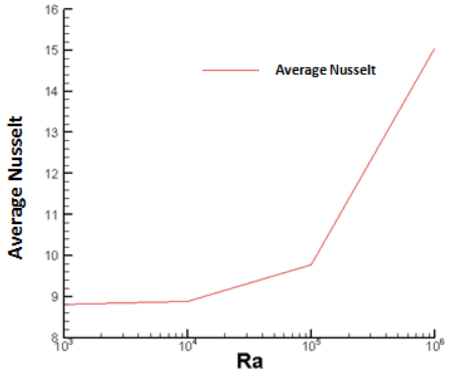


Figure 8: Variation of the Average Nusselt Number for Different Number of *Ra*

CONCLUSIONS

Based on this model, we have reached the following conclusions:

The effect of the Rayleigh number that characterized the intensity of natural convection was highlighted. Thermal transfer increases with the Rayleigh number.

In the study that was presented, the natural ventilation system seems like a very interesting solution for:

- Thermal comfort and olfactory comfort.
- Energy saving (passive solar energy).
- To eliminate the pollutants (odors, water vapor, gas,).
- To remove heat.

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