ISSN No:-2456-2165

Numerical Study of Natural Air Convection in a Domain Bounded by Two Rectangular Parallelepipeds of Square Straight Sections for Ra = 10^6 for a Value of the Hartmann Number Ha = 0.75

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Abstract:- In this numerical simulation, we have proposed to study the natural convection of air in a bounded domain between two rectangular parallelepipeds of square straight sections for a Rayleigh value Ra = 10^6. The internal cavity is subjected to a heat flow of constant density while the external cavity is kept at a constant temperature. The air fluid is subjected to a magnetic field oriented at an angle θ = 45° with respect to the horizontal. To overcome the term pressure in the equation of motion, we have used the vorticity formalism as a function of current. The equations obtained were discretized with the finite volume method and were solved by the SIMPLE algorithm. The results obtained through the commercial calculation code Ansys Fluent, in the absence of the magnetic field, show us, for isothermal lines, a stable flow which is manifested by high and low temperatures and for current lines the formation of two recirculation zones of high intensity and rotating in opposite directions. When applying the magnetic field with a Hartmann number Ha = 0.75, we have noted the formation of four recirculation zones for current lines and standardization for isothermal lines.

***Keywords**:- Ansys Fluent; Convection; Hartmann; Rayleigh Number; Finite Volume.*

I. INTRODUCTION

For some time, the numerical study of natural convection in closed cavities was at the heart of much research both experimentally and theoretically. The numerical study of natural convection in rectangular cavities of square straight cross-section in the absence of a magnetic field is almost impossible to find in the literature. Despite the rarity of subjects identical to ours, we can find similar cases as [1] working with two cavities without Hartmann number, [2], [3], [4] studied natural convection with a single square cavity.

Other researchers, however, have studied the effect of the magnetic field on convection [5], [6]. To better understand this phenomenon, we have proposed to study natural convection for two cavities with a Hartmann number Ha = 0.75 for a value of the Rayleigh number Ra = 10^6.

II. METHOD AND MATERIAL NUMERICAL

In this paper, we have proposed to study the natural convection of an air fluid between two rectangular parallelepipeds of square straight sections whose internal cavity Hi is heat flow of constant density and the external cavity He is maintained at a constant temperature. The fluid is subjected to a magnetic field oriented at an angle to the horizontal Hartmann value.

Ha = 0.75. Figure 1

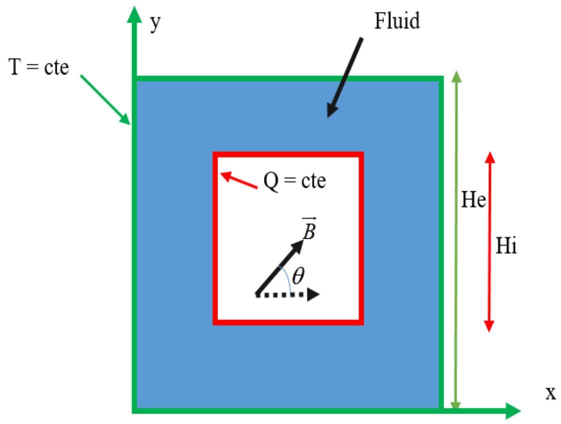

Fig 1: Diagram of the problem

To free oneself from the term of pressure which is a primitive variable, we have used the vorticity formalism function of current [7]. Since our flow is two-dimensional, incompressible and laminar, we have the Boussinesq approximation [8].

The dimensionless transfer equations are written:

$$\frac{\partial \omega}{\partial t}+u\frac{\partial \omega}{\partial x}+v\frac{\partial \omega}{\partial y}=\Pr(\frac{\partial^2 \omega}{\partial x^2}+\frac{\partial^2 \omega}{\partial y^2})+R_a \Pr\frac{\partial T}{\partial x}+Ha^2\Pr(\frac{\partial v}{\partial y}\sin 2\theta+\frac{\partial v}{\partial x}\cos^2\theta-\frac{\partial u}{\partial y}\sin^2\theta) \quad (1)$$

$$\frac{\partial T}{\partial t}+\frac{\partial}{\partial x}(uT-\frac{\partial T}{\partial x})+\frac{\partial}{\partial y}(vT-\frac{\partial T}{\partial y})=0 \qquad (2)$$

$$u=\frac{\partial \psi}{\partial y} \quad \text{et } v=-\frac{\partial \psi}{\partial x} \qquad (3)$$

To characterize the interaction between the cavity and the fluid, we have introduced a parietal quantity called the Nusselt number. The expression of the mean Nusselt number is given by:

$$Nu_{moyenne}=\frac{1}{s}\int_{s} Nuds \qquad (4)$$

We have used the finite volume method for discretizing these transfer equations implanted in a commercial Ansys Fluent calculation code [9], [10] [11]. The resolution procedure used is SIMPLE algorithm giving an easy speed estimate [12].

For any scientific study, the results must be validated. For this, we have compared our study on the right (b) with that of M.K Kane [7] on the left (a) with a single cavity whose magnetic field is omitted. (figure 2)

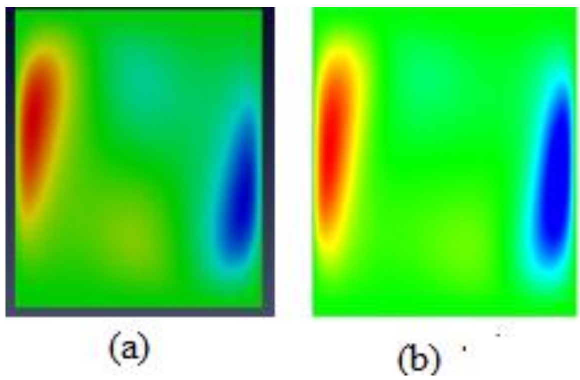

Fig 2: Comparison of vertical velocity contours

III. RESULTS AND DISCUSSIONS

The validation allowed us to make a discussion of our results which relate to isothermal lines, current lines and the Nusselt number for a Rayleigh value Ra = 106 without magnetic field and with a Hartmann number Ha = 0.75.

A. Evolution of isothermal lines without magnetic field

There is a stable flow materialized by high and low temperatures and loosening of the isotherms. These oscillations observed on the upper internal cavity are due to the fact that the buoyancy force is greater at this level. (Figure 3)

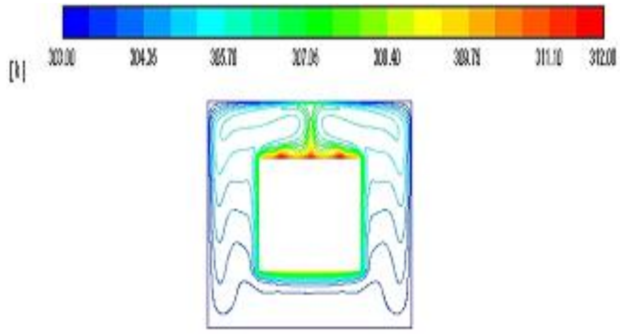

Fig 3: evolution of isotherms for Ra = 10^6

B. Evolution of current lines without magnetic field

Regarding the current lines, we note two areas of recirculation that increases in intensity and circulating in opposite directions but also the formation of small cells on the upper inner cavity a cell at the bottom due to a decrease in the density of heated particles. (Figure 4)

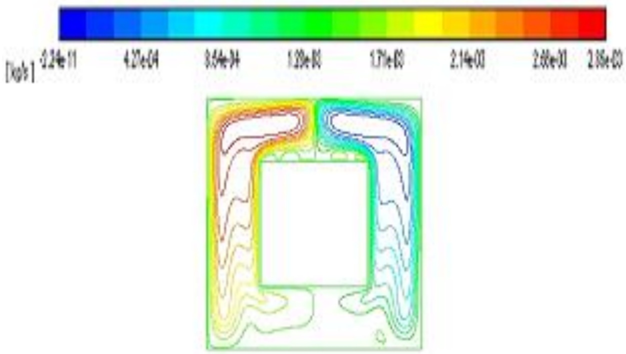

Fig 4: evolution of the current lines for Ra = 10^6

C. Effect of magnetic field on isothermal lines and current lines

For the isothermal lines figure 5 (d) there is a standardization as one moves away from the hot cavity and an acceleration on both sides according to the direction of the magnetic field while for the current lines figure 5 (e) we have noted the formation of four zones of recirculation and formation of small cells following the direction parallel to that of the magnetic field.

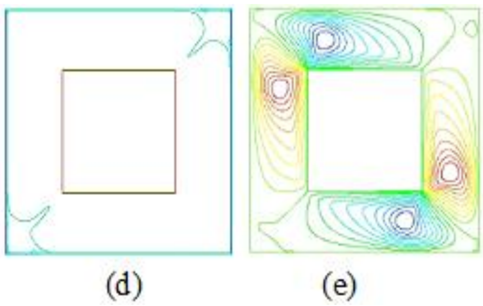

Fig 5: evolution of isothermal lines (d) and current lines (e) for Ha = 0.75

D. Evolution of the Nusselt number on the upper internal cavity

To study the interaction between the fluid and the cavity, we introduced a parietal quantity that the nusselt number.

In the absence of a magnetic field (Figure 6a), there is a stable flow with oscillations showing strong and low temperatures and a beginning of instability as soon as the middle of the cavity is exceeded. This confirms the behaviour of the isotherms.

When the magnetic field (Figure 6b) is applied with a Hartmann number Ha = 0.75, there is a change in the thermal plane due to the Lorentz force causing disturbances in the same direction as the magnetic field.

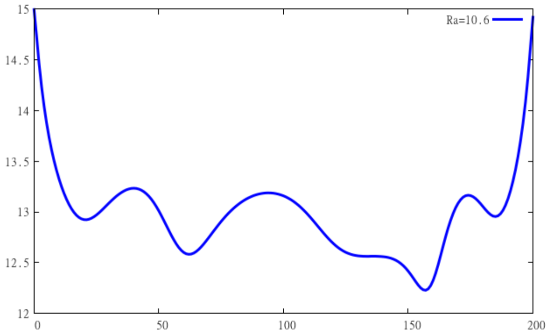

Fig 6a: Evolution of the Nusselt number on the upper internal cavity Ra = 10^6

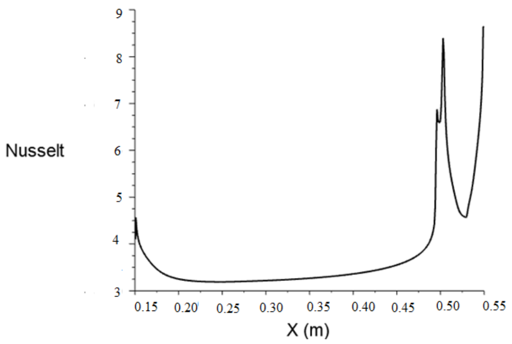

Fig 6b: Evolution of the Nusselt number on the upper external cavity for Ra = 10^6, Ha = 0.75

IV. CONCLUSION

In this paper, we have studied the numerical study of the natural convection of air between two rectangular parallelepipeds of square straight sections for a value of Rayleigh number.

Ra = 10^6 and subjected to a magnetic field of Hartmann number Ha = 0.75.

Results showed in the absence of magnetic field, decelerated isothermal lines with formation of oscillations on the upper internal cavity and for current lines, the formation of two recirculation zones. In the presence of a magnetic field, for isotherms there is standardization and for current lines the formation of four recirculation zones. The Nusselt number reflects the thermal behaviour of the isotherms.

REFERENCES

[1]. Diouf, A; Thiam, O.N ; Drame, O ; Traore, V.B ; Sow, M. L. « Numerical Study of The Influence of The Rayleigh Number on the Natural Convection of the Confined Air between two Square Cavities » Open International Journal Of Advanced Research (IJAR), Vol 10, Issue Septembre 2022.

[2]. G. De Vahl Davis, (1962), Natural convection of air in a square cavity, a benchmark numerical solution, Int. J. Numer. Methods Fluids 3 249–264.

[3]. E.K. Lakhal and M. Hasnaoui, (1995). «Natural convection in a square cavity periodically heated from below." Revue générale de thermique, 27, 480– 485.

[4]. Laour S., Abada L., Mezaache E., Daguenet M., (2007). "Unstationary natural convection in a square twodimensional enclosure - bifurcation towards chaos". 13th International Thermal Day, Albi (France), 28-30 August

[5]. Dabboura E., Sadat H. Prax C. "Influence of the position and orientation of the magnetic field on cavity thermomagnetic convection". French Congress of Thermal SFT, Ile des Embiez, France. pp.1-6. ⟨hal-00293260⟩ May (2007)

[6]. Gelfgat.A.Y, & Bar-Y. P.Z, The effect of an external magnetic field on oscillatory instability of convective flows in a rectangular cavity, Phys. Fluids, 13(8) (2001), 2269-2278.

[7]. Kane, M, K; Mbow, C; Sow, M, L. and Sarr, (2018). J. Numerique simulation of Two-dimensional Natural Convection in a Confined Environment with the vorticity-stream function formulation. Open Journal of Fluid Dynamics, 8, 44-58.

[8]. Tazi, M.N.C.; Daoudi S.; le Palec, G.; Daguenet, M. (1997) "Digital study of Boussinesq's model of natural convection permanent axisymetric light in an annular space between two spheres", Rev. Gén. Therm., 36,239-251.

[9]. Versteeg H. K. and Malalasekera W. (1995): An introduction to Computational Fluid Dynamics The Finite Volume Method, Longman Scientific and Technical, Essex,

[10]. N. Reidar and B. Olsen, (2000) "CFD Computational Fluid Dynamics Algorithms for hydraulic engineering", Department of hydraulic environmental Engineering, the Norwegian University of Sciences and Technology.

[11]. Fluent 19.0, (2017), User's Guide.

[12]. S.V. Patankar, (1980), Numerical heat transfer and fluid flow, Hemisphere, New York