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Computation of Heat Removal Efficiency for the Cases of with MHD & without MHD Flow past a Closed Trapezium Shaped Cavity

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A B S T R A C T

This paper deals with flow pattern and heat transfer characteristics over a trapezium shaped cavity in the presence of a squared heat conductive body. Two cases-with MHD and without MHD are analyzed in the current study for computing heat removal efficiency at bottom heated wall of the cavity. Navier-Stock's equations are considered as governing equations and Finite element method is adopted for solving the problem. Fluid flow and temperature field are exposed in terms of streamlines and isotherms. Moreover heat removal efficiency is shown as average Nusselt number.

Keywords: Heat removal, MHD, Trapezium, Cavity

1. Introduction

Magneto-hydrodynamics mixed convection flow and heat transfer characteristics have received great attention from the researchers for its various applications in engineering and industrial sector. This type of problems are commonly used in cooling of electric and electronic devices, ventilation of buildings, air conditioning, heat exchangers, solar collectors and chemical processing apparatuses.

A review on heat transfer enhancement in cavity with lid driven has been presented by (Saieed, Mustafa, Ayed, & Habeeb, 2020). (Sereir, Missioum, Mebarki, Elmir, & Mohammed, 2020) studied optimal conditions of natural and mixed convection in a vented rectangular cavity with a sinusoidal heated wall inside with a heated solid block. An analysis of mixed convection in a differentially heated square cavity with moving lids was carried out by (Abraham, & Varghese, 2015). Numerical study of natural convection in square cavity with inner bodies using Finite element method was presented by (Pinto, Guimaraes, & Menon, 2016). (Elsherbiny, Osama, & Ismail, 2015) analyzed heat transfer in inclined air rectangular cavities with two localized heat sources. (Guo, & Sharif, 2004) analyzed mixed convection in rectangular cavities at various aspect ratios with moving isothermal sidewalls and constant flux heat source on the bottom wall. Mixed convection enhancement in a rectangular cavity by triangular obstacle was presented by (Afluq, Siba, & Jehhef, 2020). (Ibrahim, & Hirpho, 2021) analyzed mixed convection flow in a trapezoidal cavity with non-uniform temperature using Finite element method. The author's shown that Hartmann number has negative impact on the average Nusselt number whereas Richardson number has a positive effect on average Nusselt number. (Zheng, Zhang, Yu, Wang, & Zhao, 2021) studied convection heat transfer in a closed cavity with hot and cold tubes. Natural convection flow analysis has been performed by (Akter, & Parvin, 2018) in a trapezoidal cavity containing a rectangular heated body along with external oriented magnetic field.

The goal of the current study is to analyze heat removal efficiency for the cases of with and without MHD in flow and temperature field over a trapezoidal shaped enclosure containing heat conductive square body for the variation of Grashof number.

2. Problem Formulation and Numerical Schemes

The studied domain in the present problem is a trapezium shaped cavity in where a square heat conductive square body is placed inside it. The bottom surface of the cavity maintains a high temperature T_h, upper surface maintains a low temperature T_c with $T_h > T_c$ and rest two inclined cavity sides are kept as thermally insulated. A uniform magnetic field of strength B_0 is applied to the horizontal direction of right all. No-slip conditions are assumed for all solid boundaries.

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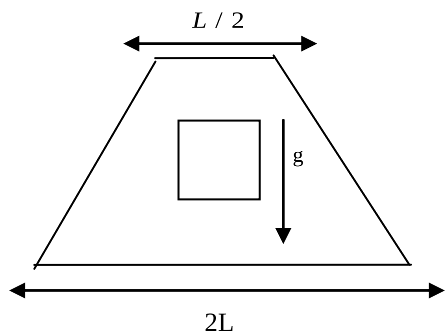

Figure 1: Geometry of the studied domain

Taking into account the considered fluid as steady state, two-dimensional, laminar, incompressible and electrically conducting with constant thermo-physical properties; the problem is designed by the governing equations that can be stated in dimensionless form as

$$\frac{\partial U}{\partial X}+\frac{\partial V}{\partial Y}=0 \qquad (1)$$

$$U\frac{\partial U}{\partial X}+V\frac{\partial U}{\partial Y}=-\frac{\partial P}{\partial X}+\frac{1}{\mathrm{Re}}\left(\frac{\partial^2 U}{\partial X^2}+\frac{\partial^2 U}{\partial Y^2}\right) \qquad (2)$$

$$U\frac{\partial V}{\partial X}+V\frac{\partial V}{\partial Y}=-\frac{\partial P}{\partial Y}+\frac{1}{\mathrm{Re}}\left(\frac{\partial^2 V}{\partial X^2}+\frac{\partial^2 V}{\partial Y^2}\right)+\frac{Gr}{\mathrm{Re}^2}\theta-\frac{Ha^2}{\mathrm{Re}}V \qquad (3)$$

$$U\frac{\partial \theta}{\partial X}+V\frac{\partial \theta}{\partial Y}=\frac{1}{\mathrm{Re}\,\mathrm{Pr}}\left(\frac{\partial^2 \theta}{\partial X^2}+\frac{\partial^2 \theta}{\partial Y^2}\right) \qquad (4)$$

For heat conducting circular body

$$\frac{K}{\mathrm{Re}\,\mathrm{Pr}}\left(\frac{\partial^2 \theta_s}{\partial X^2}+\frac{\partial^2 \theta_s}{\partial Y^2}\right)=0 \qquad (5)$$

Here, $\mathrm{Re}=\frac{u_i L}{\upsilon}$ is the Reynolds number, $\mathrm{Pr}=\frac{\upsilon}{\alpha}$ is the Prandtl number, $Ha=B_0 L\sqrt{\frac{\sigma}{\mu}}$ is the Hartmann number, $Ri=\frac{Gr}{\mathrm{Re}^2}$ is the Richardson number.

The associated boundary conditions in the dimensionless form are given below:

On the top wall: $U=0, V=0, \theta=0$

On the bottom wall: $U=0, V=0, \theta=1$

On the inclined walls: $U=0, V=0, \frac{\partial \theta}{\partial N}=0$

Where N is the non-dimensional distances either along X or Y direction acting normal to the surface.

The average Nusselt number Nu at the hot wall is given by

$$Nu_{av}=-\int_0^1\left(\frac{\partial \theta}{\partial Y}\right)dX$$

For the exact solution of the problem grid independency test is performed with grids containing different number of elements. The average Nusselt number which is the indicator of heat transfer rate at the bottom heated surface of the trapezoidal enclosure are computed for chosen elements. The results of Nu_{av} for different number of elements which is tabulated in Table 1 are followed with a small discrepancy. Thus the grid consisting of 3676 elements for calculating the average Nusselt number at the bottom heated surface of the cavity is finalized.

Table-1: Average Nusselt number at hot wall while Pr = 0.71, Re= 100, Ha = 50 and Gr= 10^4

No. of elements	905	1482	2460	3676	5672
Nu_{av}	6.3810	6.3217	6.3067	6.3048	6.3039

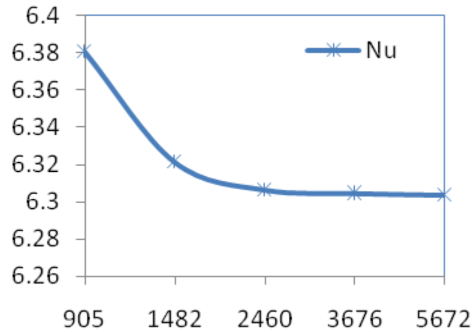

Figure 2: Grid independency check for different number of elements

A computation is carried out to compare the code validity of the current numerical simulation with the previously investigated work of the authors (Ibrahim, & Hirpho, 2021); finite element analysis of mixed convection flow in a trapezoidal cavity with non-uniform temperature. Figure 2 shows a good agreement in streamlines and isotherms between the works of (Ibrahim, & Hirpho, 2021) and present.

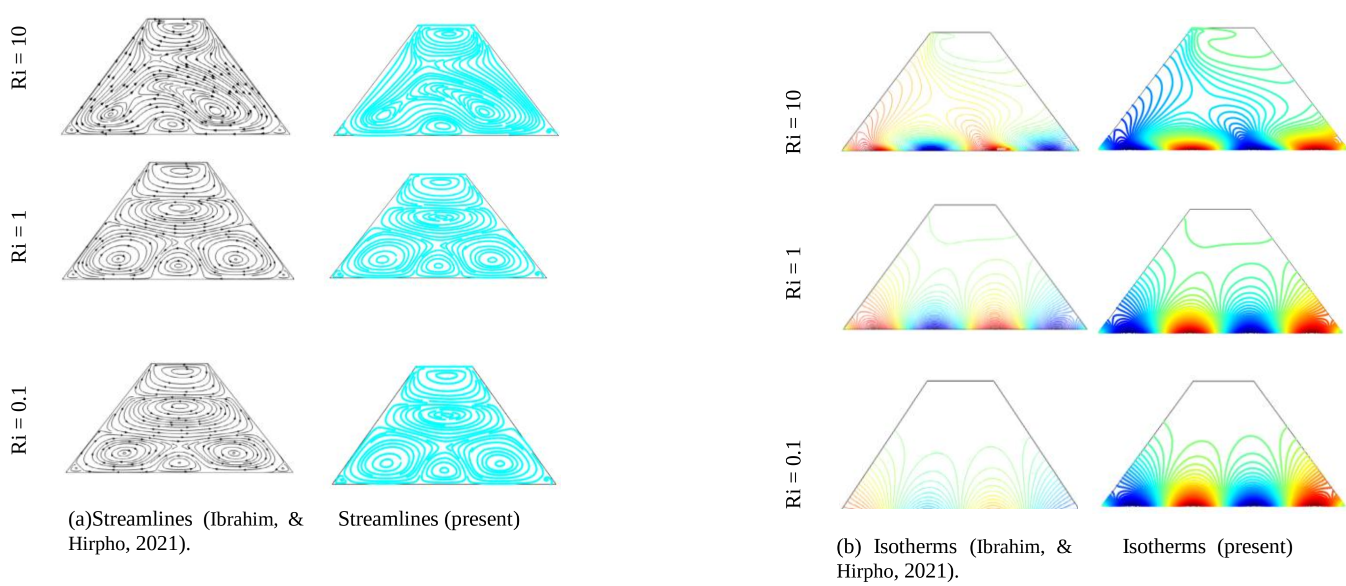

Figure 3: Comparison of (a) streamlines and (b) isotherms while Gr = 10^4, Pr = 6.2, Ha=50 and Re = 100

3. Results and Discussions

Two-dimensional steady laminar incompressible flow behavior and heat transfer characteristics have been carried out here taking into account the MHD effects along with Grashof number. A trapezoidal cavity with the presence of heat conducting square block is chosen as studied domain. The streamlines, isotherms are explored to clarify the flow and temperature fields as well as average Nusselt number for computing heat removal efficiency of the problem for the range of $10^2 \leq Gr \leq 10^4$ and fixed value of Pr = 0.71, Re=200. The outcomes are described as following two cases.

Case-1: For with MHD case (Ha=100), the effect of Grashof number on flow and thermal field varies from 100 to 10000 are depicted in terms of streamlines and isotherms in Figure 4. From Figure 4(a) it is seen that at lower value of Gr = 10^2, two large vortices are developed of the two side of the inner square body and a small variation in flow patterns is noticed for the rest two higher values of Gr = 10^3, 10^4. Moreover, flow lines are seems to be symmetric about the mid vertical line of the cavity.

The isotherms for different Grashof number are displayed in Figure 4(b), and from this figure at Gr = 10^2, 10^3, 10^4 it is observed that heat lines are distributed throw out the whole cavity and packed in the vicinity of top wall. Also, interior body is encompassed by the heat lines and high temperatured lines are seen near the hot bottom wall. A dramatically change is visible for the highest value of Gr = 10^4.

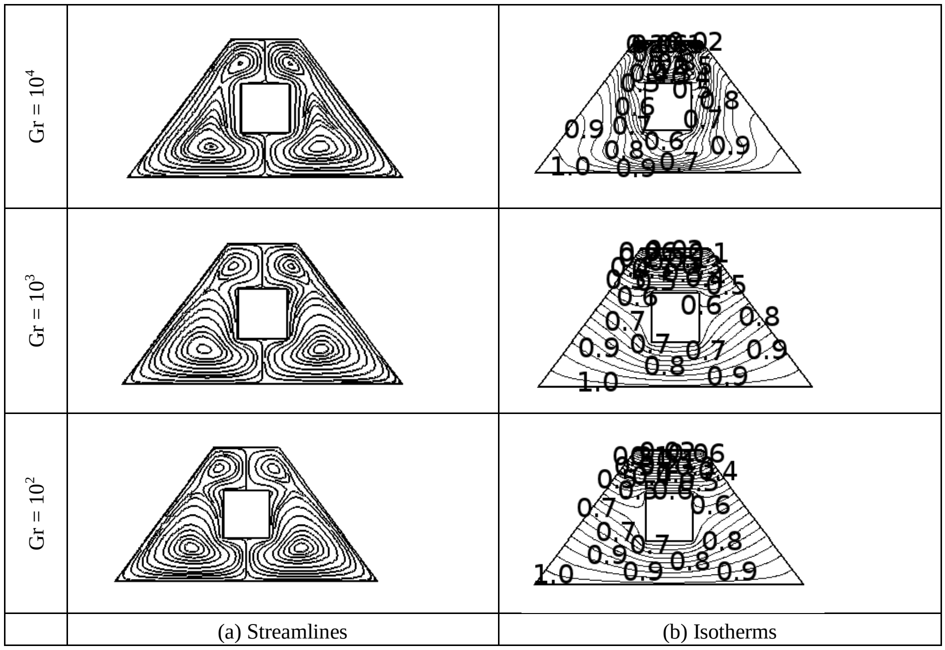

Figure 4: Streamlines and Isotherms for with MHD case (Ha=100) while Pr=0.71, Re=200

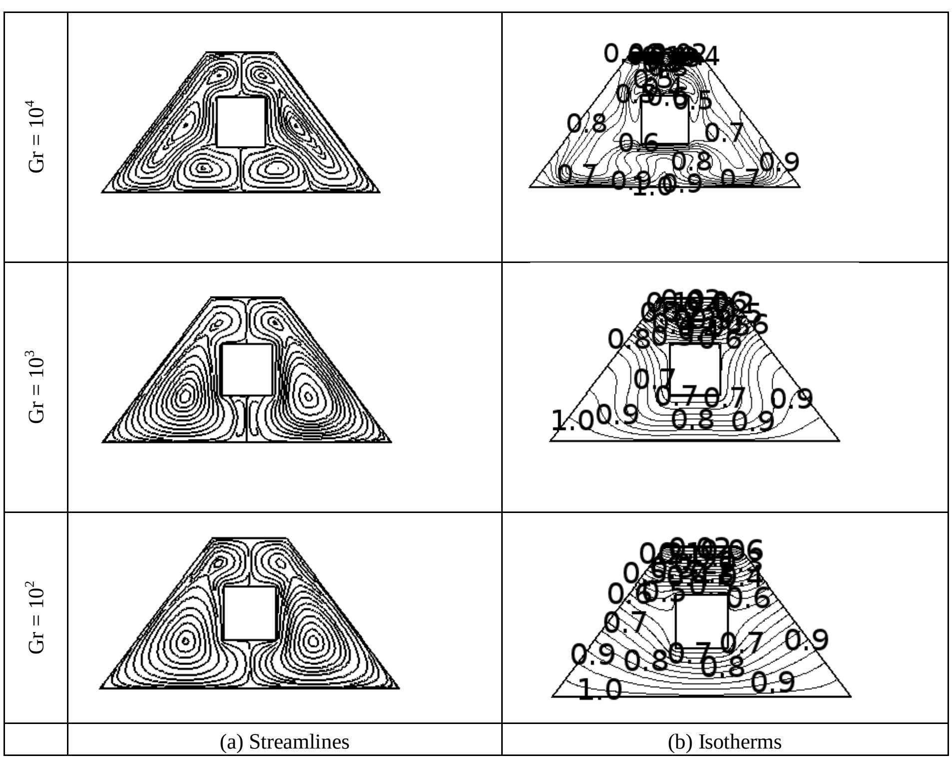

Figure 5: Streamlines and Isotherms for without MHD case (Ha=0) while Pr=0.71, Re=200

Case-2: In without MHD case (Ha=0), Figure 5 exposes the influence of Gr on flow and temperature distribution in terms of streamlines and isotherms. It is observed from Figure 5(a) that at lower value of Gr = 10^2, 10^3 two large vortex are created that elongated from bottom to top of the cavity. When Gr = 10^4, large vortices are shrinked and as a result another two small vortex are developed under the square body.

The corresponding isotherms are depicted in Figure 5(b) for selected Grashof numbers. From this figure, it is observed that at Gr = 10^2 thermal lines are uniformly distributed over the whole domain and densed near the top wall. For the remaining upper values of Gr = 10^3, 10^4 heat lines become more curved and a crucial discrepancy in temperature profile is marked for the uppermost value of Gr = 10^4.

Average Nusselt number that represents heat removal efficiency at hot surface for various values of Grashof number are tabulated in Table 2 and it is seen that heat transfer enhances with the rising values of Gr. In addition, better heat removal efficiency is found in without MHD case.

Table-2: Average Nusselt number for variation of Gr considering the effect of MHD while Pr = 0.71, Re = 200

Gr	Nu_{av}	
	Ha = 100	*Ha = 0*
10^2	1.2145	1.2160
10^3	1.2179	1.4697
10^4	2.8935	5.2560

4. Conclusions

Air filled (Pr=0.71) trapezoidal cavity flow and thermal behaviour have been performed with and without MHD effects in presence of centered squared body. In view of the above discussed results it can be concluded that-

-Higher heat removal at hot wall is found at both the considered two cases of with and without MHD for the rising values of Grashof number.
-Average Nusselt number is larger at Ha=100, accordingly low heat transfer is followed at Ha=0.
-Relatively more enhancement in heat transfer is recorded at the pick value of $Gr=10^4$.

References

Saieed, A. N. A., Mustafa, M. A. S., Ayed, S. K., & Habeeb, L. J. (2020). Review on heat transfer enhancement in cavity with lid driven. *Journal of Mechanical Engineering Research and Developments*, 43(7), 356-373.

Sereir, T., Missioum, A., Mebarki, B., Elmir, M., & Mohammed, D. (2020). Optimal conditions of natural and mixed convection in a vented rectangular cavity with a sinusoidal heated wall inside with a heated solid block. *Wseas Transactions on Heat and Mass Transfer*, 15, 195-208, DOI: 10.37394/232012.2020.15.23

Abraham, J., & Varghese, J. (2015). Mixed convection in a differentially heated square cavity with moving lids. *International Journal of Engineering Research & Technology (IJERT)*, 4(12), 602-607.

Pinto, R. J., Guimaraes, P. M., & Menon, G. J. (2016). Numerical study of natural convection in square cavity with inner bodies using finite element method. *Open Journal of Fluid Dynamics*, 6, 75-87.

Elsherbiny, S. M., Osama, I., Ismail, O.I. (2015). Heat transfer in inclined air rectangular cavities with two localized heat sources. *Alexandria Engineering Journal*, 54, 917–927.

Guo, G., & Sharif, M. A. R. (2004). Mixed convection in rectangular cavities at various aspect ratios with moving isothermal sidewalls and constant flux heat source on the bottom wall. *International Journal of Thermal Sciences*, 43, 465– 475.

Afluq, S. G., Siba, M. A. A. A., & Jehhef, K. A. (2020). Mixed convection enhancement in a rectangular cavity by triangular obstacle. *IOP Conf. Series: Materials Science and Engineering*, 881, 012083.

Ibrahim, W., & Hirpho, M. (2021). Finite element analysis of mixed convection flow in a trapezoidal cavity with non-uniform temperature. *Heliyon*, 6, 1-12, https://doi.org/10.1016/j.heliyon, 2021.e05933

Zheng, J., Zhang, L., Yu, H., Wang, Y. & Zhao, T. (2021). Study on natural convection heat transfer in a closed cavity with hot and cold tubes. *Science Progress*, 104(2), 1–25, DOI: 10.1177/00368504211020965

Akter, A., & Parvin, S. (2018). Analysis of natural convection flow in a trapezoidal cavity containing a rectangular heated body in presence of external oriented magnetic field. Journal of Scientific Research, 10(1), 11-23.