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The effect of Discrete Heaters on the rotating flow

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Abstract

The present numerical study investigates the laminar mixt convection heat in an enclosure with discrete heaters. Three different cases are considered based on the number of discrete heaters which is maintained at isothermal condition Th (Th > Tc). The right vertical wall is maintained at cold temperature Tc and the remaining all other walls are thermally insulated. The above schematic setup can be modeled into mathematical form and the governing non-dimensional equations are solved using Finite Volume Method. SIMPLE algorithm is employed for the pressure-velocity coupled momentum equations. Numerical simulations are carried out to find the effect of different Richardson Ri ranging from 0.1 to 10.0 and the distribution of discrete heaters. Results are given in the form of streamlines, isotherms, the velocity profiles and average Nusselt number. It is found that the maximum heat transfer rate is achieved for the distribution of discrete heater.

Keywords: Discrete Heater, Mixt Convection, finite volumes, Richardson number.

1. Introduction

A rapid increase in the growth of electronic equipments needs an effective cooling to achieve the optimal performance. The mechanism of cooling in closed configurations by natural convection is preferable due to its low maintenance cost and high efficiency. Hence natural convection in rectangular enclosures has received much attention among researchers to consider different combinations of aspect ratios, location of discrete heaters on the walls and boundary conditions. The numerical and experimental investigation on natural convective heat transfer in a vertical rectangular enclosure with four discrete heaters for different aspect ratios was carried out [1]. The natural convective heat transfer of micropolar fluids in an enclosure with an isoflux discrete heater on one of the sidewalls was investigated and reported that the heat transfer rate was an increasing function of Rayleigh number [2]. Later, the numerical study of the same process in a square enclosure with a heat generating fluid was done [3]. The study of discrete isothermal bottom heating was investigated [4] to report the effect of aspect ratio of the horizontal rectangular enclosure. The nine different location of heater on the vertical rectangular enclosure which was partially active to describe the natural convection has been examined [5] and they found that the middle-middle active location of the heater was effective in transferring the heat. In a similar study [6], the maximum heat transfer rate was achieved when the thermally active hot and cold location was placed at the middle of the vertical walls.

2. Mathematical Formulation

Figure 1 (a_d) shows the schematic of the problem which considers a enclosure of height H (2.0) and length L (1.0) filled with different fluids like liquid metal, air and water. Case-1 describes the enclosure with a single discrete heater placed at the middle of the left vertical wall Figure 1(a). In Case-2, the heater is divided into two discrete heaters Figure 1(b). In the same way, the heater is divided into three and four discrete heaters for the Case of 3 and 4 which is shown in Figure 1(c_d). The length of the heater is equal to the half of the height of the enclosure in each case. The thick solid lines represent the discrete heater and its position, which is maintained at constant temperature T_h while the opposite wall is maintained at cold temperature T_c and the remaining walls of the enclosure are thermally insulated. For different Richardson numbers 0.1 to 10.0 are used in the present study. Thermophysical properties of the fluid are assumed to be constant, except the variation of density in the buoyancy term due to Boussinesq approximation.

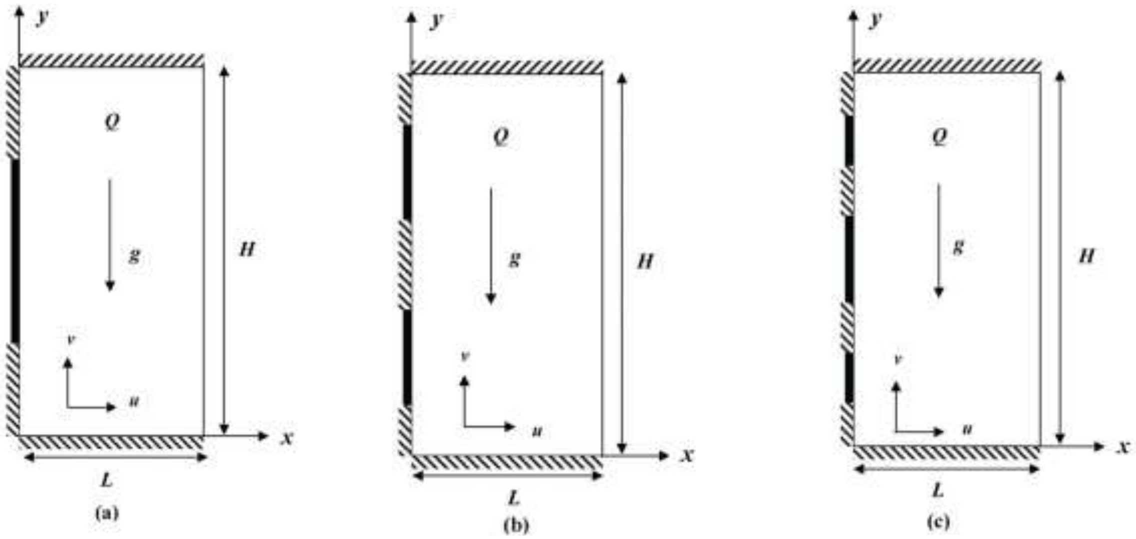

Figure 1. Schematic of the cavity with discrete heaters (a) Case-1, (b) Case-2, (c) Case-3,

The governing dimensional equations of the conservation of mass, momentum and energy can be converted into the following dimensionless form:

$$\frac{1}{R}\frac{\partial}{\partial R}(RU_r)+\frac{\partial U_z}{\partial Z}=0 \quad (1)$$

$$\frac{\partial U_r}{\partial \tau}+\left[\frac{1}{R}\frac{\partial}{\partial R}(RU_r^2)+\frac{\partial}{\partial Z}(U_rU_z)+\frac{U_\theta^2}{R}\right]= -\frac{\partial P}{\partial R}+\frac{1}{\mathrm{Re}}\left[\frac{1}{R}\frac{\partial}{\partial R}\left(R\frac{\partial U_r}{\partial R}\right)+\frac{\partial^2 U_r}{\partial Z^2}-\frac{U_r}{R^2}\right] \quad (2)$$

$$\frac{\partial U_z}{\partial \tau}+\left[\frac{1}{R}\frac{\partial}{\partial R}(RU_rU_z)+\frac{\partial}{\partial Z}(U_z^2)\right]= -\frac{\partial P}{\partial Z}+\frac{1}{\mathrm{Re}}\left[\frac{1}{R}\frac{\partial}{\partial R}\left(R\frac{\partial U_z}{\partial R}\right)+\frac{\partial^2 U_z}{\partial Z^2}\right]+Ri\,\Theta$$

$$\frac{\partial U_\theta}{\partial \tau}+\left[\frac{1}{R}\frac{\partial}{\partial R}(RU_rU_\theta)+\frac{\partial}{\partial Z}(U_zU_\theta)+\frac{U_rU_\theta}{R}\right]= \frac{1}{\mathrm{Re}}\left[\frac{1}{R}\frac{\partial}{\partial R}\left(R\frac{\partial U_\theta}{\partial R}\right)+\frac{\partial^2 U_\theta}{\partial Z^2}-\frac{U_\theta}{R^2}\right] \quad (4)$$

$$\frac{\partial \Theta}{\partial \tau}+\frac{1}{R}\frac{\partial}{\partial R}(RU_r\Theta)+\frac{\partial}{\partial Z}(U_z\Theta)= \frac{1}{\mathrm{Pr}}\left[\frac{1}{R}\frac{\partial}{\partial R}\left(R\frac{\partial \Theta}{\partial R}\right)+\frac{\partial^2 \Theta}{\partial Z^2}\right] \quad (5)$$

3. Results and Discussion

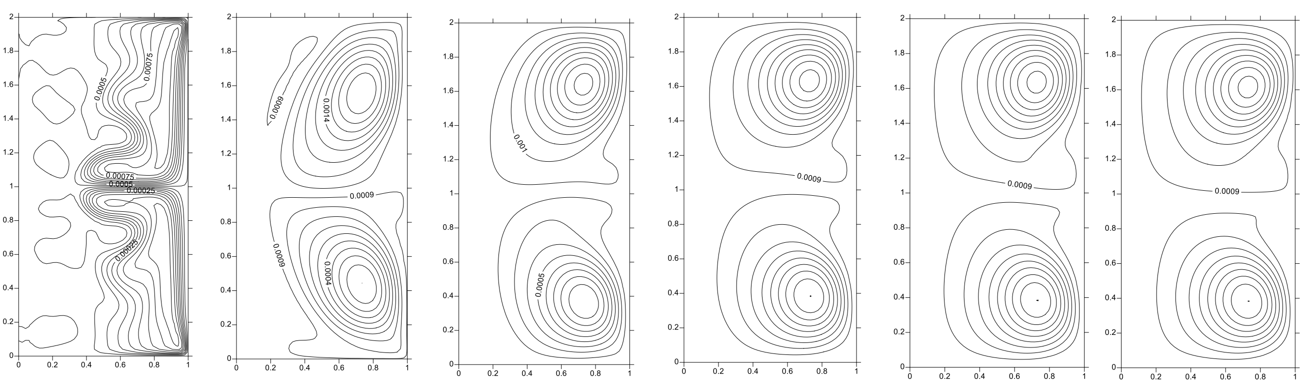

Figure.1: Streamlines for different Richardson number values (1st case).

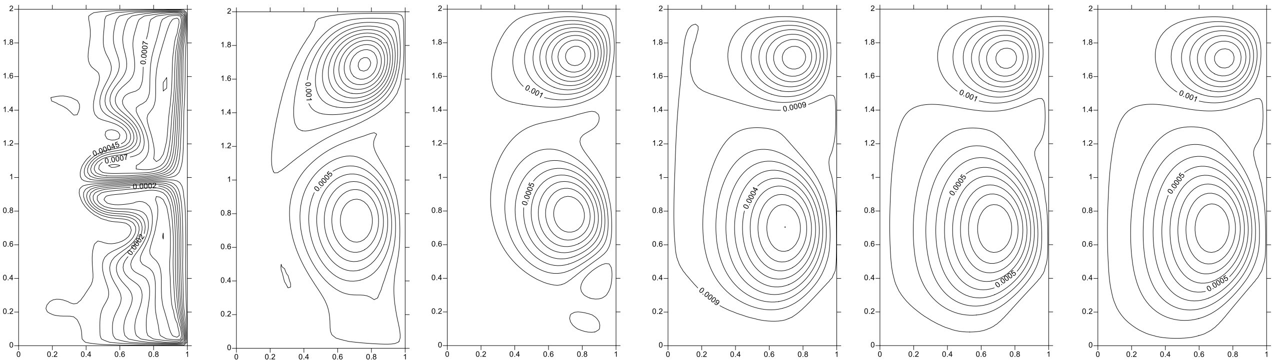

Figure.2: Streamlines for different Richardson number values (2nd case).

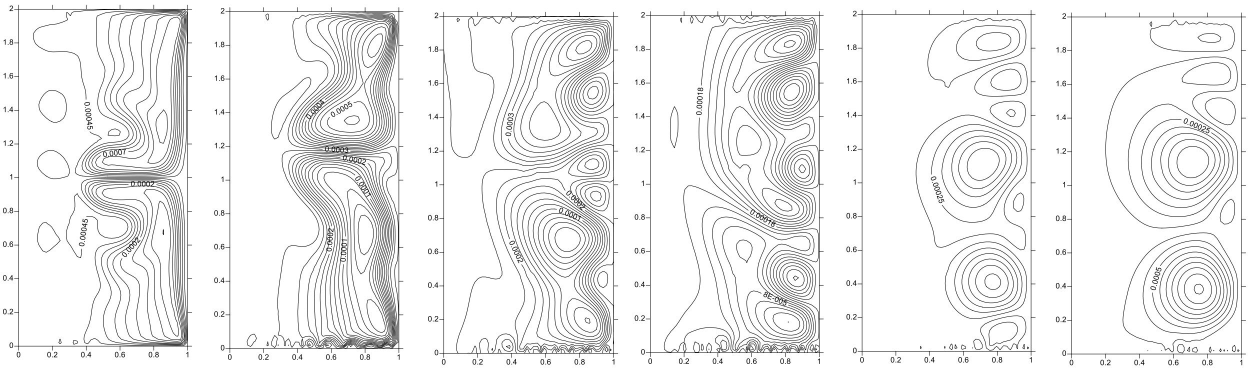

Figure.3: Streamlines for different Richardson number values (3rd case).

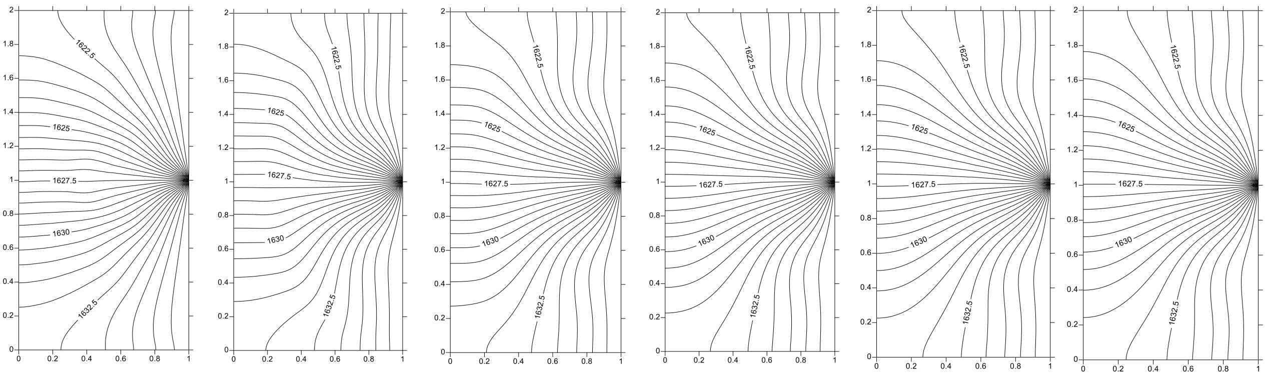

Figure.4: Isotherms for different Richardson number values (1st case).

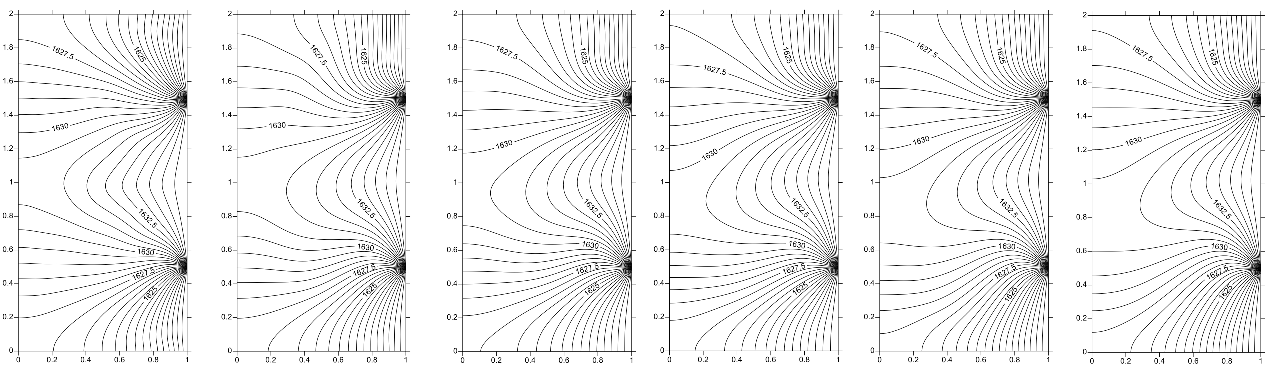

Figure. 5: Isotherms for different Richardson number values (2nd case).

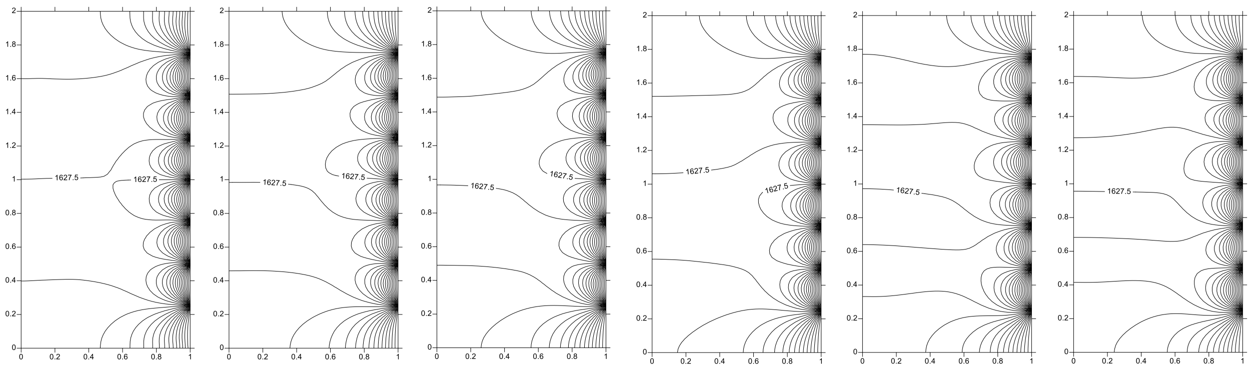

Figure.6: Isotherms for different Richardson number values (3rd case).

4. Conclusion

Numerical simulations have been performed for unsteady mixte convection in a enclosure with the presence of discrete heater. The effect of discrete heater and internal heat generation parameter have been analyzed through streamlines, isotherms, velocity profiles and heat transfer rates. From the above study, we can conclude the following remarks:

_ Among the four different cases, Case-4 yields the better heat transfer rate than the other three cases. Hence, the distribution of discrete heater produces the maximum heat transfer rate and the fluid motion than other discrete heater.

_ Increasing the values of internal heat generation parameter *Ri*, internal temperature exceeds the temperature of the discrete heater, hence the effect of discrete heater is entirely reduced.

_ The heat transfer rate increases with increase in the distribution of discrete heater and Prandtl number but decreases with increase in the internal heat generation parameter.

References

1. Ho, C. J. and Chang, J. Y., "A Study of Natural Convection Heat Transfer in a Vertical Rectangular Enclosure with Two-dimensional Discrete Heating: Effect of Aspect Ratio," Int. J. Heat Mass Transfer, Vol. 37, No. 6, pp. 917_925 (1994). doi: 10.1016/0017-9310(94) 90217-8
2. Aydin, O. and Pop, I., "Natural Convection from a Discrete Heater in Enclosures Filled with a Micropolar Fluid," Int. J. of Engg. Science,Vol. 43, No. 19_20, pp. 1409–1418 (2005). doi: 10.1016/j.ijengsci.2005.06. 005
3. Sivasankaran, S., "Buoyant Convection in a Cavity with Discrete Heat Sources and Internal Heat Generation," Int. J. of Appl. Math. and Mech., Vol. 2, No. 2, pp. 63_74 (2006).
4. Saha, G., Saha, S., Islam, M. Q. and Akhanda, M. A. R., "Natural Convection in Enclosure with Discrete Isothermal Heating from Below," J. Naval Architecture and Marine Engg., Vol. 4, No. 1, pp. 1_13 (2007). doi: 10.3329/jname.v4i1.912
5. Nithyadevi, N., Kandaswamy, P. and Lee, J., "Natural Convection in a Rectangular Cavity with Partially Active Side Walls," *Int. J. of Heat and Mass Transfer*,Vol. 50, No. 23_24, pp. 4688_4697 (2007). doi: 10. 1016/j.ijheatmasstransfer.2007.03.05