Numerical simulation of natural convection in partially open cavity with vertical conductive obstacle

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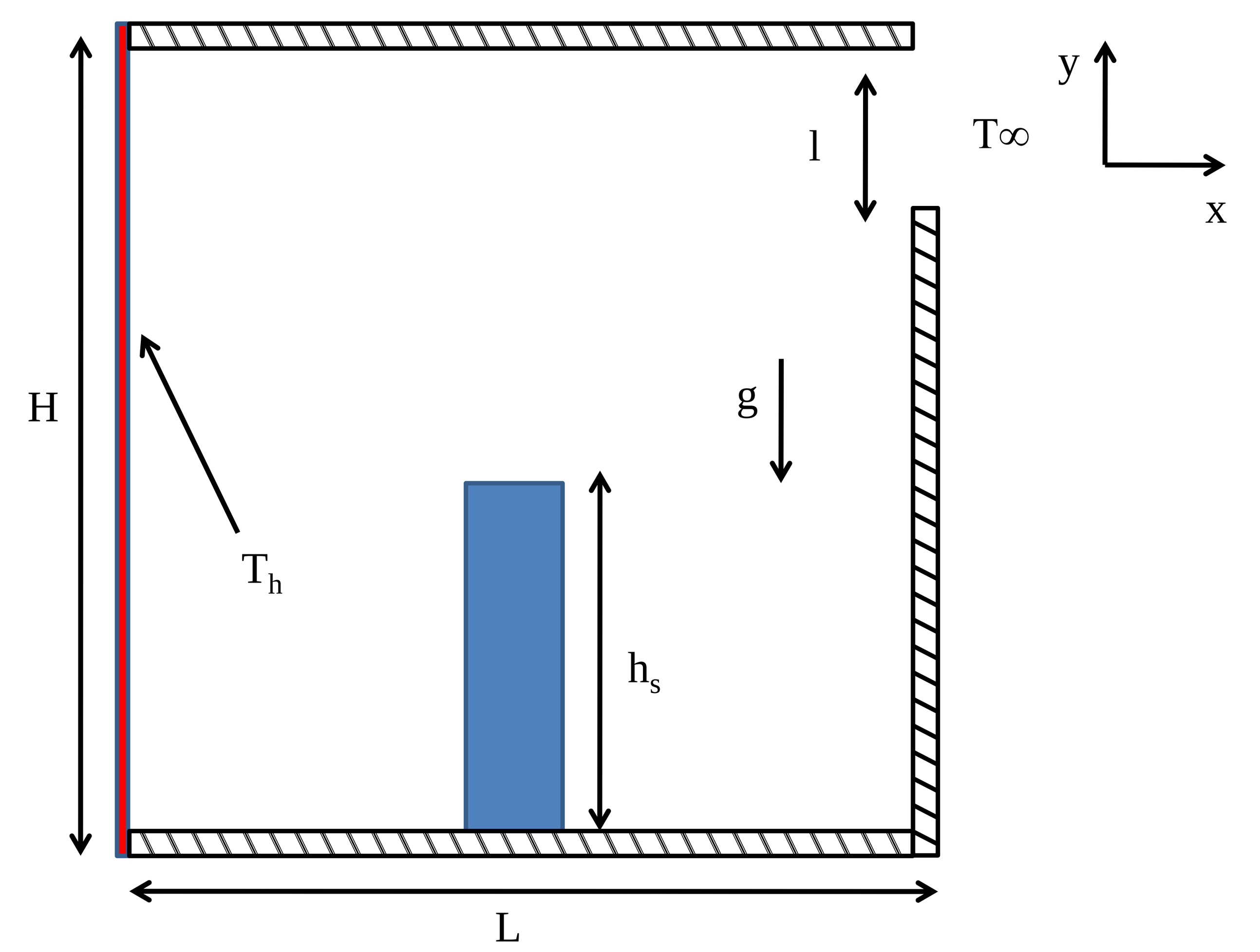
The Fifth International Symposium on Dielectric Materials and Applications

ABSTRACT

Heat transfer by natural convection in closed cavities has been extensively studied. This method of heat transfer has a wide range of applications in engineering: cooling of electronic components, air conditioning, etc. However, the heat transfer in open cavities, has not been studied as intensively although this type of cavity is very encountered in reality. Present study has offered numerical investigation for heat transfer coupled by conduction and natural convection and fluid flow in a partially open cavity containing a vertical conductive obstacle body. The cavity is partially opening in the right vertical wall. The left vertical boundary was isothermal. All the other boundaries are assumed to be adiabatic. The results of this study were obtained for various governing parameters such as the Rayleigh number, varying from 10^3 to 10^6, the conductivity ratio from Kr = 10 to Kr = 120. The control volume method was adopted for solving the conservation equations, in two dimensional forms. The results are presented in terms of streamlines, isotherms, velocity profiles, the Nusselt number and the volume flow rate of air through the opening. It is noticed that the results are strongly influenced by the selected parameters.

PHYSICAL MODEL



MATHEMATICAL MODEL

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

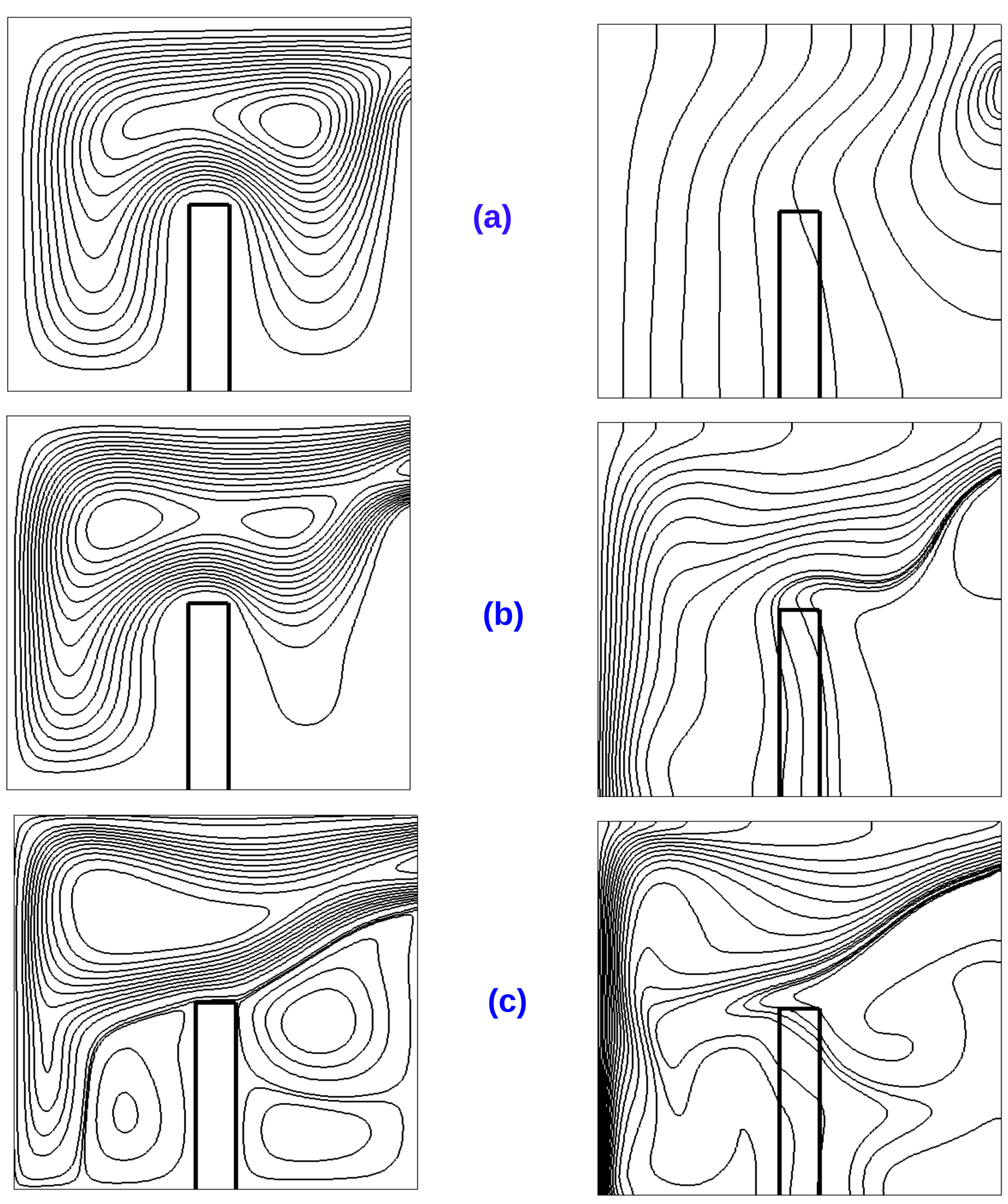
$$\frac{\partial U}{\partial \tau}+U\frac{\partial U}{\partial X}+V\frac{\partial U}{\partial Y}=-\frac{\partial P}{\partial X}+\Pr\left(\frac{\partial^2 U}{\partial X^2}+\frac{\partial^2 U}{\partial Y^2}\right)$$

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

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

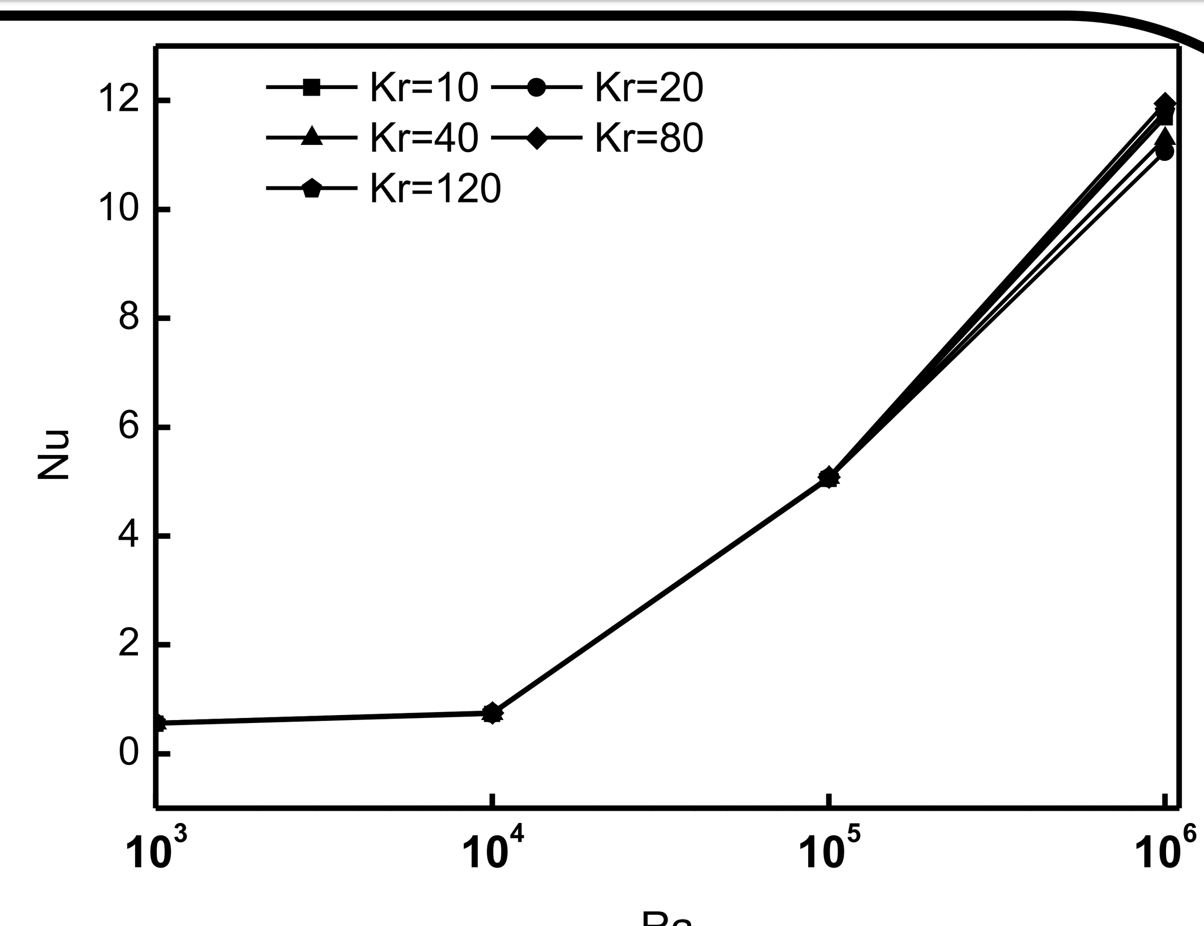
$$\frac{\partial \theta_s}{\partial \tau}+U\frac{\partial \theta_s}{\partial X}+V\frac{\partial \theta_s}{\partial Y}=\frac{1}{\alpha_r}\left(\frac{\partial^2 \theta_s}{\partial X^2}+\frac{\partial^2 \theta_s}{\partial Y^2}\right)$$

RESULTS

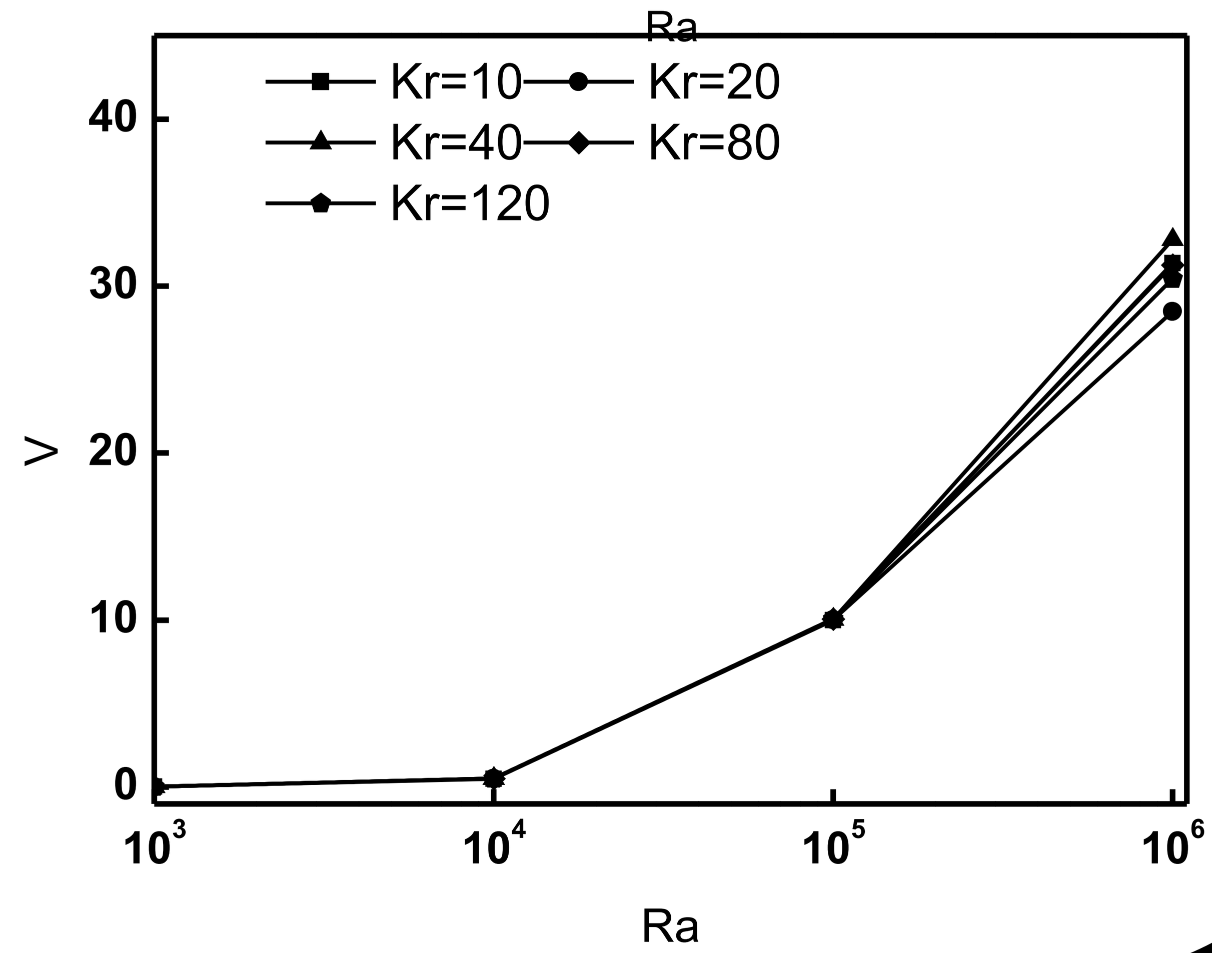


Streamlines (left) and isotherms (right) obtained for Ra = 10^4 (a), Ra = 10^5 (b), Ra = 10^6 (c), and Kr = 80

Nusselt number us function of Rayleigh number obtained for $10 \leq Kr \leq 120$



Volume flow rate us fonction of Rayleigh number obtained for $10 \leq Kr \leq 120$



CONCLUSION

Natural convection in a partially open cavity containing a vertical conductive obstacle has been studied. The objective of this work is to study the effects of Rayleigh number and the thermal conductivity of the obstacle on the convective heat transfer and the volume flow rate of air exchanged between the cavity and its external environment having an ambient temperature lower than that imposed on the active wall of the cavity. The obtained results showed that the Rayleigh number has generally no effect on the Nusselt number and on the volume flow rate from Ra = 10^3 to Ra= 10^4. On the other hand, beyond Ra = 10^4, the heat transfer and volume flow rate of air undergo significant increases by increasing the Rayleigh number. Regarding the influence of the thermal conductivity of the obstacle, we noticed that the Nusselt number and the volume flow rate undergo changes only for the case of Ra = 10^6, where they reach their minimum values in the case of Kr = 20. On the other side, the thermal conductivity of the obstacle has practically no effect on the Nusselt number and the volume flow rate for Rayleigh numbers less than or equal to 10^5.