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Numerical analysis of fluid flow due to mixed convection in a lid-driven cavity having a heated circular hollow cylinder ☆

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ABSTRACT

Mixed convection heat transfer in a lid-driven cavity along with a heated circular hollow cylinder positioned at the center of the cavity has been analyzed numerically. The present study simulates a realistic system such as air-cooled electronic equipment with a heat component or an oven with heater. A Galerkin weighted residual finite element method with a Newton–Raphson iterative algorithm is adopted to solve the governing equations. The computation is carried out for wide ranges of the Richardson numbers, cylinder diameter and solid fluid thermal conductivity ratio. Results are presented in the form of streamlines, isothermal lines, average Nusselt number at the heated surface and fluid temperature in the cavity for the mentioned parameters. It is found that the flow field and temperature distribution strongly depend on the cylinder diameter and also the solid–fluid thermal conductivity ratio at the three convective regimes.

1. Introduction

Analysis of mixed convection in a lid-driven cavity is relevant to much engineering and environmental applications. These applications include heat exchanger, cooling of electronic equipments, nuclear reactors, chemical processing equipments and drying or geophysics studies, etc. [1–5].

Obstacle or a partition is used to enhance heat transfer in cavities. There are many studies on natural convection in an obstructed cavity in the literatures. House et al.[6] studied natural convection in a vertical square cavity with heat conducting body. Dong and Li [7] performed the conjugate effect of natural convection and conduction in a complicated enclosure. Braga and Lemos [8] numerically investigated steady laminar natural convection within a square cavity filled with a fixed amount of conducting solid material consisting of either circular or square obstacles. The authors showed that the average Nusselt number for cylindrical rods is slightly lower than those for square rods. Tasnim and Collins [9] numerically analyzed the problem of laminar natural convection heat transfer in a square cavity with an adiabatic arc shaped baffle. Laskowski et al. [10] examined both experimentally and numerically heat transfer to and from a circular cylinder in a cross-flow of water at low Reynolds number. The results explained that, when the lower surface was unheated, the temperatures of the lower surface and water upstream of the cylinder were maintained approximately equal and the flow was laminar. Shih et al.[11] conducted the periodic laminar flow and heat transfer due to an insulated or various isothermal rotating objects (circle, square, and equilateral triangle) placed in the center of the square cavity. Transient variations of the average Nusselt number of the respective systems show that for high *Re* numbers, a quasiperiodic behavior is found while for low *Re* numbers, periodicity of the system is clearly found. Very recently, Costa and Raimundo [12] analyzed the problem of mixed convection in a square enclosure with a rotating cylinder centered within. They presented how the rotating cylinder affects the thermal performance of the enclosure, and how the thermo-physical properties of the cylinder are important in the overall heat transfer process across the enclosure. They have also concluded that, for small rotating velocities, the highest Nusselt numbers are obtained for the smallest values of the thermal conductivity and thermal capacity of the cylinder.

Literature on the body inserted lid-driven cavity is sparse. Dagtekin and Oztop [13] inserted an isothermally heated rectangular block in a lid-driven cavity at different positions to simulate the cooling of electronic equipments. The authors concluded that dimension of the body is the most effective parameter on mixed convection flow. Rahman et al.[14] investigated the effect of a heat conducting horizontal circular cylinder on MHD mixed convection in a lid-driven cavity along with joule heating. MHD mixed convection

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