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Lattice Boltzmann simulation of natural convection around a horizontal elliptic cylinder inside a square enclosure☆

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ABSTRACT

Natural convection between a square outer cylinder and a heated elliptic inner cylinder has been studied numerically. The inner and outer walls are maintained at temperatures T_h and T_c, respectively, with $T_h > T_c$. Lattice Boltzmann method (LBM) has been used to investigate the hydrodynamic and thermal behaviors of the fluid at various vertical positions of the inner cylinder for different Rayleigh numbers ranging from 10^3 to 10^6. The results show that streamlines, isotherms, and the number, size and formation of the cells strongly depend on the Rayleigh number and the position of inner cylinder. The changes in heat transfer quantities have also been presented.

1. Introduction

Buoyancy driven heat transfer has been the focus of numerous investigations. These studies were motivated by the desire to understand the fundamental physics of such fields as well as their wide applications in various industries, such as heat exchangers, nuclear and chemical reactors, cooling of electronic equipment, solar collector–receivers, insulation and flooding protection for buried pipes used for district heating and cooling, cooling systems in nuclear reactors, etc. [1–6].

Comparatively, there is rather little work with natural convection in fluid saturated enclosures having a built-in solid phase, which constitute another important application area. A review of the early works on this subject is found in Kuehn and Goldstein [7], in which experimental and numerical results of laminar natural convection in horizontal annuli with different Rayleigh numbers were documented as well. Asan [8] investigated two-dimensional natural convection in an annulus between two isothermal concentric square ducts for various Rayleigh numbers. His results showed that the dimension ratio and Rayleigh number have a remarkable influence on the temperature and flow field. House et al. [9] studied the effect of a square, heat conducting body on natural convection in a vertical enclosure. They have shown that heat transfer across the cavity may be enhanced or reduced by a body with a thermal conductivity ratio smaller or greater than unity. Kumar De and Dalal [10] focused on the natural convection around a square, horizontal, heated cylinder placed inside an enclosure for *Ra* ranging from 10^3 to 10^6. Effects of the enclosure geometry have been studied using three different aspect ratios placing the square cylinder at different heights from the bottom. The results reveal that the uniform wall temperature heating is quantitatively different from the uniform wall heat flux heating. Cesini et al. [11] performed the numerical and experimental analysis of natural convection from a horizontal cylinder enclosed in a rectangular cavity. The effect of the cavity aspect ratio and the Rayleigh number on the isotherms and Nusselt number was investigated. As a result, the average heat transfer coefficients increase with increasing Rayleigh number. Ghaddar [12] reported the numerical results of natural convection from a uniformly-heated horizontal cylinder placed in a large air-filled rectangular enclosure. He observed that flow and thermal behavior depended on heat fluxes imposed on the inner cylinder within the isothermal enclosure. Bararnia et al. [13] studied the natural convection in a nanofluid filled portion cavity with a heated built-in plate by LBM. The results have been obtained for different inclination angles and lengths of the inner plate. Famouri and Hooman [14] investigated the effects of the position of a heated partition on the heat transfer and local and average entropy generation rate in a partitioned cavity.

Furthermore, fewer publications were found for natural convection in or around a non-circular domain. Schreiber and Singh [15] studied the cases in horizontal confocal elliptical cylinders oriented at an arbitrary angle with respect to the gravity vector in the same coordinate system. Lee and Lee [16] focused on the natural convection for the symmetrical cases of elliptical annuli. Cheng and Chao [17] performed numerical study for some horizontal eccentric elliptical annuli.

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