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Buoyancy driven flow within an inclined elliptic enclosure

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ABSTRACT

Buoyancy driven flow and associated heat convection in an elliptical enclosure has been investigated. The enclosure which is the space between two horizontal concentric confocal elliptic tubes is heated through its inner tube surface which is maintained at either uniform temperature or uniform heat flux. The induced buoyancy driven flow and the associated heat convection are predicted at different enclosure orientations. The full governing equations in terms of vorticity, stream function and temperature are solved numerically using Fourier Spectral Method. Beside Rayleigh and Prandtl numbers the heat convection process in the enclosure depends on the geometry of the enclosure and the angle of inclination with respect to gravity vector. The geometry of the enclosure is represented in terms of major axes ratio and axis ratio of inner tube. The study considered a moderate range of Rayleigh numbers between 5×10^3 and 1×10^5 while Prandtl number is fixed at 0.7. The inner tube axis ratio is considered between 0 and 1 while the ratio between the two major axes is considered up to 3. The angle of inclination of the minor axes with respect to gravity vector is varied from 0 to 90°. The results for local and average Nusselt numbers as well as temperature distribution are obtained and discussed together with the details of both flow and thermal fields. For isothermal heating conditions, the study has shown an optimum value for major axes ratio that minimizes the rate of heat transfer in the enclosure. While in case of heating at uniform heat flux the study revealed existence of major axes ratio at which the mean temperature of the inner wall is maximum. Another aspect of this paper is the prediction of global flow circulation around the inner tube in case of asymmetrical orientation of the enclosure with respect to the gravity vector.

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1. Introduction

Buoyancy driven flow and associated heat convection in an annular enclosure has long been investigated because of its pertinence to many practical engineering applications. These applications include solar collector receivers, aircraft cabin insulation, cooling of electronic equipment, nuclear reactor systems, thermal storage systems and many others. The annular enclosure can be geometrically formed by the region between either concentric or eccentric two elliptical tubes. The region between two concentric elliptical tubes can represent different annuli configurations ranging from the annulus formed between two concentric circular tubes to annulus formed by a flat plate surrounded by an elliptical tube. In such annular spaces the induced flow is initiated due to temperature difference between the two walls of the enclosure. The temperature difference, in this study, is developed as a result of heating the inner wall and cooling the outer wall. The inner wall is heated and kept either at uniform temperature, UWT, or at uniform heat flux, UHF while the outer wall is kept at uniform temperature higher than that of the ambient cooling medium.

In case of UWT natural convection in a horizontal enclosure between two concentric/eccentric circular tubes, the volume of previous research is considerable. Kuehn and Goldstein [1] studied the natural convection between two concentric cylinders both experimentally and theoretically. Beside providing good, thorough literature review, the study covered the most details of steady heat transfer characteristics and flow patterns developed in the enclosure. The authors presented heat transfer results in terms of Nusselt number and equivalent conductivity. The equivalent conductivity is defined as the actual heat flux divided by the heat flux that would occur by pure conduction. The authors have further extended their experimental study [2] to include the natural convection between two eccentric isothermal circular tubes; the case which has been considered later by a number of researchers [3–12]. In case of UHF natural convection in a horizontal enclosure between two concentric/eccentric circular tubes only few studies are reported in the literature [13–18]. In case of eccentric circular enclosures (including both UWT and UHF), some authors considered the case of symmetrical enclosure with respect to gravity vector, while some others considered the case of asymmetric enclosure. In case of

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