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Finite-volume method for solving the entropy generation due to air natural convection in Γ-shaped enclosure with circular corners

Behrooz M. Ziapour *, Resam Dehnavi

Department of Mechanical Engineering, University of Mohaghegh Ardabili, Ardabil, Iran

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A B S T R A C T

An enhanced cell-centered finite-volume procedure was presented for solving the natural convection of the laminar air flow in a Γ-shaped enclosure with circular corners. An explicit fourth-order Runge-Kutta integration algorithm was applied to find the steady state condition. Also an artificial compressibility technique was applied to couple the continuity to the momentum equations. The discretization of the viscous and thermal conduction terms are very simplified using the enhanced scheme similar to the flux averaging in the convective term. The Rayleigh numbers from 10^2 to 10^6 were considered. In the case of corner radius as $r = 0$, then the data available in open literature were used to validate the numerical model. The effect of the artificial compressibility parameter in convergence of solution was investigated. Additionally an analysis of the entropy generation in Γ-shaped enclosure with circular corners was performed. It was seen that in the cases of the large radius corners, with a decrease of the irreversibility ratio, then the Bejan number increases.

1. Introduction

Natural convection is a fundamental mechanism for mass, momentum and heat transfer in some natural phenomena and is of interest in engineering systems. Natural convection heat transfer within an enclosure is frequently encountered in many practical fields such as furnaces, cooling of electronic devices, double glazed windows, solar collectors, etc. It has been the subject of numerous theoretical and experimental researches through the past three decades [1–10].

Heat transfer processes present irreversibility, resulting in process efficiency loss. This efficiency loss is related to the entropy generation, which exists in all heat transfer and fluid flow processes. The optimal design criteria for thermal systems by minimizing their entropy generation have recently been a topic of great interest, especially in the fields related to geometry of a duct, natural convection in enclosure has gained attraction of many researchers [11–18]. It seems that, this mentioned literature field is surprisingly scarce about the numerical problems with curvilinear solid boundary shape. It is increasingly important to be able to deal with complicated geometries in these applications. An efficient code is the key to solution methodologies witch would produce results using the least amount of computing time and memory. The finite-volume method of Jameson et al. has proved to be useful as a tool in solving the Euler and Navier–Stokes equations together with complex and curvature boundaries [19–22]. Among the various schemes proposed for flux calculation in the finite-volume model, the Jameson's flux averaging is still of use because of its simplicity. In a finite-volume method mapping is not needed. Therefore the scheme is applied directly in the physical domain. In this work, the Jameson's cell-centered finite-volume scheme for space discretization was developed.

In the last numerical solutions of the heat transfer and fluid flow for enclosures, a code based on the enhanced SIMPLE method [23], almost couples the pressure to the velocity. For example, In the Oliveski et al. work [6], the pressure-velocity coupling is obtained by the SIMPLEC method from the Van Doormmal and Raithby [24]. Or, in the Dagtekin et al. work [5],

* Corresponding author. Tel.: +98 451 5512910; fax: +98 451 5512904.
E-mail address: behrooz_m_ziapour@yahoo.com (B.M. Ziapour).

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