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Numerical analysis of entropy generation in mixed convection flow with viscous dissipation effects in vertical channel ☆

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ABSTRACT

A numerical investigation is performed into the entropy generated within a mixed convection flow with viscous dissipation effects in a parallel-plate vertical channel. In performing the analysis, it is assumed that the flow within the channel is steady, laminar and fully developed. The governing equations for the velocity and temperature fields in the channel are solved using the differential transformation method. The numerical results for the velocity and temperature fields are found to be in good agreement with the analytical solutions. The entropy generation number (N_s), irreversibility distribution ratio (Φ) and Bejan number (B_e) of the mixed convection flow are obtained by solving the entropy generation equation using the corresponding velocity and temperature data.

1. Introduction

Mixed convection flow in a parallel-plate vertical channel appears in many practical engineering applications, including heat exchangers, chemical processing equipment, transport systems for heated or cooled fluids, and so on. The earliest analysis of laminar and fully developed mixed convection in parallel-plate vertical channels with uniform boundary temperature conditions was presented by Tao [1]. Hamadah and Wirtz [2] found that the buoyancy force in mixed convection within a vertical channel enhances the heat transfer near the heated wall and may cause a flow reversal effect near the cooler wall. The problem of entropy generation has been examined in a variety of engineering contexts in recent years, including heat exchangers, turbo-machinery, electronic cooling systems, combustion engines, and so forth. The finite-time thermodynamics also has been applied to optimize the performance of various thermodynamic system [16–19]. Bejan [15] analyzed entropy generation induced by the heat transfer and the fluid viscosity as the objective function to optimize the geometry of heat transfer tubes and to find optimum parameters for heat exchangers. Datta [3] showed that the entropy generated in a confined laminar diffusion flame was primarily the result of heat transfer within the flame. Baytas [4,5] analyzed the problem of minimizing the entropy generation in an inclined enclosure and inclined porous cavity, respectively. Bejan [6] showed that the entropy generation for forced convective heat transfer is a result of the temperature gradient and viscous effects within the fluid, respectively. Ko and Cheng [7] utilized a numerical method to investigate the problem of developing laminar forced convection and entropy generation in a wavy channel. The results showed that the entropy generation was determined primarily by the aspect ratio of the channel and the Reynolds number of the flow. Ibanez, Cuevas and Haro [8] optimized the magnetohydrodynamic flow between two infinite parallel walls of finite electrical conductivity using the entropy generation minimization method. Mai, Wakil and Padet [9] investigated the transient nature of mixed convection flow and heat transfer in a vertical pipe, Famouri and Hooman [20] numerically simulated the entropy generation for free convection in a partitioned cavity.

Differential transformation theory has been applied to solve many general initial value problems in the mechanical engineering domain in recent years. For example, Chen and Ho [10,11] utilized the differential transformation method to solve general eigenvalue problems and to analyze the free vibration response of Timoshenko beams. Kuo [12] applied differential transformation theory to investigate the velocity and temperature distributions associated with a free convection boundary-layer flow over a vertical plate. Chen et al. [21] demonstrated that the hybrid differential transformation and finite difference method provide a precise and computationally-efficient means of analyzing the nonlinear dynamic behavior of fixed–fixed micro-beams. The same group also used the hybrid method to analyze the nonlinear dynamic response of an electrostatically-actuated micro circular plate subject to the effects of residual stress and a uniform hydrostatic pressure acting on the upper surface [22]. The current study uses the differential transformation method to analyze the problem of entropy generation within a mixed convection flow with viscous dissipation effects in a parallel-plate vertical

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