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STEADY AND OSCILLATORY LAMINAR OPPOSING MIXED CONVECTION IN A VERTICAL CHANNEL OF FINITE LENGTH SUBJECTED TO ISOTHERMAL DISCRETE HEAT INPUTS: COMPARISON BETWEEN SYMMETRICAL AND ASYMMETRICAL HEATING

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ABSTRACT

A detailed numerical simulation for transient laminar opposing mixed convection in a vertical channel of finite length subjected to isothermal discrete heat inputs is investigated by solving the unsteady two-dimensional Navier-Stokes and energy equations for the case of asymmetric and symmetric heating. A parametric study was carried out to evaluate the influence of buoyancy on the overall flow structure and the nondimensional heat flux (Nusselt number) from the heated surface/surfaces. For comparison purposes, results for the overall performance are presented for both heating configurations. Numerical simulations show that for any given value of the Reynolds number, a final steady or oscillatory flow response is obtained depending on the value of the buoyancy parameter. For relatively small values of the Richardson number, the transient process leads to a final steady-state. When the value of the critical Richardson number is exceeded a final oscillatory flow response is obtained. The convection instability occurs as a Hopf bifurcation with a well defined frequency. Results are particularly presented to illustrate the effect of the arrangement of the heat sources in the flow and heat transfer response.

INTRODUCTION

Mixed convection studies are important for many industrial applications where buoyant forces are comparable to pumping forces. Recently, studies on mixed convection heat transfer in vertical channels where the duct walls are heated discretely has become a subject of increased interest due to its relevance in thermal problems related to the cooling of modern electronic equipment, nuclear reactors, and solar energy collectors [1-4]. Much work, both theoretical and experimental, has been done on mixed convection heat transfer in vertical channels under different boundary and operating conditions, as is evident in the reviews conducted in [5-7]. Transient laminar opposing mixed convection in a vertical plane channel subject to a symmetric heat input was numerically investigated in [8]. The authors performed a linear stability analysis to evidence the occurrence of flow bifurcation and their results show that with higher opposing buoyancy the flow response is periodic in space and time. The buoyancy and inertia effects on a low Prandtl fluid flowing through a symmetrically and uniformly heated vertical plane channel were numerically investigated in [9]. Laminar mixed convection of air in a symmetrically or asymmetrically heated vertical channel was numerically investigated in [10]. Results are presented for the velocity and temperature profiles for Richardson numbers of 0.1, 1, 3, and 5. Particle image velocimetry (PIV) measurements were carried out for transient laminar opposing flow in a vertical duct with a differential and asymmetric heating condition [11]. Results show that buoyancy forces produce non-stationary vortex structures close to the heated region with flow patterns that are non-symmetric, periodic, and that exhibit increasing complexity and frequency for increasing buoyancy. In [12], the same authors investigated the transient laminar mixed convection in an asymmetrically and differentially heated vertical channel of finite length subject to an opposing buoyancy. Their numerical simulations show that a final steady or oscillatory flow response is obtained