Abstract
This paper details the numerical study of laminar natural convection in a square enclosure filled with a non-Newtonian fluid. Thermal boundary conditions of the Dirichlet type are applied on the vertical walls of the enclosure while the horizontal ones are assumed adiabatic. A Power-law model is used to characterize the viscous behaviour of the purely viscous non-Newtonian fluids. The governing differential equations have been solved by the standard finite volume method and the hydrodynamic and thermal fields were coupled together using the Boussinesq approximation.

The effects of Power-law index \( n \) in the range \( 0.50 \leq n \leq 1.50 \) on the heat and momentum transport are investigated for the values of Rayleigh number \( (Ra) \) in the range \( 10^1 \leq Ra \leq 10^4 \) and a Prandtl number of \( Pr = 10 \).

We report accurate results of a systematic study with a focus on the most important buoyancy-induced flow and heat transfer characteristics. It is shown that the mean Nusselt number values increases with the increasing values of Rayleigh number for Newtonian as well as Power-law fluids. However, shear-thickening fluids \( (n > 1) \) are characterised with smaller \( \overline{Nu} \) values. Finally, the onset of convection dominated heat transfer mechanism is shifted towards lower values of \( Ra \) for the shear-thinning fluids \( (n < 1) \).

Key Words: Laminar Natural Convection, Differentially Heated Cavity, Mean Nusselt Number, Critical Rayleigh Number, Numerical Modelling

1. INTRODUCTION

Today more than ever, controlled heat transfer plays an important role in the development of energy-efficient heat transfer systems and fluids which are required in many industries and commercial applications [1-4]. Natural convection (i.e. flow caused by the temperature induced density variations) is one of the most extensively analysed heat transfer configurations because of its fundamental importance as the “benchmark” problem for studying convection effects (and comparing as well as validating numerical techniques). For example, an accurate benchmark solution for natural convection of air in a square cavity with vertical boundaries kept at different temperatures are presented in [5], with reference to \( 10^3 \leq Ra \leq 10^6 \). Another benchmark solution for natural convection of air in a side heated square cavity is reported in [6] for \( 10^4 \leq Ra \leq 10^6 \). Finally, Nonino and Croce [7] have extended the results presented in [5, 6] to the case of higher values of Rayleigh number; i.e \( 10^5 \leq Ra \leq 10^8 \).

In spite of geometrical simplicity, buoyancy driven flows are complex because of essential coupling between the transport properties of flow and thermal fields. In particular, internal flow problems are considerably more complex than external ones. This is because at large Rayleigh number classical boundary layer theory yields the simplifications for external flow problems, namely, the region exterior to the boundary layer is unaffected by the boundary layer. For confined natural convection, in contrast, boundary layers form near the walls but the region exterior to them in enclosed by the boundary layers form a core region. Since the core is partially or fully encircled by the boundary layers, the core flow is not


