NUMERICAL SIMULATION OF NON-BOUSSINESQ EFFECTS IN LAMINAR AND TURBULENT RAYLEIGH-BÉNARD CONVECTION OF WATER IN A PERFECTLY CONDUCTING CUBICAL CAVITY

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ABSTRACT The effects of a non-Boussinesq fluid are numerically studied and discussed for Rayleigh-Bénard convection in a cubical cavity with perfectly conducting sidewalls at low and high Rayleigh numbers using water as a convecting fluid (*Pr*=5.9). Numerical simulations at all Rayleigh numbers considered were carried out for two different cases. In the first case a Boussinesq fluid was considered (Boussinesq Fluid Simulation-BFS) and in the second case, the dependence of viscosity and thermal conductivity of water on temperature was adopted in the simulations (Non-Boussinesq Fluid Simulation-NBFS). At the low Rayleigh numbers used in this study ($Ra=10^4$ and $Ra=5\text{x}10^4$) the flow is laminar and steady and at the high Rayleigh number considered ($Ra=10^7$) the flow is turbulent. At $Ra=10^4$ and $Ra=5\text{x}10^4$ we focus our analysis on the effect of variation of the fluid viscosity with temperature on the more stable flow structures from the set of seven different topologies reported in previous studies. At $Ra=10^7$ and *Pr*=5.9 the non-Boussinesq effects on the turbulent flow are analysed in detail and the flow structures and heat transfer rates compared with those available in the literature at *Pr*=0.71. Previous works recommend that temperature difference should be less than 4.5ºC in order to obtain less than 10% of variation in the viscosity. Non-Boussinesq simulations in the present work were calculated with a viscosity variation of 40% between cold and hot plates. The numerical simulations at high and low Rayleigh numbers were conducted with a second order finite volume code without any turbulence model because the time-steps and grid sizes used are adequate for the time and spatial resolution requirements reported in previous direct numerical simulations of Rayleigh-Bénard flows. The structure of the flow topologies at $Ra=10^4$ and $Ra=5\text{x}10^4$ are not significantly affected by the effects of the variation of viscosity and thermal conductivity with temperature. However, results obtained with a NBFS show an increase of the ascending flow velocities compared with those obtained with the Boussinesq approximation according to the decrease of viscosity with increasing temperature. At $Ra=10^7$ the instantaneous flow shows large deviations with respect to the time-average flow field that consists in two counter rotating vortex rings located near the horizontal plates. The temperature gradients and, thus the viscosity variation are located close to the walls within the thermal boundary layers. This causes that the time-averaged flow field topologies corresponding to BFS and NBFS are not greatly affected by the effects of the variation of viscosity and thermal conductivity with temperature.