Transients in Thermomagnetic Convection of Paramagnetic Fluid in Cubical Enclosure Subjected to Strong Magnetic Fields

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ABSTRACT

A cubical enclosure filled with a paramagnetic fluid and subjected to differential temperature gradients (heated from top, side or bottom) and exposed to a strong external non-homogeneous magnetic field of different orientations is studied experimentally and numerically. Despite its simple geometry, complex phenomena involving coupled fluid dynamics/electromagnetic interactions make this setup particularly challenging. Starting from a pioneering work of Braithwaite et al. [1], potentials of a magnetically controlled convection in paramagnetic, or even in ordinary fluids, have been investigated both experimentally and numerically, e.g. Tagawa et al. [2], Shigemitsu et al. [3], Bednarz et al. [4]. A major contribution of these studies was in providing the integral heat transfer (Nusselt number) behaviour under strong magnetic fields and in reporting some basic flow visualisations. The goal of our present investigation is to provide detailed insights into fluid flow and heat transfer changes under influence of combined effects of the thermal-buoyancy and magnetisation force over a wide range of working parameters (different values of Pr of working fluids and different values of imposed magnetic field). n order to achieve that, we combine the heat transfer measurements (thermal probes inside the enclosure walls and within the working fluid) with PIV for measuring the instantaneous velocity fields. In parallel to these experimental studies, a high-resolution numerical simulations with a finite volume integrated Biot-Savarts's and Navier-Stokes equations solver are also performed, Kenjereš and Hanjalić [5]. The strong magnetic field gradients are generated by a state-of-art superconducting helium free magnet, which make it possible to obtain a maximum magnetic field in the magnetic bore up to 10 T. Starting from pure thermal conductivity flow regimes (for heated from above configuration), interesting flow reorganisation takes place when the magnetisation force starts to be of the competitive magnitude to the thermal buoyancy force. Convective cells similar to the classical Rayleigh-Bénard cells appear despite the initial strong stable stratification. Dynamics of these convective cells and their influence on the heat transfer phenomena for different values of the imposed magnetic fields are studied numerically and compared with experiments. High resolution finite-volume numerical simulations in parallel mode (MPI) based on fully implicit time integration of governing equations (velocity, pressure and temperature fields). Generally, very good agreement between numerical simulations and experiments is obtained. The full paper will focus on detailed analysis of transient and fully developed turbulent states of velocity and temperature fluctuations. In addition to detection and visualisations of these intermittent states, also a long-term averaged statistics of the second-moments of velocity and temperature fields will be also presented.

References

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