Convection in vertical layer of magnetic fluid

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A stability study of a parallel buoyancy-induced flow in a differentially heated vertical layer is one of the classical problems in hydrodynamics [1]. We consider its generalization to flows of a non-conducting ferromagnetic fluid. In this case a ponderomotive magnetic force caused by the non-uniformity of fluid magnetization arises in a non-isothermal fluid layer placed in a uniform transversal magnetic field [2]. This additional physical mechanism leads to a number of new bifurcations of both pitchfork and Hopf types [3] that are observed experimentally and investigated theoretically.

The flow patterns arising in a layer of a kerosene-based ferrofluid with magnetite particles of the average diameter of 10 nm are visualized using heat-sensitive liquid crystal film. Thermocouples are used to obtain a quantitative temporal record of the temperature variation in a fluid layer. Using vertical layers with various thicknesses and aspect ratios we have gained deeper understanding of a thermomagnetically induced motion. New periodic flow patterns have been discovered that are formed in thin layers of large aspect ratio. It has been found that vertical stationary thermomagnetic rolls appear as a result of a pitchfork bifurcation while obliquely propagating thermomagnetic waves result from a Hopf bifurcation of a steady basic flow. The interaction of the magnetic and gravitational mechanisms causing them is studied theoretically. It is observed that the wavenumber of the detected convection patterns depends sensitively on the temperature difference across the layer and on the applied magnetic field. In unsteady wave regimes, its value periodically varies by a factor of almost two indicating the appearance of two distinct waves. The wavenumbers and spatial orientation of the observed dominant flow patterns are found to be in good agreement with theoretical predictions.

REFERENCES

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