Thermomagnetic convection in a ferrofluid in a cylindrical annulus under magnetic field and a radial temperature gradient

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Abstract

Ferrofluid consist of nonconducting synthetic stable colloids in which magnetic nanoparticles are suspended in a liquid carrier, either water or oil (1). A ferrofluid behaves as a paramagnetic medium and in the presence of magnetic field, its particles align with the field leading to a finite magnetization which depends on both the temperature and the applied magnetic field. The interaction of magnetic field with the ferrofluid is characterized by the Kelvin force which, in the presence of temperature gradient, contains a conservative term and a non-conservative force. The later can be assimilated to a buoyancy force with a magnetic gravity whose magnitude depends on the magnetic field, on the magnetization and on the geometry. This magnetic gravity can be used to model geophysical flows using central gravity in laboratory (2, 3) or in microgravity environment to trigger convective motion (4-6).
We consider a ferrofluid of densiy, of kinematic viscosity and thermal diffusivity contained in a cylindrical annulus of gap width with a radial magnetic field of magnitude and an outward radial heating , the electric gravity is centripetal i.e.. The control parameters are the radius ratio of the cylindrical annulus, the Prandtl number , the magnetic Rayleigh number to which one can add the Coriolis number for co-rotating cylinders at the angular frequency . The threshold of thermomagnetic convection in a stationary cylindrical annulus is independent of , it is characterized by stationary helical modes and it increases with the radius ratio . The solid body rotation increases the threshold of thermomagnetic convection; helical vortices become oscillating for low values of and they become oscillatory columns for large values of . In terrestrial condition, for small values of , thermoconvection occurs in form of thermal modes which are oscillatory and axisymmetric while for large values of , critical modes are oscillatory columnar vortices (thermomagnetic convective modes). Results from linear stability and direct numerical simulations will be compared with available experimental results (2, 6).

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