Transition to Turbulence in thermoelectric convection in a cylindrical capacitor

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We investigate the development of thermoelectric convection in dielectric liquid under a radial temperature gradient and an applied high-frequency tension between the cylindrical electrodes. The gradient of permittivity induced by the temperature gradient coupled to the electric field generates a dielectrophoretic force [1] which has a non-conservative term that can be assimilated to a buoyancy and thus can generate vorticity in the liquid. In comparison with the Archimedean buoyancy, we introduce an electric gravity g_e which is proportional to the square of the electric intensity and inversely proportional to the cube of the radius. We may use the electric Rayleigh number [2] $L = \alpha \Delta T g_e d^3 / \nu\kappa$ to monitor the transition from the conduction state to the turbulence state. Here α, ν, κ are the thermal expansion, the kinematic viscosity and the thermal diffusivity respectively and ΔT is the temperature difference between the cylindrical electrodes. To focus on the electric field effects, we introduce the dimensionless electric tension $V_E = V_0/V_i$ with V_0 is the effective applied tension to the electrodes and $V_i = (\rho\,\nu\kappa/\epsilon)^{1/2}$ represents an intrinsic electric potential of the dielectric liquid of permittivity ϵ.

We have made numerical simulations for fixed value of ΔT and varying the electrical tension difference applied to the electric capacitor either in microgravity conditions ($g = 0$) or on Earth conditions ($g \neq 0$) In the late case, ΔT was chosen below the critical value for triggering natural convection in the absence of the electric field.

In microgravity conditions, the conduction state bifurcates to stationary convective state made of helical vortices. By increasing the control parameter V_E, wavy spirals appear and then bifurcate to chaotic state. In Earth conditions, the critical convective state appears in form of columnar vortices that are destabilized when V_E increases through longitudinal regular and then irregular waves before turbulent states set in. We have computed the velocity, the temperature fields, the kinetic energy and the Nusselt number and its scaling for high values of the control parameter V_E.

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