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Convection of a Dielectric Fluid in a Cylindrical Annulus under Microgravity Conditions Due To a Radial Dielectrophoretic Force Field

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Extended Abstract

In the context of space exploration, innovative means for heat transfer control are essential. The proposed method consists in the application of the dielectrophoretic force to generate the flow of a dielectric fluid. To that effect, silicon oils with various viscosities are confined between two concentric cylindrical electrodes. The inner electrode is maintained at a fixed temperature and connected to the phase of a high voltage generator, while the outer electrode, held at a lower fixed temperature, is electrically grounded. The radial electric field applied is alternating with a frequency much larger than the inverse of the characteristic time of charge relaxation of the fluid, so it is ensured that its electric charge density never builds in.

Because of the curvature of the gap, the electric field is strongly inhomogeneous and leads to the differential polarisation of the fluid particles. As the electric permittivity of the fluid decreases with the temperature, particles close to the cold outer surface are attracted towards the inner electrode, where the electric field strength is the highest, and vice versa [1]. By analogy with the Archimedean buoyancy, the dielectrophoretic force can be interpreted as the effect of an effective “electric gravity” acting on the density stratification of the dielectric fluid. This electric gravity is centripetal, so that the steady base state can bifurcate into a convective state when the electric field and the temperature gradient are sufficiently large. When the convection arises, the rate of heat transfer between the two cylinders is increases.

The problem was investigated theoretically, numerically, and experimentally. The linear stability analysis has shown that the critical modes take the form of stationary helicoidal counter-rotating vortices. Under microgravity conditions, the viscosity has no effect on the stability of the flow [2]. Numerical investigations have confirmed the geometry of the convective regimes and has shown the increase of the rate of radial heat transport in the fluid [3]. Experiments were carried out during the microgravity phases of parabolic flights (~22s µg), as well as during a sound rocket flight (~360s µg). The flow field and temperature profiles were evaluated by particle image velocimetry and shadowgraph techniques. The 3D nature of the instability was confirmed, and the analysis of the instability amplitude helped the characterisation of the dielectrophoretic mechanism [4].

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