Abstract

In this thesis entitled 'Instabilities in externally driven hydrodynamic systems', studies on Rayleigh-Bénard (RB) convection and Faraday instability are presented. RB system presents a classic example of an instability in the bulk of a fluid, while Faraday system represents a very versatile system of surface instability in a fluid.

Direct numerical simulation (DNS) and low-dimensional modelling are used to study the RB convection in two-dimensions with stress free boundary conditions. The direct numerical simulation is performed using the pseudo-spectral method. We study the system for a wide range of reduced Rayleigh number r, which is proportional to the temperature difference across the fluid layer in the RB system. For a significantly large range in r, the convection is oscillatory in time. We also observe chaotic behaviour in a small range of r. In the chaotic regime the two-dimensional RB convection shows travelling rolls, in which the convection rolls move irregularly in time in a direction perpendicular to the roll axis. We also study the energy flow in the wavenumber space. Energy spectrum and shell-to-shell energy transfer techniques are used to study energy cascade, transfer of energy between modes and interaction between modes. We also construct a low-dimensional model of the two-dimensional RB convection. This model shows travelling rolls similar to that observed through DNS. The model also shows that the travelling rolls may lead to global flow reversal in the box, as observed in DNS.

We have analyzed the stability of the free surface of a metallic liquid driven parametrically in vertical plane in the presence of a uniform vertical magnetic field. Floquet analysis gives various subharmonic and harmonic stability zones. The magnetic field stabilizes the onset of parametrically driven surface waves. The increase in the magnetic field leads to a series of bicritical points at a primary instability in thin layers of a metallic fluid. We also present a study of the selection of surface patterns close to a bicritical point at the onset of the primary surface instability in viscous fluids under two-frequency vertical vibration. Rhombic patterns are likely candidates to appear easily at the onset of bicritical point, if the driving frequencies are selected properly.

We have analyzed instability in the bulk as well as on the surface of a viscous fluid driven externally.

Keywords: thermal convection; numerical simulation; travelling rolls; shell-to-shell energy transfer; driven surface waves; magnetic field; multiciritical points; dissipative structures; rhombic patterns