磁場の影響下での液体金属の対流：乱流への遷移過程
Transition to turbulence in liquid metal convection under a horizontal magnetic field

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Transition of flow pattern from laminar to turbulent is one of the most interesting problems in fluid dynamics. We performed both laboratory experiments and numerical simulations of Rayleigh-Benard convection of liquid metals under a uniform horizontal magnetic field. Fluids with low-Prandtl number like liquid metals are easy to be turbulent above the critical Rayleigh number. On the other hand, flow pattern can be laminar under a strong magnetic field when the fluid is electrically conductive, and the axes of convection rolls tend to be aligned in the direction of the magnetic field. Rayleigh-Benard convection of liquid metals under a uniform horizontal magnetic field is an appropriate system for a systematic study of flow transitions. Ultrasonic measurement of flow velocity profile is suitable for this setting of liquid metal convection, because it can grasp quasi-two-dimensional structure with its time variations. The process to turbulence is as follows; from steady laminar roll-structure to oscillatory rolls, to time dependent roll-numbers, and to vessel-scale circulation with turbulence. These are clearly observed with the decrease in the magnetic field. Repetition of the change of roll-numbers occurs when the magnetic field has moderate intensity for a given Rayleigh number. By analyzing the results of both laboratory experiments and numerical simulations, we clarified the decrease in mean roll-numbers as well as their mechanism. The process can be regarded as an interaction between aligned convection rolls and global-scale flow. The occurrence of global circulation bends the aligned rolls in a style of the skewed-varicose instability and induces roll number reduction. In the other point of view, the transitions can be regarded as a competition among several flow modes having different roll-numbers. To extract the fundamental flow structures and to quantify the mean roll-number existing in time varying flow patterns, we utilize the proper orthogonal decomposition (POD) analysis. We succeeded in identifying competitive modes with time variations of their amplitudes. Convective flow regimes seen in the present setting are clearly classified by a few fundamental flow modes and variations of their relative intensities.

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