Gradual changes of an ordered flow structure in a liquid metal convection with reducing magnetic field

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Studies of magnetoconvection and rotating convection by liquid metals are both important for understanding the dynamics of flow in planetary cores. On magnetoconvection, we studied the Rayleigh-Benard convection under a horizontal uniform magnetic field by laboratory experiments (Yanagisawa et al. 2013, Tasaka et al. 2016). We have established a regime diagram of convection style on the plane of the Rayleigh number (Ra) and the Chandrasekhar number (Q). Convection regimes are classified well by the value of Ra/Q; when $Ra/Q < 1$ (strong magnetic field), the flow pattern shows steady roll structure whose axes are aligned to the magnetic field. On the other hand, it shows a vessel scale turbulent flow structure with many fluctuations when $Ra/Q > 100$ (weak magnetic field). Among these two extremes, we can identify several flow regimes, such as, oscillation of rolls, repetition of roll number transitions, reversal of the flow direction in rolls. Here we focus on the transitions process from steady laminar flow to turbulent flow by gradual decreases in the Q, at fixed values of the Ra. We performed both laboratory experiments and numerical simulations, and made up a comprehensive view of the process that the convection structure loses the initial ordered roll state. In laboratory experiments, we used an ultrasonic measurement of flow velocity profiles with newly developed transducers to achieve measurements under a strong magnetic field. In numerical simulations, we used sufficient grid points to resolve well the Hartmann layers generated at side walls of the vessel. At very high Q, the pattern shows almost 2-dimensional roll structure, but we observed the existence of small velocities of flow parallel to the imposed magnetic field. Detailed study on the distribution of this flow elucidated that it is a kind of suction generated by the circulation of 2-D rolls. With reducing the Q, this component of flow velocity is getting larger, and secondary vortices emerge at the boundaries of main rolls. Time variations of the roll structure are closely related to the migration of these secondary vortices. At smaller value of the Q, the rolls begin large amplitude of oscillation and 3-D behavior becomes dominant.

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