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Spontaneous flow reversals observed in a magnetoconvection of liquid metal

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We report a finding of spontaneous flow reversals of roll-like patterns in liquid gallium Rayleigh-Benard convection under the influence of an applied magnetic field. Thermal convection in liquid metals with an external magnetic field is a basic problem in considering the flow of the outer core. Especially, to clarify the relation between a mean flow structure and turbulence under magnetic fields is important. The flow of liquid iron in the outer core of the Earth may be turbulent because of its large scale, and the characteristics of the turbulence may be controlled by the geomagnetic field.

The vessel we used has a square geometry with aspect ratio five, and a uniform horizontal magnetic field is applied to the whole vessel. The flow patterns were visualized by ultrasonic velocity measurements, and the time variation of convective flow structure including the processes of reversals of the flow direction was clearly observed. The basic flow pattern in the vessel is a four-roll structure with its axis parallel to the magnetic field. Our experiment whose duration was much longer than the thermal diffusion time for the fluid layer displayed several reversals of the flow pattern. Emergence of a new circulation at a corner of the vessel caused flow reversal by inducing reorganization of the whole pattern. For most of the duration, the basic four-roll structure is dominant and the flow keeps its two-dimensionality, while three-dimensionality of the flow accompanied by the new circulation plays an important role at the timing of reversals. The process of reversals is over in a relatively short time, which is comparable to the circulation time for a roll. The reversals of the flow occur randomly with the typical time interval between reversals much longer than the circulation time. The observed phenomena are flow reversals, but these features are analogous to the reversals of the geomagnetic field. The study of this flow reversal can provide a key for the mechanism of geomagnetic field reversals.

Keywords: flow reversal, liquid metal, magnetoconvection, velocity measurement