Liquid metal flows driven by a rotating magnetic field

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Doing experimental studies on liquid metal flows under interactions with magnetic fields is of great importance for understanding fluid dynamical phenomena including flows in planetary cores. In this research, liquid metal flows driven by a rotating magnetic field (RMF) were examined experimentally. The RMF generates eddy currents in liquid metal layers, and thus Lorentz force as the results of the interaction between the magnetic field and the current achieves the rotating flows. The fluid motions are dominated by angular velocity and magnetic strength of the RMF. In cases at which the skin effect is negligible small because of moderate angular velocity, modal transitions of the flow occur with increase of magnetic Taylor number (Ta_m), which is a dimensionless number including the angular velocity and the magnetic strength. For sufficiently small Ta_m, a quasi-two-dimensional, axisymmetric steady flow is formed. With increase of Ta_m, then, unsteady flows emerge by collapsing the symmetry. For this transition problem, theory and numerical calculation have been preceded. On the other hand, experimental approaches have essential unknows, even though there are quired to uncover the phenomena especially at higher Ta_m with stronger nonlinearity; namely, how to realize the RMF by experiment, and whether the experiment system can reproduce the flows expected by numerical simulations.

In the present experiment, we tried to produce the RMF by switching electric current in six-pair coils. A square container with aspect ratio 2 filled with eutectic of GaInSn, a liquid metal having low melting point, was arranged at the center of the coil. The GaInSn is an opaque fluid and it is impossible to be optically visualized. Ultrasonic Doppler velocimetry was used to obtain information of the flow fields. The switching frequency of the RMF was set at 50 Hz at which the skin effect did not appear, and Ta_m was modified by changing the magnetic strength. A long these methods, the flow transition depending on Ta_m was observed. As the measurement results, a stationary axial symmetric flow, that is in good agreement with the numerical simulation results, was observed under relatively small Ta_m. The increase in Reynolds number with respect to Ta_m also show reasonable agreement with the numerical simulations. Furthermore, the process of unsteady and turbulent transition in the increase of Ta_m was discussed and was compared with the numerical simulations.

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