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水平磁場下の液体金属層内に形成されるロール状対流のホップ分岐について
Hopf bifurcations on convection rolls toward flow reversals in a liquid metal layer with a horizontal magnetic field

田坂 裕司 [1*] ; 山口 勝大 [1] ; 藤田 広大 [1] ; 柳澤 孝寿 [2] ; 大石 義彦 [1] ; 村井 祐一 [1]
TASAKA, Yuji[1*] ; YAMAGUCHI, Yudai[1] ; FUJITA, Kodai[1] ; YANAGISAWA, Takatoshi[2] ; OISHI, Yoshihiko[1] ; MURAI, Yuichi[1]

[1] 北海道大学大学院工学研究院, [2] 海洋研究開発機構
[1]Faculty of Engineering, Hokkaido University, [2]JAMSTEC

Spontaneous flow reversals of convection rolls that were recently observed in experiments using a liquid metal layer in a box under a horizontal magnetic field (Yanagisawa, *et al*., 2011) have collected attentions related to geomagnetic polarity reversals. If applying magnetic field is strong enough, convection disappears because of energy dissipation in Hartmann boundary layer on the side wall of box. On the other hand, the convection in liquid metal layers that have extremely small Prandtl number easily achieves thermal turbulence condition without applying magnetic field. In the intermediate cases of magnetic field, quasi-two dimensional rolls aligned parallel to the magnetic field are formed and instabilities occur toward losing two-dimensionality with decreasing the intensity of magnetic field. The flow reversals appear in this way to the thermal turbulence. Decreasing the intensity of magnetic field also produces decrease of the dominant number of convection rolls in the fluid layer. Yanagisawa, *et al*. (2013) explained that the flow reversals consist of competition between two modes having different number of rolls and relatively fast switching of flow direction is caused by Skewed-Varicose instability that was reported as one of instabilities on two-dimensional rolls in general Rayleigh-Benard convection in shallow fluid layers. Including the instability having $O(1\text{ s})$ time scale, there are three different time scales, oscillation of convection rolls with $O(10\text{ s})$ and the flow reversals with $O(100\text{ s})$. And we can assume that the flow reversals consist of three different mechanisms.

We performed detailed experimental investigations of process of transitions on convection rolls with decreasing the intensity of magnetic field from quasi-two dimensional rolls toward flow reversals. For rectangular box filled by liquid gallium with 200 mm $*$200 mm $*$40 mm in dimensions, ultrasonic velocity profiling (UVP) and thermistor probes were adopted to capture spatio-temporal velocity profiles and time fluctuation of temperature. These information provide the number of rolls, magnitude of velocity in the directions perpendicular or parallel to the magnetic field, dominant frequency of roll oscillation and intensity of temperature fluctuations. Summarizing the results elucidated that in the process of decreasing of magnetic field primary and secondary Hopf bifurcations occur. The first bifurcation keeps two-dimensionality on the rolls and the second one provides three-dimensional motion on the rolls. Fluid motions parallel to the magnetic field become considerable and corresponding flow velocity takes from 4 to 5 mm/s. Traveling time of fluid particles in the fluid layer with this velocity scale is in $O(100\text{ s})$. We can deduce that the development of three-dimensional motion provides large scale, long time scale motion in the fluid layer triggering SV instability for the flow reversals.

Keywords: Geomagnetic polarity reversals, Liquid metal flow, Thermal convection