Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)
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SEM036-04 Room:301B Time:May 26 15:00-15:15

Strong-field dynamo action in the Earth's core

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It is generally believed that the geodynamo works in the so-called strong-field regime, where substantial part of the Coriolis force is balanced by the Lorentz force. In this regard, the ratio of the two forces defined as the Elsasser number, $¥Lambda$, is used as a measure of the strength of the dynamo-generated magnetic field. In the strong-field dynamo, it is reasonably hypothesized that $¥Lambda$ is about unity in the Earth's core. From geomagnetic field observations, however, $¥Lambda$ at the core-mantle boundary (CMB) is of the order of 0.1. It is suggested that the geomagnetic field in the outer core is much stronger than that at the CMB. On the other hand, from numerical dynamo models, the volume averaged Elsasser number can be as large as 100. Thus doubt has been casted on validity of the hypothesis of order-one-Elsasser-number.

In this study, we have obtained a strong-field dynamo using dynamo simulation with the following parameter set: Ekman number, E = 10^{-5}, magnetic Prandtl number, Pm = 2, Rayleigh number, Ra = 3 x 10^{7}, and Prandtl number, Pr = 1. In the dynamo solution, the Elsasser number is 1.6, while the magnetic Reynolds number is 76, somewhat smaller than that of the Earth's core. Notably, the magnetic energy is more than 55 times larger than the kinetic energy, indicating that the inertia is minor compared with the magnetic effect. Also, effects of strong self-sustained magnetic field on evolution of core dynamo are investigated. From the present result, it is suggested that the strong-field dynamo is likely when the inertial force as well as the viscous one is sufficiently small compared with the Lorentz force. Such a condition should be well satisfied in planetary core.

Keywords: dynamo, strong-field, Elsasser number