§2. Magnetic Levitation of Miniature-sized Spherical-shaped RE123 Bulk Superconductors

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We have been developing an active magnetic levitation system, which is composed of a field-cooled sphere-shaped high-temperature superconducting bulks (HTS bulks) and vertically piled ring-shaped electromagnets without an iron core. We suppose that this active magnetic levitation system can be applied to inertial nuclear fusion. In inertial nuclear fusion, one of the most important issues is to achieve high-accuracy position control of the fusion fuel, which consists of deuterium and tritium in order to evenly illuminate the entire surface of the target. Therefore, active magnetic levitation is applied to the levitation and position control of a sphere-shaped superconducting capsule containing nuclear fusion fuel. In this study, we designed and constructed a three-coil position control system in order to achieve the stable levitation of the sphere-shaped HTS bulk with a diameter of 5 mm by using the numerical simulation based on the hybrid finite element and boundary element analysis. Then, we carried out the experiments on the restoring force characteristics of the sphere-shaped HTS bulk in the constructed levitation system.

We carried out several experiments on the three-coil system as shown in Fig. 1 and investigated the levitation stability of HTS bulk in the horizontal direction. The experimental procedure is as follows.

a) The DyBCO bulk is placed in the same initial position as that in the previous experiment. After coil 1 is energized up to 5 A, the bulk becomes superconducting on filling the container with liquid nitrogen.
b) The coil current is gradually reduced to zero.
c) Coil 3 is energized up to 15 A with the current flow directed opposite to that of coil 1 and coil 2.
d) Coil 1 is energized again, up to 15 A this time.
e) Coil 2 is energized in order to bring the HTS bulk to the target levitation height.
f) The experimental system is moved by an X-Y-Z stage, and the restoring force is measured by the load cell.

Furthermore, we evaluated the electromagnetic behavior within the HTS bulk and the levitation characteristics using a newly developed simulation program based on the hybrid finite and boundary element method (the hybrid FE-BE method).

The experimental and numerical results of lateral force as a function of lateral position are shown in Fig. 2. It can be seen in Fig. 2 that the more the HTS bulk moves away from the center of the coils, the stronger the restoring force becomes. The lateral force has a peak at the lateral position of around 8 mm. The simulation results agree well with experiment qualitatively. Figs. 3 and 4 show the distributions of the shielding current and Lorentz force within the HTS bulk at lateral position of 8 mm. The distributions of shielding current and Lorentz force are asymmetric caused by a displacement in the lateral direction, resulting in generating the rotational force. The rotational force was thought to be causally related to the quantitative difference between the experimental result and numerical result.

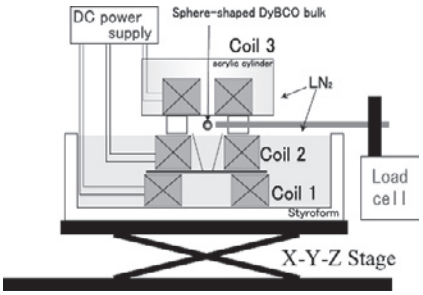

Fig. 1. Schematic drawing of experimental setup for measurement of restoring force.

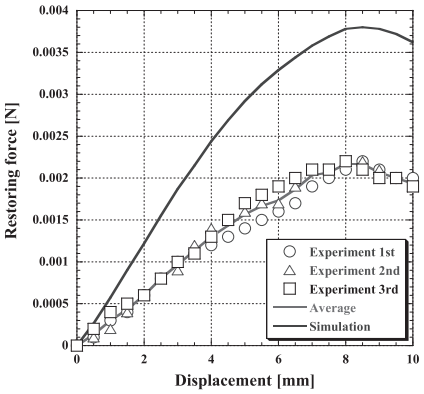

Fig. 2. Experimental and numerical results of Restoring force.

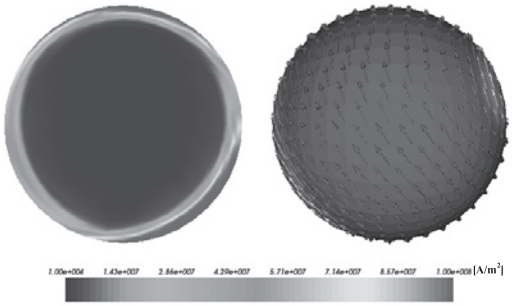

Fig. 3. Distributions of shielding current.

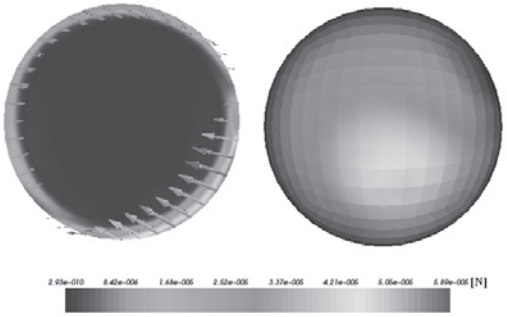

Fig. 4. Distributions of Lorentz force.

1) Ishigaki, Y. et al.: IEEE Trans. Appl. Supercond. (2009)