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

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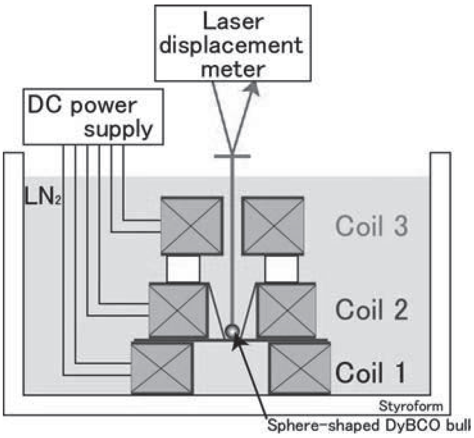
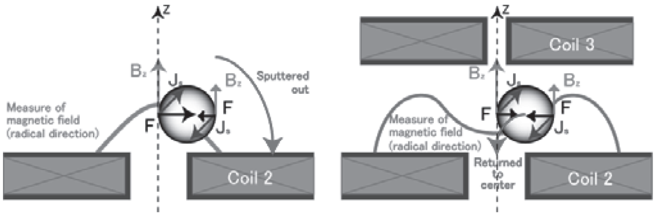
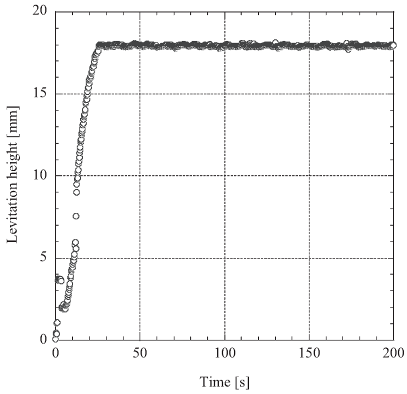
We are studying to achieve high-accuracy position control of cryogenic target containing the fusion fuel for the inertial confinement fusion. We assume to control a sphere-shaped high temperature superconducting capsule containing the fusion fuel by using the active magnetic levitation system, which is expected due to its levitation stability without mechanical supports.

We focused our attention on the spatial resolution of the levitation system, and accordingly decided the shape and distribution of the coils with a high degree of accuracy. We can control the levitation height with a high degree of accuracy as the levitation height change rate (levitation height change/current change) becomes low. Therefore, numerical simulation based on hybrid finite element and boundary element analysis is conducted in order to reduce the levitation height change rate to the least value. We obtained the specifications of the system for HTS bulk with a diameter of 5 mm as shown in Fig. 1.

The Lorentz force caused by the external field in the vertical direction and shield current produces a horizontal force on the HTS bulk. In ideal magnetic fields produced by coils, the HTS bulk can remain on the centre axis (z-axis) of the coils. However if the HTS bulk moves away from the centre, it is ejected from the magnetic field (Fig. 2(a)). Therefore, we energize the current to Coil 3 with Coil1 and Coil2 of the opposite direction to produce the magnetic field distribution as shown in Fig. 2(b). This causes the HTS bulk to return to the centre of the coils automatically in case it moves away from the centre.







The experiment of position control proceeded through the following steps:

1) The DyBCO bulk is placed at the initial position shown in Fig. 1. After the lowermost coil, Coil 1, is energized up to 5 A, the bulk becomes superconducting by filling the container with liquid nitrogen.
2) The coil current is gradually reduced to zero. Some magnetic field, called 'trapped field', remains inside the bulk. The trapped magnetic field is directed upward.
3) The top coil, Coil 3, is energized up to 15 A opposite to Coil 1 and the second coil, Coil 2.
4) Coil 1 is energized up to 15 A again.
5) After the vicinity of the target levitation height is set, the programmable logic controller is operated according to the feedback control.
6) The laser displacement meter measures the levitation height (scan time 200 ms).

The target levitation height is set to 18 mm, and the experiments are operated several times. Fig. 3 shows the result of position control. The standard variation of the observed height from when the HTS bulk begins to be controlled is assumed to be 58.58 μm or less. From the above results, we can conclude that a position control system with very high accuracy has been achieved.

1) Suga, K., Riku, K., Agatsuma, K., Ueda, H., Ishiyama, A. : Journal of Physics, Conference Series **97** (2008) 012162