§7. Fundamental Study on Application of Magnetic Levitation Using YBCO Bulk Superconductor to Fusion Research

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For the application of HTS bulk to a spherical cryogenic target in a laser fusion system, stable levitation and large levitation force should be realized by a concentric spherical thin layer of HTS bulk. The stability of levitation has been already investigated in many kinds of HTS bulks both experimentally and theoretically. The most of investigations, however, are about disk-shaped bulks and the characteristics of levitation in a concentric spherical thin-shaped HTS bulk have not been investigated yet. The thickness of HTS layer in a spherical cryogenic target should be less than 100 μm and levitation force, larger than the weight of cryogenic target, should be produced in such the thin HTS layer. Since levitation force is closely related to supercurrent distribution, we prepared four types of cylindrical HTS bulk samples with the same outer diameter and height but different inner diameter to investigate influence of HTS layer thickness on levitation force. A spherical HTS bulk sample was also prepared to compare supercurrent distribution in the spherical bulk with that of disk-shaped one.

For high efficiency levitation of a cryogenic target with a thin HTS layer, supercurrent should be flowed in the whole HTS layer. When the supercurrent flows in the whole HTS layer, levitation force depends on the thickness and critical current density of the HTS layer. The critical current density can be estimated by both measurements and numerical simulations of levitation force and trapped flux density. Therefore, we measured the levitation force and trapped flux density as a function of coil current in field-cooling process in four types of cylindrical DyBCO bulks. The trapped flux density on a top surface of the bulk was measured by a hall probe at the coil current of 0 A. Then the levitation force was measured by a load cell as a function of the coil current. The height and outer diameter are 10 mm in the four DyBCO bulks, while the inner diameters are 5 mm, 6 mm, 7 mm and 8 mm. The inner and outer diameters and height of electromagnets were 200 mm, 500 mm and 55 mm, respectively.

An experimental result of trapped flux density as a function of coil current in field-cooling process is shown in Fig.1. The trapped flux density was almost proportional to the coil current in field-cooling process less than 6 A. The difference between applied magnetic flux density and trapped flux density gradually increased with the coil current in field-cooling process. Finally, the trapped flux density became almost constant as seen in Fig.1. The magnitude of the constant trapped flux density decreased with the inner diameter of DyBCO bulk. Independent of the magnitude of coil current in field-cooling process, the levitation force was increased with the coil current after the field-cooling process. As observed in Fig.1, however, the increase of levitation force became smaller with the coil current, and finally the levitation force became constant. The magnitude of the constant levitation force decreased with the inner diameter of DyBCO bulk. The constant trapped flux density and levitation force mean that the DyBCO bulk was finally saturated by supercurrent; the maximum supercurrent flowed within the bulk when the trapped flux density and levitation force became constant. The maximum supercurrent depends on the thickness and critical current density of DyBCO bulk.

We also investigated stability, levitation force and trapped flux density in a spherical DyBCO bulk sample, 10mm in diameter. Anisotropy of critical current density may affect the stability, levitation force and trapped flux density. Therefore, trapped flux density and levitation force were measured in the following two cases: 1) the magnetic field was parallel to the c-axis of the bulk; and 2) the magnetic field was perpendicular to the c-axis. An experimental result of trapped flux density as a function of coil current in field-cooling process is shown in Fig.2. The trapped flux density as well as levitation force in the parallel magnetic field to the c-axis was much larger than that of perpendicular magnetic field. Stable levitation, however, was achieved in both cases; this means a spherical HTS bulk could be levitated stably independent of the directions of c-axis.

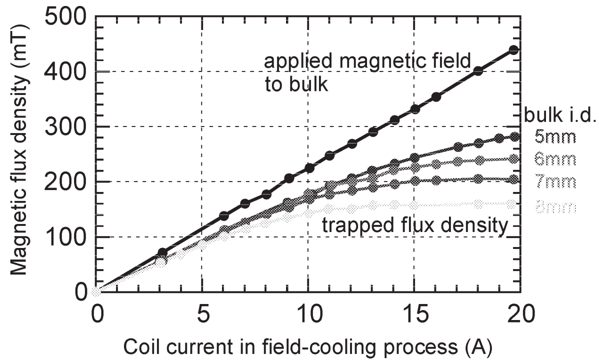

Fig. 1. Dependence of trapped flux density on coil current in field-cooling process in four types of cylindrical bulk samples.

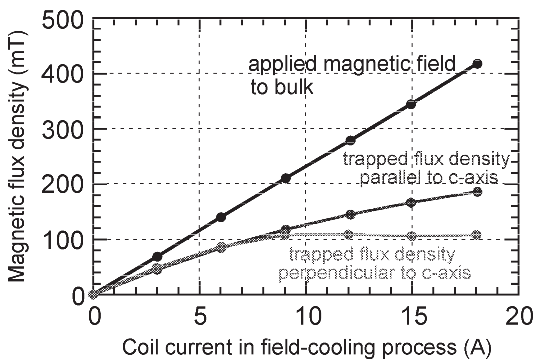

Fig. 2. Dependence of applied magnetic field direction against the c-axis of a spherical bulk sample on trapped flux density.