§24. Study on an Advanced Plasma Confinement Device with Levitated Super-conducting Coil

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We are now exploring a utilization of a High Temperature Superconductor (HTS) coil for a plasma confinement device with a floating coil. The HTS has many advantages in coil operation and plasma experiment, in comparison with a low temperature conductor. This is a first challenge to introduce the HTS coil into the plasma confinement device.

It is well known that the bulk material of the HTS can be easily floated by use of the pinning effect. Since we can not expect this pinning effect for the HTS tape conductor composing with multi filaments, the feedback control of the HTS coil position is indispensable. Here we have fabricated a small-size HTS coil, and carried out the levitation experiments, so as to study the feasibility on the feedback control of the coil position with an accuracy of a few tens micrometers.

Recently a manufacturing process has been developed for Ag-sheathed Bithmas-2223 tape conductor with a critical current more than 100 A. We employed the BSCCO-2223 tape conductor (American Superconductor Corporation), which is 4.1 mm width × 0.31 mm thickness, I_c = 120 ~ 130 A (at 77K, self-field, 1 μV/cm). The tape conductor is wounded on the bobbin made of GFRP with the diameter of 7.7 cm, and a double pancake winding with a total winding turns of 44 are adopted. The tape conductor is connected with a lap joint method by handa. The winded coil is covered with the casing made of polycarbonate, and immersed with the liquid nitrogen. The total weight is around 321 g with the liquid nitrogen (296 g with no liquid nitrogen).

We have carried out the levitation experiments of the HTS coil. To measure the position of the floating coil, we have tried two techniques; one is a shadow method and another is a reflection one. In the shadow method the floating coil is irradiated by the laser light, and the shadow of the floating coil is measured with the PSD (Position Sensitive Detector). In the reflection method the collimated laser light is emitted to the floating coil from the lower portion, and the reflected light is measured with the CCD detector. In this situation we need three detection signals, because there exist three freedoms (i.e., vertical and two tilting modes). By averaging three detected signals, we could evaluate the vertical position of the floating coil. We have carried out the levitation experiments with two detection methods, and succeeded to control the floating coil for both cases.

The detected signals of the floating coil position are transferred to the feedback system, which is constituted by a proportional and differential feedback control (so-called PD feedback control). Figure 1 shows the photo of the levitation experiment with the reflection method. Nitrogen vapor can be seen, because the HTS coil immersed with liquid nitrogen is open to the air. The laser light injected from the bottom of the HTS coil is sometimes interrupted by this nitrogen vapor, resulting in making the position control worse.

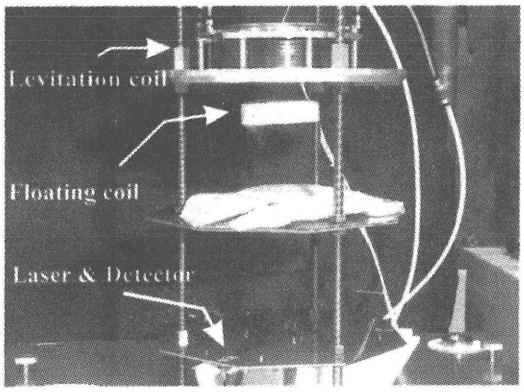

Fig. 1 Photo of the levitation experiment of the HTS coil.

The position data of the HTS coil is shown in Fig. 2, and we can see that the HTS coil position can be successfully controlled within an accuracy of 25~30 μm.

The dynamic response of the floating coil has been tested. In Fig. 2 the coil position is actively changed by Δz ~ 0.2 mm at t = 0, and the coil is smoothly shifted to a new reference position with a time constant of 0.1 ~ 0.2 s. The dynamics of the HTS coil can be calculated with the following equations. The calculation results with these equations are in good agreement with experimental data.

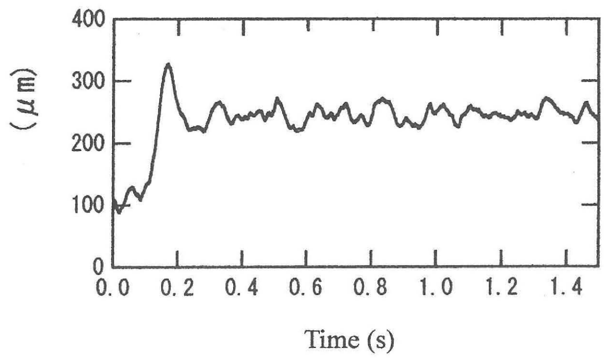

Fig. 2. The HTS coil position. The coil position is actively changed by Δz ~ 0.2 mm at t = 0.