Enhancement of trapped magnetic field using a large-size REBCO bulk in a desktop type superconducting bulk magnet

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Background
A REBCO bulk magnet can generate strong magnetic fields exceeding 2 T in a compact and inexpensive device with a low running cost; thus, various industrial applications, including magnetic separation, motor/generators, drug delivery systems (DDSS), are being considered.

We developed a desktop type superconducting bulk magnet using a Stirling cryocooler with the aim of miniaturizing the system in order to improve an easiness of handling and to reduce power consumption.

Purpose of this study
To increase magnetic fields in a desktop type bulk magnet system, it is necessary to increase the total magnetic flux as well as the magnetic flux density. The total magnetic flux can be increased by using a large sample. On the other hand, we were anxious about cooling due to large volume of the bulk and low cooling capacity of the refrigerator. A GdBCO bulk 60 mm in diameter and 20 mm thick was attached in the desktop type bulk magnet system, and cooling and magnetizing tests were carried out. The trapped field performance was evaluated by numerical analysis.

2. Desktop type superconducting bulk magnet system

Experimental method
1) The bulk was cooled from room temperature to the lowest one while monitoring at the sample stage every 5 minutes.
2) A single pulsed field was applied and flux density on the bulk surface was monitored. After the magnetization, trapped field distribution was measured on the vessel surface (4 mm above the bulk surface).

● Applied field: μ0H = 3.1-7.0 T (rising time: 10 ms)
● Flux density was monitored on the bulk surface with a Hall sensor (BH-921, F.W.BELL) (sampling rate: 100 μs).
● A three-dimensional Hall sensor (BH-703, F.W.BELL) was scanned on the vessel with a pitch of 2 mm.
● The total magnetic flux was calculated using the measured flux distribution data.

Analysis method
1) One-dimensional distribution was prepared from experimental data and the Jc was estimated according to Bean model.
2) The magnetic field distribution was calculated based on Biot-Savart law using the estimated Jc.
3) The total magnetic flux was calculated assuming that the distribution was concentric.

3. Results and discussion

A. Cooling characteristics

The ultimate temperature of a 60-mm bulk was about 4 K higher than that of a 45-mm bulk, and the cooling time was approximately 1.6 times longer.

The volume of the bulk was approximately 2.4 times larger

In a 60-mm bulk, the maximum total flux reached 2.0 mWb, which was 2.1 times larger than that of a 45-mm bulk.

Fig. 1. Time responses of temperature at a sample stage

B. Comparison of total magnetic flux and flux density

In a 60-mm bulk, the maximum total flux reached 2.0 mWb, which was 2.1 times larger than that of a 45-mm bulk.

The results we sought surely were obtained.

In a 60-mm bulk, the flux density of 3.0 T was achieved.

Fig. 2. Comparison of total magnetic flux and flux density between 60-mm and 45-mm bulks

C. Evaluation of trapped field performance by numerical analysis

The difference in the estimated Jc between 60 and 45 bulks was 4%.

The simulation showed good agreement with the experiment even though Bean model was assumed and a simple calculation based on Biot-Savart law was carried out in this analysis.

These results show that enhancement of the total magnetic flux by enlarging the size of bulk was achieved as our original aim.

Fig. 3. One-dimensional magnetic flux distributions

D. Conclusions

With the goal of improving the total magnetic flux in a desktop type bulk magnet, a large bulk was adopted, and cooling and magnetizing tests were carried out. Moreover, trapped field performance was evaluated numerically.

Although the cooling time was extended and the ultimate temperature became high, we attained the objective of enhancing the total magnetic flux and improving the magnetic flux density.

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