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Single pulsed field magnetization for a Gd–Ba–Cu–O high-temperature superconductor large bulk with a diameter of 140 mm

K. Yamaguchi [a,*], Y. Kimura [a,b], M. Izumi [a], S. Nariki [b], I. Hirabayashi [b]

[a] Laboratory of Applied Physics, Tokyo University of Marine Science and Technology, 2-1-6 Koto-ku, Tokyo 135-8533, Japan
[b] Superconductivity Research Laboratory, ISTEC, 1-10-13 Shinonome, Koto-ku, Tokyo 135-0062, Japan

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ABSTRACT

For practical machine application of high-temperature superconductor (HTS) bulk magnet, a pulsed field magnetization (PFM) using small-sized magnetization coils is quite essential. HTS bulk with a diameter of 60 mm has been magnetized successfully and has made the tested axial-type motor to be stable operation by using a couple of vortex-type armature coils. In the present study we report the pulsed magnetization of HTS bulk with a diameter of 140 mm. The crystallization of such large bulk tends to be inhomogeneous around the periphery. For the sample of $GdBa_2Cu_3O_{y-\delta}$ with 140 mm in diameter and 20 mm thickness, new split-type magnetizing coils of 100 and 140 mm in diameter were employed. When the PFM was performed with the coils of 100 mm in diameter, magnetic fluxes penetrate near the center rather than periphery. On the other hand, when we used the coils of 140 mm in diameter, magnetic flux penetrates the whole body, and magnetic flux tends to be immobile in the area. Thus, the PFM with the coils of 100 mm in diameter is effective to magnetization for near the center of HTS bulk. They are also effective to obtain a conical shape trapped flux density distribution. The PFM with the coils of 140 mm in diameter is effective to enhance the total magnetic flux.

1. Introduction

We have applied a high-temperature superconductor (HTS) $GdBa_2Cu_3O_{y-\delta}$ (Gd123) bulk (60 mm diameter, 19 mm thickness) to a field-pole magnet of synchronous rotating machinery [1]. The trapped magnetic flux contributes to an increase torque of the motor. The bulk magnets are used as an equivalent role of the conventional permanent magnet as field-pole in the motor. The key technology is how to introduce the intensified flux into the rotor pole-field. The technical gates to make total magnetic flux larger are the cooling down to low temperatures, the improvement of an electromagnetic process upon magnetization and to use larger HTS bulk, etc. Recently, a Gd123 bulk superconductor disk with a diameter up to 140 mm has been fabricated [2]. According to this success, we may apply the present large HTS bulk to intensify the total magnetic flux leading to the enhancement of the torque density of the rotating machine. In the rotating machines, the HTS bulks are magnetized with pulsed field magnetization (PFM), because the PFM machinery provides more compact than field cooling (FC) magnetization machinery. Conventionally, a solenoid-type coil has been used for the PFM (see Fig. 1). The feature of solenoid-type coils is generating *B* vectors are not parallel to the *c*-axis of the Gd123 bulk and the density distribution is uniform. Moreover, the solenoid-type coil has to include the bulk inner space, which means that we need a considerable space to put the solenoid in addition to the bulk itself. On the other hand, in 2002, we suggested the PFM using a split-type of vortex-type coil [3]. The generated *B* vectors become strictly parallel to the *c*-axis of the Gd123 bulk and the flux density distribution is conical shape which provides an advantage of avoiding invasion of excess flux inside the bulk. In the present PFM, the bulk is between the armature coils which means there is no excess space to put the magnetization coil inside the machines.

Large HTS bulk tends to show an inhomogeneous crystal growth leading to a flux trapping performance which has been distorted. This may cause unsatisfactory loss of synchronism in the motor operation. The rotating machine prefers rather HTS bulks with a conical/sinusoidal trapped flux density distribution to activate a smooth operation. Therefore, we clarify a dynamical process of PFM of Gd123 bulk of a diameter of 140 mm and determine the essential relationships between diameter of coil and applied magnetic field exerting on trapped flux density distribution.

2. Experimental details

HTS bulk sample is a melt-textured Gd–Ba–Cu–O bulk sample (Gd123:Gd211 = 1.0:0.4, Pt: 0.5 wt.%, Ag: 27.9 wt.% in composition,

* Corresponding author. Tel.: +81 3 5245 7466; fax: +81 3 5245 7466.
E-mail address: m074034@kaiyodai.ac.jp (K. Yamaguchi).

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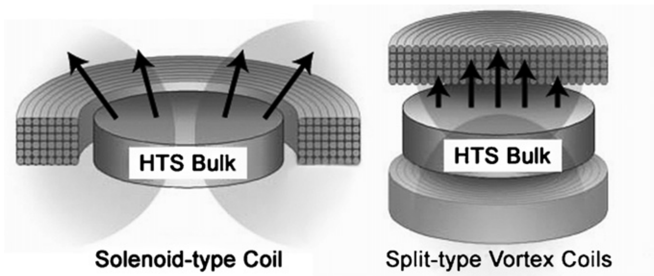

Fig. 1. Comparison of magnetizing pulsed current coil made with copper wire. The split type vortex winding is superior to a conventional solenoid since the vector of the applied magnetic field is parallel to the crystallographic *c*-axis of the Gd123 bulk sample [1].

Fig. 2. Gd123 bulk sample of 140 mm in diameter indicating a growth sector boundary (GSB).

140 mm in diameter and 20 mm in thickness) as shown in Fig. 2. Fig. 3 shows trapped magnetic flux density distribution obtained under 3 T at liquid nitrogen temperature by a FC. There are a few valleys in the magnetic flux density profile as signed by circles.

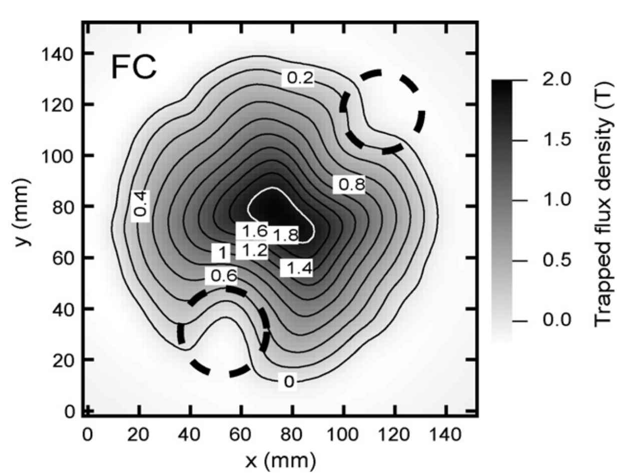

Fig. 3. Trapped flux density distribution of magnetized a large Gd123 bulk of 140 mm diameter with a conventional field cooling (FC) down to liquid nitrogen temperature. The applied static magnetic field was 3 T.

Table 1
Specifications of the controlled magnetic density distribution coils (CMDC)

Mode	A	B
Diameter [mm]	140	100
Number of turns	330	230
Thickness [mm]	20	20

They are attributed to a crystal defect formed in the growth sectors. Fig. 4 shows the geometry of the present PFM study. The Gd123 bulk of 140 mm in diameter was magnetized by a couple of controlled magnetic density distribution coils (CMDC; Fig. 5) made of copper wire winding in liquid nitrogen (77 K). Each coil forming a split magnet configuration is a vortex-type coil which plays a role as two those are 100 and 140 mm in one of them. We can change the exciting coil diameter by changing the electric leads connection outside the motor. Thus, the CMDC is activated to two modes (Table 1). In the present study, the coil mode A provides a 140 mm of effective diameter by connecting inner and outer coil as shown in Fig. 5a. The coil mode B gives an effective 100 mm of diameter for activation winding by using the inner coils only as shown in Fig. 5b. We measured the position-dependent local dynamical motion of magnetic flux by using six Hall sensors (THS118 Toshiba Semiconductors Co. Ltd.) during PFM. Hall sensors are lined up straight from the center to the periphery. Then, the trapped flux density distribution was taken by a scanning Hall sensor (BHT921 F.W. Bell). The gap distance between the HTS bulk surface and the Hall sensor was 4 mm.

3. Experimental results and discussions

In the case of Gd123 bulk 60 mm in diameter, the coil whose diameter is smaller than that of the HTS bulk is effective to obtain the trapped flux density distribution with a conical shape [4]. We magnetized Gd123 bulk of 140 mm diameter with mode B, by employing a couple of vortex type coils of 100 mm diameter, to examine whether the similar tendency appears effectively in even

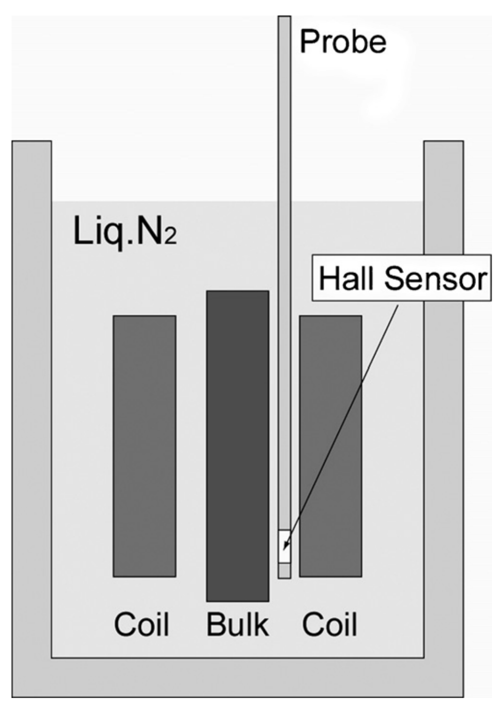

Fig. 4. A schematic drawing of the experimental geometry of a pulsed magnetic field magnetization (PFM).