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ScienceDirect

Physics Procedia 81 (2016) 45 – 48

Physics Procedia

28th International Symposium on Superconductivity, ISS 2015, November 16-18, 2015, Tokyo, Japan

Uniform magnetic field between face-to-face HTS bulk magnets combining concave and convex magnetic field distributions

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Abstract

The authors have been attempting to obtain the uniform magnetic field distribution in the space between the face-to-face HTS bulk magnets. The magnetic poles containing the HTS bulk magnets are usually characterized as non-uniform magnetic field distribution. Since the distributions show the conical or convex shapes, it is difficult to obtain the uniform magnetic field spaces even when the magnetic poles would be placed face-to-face. The authors have modified the shape of the distribution of one-side magnetic pole by attaching an iron plate on the surface, and formed the concave magnetic field distribution on the pole surface. The steep concave or convex distributions at each pole surface change to be flat with increasing distance from the pole surface. After the experimental result recording the best uniformity of 358 ppm by combining the concave and convex field distributions face-to-face, we attempted to simulate the feasible performance in this configuration. In the numerical simulation, the concave field distribution modified by attaching an imaginary spiral coil on the pole surface was coupled with the original convex field. We succeeded in obtaining the best uniformity of 30 ppm at 1.1 T in 4 x 4 mm^2 *x-y* plane at 7 mm distant from the pole surface in the gap of 30 mm. This result suggests that the concave and convex magnetic field distributions compensate the field uniformity with each other with keeping the magnetic field strength in the gap, and also suggests the novel compact NMR/MRI devices in the future.

Peer-review under responsibility of the ISS 2015 Program Committee

Keywords: Bulk magnet; superconductor; pulsed-field magnetization; magnetic field distribution; NMR

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Peer-review under responsibility of the ISS 2015 Program Committee
doi:10.1016/j.phpro.2016.04.019

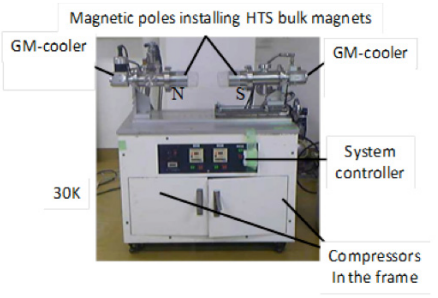

Fig. 1. Face-to-face HTS bulk magnet system.

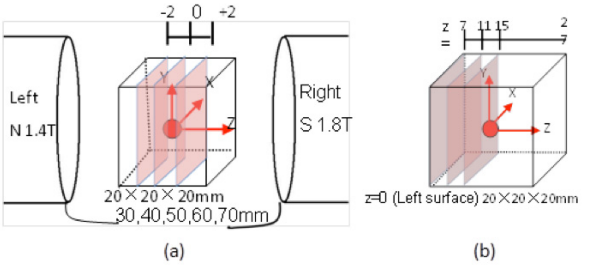

Fig. 2. Schematic views of the measuring space between the magnetic poles (a), and the space measured from one pole surface (b).

1. Introduction

As reported or evaluated by the record-high magnetic flux trapping of 17.6 T [1] and various HTS bulk magnet (abbreviated as bulk magnet) systems [2], the feasible applications of bulk magnets have been expanding in the R&D trends for the compact NMR/MRI magnets. Among them, Nakamura *et al.* succeeded in detecting the NMR signals in the bore of piled-up bulk magnets for the first time in the world [3]. Furthermore, Ogawa *et al*. showed the MRI picture of an embryo of a mouse with use of the same system [4]. After such homogeneous fields, we aim to obtain another uniform magnetic field in the gap between face-to-face magnetic poles which contain a pair of bulk magnets in order to apply them to compact NMR device magnets [5]. In this paper, we report the present data of the magnetic field distributions formed by the bulk magnets which were activated by the pulsed field magnetization (PFM) technique, and discuss the uniformity of the magnetic field from the view point of possible utilization for the compact NMR/MRI magnets.

2. Experimental

Figure 1 shows the face-to-face bulk magnet system which was employed in the experiment. We installed a pair of Gd- and Sm-based bulk magnets manufactured by Nippon Steel Sumitomo Metal Co. and Dowa Mining Co. The dimensions are 60 mm in diameter and 15 mm in thickness. The pulsed magnetic fields up to 7 T were successively applied to the bulk magnets with use of the pulse coil by the IMRA method [6]. The magnetic poles were activated to 1.8 T (N) and 1.4 T (S), and horizontally settled face-to-face with gaps less than 70 mm.

As shown in Fig. 2, the magnetic field distributions in the gap between the magnetic poles were measured by scanning the 3D Hall sensor (F. W. Bell, BH703). The sensor was intermittently scanned with 2 mm pitch in every 1 s. The data were expressed in their vector magnitudes. The uniformity in the 4 x 4 mm^2 *x*-*y* planes was estimated as a function of the distance from the pole surface by the following equation in two cases of (a) and (b) in the figure.

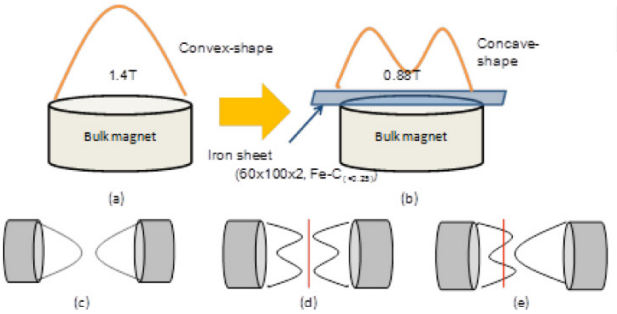

Fig. 3. Illustration of the trapped field distribution on bulk magnet (a) and that when the iron plate is attached on it (b). (c) and (d) show the possible combinations of the magnetic poles with convex and concave distributions.

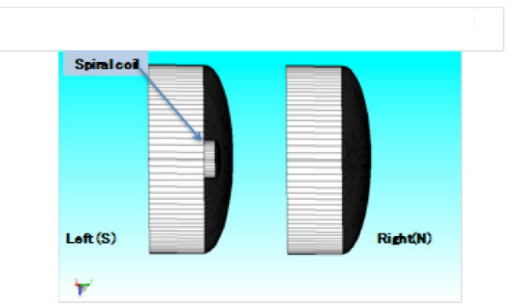

Fig. 4. Facing spiral coils with small spiral coil attached on the one side magnetic pole.