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IMPROVEMENT OF AZIMUTHAL HOMOGENEITY IN PERMANENT-MAGNET BEARING ROTORS*

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IMPROVEMENT OF AZIMUTHAL HOMOGENEITY IN PERMANENT-MAGNET BEARING ROTORS

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Introduction

Permanent magnets that are levitated and rotating over a bulk high-temperature superconductor (HTS) form the basis of many superconducting bearing designs [1]. Experiments have shown that the rotational-loss "coefficient of friction" for thrust bearings of this type can be as low as 8×10^{-6} [2]. While the loss mechanisms of such bearings are not well understood, the azimuthal homogeneity of the rotating permanent magnet is believed to play an important role in determining the loss. One possible loss mechanism is magnetic hysteresis in the HTS, where the energy loss E per cycle is derived from the critical state model [3] and given by

$$E = K (\Delta B)^3/J_c \qquad (1)$$

where K is a geometric coefficient, ΔB is the variation in magnetic field at the surface of the HTS experienced during a rotation of the levitated magnet, and J_c is the critical current density of the HTS. It is clear from Eq. (1) that a small decrease in ΔB (i.e., decreasing the azimuthal inhomogeneity of the rotating magnetic field) could have profound effects on decreasing E and the rotational coefficient of friction. The role of ΔB is also expected to be significant in reducing losses from eddy currents and other mechanisms. Low rotational losses in HTS bearings have been demonstrated only for levitated masses of several grams [2]. For practical bearings, it is important to obtain these low losses with larger levitated masses.

There are two main routes toward decreasing ΔB. The first is to improve the alignment of the magnetic particles during fabrication and to maintain close tolerances on grinding angles during manufacture of the permanent magnet. The second, the subject of this paper, is to provide correctional procedures after the magnet is fabricated.

Experimental Results

Ring magnets composed of sintered NdFeB are preferred for many thrust bearing designs because of their high magnetization and favorable geometry. The vertical component of magnetic field for several ring magnets,with ID = 42 mm, OD = 76 mm, and height = 6.4 mm, was measured with a Hall probe at a distance from the lower face of the ring that corresponds approximately to the expected levitation height in an HTS bearing. The results for two individual rings (denoted CR4 and CR6) are shown in Fig. 1(a). Similar field distributions are obtained below each ring. We define a crude measure of homogenity h as

$$h = \Delta B/(2B_{min}) \qquad (2)$$

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Above the top surface of magnets CR4 and CR6, h is 0.0238 and 0.0215, respectively; below the bottom surface, h is 0.0336 and 0.0185, respectively. Magnet CR6 was then placed directly above CR4, but with CR4 rotated 180° azimuthally from the alignment shown in Fig. 1(a). The resulting magnetic field for the combination is shown in Fig. 1(b). Above the top (CR6) face, h = 0.0089; below the bottom (CR4) face, h = 0.0161. More than two rings could be similarly combined in a stacked series to further improve the homogeneity.

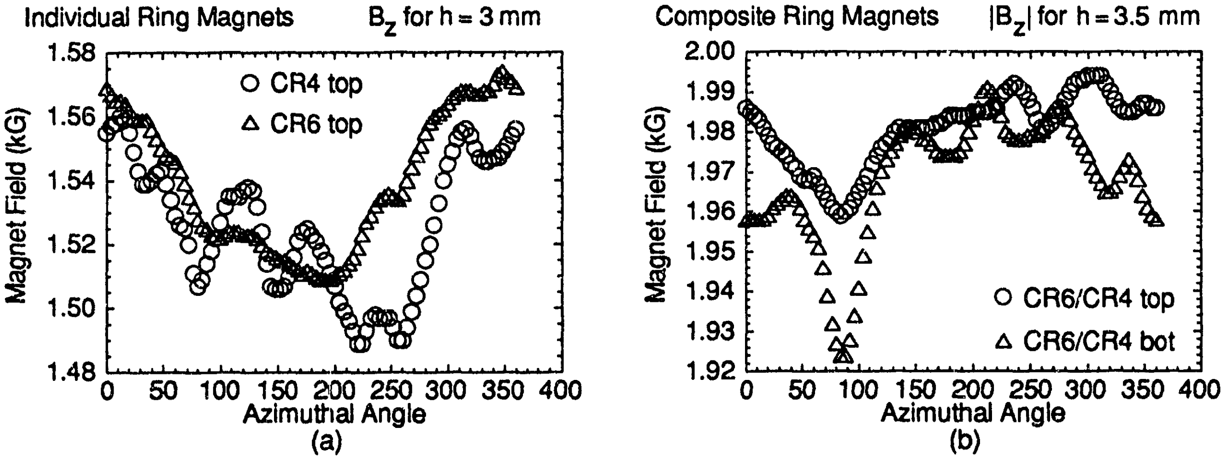

Fig. 1 Vertical magnetic field vs. azimuthal angle for individual and composite ring magnets.

A single NdFeB ring magnet with ID = 68 mm, OD = 89 mm, and h = 11 mm was used to levitate a rotor with combined mass of 500 g above four HTS disks placed in a circle under the ring. This rotor was spun in a vacuum of 5×10^{-6} torr. The HTS disks were composed of melt-textured Y-Ba-Cu-O and were cooled in liquid nitrogen. A Mylar sheet separated the HTS disks from the vacuum. Homogeneity of the magnet was 0.031. The measured coefficient of friction during spindown was 1.8×10^{-4}.

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