Levitation property of a magnetically levitated spinning top on a PM and a bulk HTS

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Keywords

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Abstract

Properties of a magnetically levitated spinning top are reported from experimental measurements. The spinning top, which is hand-made with two small ring magnets, is levitated without control on a ring base magnet. Measured magnetic field profiles with a gauss meter are compared with calculated result where the ring magnets are replaced by ring currents. Different properties of the rotational decay of the spinning top on the ring magnet are discussed from comparison with its stable levitation of the on a bulk high-temperature superconductor. There is a rotational limit for the levitation of the spinning top on the magnet.

1 Introduction

There are many reports about a magnetically levitated spinning top on a permanent magnet (PM) named U-CAS in Japan or LEVITRON and in U.S.A. [1-3]. A square base ferrite magnet is magnetized axial direction except for the center part, and the spinning top is made from a ring ferrite magnet. When weight of the top is adjusted, the spinning top is a magnetically levitated on a square base magnet without any active controls. Principle of the U-CAS was reported in detail with an analytical simple model by Murakami [1], and another discussion was also reported by Jones et.al. where the horizontal stability comes from tilting of the top [2]. Hand made sppining top is also reported with ring ferrite magnets [3]. On the other hand, stable levitation without control is obtained with a PM and a bulk high-temperature superconductor (HTS). The stable levitation, which is caused by pinning effect of the superconductor, is one important feature of the HTS for practical applications, such as a flywheel or a magnetic bearing systems. Authors have been numerically analyzed the stable levitation between a PM and a bulk HTS with macroscopic simulation code [4-6]. The simulation code is based on the critical state model [7,8] and is useful to evaluate macroscopic electromagnetic phenomena in the HTS.

In the present analysis, both the base and the spinning top are arranged with ring ferrite magnets [3]. Magnetic field profiles of the ring magnets are measured with a gauss meter and are compared with calculated result where the ring magnets are replaced by ring currents. Levitation properties of the spinning top are discussed from experimental measurements. Vibration and rotational decay properties of the spinning top are discussed for the stable levitations on the PM and on the bulk HTS.

2 Magnetically levitated spinning top

Figure 1 shows the hand-made magnetically levitated spinning top on the base PM in the present experiments. The thickness, inner and outer diameters of the base magnet are 12.0, 40.0 and 80.0 mm.

The spinning top is also made from two ferrite ring magnets whose thickness, inner and outer diameters are 3.0, 9.5, 28.0 and 5.0, 7.0, 25.0 mm. The levitaion of the top is obtained in the special magnetic field configulation made by the ring base magnet. When weight of the top is adjusted, the spinning top is a magnetically levitated at the point where the weight of the top equals to repulsion force between the ring PM of the top and the base ring PM. Figure 2 shows experimental and numerical results for axicial magnetic field on z-axis of the base magnet. Solid line shows the measurement and doted line shows the numerical result. The magnetic field profiles of the ring magnets are measured with a gauss meter in the experiment, and the ring magnets are replaced by ring currents in the numerical evaluation. Since the gap between the levitated spinning top and the base magnet is about 32 mm, the levitaion is obtained before the peek of the axical magnetic field. From comparison of the experimental and the numerical results, magnetization of the base magnet is about 0.38 [T], and those of the top are about 0.28 and 0.38 [T], respectively. Figure 3 shows magnetic field profiles of the cross section of the base magnet and the top. The sppining top levitates on a hollow of the magnetic field.

3 Rotational decay of the top on the PM and on the HTS

It is well known that stable levitation without control is obtained with a PM and a bulk HTS. Figure 4 shows levitation of the top on the HTS. The stable levitation is caused by pinning effect of the superconductor. Rotational decay of the spinning top is measured for three cases, i.e., on the PM, on the HTS and on a table in Fig. 5. The decaies of the levitated rotation both on the PM and the HTS are small because of small rotational loss. There is a rotational limit for the levitation of the spinning top on the magnet, while the spinning top is levitated stably on the HTS until and after it stops the rotation.

Figure 6 shows vertical displacement of the spinning top during levitation on the PM, where the displaceement is measured with a laser instulement. Frequency of the secndary vibration is about 21 Hz. The rotational limit of the levitation on the PM in Fig.5 is about 1160 rpm and 19.3 Hz. The secndary vibration will be related to unstability of the levitated spinning top on the PM.

4 Concluding remarks

The spinning top is hand-made with two small ring magnets and is levitated without control on a ring base magnet. Magnetic field profiles of the ring magnets are measured with a gauss meter and are compared with calculated result where the ring magnets are replaced by ring currents. The rotational decay properties of the spinning top are discussed for the stable levitations on the PM and on the bulk HTS. The secndary vibration will be related to the limit of the levitation of the top on the PM.

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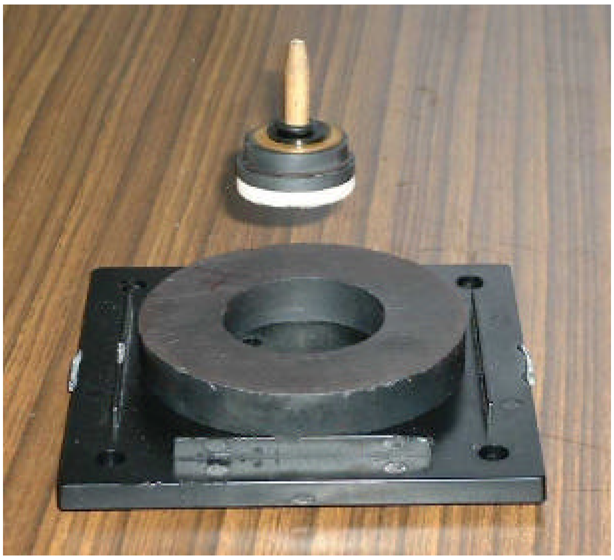

Fig. 1 Hand-made magnetically levitated spinning top on a base PM

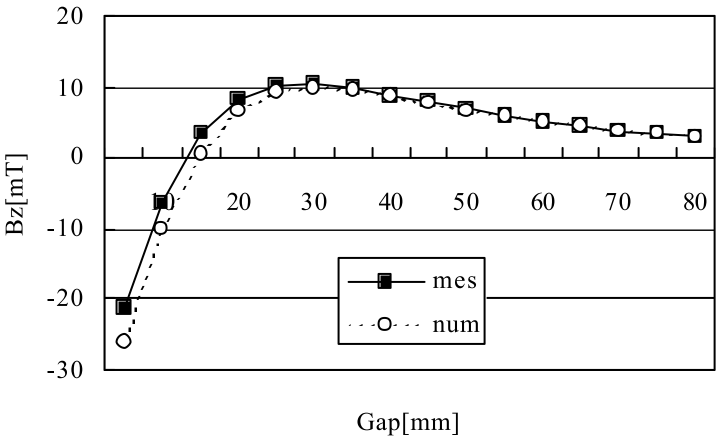

Fig. 2 Experimental and numerical results for axicial magnetic field on z-axis of the base magnet

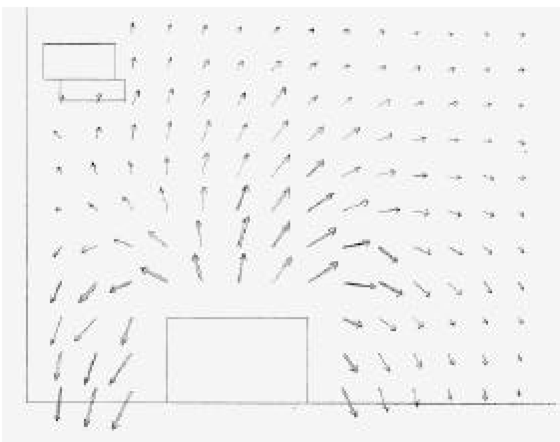

Fig. 3 Magnetic field profiles of the cross section of the base magnet and the top

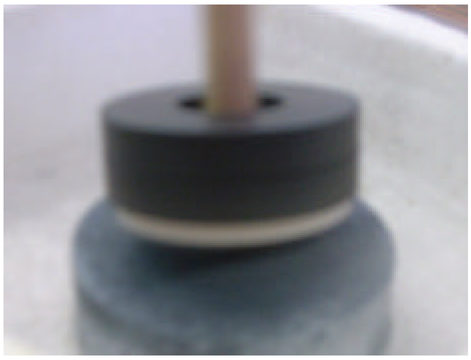

Fig. 4 Levitation of the top on the HTS

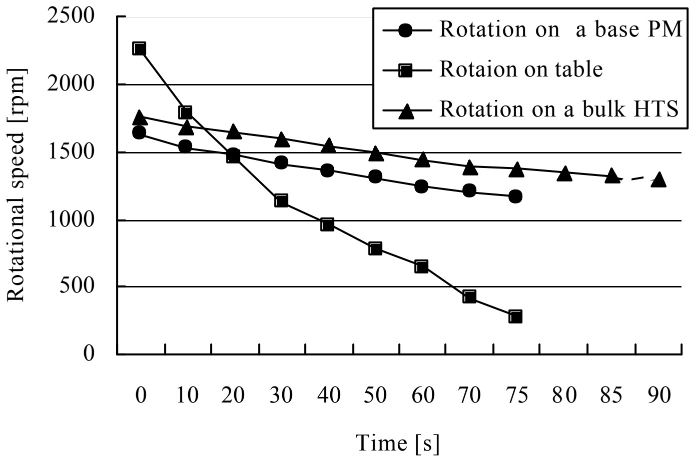

Fig. 5 Rotational decay of the spinning top

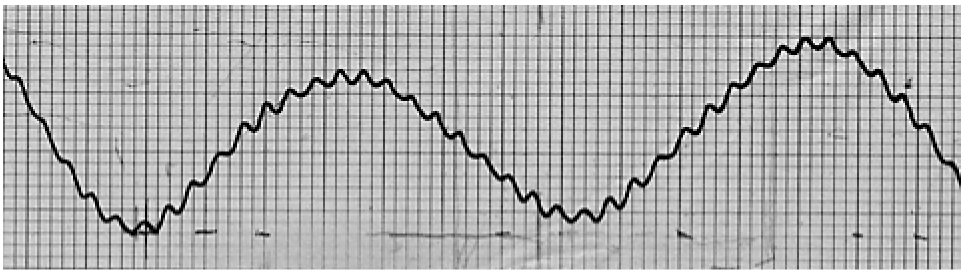

Fig. 6 Vertical displacement of the spinning top during levitation on the PM