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STUDY ON THE LEVITATION AND RESTORING FORCE CHARACTERISTICS OF THE IMPROVED HTS-PERMANENT MAGNET HYBRID MAGNETIC BEARING

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Abstract

We have developed the hybrid magnetic bearing using permanent magnets and high temperature bulk super conductor (HTS). In this system, the permanent magnet has ring type structure so that the permanent magnet and the HTS can be set to the stator. The pinning force of the HTS is used for the levitation and the guidance. Repulsive force of the permanent magnets was used in the conventional hybrid system. However the restoring force in the guidance direction of the conventional hybrid system decreases by the side slip force of the permanent magnets. In this research, attractive force of permanent magnets is used for increasing the load weight in the guidance direction.

In this paper, influence of the hybrid system on the static characteristics of the rotor is studied. Three-dimensional numerical analysis of the linkage flux (in the levitation and the guidance direction) in the HTS is undertaken. The stator side permanent magnet increases the linkage flux of the levitation direction. Therefore in the hybrid system the linkage flux of the levitation direction increases. The levitation and restoring force of the rotor is measured. The levitation force of the hybrid system becomes smaller than that of the non-hybrid one by attractive force. The rotor in the hybrid system is supported by the pinning force and attractive force. The restoring force of the hybrid system becomes larger than that of the non-hybrid one because of increasing the linkage flux of the levitation direction.

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Keywords: Permanent magnet; Hybrid sysytem; Pinning force; three-dimensional numerical analysis

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1. Introduction

Pinning effect of the high temperature superconductor (HTS) is introduced to realize magnetic levitation without gap control [1] [2]. To increase the levitation force, repulsive force of the permanent magnets was used in the conventional hybrid system [3] [4]. However the restoring force in the guidance direction of the conventional hybrid system decreases by the side slip force of the permanent magnets. The restoring force of the rotor by pinning force influences stability of the levitation. To increase the restoring force, the improved hybrid system is introduced. In this hybrid system, the attractive force of the permanent magnets is used for support of the guidance direction. The restoring force of the guidance is increased. In this system, one permanent magnet is installed in the rotor, and the other ring shaped permanent magnet is introduced in the stator [5]. Pinning force and attractive force are used effectively by this hybrid system [6].

In this paper, three-dimensional numerical analysis of this hybrid system is undertaken. The levitation and restoring force of the rotor are measured. Relationship between their characteristics and the flux on the surface of the HTS is considered, and that of the hybrid system is compared with the non-hybrid one [7].

2. Experience device

Fig.1 shows the experimental device of the levitation and restoring force characteristics. Fig.2 shows the picture of the experimental device. Fig.3 shows the side view of the rotor and stator. The permanent magnet is installed in the rotor (the upper permanent magnet), and it has two poles. The ring shaped permanent magnet is installed in the stator. The HTS is put inside the ring shaped permanent magnet. The air gap between the permanent magnet of the rotor and the HTS is defined as the upper gap *g*. The gap between the surface of the HTS and the permanent magnet of the stator is defined as the lower gap *g*'. The aluminum stage in the aluminum container is filled with the liquid nitrogen. The HTS is cooled by the liquid nitrogen for about fifteen minutes (field cooling). The flux from the permanent magnet of the rotor is pinned by the HTS. The laser displacement sensors are set to measure the position of the rotor, and the load cell is set to measure the levitation and restoring force of the rotor. Table 1 shows the specifications for the permanent magnets. Table 2 shows the specifications for the REBaCuO bulk superconductor [8].

Table 1. Specifications for the permanent magnet

	Rotor side permanent magnet	Stator side permanent magnet
Material	Nd-Fe-B	Nd-Fe-B
Dimension(mm)	ϕ 62.5X10	ϕ 67.5X4
Pole	2(circle-ring)	1(ring)

Table 2. Specifications for the HTS

	HTS
Material	REBaCuO
Critical temperature	91K
Dimension(mm)	ϕ 46 X 15

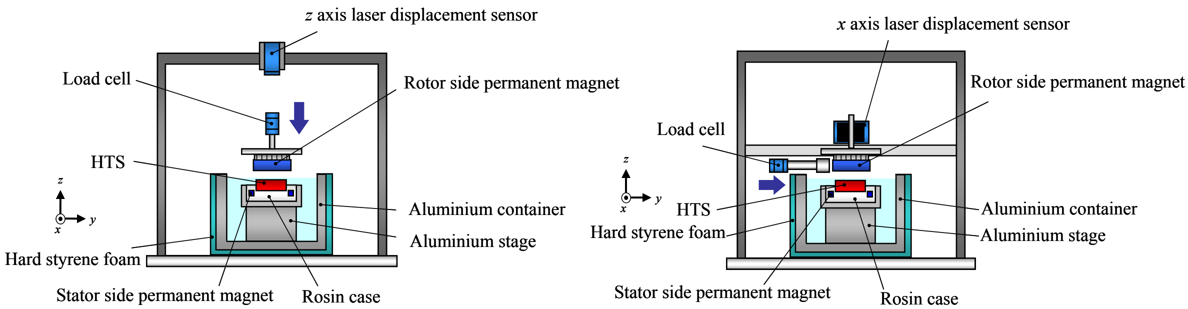

Fig.1 Experimental device (a) Levitation force characteristic; (b) Restoring force characteristic

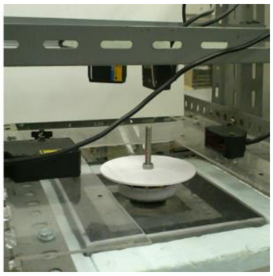

Fig.2 Picture of experimental device

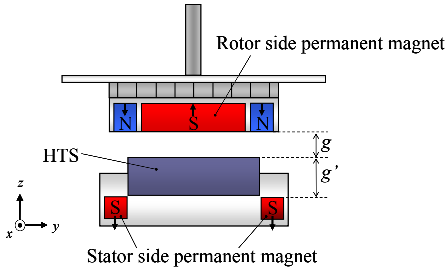

Fig.3 Side view of the rotor and stator

3. Result

3.1. Three-dimensional numerical analysis of the flux

Table 2 and Table 3 show the flux on the surface of the HTS in case of non-hybrid system and hybrid one (the upper gap g = 6,8,10,12[mm] and the lower gap g'= 16[mm]).

From the analysis result, the flux in z direction (levitation direction) of the hybrid system becomes larger than that of the non-hybrid one in every air gaps. The flux in z direction influences the restoring force in the guidance of the rotor. Improvement of the restoring force in the hybrid system is expected because the flux in z direction increases. On the other hand, the flux in x direction (guidance direction) of the hybrid system becomes smaller than that of the non-hybrid one in every air gaps. The flux in x direction influences the levitation force of the rotor. Therefore the levitation force in the hybrid system decreases.

Table 2. Linkage flux in the HTS (Non-hybrid)

Upper gap g[mm]	Magnetic flux ϕ_x[mWb]	Magnetic flux ϕ_z[mWb]
6	0.284	0.240
8	0.213	0.175
10	0.157	0.128
12	0.114	0.089

Table 3. Linkage flux in the HTS (Hybrid system)

Upper gap g[mm]	Magnetic flux ϕ_x[mWb]	Magnetic flux ϕ_z[mWb]
6	0.279	0.244
8	0.204	0.179
10	0.150	0.132
12	0.110	0.093

3.2. Levitation and restoring force characteristics

Fig.4 shows the levitation force characteristic. Fig.5 shows the restoring force characteristic. The levitation force F_L is given to measure the load weight in z direction. The restoring force F_R is given to measure the load weight in x direction.

From Fig.4, the levitation force in the hybrid system becomes smaller than that of the non-hybrid one. The force in minus direction to the levitation is occurred by the attractive force in the hybrid system. The flux in x direction of the hybrid system becomes smaller than that of the non-hybrid. So the levitation force in the hybrid system decreases.

From Fig.5, the restoring force in the hybrid system becomes larger than that of the non-hybrid one. The rotor is supported by the pinning force of the HTS and attractive force in the hybrid system. The flux in z direction of the hybrid system becomes larger than that of the non-hybrid. So the restoring force in the hybrid system increases. As the result, the rotor in the hybrid system is improved stability of the levitation because the restoring force influences stability of the levitation.

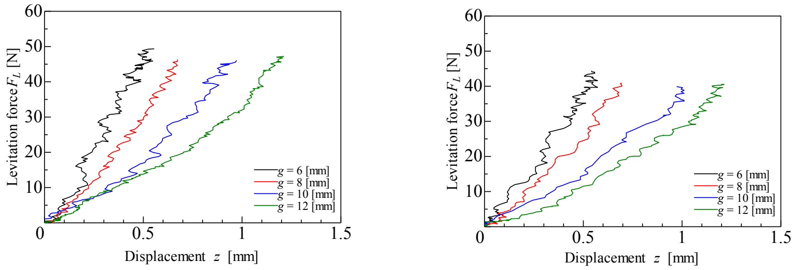

Fig.4 Levitation force characteristic (a) Non-hybrid; (b) Hybrid system

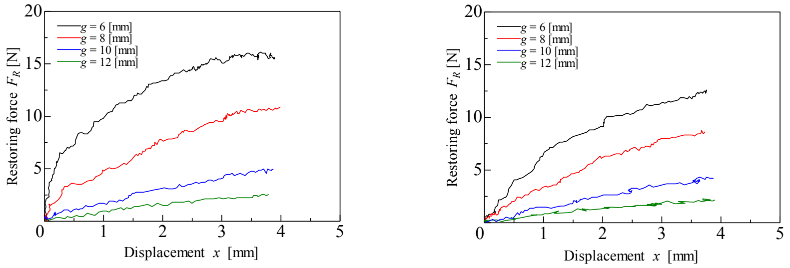

Fig.5 Restoring force characteristic (a) Non-hybrid; (b) Hybrid system

4. Conclusion

The improved HTS-permanent magnet hybrid magnetic bearing is studied. The conventional hybrid system used repulsive force of the permanent magnets was instability of the levitation by the side slip force. In this configuration, attractive force of the permanent magnets is introduced to improve stability in the improved hybrid system. Three-dimensional numerical analysis of the flux and the experiments are shown.

The flux in z direction of the hybrid system increases. However the flux in x direction of the hybrid system decreases.

The levitation force in the hybrid system becomes smaller than that of the non-hybrid one by attractive force and decreasing the flux in x direction. On the other hand, the restoring force of the guidance direction in the hybrid system becomes larger than that of the non-hybrid one by attractive force and increasing the flux in z direction. As the result, the rotor in the hybrid system is improved stability of the levitation because the restoring force influences stability of the levitation.

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