

Study on Pulsation Suppression Method of Zero Power Magnetic Bearing Using Square PM

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1. Introduction

Bearings are important components that allow the drive part of a machine to operate smoothly and support the rotating shaft of the motor. However, they are prone to breakdowns due to mechanical loss, ball cracking, and rust, and require regular maintenance, and their lifespans are shortened due to lubricant leaks and excessive friction when submerged in liquid or in high-speed rotation areas. Magnetic bearings, which do not have mechanical contact, are also being considered as an alternative to ball bearings, but they generally require an external power source and control for support, so their applications are limited[1]. In this study, we propose a magnetic bearing that can be passively controlled with zero power by using magnetic repulsion when PMs with the same poles are brought close to each other. We will also consider applying magnetic bearings to implantable artificial hearts, food processing machines, and drones.

PMs are arranged in a ring, one row is sandwiched between two rows of PMs, and magnetic repulsion levitation support is passively performed in the radial and thrust directions with zero power. In this paper, we proposed that square-shaped PMs, which are highly productive and inexpensive, be aligned in a regular polygonal shape and formed into a pseudo-annular shape for use in magnetic bearings. However, large pulsations occurred due to gap fluctuations between the rotor and stator PMs and large changes in the direction of opposite poles of the PMs. Since this pulsation is a major drawback, we will propose a method to suppress pulsation using a magnetic yoke and examine its usefulness.

2. Principle of zero power magnetic bearing using PM

Magnetic bearings support shafts by controlling five degrees of freedom. Two bearings are used to control the rotation angle of an axis perpendicular to the rotary motion axis, and support the rotor to prevent eccentric rotation even when a load is applied to the shaft end. We also propose a support mechanism that passively controls five degrees of freedom by using magnetic repulsion when the same poles of a PM are brought close to two magnetic bearings.

Fig. 1 shows a cross sectional view of a passively controlled zero-power magnetic bearing using PM. In this way, the rotor is supported in the radial direction by magnetic repulsion levitation. Furthermore, applying Earnshaw's theorem, the stator-side PM and the rotor-side PM are staggered so that they do not overlap in an extended manner, and magnetic repulsion is generated so that the rotor-side PM moves inward to sandwich the stator-side PM, thereby providing support in the thrust direction at the same time. At this time, repulsive levitation support is performed during one rotation by arranging the PMs on the rotor side and stator side in a ring shape so that the same polarity of the PMs faces during one rotation. Fig. 2 shows the definition of each coordinate system shown in the results of the three-dimensional finite element method analysis, and Table 1 shows the parameters used in the analysis.

3. Passive control type zero power magnetic bearing using square PM

Fig. 3 shows the shapes of the square PM model and ring PM model in the z direction, and Fig. 4 shows the shapes in the x direction. Furthermore, Fig. 5 shows the comparison results of support characteristics.

Fig. 5 shows in the square PM model, large fluctuations occurred in the distance between the rotor and stator magnets during rotation, and the repulsion direction of the opposing PM changed moment by moment, resulting in large pulsations.

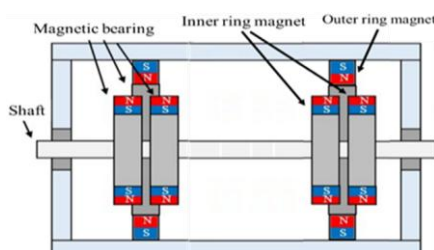


Fig. 1 Cross sectional view.

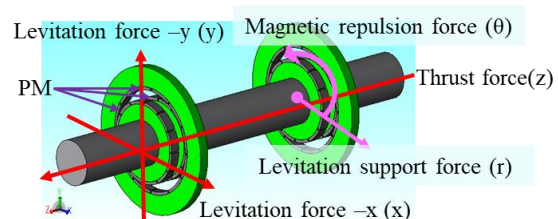


Fig. 2 Analysis coordinate direction.

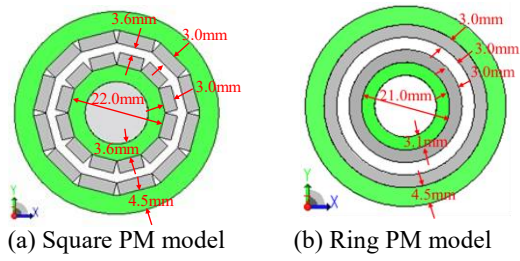


Fig. 3 Model diagram in z direction.

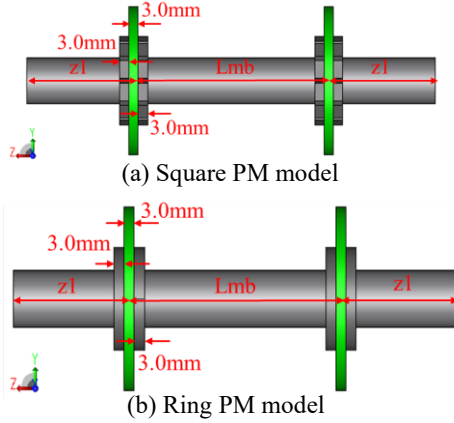


Fig. 4 Model diagram in x direction.

Table 1 Use tables for a clear overview of your data

Parameter	Value
Magnet material	NdFeB_Br = 1.4 [T]
PM fix disk material	SS400
Shaft material	Aluminum
Lsh Shaft length	132.0 [mm]
Lmb Distance between magnetic bearing pairs	54.0 [mm]
z1 Distance between shaft end and magnetic bearing center	63 [mm]
Mesh size	1 [mm]
Step angle	2.25 [deg]
Rotation speed	1500 [rpm]

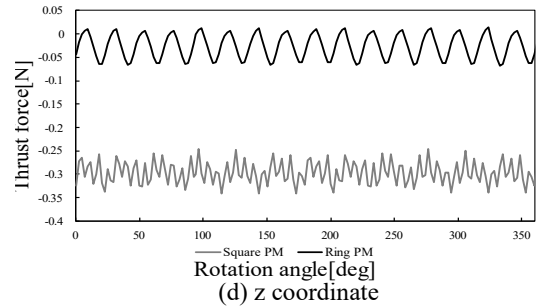
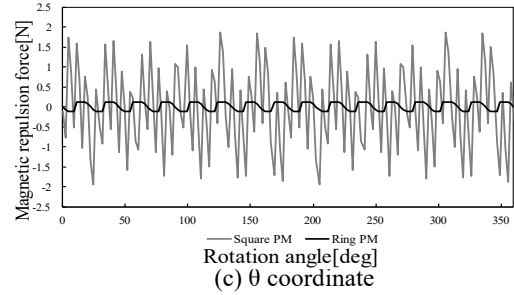
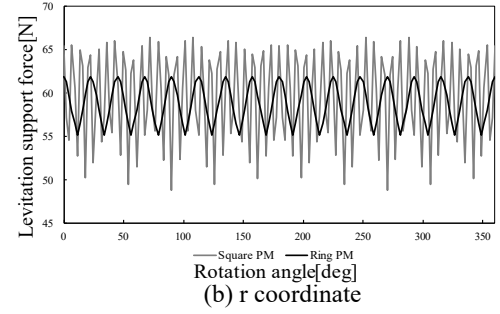
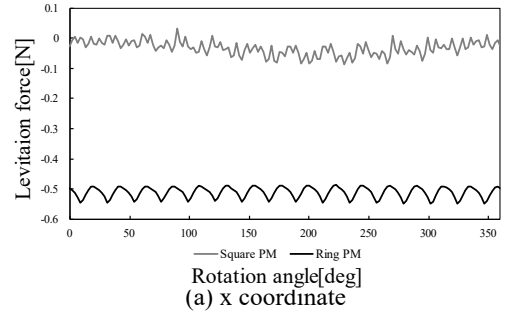


Fig. 4 Analysis result of square PM model.

This suggests that the pulsations that occur during rotation not only cause vibrations, but also act as resistance to rotation, suggesting that it is important to consider methods to suppress pulsations.

4. Consideration of pulsation suppression methods

There are two reasons why pulsation occurs the magnetic flux density changes greatly due to large fluctuations in the distance between PMs during rotation, and the repulsion direction of opposing PMs changes significantly. Therefore, we propose a method to magnetically repel the rotor and stator via a magnetic yoke, a method to make the PM closer to an annular shape by increasing the number of divisions, and an improvement method to reduce the magnetic flux of the bearing by thinning the PM to stabilize support. We will also analyze the improved model, verify the usefulness of the proposed structure, and reconsider the optimal method for suppressing pulsation.

References

- [1] Yusuke YATSU, Arisa MATSUO, Satoshi MURAYAMA, Kenji SUZUKI, "Proposal of Pediatric Centrifugal Pump Type Ventricular Assist Device Using a Bearingless Motor", 27th International Conference on Electrical Machines and Systems, PS-3-4-2, 2024.