Control of Propulsion Direction and Speed for Magnetic Floating Systems using rotating permanent magnets

T. Saiki[1], D. Yonetsu[1], M. Inada[1]

[1]Faculty of Engineering Science, Kansai University, 3-3-35 Yamate, Suita, Osaka. 564-8680, Japan

E-mail: tsaiki@kansai-u.ac.jp

Abstract

Until now, various magnetic levitation systems such as linear have been proposed. Among them, a magnetic levitation system using a rotating permanent magnet that does not use a superconducting magnet has already been proposed. In this proposal, regarding the magnetic levitation system using this permanent rotating magnet, the propulsion direction and speed were controlled by the imbalance of the propulsive force based on braking torque of multiple fixed magnetic wheels, which are generally considered to be harmful.

1. Introduction

Until now, levitation systems using various magnetisms such as linear have been proposed. There are two types of magnetic levitation methods: suction-type and repulsion-type that use magnetic force. Commnoly, a magnetic levitation system using superconductivity for generating a strong magnetic field as used in a linear motor has been proposed, however, it has a hardness and high cost that it requires a very low temperature. Further, a magnetic levitation method using an electromagnetic coil has been proposed, but when an electromagnetic coil is used, it is difficult to obtain a strong magnetic field unless a considerably large current is applied. A magnetic levitation system using a rotating permanent magnet has been proposed for over 10 years [1-3]. The merits of this method are that 1) it moves at ultra-high speed without friction with the installation surface, 2) no superconducting magnet is required, and 3) only a metal plate needs to be installed and no coils are required. The above problem is solved by using a permanent magnet for magnetic levitation. Disadvantages are 1) a metal plate which generates buoyancy is essential, 2) high power consumption, and 3) control of the propulsion direction and speed.

Hyperloop project is proposed by Mr. Elon Musk that uses natural energy as an electrical energy source. An aerodynamic levitation system was first proposed, but later a proposal using magnetic levitation was made. Researchers at the Livermore Institute in the USA have proposed an induction track system. Specifically, the proposal has been made to accelerate to a speed that is a linear motor and to levitate using a Halbach array with a strengthened magnetic field [4]. This should be called a hybrid system. In other researches, as part of the Hyperloop project, a levitation system using the above-mentioned rotating permanent magnets is also being studied. Although a levitation system using a rotating permanent magnet has been proposed, we think that the propulsion method has not been studied adequately. Here, we propose a different method from the conventional method for additional propulsion in levitation systems using rotating permanent magnets. In this time, regarding the magnetic levitation and propulsion system using this permanent rotating magnet, we propose the control of the propulsion direction and speed for magnetic levitation and propulsion system using the imbalance of braking torque for magnetic wheels, which is generally considered to be harmful. In this method, it is possible to eliminate moving parts except magnetic wheels as much as possible and control the propulsive force only by the rotation speed of the multi motors.

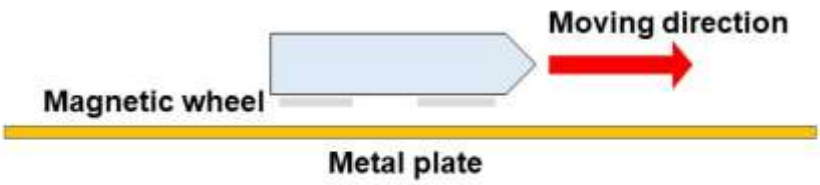
２． Experimental method

Regarding the basic operation of magnetic wheels, the principle is that: A rotating magnetic field obtained by mechanically rotating a permanent magnet acts on a conductor plate to generate an eddy current and repel the newly generated magnetic field and the magnetic field of the magnet.

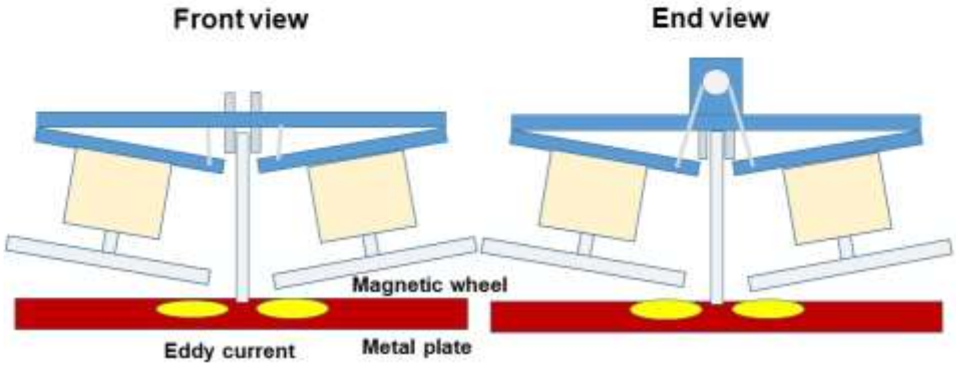
There are proposals for tilting and biased propulsion [3], but here we use the generation of the tilting propulsion, in which we use the slight tilting of magnetic wheels. The method uses braking torque that is generally considered harmful and is generated at the same time as the levitation force.

A magnetic levitation propulsion system that can control propulsion force in addition to levitation force using a rotating permanent magnet is shown in Fig.1. In the method shown here, the magnetic levitation system is assumed to move on rails in one dimension. Although the direction of propulsion is fixed by rails, it can also be applied when moving freely without using rails. This method requires four magnetic wheels at least to control the propulsion direction. We consider the case where magnetic wheels are directly attached to the motor, such as a brushless motor. The two front magnetic wheels are fixed to the motor, that is, the tilt angles of the magnetic wheels are also fixed. In the two rear magnetic wheels, the magnetic wheels are similarly tilted, but the tilting of the magnetic wheels and the forms of peaks and valleys can be adjusted in two steps so that they can be reversed. It is possible even if the angle can be adjusted step by step. At this time, the inclination angle is about several mrad.

Normally, the magnetic wheels are rotated in some way. It is necessary to control the rotation speed of brushless motors, etc. through electrical amplifier (ESC) such as current.

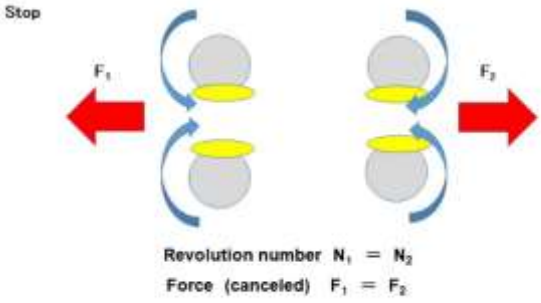


(a)



(b)

Fig1. Magnetic levitation and propulsion system using this permanent rotating magnet. (a)Side view, (b) Forward and end view. The yellow parts show the generation of more strong eddy currents.



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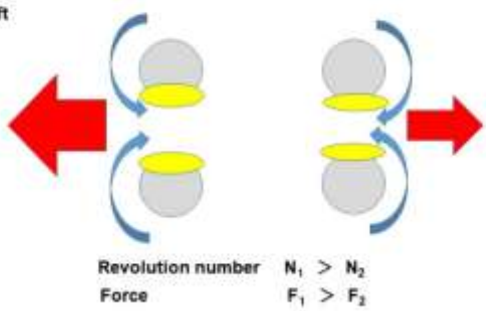

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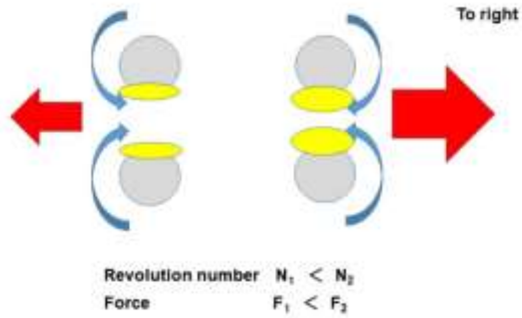
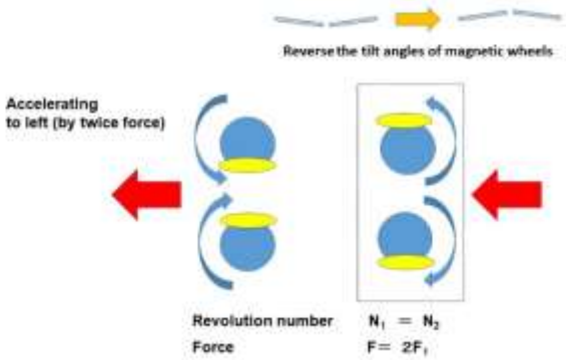


(c)



(d)

Fig2. Magnetic levitation and propulsion system. (a)Stop, (b) Propulsion to left side, (c) Propulsion to right side, (d) Propulsion to right side with more strong force. Acceleration type.

A diagram for a magnetic levitation propulsion method is shown in Fig.2. In Fig.2(a), when the system is stationary, the rotation speed is set to the same level. It is shown that the propulsive force generated by the two magnetic wheels at the front is the same but the directions are opposite, so that the propulsive force is canceled and becomes 0. In Fig.2(b), when the system is propelling to the left, the rotation speed is set to be slightly higher on the left two. Since the propulsive forces generated by the two magnetic wheels in the front and rear parts are different, it is shown that the propulsive force of the difference is generated in the left direction. Similarly, in Fig.2(c), when propelling to the right, the rotation speeds are set slightly higher on the right two. Because the propulsive forces generated by the two magnetic wheels in the front and rear parts are different, it is shown that the propulsive force of the difference is generated in the right direction. Finally, in the case of propelling at high speed to the left side with respect to Fig. 2 (d), the inclination of the propulsion force for two rear magnetic wheels when the peaks and valleys are exchanged. It is because the propulsive forces generated by the two magnetic wheels in the front and rear parts are in the same direction, the sum of the propulsive forces is generated in the left direction.

In addition, although it is another method shown in Fig.2(d), when propelling at high speed to the left, it is possible to construct a solid-state system by only reversing the rotation directions of the two magnetic wheels at the rear.

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