자기부상 인덕션 평면 구동 시스템의 설계 및 해석
Design and Analysis of Maglev Induction Planar Motion System

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1. Introduction

Magnetic levitated system can eliminate mechanical components, reduce the mechanical alignment and maintenance cost, satisfy environmental demand, and enable the carrier to travel. It was used in the vehicle suspension system and magnetic bearing system by B. A. Holes in 1937 for the first time. In 1954, this system was utilized by Laurencean and Tournier for the purpose of aerodynamic test in wind tunnels [1]. Furthermore, the system is being used in many other applications such as magnetic suspension high speed trains. In this paper, the design and fabrication of a magnetic levitated induction planar motion system, simulation of propulsion and levitation actuators are addressed.

2. Maglev System Design and Modeling

2.1 Electromagnet Design

In preliminary stage of the study, we designed an electromagnet design with E core. Computer simulation program was used to find the most powerful and useful magnet design by changing length, width and height of the core, diameter and number of turns of the coil. A very brief analytical model of electromagnet is proposed in Fig.1. The basic laws of electricity and magnetism can be summarized by the Maxwell equations, and we consider a closed path and denote the surface enclosed by the path by S. A surface integral over the area S is

$$\int_s HdS = \int_s jdS$$

By applying Stokes' theorem to the left-hand side, we have

$$\oint_c HdS = I, \quad I = \int_s jdS$$

where I is the total current enclosed by the path S. We

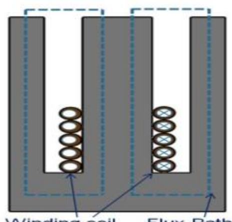

Fig.1 Analytical Model of Electromagnet

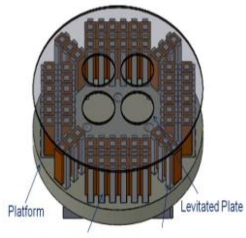

Fig. 2 Schematic Design of MPMS

use a simple geometry with a core made of iron with a gap g and a coil of n turns and of a current I, then we have the following expression relating the magnetic flux density and the current:

$$\frac{B_0 g}{\mu_0} + \frac{B_i l_i}{\mu_0 \mu_r} = nI$$

In the above, for simplicity's sake, we have assumed that the magnetic flux density in the gap and the core is constant and given by B_0 and B_i, respectively. l_i is the path length through the core. The permeability of the air gap is virtually the same as the permeability of vacuum ($\mu_0 = 4\pi * 10^{-7} H \cdot m^{-1}$), while the permeability of magnetic materials, $\mu_0 = (\mu_0 \mu_r)$, depends on B_i. μ_r is the relative permeability, and we often call μ_r just the permeability [2].

Table 1. Specifications of the System

Length of electromagnet	31mm
Width of electromagnet	10mm
Height of electromagnet	50mm
Diameter of coil	0.45mm
Number of turns	500 turns
Diameter of aluminum plate	310mm
Thickness of aluminum plate	2mm
Weight of the aluminum plate	3.59N

2.2 Maglev System Design

Based on the simulation results of the electromagnets, the proposed design assembly provides a levitation force and a propulsion force. Levitation actuators are used to lift the moving platform and control its vibrations. Propulsion actuators are used to achieve x- and y- direction motion. A schematic outline of the novel maglev planar motion system (MPMS) is proposed in Fig. 2 and the specifications are listed in Table 1.

3. Finite Element Analysis

To further verify the electromagnetic characteristics and forces of the system, propulsion and levitation actuators are respectively analyzed by FEA using Ansoft-Maxwell software.

Every winding can generate two kind of magnetic force. The one is vertical force, the other is lateral force [3]. Six electromagnets are put together as one set of the actuator model. The objective of FEA, taking into account of the air gap change from 0.5 mm to 5 mm, is to find sufficient lift force for levitating the moving part and sufficient drag force for driving planar motion of moving part. Fig. 3 shows the schematic model of the single set of the levitation actuator. Fig.4 and Fig.5 shows the simulation result of the propulsion and levitation force of electromagnet array according to the U-V-W input frequency when the current of coil is 1.5A.

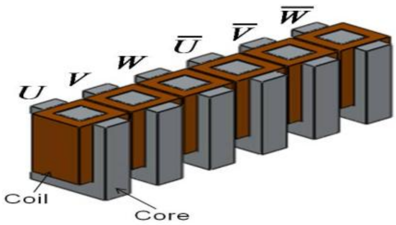

Fig. 3 Schematic Simulation Model of Levitation Actuator

4. Control Design

The force and position control algorithm of the proposed levitated system can be divided into two parts. The first part is the magnetic suspension control (z-axis) and the second part is the propulsion control (x-y-axis) [4]. The rotation and levitation of the levitated plate can be controlled by changing the

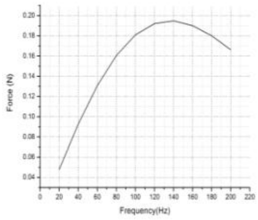

Fig. 4 Simulation result of the propulsion force

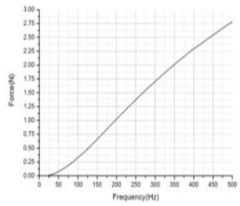

Fig. 5 Simulation result of the levitation force

value of currents of inside and outside levitation actuators. There are four laser displacement sensors to detect the 4-DOF movements. When yaw disturbance occurs, the electromagnets will be excited with different currents to provide restoring forces.

5. Conclusion

Modeling, simulation and concept of control have been discussed in this paper. In order to validate the proposed system, an experimental setup of this system is designed and being constructed. The method can be extended without difficulty to use large coil arrays and levitated platforms with multiple magnets to increase the planar motion range and lifting capacity. The proposed system is very suitable for applications with problems of friction, noise, metal dust contamination, and it can be also used as multi DOF motion stages of the entertainment facilities.

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