새배열 영구자석형 Planar Motor의 수직력 최소화

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Normal Force Minimization in the SPMPM with New Permanent Magnet Array

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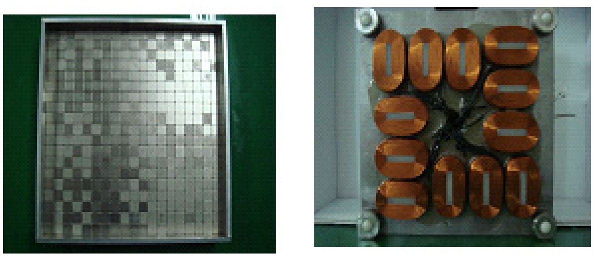
Abstract - This paper presents the normal force minimization design and the analysis of normal force effect which acts on the characteristics of the Synchronous Permanent Magnet Planar Motor (SPMPM) with new array. The experiments are applied to verify the analytical analysis. There is no doubt that the significant reduction of normal force and the experimental values dovetail nicely with the simulation.

1. Introduction

The knowledge of the behaviour of the normal force is important to the development of the bearing system of planar motor and to obtain a good thrust characteristic. The reason is that in planar motor, especially the SPMPM which has the high energy density, the normal force is the main contribution to the friction force which causes an undesired effect on the thrust characteristic [1]. A fine bearing system can keep the friction force a very small value even to zero by reducing the normal force and the gravity of the mover. Generally, there are three methods to solve the bearing: air-bearing system, magnetic suspension system, and ball bearing system. The air-bearing system and magnetic suspension system have the friction force which nero zero but they are complex and expensive. In case the normal force and gravity is small, the ball bearing system is a good choice. So, it is necessary to analyze the normal force of the SPMPM and to get a minimize value. And moreover, normal force, back-EMF, and thrust experiments are achieved to observe the effect of normal force.

2. Modeling and Normal Force Minimization

2.1 Modeling



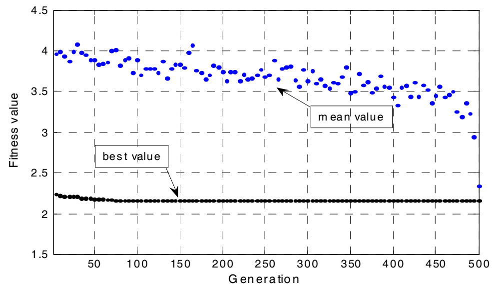
<Fig.1> The stator and mover of the SPMPM

Fig.1 shows the stator and the mover of SPMPM. The stator is comprised by the new magnet array. There are four sets of windings on the mover. Two sets of armature windings are used to drive the mover in the x direction and others are uesed to drive the mover in y direction. Four ball bearings are installed on the mover to comprise a bearing system. The demisions of the models are described in Table 1.

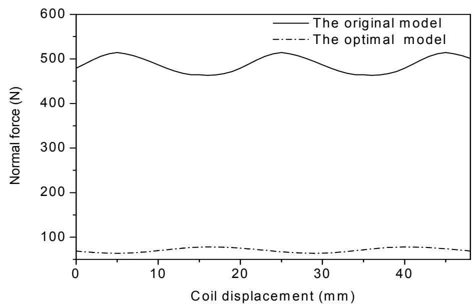
The methods to evaluate the characteristics of SPMPM such as magnet field distribution, back-EMF, and thrust have been analyzed in previous papers [2]-[3]. In these papers, the undesired effect of the normal force which acting on thrust was clearly described: the friction force generated by the normal force reduced thrust greatly especially the input current was small.

2.2 Normal force minimization by Genetic Algorithm

To reduce the undesired effect of the normal force, genetic algorithm is adopted to minimize the normal force. The magnet width p, magnet thickness l_m, coil terminal interval w, coil width w_c, coil effective length d, and coil thickness l_c are choose as input variables. Genetic algorithm opteration process is shown in Fig.2 and the optimal results can be seen in Table 1. The peak value of normal force is reduced from 514.33 N to 78.05 N as shown in Fig.3 and thrust is increased from 30.57 N to 33.27 N as shown in Fig. 6.



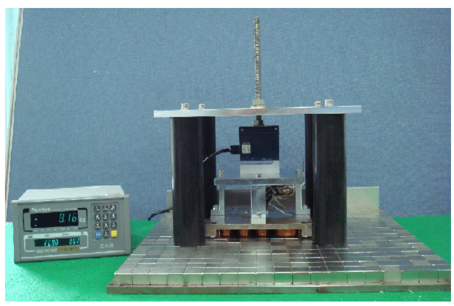
<Fig.2> Genetic Algorithm operation process



<Fig.3> The Normal force

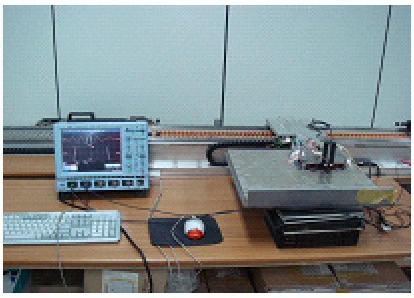
3. Experiments and Comparison

To verify the simulation results, normal force, back-EMF and thrust experimental values are obtained by measurement. Fig. 4 shows the experiment equipments.

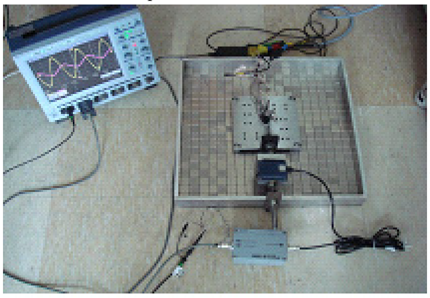


a. The experiment of normal force

from 514.33 N to 78.05 N. Consequently, the thrust performance has a remarkable increase, the measured thrust and the simulation have a good agreement.



b. The experiment of Back-EMF



c. The experiment of thrust

<Fig.4> Experiment equipments

<Table 1> The dimensions of the analysis model

Symbols	Units	Original Model	Optimal Model
magnet width P	mm	20	24
magnet thickness l_m	mm	10	15
coil terminal interval w	mm	6.6	4
coil width w_c	mm	9	13
coil effective length d	mm	20	24
coil thickness l_c	mm	6	15
Turns/phase		770	1368
Normal force	N	514..33	78.05
Thrust	N	30.57	33.27

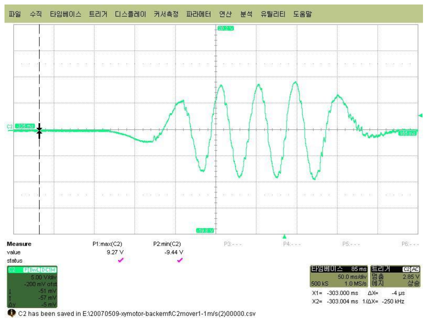
The normal force of optimal model is measured by Load cell (model: NT-505A INDICATOR), the peak value of experiment is 79.38 N, it is a little bigger than the simulation.

In the experiment of back-EMF, the mover of the optimal machine is contacted with another linear machine with a speed of 1 m/sec. The output back-EMF value are measured by Oscillo-Scope (model Wavesurfer 424). Fig. 5 (a) shows the wave form of back-EMF, the simulation and experiment values are shown in Fig. 5 (b).

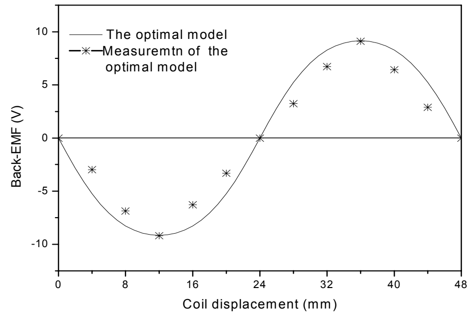
The simulation peak value of back-EMF is 9.16 V and that of experiment is 9.27 V. The simulation and experimental back-EMF values match each other well.

Thrust is measured by Load cell (model UU-k010(Cap.20kgf), DACELL. Co). Two coil sets which drive the mover in one direction are considered in this experiment. Three phases current are supplied to the windings and Oscillo-Scope (model Wavesurfer 424) is used to measure the output of Load cell. A amplifier (model STT-100, SCALE-TRON) are uesd because the magnitude of the output voltage of Load cell is small. Fig.6 reveals the comparison between the simulation and experiment results of thrust.

When the peak value of input current is 1 A, the peak value of thrust in experiment is 31.5 N. It is 94.68% of the maximum simulation which is 33.27 N. According to the paper [1], the maximum experimental value of thrust is 44.04% of simulation when the peak value of input current is 1 A, the friction force generated by the normal force is very big and the thrust performance is abased greatly. But in optimal model of this study, the friction force is greatly reduced because the normal force has a obvious decrease

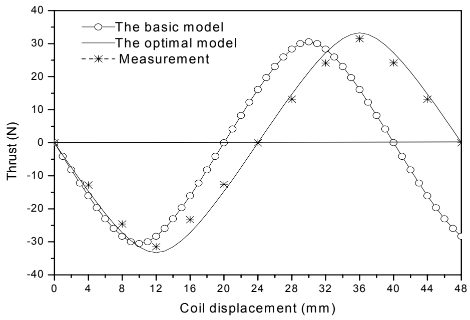


a. The wave form of the back-EMF in experiment



b. Comparison between the simulation and experiment results

<Fig.5> The back-EMF characteristic



<Fig.6> Thrust characteristic

4. Conclusion

In this paper, the normal force of the SPMPM with new array is minimized by genetic algorithm. The experiments of normal force, back-EMF and thrust are implemented to obverse the effect of the optimization. It can be concluded that the smaller the normal force is, the better the thrust characteristic is. Through the experiments, the propriety of characteristics analysis of the SPMPM are verified.

[References]

[1] Duk-Hyun Kim and Gyu-Tak Kim, "Normal Force Minimization of the Synchronous Permanent Magnet Planar Motor with Halbach Magnet Array", The transactions on KIEE, vol .55B, No. 11, pp. 582 – 588, 2006

[2] Jianpei Zhou, Rui Huang, and Gyu-Tak Kim, "Characteristics Analysis and Optimization of a Novel Synchronous Permanent Magnet Planar Motor", CEFC2006 Digest Book, pp. 153, 2006

[3] Jianpei Zhou, Rui Huang, Dong-Yeup Lee, and Gyu-Tak Kim, "Characteristics Analysis of Synchronous Permanent Magnet Planar motor with Halbach Array", The transactions on KIEE, vol. 55B, No. 9, pp. 465-471, 2006