

# Design Technique of Magnetic Suspension for Vibration Free Table

Jae-Woo Jung<sup>1</sup>, Sung-Il Kim<sup>1</sup>, Jung-Pyo Hong<sup>1</sup>, Senior Member IEEE,  
 Ji-Young Lee<sup>2</sup>, and Ju-Hoon Lee<sup>3</sup>

<sup>1</sup>Department of Electrical Engineering, Changwon National University

#9 Sarimdong, Changwon, Gyeongnam, 641-773, Korea, E-mail: saltacello@changwon.ac.kr

<sup>2</sup>Transverse Flux Machine Research Group, Korea Electrotechnology Research Institute

<sup>3</sup>Department of Power Facility Diagnosis Research group, Korea Electrotechnology Research Institute

#28-1, Seongjudong, Changwon, Gyeongnam, 641-120, Korea, E-mail: jhlee@keri.re.kr

**Abstract**— This paper proposes the design method of a magnetic suspension that is controlled actively on the exterior vibrations by low frequencies. The magnetic suspension is able to compensate the vibrations with individual controls unlike a mechanical suspension. In the magnetic suspension, two characteristics are required. That is, firstly, magnetic motive force (MMF) by armature winding must be increased linearly. Lastly, the other is same output force as direction of MMF. In this paper, response surface method combined with experimental design is applied to investigate the characteristics and optimize the magnetic suspension for vibration free table

## 1. INTRODUCTION

Fig. 1 shows the principle of compensation and cross section of a inserted permanent magnet (PM) type magnetic suspension that composed of armature winding, PM and steel. Reference force,  $F_{REF}$  is produced by PM, and that always exists between two steel bodies. When exterior vibration,  $F_{EXT}(-)$ , happens during  $t_1$ , input MMF that flows into each magnetization direction creates resultant force,  $F_{INC}$ , in the air gap. In the same manner, as exterior vibration,  $F_{EXT}(+)$  is generated during  $t_2$ , input MMF that flows into each demagnetization direction brings about resultant force,  $F_{DEC}$ , in the air-gap. Thus, in order to operate the suspension,  $F_{INC}$  and  $F_{DEC}$  should have linearity according to the change of MMF and  $F_{INC}$  and  $F_{DEC}$  should be same, according to each opposite directions of MMF produced by same current.

The characteristics of the above mentioned magnetic suspension is designed by response surface method (RSM) combined with design of experiment (DOE). The results of the optimal designed magnetic suspension will be verified by comparison with experimental result.

## II. ANALYSIS METHOD

Full factorial design (FFD), one of the experimental designs, is performed to investigate the effect with respect to the amplitude of the force and the balance of the force, the ratio between  $F_{INC}$  and  $F_{DEC}$ , according to variation of design factors. And then, the important factors greatly influenced on the response are selected. The design factors considered in this paper were as follows; A(return path air-gap), B(PM length), C(main path) and D(upper&lower path length). In the end, RSM is applied to optimize magnetic suspension with the factors [1], [2].

## III. ANALYSIS RESULT

Fig. 2 shows the characteristic of optimal model designed by proposed method in this paper. According to variation of MMF, output force is changed linearly, and the value of Balance approximates almost 1.

## IV. REFERENCES

- [1] Sung-Il Kim, Ji-Young Lee, Young-Kyoun Kim, Jung-Pyo Hong, Yoon Hur, and Yeon-Hwan Jung, "Optimization for Reduction of Torque Ripple in Interior Permanent Magnet Motor by Using the Taguchi Method", *IEEE Transaction on Magnetics*, Vol. 41, No. 5, pp. 1796-1799, May 2005.
- [2] Frederic Fillon and Pascal Brochet, "Screening and Response Surface Method Applied to the Numerical Optimization of Electromagnetic Devices", *IEEE Transaction on Magnetics*, pp. 1162-1167, Vol. 26, No. 4, July 2000.

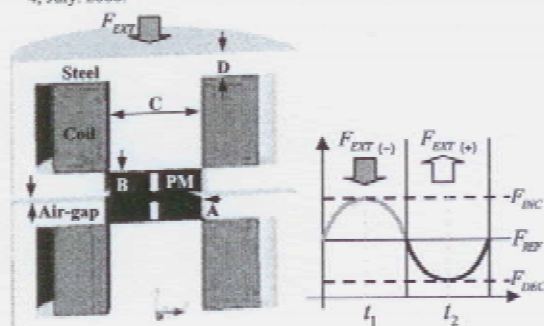


Fig. 1. Cross section of Magnetic suspension and Principle of compensation

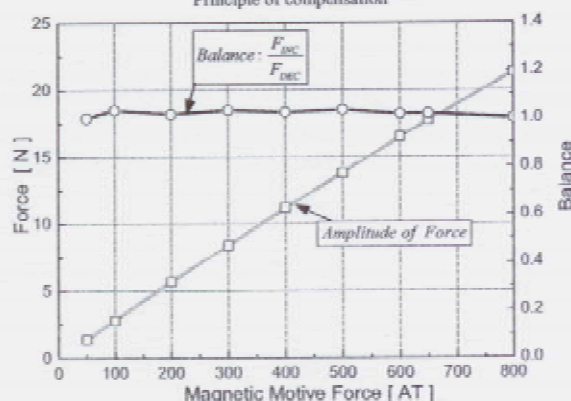


Fig. 2. Characteristics of optimal model

# THE TWELFTH BIENNIAL IEEE CONFERENCE ON ELECTROMAGNETIC FIELD COMPUTATION

## Digest Book



April 30<sup>th</sup> - May 3<sup>rd</sup>, 2006

IEEE Catalog Number: 06EX1354

ISBN: 1-4244-0319-7

Jointly Sponsored by  
IEEE Magnetics Society, IEEE Miami Section, and  
Florida International University



C7-2	<b>Design of a New Linear Magnetic Damper for Shock-Absorbing From Crash Accident of High Speed Vehicles</b> .....	237
	<i>Yongdae Kim, Heon Lee, Semyung Wang, and Kyihwan Park</i> Gwangju Institute of Science and Technology, Korea	
C7-3	<b>Design of Flux Barrier for Reducing Torque Ripple and Cogging Torque in IPM type BLDC motor</b> .....	238
	<i>Byoung-Yull Yang<sup>1</sup>, Hyun-Kag Park<sup>2</sup>, and Byung-Il Kwon<sup>2</sup></i> <sup>1</sup> Samsung Electronics, Korea, <sup>2</sup> Hanyang University, Korea	
C7-4	<b>Design of Permanent Magnet DC Motor Using FEA --Based Optimization and Parallel Computing Method</b> .....	239
	<i>Cheol-Gyun Lee<sup>1</sup>, Myung-Soo Cho<sup>1</sup>, Sang-Yong Jung<sup>2</sup>, Sung-Chin Hahn<sup>2</sup>, Hae-Ryong Chor<sup>3</sup>, Jae-Kwang Kim<sup>4</sup>, and Hyun-Kyo Jung<sup>4</sup></i> <sup>1</sup> Dong-Eui University, Korea, <sup>2</sup> Dong-A University, Korea, <sup>3</sup> Design Center Hyundai Motor Company, Korea, <sup>4</sup> Seoul National University, Korea	
C7-5	<b>Design of the Rotary Magnetic Position Sensor With the Sinusoidally Magnetized Permanent Magnet</b> .....	240
	<i>Seung-ho Jeong, Se-hyun Rhyu, and Byung-il Kwon</i> Hanyang University, Korea	
C7-6	<b>Design of the Starting Device Installed in the Single-Phase Switched Reluctance Motor</b> .....	241
	<i>Jun-Ho Kim<sup>1</sup>, Eun-Woong Lee<sup>2</sup>, and Jong-Han Lee<sup>2</sup></i> <sup>1</sup> LS Industrial Systems, Korea, <sup>2</sup> ChungNam Nat'l University, Korea	
C7-7	<b>Design Technique of Magnetic Suspension for Vibration Free Table</b> .....	242
	<i>Jae-Woo Jung<sup>1</sup>, Sung-Il Kim<sup>1</sup>, Jung-Pyo Hong<sup>2</sup>, Ji-Young Lee<sup>2</sup>, and Ju-Hoon Lee<sup>2</sup></i> <sup>1</sup> Changwon National University, Korea, <sup>2</sup> Korea Electrotechnology Research Institute, Korea	
C7-8	<b>Development and Analysis of a New Type of Switchgear for High Voltage Gas Circuit Breaker: Electromagnetic Force Driving Actuator</b> .....	243
	<i>Jong-Ho Kang<sup>1</sup>, Sang-Hun Park<sup>1</sup>, Woo-Young Lee<sup>2</sup>, Hong-Kyu Kim<sup>2</sup>, Wang-Byuck Suh<sup>3</sup>, Won-Seok Kim<sup>3</sup>, and Hyun-Kyo Jung<sup>1</sup></i> <sup>1</sup> Seoul National University, Korea, <sup>2</sup> Korea Electrotechnology Research Institute, Korea, <sup>3</sup> ILJIN Electric Co., Ltd. Korea	

**POSTER SESSION PCB**  
**Devices and Applications VI**  
**May 2, 2006, Tuesday**  
**10:30 - 12:10**

C8-1	<b>Dynamic Analysis of Linear Synchronous Machines</b> .....	244
	<i>H. Yu<sup>1</sup>, W. Dai<sup>1</sup>, S. Ho<sup>2</sup>, M.Q. Hu<sup>1</sup>, S. Yang<sup>2</sup>, K. Cheng<sup>2</sup>, and K.F. Wong<sup>2</sup></i> <sup>1</sup> Southeast University, China, <sup>2</sup> Hong Kong Polytechnic University, Hong Kong	