Design and Characteristic Analysis of Moving Coil Type Linear Oscillatory Actuator Considering Asymmetric Magnetic Circuit

Duk-Hyun Kim
Department of Electrical Engineering, An-dong Information College, An-dong, Kyungbuk, 762-170, Korea.
E-mail: dh0710@www.ait.ac.kr
Gyu-Hong Kang, Jung-Pyo Hong, *Member*, *IEEE* and Gyu-Tak Kim
Department of Electrical Engineering, Changwon National University, Changwon, Kyungnam, 641-773, Korea

Abstract—**This paper deals with an application of Finite Element Method (FEM) to design and characteristic analysis of Moving Coil type Linear Oscillatory Actuator (MC-LOA). The unbalanced thrust values caused by asymmetric magnetic circuit are accurately estimated by FEM, and the results are used to improve the performance of MC-LOA.**

INTRODUCTION

Although Moving Coil type Linear Oscillatory Actuator (MC-LOA) including Permanent Magnet (PM) is suitable for a short stroke reciprocating system, there is an asymmetric magnetic circuit due to the unbalanced structure. Moreover, it causes a different flux distribution in the air-gap along the current direction. The interaction driven by two fluxes between the PM and the current causes the unbalanced thrust and interferes with the proper oscillation of MC-LOA [1-2].
The aim of this paper is therefore to solve the above problems and to improve the driving performance of MC-LOA. In order to achieve the aim, it is necessary to estimate the rate of the unbalanced thrust. Once it is done, it will be easier not only to design the machine having the balanced magnetic circuit but also to use a simple control method without an intricate structure.

ANALYSIS OF UNBALANCED THRUST

The structure of MC-LOA is symmetric along up to down. Therefore, the half model is selected for the analysis and Derichlet boundary condition is applied to it.

Fig. 1 and Fig. 2 respectively show the flux density distributions in air-gap of the initial and the improved model. When the mover goes into inner core direction ($+x$), forward, the air-gap flux density has a larger value than the other case that the mover goes to the opposite direction ($-x$), backward.

RESULTS AND APPLICATION

Fig. 3 shows the dimension of initial designed model. From the result of the characteristic analysis, it is confirmed that the rate of saturation in core has a great influence on the thrust characteristic. In other words, the increase of the saturation rate causes the decrease of thrust difference along the current direction. For this reason, although when generally designing electric machines, the saturation effect should be avoided, this paper proposes an improved model for the balanced magnetic circuit and the fewest unbalanced thrust by using a saturated core. Fig. 4 shows the displacement characteristic of both the initial and the improved model. Due to the saturated core, there is a little decrease of thrust. However, it can be compensated by adding even a small amount of the input current.

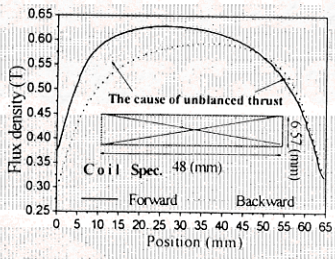

Fig. 1 Flux density distribution of initial designed model in air-gap

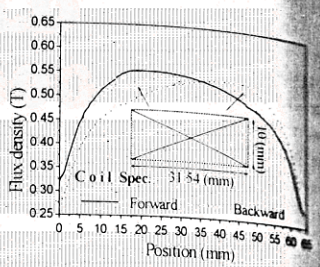

Fig. 2 Flux density distribution of improved model in air-gap

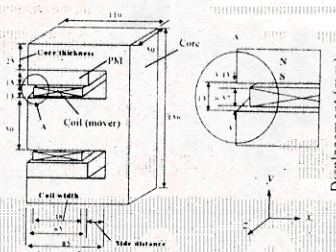

Fig. 3 Dimension of initial model

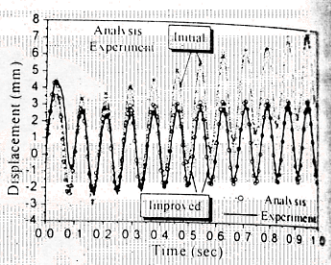

Fig. 4 Displacement characteristic

As compared with the decrease of efficiency, the stability of MC-LOA becomes satisfactory enough. There is also an alternative way such as using a specific controller. Since it is possible to predict the thrust characteristic by FEM, we can use it to reduce the burden of the controller. Hence, a very simple control system, such as an open loop control method, can be carried out. Controlling the input current values along the mover directions can easily accomplish the proper oscillation of MC-LOA.

CONCLUSION

This paper has proposed the approach toward improving the performance of MC-LOA. The unbalanced thrust along the current direction is accurately estimated by FEM. Both the initial and the improved model are introduced. The characteristic analysis of both models is also performed by FEM and the analysis results are used for the control system in order to reduce the burden of the controller. The propriety of the proposed approaches is verified by the comparison with the experimental results.

REFERENCES

[1] Naila Mikhael-Boules, "Design and analysis of linear actuator for active vibration cancellation", General Motors Corporation, 1995.
[2] H. Wakiwaka, H. Yajima, S. Senoh and H. Yamada, "Simplified Thrust Limit Equation of Linear DC Motor", *IEEE*, Vol. 32, pp. 5073-5075.

DIGESTS OF THE 9th

BIENNIAL IEEE CONFERENCE ON ELECTROMAGNETIC FIELD COMPUTATION - CEFC-2000

June 4-7, 2000
Hyatt Regency Hotel
Milwaukee, Wisconsin USA

Jointly Sponsored by
IEEE- Magnetics Society, IEEE-Milwaukee Section,
IEEE-Miami Section and Marquette University