A Novel Design of an Air-core type Permanent Magnet Linear Brushless Motor by Space Harmonics Field analysis

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***Abstract*—This paper presents the design and characteristic analysis of an air core type Permanent Magnet (PM) linear motor based on Space Harmonics Field Analysis. The motor phenomena due to the variation of coil shape under a constant Magneto Motive Force (MMF) are analyzed and its result is applied to the design process.**

INTRODUCTION

To obtain a precise design result of the air core type PM linear motor it is necessary to analyze the magnetic field. As one of numerical methods, the Finite Element Method (FEM) allows an accurate analysis of electrical machines and can consider geometric details and the non-linearity of magnetic materials. However, it requires geometrical structure as well as additional processing such as pre and post process. Therefore, it is time consuming and unsuitable to use FEM for both the basic design stage and the optimization. An Equivalent Magnetizing Current (EMC) method, which is to solve the Poisson equation by replacing independent sources with the distribution of EMC, is usually used for magnetic field analysis because of their fast and flexible computation [1-2].

This paper presents a design process and a characteristic analysis by using EMC. The proposed analysis and design process is verified by comparison with the 2D Finite Element (FE) analysis and experimental results.

ANALYSIS AND DESIGN PROCESS

Fig.1 shows the topologies of air core type linear motor. The structure of double side PM linear motor has a symmetric both sides. Hence, one of them is selected as its analysis region and assumed to simplify the 2-D analysis and compute the magnetic fields of each region [1-2]. Fig. 2 shows the analysis model for the magnetic field of air core type linear PM motor using EMC method.

In Fig. 3, PMs are replaced by the EMC distribution and the characteristic equation of each region is as follows [1].

$$\frac{\partial^2 A(x,y)}{\partial x^2} + \frac{\partial^2 A(x,y)}{\partial y^2} = -\mu_0 J_p(x_i) \qquad \text{Region III (1)}$$

The EMC distribution by PMs, $J_p(x)$, which is located in the region III of Fig. 2, is described as the Fourier series [1].

Fig 1. Motor topology

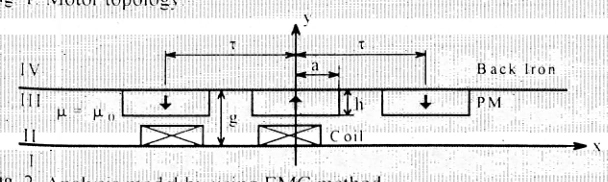

Fig 2. Analysis model by using EMC method.

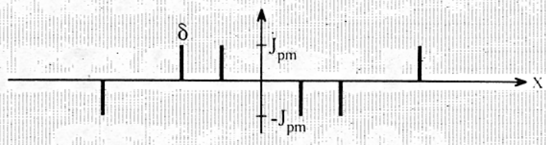

Fig. 3. Equivalent Magnetizing Current (EMC) of Magnets

By applying the boundary condition at the interfaces between regions of different material properties, the characteristic equations given by equation (1) can be solved.

$$B_{II}^{x} = \frac{\mu_0}{2}\sum_{n=1,3}^{\infty}\left(\frac{\sinh(nkh)}{\sinh(nkg)}\right)\left(\frac{e^{nky}}{e^{nkg}} - \frac{e^{nkg}}{e^{nky}}\right)\cdot\frac{b_n}{nk}\cdot\sin(nkx) \qquad (2)$$

$$B_{II}^{y} = -\frac{\mu_0}{2}\sum_{n=1,3}^{\infty}\left(\frac{\sinh(nkh)}{\sinh(nkg)}\right)\left(\frac{e^{nky}}{e^{nkg}} - \frac{e^{nkg}}{e^{nky}}\right)\cdot\frac{b_n}{nk}\cdot\cos(nkx) \qquad (3)$$

The resultant magnetic field is calculated by superposition of the magnetic field due to PM and armature current.

Fig. 4 shows the design process of air core type PM linear brushless motor by using EMC in order to search maximum thrust under fixed design parameters.

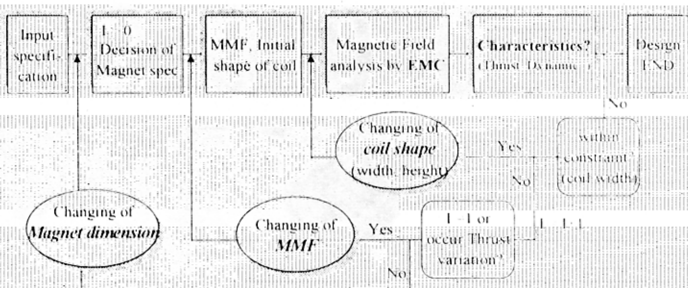

Fig. 4. Design process of air core type PM linear brushless motor by EMC

CONCLUSION

The EMC method has been developed to aid the magnetic field analysis of air core type PM linear brushless motors. It is based on the calculation of the spatial distribution magnetic field.

In this paper, a design process and characteristics analysis by using EMC method are presented and the result is verified from the 2-D FE analysis and experiment.

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Fig. 5. Equi-potential distribution by 2-D FE analysis

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