3-Dimensional Force Analysis of Magnetic Levitation stage based on Current Vector Control

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Abstract **– This paper deals with the effect of lateral force in the Permanent Magnet Linear Synchronous Motor (PMLSM) for the guidance in magnetic levitation stage. In order to analyze not only overhang effect of the PMLSM, but also lateral asymmetry of secondary (mover), 3-Dimensional Equivalent Magnetic Circuit Network (3-D EMCN), considering movement of the secondary in lateral direction is introduced. The current vector control scheme is applied for the analysis of propulsion, levitation, and lateral force in the PMLSM for magnetic levitation stage.**

INTRODUCTION

The force characteristics, especially the lateral force, of the PMLSM for magnetic levitation stage without guards are very important for its stability in speed and levitation control systems. Furthermore, its lateral displacement by external disturbance produces the pulsations of the levitation force and the thrust and as results of that, the overall performance of the PMLSM becomes deteriorated. Therefore, in the PMLSM for magnetic levitation stage, the lateral characteristic analysis is highly required for the precise design, considering chang of the lateral displacement for restoration [1]-[2].

To perform such a magnetic field analysis, 2-dimensional analysis cannot consider lateral characteristics. Therefore, in this paper, 3-D Equivalent Magnetic Circuit Network (3-D EMCN) is used to solve detailed field computation. The purpose of this paper is to analyze the lateral force characteristics of the PMLSM using 3-D EMCN, considering lateral offset displacement and determine optimal current phase angle in the controlled magnetic levitation stage.

METHOD OF ANALYSIS AND RESULT

The characteristic analysis of the PMLSM is usually modeled on d-q axis plane by controlled current vector [1]. The total airgap flux is modulated by controlled current vector, so that the thrust and attraction force are controlled by current phase angle, γ , on d-q axis plane. In magnetic levitation stage by using the PMLSM, the control of position and levitation is performed by not only current amplitude but also controlled current vector like operation of controlled synchronous motor. Therefore, characteristic analysis of PMLSM that is thrust, levitation force and lateral force for restoration to the original state must be require effect of controlled current vector for precise position control [1], [4].

The lateral force is calculated as the derivative of the stored magnetic energy with respect to a small lateral displacement then the lateral displacement of mover is considered by 3-D EMCN method.

Fig. 1 shows analysis model of PMLSM for magnetic levitation stage with lateral direction (z-axis) length.

Fig. 2 shows the distribution of the flux density vector at x-y and y-z plans and compares align and asymmetrical cases of primary and secondary by using 3-D EMCN. In the asymmetrical case, the z-direction component of fluxes is generating and lateral force increases due to z-direction fluxes.

Lateral force change nonlinearly owing to lateral flux leakage. Therefore, it is indispensable to consider the lateral effect due to the variation of overhang length and lateral displacement. Fig. 3 (a) shows the lateral force according to offset length, it is variation nonlinearly due to overhang effect. Lateral force characteristics according to current phase angle at lateral displacement of 7.5[mm] are shown in Fig. 3(b). It is changed greatly with control scheme. From the analysis results, we confirm that it is necessary to lateral effect analysis consider control scheme in PMLSM for magnetic levitation stage.

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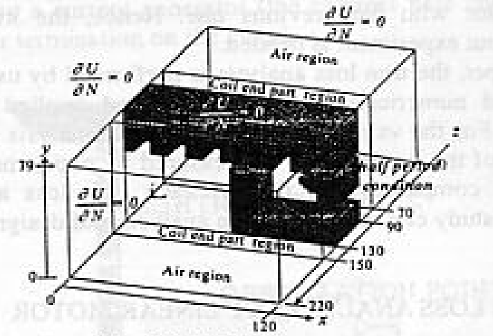
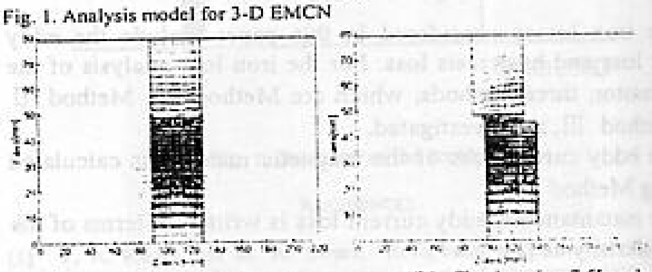
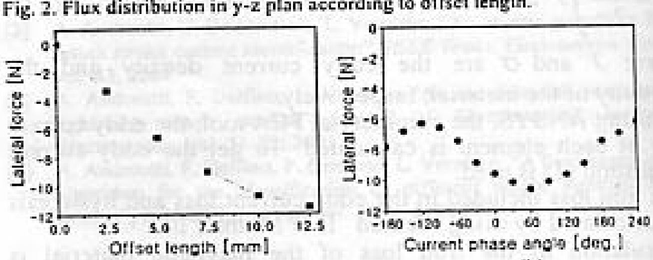


Fig. 1. Analysis model for 3-D EMCN



(a) offset length = 0 (b) offset length = 7.5[mm]

Fig. 2. Flux distribution in y-z plan according to offset length.



(a) (b)

Fig. 3. Lateral force characteristic of PMLSM

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