THE NOVEL TECHNIQUE CONSIDERING SLOT EFFECT BY EQUIVALENT MAGNETIZING CURRENT

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Abstract – This paper presents the efficient space harmonic analysis method (so-called EMC method) for the permanent magnet linear synchronous motor (PMLSM) by which can be taken into consideration the effect of slot geometry using the Equivalent Magnetizing Current (EMC). Applying the EMC method to a PMLSM, the resultant flux density distribution including the slot effect is easily calculated by the superposition of each independent magnetic field. And the calculated characteristics of a PMLSM are compared with those obtained from both the experiment and the finite element method (FEM).

Introduction

Recently, many numerical methods have been proposed to analyze machine performance through the magnetic field analysis. As one of the numerical calculation methods, the finite element method(FEM) allows an accurate analysis of electrical machines and can consider the geometric details and the non-linearity of magnetic material. But it needs much time to be carried out, especially for machine designs in which geometric variations must be examined. To alleviate this problem, many researches have proposed the EMC method, which is easily applied to a simple structure such as PMLSM's and helps save the computing time. The conventional EMC method, however, has simplified the geometry of slots into flat surface for the sake of convenience. For this reason, it is inevitable to change machine characteristics in that EMC method because of excluding the effect of a slotted geometry and this induces the space harmonic components leading up to the deterioration of the machine characteristics [2].

This paper, therefore, proposes the advanced EMC method in which the slot effect, essential for obtaining accurate analysis for machine performance [3], can be considered.

Magnetic Field Analysis

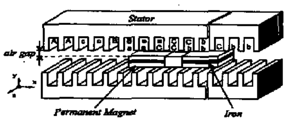

Fig. 1 Double-sided PMLSM

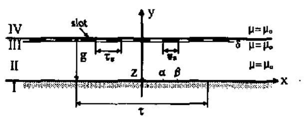

Fig. 2 Virtual EMC model of slots

Fig. 1 shows the basic structure of a PMLSM. In the conventional EMC method, it is assumed that the shape of slots is flat and then the magnetic field by permanent magnet (PM) and primary current is easily calculated by solving the characteristic equation, (1), combined with boundary condition [2].

The primary core with great permeability has the magnetization **M** at its surface resulting from the external magnetic field which is, in turn, induced by the periodically arranged PM's in region II of Fig. 2. And **M** can be replaced by the EMC, which is equivalently obtained from the difference in flux densities at the interfaces between the region III and IV in Fig. 2 and can be expressed as (2), the surface current density $\mathbf{K}_m$.

$$\frac{\partial^2 A(x,y)}{\partial x^2} + \frac{\partial^2 A(x,y)}{\partial y^2} = -\mu_0 J(x) \quad (1)$$

$$\mathbf{K}_m = \frac{1}{\mu_0} \nabla \times (\mathbf{B}_{t2} - \mathbf{B}_{t1}) \quad (2)$$

In (2), Each $\mathbf{B}_{t2}$ and $\mathbf{B}_{t1}$ is tangential component of flux density on the condition that the region IV is assumed to flat core and air, respectively. Therefore, the magnetic field by the EMC of the primary core is obtained from the solution of characteristic equations for each region. In the case of being slots, it can be thought that there exists the virtual flux at the surface of the core, which functions to turn the flux caused by PM into zero in slot area. Hence the slot effect can be included in the characteristic analyses by calculating the virtual EMC distribution in slot area.

Conclusion

As Fig. 3 shows, each flux density distributions at the center of air gap obtained respectively from the proposed analytical method including slot effect, FEM, and experiment, is almost identical. From a result, the slot effect is taken into good consideration. The static trust of PMLSM in relation to displacement of PM's is shown in Fig.4. And the static thrust evaluated by the proposed method agrees closely with that of FEM, but is larger than that of experiment, which mainly results from the assumption of infinite permeability and experimental error.

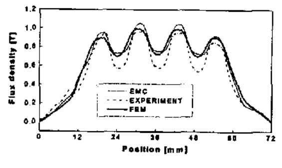

Fig. 3 Airgap flux density distribution

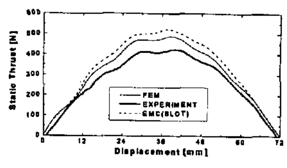

Fig. 4 Static thrust

In this paper, the proposed EMC method is based on the conventional one in calculating the magnetic field of the PMLSM but it has capability to take into account the change of magnetic field using the virtual EMC caused by slot geometry. And it shows that the slot effect can be simply considered without using the numerical methods.

The proposed EMC method, therefore, is useful for initial design of electrical machine in which it is essential to reduce the space harmonic components resulting in mechanical vibration and noise.

References

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