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Analysis of Dynamic Model with 3-D Finite Element Method for Linear Induction Motor

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Abstract

This paper presents the analysis of electromagnetic coupling characteristics for linear induction motors (LIMs) using the 3-D finite element method (3D-FEM). LIMs have advantages of simple structure, easy maintenance, less environmental pollution, and they are widely used for high accuracy transport systems. Due to the three-dimensional geometry traveling at limited distance and ends effect of LIMs, it is difficult to analyze the coupling effects of LIMs numerically. In this paper, the 3D geometry with coils of a linear induction motor will be described by 3D-FEM model, which it is induced from the sided areas of LIMs would have magnetic distribution different from the central area, and the exciting current and air gap will be defined as design parameters to calculate the flux leakage and electromagnetic normal force at different operating conditions. Finally, the dynamic characteristics can be described in the proposal model.

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Keywords: Linear Induction Motor(LIM); Finite Element Method

1. Introduction

Due to the development of motor design technology in industrial techniques, the rotary machine is usually applied in engineering and research areas as the main power source for years. As driving rotation motion to linear motion in industrial application, some mechanical accessories will be assembled in the motion transformation. LIMs have advantages of simple structure, easy maintenance, less environmental pollution, and are widely used for high accuracy transport systems. In the linear system power transformation processes, the energy loss and noise will affect the accuracy of dynamic motion performances, the analysis and design of LIMs technique has rapidly been applied on industry [1-6].

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The characteristics of limited travel-distance and three-dimensional geometry of side ends, the performance of motors will be influenced by magnetic distribution. So, it is difficult to numerically predict the coupling characteristics on LIMs.

2. Model descriptions and results

The proposal model is an **E** type shaded-pole flat single-sided LIM [7]. The construction is very simple, its physical model and specification as shown in Table 1. There are 3 magnetic poles with 500 winding coils as primary rotor, which are exciting by 3 phases AC currents, the magnetic poles can be modified as shown in Figure 1. The linear travelling rail is 2 meters, and it is included two parts as secondary stators, which are a thickness 3.18mm and width 5 cm of Aluminium material and a thickness 2.67mm and width 5 cm of Iron material part. Due to a large air gap and the phase shift by 3 phases' current sources between winding coils, the power loss and energy converter can be described as shown in Figure 2. In this figure indicated that P1 is power sources, P2 is magnetic pole loss, P3 is winding coils loss, P4 is energy transfer from primary rotor to secondary stator, P5 is rail loss, P6 is different material energy transfer, P7 is mechanical friction loss, and finally P8 is the energy can be transferred from power sources. So, the ratio between P1 to P8 can be obtained as the efficiency of the LIM. The material loss can be observed on P2 and P3. Considering power loss of physical constructions, the equivalent magnetic circuit model as shown in Figure 3.

In this paper, the exciting current and air gap are defined as parameters of design and analysis to observe the characteristics of transient response for LIM. First, the exciting current will be defined from 1.4 A, 1.7 A, 2.0 A to 2.3 A, and the air gap will be defined from 1 mm, 2 mm, 3 mm to 4 mm. Then, the transient flux distribution of exciting current at 1.4 A and air gap 1 mm can be obtained as shown in Figure 4, the transient flux distribution of exciting current at 1.7 A and air gap 1 mm can be obtained as shown in Figure 5.

Table 1

ITEM	SPECIFICATION
Poles	3
Length of magnetic pole	150mm
Width of magnetic pole	3.1mm
Height of magnetic pole	104.3mm
Between two poles	0.031m
Length of rail	2.0m
Thickness/width of Aluminium part of rail	3.18mm/5 cm
Thickness/width of Iron part of rail	2.67mm/5 cm
Rated voltage	125 V
Rated current	3.0 A
Resistance	46.67Ω
Coils	500
Air gaps	1mm~5mm

3. Discussions and conclusions

According to the proposal model, the physical construction of linear induction motor can be simulated and analysed by the equivalent magnetic circuit model of the finite-element method (FEM). The changing parameters of exciting current and air gap at different operating conditions can also be taken into account in this paper. Even though linear induction motors are a large air gap and low power efficiency, based to the obtained results in this paper, the dynamic performances of flux distribution and electromagnetic normal force can be predicted and obtained by the proposal parameters of exciting current and air gap. From the obtained data can indicate that, as increasing the exciting current and air gap, the leakage rate between primary rotor and secondary stator can be calculated about 6.15%, 14%, 19%, 22.06% as shown in Table 2.

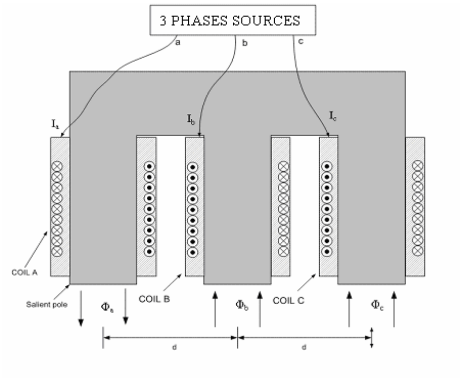

Figure1. Primary rotor of winding coils and magnetic poles

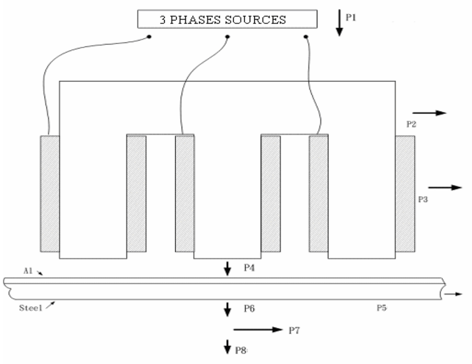

Figure 2. Power distribution between primary rotor and secondary stator

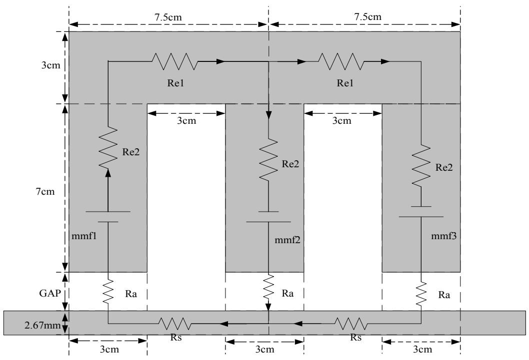

Figure 3.Equivalent magnetic circuit model

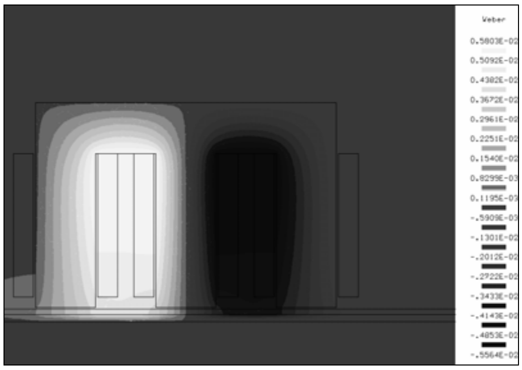

Figure 4. Flux distribution at exciting current 1.4 A and air gap1 mm

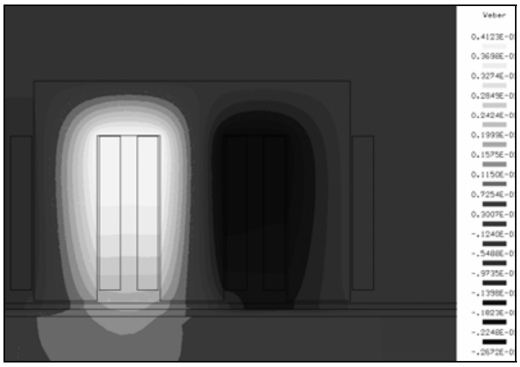

Figure 5. Flux distribution at exciting current 1.7 A and air gap1 mm

Table 2

Exciting currents	Air gaps			
	1 mm	2 mm	3 mm	4 mm
1.4 A	6.2595	5.5356	4.9174	4.3762
1.7A	7.6009	6.7219	5.9712	4.7317
2.0A	8.9422	7.9085	7.0249	6.2517
2.3A	10.284	90947	8.0787	7.1894
Leakage Rate	6.15%	14%	19%	22.06%

(Unit:Tesla)

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