International Journal of Advancements in Electronics and Electrical Engineering– IJAEEE
Volume 4 : Issue 2 [ISSN : 2319-7498]
Publication Date : 30 October, 2015

Effect on Motor Performance of The parameter τ_{pm} of Linear Permanent Magnet Synchronous Motors Matlab/Simulink based

Özcan Otkun, Faruk Demir and A. Sefa Akpınar

***Abstract*— In this study, Linear Permanent Magnet Synchronous Motor (LPMSM) was carried out in order to increase the performance. The study was carried out speed control by vector control methods. For performance analysis of the motor, pole pitch (τ_p) kept constant and pitch of permanent magnet (pole shoe, τ_{pm}) value is changed, and the condition examined the effect on motor performance. The study simulation model has been carried out in Matlab/Simulink software. According to the results obtained, τ_p Value, τ_{pm} is selected at a value close to the value, and was observed that positive effect performance of the motor.**

***Keywords*—motor performance, pole pitch, LPMSM, simulink**

I. Introduction

Linear movement is to grow in importance depending on to the technological developments. The history of linear motor (LM) is based on the end of 19th century. These motors were not used in practice for the next 30-40 years, but various studies have been made on the LM [1, 2]. After the 1960 implementation of LM developed rapidly, and has found many applications until from the drive of high-speed trains, magnetic pillow. In the literature, the design work was made usually between the years 1960-2000, after the 2000s both design and control studies has increased [2, 3].

The motor performance is important in this system, the contribution of the structural design is extremely important. In transportation and automation systems, permanent magnet synchronous motors are preferred because of high thrust force. And it is important to design the placement of the permanent magnet in terms of thrust and speed control [3].

Özcan Otkun
Department of Computer Technology/Gümüşhane University
Gümüşhane/Turkey

Faruk Demir
Computer and Instructional Technologies / Atatürk University
Erzurum/Turkey

A.Sefa Akpınar
Department of Electric-Electronic/Karadeniz Technical University
Trabzon/Turkey

According to the study, LMs are designed in different structures. In this respect, the surface magnetic design in low speed applications and the buried magnet design in high speed applications are preferred [4, 5].

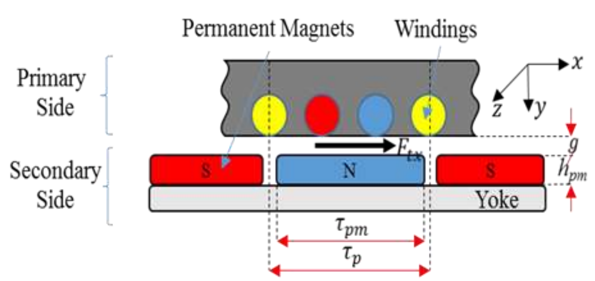
In this study, the linear motor is proposed a study to increase the performance. In the study conducted, τp kept constant τpm the value is changed. In this case, the motor performance was investigated. First, the mathematical equations known about the linear motors are given. Then, the method of study related to the magnet is described. This study has been modeled in Matlab/Simulink Software and the results obtained from this model were analyzed.

II. Material and Method

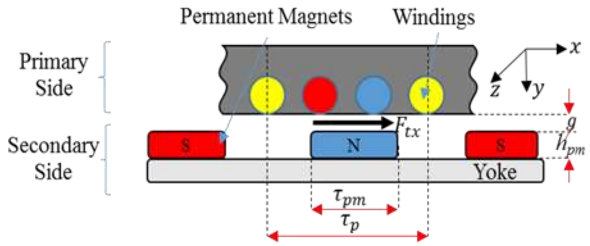
The structure of the LPMSM, classic rotary synchronous motor was created with the opening cut considered. Here, moving part shows primary side (3-phase windings on it) and fixed part shows the secondary side (the part where permanent magnets were placed).

In the literature, the pole pitch is called as the distance between the windings of one phase. There are permanent magnets on the secondary side. Here, permanent magnets are positioned below the pole pitch. This situation is shown in Fig. 1.In Fig. 1a and b, $\boldsymbol{\tau_p}$ was kept constant. Effects occurring in the motor have been investigated of changes in the value $\boldsymbol{\tau_{pm}}$ using Matlab / Simulink.

The thrust force of a LPMSM can be calculated directly on the basis of the electromagnetic field distribution [6]. Fig. 1 shows a single side LPMSM with surface configuration of PMs for two dimensional electromagnetic field analysis [7].



(a)



(b)

Figure 1. The model of a LPMSM with surface configuration of PMs
(a) The first test model
(b) The second test model

The time-space distribution of the primary side line current density for the fundamental space harmonic can be obtained by taking the first derivative of the primary MMF distribution with respect to the x coordinate. The thrust for the fundamental harmonic can be found on the basis of Lorentz equation. According to this, F_{tx} (thrust force) [7],

$$F_{tx} = \frac{4}{\pi} p\tau_p L B_r A_m \sin\left(\frac{\alpha\pi}{2}\right) \frac{\tanh \beta h_{pm}}{\mu_{rrec} \sinh \beta g + \tanh \beta h_{pm} \cosh \beta g} \quad (1)$$

The above Equation (1) has been derived and verified by H. Mosebach and then developed further for armature line current waveforms other than sinusoidal [7].

Where,

$$A_m = \frac{m\sqrt{2} N k_w I_s}{p\pi} \quad (2)$$

And

$$\beta = \frac{\pi}{\tau_p}, \qquad \alpha = \frac{\tau_{pm}}{\tau_p} \quad (3)$$

In Matlab, when the simulation model of the linear motor was generated, the rotary synchronous motor was adopted similar to with mathematical model of the two-axis (d-q), mathematical expressions were used as known in the literature [8]. According to this;

The voltage equations in the d-q axis:

$$u_d = Ri_d + \frac{d\psi_d}{dt} - w\psi_q, \qquad u_q = Ri_q + \frac{d\psi_q}{dt} + w\psi_d \quad (4)$$

Where, u_d and u_d: Primary side voltages, i_d and i_d: Primary side currents, w: Angular velocity. And,

$$w = 2\pi f = v\frac{\pi}{\tau_p} \quad (5)$$

Where, τ: Pole pitch, v: Linear speed. And linear speed:

$$v = 2 f \tau_p \quad (6)$$

The flux equations in the d-q axis:

$$\psi_d = L_d i_d + \psi_{pm}, \qquad \psi_q = L_q i_q \quad (7)$$

From here, the electromagnetic thrust force is obtained [9].

$$F_t = \frac{3}{2} p \frac{\pi}{\tau_p}\left(\psi_d i_q - \psi_q i_d\right) = \frac{3}{2} p \frac{\pi}{\tau_p}\left[\psi_{pm} + \left(L_d - L_q\right) i_d\right] i_q \quad (8)$$

LPMSM mechanical thrust force equation:

$$F_t = F_h + Bv + M\frac{dv}{dt} \quad (9)$$

Where, F_h: External (outside) force, B: Friction force, M: Motor (moving part) mass.

In these equations given instead of Equation (8), in order to use τ_{pm} and τ_p parameters the Equation (1) is used in simulation model. Excitation in this motors is provided with permanent magnets located in the secondary side, i_d current that is the component generating the secondary side magnetic field is not required. Therefore, the motor control was carried out with vector control depending on i_q [10, 11].

Matlab/Simulink simulation block model is shown in Fig. 2.

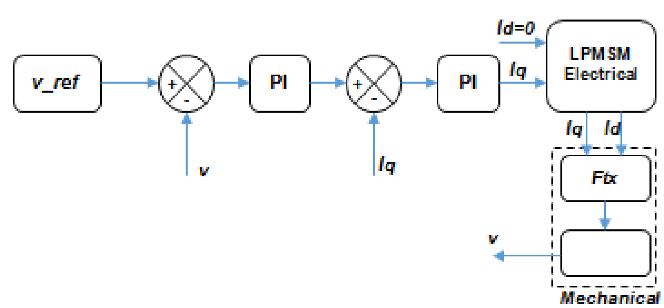


Figure 2. The simulation block model of LPMSM

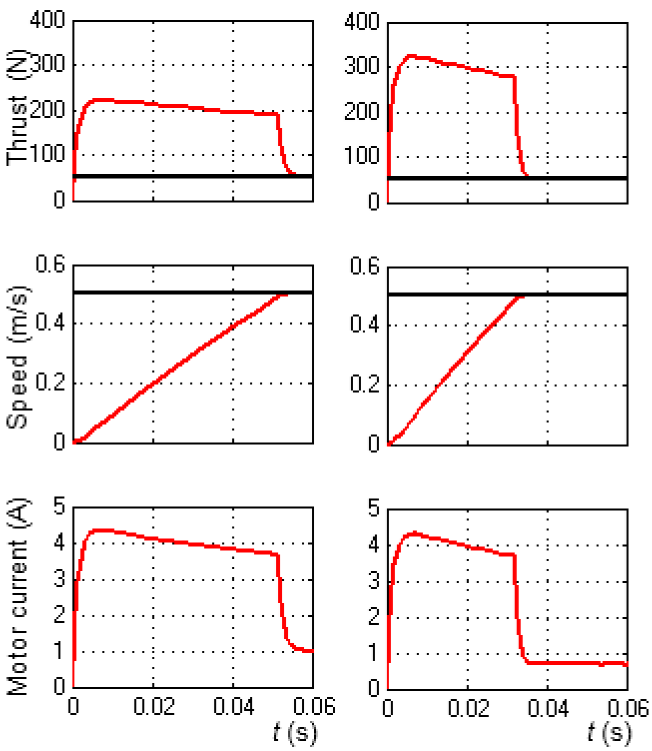
III. Simulation Results

Simulation results are obtained from τpm and τp values given in Table 1. In this study, the two different values are used for τpm.

TABLE I. τ_{PM} VALUES USED IN SIMULATION TESTS

Tests	τ_{pm} (mm)	h_{pm} (mm)	τ_p (mm)
First test	20	10	42
Second test	40	10	42

Correspond to the values of Table 1, obtained from the simulation model; thrust force, speed control and motor current graphs are shown in Figs. 3. Here, Fig. *a* the first test, Fig. *b* the second test is results.



(a) (b)

Figure 3. The results of simulation models

Examined the thrust force's graphs; while τ_{pm}=20mm, during takeoff thrust force the motor is 200 N. While τ_{pm}=40mm, during takeoff thrust force the motor is 300 N. In this case, while τ_{pm}=40mm the motor during takeoff thrust force is seen that the increase rate of 50%. At the same time, while τ_{pm}=40mm reference to thrust force reaches 0.035 second, while τ_{pm}=20mm reference to thrust force reaches 0.035 second. In the second test of the motor relative to the other before 0.02 seconds has reached the reference thrust force.

Examined the speed control's graphs, the motor reference speed access time while τ_{pm}=20mmis 0.052 sec., while τ_{pm}=40mm is 0.033 sec. In the second test of the motor relative to the other before 0.02 seconds has reached the reference speed. Thus, the speed control is realized in a shorter time.

Examined the motor current's graphs, in two tests, during takeoff the motor did not change the current drawn. At the same time, while τ_{pm}=40mm, the current drawn by the motor when it reaches the reference speed, 0.7 A. In this case, in comparison to the first test the motor can be seen that 30% less current.

As a results, thrust force, speed control, and the positive effects in the motor current can be said that a favorable effect on motor performance while τ_{pm}=40mm.

IV. Conclusions

In this study, of τ_{pm} value have investigated the effect on the performance LPMSM. The permanent magnets on the secondary side value τ_{pm} was selected as possible as near valueτ_p, it is observed that the motor performance was increased. Matlab / Simulink environment carried out in this study can be said to contribute to the control study. Studies on the linear motor are currently active research topics in many countries, and the studies are thought to contribute to the literature. This study can be advised for automation systems and practice. Thus, an important contribution in both academic and industrial areas can be obtained.

References

[1] R. Thornton, M. T. Thompson, B. M. Perreault and J. Fang, Linear Motor Powered Transportation, IEEE Journals & Magazines , vol. 97, no. 11, pp. 1754 - 1757 , 2009.

[2] M. Salman, Analysis, Design and Control Aspects of Linear Machines Using Co-simulatio', Master Thesis, Stockholm, Department of Electrical Energy Conversion, School of Electrical Engineering, Royal Institute of Technology (KTH), 2012, pp. 18-19.

[3] W. Li, K. T.Chau, Design and qnalysis of a novel linear transverse flux permanent magnet motor using HTS magnetic shielding, IEEE Transactions On Applied Superconductivity, cilt 20, no. 3, pp. 1106-1109, 2010.

[4] K. Minoru, Application of permanent magnet synchronous motor to driving railway vehicles, RailwayTechnology, Avalanche, cilt 1, no. 1, p. 6, 2003.

[5] D. S. Krishna and C. S. Rao, Speed Control of Permanent Magnet Synchronous Motor Based on Direct Torque Control Method, International Journal of Advances in Science and Technology, cilt 3, no. 2, 2011.

[6] K. Alicemary, B. Arundhati and P. Maridi, Modelling, Simulation and Nonlinear Control of Permanent Magnet Linear Synchronous Motor, International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, vol. 1, no. 6, pp. 555-562, 2012.

[7] J. F. Gireas, Z. J. Piech, Linear Synchronous Motors: Transportation and Automation Systems, Boca Raton, London: CRC Press, 2001.

[8] L. H. Zheng, J. X. Jin, Investigation of HTS bulk magnet linear synchronous motors, Chengdu: Proceeding of IEEE on Applied Superconductivity and Electromagnetic Devices, pp. 17-21, 2009.

[9] P. Ponomarev, Control of Permanent Magnet Linear Synchronous Motor in Motion Control Applications, Lappeenranta: Department of Electrical Engineering, Faculty of Technology, Lappeenranta University, Master's thesis of Technology, 2009.

[10] A. Haitham, I. Atif, G. Jaroslaw, High Performance Control of AC Drives With Matlab/Simulink Models, Noida, India: Wiley, 2012.

[11] T. R. Fernandes, Short Primary Linear Drive Designed for Synchronous and Induction Operation Mode with On-Board Energy Storage, Darmstadt: Technischen Universität, 2012.

Özcan Otkun

He received M.E degree in Electrical-Electronic Engineering from Selçuk University and PhD degree from Karadeniz Technical University. His research interests are power electronic, electrical machinery and control.

Faruk Demir

He received M.E degree in Institute of Educational Sciences from Karadeniz Technical University. His research interests are computer programming, software visualization, computerized control.

A. Sefa Akpınar

He received his BE degree from İstanbul Technical University, and PhD degree from University of Strathclyde. He is a professor of Department of Electrical Engineering in Karadeniz Technical University.