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SOME ASPECTS OF THE MAGNETIC FIELD DISTRIBUTION PROBLEMS OF LINEAR INDUCTION MOTOR

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Abstract- In this study, linear motors has been examined with three-phase moving magnetic field models and insufficiently-research parts of the problem have been interpreted as different models in the literature has been evaluated. Polar step-change on the moving area has been modeled with variation of magnetic flux. The rotor and stator magnetic flux change has been demonstrated graphically and envelops during in different times calculated theoretically. When these changes are taken into consideration, possible changes of graph in the moving magnetic field consist of three-phase has been plotted. Possible change model in parts of rotor and stator of magnetic field are interpreted. In fact, taking into consideration the magnetic field, change of moving magnetic field on graph discussed the necessity of the disclosure in terms of the electromagnetic field theory or ponders motive force assumptions.

Keywords: Linear Motor, Moving Magnetic Field, Magnetic Flux, Electromagnetic Force.

I. INTRODUCTION

Nowadays, due to the acceleration of technological and scientific advances, scientist required to design and use advanced technological application in technology and electro mechanism. One of the most important elements of the technological processes used in the industry is electrical motors and drivers. With the progress of technology developments in power electronics and microprocessor technology allows that more efficient operation of electrical machines and drivers and the creation of more flexible control systems. Therefore, today, the electrical machines drivers, is one of the components which base on robotic technology and flexible control systems.

About 40 percent of electric motors used in industry are used machines and mechanisms which forward-backward linear motion. Therefore, additional mechanisms are needed for converting linear motion to rotary motion of the motor shaft. These additional mechanisms are causes an increase in losses and decrease the flexibility of the machine's operating.

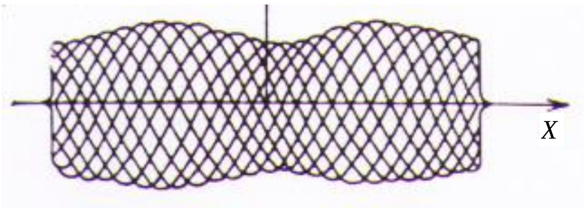
Linear electric motors that have the ability to move forward-backward allow the removal of transmission elements such as repulsive, converter. This is provide that mechanisms which working with linear electric motor connect to same body. Thereby, a linear motor contributes to elimination of additional losses and flexible operation of the system.

In some of the working mechanism is not possible determine the boundaries between linear electric motor drivers system with working mechanisms of automatic control system. In other words, linear motors constitute part and parcels with operating mechanisms.

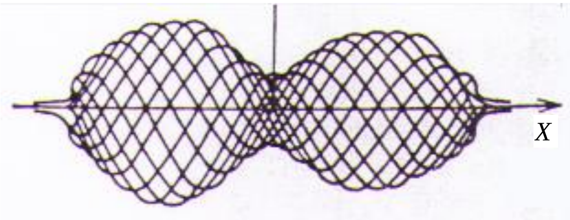
Today, vast majority of hundreds of scientific studies which published in the field of linear induction motors survey are take into account the effect of edge and tip theoretical research [1-9]. One of the problems encountered in the study of linear induction motors investigate the moving linear magnetic field [6, 7].

The magnetic field of an linear motors more complex than that of a rotating induction motor. At analysis of linear motor limited dimensions of the inductor should be considered. Therefore it is necessary to investigate the magnetic fields beyond the inductor boundaries (edge effect and end effect), and interdependencies of these fields. Because of the phenomenon of end effect, additional factors must be considered: there is a reduction of attraction force, and despite a balanced supply voltage, increased phase impedance and phase differences of leading currents [8]. There are many methods of analysis and syntesys of the magnetic field and end effects. From these approches three methods are significiant which give reliable results of calculations for linear methods, i.e. Shturman's [3], the Yamamura's method [10] and a method which utilizes the coefficient of longitudinal end effects [7].

An aproach which are sperated of magnetic field of linear induction motors and proposed by Sadovsky [9] has been shown in Figure 1. This approach has been used by many investigators [9].



(a)



(b)

Figure 1. Propogation curves of magnetic flux density in the air-gap of linear induction motor (Sadovski model [9])

Although there is a large number of moving magnetic field models presented in the literature, there are not different approaches and interpretations belonging to the formation and effect of such areas.

The concept of linear electric motors is more than 170 years old. The first proposal was patentetin 1841. The first linear induction motor (LIM) was patendent in 1890 [7]. The physical meaning of the amplitude of magnetic induction pulsation in inductor bank range has been announced for the first time scientific study of Shturman G.I. [3]. This study demonstrated that getting the area two pulsations, another walking wave with constant amplitude in air gap. When one of these areas variables the hyperbolic cosine law, other varies with hyperbolic sine law. Sliturman's model which has been created to assess magnetic shunting event is assumed that there are hypothetical areas of uncertain length in magnetic field between ends of magnetic circuit.

In reference [4], the installed state of open magnetic circuit induction motor is examined. Here, using the method of superposition, primer and secondary areas has been examined separately. As a result of theoretical analysis, it is different losses of secondary circuit, speeds that ideal no-load operation, induction of moving magnetic field. This analysis are examined that secondary speed is different than synchronic speed, length of shunt ranges and other problems [2]. Other sources are taking into the spread of waveform area.

Simulation of flux density under different tooth's obvious that magnetic field under ending and middle tooth pulsates with different amplitudes and phases [8]. By investigating magnetic flux outside the inductor at different air gap widths, it is shown that characteristic are not linear: then is big air gap width, when dependency on air gap width changing is lower. Magnetic flux density in the air gap varies more in cross-section near inductor and in cross-section near secondary element.

The examining theoretical and experimental results presented in literature of moving magnetic field are shown that different models in this topic are described under different condition. Moreover, none of the models is not completely explain the formation of walking magnetic area and effect of mechanisms. For this reason, lack of these problems in walking magnetic fields, both theory and practical application, examined and more detail investigations are needed.

II. MODELING OF MOVING MAGNETIC FIELD

As is known, the running of the motor and other theoretical examining are performed in rotating electric motors, however, take into consideration the rotating magnetic field. Electrical field which occurring in this situation is not considered because of it is very small. In analysis and design of linear electrical motors are used electromagnetic wave theories.

Therefore, in the literature there are no knowledge about two pulsations field which is reported in [3], secondary speed which is different from synchronous speed in [4] and the length and formation of shunt ranges. In this study, the effect of this fields has been neglected in linear motors because of the effect of electrical field to operating motor is less than and considering the effect of magnetic field, moving magnetic field are examined. The laboratory model of the linear induction motor has been made and examined for comparing the theoretical and experimental investigation and consolidation of result which are obtained (Figure 2).

(a)

(b)

Figure 2. Views of linear induction motor: (a) side view; (b) top wiev

Part of the model which is used to perform the experiments is presented in Figure 3.Width and length of magnetic circuit is respectively 0.01m and 1m. Magnetic circuit has been constituted ш-shaped sheets which has been prepared electrical steel with thickness of 0,35 mm.

Placement of bobbin and magnetic flux lines which generated A-phase represented in Figure 3. Bobbins of each phase are connected to as back to each other. Magnetic flux lines which generated by A-phase represented in Figure 4. Here, major flux line from the parts of the magnetic circuit placed A-phase bobbin, φ_{σ} magnetic flux from the magnetic circuit of B and C are covered infinite discontinuity. In the sub-grade, according to flux lines are covered with ferromagnetic material, leakage areas may not be taking into consideration.

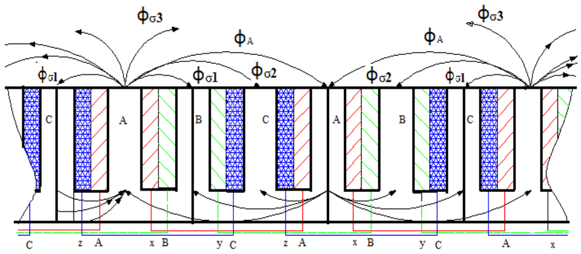


Figure 3. Placement of bobbins in linear induction motor Φ_a-magnetic flux formed by A phase bobbin and lines of fugitive magnetic flux-Φ_{6k}

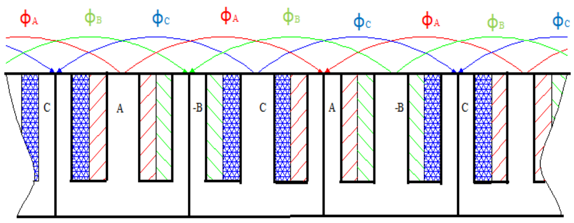


Figure 4. The distribution of magnetic flux lines Φ_A, Φ_B, Φ_C in the values of $I_a'=I_{max}$, $I_b'=I_{max}$, $I_c'=I_{max}$.

The same way as it is magnetic flux line propagation of B and C phases are not shown for not having complex the shape. Clearly, phase B and C can be including with a specific phase shift which assume for A phase. Magnetic flux lines composed by each of three phases are presented in Figure 4. In this figure, lover part of closing ferromagnetic materials of flux is shown to avoid complex shape.

As linear asynchronous motors fed by three-phase sinusoidal current, magnetic flux will vary with the sine law. In other words;

$$\varphi_A = \varphi_{\omega} \sin \omega t \quad (1)$$

$$\varphi_B = -\varphi_{\omega} \sin(\omega t - 120°) \quad (2)$$

$$\varphi_C = \varphi_{\omega} \sin(\omega t - 240°) \quad (3)$$

It will describe. We can calculate the phase flux which values corresponding to these values with ωt argument by giving different values. In this way;

ωt =0°, φ_A=0

φ_{-B}=-φ_{ω}.sin(-120°)=0.866φ_m

φ_C= φ_m.sin(120°)=0.866φ_m

$$\sum \varphi_T = \varphi_A + (-\varphi_B) + \varphi_C = \\ = (0 + 0.866 + 0.866)\varphi_m = 1.732\varphi_m \quad (4)$$

In this procedure, values that are calculated at different time of φ_T are presented in Table 1.

Table 1. Values that are calculated at different time of φ_T

ωt	$\sum\Phi$	ωt	$\sum\Phi$
0°	(0+0.866+0.866). Φ_m =1.732 Φ_m	300°	(0.866+0+0.866). Φ_m=0
30°	(0.5+1+0.5) Φ_m=2Φ_m	330°	(0.5–0.5+1) Φ_m=Φ_m
60°	(0.866+0.866+0) Φ_m =1.732Φ_m	360°	(0+0.866+0.866) Φ_m =1.732Φ_m
90°	(1+0.5–0.5) Φ_m=Φ_m	390°	(0.5+1+0.5) Φ_m=2Φ_m
120°	(0.866+0–0.866) Φ_m=0	420°	(0.866+0.866+ 0) Φ_m =1.732Φ_m
150°	(0.5–0.5–1) Φ_m=-Φ_m	450°	(1+0.5–0.5) Φ_m=Φ_m
180°	(0-0.866-0.866) Φ_m =-1.732φ_m	480°	(0.866–0–0.866) Φ_m=0
210°	(-0.5–1–0.5) Φ_m =-2Φ_m	510°	(0.5–0.5-1) Φ_m=-Φ_m
240°	(–0.866–0.866+0) Φ_m =-1.732Φ_m	-30°	(-0.5+0.5+1) Φ_m=Φ_m
270°	(–1–0.5+0.5) Φ_m=-Φ_m	-60°	(-0.866+0+0.866) Φ_m=0

According to algebraic calculations to the data in table 1and as a result of graphically calculation of waveform in Figure 5, total magnetic flux waveform is considered in Figure 6.

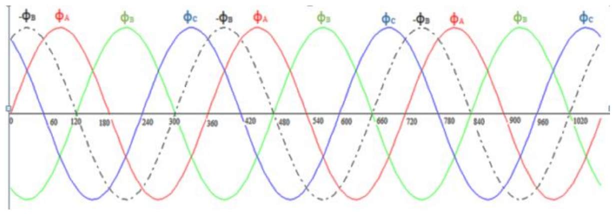


Figure 5. The distribution of magnetic flux lines Φ_A= $\Phi_m$sin(ωt), Φ_B=$\Phi_m$sin(ωt+120), Φ_C=-$\Phi_m$sin(ωt)

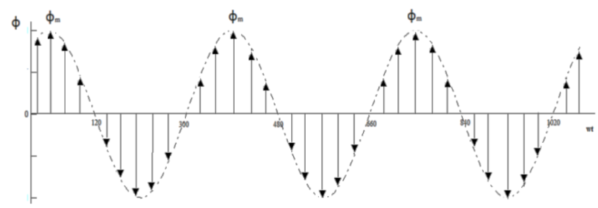


Figure 6. Wave diagram of Φ=(Φ_A+Φ_C-Φ_B)=$\Phi_m$sin(ωt+φ)

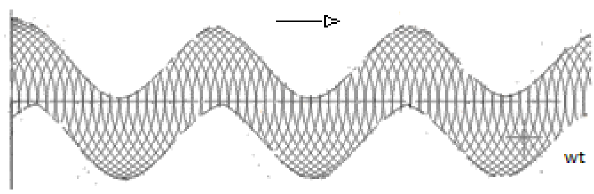


Figure 7. Φ=$\Phi_m$sin(ωt+φ) space diagram of the magnetic field and direction of progress

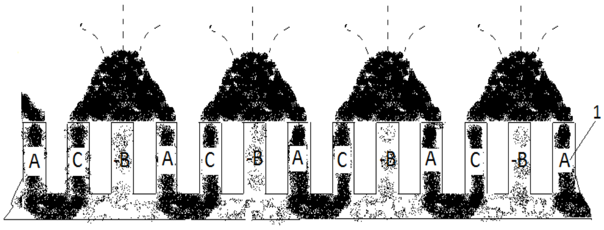
If reflected spaces which seen in Figure 3 is taken into account, area form that shown in the Figure 7 can be obtained. This moving field is consist of the sum of two fields according to wt axis.

Envelops of these areas has been limited with sinus-like, one of them(see above section) is ferromagnetic layers that make up rotor of the motor, the other(see the following section) are covering the magnetic circuit of the stator is able to wave with the *V* speed (Figure 8).

$$V = 2\tau f(1-S) = \frac{\omega}{a}(1-S) \tag{5}$$

where:

$$a = \frac{\pi}{\tau}$$



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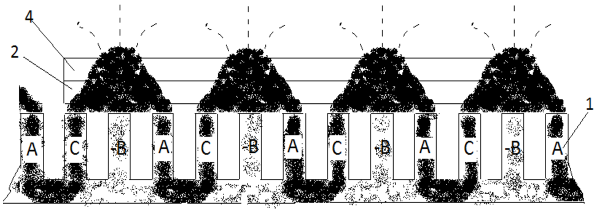

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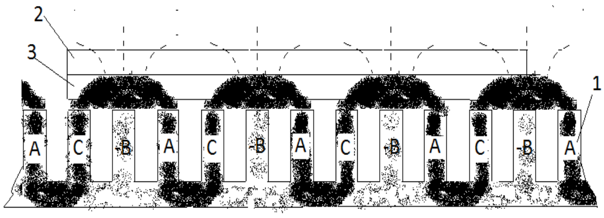

(c)

Figure 8. The appearances of the walking magnetic field for different occasions in linear induction motor. (a) without rotor, (b) use of diamagnetic material as rotor, (c) use of ferromagnetic materials and aluminum as rotor; 1- Ferromagnetic core, 2- Aliminum layer, 3- ferromagnetic layer, 4- bronze layer

Due to the assence of paper constitute the mathematical and graphical modeling; one further additional of paper the chapter is not necessary.

III. CONCLUSIONS

1. In the literature, motion of the lineer motors explained within the framework of electromagnetic wave theory. In this case, examination of the field changes, the driving force and synchronous speed come to light some problems. Explanation of this problem according to electromagnetic wave theory is not sufficent.
2. The evaluation of lineer motors theory in terms of magnetic field theory will allow the solution of many problems. Description of moving magnetic field which it is active in lineer motors modeled as similar to the general theory of induction motor. His approach is allow that creating equivalent magnetic circuit of lineer motor, determining the graphically and analytically the change of the magnetic field in different parts of rotor and stator phase.
3. Examination method suggested in the article can be used in the design of the linear electric motors, determination of the characteristics and laboraatory experiments.
4. Approach is presented the ideas of the authors and is open to debate.

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