Study characteristics linear induction motor in the transport system package forming machines

authors: Taras Gnativ, Oleksandr Volodin
scientific adviser: assoc.prof. Ludmila Kryvoplias-Volodina
prof. Alexander Gavva

Abstract: *In this work considered and implemented computational and theoretical studies of the characteristics of the linear induction motor (LIM) based on the basic design data package forming machines, articulated sequence of rational choice of their values. The object of research: the work is a linear induction motor of the electric vehicle as part of the module package forming machines. The results of computational and theoretical studies allow you to select parameters in the design of low-speed transport system with a linear induction motor. The results may be useful for other technological machines and industrial complex lines.*

Key words: *linear induction motor, the design parameters of the model, rational values*

INTRODUCTION

The widespread use of automated electric drive will improve the productivity and competitiveness of domestic system package forming systems. An increase in the areas of industrial process systems require a comprehensive mechanization and electrification of technological processes with the introduction of modern equipment. [1,3,7]. The transport system in package forming machines is a major influencing the performance of the technological industrial complex as a whole. Currently, there is an opportunity to increase productivity by 1.5-2 times [1,2,8], but it is necessary to solve the task of creating a modern transport system that would be able to cope with the increased volume of production. The transport system package forming machines with electric drive on the basis of a linear induction motor to simplify the kinematic scheme and improve reliability.

Materials and methods. The material of the study were towing power indicators LIM, depending on the design parameters of package forming machines. As a research method set out in the present work tasks, the methodology of calculation of the characteristics of LIM [3], based on the consideration of three-dimensional magnetic field in the gap, and the operators of MathCAD software.

An alternative type of electric monorail transport systems can be asynchronous drive on the basis of the linear motor. The advantages of such a system: the lack of traction link "wheel - shelf I-beam" that is, the simplification of the kinematic scheme; no moving parts, thus increasing reliability; for more accurate speed control and positioning; use the normal force to unload the support rollers; in the event of a power failure transport platform can be readily delivered to the desired location (without a clutch).

Depending on the assumptions made in the solution, ie the degree of idealization, the calculated LIM model is divided into one-dimensional, two-dimensional and three-dimensional. The most accurate are the three-dimensional model, which takes into account the distribution of the electromagnetic field in all three coordinates, Fig. 1. The method of calculating the characteristics based on these models give the most reliable

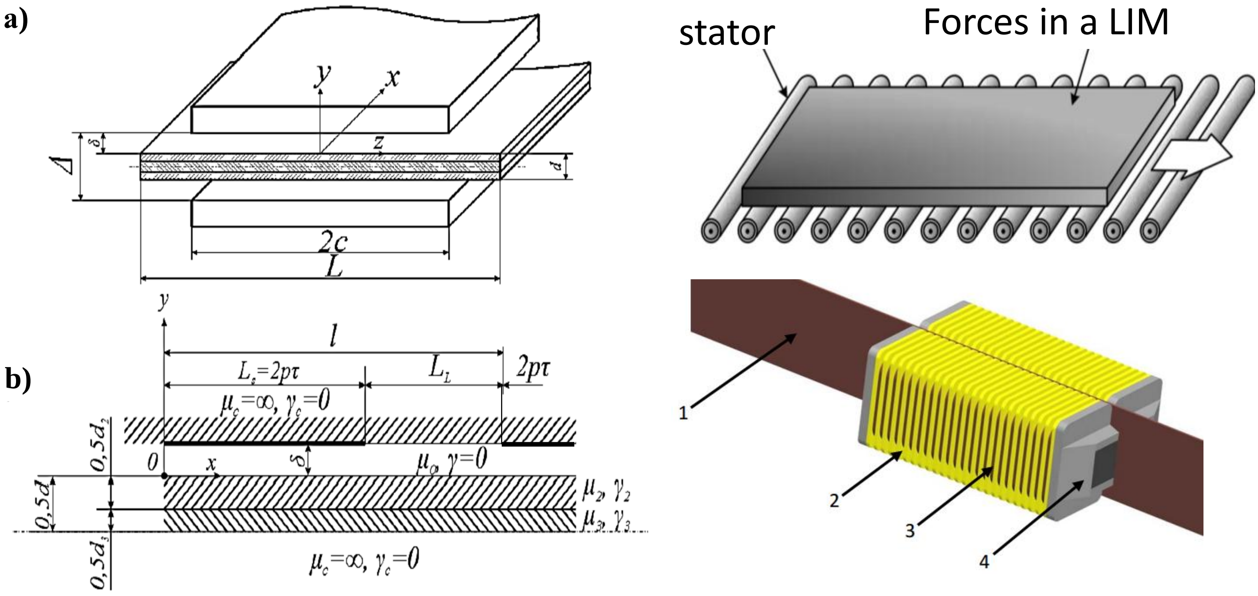

Fig. 1. Three-dimensional design model. Geometrical model of the linear induction motor: 1-mobile plate armature; 2- inductors; 3-windings; 4- yoke.

LAYOUT

He assumptions in the preparation of the model:

1. The model-linear, ie the magnetic permeability of iron core or permanent (μ_3 = const for a continuous OM) or $\mu_1 >> \mu_0$ (for stratified core inductor).

2. The winding distribution is not taken into account, consider the structure without grooves with a traveling sine wave linear current density.. The presence of the slots taken into account by the Carter factor, $\delta`=\delta\ K\delta$

3. The edge effects in the longitudinal and transverse directions into account the finite magnetizing forces but not cores. The end effect is at speeds up to 3 m/s ,(Reynolds magnetic number ε_0 <5) may not be taken into account [4,5].

4. Solution of the problem in most methods performed with a constant current in the winding I1 = const. Obviously, in this case a so-called inner solved task, only processes characterized in the gap and the secondary structure. This voltage will vary depending on the characteristics of the slip s and U (s) can be obtained by entering into account external scattering (winding resistance) . Also consider new systems of frequency control induction motor using the correction and direct torque control blocks. The control system maintains the motor torque at a critical level, i.e. engine as the control object is in an unstable state, and the control system it must have time to keep it unstable state. Three-dimensional computational model for rice. 2, based on the basis of its program and methods of calculating the integral and local characteristics have been developed by the authors of [4,5]. In formulating our problem taken the above assumptions and the winding current is laid on 2pт length, concentrated in an infinitely thin current sheets and creates a pure sinusoidal traveling wave magnetomotive force (MMF). (fig.2)

$$F=F_m\cdot f(z)\exp j(\omega t-x). \qquad (1)$$

MMF associated amplitude known [1] ratio with linear current load,

$$F_m = \frac{J_m \tau}{\pi} = \sqrt{2} A \frac{\tau}{\pi} k_o, \tag{2}$$

where $A = \frac{mwI}{p\tau}$ - linear current-carrying capacity - winding coefficient 1st harmonic, the primary field is approximated by an exponential function [6] in the field of the coil ends. Considering Fig. 2 shows the distribution of MMF longitudinal and transverse axes.

$$f(Z) = 0.83 e^{\frac{c-Z}{\Delta}}. \tag{3}$$

Getting a fixed coordinate system x, y, z in the early part of the wound inductor, Figure 2. MMF in the form of a double Fourier series :

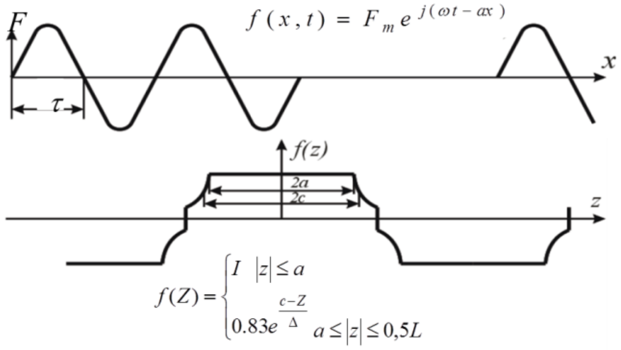

Fig. 2. Magnetomotive force of motor windings, along the longitudinal and transverse axes

$$F(x,z,t) = \sum_{n=-\infty}^{\infty} \sum_{v=-\infty}^{\infty} C_{n,v} e j \left(\frac{\pi n z}{L} + \frac{2\pi v x}{l} \right); \tag{4}$$

Initial areas for clearance δ, SRT (layers d2, d3) are the equations of the electromagnetic field [7]:

$$\begin{aligned} &rot\overline{H} = \overline{J}; \qquad rot\overline{E} = -\frac{\partial \overline{B}}{\partial t}; \\ &div\overline{B} = 0; \qquad div\overline{J} = 0; \\ &\overline{J} = \gamma \overline{E}; \qquad \overline{B} = \mu \overline{H}, \end{aligned} \tag{5}$$

where J - current density; E - electric field intensity; γ - conductivity material. Reactive bus consists of two layers of thickness d_2 and d_3 for a linear induction motor (LIM) with parameters γ_2, μ_2 , γ_3, μ_3 = const. Lack of experience in the creation and operation of industrial low-speed transportation systems to LIM and massive reverse magnetic circuit eliminates the possibility of using a single universal criterion LIM assessment as part of the system, so in the future as the analyzed indicators adopted by the main traction and energy characteristics Fx, efficiency η, the power factor cosφ. When this pulling force indirectly through the induction and flow in the gap, the core dimensions reflect capital costs and efficiency, and cosφ – operating costs. power factor at the terminals of the network (or inverter) is close to the value (0,9 ÷ 0,95) [7] for selecting respective capacitance $C_ф$, however, this figure does not reflect the economy is consumption of active power from the network, and only affects the losses in the winding way. These characteristics are not only the design parameters of the functions, but also slip, so you should decide on the operating mode, with the determination of the nominal slip and surge capacity at LIM, *U=const.* It is important to know how the relative magnitude of $s_н$ and secondary currents frequency f_2. For nominal value characteristics should be taken when *sн=sm*, where the driving force reaches its maximum value *Fx=Fxm* when *A=const (and* I_1*=const): Fxm, efficiency ηн, cosφн, U=Uн.*

Conversion to *U = const* regime confirms (1,5 ÷ 2) times the overload capacity of the LIM for traction power. Thus, the computational and theoretical studies were performed for the following parameters at *A=const*:slip *sm;*; specific traction $\mathcal{F}xm=Fxm\mathcal{S}$i; public and electromagnetic efficiency: η, η_{em}, electromagnetic and total power factor *cosφ*, $cos\varphi_{em}$ for s=*sm* . additionally calculated (for control) values Bδy induction in the gap, the normal force *Fy.* LIM test performance according to the model in Figure 1 is recorded in the form of functional dependencies:

$$\left.\begin{matrix} F_x \\ F_y \end{matrix}\right\} = f(\delta, 2\mathrm{p}, \tau, \mathrm{f}_{1,} 2c, L, d_2, d_3, \gamma_2, \gamma_3, \mu_3, A),$$

$$\left.\begin{matrix} \eta_{ЭМ} \\ cos\varphi_{ЭМ} \end{matrix}\right\} = f(\delta, 2\mathrm{p}, \tau, \mathrm{f}_{1,} 2c, L, d_2, d_3, \gamma_2, \gamma_3, \mu_3), \tag{6}$$

$$\left.\begin{matrix} \eta \\ cos\varphi \end{matrix}\right\} = f(\delta, 2\mathrm{p}, \tau, \mathrm{f}_{1,} 2c, L, d_2, d_3, \gamma_2, \gamma_3, \mu_3, J_1, r_1, x_{\sigma_1}),$$

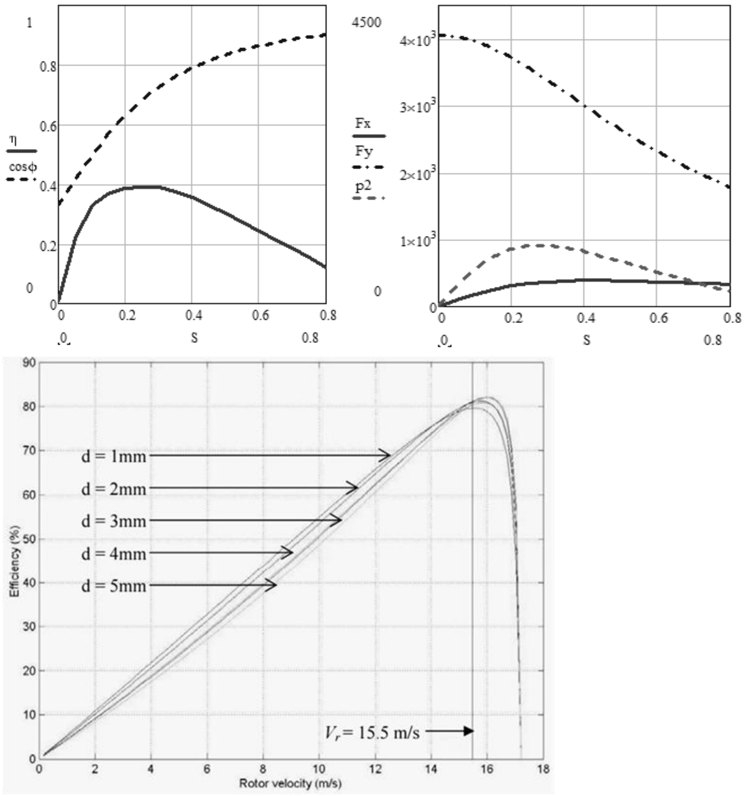

Fig. 3. Dependence of traction-energy indicators

The air gap delta δ and the thickness d_2 SRT form a common non-magnetic gap Δ / 2 = δ + d2 / 2, (Fig.1), which, by analogy with rotating asynchronous machine should be minimized. Obviously, the condition must be satisfied:

δ ≥ δmin, and δmin = (2 ÷ 4) mm, depending on external factors. Therefore, the minimum possible and shall be the value d_2.

However, for specific values of conductivity γ_2, d_2 value SRT determines the overall conductivity, hence the magnitude sliding loss. $\Delta Pem._2 = s \cdot Pem$ and efficiency.

We are see on the Fig. 3 shows the characteristics of LIM for two values of the gap δ = (2 ÷ 4) mm, other parameters remain unchanged (d_2 = const).

CONCLUSIONS AND FUTURE WORK

Increasing the thickness of RSH on the one hand leads to an increase in non-magnetic gap with all its consequences, and on the other increases the G_2, reduces slip *sm*. The value of the integral conductivity $G_2=\gamma_2 d_2$ can be achieved by selecting the material, - γ_2 (Practically the same may be copper or aluminum). Therefore γ_2 accepted for one of the independent variables. Perhaps the performance of the tire, as a combination of copper and aluminum tires of different thicknesses for the intermediate values G_2 and γ_2.

In particular thickness d_2 SRT variation layers d_2al aluminum and d_2cu copper is possible to achieve change interval γ_2=(3,5÷5,7) 107 sm/m. Thus, it solved the problem reduces to the study of functions of three independent variables: pole pitch T, the air gap δ and conductivity SRT γ_2. Other parameters are assumed to be constant or dependent. Further research is planned to conduct an experiment, with regard to the task at hand, and the calculation for the three-dimensional characteristics of the three-dimensional method

REFERENCES

[1] Епифанов А.П., Суслов А.М. Экспериментальная установка по исследованию частотно-управляемого асинхронного электропривода. Энергосбережение, электропривод, эксплуатация электрооборудования и автоматизация технологических процессов в АПК. Сборник научных статей, -СПб., 2004.-№3.-С.67-78.

[2] Епифанов А.П., Гущинский А.Г., Малайчук Л.М. Электропривод в сельском хозяйстве. - СПб: Лань, 2010. – 220 с.

[3] Москаленко В. В. Системы автоматизированного управления электропривода. - М.: ИНФРА-М, 2007. – 208 с.

[4] Технические информационные рессурсы. Электромагнитная совместимость. Практика приводной техники. [Електронний ресурс] : [Веб-сайт]. – Електронные данные. – EURODRIVE (SEW).- 2003. – 91 с - Режим доступа к каталогу: http://www.sew-eurodrive.ru/files/pdf/10530452.pdf — Название с экрана.

[5] Ямамура С. Теория линейных асинхронных двигателей. - Л.: Энергоатомиздат, 1983 - 180 с.

[6] Rinkeviciene R., Petrovas A. Dynamic Models of Linear Induction Drives. // Electronics in Electrical Engineering. - 2005.- Nr.5(61) –p.23-32.

[7] Eduard Biletskyi, Olena Petrenko, (2016), Three-dimensional model of non-Newtonian fluid flow in the rectangular channel // Journal of Food and Packaging Science, Technique and Technologies, Volume 5. Issue 3, p. 550-558.

About the authors:

Gnatov T., master's degree, Department of Technical Mechanics and Packaging Machinery, National University of Food Technologies.

Volodin A., student, Igor Sikorsky Kyiv Polytechnic Institute, The Department of Industrial Electronics.

Assoc.Prof. Kryvoplias-Volodina L., PhD, Department of Technical Mechanics and Packaging Machinery, National University of Food Technologies, E-mail: kryvopliasvolodina@camozzi.ua

Head of the Department, Prof. Gavva A., Dr., Department of Machinery and Equipment for Food and Pharmaceutical Industries, National University of Food Technologies, E-mail: aleksandrgavva@inbox.ru