Influences on Performance of the Linear Induction Motor for the Mining Systems with Different Parameters of the Power Source

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***Abstract*— This paper considers the possibilities of improving the energy and mechanical characteristics of the linear induction motor for the mining industry. The mathematical model of the linear induction motor takes into account the magnetic nonlinearities of materials, and also considers the possibilities to take into account edge effects in two-dimensional formulation of the problem. In this paper was considered the influence of parameters of the power supply source on the features of the linear induction motors. Firstly, the obtained results are compared with the actual characteristics of the object. All of the above studies have been carried out in accordance with the requirements and capabilities of the mining industry.**

Keywords—linear induction motor; energy characteristics, mechanical features, FEM, detailed equivalent circuit.

I. Introduction

Currently, development of a transport system technology requires new approach for design. Nowadays, conventional driver using in transport system reaches its peak of development. Therefore, at the present time it is increasingly possible to meet investigation of linear induction drivers [1-3]. The type of driver allows overcoming limitation of velocity, which is characterized by slippage of wheel pair [4-7]. Also in most cases, the use of linear drivers allows to decrease running resistance [8].

The work is considering analyze of linear induction motor (LIM) performance for the mining industrial depending on parameters of a supply source. The main used method for calculation of both mechanical and energy features are finite element method. The variety of linear induction motor designs cause difficult in the process of them design. The presence of edge effects changes behavior of curve of mechanical features. Therefore, in the paper is exploring shift of operating slips depending on parameters of a supply source. Comments are given for the optimal choice of parameters of a source for different operating modes. Validation of obtaining results by comparison with the gotten data from detailed magnetic equivalent circuits is given.

II. Formulation Problem

The section considers features of design and operating modes of the linear induction motor for mining industrial. The velocity of the motion of the conveyor train during time of a wagon load and unload a wagon is equal 0.4…0.6 m/s and 0.6…1 m/s, accordingly [9]. The most loaded modes of the driver on sections with elevation angle of 18-20 degrees. The system of the mining transport has designed with possibility of turn on simultaneously until 54 motors [9-11]. Wherein distribution of the load between the separate motor of the electric driver system is quite slightly. It is ensuring by soft mechanical characteristics (rated slip is about 25%) and the same non-magnetic gap between secondary and primary element of the motor [11]. The requirements of velocity control quality are not high in the section of a wagon load and a wagon unload and full mass of the conveyor train reach 200…225 tones and more, which makes it expedient using impulse control technique of the motion velocity of the conveyor train[9]. Implementation of the above technical requirements is realized at the expense of the LIM with nameplate data (Table 1) [10]. The transport system mining complex represents the conveyor train. The electric driver (ED) of the conveyor train is based on LIM. Implementation of the conveyor train is shown on the Fig.1. The length of the primary element is 1500 millimeters and the total length can vary , but according technical data not more than 101150 millimeters as shown on Fig. 1, a.

The basic elements of transport system are the primary element and the secondary element creating thrust. The power is supplied from the industrial power main through a removable cable entry. Inductor or other words primary element is static part of ED located under wagon and fastened by the support legs. The conductive layer of the secondary element (SE) is applied on back iron with help blast technique. In turn, back iron fastened on bogie bottom. The lid of screen serves for protection of the primary element (PE) against mechanical external impacts (for instance, falling charge or minerals).

Magnitudes of system geometry parameters “Primary element - secondary element” are displayed in Table 2. Parameters are general for creation of two-dimensional and three-dimensional mathematical model in computer environmental (Fig.2). Connection of windings for purpose to obtain traveling field is realized as shown on Fig.3.

The magnitude of geometry parameters of the system “Primary element – secondary element” is shown in Table 2. These parameters are the general ones for constructing two- and three-dimensional mathematical model in computer environments (Fig.2). The connection of windings to create a traveling field is implemented, as in Fig.3.

TABLE I. RATED PARAMETERS OF THE LIM

Rated Voltage, V	660
Frequency, Hz	50
Rated current, A	780
Starting current, A	1070
Power, kW	150
Rated velocity, m/s	11
Maximal thrust, kN	18.5
Efficiency	0.62
Power coefficient	0.32

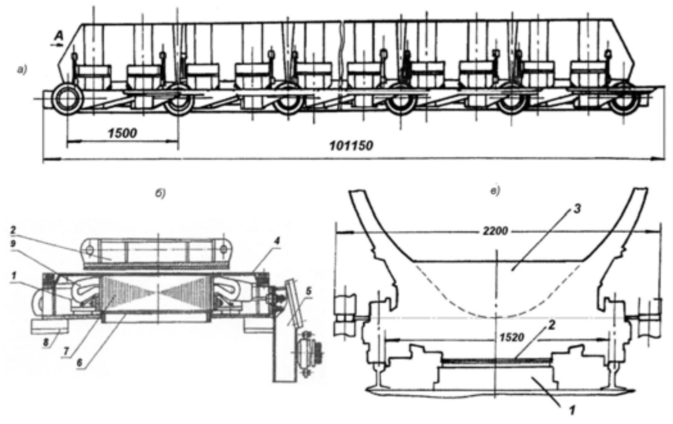


Fig. 1. General view of the conveyor train (a), aragment of the LIM (b) and the main geomtry of system «motor - bogie» (c).

where 1 – PE; 2 – SE; 3 – bogie;4 –lid of the screen; 5 – removable cabel entry; 6 –bottom of the PE body; 7 – core; 8 – support paws; 9 – end winding;

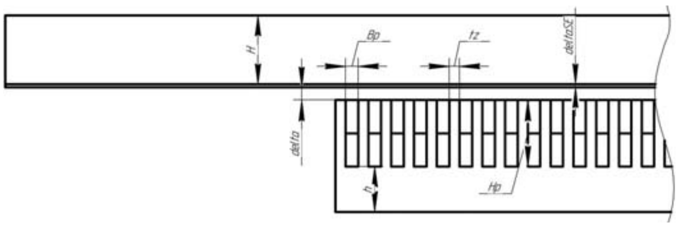


Fig. 2. Basic noatation of the geometric dimensions of the system "Primary element - secondary element"

TABLE II. GENEARAL GEOMETRY PARAMETERS OF THE LIM

Symbol	Values, mm
H	32
h	44
Bp	12
delta	12
deltaSE	3
Bz	10
Hp	64

						X	X	C	C	Y	Y	A	A	- - -	B	B	X	X	C	C	Y	Y
A	A	Z	Z	B	B	X	X	C	C	Y	Y	A	A	- - -	B	B						

Fig. 3. Basic circuit of inductor winding connections

III. MATHEMATICA

The problem was solved in Comsol Multiphysics software with formulation as expression (1). Common Dirichlet condition is applied at the boundaries of the computational problem. The distribution of a stationary magnetic field is described by the equation for the magnetic vector potential **A**. Changing of the physical properties of material in dependence on temperature is neglected.

$$curl\,\frac{1}{\mu(|\mathbf{B}|)}\,curl\mathbf{A} = \mathbf{J}_{ext},\ \ \mathbf{B} = curl\mathbf{A} \qquad (1)$$

where μ stands for magnetic permeability, $\mathbf{J}_{ext}$ is the field current density and $\mathbf{B}$ denotes the vector of the magnetic flux density. The formulation of the task is non-linear problem.

IV. REUSLTS

A. Mechanical features

Starting regimes and velocity control can be to predict by mechanical features. It should be noted, mechanical features of a LIM differ from the characteristics of rotary induction motor. The type of a LIM, namely, low- and high-speed motor, affects the characteristics of the mechanical characteristic. These features aforementioned connect with edge effect of a LIM.

Initially, the unit is powered by power source with values of frequency is equal 50 Hz and voltage is 660 V. The magnitude of voltage is standard value for mining processing complex. Phase current according rated parameters is equal 780 A. The side of the coil was designed with two parallel branches, because the phase current will be twice smaller in the part of coil lying in the slot. This section examines the power supply capabilities of an installation from a network with variable frequency and at different currents

The mechanical characteristic for power supply from a current of 760 A at different frequencies is given in Fig.4 a. Operating slips for this of the motor are approximately 0.2-0.3, according to the working documentation. Therefore, it can be concluded that maximum effort for these slips can be obtained at frequencies below 50 Hz. Frequencies very close to zero less than 10 Hz shift the operating point of the mechanical feature to zero values of velocities. This mode of LIM operation is effective during starting transport system.

The change in the value of the supply current does not significantly change the behavior of the curves of the mechanical characteristics (Fig.4). With the change in the value of the current of the power source, the working forces are basically changed. But it is worth noting that to change the speed of the SE, it is necessary to adjust the frequency. Also, the behavior of the mechanical characteristic from changing source parameters is not typical for classical machines.

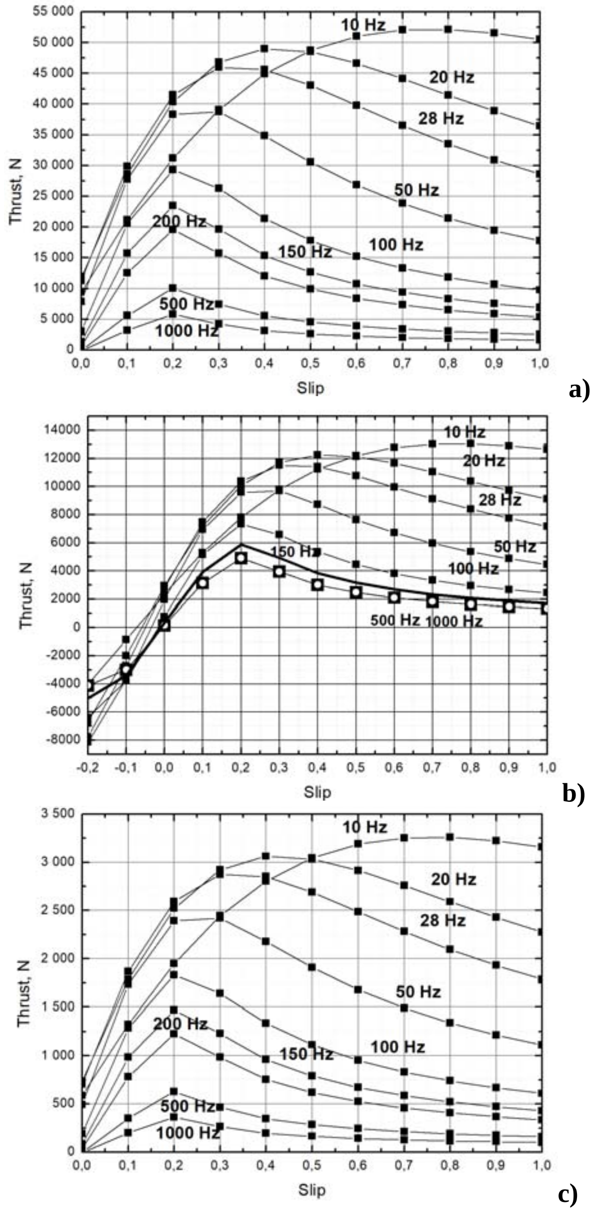


Fig. 4. Family of mechanical characteristics at different frequencies when powered by current (a) 760 A, (b) – 380 A, (c) – 190 A.

B. Energy characteristics

Important qualities of a LIM are energy characteristics in the modern world. The indicators also depend on the parameters of power supplies. According above, it is possible to select optimal parameters of the power source for maximum efficiency. Power coefficient is maximum at frequencies from 50 to 10 Hz (Fig.5). This is especially evident in the starting regime (slip equal to 1) and the nominal speed (for values of slip is 0.2-0.3). Therefore, it can be concluded that the least impact on network will occur at low frequencies during LIM operation.

The efficiency analysis shows the opposite results that were mentioned above. The highest efficiency at higher frequencies. This is due to the depth of current penetration in the SE. The depth of current penetration decreases with increasing frequency and becomes practically equal to the width of the conductive layer of SE at higher frequencies. While at low frequencies the penetration depth is large and high current densities are observed. Due to the increased value of current density in conductive SE, heat release and thrust increase. But it is worth noting, the efficiency is not much different at frequencies ranging from 20 Hz to 50 Hz in comparison with higher frequencies. Consequently, it possible to have enormous thrust at the output. It can also be concluded that in milder modes, for example, not full load or movement from a slide, it is advisable to use higher frequencies to increase the efficiency of the entire system.

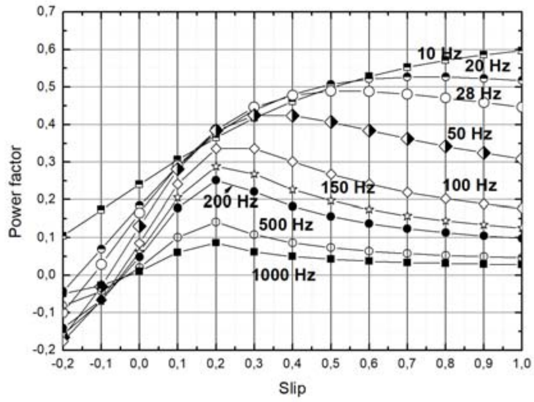


Fig. 5. Coefficient of power as a function of slip when the inductor is supplied with a rated current

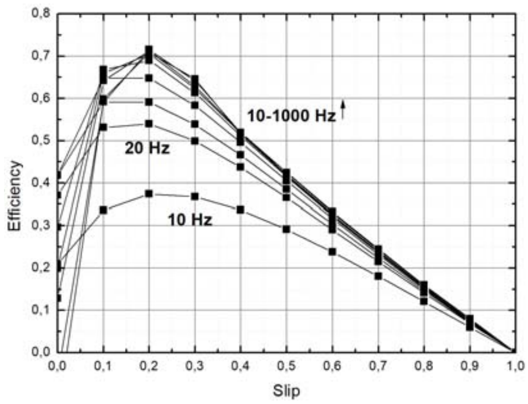


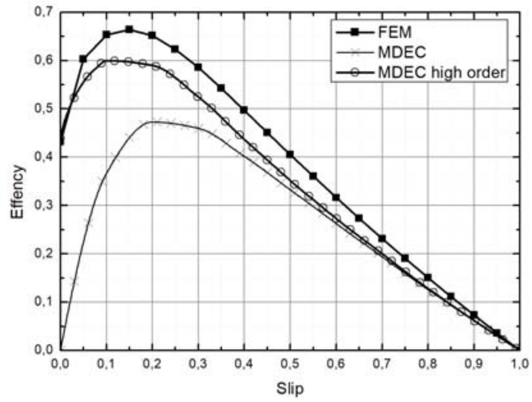
Fig. 6. Coefficient of efficiency as a function of slip when the PE is supplied with a rated current

C. Verification

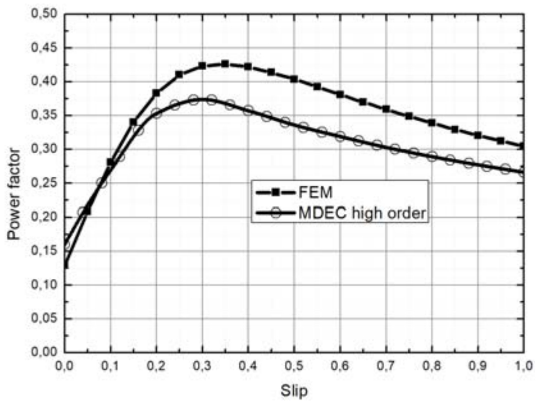
The main indicator of qualitative analysis is the accuracy of the mathematical model. For this purpose, the verification results were verified using the method of magnetic detailed replacement schemes. This method was used to calculate the modes in [7, 5, 9-11].

For comparison, the energy characteristics were chosen, namely the power factor and efficiency factor (Fig.7, a). A comparison of the power factor as a function of slip, calculated with the help of FEM and DMEC, gives a sufficient accuracy not exceeding the relative divergence of 5% in the entire range of slip. This discrepancy is largely due to the fact that the FEM ignores the account of the frontal parts of the coils of the inductor. More details about this can be found in [7].

Comparison of efficiency by different methods (Fig.7, b) shows the greatest divergence of results. This is due to the specificity of the DMEC. The DMEC has fewer details of the model by several orders of magnitude. To increase the accuracy, it is necessary to use the DMEC with approximation with high orders. More details about this can be found in [12].



a)



b)

Fig. 7. Power factor (a) and efiency (b) depending on slip

V. CONLUSION

The paper was presented influence of supply source parameters on mechanical and energy features. Dependences of displacement of nominal values of force and speed are revealed at variation of parameters of a power source. Comments are given for raising energy efficiency and efficiency. The accuracy of the results is tested by comparing the results with different methods, namely, FEM and DMEC. These results will later be used to model the LIM management system for the mining industry.

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