ISSN 1392 – 1215
ELECTRONICS AND ELECTRICAL ENGINEERING
ELEKTRONIKA IR ELEKTROTECHNIKA
2008. No. 7(87)

T190
ELECTRICAL ENGINEERING
ELEKTROS INŽINERIJA

Unconventional Methods of Regulation and Control of Linear Electric Drives

A. J. Poška, Z. Savickienė, A. Šlepikas
Department of Automation, Vilnius Gediminas Technical University,
Naugarduko str. 41, LT-03227 Vilnius, Lithuania, phone: +370 5 2744763, e-mail: algimantas.poska@el.vtu.lt; zita.savickiene@el.vtu.lt; alvydas.slepikas@el.vtu.lt

Introduction

Production of unconventional linear mechatronic systems with linear motion electric drives [1, 2], meets with different uncertainties, because not every system with linear electric drive is more competitive against traditional rotation movement drive with kinematics elements, where electric motor rotational movement is changed to the translation motion.

This problem should be solved very often, because in the nonfiction publications [3, 4] noted that about 50% of rotational movement electric motors which used in the mechatronic systems the executive elements moves in translation or excursion. The mechanical device which changes method of movement increases the size and mass also reduces dynamic characteristics' of all system. For this reason the linear motion electric drives which directly transmit motion to the executive elements are produced.

The simplest, easy adaptable with technological device constructions, so the most universal are linear induction motors (LIM). However the characteristics of the linear induction electric drives (LIED) often are worse than the rational motion drives. Therefore LIED are not mass production product, they are designed and produced for specific devices if the linear mechatronic system in general has advantages comparing with the conventional system. So it is advisable to elaborate not separate the LIM and LIED, but there classes (finite sets) analyzes and synthesis, i.e. unconventional calculation methods, which allows us to find new areas of applications [3].

Often unconventional linear mechatronic systems competitiveness can be increased by using unconventional control methods of variable drives; it can be realized with the help of specific LIM characteristics.

This paper presents the calculation of sets LIM parameters and characteristics and their results analyzing methodic, which enables to evaluate LIM typical features influence to LIM characteristics and unconventional methods of linear induction electric drive regulation and control.

Set of parameters and characteristics of linear induction electric drive (LIED)

Linear induction motors are usually not produced by mass production, because every application requires new motor construction. Very important is to analyze the linear induction drive features which influences the static and dynamic characteristics also the end and side effects while the construction and control parameters are varying. This should be done for selection of the optimal motor control algorithm and motor parameters.

Mechatronic systems are best characterized by the linear induction electric drive static and dynamic characteristics. The shape of it changes with change of electromechanical and valve power transducer construction parameters and adjustment of control parameter. For comprehensive analysis unconventional linear electric drives, the calculations of static and dynamic mechanical characteristics should be done. The set of parameters should correspond to the theory and real technical control and construction approximations [5, 6].

Mechanical characteristics set (Fig.1) features are adequate to linear part hardness describing coefficient set, points, adequate to this characteristic linear part end, set, linear induction drive with no load speed, which are depending on power supply frequency and end-effect intensity, set, starting force set and critical and slip set. Dynamic LIED is characterized by the LIM currents, force and speed dynamic characteristics (minimum and maximum vibration amplitudes, transients process time) set.

Discrete change of mentioned parameters set can be done by electrically and magnetically switching double site LIM winding (Fig. 2):

a) applying the electrically and magnetically one site LIM (Fig. 2, a);

b) by using magnetically double site and electrically one site LIM inductor (Fig. 2, b) (this mode can be chosen by disconnecting one of the Fig. 2, c presented inductor winding);

c) electrically and magnetically double site LIM (Fig 2., c) connecting in parallel and series.

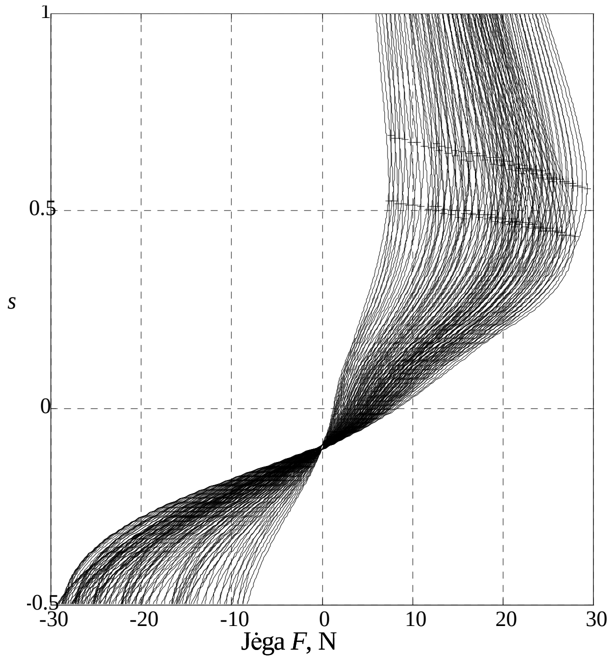

Fig. 1. Set of LIM mechanical characteristics

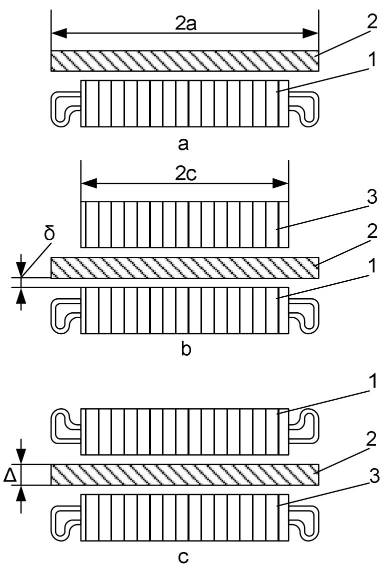

Fig. 2. Models of flat construction LIM: a) electrically and magnetically single-sided; b – electrically single-sided, magnetically double-sided; c – electrically and magnetically double-sided

LIED control and adjustment

LIM is the type of asynchronous induction motors. Therefore variable linear electric drives can be produced on the base of traditional methods (change of frequency or voltage). However individual features of electric drives expand of LIED control opportunities. For example, starting force of LIM can be changed while controlling in serial connected cylindrical linear induction motor (CLIM) phase windings number and polarity (Fig. 3).

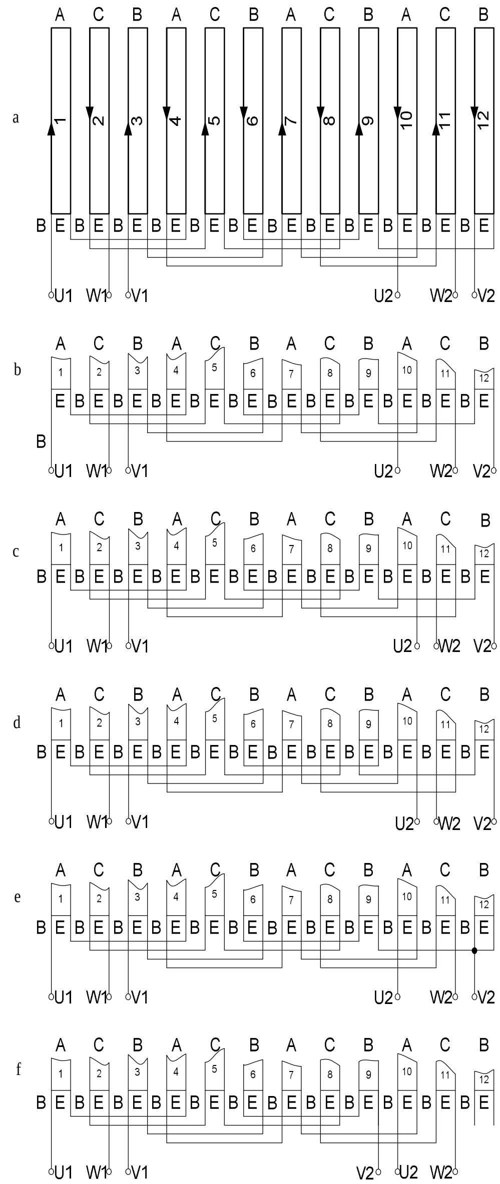

Fig 3. Starting force switching of CLIM while changing winding connection method

If CLIM windings are connected by Fig. 3, a, motor should create designed force. If the inaccuracy of calculations or production deviation occurs and the CLIM produced force differs from the designed, it can be corrected, while changing winding connection schematics. For example, changing one coil connection polarity (Fig. 3, b), two (Fig. 3, c), or in all three phases (Fig. 3, d), CLIM produced force can be reduced in a boundaries of 16 – 19 %. Shot-circuit of one phase of final coil (Fig. 3, e), CLIM produced starting force increases 3 %, and one coil disconnected (Fig 3, f), starting force increases 13 %. There are also many did not displayed schematics in Fig. 3. The connections of CLIM windings enable us to correct CLIM starting force.

The fact that LIM starting (shot-circuit) current is close to the work current, enable us to use different LIM inductor regulation methods, for example, asymmetric pulses, frequency converter voltage regulation method [3].

Flat construction LIM (Fig. 4) enable widest opportunities of LIM produced force correction and control possibilities. For example, pulling back inductors from one another to 3, 5 directions, this can decrease LIM produced force.

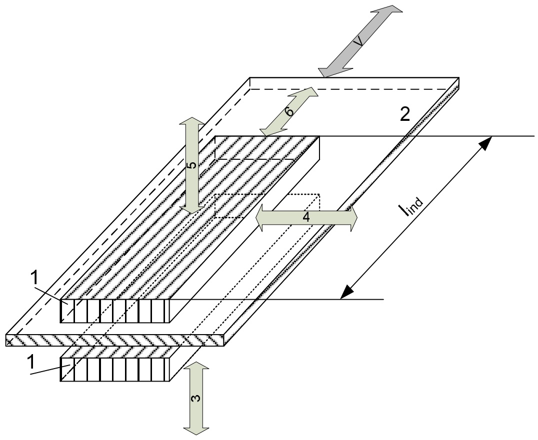

Fig. 4. Flat construction LIM: 1 – inductors; 2 – secondary element; 3, 4, 5, 6 – movements of inductors to different directions, v – speed of secondary element; l_{ind} – LIM inductor length

LIM starting force can be changed by adding vectors of the fluxes produced by different inductors. This can be done only by moving electrically double-sided LIM backwards from the magnetically double sided LIM 6 (Fig. 4):

$$F_p = \frac{m_1 a_1}{v_{1N}} \cdot \frac{\varepsilon_{0N} \Phi^2 c_1^2 f_{1N}^2}{1+\varepsilon_{0N}^2 (1-2a_2+a_1^2) \cdot X_{mN}}; \qquad (1)$$

where m – number of phases; v_{1N} – synchronous speed; Φ – magnetic flux; c_1 and a_1, a_2 – coefficient of LIM phase winding and approximation coefficients; f_{1N} – frequency of power supply; ε_{0N} – magnetic Reynolds number; X_{mN} – magnetizing reactance.

Also LIM produced force can be changed with respect of secondary element covered way, if the electrical or geometrical parameters are changed 2 (Fig. 4.).

Fig. 5 presents the LIM starting force dependences of the air gap between inductor and secondary element. The comparative weak correlation between starting force and thickness secondary element and reduction of this force expanding the air gap are coherent to variation of magnetic flux density receding from the inductor. Is known that flux density component B_z in the distance of z from inductor weakens, while the flux density B_c on the inductor surface, k_B

$$k_B = \frac{B_z}{B_c} = \mathrm{e}^{-\frac{z}{\tau'}}; \qquad (2)$$

where $\tau' = \frac{\tau}{\pi}$.

Electromagnetic force developed the secondary element of the LIM is proportional to the square of flux density, so

$$F_z = F_{\max} e^{-\frac{2}{\tau'}(z-z_{\min})}. \qquad (3)$$

If the $F_{\max}$ force, adequate to smallest air gap $z_{\min} = \delta_{\min}$, and coordinate $z = \delta + \Delta/2$, can be calculated theoretical force dependence from air gap. It is marked in squares and conform experiments.

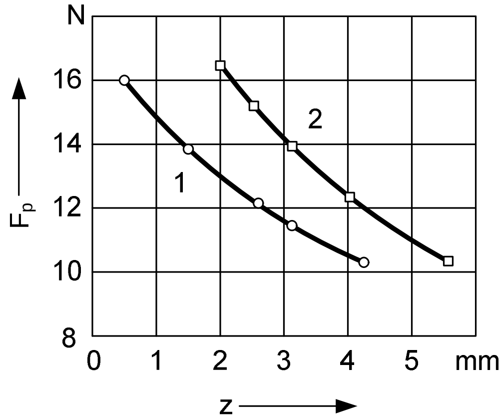

Fig. 5. LIM starting force dependences of the air gap $(z = \delta)$ (first curve) and of the distance between inductor surface and middle of secondary element $(z = \delta + \Delta/2)$ (second curve)

Conclusions

1. LIM are not standardized, so the spectrum of their parameters is continuous and it is advisable to investigate LIM static, dynamic and regulating characteristics as sets.

2. LIM and cylindrical LIM construction enables unconventional produced force control and adjustment methods.

References

1. **Boldea I.** Linear electric actuators and their control: a review // Proceedings of the 10th International Conference European Power and Drives Association PEMC 2002, 9 – 11 September 2002, Cavtat&Dubrovnik, Croatia. ISBN: 953 – 184 – 047 – 4. – P. 12 – 19.
2. **Budig P. K.** The aplication of linear motors // Proceedings of the International Conference on Power Electronics and Motion Control, 2000. – Vol. 3. – P. 1336 – 1341.
3. **Rinkevičienė R., Poška A. J., Smilgevičius A.** Tiesiaeigės mechatroninės sistemos. Teorija ir taikymas: monografija. Vilnius : Technika, 2006. 224 p.
4. **Веселовский О. Н., Коняев А. Ю., Сарапулов Ф. Н.** Линейные асинхронные двигатели. – Москва: Энергоатомиздат, 1991. – 256 с.
5. **Poška A., Rinkevičienė R., Meilūnas M.** Mažų greičių tiesiaeigių asinchroninių elektros pavarų klasės tyrimas // Elektronika ir elektrotechnika. – Kaunas: Technologija, 1999. – Nr. 1(19). – P. 63–65.
6. **Poška A., Rinkevičienė R., Zubaitis J.** Theoretical characteristics of linear induction electric drives and experimental equipment for their investigation // Information

technology and control. – Kaunas: Technologija, 2001. – Nr. 2(19). – P. 50–55.
7. **Smilgevičius A.** Tiesiaeigių elektros variklių tyrimai Lietuvoje // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2004. – Nr. 1(50). – P. 22–27.
8. **Rinkevičienė R., Lisauskas S.** Tiesiaeigių mechatroninių sistemų modeliai // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2003. – Nr. 4(46). – P. 69–73.
9. **Faa-Jeng Lin, Rong-Jong Wai.** Robust control using neutral network uncertainty observer for linear induction motor servo drive // IEEE Transactions on Power Electronics. March 2002. – Vol. 17, Issue 2. – P. 241–254.

Received 2008 03 12

A. J. Poška, Z. Savickienė, A. Šlepikas. Unconventional Methods of Regulation and Control of Linear Electric Drives // Electronics and Electrical Engineering. – Kaunas: Technologija, 2008. – No. 7(87). – P. 65–68.

The calculation of sets linear induction motors (LIM) parameters and characteristics and their result analyzing methodic is presented, which enables to evaluate linear induction motor typical features influence to LIM characteristics. LIM are not standardized, so the spectrum of parameters is continuous and it is advisable to investigate LIM static, dynamic and regulating characteristics as sets. Often unconventional linear mechatronic systems competitiveness can be increased by using unconventional control methods in variable drives; it can be realized with the help of specific LIM characteristics. The paper also presents unconventional methods linear induction electric drive regulation and control. Ill. 5, bibl. 9 (in English; summaries in English, Russian and Lithuanian).

А. Ю. Пошка, З. Савицкене, А. Шлепикас. Нетрадиционные способы настройки и управления линейным электроприводом // Электроника и электротехника. – Каунас: Технология, 2008. – № 7(87). – С. 65–68.

Представлены методики расчета множеств параметров и характеристик линейных асинхронных двигателей (ЛАД) и анализа их результатов. Эти методики дают возможность оценить влияние характерных свойств линейных асинхронных двигателей на их характеристики. ЛАД нестандартизированы, поэтому их параметры составляют непрерывный спектр, и статические, динамические и регулировочные характеристики целесообразно исследовать как множества. Часто конкурентабильность нетрадиционных линейных мехатронных систем можно увеличить в регулируемом (управляемом) электроприводе используя нетрадиционные методы управления, реализировать которых позволяют специфические свойства ЛАД. Также представлены нетрадиционные способы управления (регулирования, подбора, настройки параметров) нетрадиционного линейного электропривода. Ил. 5, библ. 9 (на английском языке; рефераты на английском, русском и литовском яз.).

A. J. Poška, Z. Savickienė, A. Šlepikas. Netradiciniai tiesiaeigių elektros pavarų derinimo ir valdymo būdai // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2008. – Nr. 7(87). – P. 65–68.

Pateikiamos tiesiaeigių asinchroninių variklių (TAV) parametrų ir charakteristikų aibių skaičiavimo ir jų rezultatų analizės metodikos, įgalinančios įvertinti tiesiaeigių asinchroninių variklių būdingų savybių įtaką TAV charakteristikoms. TAV nėra standartizuoti, todėl jų parametrai sudaro nenutrūkstamą spektrą, ir TAV statines, dinamines bei reguliavimo charakteristikas tikslinga tirti kaip aibes. Dažnai netradicinės tiesiaeigės mechatroninės sistemos konkurencingumą galima padidinti taikant netradicinius reguliuojamų (valdomų) pavarų valdymo metodus. Juos realizuoti įgalina specifinės (savitosios) TAV savybės. Taip pat pateikiami netradiciniai tiesiaeigių asinchroninių elektros pavarų valdymo (parametrų reguliavimo, parinkimo, derinimo) būdai. Il. 5, bibl. 9 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).

DOI: 10.5755/j02.eie.11216