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Mechatronic System Linear Swing Vibrating Screen of a Grain Cleaner

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Abstract: After harvest grain mixture separation is a very essential operation. The most common way of grain mixture processing is based on swing vibrating screeners. In terms of mechanics and energy their bottleneck is a reduction electric drive based on induction rotation engines. As the result the electric drive has low efficiency, higher weight, limited ways to regulate oscillation motion of screens. The aim of the investigation is to develop a gearless electric drive for swing vibrating screeners with regulated oscillation properties. The study deals with a mechatronic system based on a linear induction engine. It enables to simplify an electric drive as well as to adjust necessary settings for complex oscillating movement of screens. Screen vibrations are controlled by changing turn-on period and frequency of the linear induction engine. Amplitude of regulated vibrations can be more than 0.01 m with frequency <3 Hz.

Key words: Mechatronic system, swing vibrating screens, linear induction engine, separation, vibration, grain

INTRODUCTION

In most cases grain mixture separation is performed on flat swing vibrating screeners (Bohnet, 2004). Requirements for a drive of grain separating machines are due to specifics of working operations: available efficiency extremum distinct from kinematic parameters and its drift resulted from random disturbances from changes in operation rate, initial mixture composition and properties (particular humidity). The conducted studies as well as research and development prove that oscillation mode of dressing shoes with relatively high amplitude (more than 0.01-0.05 m) and low frequency (lower than 2-5 Hz) maintain more favorable conditions to dress grain mixtures as compared to other grain cleaners. These grain cleaner's vibration parameters are found to reduce significantly energy cost on grain mixture separation (Bykov, 1999). It is known to be reasonable to use regulated vibration modes to achieve quality in separating free running mixtures on flat swing vibrating screens.

Designing a regulated drive to reproduce these kinematic characteristics of vibrating scrrens is a vital task. An inertia vibration drive turns to be bulky and of high density. It doesn't provide stable kinematic characteristics (Badin, 2010). A kinematic resonant drive requires a specific starter. When adjusted for better process conditions it moves out of resonance and is followed with higher dynamic force in kynematic pairs (Koshelev, 2017).

Another important task is to develop a self-excited electric drive with vibration induced by a rotor (Sannomiya *et al*., 2017). This significantly simplifies a design of the machine and its density. Moreover, it provides better control on a separating equipment as well as on the whole processing line further on. Such developments are very promising that is proved with research results by the Institute of Machine Studies named after Blagonravov.

The given tasks can be solved by using a Linear Induction Engine (LIE) to regulate a drive of separating machines (Ganesh *et al*., 2016). When using an electric

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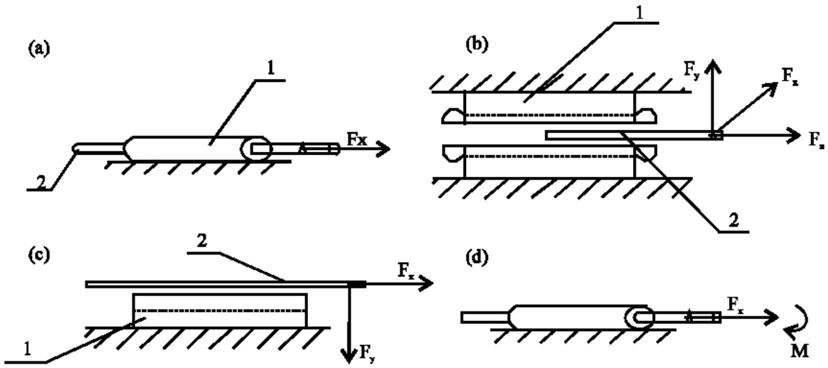

Fig. 1a-d): Possible types of LIE drives and forces they develop: 1) Stator and 2) Rotor

drive based on a linear induction engine there is no need in heavy and energy consuming parts such as: a reducer and a mode transformer. It should be noted, the LIE is characterized to be of a simple construction, manufacturable, easy to install and dismantle, cheap, reliable and having different design (Ahmadinia, 2014; Jeong *et al*., 2017).

Figure 1 presents possible types of LIE drives and forces they develop: α a unidirectional linear induction engine (cylindrical) with effective traction force F_x; б a bidirectional linear induction engine (flat) with effective forces F_x and F_y; в a three-directional linear induction engine with effective forces $F_{\ddot{o}}$, F_y and F_z; ɕ a rotary and reciprocal linear induction engine with effective force F_x and rotating force M (Linenko, 2015; Vinod, 2017).

Unwatched advantage of drives based on linear induction engines is that you can regulate vibratory motion of a rotor (amplitude, frequency) when using spring storage for mechanical energy (Aipov and Linenko, 2013). Figure 2 shows functional diagrams of linear electric drives with spring Storages for Mechanical Energy (SME) provided by cylindrical spiral springs.

Spring storages of mechanical energy provide braking and starting up of the rotor releasing mechanical energy within the cycle of vibratory motion. The LIE consumes electric power only to compensate loss of mechanical energy resulted from dead load (friction). There is no winding on the rotor of the LIE. Thus, its moving body can be a flat or cylindrical working body of a grain cleaner. It additionally simplifies a construction that can be of a modular and multipurpose design, for instance for grain separation and drying (Sarapulov *et al*., 2017).

Synergetic union of a grain cleaner's working body part with a linear induction engine results in a simplified drive and a mechanism working as a whole. These all corresponds to a Mechatronic System (MS). Figure 3 demonstrates a possible functional scheme of a control unit for MS based on LIE.

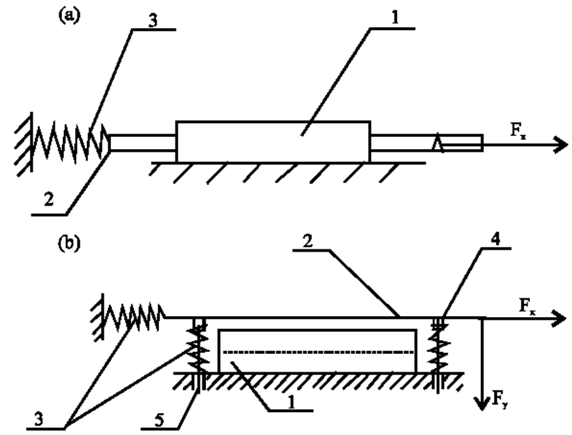

Fig. 2: Kinematic schemes of oscillating drives with a cylindrical: a) Flat and b) Linear electric engines with spring storages for mechanical energy in different planes: 1) Stator; 2) Rotor; 3) Spring elements; 4) Roller and 5) Rod

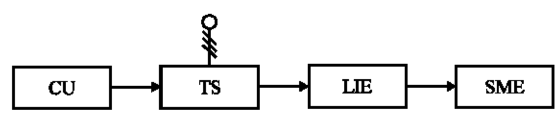

Fig. 3: Functional scheme of a control unit for MS based on LIE operating in the forced vibration mode

A Control Unit (CU) assigns a vibration mode with a Thyristor Switch (TS) by regular turning the linear induction engine on and off. LIE can be regulated according to the length and frequency of its operation. MC base on LIE in forced vibrations can operate in preresonant mode at the uprising branch of the resonant curve when its own frequency is higher than that of actuating force. This mode provides higher output at less energy consumption. In this respect, accurate and stable settings have a decisive role. Being close to resonance can result in unstable work of the grain cleaner. Being distant to resonance requires larger energy store to get operation amplitude. It implies higher weight and larger size of MS. Additional control of LIE in MS is possible by changing supply voltage of the stator. The latter has a great effect on tractive effort of the engine (Vinod, 2017; Alonge *et al.*, 2017). To alternate present voltage in a symmetrical power system means and methods typical for induction rotation engines including methods of amplitude and mode control are applicable.

As symmetrical sources of regulated voltage, it is better to use a TS. When using TS there is a chance to save power in the drive. At every load of LIE, there is the voltage when the engine consumes less power.

MATERIALS AND METHODS

An electric drive of grain cleaner MVR-2 (SU-0.1) was upgraded to verify the above mentioned ideas. Figure 4 presents a kinematic scheme of its linear electric drive that corresponds to the kinematic scheme (Fig. 2a).

The control unit connects the stator 6 of the flat LIE to the voltage supply. This creates a traveling electromagnetic field on the stator. Interaction of the traveling electromagnetic field of the stator 6 with the rotor 4 stiffened to the screener 1, makes the latter to move towards F_x (longitudinal direction) and F_y (transverse direction), perpendicularly to F_x.

Screener 1 hinged with spring suspensions 5 of the same length at the angle C to the horizont in OX-direction is attracted to the stator 6 when LIE is forced to turn on by force F_y. Under F_{δ} it gets a translational motion to the traveling electromagnetic field. Thereby. spring elements 2 and 3 (cylindrical spiral springs) warp. At a certain point of time the LIE stator turns off. Forced with energy stored in spring elements 2 and 3 the screener moves back. While the screener 1 sharply breaks its movement, there is friction-powered movement of grain in the screener. Thus the screener makes compound reciprocal vibratory motion. Grain particles that don't pass through the screen go to the coarse grain spout while particles dropped through the screen go to the undersize grain spout.

Figure 5 introduces a functional chart of the MS control unit based on the scheme of an extreme regulator (Ilinskii and Moskalenko, 2008) that enables to minimize power consumption at different resistant Forces (F_c). The chart contains Currrent Sensors (CS), Voltage Sensors (VS), a Functional Generator (FG) and a Relaxation Circuit (RC). By choosing certain characteristics of the FG there is minimal consumption of current at different loads of the engine. Meanwhile, RC alongside with negative voltage feedback eliminates possible free vibration in the system.

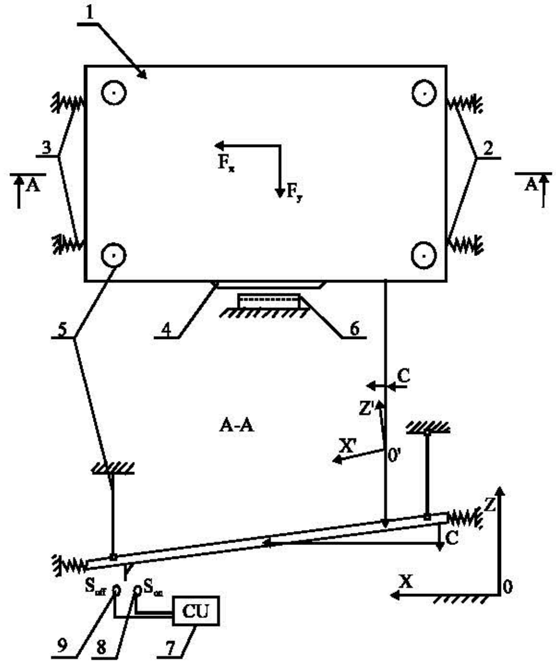

Fig. 4: Kinematic scheme of the linear electric drive of the screener of in grain cleaner MVR-2 (SU-0.1); 1) Screener; 2 and 3) Spring elements; 4) LIE rotor; 5) spring suspension of the screener; 6) LIE stator; 7) Control unit of the MS; 8) LIE switch on sensor and 9) LIE swith off sensor

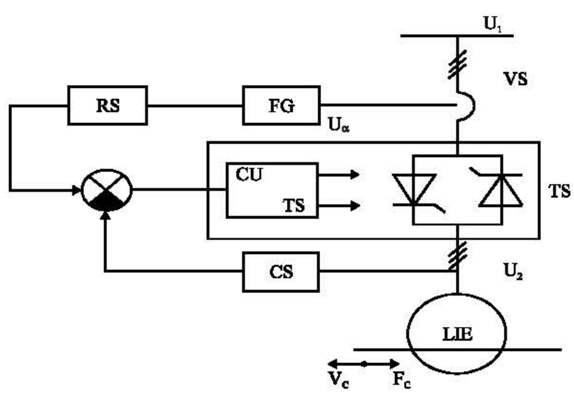

Fig. 5: Functional chart of the MS control unit based on LIE with an extreme regulator; U_1, voltage of the power supply; U_2, voltage of the LIE inductor; V_{fi}, synchronous linear speed of the LIE; U_{α}, thyristor opening angle and F_{fi}, the LIE resistant force

RESULTS AND DISCUSSION

Prooduction tests of MVR-2 (SU-0.1) with a mechatronic system based on the LIE were conducted in limited liability farm "Ilish_Agro" located in the Ilishevo District of the Bashkortostan Republic. To assess efficient

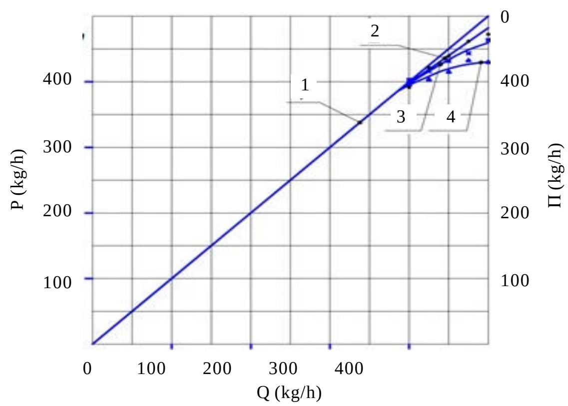

Fig. 6: Change in grain separation and loss depending on output and a kinematic mode of grain screen Ђ$_2$: 1) Maximal screenability; 2) Mode $A_{long}\cdot f_{vibr}$ = 43.5 mm Hz; 3) Mode $A_{long}\cdot f_{vibr}$ = 48 mm Hz and 4) Mode $A_{long}\cdot f_{vibr}$ = 52.5 mm Hz

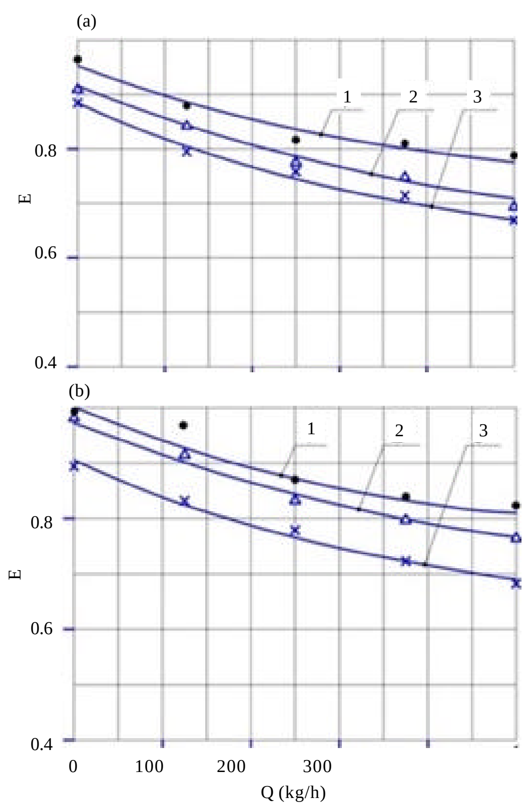

Fig. 7: Change in grain separation completeness depending on efficiency and kinematic mode of the cleaning screen B: a) and the separating screen Γ; b): 1) Mode $A_{long}f_{vibr}$= 43.5 mm Hz; 2) Mode $A_{long}f_{vibr}$ = 48 mm Hz and 3) Mode $A_{long}f_{vibr}$= 52.5 mm Hz

separation of trash from grain according to the method there are dependences of complete separation of grain E, grain loss П and grain screenability P on output Q and kinematic modes of screeners taking into account grain damage (Fig. 6 and 7).

The dependences got in the course of the research make it possible to draw the following conclusion. When MS is installed on the grain cleaner MVR-2 (SU-0.1) having an amplitude of longitudinal vibrations of the screener A_{long} = 14.5 mm as well as transverse ones A_{transv} = 2 mm and its vibration frequency f_{vibr} = 3 Hz (mode $A_{long}\cdot f_{vibr}$ = 43.5 mm Hz), there is better separation rate E (up to 0.81 for one passage of grain on the screen), increased screenability P and less grain loss П (no more than 1 %) while grain damage isn't higher of the value accepted by the Russian standards GOST (3.5 %).

If energy datum of the drive before and after upgrading is compared, the design efficiency of the drive MVR-2 (SU-0.1) is η_1 = 0.41. After installation of the MS based on the LIE efficiency of the developed linear electric drive is η_2 = 0.45. It demonstrates its higher efficiency by 4%. Energy efficiency ratio E_{er} being characterized by ratio of the amount of consumed power P to average output Q increased by 32.8%.

CONCLUSION

To get higher oriented motion of screens with longitudinal holes was used longitudinal and transverse vibrations. These vibrations enlarged the total motion trajectory of grain on the screen resulting in better separation and screening as well as reduced grain loss.

Moreover, the research results proved that grain mixture dressing on swing vibrating screens at higher amplitudes and lower frequency is better compared to these processes in existing grain cleaners.

Synergetic union of a flat screen of the operation machinery with a LIE rotor results in development of a mechatronic system. Mechatronic system as a smart control unit of the grain cleaner with a flat swing vibrating screen enables to consider possible electromechanic, electronic and computer control over energy as well as data streams aimed at lower energy costs at higher efficiency and quality of grain material dressing.

REFERENCES

Ahmadinia, N., 2014. The Linear Induction Motor (LIM) and Single Linear Induction Motor (SLIM). Am. J. Electr. Power Energy Syst., 3: 71-75.

Aipov, R.S. and A.V. Linenko, 2013. Linear Electric Machines and Linear Asynchronous Electric Drives of Production Machines. Bashkir State Agrarian University, Ufa, Russia, Pages: 308.

Alonge, F., M. Cirrincione, F. D'Ippolito, M. Pucci and A. Sferlazza, 2017. Active disturbance rejection control of linear induction motor. IEEE. Trans. Ind. Appl., 53: 4460-4471.

Badin, G.M., 2010. Reference Book of Constrauction Technologists. 2nd Edn., Publisher BHV-Peterburg, Saint Petersburg, Russia, Pages: 528.

Bohnet, M., 2004. [Mechanical Process Engineering]. Wiley-VCH, Weinheim, Germany, Pages: 270 (In German).

Bykov, V.S., 1999. Higher efficiency of the grain mixture separation processes on flat swinging sieves. Ph.D Thesis, Voronezh State University, Russia.

Ganesh, S.V., K. Abhishek and N.C. Lenin, 2016. Design, development and electromagnetic analysis of a linear induction motor. Appl. Mech. Mater., 852: 794-798.

Ilinskii, N.F. and V.V. Moskalenko, 2008. Electric Drive and Resource Saving: Study Guide for Students of Higher Educational Institutions. Akademiia Publisher, Moscow, Russian, Pages: 208.

Jeong, J.H., J.Y. Choi, S.Y. Sung, J.W. Park and J. Lim, 2017. Thrust analysis and experiments on Low-speed Single-sided linear induction motor. J. Electr. Eng. Technol., 12: 230-235.

Koshelev, A.V., 2017. Experimental studies on efficient performance of a parametric resonant electric drive. Fundam. Stud., 11: 996-999.

Linenko, A.V., 2015. Linear Asynchronous Electric Drives of a Complex Oscllatory Motion for Production Machines: Study Guide. Bashkir State Agrarian University, Ufa, Russia, Pages: 184.

Sannomiya, K., T. Morizane, N. Kimura and H. Omori, 2017. Experimental confirmation of thrust and attractive force control for linear induction motor by two different frequency components. Proceedings of the 2017 11th International Symposium on Linear Drives for Industry Applications (LDIA), September 6-8, 2017, IEEE, Osaka, Japan, ISBN:978-4-88686-400-0, pp: 1-6.

Sarapulov, F., S. Sarapulov and I. Smolyanov, 2017. Research of thermal regimes of linear induction motor. Proceedings of the 2017 18th International Conference on Computational Problems of Electrical Engineering (CPEE), September 11-13, 2017, IEEE, Kutna Hora, Czech Republic, ISBN:978-1-5386-1040-4, pp: 1-4.

Vinod, K., 2017. Design of linear induction motor works as conveyer. Intl. Eng. Res. J., 1: 279-283.