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Performance of Linear Electric Drive at Localizing of Dust Explosions

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Introduction

Linear induction motors (LIM) whose moving elements are aligned with the moving elements of dampers are applied in the dust explosion localizing systems for ensuring great speediness of operation. Spreading wave of explosion during closing the pipeline deforms the secondary element and begins to touch the inductor. Therefore the sliding or rolling bearings are mounted in the active zone of inductor to reduce friction and prevent damaging of LIM. The paper deals with modeling of deformation of the LIM moving element due to raising gas pressure and simulation of transients in the case when moving element begins to touch the supporting bearings.

Explosions of industrial dust and their localizing

The organic dust (flour, bran, mills, elevators, combined fodder enterprise dust) of corn processing enterprises mixed with air (aerosol) usually bursts.

Primary explosions are usually weak, but the wave of explosion, spread by the spaces of the technological equipment and by pipes, blows the rest of the dust from walls, and the fire spreading afterwards sets fire to new aerosol masses and provokes severe explosions. If the technological machinery or pipe walls are incapable to withstand the increased pressure and fall into pieces, the fire reaches the production premises. There is always some dust on the edges of constructions, technological walls or on the floor. The wave of explosion raises it, and the fire, spreading from the aspiration system burns it up. The destructive force of power explosions rises: the windows are broken, the technological equipment is damaged, and capital constructions are ruined.

In order to limit the number of accidents, it is necessary to use automatic system for localizing dust explosions [1], which prevents heat and fire in the center of weak initial explosions from spreading on to the aspiration systems, silos, bunkers where the secondary destructive explosion arises. These systems consist of high-speed dampers with a linear induction electric drive and system controlling equipment with sensors, reacting upon the explosion parameters. Similar system (Fig. 1) is investigated theoretically by modeling of system dynamics and tested experimentally in special explosions testing polygon and had a wide implementation [3]. Nevertheless during experimental investigation of explosions localizing system it was stated that in the case of high pressure of dust explosion wave, the moving element of damper, which is aligned with the secondary element of linear induction motor (LIM) was deformed severely and afterwards it began to graze the inductor of LIM. In order to avoid system failure it was proposed to install the supporting bearings in the active zone of LIM inductor (Fig. 2). The paper considers dynamics of automatic dust explosion localizing system with special construction LIM.

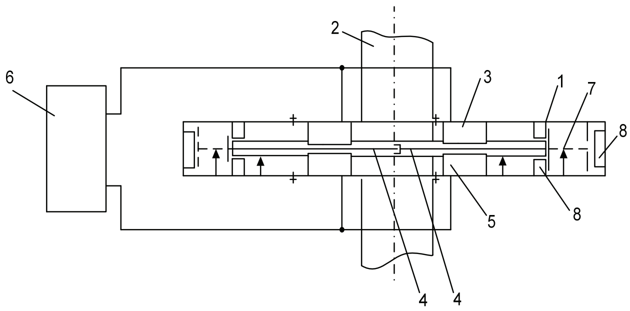

Fig. 1. Construction of flame occlusive damper: 1– case; 2 – pipe; 3 – directives (sliding bearings of the moving element); 4 – moving element of damper (secondary element of LIM); 5 – LIM inductor; 6 – control unit of damper drive; 7 – fixers of the damper moving element; 8 – shock-absorbers

Flame closing pipe with special linear induction motors

High speed dampers can be designed by aligning the moving element of damper with the moving (secondary) element of linear induction motor (Fig. 1) [2, 4]. The damper with two moving elements 4 is shown in Fig. 1. If the cross area of pipes is small, it is enough to use single moving element and single electrically and magnetically two-sided LIM 5. For large cross area pipes, as corn dryer pipes, the damper comprises some sections, controlled by separate LIM's.

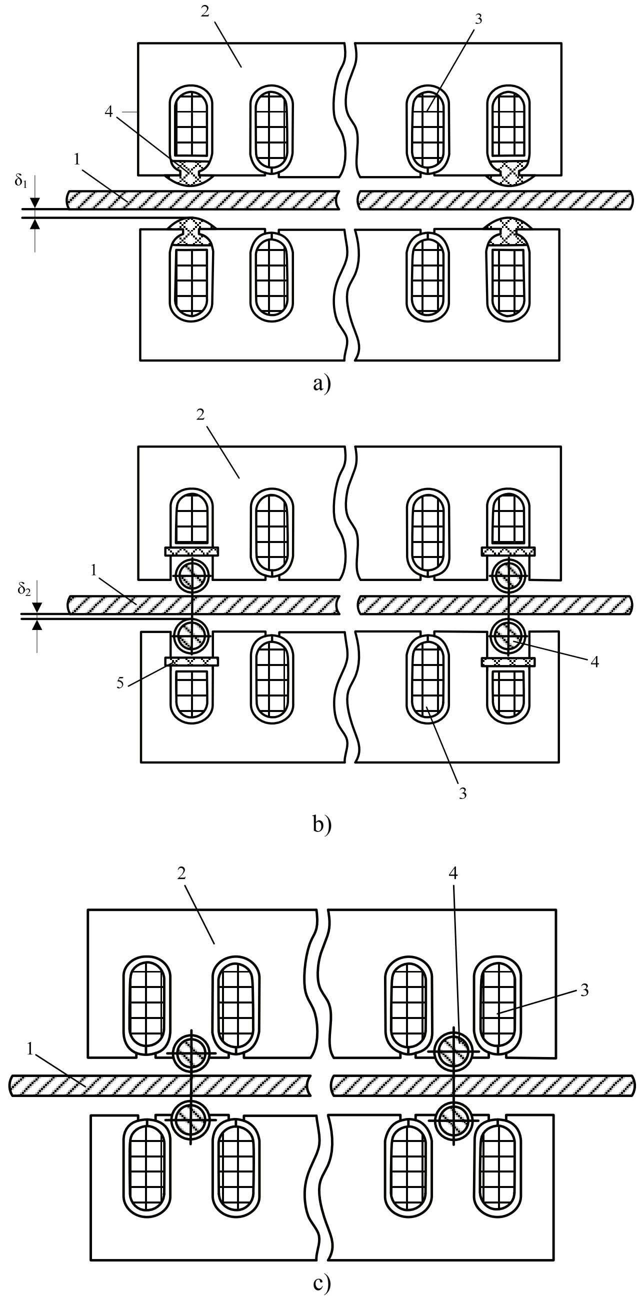

Fig. 2. LIM with sliding (a) and rolling bearings (b, c) in the active zone of its construction, where 1 is LIM secondary element (moving element of damper); 2 is magnetic core of LIM; 3 is LIM winding; 4 is supporting bearings; 5 is holder of winding coil; δ_1 (δ_2) is air gap between the damper moving element and additional sliding (rolling) bearings

The flame occlusive dampers are installed in the pipelines in which the flame of the primary fire can spread. After the weak primary explosion the signal of pressure sensor is sent to drives of dampers and those block all possible flame spreading ways and the primary explosion dies and does not cause powerful explosions.

The damper will be in time to close the way for fire, if the condition will be fulfilled [2]:

$$t_{\Sigma} = k(t_{disp} + t_k + t_{damp}) < \frac{S}{v}; \qquad (1)$$

where t_{Σ} is the whole time needed for the automatic system for localizing dust explosions to react; k is stock coefficient; t_{disp} is pressure sensor reaction time; t_k is commutation apparatus reaction time; t_{damp} is damper closing time (linear drive reaction time), S is distance between a possible initial explosion place and a damper building place (flame path); v is flame speed.

Deformation of the damper moving element from dust explosion pressure

Deformations of LIM secondary element (damper moving element) under explosion wave pressure were modeled with Solid Works software. Distribution of deformations along the width of pipe during closing in the middle of pipe cross area is shown in Fig. 3.

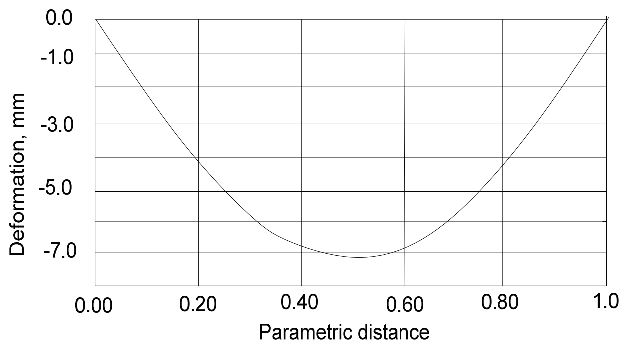

Fig. 3. Deformation graph of duralumin damper at 25000 N/m^2 pressure of explosion

The portion of moving element between inductors also behaves with deformation. If the sliding bearings are installed in the inductor slots (Fig. 2, a) whose friction coefficient is greater than that of damper main directives, and deformation reaches value δ_1 (Fig. 2, a), the friction force increases. Therefore the damper shutting time t_{damp} according to formula (1) can increase up the value while condition (1) will not be fulfilled. And inverse, in the case of installation of rolling bearings in the LIM slots (Fig. 2, b) or teeth (Fig. 2, c) and deformation of moving element increases up to δ_2, the static load force, applied to secondary element of LIM can be reduced and condition (1) will be satisfied with some margin. Therefore dampers with considered LIM can be installed nearer possible primary explosions places.

Dynamics of explosion localizing damper linear electric drive

Model of linear electric drive of damper is shown in Fig. 4 [5]. The model involves the block to simulate the load forces rising during localizing of explosion source.

This force depends proportionally to rising explosion pressure and stepwise rising of friction forces, when explosion wave moves and presses the moving element of damper (secondary of LIM) towards the additional bearings (Fig. 2). Despite the friction force change in time, during simulation the first approach can be assumed as stepwise change of LIM load force. The LIM load force, increasing with pressure during explosion at the instant of time, when the secondary element begin to graze additional sliding or rolling bearings in the active zone of LIM inductor, rises.

The model of induction drive with load force, changing in time according is presented in Fig. 4.

The model is elaborated in synchronous reference frame. Reference load force is shown in Fig. 5.

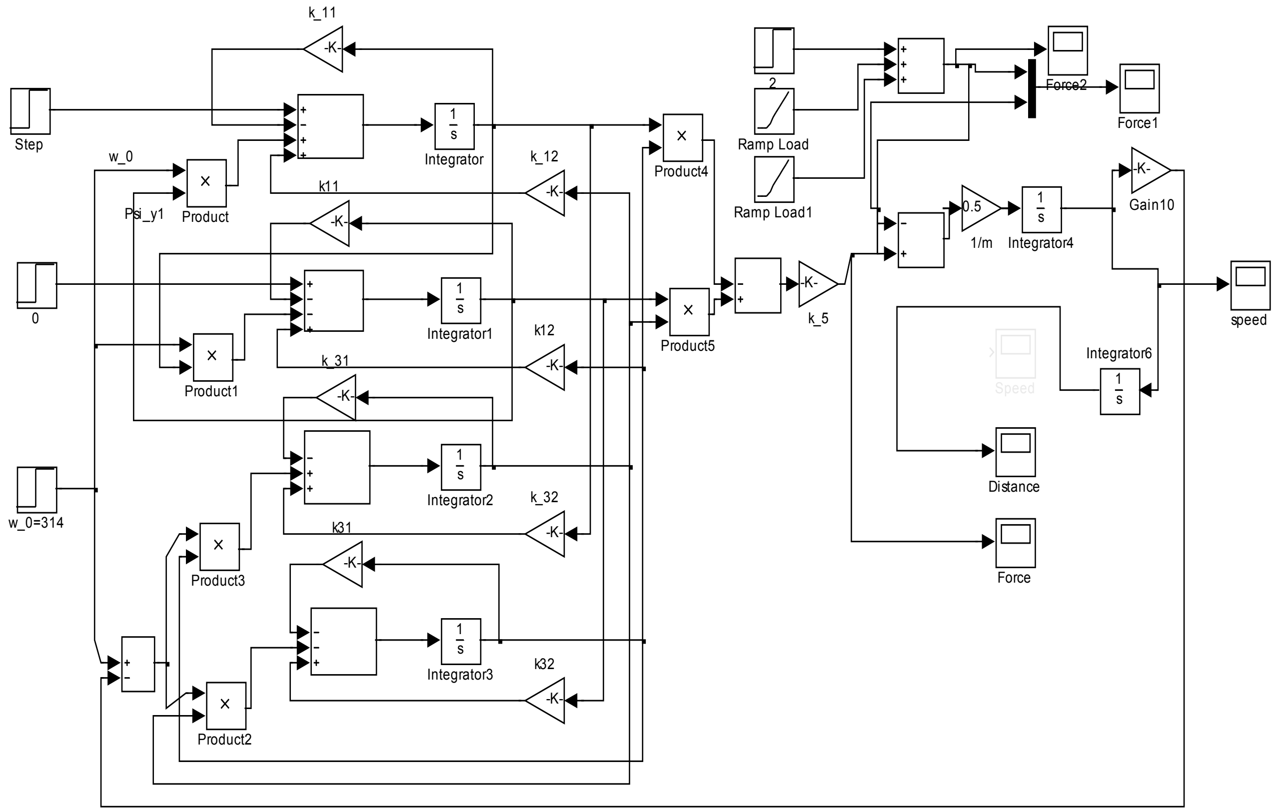

Fig. 4. Simulink model of linear induction drive of ADELS

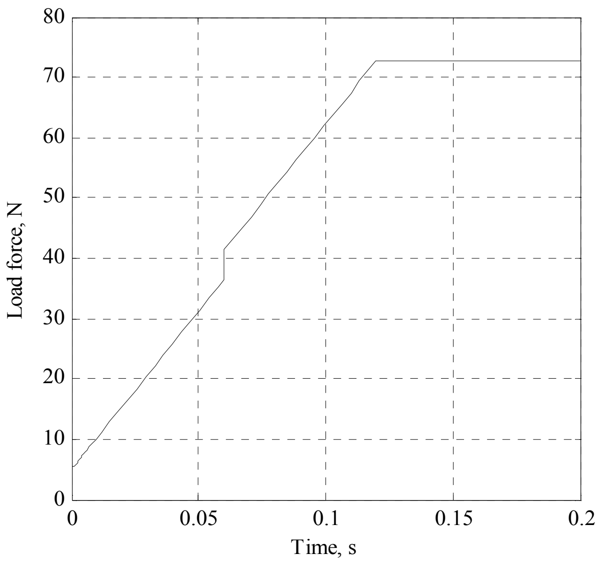

Fig. 5. Reference load force of linear induction drive

Simulation results, presented in Fig. 6 indicates dynamic torque overshoot and its reducing because raised LIM speed and again increasing due to load torque up to 70 N·m, i.e. to reference load. Dependence of linear motor speed against time at the closing of damper is shown in Fig. 7.

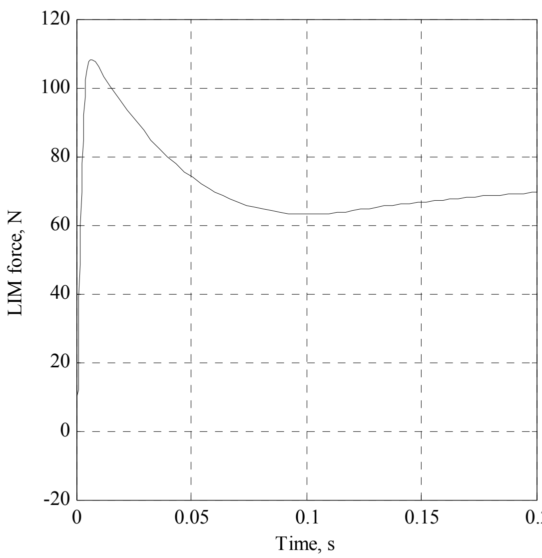

Fig. 6. Dependence of delivered LIM torque against time

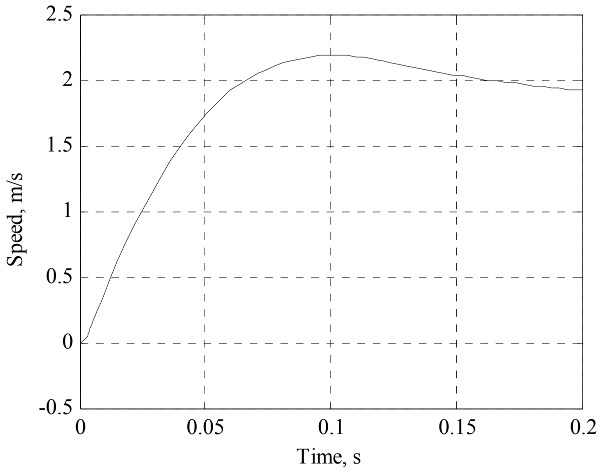

Fig. 7. Dependence of LIM speed during closing of damper

Speed reaches value 2,2 m/s and then reduces due to raising load force.

Conclusions

1. It is stated, that moving element of flame occlusive damper aligned with the secondary element of LIM under the action of explosion wave can move towards LIM inductor and rub it. Therefore at localizing of primary dust explosions the flame occlusive dampers with additional supporting bearings in the active zone of linear induction motor should be used.

2. Simulation results of linear electric drive at powerful dust explosions indicates reliable operation of automatic dust localizing system with LIM equipped by rolling or sliding bearings in its active zone.

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Performance of dust explosion localizing systems with fire blocking dampers, whose moving element is aligned with linear induction motor (LIM) secondary element, is considered. It is stated experimentally, that dust explosion wave can deform moving element and it will begin to graze LIM inductor and could be lost control of ADELS. Therefore additional sliding and rolling bearings should be mounted in the active zone of LIM; sliding index of those differs from that of damper directives. Simulation of linear induction drive with load, depending on dust explosion pressure and degree of deformation of damper moving element with indicated capability of damper with the additional bearings in LIM active zone to block even strong primary explosion sources. Ill. 7, bibl. 5 (in English; abstracts in English and Lithuanian).

R. Rinkevičienė, Z. Savickienė, A. J. Poška. Sklendės tiesiaeigės elektros pavaros veikimas dulkių sprogimo sąlygomis // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2012. – Nr. 6(122). – P. 100–104.

Nagrinėjama, kaip lokalizuojant pirminio dulkių sprogimo židinį veikia dulkių sprogimų automatinės lokalizacijos sistemose (DSALS) taikoma ugnį užtverianti sklendė, kurios judrusis elementas sutapdintas su tiesiaeigio asinchroninio variklio (TAV) antriniu elementu. Eksperimentiškai nustatyta, kad sprogimo banga gali tiek deformuoti sklendės judrųjį elementą, kad jis pradės liesti TAV induktorių ir DSALS gali nesuveikti. Todėl TAV aktyviojoje zonoje įtaisomi papildomi slydimo ar riedėjimo guoliai, kurių trinties koeficientas gali skirtis nuo sklendės kreipiamųjų trinties koeficiento. Modeliuojant sklendės tiesiaeigę pavarą, kai statinė pasipriešinimo jėga priklauso nuo dulkių sprogimo slėgio ir sklendės judriojo elemento deformacijos laipsnio, įrodyta, kad sklendė su papildomais guoliais TAV aktyvioje zonoje gali patikimai blokuoti ir smarkių pirminių dulkių sprogimų židinius. Il. 7, bibl. 5 (anglų kalba; santraukos anglų ir lietuvių k.).