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Study of the rotary cleaners of the holes of cylindrical sieves on a vibrocentrifugal separator

Abstract*. This document presents the results of research into the process of cleaning the holes of the vibrocentrifugal separator cylindrical sieves with rotary cleaners. The study of the nature of the movement of rotary sieve cleaners was carried out using electrooscillography methods. An original recording device with a sensor system was developed, which ensured the determination of the speed of the cylindrical sieve and the movement of the rotary cleaners of the sieve holes. The efficiency of the separator was confirmed experimentally*

Streszczenie. *W dokumencie przedstawiono wyniki badań procesu oczyszczania otworów sit cylindrycznych wibroseparatora odśrodkowego za pomocą oczyszczaczy obrotowych. Badania natury ruchu oczyszczaczy sit obrotowych przeprowadzono metodami elektrooscylograficznymi. Opracowano autorskie urządzenie rejestrujące wraz z układem czujników, które umożliwiało określenie prędkości obrotowej sita cylindrycznego oraz ruchu oczyszczaczy obrotowych otworów sitowych. Skuteczność separatora została potwierdzona doświadczalnie. (****Badanie obrotowych oczyszczarek otworów sit cylindrycznych na separatorze wibrowirówkowym****)*

Keywords: *Rotary cleaners, electrooscillography methods, vibrocentrifugal separator.*
Słowa kluczowe: *Oczyszczarki rotacyjne, metody elektrooscylograficzne, wibracyjny separator odśrodkowy*.

Introduction

In agricultural production, the separation of the grain mixtures into fractions is performed on machines of various types, the principle of operation of which is based on the difference in the physical and mechanical properties of impurities and various components of the grain material, such as size, weight, density, aerodynamic resistance, etc. Separation of grain material by an air flow has some advantages over other separation methods. This is a simple design, high specific productivity, minor grain injury, the possibility of removing inferior grain to the forage fraction.

Pneumatic separating channels are used in all types of air grid separators to remove light impurities before feeding the grain to the sieve, which increases the productivity of sieve working bodies [1-3]. Vertical pneumatic channels [4], inclined air channels [5] and grain separators with horizontal air flow [6-7] are widely used in grain cleaning practice. In addition to cleaning, they make it possible to divide the grain material into several fractions according to aerodynamic characteristics.

The efficiency of grain cleaning in pneumatic channels largely depends on the properties of the initial grain material, parameters of the grain flow [8], the thickness of the grain layer, its porosity and the distribution of impurities in the volume of the flow [9-10].

The operation of air separators is significantly complicated by the uneven air speed in the channels and the uneven supply of grain into the channels [11].

Existing methods of increasing the productivity and efficiency of air grain separation involve increasing the size of the channels, using additional devices that change the air velocity fields, tiered feeding of grain into the channels [12-14], the application of an electric field [15-17], the use of preliminary pneumatic stratification of the grain flow before feeding into the channel [18].

However, most of the analyzed innovations, despite certain improvements in the material separation process, significantly complicate the design of separators and do not solve the main problem of ensuring complete separation of grain material due to the overlapping values of the signs of separation of grain and impurity particles [19]. They do not allow separating grain materials into more than two components: pure grain and light impurities.

Fractionation of grain material by an air flow at the initial stage of post-harvest processing ensures the preliminary formation of grain flows, which with minimal energy consumption allow obtaining grain of different conditions [20-22].

A perspective trend in the development of the design of grain separating machines is the integration of several separating working bodies into one machine, which makes it possible to implement the entire complex of technological operations from the purification of grain material to its separation into commodity factions. The study of such combined grain-separating units has received insufficient attention.

The use of sieves in separating machines increases the efficiency of the distribution of materials by size. But sieves have a number of disadvantages, such as low specific productivity, the ability to clog holes with granular material and impurities.

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An increase in the specific productivity of sieve separators is possible due to the use of the principle of vibrocentrifugal separation, that is, the use of cylindrical rotating sieve with a vertical axis of rotation. However, their use leads to an increase in the clogging of the sieve holes due to the more complex geometry of the movement of the cleaners compared to flat sieve separators.

In this work, the authors tried, study the trajectories of movement rotary cleaners of cylindrical sieves in a combined vibrocentrifugal separator and evaluate their effectiveness experimentally.

Purpose of research

The purpose is to substantiate the rational structural and kinematic parameters of rotary cleaners of cylindrical sieves of the combined vibrocentrifugal separator by using methods of electrooscillography of their kinematics.

Materials and methods

The study of the nature of the movement of rotary sieve cleaners, was carried out using electrooscillography methods. For this purpose, an original recording device was developed with a system of movement sensors, both of the material and of the sieve cleaners, which provided determination of the speed of the air flow in the aspiration channel of the separator, the speed of rotation of the cylindrical sieve, the speed of rotation of the rotary cleaners of the sieve holes and the movement of the latter around the axis of rotation in the vertical and horizontal planes on the condition of 100% copying of the surface of the cylindrical sieve.

Automatic recording of the kinematic characteristics of movement of grain material, cylindrical sieve and cleaners was carried out on a Siglent SDS digital four-channel oscillator with a bandwidth of 200 MHz and a sampling rate of 1 Gbit/s. Setting the time of movement of the material, as well as the process of cleaning the cylindrical sieve, was carried out using the TFA "Triple Time XL" digital timer. It should be noted that the duration of automatic data recording corresponded to the duration of at least ten rotations of the cylindrical sieve.

In the process of scientific research, the phenomenon of sliding of the cylindrical cleaner along the arc of the sieve surface was observed, which we characterized by the difference in the rotational speeds of the sieve surface and the cleaner at the point of their mutual contact. The sliding phenomenon was quantitatively estimated by the sliding coefficient K_R according to the following dependence:

(1) $$K_R = \frac{v_S - v_C}{v_S}$$

where v_S is circular velocity of the sieve surface, v_C is circular velocity of the rotary cleaner.

The stability of the contact of the rotary cleaner with the sieve surface was characterized by the stability coefficient K_S, the value of which was determined according to the following relationship:

(2) $$K_S = \frac{t_C}{t_R},$$

where t_C is the average total contact time of the rotary cleaner with the sieve surface for 1 revolution of the sieve, t_R is sieve rotation period.

Automatic recording with an oscilloscope was carried out under the established kinematic mode of the cylindrical sieve. The duration of the recording corresponded to 10 revolutions of the sieve. The obtained experimental measurement data were processed by statistical methods.

The research was carried out on an experimental device, the general view of which is presented in Fig. 1.

To conduct research, a special recording device (Fig. 2) with a system of motion sensors was developed, which ensured the measurement and registration of the following parameters: the speed of sieve rotation ω_S, the speed of cleaner rotation ω_R, angular movement of the axis of the cleaner in the vertical plane α; angular displacement of the axis of the cleaner in the horizontal plane γ.

Experiments were carried out with cleaners of three variants: nylon brush, rubber cleaner, polyurethane cleaner together with a sieve with rectangular holes measuring 2.2x25 mm

The force of pressing the cleaner to the surface of the sieve was set in the range of 2-5 kg with an interval of 1±0.1 kg and was kept constant with the help of a spring *5.*

At the same time, the specific pressing force P of the following limits for cleaners was ensured: nylon brush is 0.254–0.635 kg/cm; rubber cleaner is 0.129–0.322 kg/cm; polyurethane cleaner is 0.211–0.526 kg/cm.

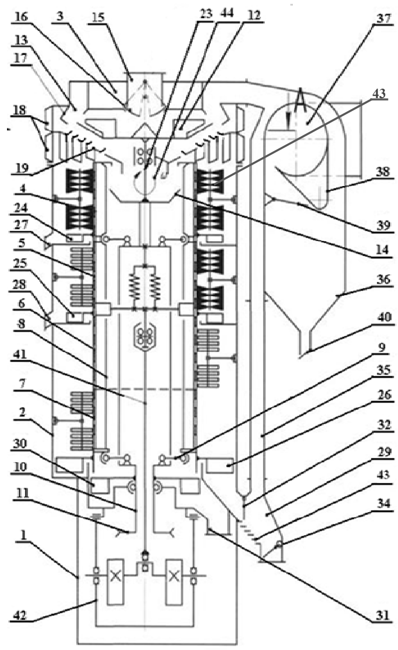

Fig.1. Scheme of the experimental device: 1 is frame; 2 is grain cleaning unit; 3 is pneumocentrifugal fan; 4-7 are sieve; 8 is frame; 9 is lever-hinged suspensions; 10 is bone; 11 is pulley; 12 is spreader; 13 is pneumoseparating channel; 15 is dispenser; 16 are adjustable shutters; 17 is conical surface; 18 are blinds; 19 is cone; 20-22 are scales; 24-26, 30 are shoulder blades; 27-29, 31 are trays; 32 is inlet valve; 33 are blinds; 34 is outlet valve; 35 is air duct; 36 is pan chamber; 37 is air intake window; 38 is fairing; 39, 40 are valves; 41 is connecting rod; 42 is vibrator; 43 are rotary cleaners.

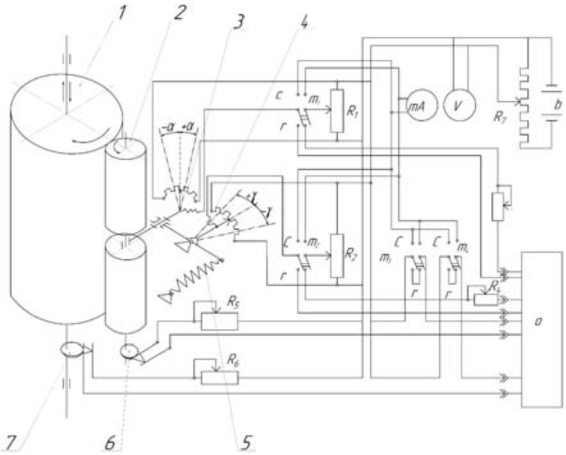

Fig.2. Scheme of the recording device: *1* is a sieve; *2* is a cleaner; *3* is a movement sensor in the vertical plane; *4* is a movement sensor in the horizontal plane; *5* is a spring; *6* is a cleaner rotation sensor; *7* is a sieve rotation sensor; $m_1 – m_4$ are mode switches; *C* is control; *r* is recording; *b* is battery pack; *O* is oscillograph; R_1 and R_2 are balancing resistance of bridges; *α* and *γ* are angular coordinates, respectively; $R_3 – R_6$ are scale potentiometers.

The kinematic parameters of the cleaner were recorded in the following variants: a is the established idling mode of the installation; at the same time, the force of pressing the cleaner changed within the specified limits; b is the installation mode is set with a sieve loading of 28.3 kg/hour.

The research was carried out on grain mass of natural granulometric composition as winter wheat with a moisture content of 11.6%, with a small fraction content of 7-8.5%.

All recordings were made with the sieve's kinematic mode unchanged: eccentricity coefficient K_C = 4.3; oscillation frequency n = 870 cycles/min; oscillation amplitude a = 6 mm.

The position of the sieve and cleaner was fixed in the form of angular coordinates α and γ.

Experimental studies were carried out on a laboratory bench made on the basis of an industrial separator BTSM-50A (Fig. 1). Conical spreaders with radial blades are used as rotary spreaders. The air speed in the aspiration channel was 4-9 m/s; disk speed 100-160 rpm. The flow speed in the pneumatic gravity channel is 4-9 m/s.

Changing the supply of the seed mixture was carried out by adjusting diaphragms with different cross-sections, which were installed at the base of the loader hopper and pre calibrate on the experimental material.

The experimental material was an artificially prepared mixture of wheat and barley seeds in a ratio of 9:1 by weight and with up to 5% impurities. The air speed was changed by throttling the discharge section of the fan.

The separation efficiency was determined depending on the speed of the airflow and the rotation frequency for the rotary spreader.

The efficiency of pneumatic gravity separation was estimated by the mass of 1000 grains in each grain sampler.

Results and discussion

As result of the studies carried out in different modes, the dependences of the change in the relative movements of the rotary cleaners during rotation of the cylindrical sieve were obtained (Fig. 3-4).

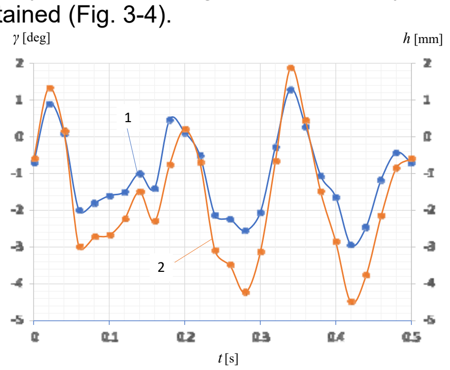

Fig.3. Change in relative displacements γ, degrees (1) and h, mm (2) of the rotary cleaner (brush) during the rotation of the cylindrical sieve at idle speed of the experimental installation under the specific pressing force of the rotary brush P=0.495 kg/cm

According to the research results, it was established that the average value of the movement of the cleaner relative to the surface of the sieve was 2.36–2.55 mm, and the amplitude of the movement to the axis of rotation of the sieve was 0.75–1.2 mm.

It was established that the existing technological gap on the surface of the cylindrical sieve, formed as result of the coupling of two semi-cylindrical sieves, is an insignificant factor in the mechanical disturbances of the movement of the sieve.

According to the research results, the optimal values of the specific clamping force for each cleaner were determined, provided the same quality of hole cleaning, namely: nylon brush – 0.495 kg/cm; rubber cleaner – 0.285 kg/cm; polyurethane cleaner – 0.316 kg/cm.

Rotary cleaners, made in the form of rubber rings with a diameter of 100 mm and a width of 10-12 mm and located at a step of 2-4 mm from each other, ensured a high-quality process of cleaning the sieve.

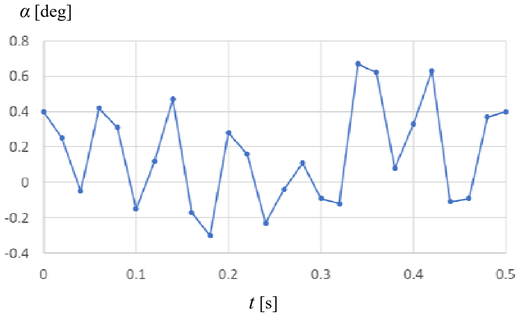

Fig.4. Change in relative displacements α, degrees of the rotary cleaner (brush) during the rotation of the cylindrical sieve at idle speed of the experimental installation under the specific pressing force of the rotary brush P=0.495 kg/cm

This placement of the rubber rings of the cleaner brush ensures that during the rotation of the cylindrical sieve, the rectangular openings of the sieve are overlapped and thereby squeezes out the seeds stuck in the sieve in the opposite direction, thus cleaning it for the passage of other seeds, which are smaller in terms of their geometric dimensions.

Figure 5 shows experimental graphical dependences of the efficiency indicators of the separation process on air speed and specific load of the separator.

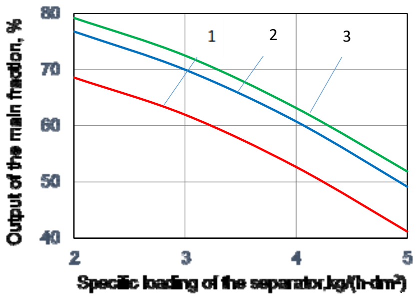

Fig.5. Dependence of the output of the main fraction on the specific loading of the separator at different values of the rotation frequency of the rotary spreader, where 1 - ω = 80 rpm; 2 – ω = 100 rpm; 3 - ω= 120 rpm

Dependence of the output of the main fraction on the specific loading (Fig. 5) is complex in nature. At a low specific load of 1.8-2.0 kg/(h dm^2) at different values of ω, an increase in purity is observed from 69% to 80% depending on the rotor speed. This is explained by the fact that with a small specific supply of material, the thickness of the layer of seeds supplied to the aspiration channel for further separation is insignificant and the airflow penetrates the grain material from all sides and, accordingly, carries non-condensed seeds and the light fraction (impurities) into the waste fraction.

It should also note that with an increase in the specific load, the thickness of the seed layer supplied for subsequent processing increases proportionally over the cross-sectional area of the aspiration channel. Consequently, the airflow passes rather compressed through the corresponding section of the seed layer, so the efficiency of the process of separating the mixture into heavy and light fractions decreases. With a further increase in feed to 4.7-5.0 kg/(h dm^2), the thickness of the seed layer on the working surface increases so much that the intensity of the action of the spreading disk guide elements on the upper part of the seed layer decreases. At the same time, the amount of heavy grains coming from this part for unloading decreases, which causes a decrease in purity. The yield of the main fraction is reduced to 41-53%.

Conclusions

1. Research has established that the smallest value of relative slip in the rational mode of operation of the rotary grate cleaner is $K_R = 0.03$.

2. It was established that the average value of the range of movement of the cleaner relative to the surface of the sieve was 2.36–2.55 mm, and the average value of the amplitude of movement towards the axis of rotation of the sieve was 0.75–1.2 mm.

3. It should be noted that the existing gap on the surface of the cylindrical sieve in the area of the junction of two semi-cylinder sieves with a value of 3.5–4.0 mm is an insignificant factor in the mechanical disturbances of the movement of the rotary cleaner, and the radial beating of the surface of the sieve with a value of 1.5–1.6 mm at a length of 150–160 mm is clearly reflected in the stability of the contact.

4. The results of experimental studies confirmed the possibility of dividing grain material into two fractions: heavy with a mass of 1000 grains of 36 g and light – 30.2 g with a percentage of fractions in the output of 39 % to 61%.

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