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ENERGY ASSESSMENT OF THE PNEUMATIC SIEVE SEPARATOR FOR AGRICULTURAL CROPS

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ABSTRACT

As a result of energy assessment of a pneumatic sieve separator for agricultural crops it was determined that the specific energy consumption of the experimental pneumatic sieve separator was 0.18 $kW{\cdot}t^{-1}$. It is lower than in case of its domestic and foreign equivalents. For instance, the specific energy consumption of the separator of preliminary grain purification called SPO-50 (Ukraine) is 0.31 $kW{\cdot}t^{-1}$, and that of the machine of preliminary grain purification called MPO-50 (Russia) is 0.38 $kW{\cdot}t^{-1}$. Specific energy consumption of a pneumatic sieve separator is 1.72-2.11 times lower than in case of its domestic and foreign counterparts.

Introduction

In the seed production system, there is a multi-stage technology for cleaning, sorting, calibrating seeds after harvesting under conditions of minimal damage (Badretdinov et al., 2019).

Preliminary cleaning of agricultural seeds is one of the most important technological operations of its post-harvest processing in the system of seed preparation (Shymko et al., 2020). The basic material after harvesting is more vulnerable to the influence of various harmful organisms, since it is a mixture of the main crop (Kroulík et al., 2016) extraneous cultivated plants and weeds (Kovalenko et al., 2021).

Therefore, it is an urgent task to intensify preliminary cleaning of seeds of agricultural crops, subject to a decrease in specific energy consumption (Muratov et al., 2020).

The preliminary grain cleaning consists in separation of at least 60% of the large and air-separable foreign materials from the grain (Wang et al., 2020). This increases their safety in temporary storage. Seed and all food grain are subject to pre-cleaning after harvesting (Jin et al., 2021).

The paper presents analysis of operation of preliminary cleaning means and methods of their investigation. Studies on the procedure of determination of parameters and operating modes of air-sieved separators are presented to a lesser extent (Linenko et al., 2017).

Devices and technological processes of operation of air-sieved separators with a closed air system, providing preliminary cleaning of the grain, are known (Postnikova et al., 2019; Mykhailov et al., 2020; Kharchenko et al., 2019).

A special novelty in the study of air flow parameters of air-sieved separators is provided by a two-stage sedimentation chamber and a suction channel of the fan, which influence validation of the airflow parameters in the fluidization zone of grain materials (GM) and their air separation.

The blowing airflow, which diametrically permeates a cylindrical sieve, plays an important role here (Krzysiak et al., 2020).

The state of the airflow structure and the analysis of factors ensuring the quality of grain material purification form the main task of the study of the air-sieved separators' working process (Konopka at al., 2017).

In Ukraine, the most often used are grain cleaning machines produced in Russia and Ukraine. For a comparative energy assessment of the pneumatic sieve separator, a preliminary grain separator SPO-50 (Ukraine) and a preliminary grain cleaning machine MPO-50 (Russia) were adopted.

A pneumatic sieve separator (PSS) with a closed air system is offered. Estimated specific capacity of the pneumatic sieve separator is 1.5-2.0 times higher than the productivity of existing grain cleaning machines equipped with cylindrical sieves with a horizontal axis of rotation and an external working surface.

The pneumatic sieve separator is simple in design, has a lower metal and energy consumption compared to existing grain pre-cleaning machines, does not have vibrating structural elements, provides high technological and operational reliability, and practically does not injure the processed material (Mykhailov et al., 2020).

Methodology of research

The objective of the paperis to conduct an energy assessment of the pneumatic sifter for crops. A pneumatic sieve separator with a closed air system is offered.

The state of the airflow structure and the analysis of factors ensuring the quality of grain material purification form the main task of the study of the air-sieved separators' working process (Nesterenko et al., 2019; Ushakov et al., 2019; Chernyakov et al., 2021).

The proposed separator is equipped with a pneumatic separation sediment chamber with a complex geometric surface connected to the suction channel of a cross-flow fan, which creates a closed pneumatic separation air system, thus improving the process of extracting light impurities, reducing energy consumption for pneumatic separation and does not pollute the environment.

Based on the performed studies, an air-sieved separator with a technological scheme shown in Fig. 1 (Zadosnaya, 2020) is suggested.

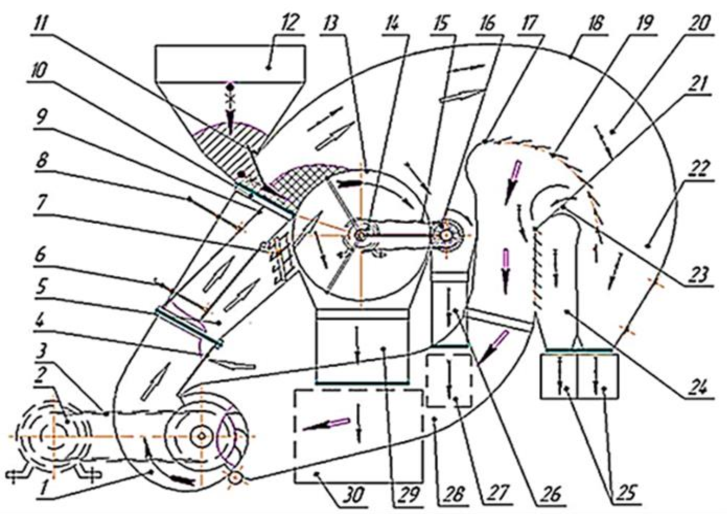

Figure 1. Technological scheme of an air-sieved separator

1 – diametric fan; 2 – direct current motor; 3 – fan drive; 4 – louvers for additional airflow inlet in the fan; 5 – air distributor; 6 – middle movable wall control lever; 7 – air distributor louvers; 8 – rear movable wall control lever; 9 – extension of the rear movable wall; 10 – tray-intensifier; 11 – charging hopper flap; 12 – hopper; 13 – cylindrical sieve; 14 –reducing gear motor; 15 – brush cleaner drive; 16 – brush cleaner; 17 – airflow cutter; 18 – shell of the air channel of a sedimentation chamber; 19 – working surface of the 1st stage cleaning louver; 20 – air channel of the 1st stage cleaning; 21 – surface of the 2nd stage cleaning louver; 22 – sedimentation chamber of the 1st stage of purification; 23 – input channel of the 2nd stage of purification; 24 – sedimentation chamber of the 2nd stage of purification; 25 – hopper for impurities of the 1st and 2nd stage of the sedimentation chamber; 26 – the channel and the valve for the large impurities outlet; 27 – hopper of large impurities; 28 – the suction channel of the fan; 29 – channel and valve of the purified grain material; 30 – hopper of purified grain material.

Research results

According to the creative cooperation agreement between Tavria State Agrotechnological University and Motor Sich OJSC (Gulaypole) subsidiary Gulaypole Mechanical Plant, an experimental pneumatic separator has been produced (Fig. 2 and 3)

Figure. 2. Pneumatic sieve separator for preliminary cleaning of seeds of agricultural crops

a b

Figure 3. Operational parts of the pneumatic sieve separator

a – control panel with D.C. motor; b – drive of the diametric fan.

The main parameters and design dimensions are defined based on the results of theoretical studies and previous search experiments (Mykhailov et al., 2020).

To calculate indicators of the specific energy consumption of the experimental pneumatic sieve separator, the generally accepted method of determination of the energy consumption per unit of processed material was applied (Tishchenko and Kharchenko, 2013)

Since energy consumption is one of the most important characteristics when selecting a separator, the research was carried out to measure the power consumed by the separator.

It is reasonable to divide power consumed by the separator into the following components

– power consumption when there is no grain material in the separator (idle running);
– power consumption of the separator's operating mode (Shaker, 2015).

Determination of power consumption makes it possible to determine the energy consumption for experimental PSS operation (Aliev et al., 2018).

We measured voltage and current at PSS's idle running and at its operating mode. The calculation was carried out with the help of the formula (Postnikova et al., 2019):

$$P = 3 \cdot I_c \cdot U_v \cdot cos\ \varphi \tag{1}$$

where:
I_c – phase current,
A; U_v – phase voltage,
V; φ – phase shift angle between current and voltage.

To calculate the experimental PSS specific energy consumption, we used the standard practice of determination of the energy consumption per unit of processed material.

To determine the cost of electricity for the fan drive, experimental studies were carried out, the results of which are shown in Table 1. The determination of indicators Ip, Up and the calculation of the value was carried out at various values of the fan rotor speed n.

Table 1.
Indicators of energy consumption for the fan drive

Number	*N* (rpm)	I_p (A)	U_p, (V)	*P* (kW)
1	425	1.6	70	0.164
2	470	1.8	80	0.212
3	510	1.9	90	0.251
4	560	2.2	100	0.323
5	620	2.3	110	0.372
6	640	2.5	120	0.441
7	680	2.7	130	0.516
8	740	3.2	140	0.659
9	780	3.4	150	0.750
10	840	3.8	160	0.894
11	890	4.0	170	0.944
12	940	4.5	180	1.125
13	970	4.8	190	1.266
14	1020	5.1	200	1.417
15	1060	5.5	210	1.604
16	1080	5.8	220	1.770
17	1140	6.5	230	2.076

In the range of measurement n from 425 to 1140 rpm electricity costs *P* vary from 0.2 to 2.1 kW. When cleaning seeds that have a hovering speed of 3.0 to 6.5 $m \cdot s^{-1}$ (e.g., sunflower seeds), at values of *n* – 425-650 rpm, the value of *P* does not exceed 0.42 kW.

In the measurement range of n from 900 to 1175 rpm when cleaning seeds, which have a hovering speed of 8.0 to 13.0 $m \cdot s^{-1}$ (e.g., wheat, corn), the values of *P* can reach 2.1 kW.

The conducted research on the cleaning of sunflower seeds made it possible to obtain the dependence of the unit consumption of electricity N_n of the PSS on its specific productivity q, taking into account the change in the length of the cylindrical sieve in decimeters. (Fig. 4)

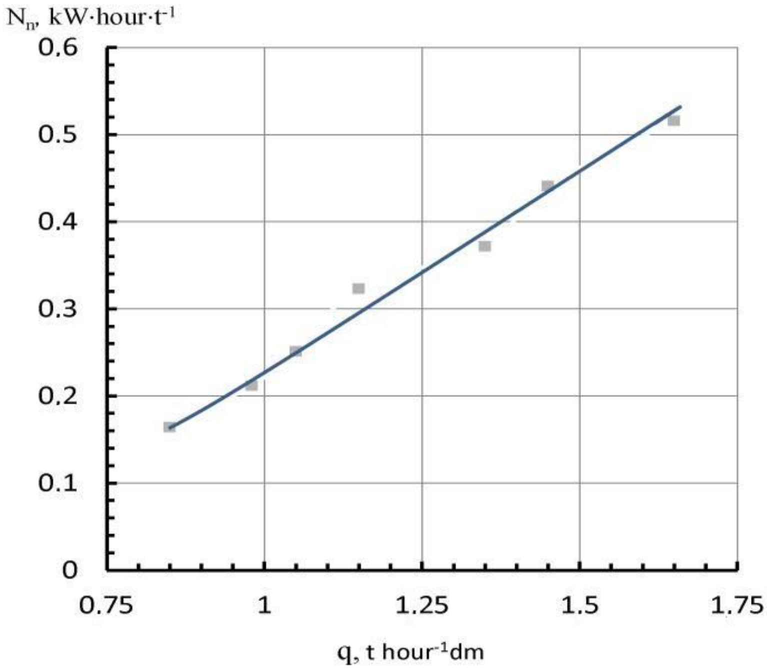

Figure 4. Dependence of the unit costs of electricity N_n of the PSS on its specific productivity q

So, with an increase in q from 0.85 to 1.75 t^{-1}, the value of the specific energy consumption per ton of treated seeds N_n is within the range of 0.16-0.52 $kW \cdot t^{-1}$.

Taking into account the agrotechnical requirements for permissible losses and the effect of cleaning seeds, the specific energy consumption is 0.16-0.18 $kW \cdot t^{-1}$.

The indicator of the specific energy consumption of the experimental pneumatic sieve separator, in contrast to the existing technical equivalents, is lower and amounts to 0.18 $kW \cdot t^{-1}$ (Table 2).

Table 2.
Rates of the experimental PSS's specific energy consumption as distinct from existing technical counterparts

Technical counterparts	Pneumatic sieve separator	Separator of preliminary grain purification SPO-50 (Ukraine)	Machine of preliminary grain purification MPO-50 (Russia)
Specific energy consumption of technical means, $kW{\cdot}t^{-1}$	0.18	0.31	0.38
PSS's energy efficiency coefficient compared to its counterparts	1.0	1.72	2.11

Estimated specific capacity of the pneumatic sieve separator is 1.5-2.0 times higher than the productivity of existing grain cleaning machines equipped with cylindrical sieves with a horizontal axis of rotation and an external working surface.

The pneumatic sieve separator is simple in design, has a lower metal and energy consumption compared to the existing grain pre-cleaning machines, does not have vibrating structural elements, provides high technological and operational reliability, and practically does not injure the processed material.

Conclusions

1. As a result of energy assessment of the pneumatic sieve separator for agricultural crops it was determined that the specific energy consumption of the experimental pneumatic sieve separator was 0.18 $kW{\cdot}year{\cdot}t^{-1}$. It is lower than in its domestic and foreign counterparts. For instance, the specific energy consumption of the separator of preliminary grain purification called SPO-50 (Ukraine) is 0.31 $kW{\cdot}year{\cdot}t^{-1}$, and that of the machine of preliminary grain purification called MPO-50 (Russia) is 0.38 $kW{\cdot}year{\cdot}t^{-1}$.
2. According to the obtained results, specific energy consumption of a pneumatic sieve separator is 1.72-2.11 times lower than its domestic and foreign counterparts have.

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OCENA ENERGETYCZNA PRACY PRZESIEWACZA PNEUMATYCZNEGO DO PŁODÓW ROLNYCH

Streszczenie. W wyniku oceny energetycznej pneumatycznego separatora sitowego dla płodów rolnych ustalono, że jednostkowe zużycie energii eksperymentalnego pneumatycznego separatora sitowego wynosi 0,18 $kW \cdot t^{-1}$. Jest ono niższe niż w przypadku jego krajowych i zagranicznych odpowiedników. Na przykład, jednostkowe zużycie energii separatora do wstępnego oczyszczania ziarna o nazwie SPO-50 (Ukraina) wynosi 0,31 $kW \cdot t^{-1}$, a urządzenia do wstępnego oczyszczania ziarna o nazwie MPO-50 (Rosja) – 0,38 $kW \cdot t^{-1}$. Jednostkowe zużycie energii przez pneumatyczny separator sitowy jest 1.72-2.11 razy niższe niż jego krajowych i zagranicznych odpowiedników.

Słowa kluczowe: separator pneumatyczny, nasiona upraw rolnych, ocena energetyczna