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DOI <https://doi.org/10.15673/gpmf.v21i4.2235>**A. Aleksashin, Ph.D., Associate professor, E.mail: aleksashin48@gmail.com**

ORCID.org/0000-0001-6423-4605, RESEARCHERID.com/rid/U-7832-2017

G. Goncharuk, Ph.D., Associate professor, E.mail: ganna.goncharuk22@gmail.com

ORCID.org/0000-0002-8361-0810, RESEARCHERID.com/rid/U-7642-2017

M. Lisak, student, E.mail: misalysak544@gmail.com²Department of grain storage technology,

Odessa National Academy of Food Technologies, 112, Kanatna Str., 65039, Odessa, Ukraine

MODERNIZATION OF CORN GRAIN CRUSHER IN THE CONDITIONS OF IT-SYSTEM EQUIPMENT

Abstract

Corn is widely used as a source of starch in the food, pharmaceutical, paper, mining and construction industries. This starch is usually obtained after the cleaning process, and corn germ, fiber and protein are also produced. It is used in the production of biodegradable plastic bags, medicines, paper, corrugated cardboard, detergents, paints, diapers, cosmetics, glue, surfactants and agrochemicals. Corn is the most important grain in the world. After all, in addition to the highest consumption of all grains, corn is also a universal product from which you can get fuel, electricity and household goods. This means that by increasing the volume of corn processing, it is possible to go beyond the agricultural sector and create goods with high added value. Growing corn for grain allows better use of agricultural machinery due to the later dates of sowing and harvesting. Valuable properties of corn cause its consistently high demand on the world market.

Corn grain processing is part of the technological lines that are part of cereals. The main equipment that ensures high quality products are impact centrifugal crushers.

Analysis of the operation of the impact-centrifugal crusher revealed the possibility of its operation in a wide range of changes in design parameters. The theoretical aspects of the dependences of crusher productivity, which basically take its design parameters and modes, include: rotational speed of grinding discs, disc diameter, disc tooth length, thickness, and properties and parameters of grain material.

As a result of the conducted researches the possibility of increase of qualitative characteristics of the processed products, and also productivity of the shock-centrifugal crusher is defined.

To increase productivity, it is proposed to implement two options. On the one hand to make the rotational speed of the adjustable working body, on the other hand to increase the sizes of diameters of working disks, taking into account a design of the crusher for corn grain, having provided productivity of the crusher.

The purpose of this work is to increase the efficiency of the grain crusher, which is part of the preparation of grain for grinding, to ensure the reliability of the machine, its productivity, improve the quality of finished products by implementing automation based on SMART-technology, defined as self-control technology and reporting. This technology provides long-term archiving of the received data that allows the dispatcher to watch work of the corresponding equipment, reacting by means of the IT- service program.

Key words: corn crusher, speed, working disks, SMART-technology, IT- service program.

Formulation of the problem

Corn is the №1 grain in the world. After all, in addition to the highest consumption of all grains, corn is also a universal product from which you can get fuel, electricity and household goods. This means that by increasing the volume of corn processing, it is possible to go beyond the agricultural sector and create goods with high added value. Thus, if Ukraine uses corn not as a raw material for export, but for the sake of increasing industry, it will help increase the country's GDP much faster. Corn is widely used as a source of starch in the food, pharmaceutical, paper, mining and construction industries. This starch is usually obtained after the cleaning process, and corn germ, fiber and protein are also produced. It is used in the production of biodegradable plastic bags, medicines, paper, corrugated cardboard, detergents, paints, diapers, cosmetics, glue, surfactants and agrochemicals.

Maize is of great and agro-technological importance, as it clears the soil of weeds and is a good precursor in crop rotation. In terms of carbon dioxide ab-

sorption and oxygen release, corn is one of the first among all cultivated plants and is even more efficient than a forest of similar area [1]. Growing corn for grain allows better use of agricultural machinery due to the later dates of sowing and harvesting. Valuable properties of corn cause its consistently high demand on the world market.

Corn grain processing is part of the technological lines that are part of cereals. The main equipment that ensures high quality products are impact centrifugal crushers.

Analysis of the operation of the impact-centrifugal crusher revealed the possibility of its operation in a wide range of changes in design parameters. Theoretical aspects of crusher productivity dependences are revealed, which basically take its design parameters and modes, in particular: rotational speed of grinding discs, disc diameter, disc tooth length, thickness, as well as properties and parameters of grain material.

As a result of the conducted researches the possibility of increase of qualitative characteristics of the



processed products, and also productivity of the shock-centrifugal crusher is defined.

To increase productivity, it is proposed to implement two options. On the one hand to make the speed of the adjustable working body, on the other hand to increase the size of the diameters of the working disks, taking into account the design of the crusher for corn grain, ensuring the productivity of the crusher equal to 12t / h. Take as a basis a disc crusher for corn type ZDD.

Materials and methods of research

Technological calculation

Output data

- Productivity $Q = 12 \text{ t/h} = 3,3 \text{ kg/s}$;
- Corn grain sizes [2]: length $l_3 = 5.5 \dots 13.5 \text{ mm}$;
- Width $e_3 = 5 \dots 11.5 \text{ mm}$;
- Thickness $c_3 = 2,5 \dots 8 \text{ mm}$;
- Diameter of a feeding drum = 275 mm;
- Length of a feeding drum $L_{pb} = 200 \text{ mm}$;
- Volume weight of maize grain $\gamma = 750 \text{ kg/m}^3$ [3]

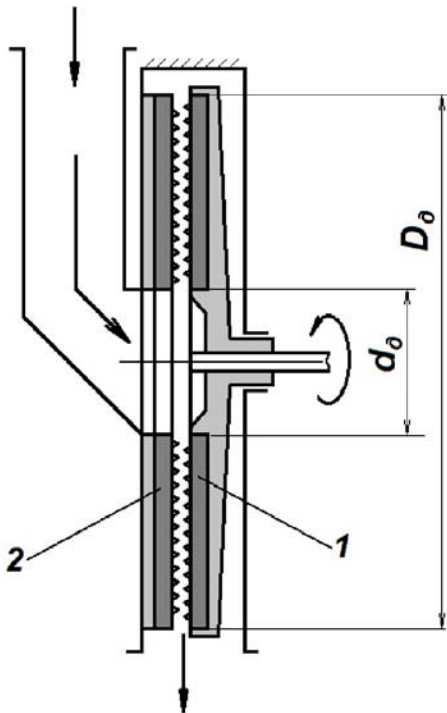


Fig.1 Scheme of calculation

1 - rotating disk; 2 - fixed disk; D_d - outer diameter of the disks;
 d_d - diameter of disks, n_d - frequency of rotation of a moving disk (Fig. 1)

We accept internal diameter of disks as in the car ZDD $d_0 = 475 \text{ mm}$;

The speed of rotation of the moving disk $n_0 = 986 \text{ rpm}$

Research results

Calculation

Machine performance

$$Q = 0,9q_0 \frac{D_d^2 v (k-1)}{2k^2} \text{ t/h,} \quad (1)$$

where: q_0 is the specific stress of 1 m^2 of the work-

ing field area (for crushing corn $q_0 = 2.4 \text{ kg/m}^2$ [3]);

D_0 - outer diameter of the disks in m;

v is the circumferential speed of the rotating disk, m / s;

k is the ratio D_0 / d_d ($K = D_0 / 0.475$).

$$v = \frac{\pi D_0 n_d}{60} = \frac{3,14 \cdot 986 D_0}{60} = 51,6 D_d \text{ m/c.} \quad (2)$$

Substitute in formula (1) known values

$$Q = 0,9 \cdot 2,4 \frac{D_0^2 v (K-1)}{2 \left(\frac{D_0}{0,475}\right)^2} = 12,57 D_d \left(\frac{D_0}{0,475} - 1\right) = 12 \text{ t/h} \quad (3)$$

Determine the outer diameter of the disks D_0 to do this we solve the quadratic equation

$$2,105 D_d^2 - D_d - 0,955 = 0,964 \quad (4)$$

we accept $D_d = 0,965 \text{ m}$;

then:

$$v = 51.6 \cdot 0.965 = 49.8 \text{ m/s};$$

$$k = 0.965 / 0.475 = 2.03.$$

Calculation of the feeding mechanism (Fig. 2. 1 - feed drum; 2 - damper; 3 - pipe)

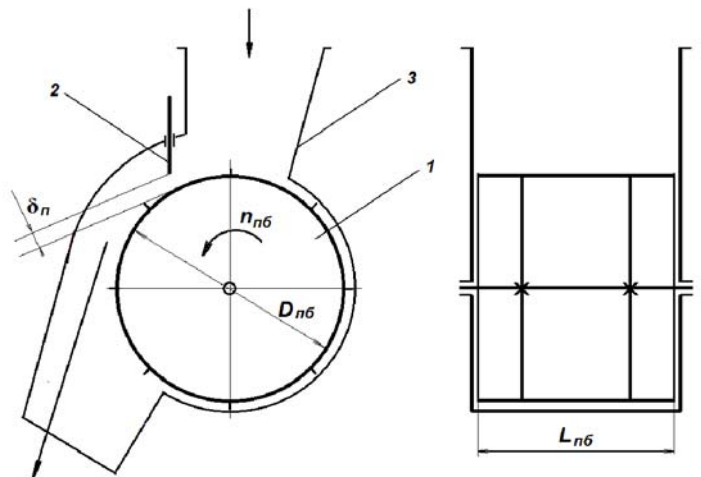


Рис.2. Схема розрахунку живильника

Determine the average grain size of corn: length $l_3 = (5.5 + 13.5) / 2 = 9.5 \text{ mm}$;

width $e_3 = (5 + 11.5) / 2 = 8.25 \text{ mm}$; thickness

$c_3 = (2.5 + 8) / 2 = 5.25 \text{ mm}$.

The volume of the grain $V_3 = V_m$,

where: $V_m = \frac{\pi d^3}{6}$ is the volume of the sphere;

d is the reduced particle diameter.

$$V_3 = 0,15 l_3 (1,6 e_3^2 + c_3 (e_3 + c_3)) \text{ mm,} \quad (5)$$

$$V_3 = 0,15 \cdot 9,5 \cdot (1,6 \cdot 8,25^2 + 5,25 \cdot (8,25 + 5,25)) = 168,8 \text{ mm}^3.$$

$$d = \sqrt[3]{\frac{V_3 \cdot 6}{\pi}} = \sqrt[3]{\frac{168,8 \cdot 6}{\pi}} = 0,8 \text{ mm} \quad (6)$$



The average speed of the product in the slot of the feeder

$$v_n = \frac{Q}{\gamma \delta_n L_n} \text{ м/с,}$$

Where: $L_n = L_{n\delta} = 200 \text{ mm}$ - the length of the feeder;

δ_n is the width of the feeder slot;

$$\delta_n > 5d = 5 \cdot 6.8 = 34 \text{ mm,}$$

we accept ; $\delta_n = 35 \text{ mm.}$

$$v_n = \frac{Q_n + v_b}{2}, \text{ м/с} \quad (9)$$

$$v_n = 3,3 / (750 \cdot 0,035 \cdot 0,2) = 0,62 \text{ м/с.}$$

Where: $v_b = 0$ - the speed of the valve; v_b - circumferential speed of the drum.

$$v_b = 2v_n = 2 \cdot 0,62 = 1,24 \text{ м/с.} \quad (10)$$

The frequency of rotation of the feed drum

$$n_{nb} = (60 \cdot v_b) / (\pi \cdot D_{pb}) = \\ = (60 \cdot 1,24) / (3,14 \cdot 0,275) = 86 \text{ r/min.} \quad (11)$$

Conclusion from the calculation

Productivity of the machine of the machine for crushing of corn grain $Q = 12 \text{ t/h}$; the speed of rotation of the moving working disk PD = 986 rpm; outer diameter of disks $D_d = 965 \text{ mm}$; inner diameter of disks $d_d = 475 \text{ mm}$; circumferential speed of the rotating disk (outer diameter) $v = 49.8 \text{ m/s}$; the length of the feed drum $L_{pb} = 200 \text{ mm}$; the diameter of the feed drum $D_{pb} = 275 \text{ mm}$; the speed of the feed drum $PPB = 86 \text{ r/min}$

Description of the kinematic scheme

Rotation from the electric motor 1 (fig. 3) through the elastic coupling 2 is transmitted to the shaft (7) on which the rotating disk 3 is fixed.

Shaft bearings I are located on the sleeves 5 and 6, which rotate together with the shaft, while the shaft is able to move in the axial direction. One half-clutch is mounted on the sleeve 6, and the second half-clutch is mounted on the motor shaft. On the sleeve 5 is fixed the drive pulley 7 of the flat belt transmission, which transmits rotation to the shaft II, which is fixed to the driven pulley 8 and the worm 9 of the worm gear. The worm gear transmits rotation to the shaft III, which is fixed to the worm wheel 10 and the feed drum 22.

Adjusting the gap between the disk 3 and the fixed disk 4 is as follows: when you turn the fork 17, the spring 20 ceases to act on.

Kinematic calculation Output data

Frequency of rotation of a mobile working disk $n_d = 986 \text{ r/min}$;

Frequency of rotation of the feed drum $n_{n\delta} = 86 \text{ r/min}$;

Axial distance of worm transmission $a_w = 100 \text{ mm}$;

The diameter of the drive pulley of the flat belt transmission $D_1 = 125 \text{ mm}$.

Determine the kinematic parameters of the machine drive (Fig.4)

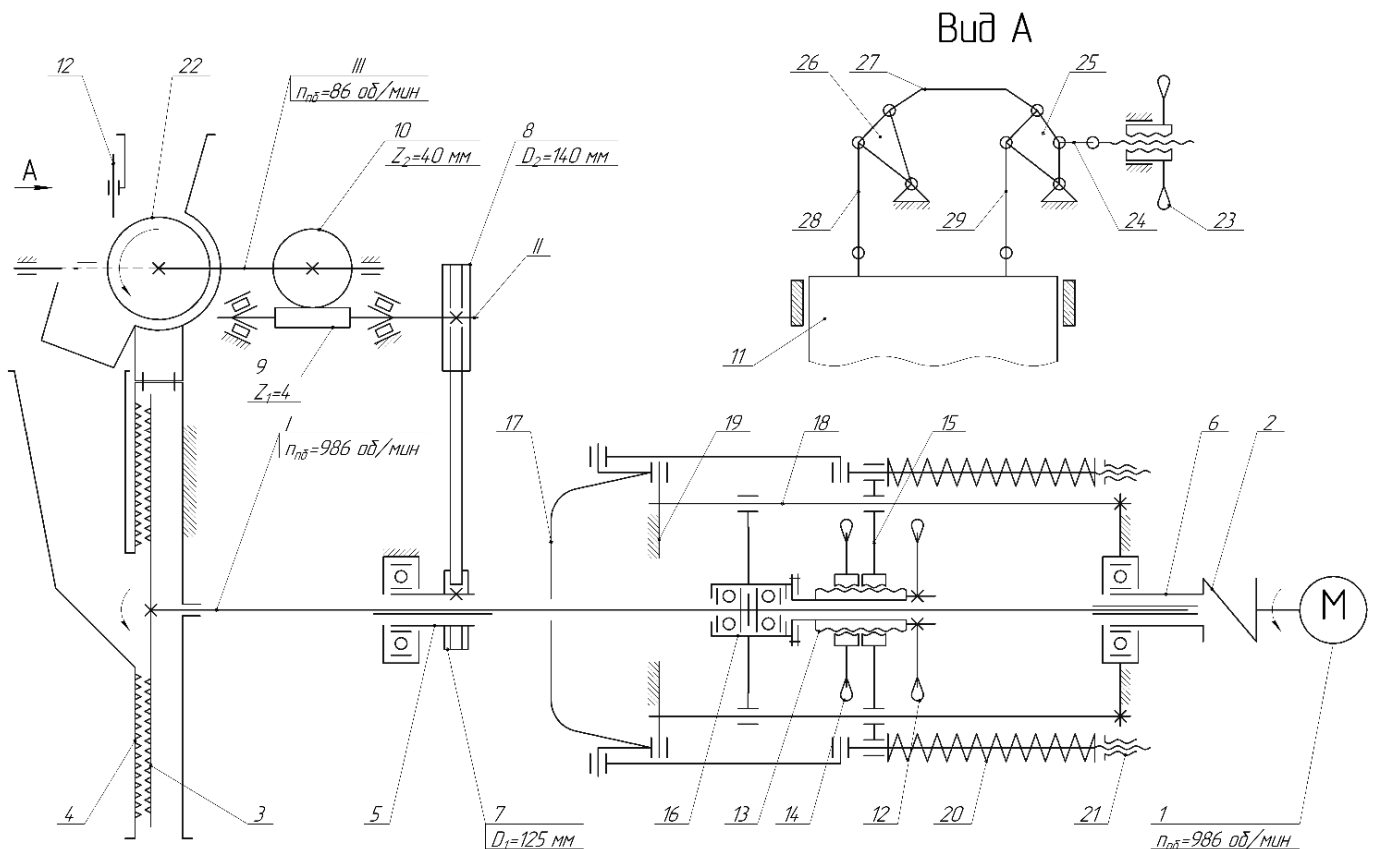


Fig. 3. Kinematic scheme

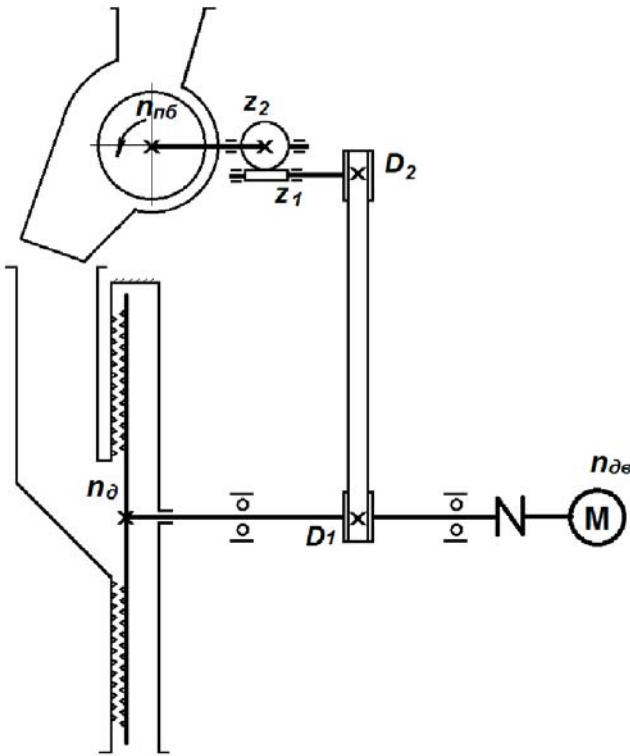


Fig. 4. Kinematic scheme for calculation

Calculation

The rotating shaft of the rotating disk receives rotation from through the coupling, then $n_{\delta} = n_{oe} = 986$ r/min

The gear ratio of the feed drum drive is required

$$i = \frac{n_{\delta}}{n_{n6}} = \frac{986}{86} = 11,5 \tag{12}$$

Take the gear ratio of the worm gear $i_w = 10$ and determine the gear ratio of the flat belt drive

$$i_p = \frac{i}{i_w} = \frac{11,5}{10} = 1,15 \tag{13}$$

Determine the dividing diameter of the worm

$$d_1 = qm = 10 \cdot 4 = 40 \text{ mm}, \tag{14}$$

here: q is the coefficient of the diameter of the worm; m is the modulus (we assume $q = 10, m = 4$ mm [3]).

At $i_w = 10$ the recommended number of measures of the worm $Z_1 = 4$, then the number of teeth of the worm wheel will be $Z_2 = Z_1 \cdot i_{ch} = 4 \cdot 10 = 40$ mm.

Determine the dividing diameter of the worm wheel:

$$d_2 = Z_2 m = 40 \cdot 4 = 160 \text{ mm} \tag{15}$$

Specify the wheelbase of the worm gear:

$$a_w = \frac{(d_1 + d_2)}{2} = \frac{40 + 160}{2} = 100 \text{ mm}. \tag{16}$$

Determine the diameter of the driven pulley flat belt transmission:

$$D_2 = i_p \cdot D_1 (1 - \varepsilon) = 1,15 \cdot 125 \cdot (1 - 0,015) = 141 \text{ mm}$$

here: $\varepsilon = 0,015$ - relative slip. We accept $D_2 = 140$ mm.

Conclusion from the calculation

Worm gear parameters: wheelbase $a_w = 100$ mm; gear ratio $i_w = 10$; the number of measures of the worm $Z_1 = 4$; the number of teeth of the worm wheel will be $Z_2 = 40$ mm; dividing diameters $d_1 = 40$ mm; $d_2 = 160$ mm.

When the diameters of the pulleys $D_1 = 125$ mm and $D_2 = 140$ mm, the gear ratio of the flat belt transmission will be $i_p = 1.15$.

Thus, the efficiency of the machine for crushing corn grains can be achieved through the following indicators:

- machine productivity $Q = 12$ t / h; the frequency of rotation of the moving working disk $n_{\delta} = 986$ r/min; outer diameter of disks $D_{\delta} = 965$ mm; inner diameter of disks $d_{\delta} = 475$ mm; circumferential speed of a rotating disk (on external diameter) $v = 49,8$ m / s; length of the feeding drum $L_{n6} = 20$ mm; diameter of the feeding drum $D_{n6} = 275$ mm; the speed of the feed drum $n_{n6} = 86$ r / min;
- the technological and kinematic characteristics of the machine for crushing corn grain are significantly affected - the speed of rotation of the rotor, the interdiscal gap between the rotating and stationary working body;

At introduction of SMART-technologies for maintenance of an optimum mode of work in a production line it is necessary to apply such technical means, and also means of computer engineering:

- organization of an automated workplace of the operator on the basis of a personal computer with a control system and data collection, designed to monitor and automatically control a large number of remote, geographically distributed objects and visualize the state of technological and transport equipment, control it, archive parameters;
- temperature sensors of bearings of the driving electric motor, reducer, bearing supports of a working shaft of the car for crushing of corn grain;
- control of grain consumption by means of the executive mechanism in the working chamber;
- control and management of frequency of rotation of the driving electric motor of a working shaft of the car for crushing of corn grain;
- control of current load of the driving electric motor of the shaft of the machine for crushing corn grain.

The most important component of the remote automated control system is the need to receive service messages. Current service messages are used to implement the dialog mode of the control system and the operator. Such messages are accompanied by an audible signal to attract the attention of the operator and are displayed on the control field in the central part of the monitor of the personal computer of the automated workplace. To confirm to the control system that the operator has read the message, he must press the interactive button "acknowledge" and the button "close", turn off the automatic warning sound alarm.

**Table 1 - Example of presenting alarm messages**

Archive of messages				
Emergency For the period from 01.01.2022. to 31.01.2022.				
Date	Time	Name	Messages	Confirmed
05.01.22.	10.11.45.	Conveyor 1	Not ready for work. Check all sensors	Administrator
05.01.22.	10.12.49.	Conveyor 1	Not ready for work. Check all sensors	Operator
11.01.22.	08.32.38.	Elevator 2.	Check speed control sensor	Administrator
11.01.22.	08.34.23.	Elevator 2.	Check speed control sensor	Operator
19.01.21	14.23.48	Dispenser of grain 1	Sensor scales alarm	Administrator
19.01.22.	19.24.12.	Dispenser of grain 1	Sensor scales alarm	Operator

Table 2 - Example of presenting alarm messages

Archive of messages				
Warning situation For the period from 01.01.2022. to 31.01.2022.				
Date	Time	Name	Messages	Confirmed
17.01.22.	13.28.50.	Dryer 1	No heat agent	Administrator
17.01.22.	13.31.21.	Dryer 1	No heat agent	Operator
21.01.22.	16.20.48.	Crusher 2	The temperature of the shaft bearing is increased	Administrator
21.01.22	16.22.35.	Crusher 2	The temperature of the shaft bearing is increased	Operator
26.01.22.	09.08.29.	Separator 3	Depressurization of the case	Administrator
26.01.22.	09.10.35.	Separator 3	Depressurization of the case	Operator

All service messages are stored in the archive of technological messages, available for viewing and further correct analysis of the operator and the state of the technological process, in general, and each technological object, in particular, at any time, due to the need for IT service equipment. In this case, the archive table consists of the following columns - date, time, message text, and all technological messages displayed on the information board in different colored backgrounds are divided into:

- emergency (blue background);
- warning (blue background, tabl. 1);
- auxiliary (blue background tabl. 2);
- condition of equipment (tabl. 1);
- logical messages (tabl. 2).

Duplicate message on a white background captures the time of acknowledgment by the operator finding the message. For example, table 1, 2 in the form of layouts, which shows in what form the information can be provided to the operator and stored in the archive.

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О.В. Алексахин, канд. техн. наук, доцент, *E.mail:aleksashin48@gmail.com*
Г.А. Гончарук, канд. техн. наук, доцент, *E.mail:ganna.goncharuk22@gmail.com*

М.Я. Лисак, студент

Одеська національна академія харчових технологій, ул. Канатная, 112, м. Одеса, 65039, Україна

МОДЕРНІЗАЦІЯ ДРОБАРКИ ЗЕРНА КУКУРУДЗИ В УМОВАХ РОБОТИ СИСТЕМИ ІТ-СЕРВІС ОБЛАДНАННЯ

Анотація

Кукурудза широко використовується як джерело крохмалю в харчовій, фармацевтичній, паперовій, гірничодобувній та будівельній галузі промисловості. Такий крохмаль зазвичай виходить після процесу очищення, також виробляють кукурудзяні зародки, клітковину та білок. Застосовується у виробництві біорозкладних пластикових пакетів, лікарських препаратів, паперу, гофрокартону, миючих засобів, фарб, підгузків, косметики, клею, поверхнево-активних речовин та агрохімікатів. Кукурудза – це найважливіше зерно у всьому світі. Адже, крім найбільшого споживання серед усіх зернових, кукурудза також є універсальним продуктом, з якого можна отримати паливо, електрику та побутові товари. Це означає, що нарощуючи обсяги переробки кукурудзи можна вийти за межі агросектору та створювати товари з високою доданою вартістю. Вирощування кукурудзи на зерно дозволяє краще використовувати сільськогосподарську техніку за рахунок пізніших термінів посіву та збирання. Цінні властивості кукурудзи викликають її стабільно високий попит на світовому ринку.

Переробка зерна кукурудзи складає технологічних ліній, які входять до складу крупозаводів. Основним обладнанням, що забезпечує високу якість продукції є ударно-відцентрові дробарки.

Аналіз роботи ударно-відцентрової дробарки виявив можливість її роботи у широкому діапазоні зміни конструктивних параметрів. Виявлено теоретичні аспекти залежностей продуктивності дробарки, які у своїй основі приймають її конструктивні параметри та режими, зокрема до них відносяться: частота обертання подрібнювальних дисків, діаметр дисків, довжина зубів дисків, товщину, а також властивості та параметри зернового матеріалу.

В результаті проведених досліджень визначено можливість підвищення якісних характеристик продуктів, що обробляються, а також продуктивність ударно-відцентрової дробарки.

Для збільшення продуктивності запропоновано реалізувати два варіанти. З одного боку зробити частоту обертання робочого органу, що регулюється, з іншого боку збільшити розміри діаметрів робочих дисків, з урахуванням конструкції дробарки для зерна кукурудзи, забезпечивши продуктивність дробарки

Метою даної роботи є підвищення ефективності роботи машини для дробарки зерна, що входить в ділянку підготовки зерна до помелу, для забезпечення надійності роботи машини, її продуктивності, поліпшення якості готової продукції шляхом впровадження автоматизації на основі SMART-технології, що визначається як технологія самоконтролю та звітності. Дана технологія забезпечує довгострокове архівування отриманих даних, що дозволяє диспетчеру спостерігати за роботою відповідного обладнання, реагуючи з допомогою програми ІТ-сервіс.

Ключові слова: дробарка для кукурудзи, швидкість, робочі диски, SMART-технологія, ІТ-сервісна програма

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