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THE RESULTS OF EXPERIMENTAL RESEARCH OF THE HULLER-POLISHER MACHINE FOR GRAIN

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Summary. The appropriateness of improving the huller-polisher machines for processing grain was grounded. It was proved that a minor upgrade by installing guiding sectors and rotary scrapers above the abrasive wheels and an impeller under the lower wheel will increase the efficiency of grain hulling.

The improved huller-polisher machine has a number of characteristic differences from the analogue one. They are the following:

- guiding sectors are mounted with a tilt to the abrasive wheels and provide supply of grain in the central surface of the wheels. This allows processing of grain by horizontal surface of the wheels and thus reducing their number almost doubled;
- rotary scrapers, depending on the angle settings allow adjusting the time spent by the grain on the relevant part of the horizontal surface of the wheels and thus determine the intensity of processing of grain surface by each wheel;
- the impeller that is mounted over the last abrasive wheel provides compulsory extraction of the processed grain out of the machine and thus optimizes the cost of power.

On the basis of the methodology of planning a multifactor experiment we got the statistical mathematic model that allows assessing the impact of structural and technological parameters of the huller-polisher machine on the hulling coefficient. The rational values of some design parameters and operating modes in the process of hulling wheat grains were received.

The limits of rational values of the parameters and operating modes of the huller-polisher machine with the maximum hulling coefficient were received experimentally 80…84 %: specific performance (loading grain material) 2000…2200 kg/h; angle of the guiding sectors 35…40°; rotation speed of the shaft of the huller-polisher machine 850…900 rpm; the number of abrasive wheels 4…5 pieces; angle of adjusting of the regulating scrapers 15…20°.

Key words: a huller-polisher machine, rotary scrapers, guiding sector, intensification of hulling, hulling coefficient, regression equation.

STATEMENT OF THE PROBLEM

Today agricultural production of Ukraine has one of the leading roles in filling GDP, exporting products, cooperation with foreign investors and so on. A significant negative aspect is that about 75-80% of grain is sold immediately after harvesting as a raw material without additional processing. That is the limiting factor which does not allow providing maximum economic efficiency in the sphere and reduces the number of employed population in manufacture and actually makes our country a raw materials supplier.

This acute issue arose after Ukraine's aspiration to join the EU and refocusing on the Western European market. The existing capacity of processing plants, old power-consuming equipment, differences in standards and other factors do not allow ensuring the processing of raw materials fully. But the policy aimed at reviving the processing industry will quickly and efficiently solve a complex of financial and economic problems.

Many modern processors, bakeries, silos and grain trading companies operating in Ukraine mostly have foreign equipment. But it is expensive and also requires expensive maintenance and repair. Therefore the issue of providing quality domestic equipment and improvement of existing machines for processing grain is a relevant scientific and applied task [7-9].

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

It is known that one of the most power consuming operations during processing grain is its hulling and polishing. For these purposes in cereal and mix feed industries different machines are used and most of them are complex power-consuming inertial units with grating cylinders and abrasive wheels [1-7, 15-25]. General disadvantages of these machines are low intensity of processing grain surface and increased material consumption. And to achieve the desired quality of products it is necessary to pass grain through the machine many times or to use several machines. To increase the intensity of the interaction of structural elements with grain it is possible to install a horizontal disk and a split ring with vertical blades above the abrasive wheels but this improvement does not solve the problem of intensification of processing. And the increase of the capacity leads to a considerable decrease in the quality of the finished product as the processing time is reduced [26, 27, 31].

In order to improve the quality of hulling and polishing of grain we took the machine A1-ЗШН-3 as a prototype, which at present time is used in cereal and mix-feed industries. The machine is made up of housing, inlet and outlet pipes, grating cylinder with a vertical shaft with abrasive wheels installed in the middle. The main disadvantage of the huller-polisher machine is the inefficient use of working surfaces of abrasive wheels as only end surfaces operate. In addition, the working process of the machine with satisfactory indicators of the outlet material is provided with productivity of not more than 2 tons per hour. This stipulates for using an unreasonably large number of abrasive wheels.

OBJECTIVE OF RESEARCH

Taking into account the above-mentioned facts, the objective of this article is to show the improvement of the design of the A1-ЗШН-3 huller-polisher machine for grain and experimental assessment of the effectiveness of polishing.

MAIN MATERIAL

We suggested a number of technical solutions [2, 3, 10-14, 20, 27-31] to improve huller-polisher machines. Based on the synthesis of the solutions we also put forward a working hypothesis of increasing the intensity of grain surface processing, reducing material consumption and increasing productivity. It is necessary to install guiding sectors and rotary scrapers above the abrasive wheels and the impeller under the lower wheel. The improved huller-polisher machine has a number of characteristic differences from the analogue one. They are the following:

- guiding sectors are mounted with a tilt to the abrasive wheels and provide supply of grain in the central surface of the wheels. This allows processing of grain by horizontal surface of the wheels and thus reducing their number almost doubled;
- rotary scrapers, depending on the angle settings allow adjusting the time spent by the grain on the relevant part of the horizontal surface of the wheels and thus determine the intensity of processing of grain surface by each wheel;
- the impeller that is mounted over the last abrasive wheel provides compulsory extraction of the processed grain out of the machine and thus optimizes the cost of power.

The huller-polisher machine with the improved design (Fig. 1) consists of a housing 1, which is installed on the frame 2, the inlet 3 and outlet 4 pipes. In the middle of the housing on the vertical shaft 5 installed in the support bearing anchors 6 and 7, firmly seated abrasive wheels 8 covered by the grating cylinder 9. Above each wheel there are two guiding sectors 10 and adjusting scrapers 11, the turning of the two upper scrapers is carried out by the steering control 12 with the lock 13 and the two lower scrapers are controlled by the steering control 14 with the lock 15. For directing and regulating grain supply on the upper wheel a special device is used which consists of the guiding cone 16 and the funnel 17, the latter is moved vertically with the help of the steering control 18 of the screw mechanism. Position the funnel vertically is fixed by the nut 19. Aspiration is carried out through the shutters 20 in the housing of the machine and the clogged air goes out through the suction device 21. The drive of the machine is carried out by the electric motor 22 via the v-belt transmission 23.

The machine works in the following way: the funnel of grain material 17 is positioned on the required height and fixed by the nut 19 above the first wheel, and the steering controls 12 and 14 define the position of the scrapers and fix their position above the abrasive wheels by the locks 13 and 15, then turn on the electric motor 22, deliver air and open the shutter so that the material under the influence of gravitational forces got into the machine. Grain goes to the cone 16 through the inlet pipe and through the ring slot between the cone and the funnel 17 is supplied to sectors 10 on the surface of the first and then on other abrasive wheels 8. The grain is processed between horizontal surfaces as well as between end surfaces and perforated grating cylinder 9. The intensity of processing depends on the position of guiding scrapers 11 between the abrasive wheels. Unloading of the processed product is regulated by the valve installed in the outlet pipe. In case of deviation from the specified processing performance we can regulate the opening of the funnel 17 and the intensity of processing is regulated by changing the position of the scrapers 11 above the abrasive wheels 8.

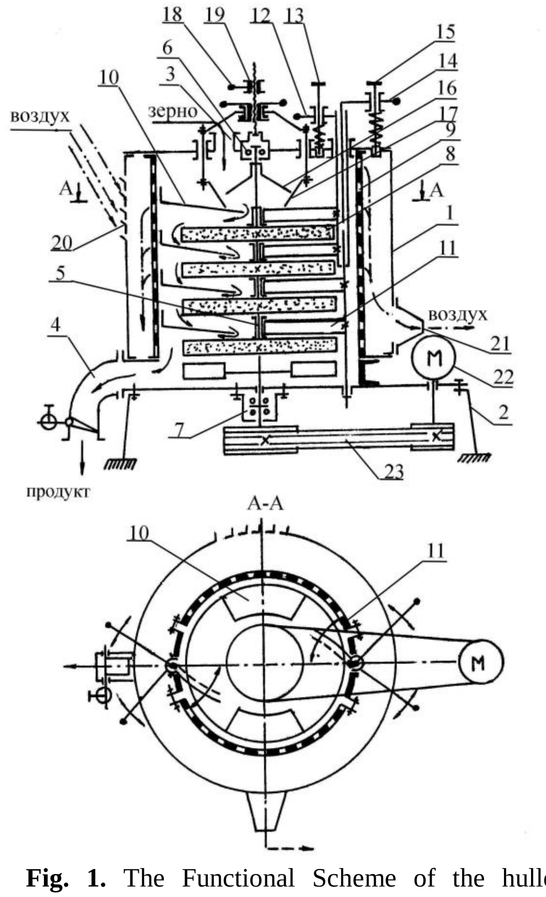

Fig. 1. The Functional Scheme of the huller-polisher machine: 1 – housing; 2 – frame; 3 – inlet pipe; 4 – outlet pipe; 5 – vertical shaft; 6, 7 – support bearing anchors; 8 – abrasive wheels; 9 – grating cylinder; 10 – guiding sectors; 11 – adjusting scrapers; 12, 14 – steering control; 13, 15 – lock; 16 – guiding cone of grain; 17 – funnel of material; 18 – steering control of funnel adjustment; 19 – adjusting nut of the funnel position; 20 – aspiration shutters; 21 – clogged air suction device; 22 – electric motor; 23 – V-belt transmission

Table 1. Variation levels of the factors of the experimental study

№	Factors		Variation levels		Variation interval
	Name	Marking	upper (+)	Lower (-)	
1.	Specific performance (loading grain material) Q, kg/hour.	x_1	3000	1000	1000
2.	Angle of guiding sectors α, degrees	x_2	65	35	15
3.	Rotation speed of the shaft of the huller-polisher machine n, rpm	x_3	1000	500	250
4.	Number of abrasive wheels z, pieces	x_4	8	4	2
5.	Angle of adjusting guiding scrapers β, degrees	x_5	30	10	10

On the basis of the previous exploratory studies we found main factors that have the most significant impact on the quality of polishing and defined indicative levels of the variation of the defined factors. The most important factors that have a significant impact on the process include: specific performance (loading grain material) Q; the angle of the guiding sectors α; rotation speed of the shaft of the huller-polisher machine n; the number of abrasive wheels z; angle of adjusting the guiding scrapers β.

In order to establish the constructive and rational technological parameters of the proposed huller-polisher machine we conducted the procedure of planning of a multivariate experiment and processed the received data within the established levels of variation of influential factors in the system of applied software "STATISTICA 10". (Table 1).

We chose the hulling coefficient as the optimization criterion of hulling and polishing in the production of cereals from wheat. The coefficient should not be less than 80% according to the requirements.

In order to investigate the relationship between the design and technological parameters of the huller-polisher machine and to get their rational values we used the methodology of mathematic planning of the multifactor experiment. The objective of the methodology is to obtain a statistical mathematic model of the object of research in the form of regression equation.

The possibility of reproducibility of experimental research data were determined using Kochran's Q test (G), and the adequacy assessment was performed using *F*-test (F). The tests were carried out automatically in the system "STATISTICA 10".

For visual estimation of the pair-wise influence factors on the optimization criterion (hulling coefficient *Y* (*K*), %), the implementation of the matrix of planning of a multi-factor experiment can be represented in the form of surfaces of responses and lines of equal output (Fig. 2).

After a series of experiments and constructing surfaces' recoils we received a regression equation of the dependence of the hulling coefficient on the researched factors in the coded meanings:

$$Y = 73,437 - 2,937x_1 - 0,812x_2 + 5,062x_3 + 3,562x_4 + \\ +0,062x_5 - 0,687x_1x_2 - 1,062x_1x_3 - \\ -0,562x_1x_4 - 3,562x_1x_5 + \\ +0,812x_2x_3 + 0,562x_2x_4 - 0,937x_2x_5 - \\ -1,062x_3x_4 + 0,437x_3x_5 + 2,687x_4x_5$$

The analysis of the mutual influence of the factors on the hulling coefficient *Y* (*K*) (Fig. 2) showed the following. The increase of the specific productivity (loading grain material) Q affects the quality of hulling. This is due to the amount of grain in the area of its interaction with abrasive wheels. Taking into account the results of experimental studies we found that if $Q = 2000...2200$ kg/h then the hulling coefficient will be $K = 80...85\,\%$.

The angle of the guiding sectors α influences the speed of grain loading to the abrasive wheels and the groundless increase of this angle may also increase the amount of material in the area of hulling which negatively reflected on the quality characteristics of the process. Taking into account the proposed improvements the angle of the guiding sectors is $\alpha = 35...40\,^{\circ}$. Under these parameters of the initial speed of the material will be enough for quality interaction of grain with both horizontal and vertical surfaces of the abrasive wheels.

A twofold situation is observed with the speed of rotation of the shaft of the huller-polisher machine n. On the one hand increasing the speed must intensify the interaction of the wheels with grain, on the other hand increasing the rotation speed the interaction time of the grain with each abrasive wheel will decrease, and the grains not even completely hulled leaves the machine faster. This parameter is connected with energy consumption. So, rational values are within $n = 850...900$ rpm.

Another factor that influences the energy of the process is the number of the abrasive wheels z. The more wheels, the better grain is hulled, although an unreasonable increase in the number of wheels leads to a sharp increase of not only power but metal consumption, which leads to technical complications in the design of the machine and its maintenance. The results of experimental studies indicate that a sufficient number of wheels for quality grain hulling will be $z = 4...5$ pieces.

After all the intensity of grain processing is regulated by the position of the adjusting scrapers which is given by the angle of their installation β. To ensure the requirements for grain hulling we found that the angle of the regulating scrapers should be within $\beta = 15...20\,^{\circ}$. Under these conditions we may achieve the set performance and quality of grain hulling with 4-5 abrasive wheels.

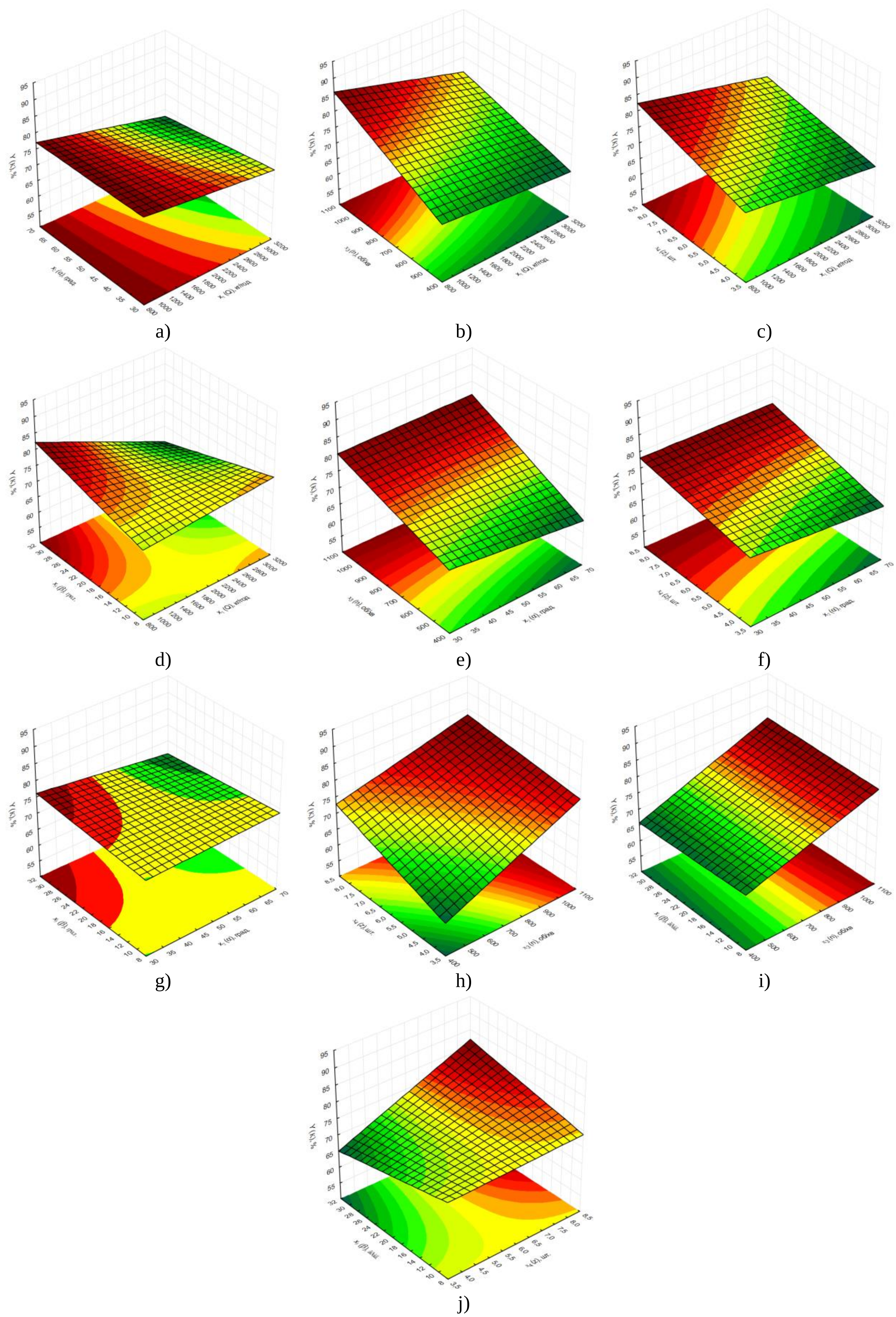

Fig. 2. Graphical presentation of the pair-wise influence of the main factors on the optimization parameter in the process of operation of the improved machine design:

а) – $Y = f(x_1 x_2)$; б) – $Y = f(x_1 x_3)$; в) – $Y = f(x_1 x_4)$; г) – $Y = f(x_1 x_5)$; д) – $Y = f(x_2 x_3)$;
е) – $Y = f(x_2 x_4)$; є) – $Y = f(x_2 x_5)$; ж) – $Y = f(x_3 x_4)$; з) – $Y = f(x_3 x_5)$; и) – $Y = f(x_4 x_5)$

Thus, as a result of experimental studies demonstrated feasibility of the proposed improvements, and received the individual rational design parameters and operating modes designed machine. It was during the shelling corn machine with proposed improvements achieved significant intensification of the process, lower energy costs process and reduce metal the huller-polisher machine.

CONCLUSION

1. As a result of experimental studies we obtained the regression equation and graphical dependencies for the hulling coefficient of wheat which confirm the current hypothesis about the feasibility of the installation of guiding sectors and rotary scrapers above the abrasive wheels and the impeller under the lower wheel.

2. The limits of rational values of the parameters and operating modes of the huller-polisher machine with the maximum hulling coefficient were received experimentally ($K = 80...84\,\%$):

- specific performance (loading grain material) kg/h;
- angle of the guiding sectors $\alpha = 35...40\,°$;
- rotation speed of the shaft of the huller-polisher machine $n = 850...900$ rpm;
- the number of abrasive wheels $z = 4...5$ pieces;
- angle of adjusting of the regulating scrapers $\beta = 15...20\,°$.

3. The proposed improvements allow increasing the intensity of processing as well as decreasing of material consumption of the machine.

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РЕЗУЛЬТАТЫ ЭКСПЕРИМЕНТАЛЬНЫХ ИССЛЕДОВАНИЙ ШЕЛУШИЛЬНО-ШЛИФОВАЛЬНОЙ МАШИНЫ ДЛЯ ЗЕРНА

Аннотация. В статье обосновывается целесообразность совершенствования шелушильно-шлифовальных машин для обработки зерна. Доказано, что незначительная модернизация путем установки над абразивными кругами направляющих секторов и поворотных скребков, а под нижним кругом – крыльчатки, позволит повысить эффективность шелушения зерна.

Усовершенствованная таким образом шелушильно-шлифовальная машина имеет ряд характерных отличий от аналогов:

- направляющие сектора устанавливаются наклонно по отношению к абразивным кругам и обеспечивают подачу зерна в центральную зону их поверхности. Это позволяет вести обработку зерна горизонтальными поверхностями кругов, а следовательно сократить их количество почти вдвое;

- поворотные скребки, в зависимости от угла установки позволяют регулировать время пребывания зерна на соответствующей части горизонтальной поверхности кругов и тем самым определяют интенсивность обработки - поверхности зерна.