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HARVESTING FLAT CROPS WITH MINIMAL LOSS

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Abstract

The most responsible resource-consuming stage of grain production is harvesting. Improving the efficiency of harvesting can be achieved by equipping combine harvesters with stripper headers. Stripper headers can be operated at higher speeds, which contributes to a 35-50% increase in productivity and a 20-25% reduction in fuel consumption. Stripper headers are especially effective when harvesting high-yielding crops with high humidity and weeds. However, their use in harvesting flat crops leads to large losses of grain, since there are no devices that can raise flat stems and feed them to the stripper zone. This problem is especially acute in the production of seeds of elite crops. Laboratory studies substantiated the basic design parameters and the operating mode of the copying stem lifter. A production audit confirmed that with stripper header, losses are reduced by 70%.

Key words*: stripper header, combine harvesters, harvesting.*

INTRODUCTION

Harvesting is the most critical stage in the production of crops. To increase the efficiency of harvesting grain crops every year more and more, both in our country and abroad, find combing reapers. This is due to the fact that stripper headers can be operated at higher speeds, which contributes to an increase in productivity by 35-50% and a decrease in fuel consumption by 20-25%. Combine harvesters are especially effective when harvesting high-yielding breads with high humidity and weedy weeds. However, their use in harvesting lodged bread leads to large losses of grain, since there are no devices that could lift lodged stems and feed them to the tow zone (Kuhmazov et al., 2018).

Therefore, the aim of the study is to develop the stem lifter of the stripper header and justification of its design parameters and operating modes.

MATERIALS AND METHODS

Experimental studies were carried out in laboratory and field conditions on the basis of generally accepted methods in accordance with the current Interstate Standards (IS), as well as using the theory of planning a multifactor experiment.

To obtain a mathematical model of the process, the optimal design of the experiment was used.

When planning an experiment, the optimization criterion is initially selected, that is, the parameter by which the studied object is evaluated and which links the factors into a mathematical model.

It is necessary to strive to ensure that the optimization criterion is one and has clear physical meaning and a quantitative assessment. Therefore, it is best to choose a criterion that would be the aggregate and comprehensive characteristic of the studying object. For any trimmer, the evaluation criteria of the process are completeness of removal, injury, productivity and energy intensity. In this case, as the optimization criterion, we adopted the value of grain losses, and the remaining criteria were used as limitations.

When researching the process, factors influencing the process of work were identified, and initially more than 12 were selected, which characterized the design and operating parameters of the working body, the technological conditions of the process, as well as the physical and mechanical properties of the materials. In research it is impossible to capture the influence of all factors and their interaction. Therefore, based on a priori information, as well as on the basis of specific research tasks, the most significant factors were identified.

Moreover, some of them did not change during the research process and were fixed at constant levels.
Subsequently, a screening experiment was carried out, according to its results, after processing, information was obtained on the significance of each parameter. This made it possible to exclude insignificant factors from further consideration and, consequently, the quantity of further studies was reduced.
The plans for the experiments, methods for processing the results are described in details in many sources. In accordance with them, experiments and mathematical data processing were organized (Kuhmazov and Tizov, 2018).
To realize a screening experiment, we composed a matrix taking into account the initially selected factors by randomly mixing two half-replicas of the type 2^{4-1}. One semi-replica attributed to factors $X_1 - X_4$, another - to factors $X_5 - X_8$. The number of experiments in the matrix should be a multiple of 2k and exceed the number k + 1 (k is the number of factors). Therefore, experiments 9 and 10, formed by a random selection of both half-replicas, were included in the matrix. The experimental design was randomized using random number tables. First of all, the reproducibility of plans was checked by testing the hypothesis of homogeneity of variances.
Since the number of repetitions in each series of experiments was the same (n=3), the homogeneity of a number of dispersions was determined by $G_{îï}$ – Cochren's criterion. Processing of experimental data began with their graphical representation on the initial scattering diagram.
The influence degree of the factors was evaluated by the difference in the medians of the values of the experimental data at upper and lower levels of the factors and the number of distinguished points. After isolating factors X_1 and X_2 carried out the adjustment of the results of the screening experiment in order to more clearly identify the remaining factors and their pair interactions. The correction consisted of summing the experimentally obtained values of the optimization parameter in the matrix of the screening experiment of the found values of the effects of factors X_1 and X_2, taken with the opposite sign. Based on the adjusted results of the optimization parameter, a second scattering diagram was constructed and its analysis made it possible to distinguish two factors X_3. At each stage of the research, scattering diagrams were used to select pair interactions using the “distinguished points” method. The significance of the effects of pairwise interactions was evaluated similarly to the effects of individual factors.
Together with the significance assessment of the effects of factors at each stage, a statistical analysis of the corrected observation results was made, as a result the need for further identification of significant factors was identified. If the calculated value of the Fisher criterion is less than the tabulated one, the screening of factors and their interactions can be stopped. Based on the results of adjusting the experimental data, a scatter plot of the distribution of optimization parameter values was built.
It was decided not to conduct a steep ascent along the response surface, since in the implementation of the planning matrix the values of the optimization parameter in most cases turned out to be in an almost stationary region.
In screening experiments, it is assumed that the response surface is described by a linear model of the form:

$$Y = b_0 + b_1x_1 + \ldots + b_{n-1}x_{n-1} + d,$$

b_0, b_1, b_{n-1} - regression coefficients with selected linear terms;
n - the total number of linear factors;
1 - the number of screening effects;
d - the response component related to the noise field along with the experimental error.
As a rule, it is not completely possible to approximate the response surface, and in this case it is necessary to switch to second-order plans.
To describe the response surface by a second-order equation, central compositional orthogonal second-order planning was used, which is simple and easy to calculate, and also quite economical in the number of experiments.
Based on the results of the screening experiment, the main levels of variation of the selected factors were selected.

Before the experiment, factors were encoded according to the formula:

$$x_i = \frac{X_i - X_{0i}}{\varepsilon}$$

x_i - the coded value of the factor (dimensionless quantity), the upper level is designated +1, and the lower level -1 (in the center of the experiment there will be zero level); X_i - natural value of the factor; X_{0i} - the natural value of the factor at zero level; ε - the natural value of the interval of variation of the factor, determined by the formula:

$$\varepsilon = \frac{X_i^{â} - X_i^{í}}{2},$$

$X_i^{â}$ - the value of the factor at the upper level;

$Õ_i^{í}$ - the value of the factor at the lower level.

To obtain a mathematical model of the process of removing onion and weed tops in the form of a polynomial of the second degree, we implemented an orthogonal compositional plan, the planning matrix of which with the obtained experimental data. The total number of experiments N depends on the number of factors k and is determined by the expression N = 2k + 2k + n. The magnitude of the "star shoulder" α and the number of experiments n_0 in the center of the plan choose depending on the accepted criterion of optimality. If orthogonality is taken as a sufficient criterion for the optimality of the experimental design, then there is no restriction on the number of experiments in the center of the design, and usually n_0=1. And the value of the "star" shoulder with the number of factors k = 3 is - α =1,215.

When processing the experimental results, the following formulas were used:

a) The arithmetic average value of the completeness of removal of tops of onions and weeds:

$$\bar{Õ} = \frac{\sum Õ}{n},$$

$\sum Õ$ - the sum of all measurement options;

n - the number of measurements.

b) standard deviation:

$$S = \sqrt{\frac{\sum \left(X - \overline{X}\right)^2}{n-1}},$$

c) the coefficient of variation of the completeness of removal of tops of onions and weeds:

$$\nu = \frac{S}{X} \cdot 100\%,$$

Upon receipt of an adequate mathematical model of the second order, it is necessary to determine the coordinates of the optimum and study the surface properties in the vicinity of the optimum.

To do this, we produce the canonical transformation of the obtained mathematical models. For analysis and systematization, second-order equations led to the canonical form:

$$Y - Y_S = B_{11} X_1^2 + B_{22} X_2^2,$$

Y - optimization criterion value;

Y_S - the value of the optimization criterion at the optimal point;

X_1, X_2 - new coordinate axes rotated relative to the old x_1, x_2;

B_{11}, B_{33} - regression coefficients in canonical form.

During the canonical transformation of the equations, the origin was transferred to a new point S and the old shafts were rotated by a certain angle in the factor space, as a result of which linear terms disappear and the value of the free term changes.

To carry out the transfer of the origin to a particular point on the response surface, we differentiated the response function with respect to each variable and, equating the partial derivatives to zero, solved the resulting system of equations, that is, found the values of factors optimizing the value of the optimization criterion.

After the canonical transformation and determination of the type of response surface, its analysis was carried out using two-dimensional sections.

For this, giving different values to the optimization criterion in the canonical equation, we built a series of equal output curves (isolines) in the range of permissible values of the variation of independent variables. Consideration of two-dimensional sections gives a visual representation of the values of the optimization criterion, which it takes when varying the levels of each pair of factors.

The main calculations and processing of experimental results were performed on a PC using standard programs MathCAD, Microsoft Excel and Statistica 6.0.

RESULTS AND DISCUSSIONS

To reduce losses during harvesting of laid-down breads by the towing method, we developed a copying stem-lifter of a combing header, consisting of a slide 1, which is pivotally connected to the base of the slide 2. Lift feather 3 is rigidly fixed to the slide 1, and the angle between the slide 1 and lifting pen 3 is 35º. Between the base 2 and the lifting pen 3 there is a gas stop 4 consisting of a pressure cylinder and a rod with a piston package. Gas under pressure in the rodless cavity of the pressure cylinder plays the role of an elastic element. The gas stop rod 4 is pivotally connected to the lifting pen 3, and the pressure cylinder with the base 2.

The copying window lifter is attached to a horizontal holder of 5 square sections. The right end of the horizontal holder 5 is bent up and fixed in the sleeve 6, welded to the lower pipe of the housing combing header.

To determine the optimal values of the design parameters and the operating mode of the copying window lifter of the combing header, we developed a laboratory setup consisting of frames 1 and 2 (Figure 1), on which a feeding belt conveyor 3, a cutting device 4 and a copying window lifter 5 are installed. A belt conveyor 3 is installed on the frame 1, and the cutting apparatus 4 and the stem lifter 5 on the frame 2. The feed belt conveyor 3 is driven from the gear motor 6 through a chain transmission. The speed of the feed belt conveyor 3 is regulated by interchangeable sprockets. To the conveyor belt 3 are attached the stalks 7 of a grain crop with a given lodging. The height of the cutting apparatus 4 is installed in the area of the tow, and is driven by an electric motor 8, V-belt transmission 9 and the mechanism of the swash plate 10. To collect the cut stems under the cutting apparatus is a box-collector 11.

The laboratory machine works as follows: first, on the feed conveyor belt 3, we fix the stems 7 with a given lodging. On the frame 2, we install the tested copying window lifters 5. Then it is necessary to select the appropriate speed of the feeding belt conveyor 3. After that you should sequentially turn on the drive of the cutting device 4 and the feeding conveyor 3. When the conveyor belt 3 moves, the dead stems rise by the copying window lifter 5 into the tow area, cut off by the cutting device 4 and fall into the collection box 11. Not cut stems 12 remain on the conveyor belt 3.

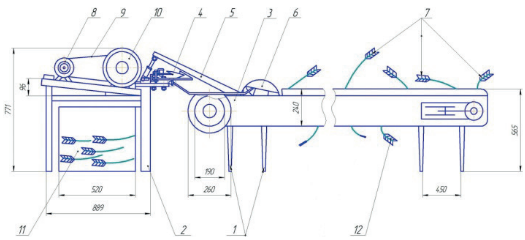

Figure 1. Laboratory machine diagram:

1,2-frames; 3-feed conveyor; 4-cutting unit; 5-copy stalk lifter; 6-gear motor; 7-stems; 8-electric motor; 9-belt drives; 10-mechanism swash plate; 11-box-compilation; 12 - uncut stems

The quality indicators of the copying power window of the combing header depend on many factors. Therefore, laboratory studies were organized with using the methodology of planning a multifactor experiment.

As an optimization criterion, we took the loss of crops (G,%) in the form of uncut stems.

$$G = \frac{\sum_{i=1}^{100}(ni - ncp)}{ni} * 100,$$

n_i - the number of fixed stems before the experiment, pcs;

n_{cp} - the number of cut stems after the experiment, pcs.

Based on a priori information from the results of studies on the state of sowing crops during the harvesting period, as well as on the basis of specific research tasks, the most significant factors affecting the loss of crops during harvesting with a stripper header were identified. During the study, some of them did not change and were fixed at constant levels (Tizov et al., 2018). The levels and ranges of variation of the three most significant factors are presented in Table 1.

Table 1. Factor affecting the loss of crops during harvesting with a stripper header with the copying stem lifter, their levels and variation intervals

Factors	Code value	Equation of variation			Range of variation
		+1	0	-1	
Long runner (skid) L, mm	x1	510	460	410	50
The value of the gas stop load (rod), P	x2	40	60	80	20
Working speed Vp, m/s	x3	2.8	2.2	1.6	0.6

For these factors, a matrix of a non-compositional plan of the second order was compiled.

After processing the experimental results, we obtained an adequate second-order mathematical model describing the dependence G = F (α, P, Vp) in encoded form:

Y= 0.58857-1.64000X1-
-1.66000X2+5.32857X1^2+5.92857X3^2+
+0.36250X1*X2+0.28750X1*X3+
+0.98750X2*X3

The multiple correlation coefficient will be R = 0.96, the final balance is 0.026, and the F-test = 0.98. Consequently, the obtained model adequately describes the experimental results. The response surface was studied using two-dimensional cross sections (Figures 2, 3 and 4).

The optimal values of the factors after solving equation 1 in encoded form have the following values: X1 = -0.207877, X2 = -0.210412, X3 = 0.403078. In the decoded form, the factors will have the following values: length of the runner L = 449.6 mm, load of the gas stop, P = -55.79176, working speed Vp = 0.403078 m/s.

Analyzing graphic images of two-dimensional sections, we can conclude that the optimal values of the studied factors are in the intervals: the length of the stem lifter L = 465-480 mm; the load of the gas stop P = 58-66 mm; the working speed of the combine with a stripper header Vp = 1.6-2.56 m/s.

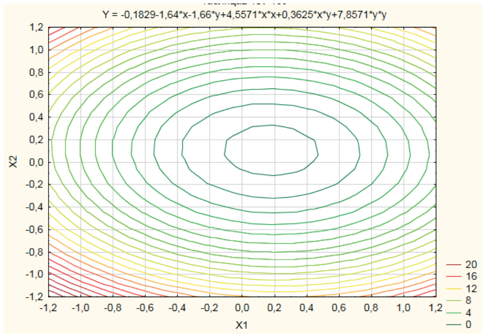

Figure 2. Two-dimensional cross-section of the response surface, characterizing the dependence of the losses of crops during harvesting with a combing header on the length of the runner (L) and the load of the gas stop (P)

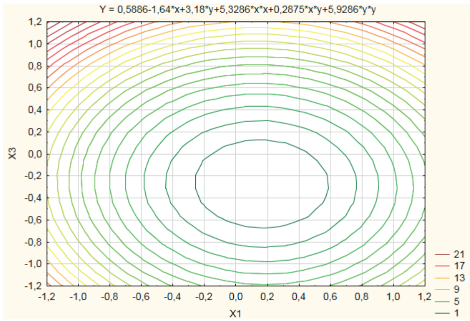

Figure 3. Two-dimensional cross-section of the response surface, characterizing the dependence of grain losses during harvesting with a combing header on the length of the runner (L) and the working speed (Vp)

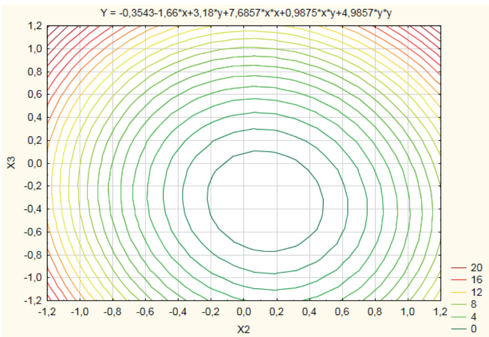

Figure 4. Two-dimensional cross-section of the response surface, characterizing the dependence of the loss of crops during harvesting with a combing header on the load of the gas stop (P) and operating speed (Vp)

Table 2. Planning matrix for a three-factor experiment of a plan close to D - optimal

Experience number	X1	X2	X3	Y_{cp}
1	+1	+1	+1	12.8
2	+1	+1	-1	5.9
3	+1	-1	+1	17.2
4	-1	+1	+1	18.3
5	+1	-1	-1	8.3
6	-1	+1	-1	6.6
7	-1	-1	+1	18.2
8	-1	-1	-1	16.4
9	+1	0	0	0.9
10	-1	0	0	2.0
11	0	+1	0	4.7
12	0	-1	0	4.8
13	0	0	+1	3.3
14	0	0	-1	0.8
15	0	0	0	1.2

CONCLUSIONS

Thus, the optimal values of the factors would have the following values: length of the runner L = 449.6 mm, load of the gas stop, P = -55.79176, working speed Vp = 0.403078 m/s, while losses of crops during harvesting reaper will not exceed 4%.

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