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Design of the universal agricultural working body and study of its parameters

Sergey V. Belousov[1,*], *Sergey* A. Pomelyayko[1], and *Vladislav* V. Novikov[1]

[1]Federal State Budgetary Educational Institution of Higher Education “Kuban State Agrarian University named after I.T. Trubilin”, Krasnodar, Russian Federation

Abstract. The article is devoted to the scientific approach with the help of computer-aided design tools for modeling the processes of interaction of tillage tools with soil. The article has an applied character, which is expressed in the fact that the method of computer-aided design in Mathcad using software CAD COMPASS 3D has been used. The analyses of expressions in the form of three-dimensional graphs are widely presented and their detailed review is given, which can be used to perform the improvement of the design of units that perform the main treatment of the soil with a turnover of a layer. As a result of the work done, there was obtained a combined plowshare with additional flat-cutting working bodies, there was made a matrix of experiment planning, there was obtained a graph of the dependence of the width grip of the flat-cutting razor on the speed of the arable unit. There were substantiated the factors of influence on performance as a result of using the planning of the two-factor experiment due to the orthogonal plan, there were determined the optimal settings of the operation modes of the plowshare.

In Kuban State Agrarian University at the department of "Processes and machines in agribusiness" there were conducted the researches in the field of basic tillage. A number of works is aimed at improving this process, namely the development of a set of additional working bodies for their installation on the existing structure of the plowshare which leads to the advance of the process of basic tillage with a turnover of the layer to improve the quantitative and qualitative rates of this technological operation. All processes of work of agricultural machines are based on principles of mathematical model construction, their theoretical checking up, the inspection on laboratory stands and conducting the full-scale field experiments. We propose to install a set of additional working bodies (Figure1) in the form of flat-cutting working bodies on each side of the plowshare. This design will improve the qualitative rates of the arable unit work, namely to reduce the number of passages of agricultural machines on the field when it is preparing for sowing.

The works are conducted on the basis of patents of the RF № 2491807; 136275; 136674 which allow to increase the turnover of the payer at minimum expenses for energy. Researches were conducted on the territory of Krasnodar region. The choice of the tractor’s type is implemented proceeding from the fact that we created the working arable unit of the PLN-4-25 type and the tractor MTZ-80 of the class 1,5-2 tons was suitable for use due to

* Corresponding author: sergey_belousov_87@mail.ru

operational characteristics [1].

The design of Figure 1, where schematically the plowshare (top view) is showed in Figure 1: In Figure 2 - general view of the of a plowshare’s body; in Figure 3 - general view of the plowshare’s body in axonometric projection, Figure 3.

The plowshare contains the frame 1 determined the plow body 2, each of one is consisted of bay 3, plowshare 4, mouldboard 5 and regulated in height the flat-cutting razor 6 which is installed on bar 3from the side of field cut under the angle α= 15 - 45° to the movement of the plowshare oppositely to the angle of the slope of the plowshare and has a width, which is equal to the width of the grip of one body of the plowshare, such unit of flat-cutting razor gives the mirror reflection of the plowshare. The flat-cutting razor unit under the angle α= 15 - 45° is conditioned that the work of the flat-cutting razor installed in specified limits supplies with optimal parameters of soil crumbling on specified depth of processing [2].

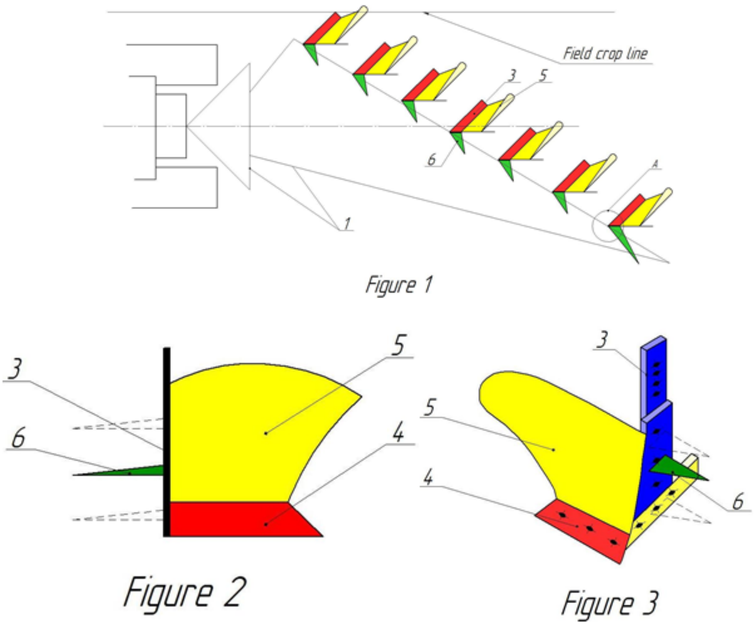
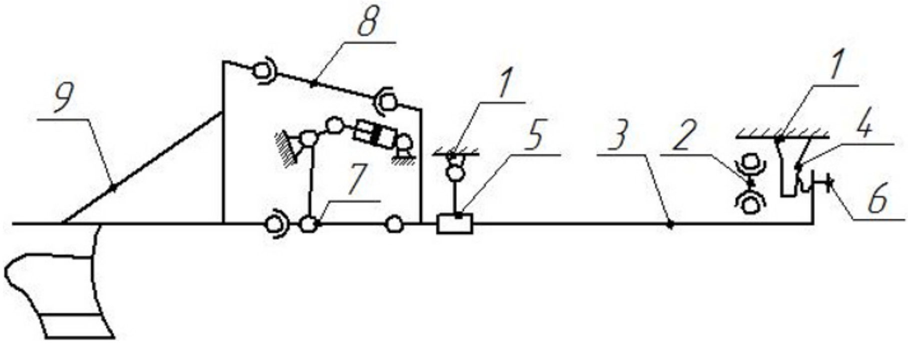


Fig.1. Plow RU 2491807 C1

According to the patent, the plow RU 2491807 C1 was made as the laboratory model and there were conducted its tests [3]. Such constructive performance will allow to increase a degree of soil crumbling due to its diffused processing on depth by the main and additional working bodies depending on a condition of soil and the predecessor, and also the decrease in traction resistance of a plow due to decrease in pressure of a field board on a wall of a furrow [4]. The technical result is the reduction of steel intensity in comparison with plowshares in which coulters are used. There is a decrease in traction resistance and improve the quality of tillage by reducing the quantitative and qualitative rates of the plow body [5].

There was made the special installation on Figure 2 by means of which it was possible to make field tests to carry out the laboratory and field researches.



1 – frame of tractor; 2 – pendulum mount; 3 (BC) – load-bearing element of transition frame; 4 – primary measuring reformer of force of equal resistance (cantilever beam) with tension resistors; 5 - bearings; 6 – controlled support; 7 – lengthwise rods of tractor; 8 – central rod of tractor; 9 – hanged up unit with working bodies.

Fig. 2. Kinetic scheme of transition frame to the tractor MTZ.

The present results are shown in the form of a graph shown in Fig.1. The determination of factors affecting the productivity and quality of processing. When considering factors affecting the productivity and quality of processing, their location in space relative to each other and their geometric dimensions were taken into account [6].

The analysis of continuous symmetric plans of the second order showed that the maximum value of the determinant of the information matrix is achieved when the moments of the plan are equal respectively [13].

For this purpose, the orthogonal symmetrical plan (star points of which are equal ±1). The influence of two factors was studied and there were fixed their values at optimal levels. Factors, intervals and levels of variation are presented in Table 1. Also, according to this method, we conduct researches of flat-cutting working organs. Thus, when considering factors affecting the productivity and quality of processing, their location in space relative to each other and their geometric dimensions were taken into account. The analysis of continuous symmetric plans of the second order showed that the maximum value of the determinant of the information matrix is achieved in the case when the moments of the plan are respectively equal. For this purpose, there was used the orthogonal symmetrical plan (the star points of which is equal to ± 1).

Table 1. Factors, intervals and levels of variation.

Factors	Coded designation	Interval of variation	Levels of factors		
			-1	0	+1
Diameter mm.	x_1	150	0	150	300
Velocity of movement km/h.	x_2	2,7	5,34	8,05	10,76

The quality of treatment is affected by the speed of movement and the diameter of the rotary working body. The levels of factors were chosen so that their optimal values, calculated theoretically or taking into account the existing limitations fell into the center of the variation interval. The maximum value for the first factor x_1 was the width of grip of the flat-cutting razor which is equal to n_{max} = 300 mm and decreased to n_{min} = 0 mm, which corresponded to the variation interval [7].

For the second factor x_2, the speed of movement of the arable unit k_{vmax} = 10.76 and decreased to k_{vmin} = 5.34, which corresponded to the range of variation. There were chosen the ranges of variation and levels of factors, the values of which are listed in Table 4.

The planning matrix is presented in Table 3. Experiments were carried out according to the above-described method. The order of the experiments was performed according to the table of random numbers [8]. Average values of optimization parameters are presented in Table 4.

Table 2. Matrix of planning in the optimization of performance of plowshare with flat-cutting working bodies.

№ experiment	x_0	x_1	x_2	x_1	x_2	x_1x_2	x_1^2	x_2^2	traction resistance Y kN.	
1	+1	0	5.34	+1	+1	+1	+1	+1	13.1	PFE
2	+1	0	8.16	-1	+1	-1	+1	+1	14.37	
3	+1	0	10.15	+1	-1	-1	+1	+1	15.73	
4	+1	200	5.52	-1	-1	+1	+1	+1	11.9	
5	+1	200	8.39	+1	0	0	+1	0	13.0	Star points
6	+1	200	10.61	-1	0	0	+1	0	13.63	
7	+1	300	5.65	0	+1	0	0	+1	11.1	
8	+1	300	8.57	0	-1	0	0	+1	11.9	
9	+1	300	10.76	0	0	0	0	0	12.5	Experiments in the center of plan

After mathematical processing of experimental data, the following regression equations were obtained:

$$Y = 13{,}567 + 0{,}965 * X_1 + 0{,}1095 * X_2 - 1236 * X_1 * X_2 - 9{,}155 * X_1^2 - 3{,}605 * X_2^2 \quad (1)$$

where Y – productivity of plowshare under interaction 1 and 2 factors.

Performing a canonical transformation and solving a system of linear equations, we find the coordinates of the center of the response surface

$$X_1 = -0{,}05436, \quad X_2 = -0.02451$$

Substituting the found values x_1, x_2 in equation (3) we determine the value of the optimization parameter in the center of the response surface.

The angle of rotation of the axes α is equal -6,27 ° C and regression coefficients in the canonical form are equal B_{11} = 9,22; B_{22} = 3,54:

Equation of regression in canonical form

$$Y_{12} + 13{,}54 = +9{,}22 * X_1^2 - 3{,}54 * X_2^2 \quad (2)$$

Parabolas (Figure3). One of the coefficients of canonical equation is equal 0, the center of the figure is in infinity. The surface of the response is a doubling increase (crest). In this case we can place the beginning of coordinates in any point (usually near the center of the experiment) on the axis corresponding to insignificant canonical equation and to obtain the equation of parabola [8]. For example, if B_{22} is equal to 0 and a new center s', it is possible to get the equation of parabola $y - y_{s'} = B_{11}\tilde{X}_1^2 + B_2\tilde{X}_2^2$, where B2 – coefficient determining the steepness of slope increase, e.g. increase of optimization parameter in axis $\tilde{X}_2$. In practical tasks the center of the figure s often was moved off the experiment and so one of the coefficients (B_{11} and B_{22}) is close to 0. In this case dependent on slope, the surface of response will approximate either by stationary or double increase [9].

Substituting different values of the response *Y* of the canonical equation (2) there was obtained a range of conjugated isolines (Figure 3). The location of the elements of the performance in the experiment resembled the surface of the "ellipse" type. The center of the experiment is in the redistribution of the experiment area. Maximum efficiency in this case is when the width of grip of flat-cutting razor is equal 190,54 mm and speed of 6.15 km/h [10].

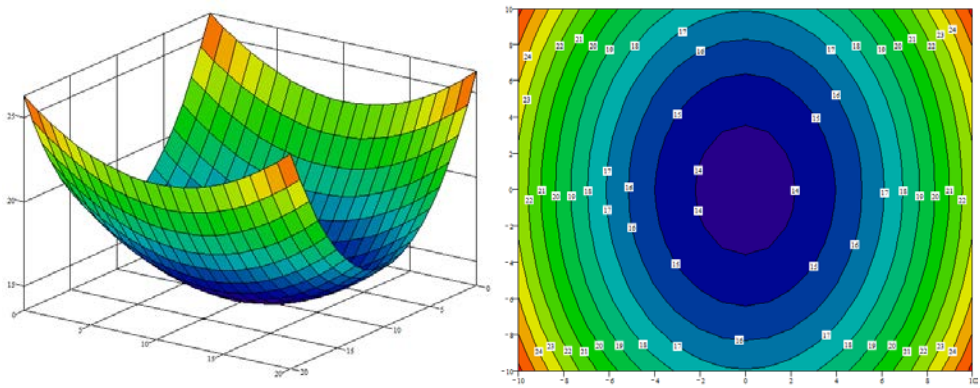


Fig. 3. Surface dependence of the width of grip of flat-cutting knife from speed of movement

– There was obtained the structure of the combined share of a plowshare with additional flat-cutting working bodies.

The experiment of planning matrix has been compiled.

– There was obtained the graph of the dependence of the width of grip of flat-cutting razor from speed movement of the unit, from where it is seen that with increasing ratio of the flat-cutting razor grip width, reducing performance, and thus the deterioration of quality rates of work of the plowshare.

- Factors of influence on productivity (width of grip of a flat-cutting razor and speed of movement) are proved. Using the planning of the two-factor experiment on the orthogonal plan, the optimal parameters of the modes of operation of the plowshare are determined. According to the obtained regression equation according to the criterion of maximum productivity of plowshare tillage, the center of the experiment is in the redistribution of the experimental area, while the maximum productivity in this case will be at the width of the grip of flat-cutting razor of 190.54 mm. and the speed of movement of 6.15 km/h [9],[10].

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