RESEARCH OF THE NEW GENERATION CHISEL PLOW

ИССЛЕДОВАНИЕ ЧИЗЕЛЯ НОВОГО ПОКОЛЕНИЯ

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Abstract: *The article presents the chisel plow of the new generation developed on the basis of the systematic approach and adaptability of technological impacts from soil-climatic and agro landscape conditions. The principle of the use of the alternating movement of working elements for the destruction of the layer in the so-called lines of the least connections was built into the basis of the chisel plow construction. The chisel plow is multipurpose: it performs the present technological process of soil processing of fields on different depth and spaces between rows of perennial plants on the depth which is differentially changed distancing from the bole due to the architectonics of the root system disposition. Working elements of the chisel plow contain the fastened clutches on hinges, the angle of the mounting is determined by the action of soil resistance forces but the destruction of the layer is executed by differently directed deformations. Researches showed that the chisel plow qualitatively fulfills the present technological process and corresponds to agro-technical demands. The amount of agronomically valuable aggregates increases in the arable layer under the processing of soil by the chisel plow. The chisel plow is fairly aggregated with the T-150K according to energetic indexes. The decrease in traction resistance (by 12.27%) and specific energy consumption (1.14%) when using the working elements with self-centered clutches have been observed. There was set the reasonability of the application of the type without clutches at the deeper tillage, and it is necessary to use the chisel plow with self-centered clutches under the soil treatment on small and medium depth. To treat soil in arid conditions there was developed the construction of the combined chisel plow presenting the combination of the chisel plow with a roller. The comparative analysis of technological process indexes testifies increasing the quality under function of the chisel plow with a roller and unimportant increase of power inputs in normal ranges. According to the acceptance tests on the South-Caucasian MIS chisel plow is recommended to the application in agricultural production.*

KEYWORDS*: CHISEL, SOIL, WORKING ELEMENTS, DEFORMATION, TECHNOLOGICAL PROCESS, TRACTION RESISTANCE*

1. Introduction

Modern trend of mechanization of agricultural production provides for the creation of a new generation of machines and aggregates to treat soil developed on the basis of the systemic approach and adaptability of technological effects from soil-climatic and agro-landscape conditions. The solution of the present problem must be based on the analysis of interaction of working elements with soil, the choice of optimal parameters and regimes of functioning allowing us to execute the present technological process with required qualitative rates under the least power inputs.

2. The problem of the discussion

Under designing the soil-cultivating machines it is necessary not only to eliminate fluctuations leading to the loss of stability but to use the alternating movements of working elements to destruct the layer by the so-called lines of the least links. This method is based on the principle of operation of working elements of the chisel plow (CDA-3,6) which is versatile, it executes the specified technological process of field soil tillage at different depths and between rows of perennial plants in the depth which is differentially varying as the distance from a tree (shrub) respectively to architectonics of the root system disposition.

The working elements of the chisel plow contain the hinged fastened clutches whose angle of mounting, relatively to the bay with chisel in cross-vertical plane, is determined by the action of soil resistance forces but the destruction of the layer is implemented by differently directed deformations at the expense of alternating movable elements (clutches). The hinged assembly of clutches with the bay promotes fluctuations of a working element not worsening the stability of a machine.

The object of researches is the technological process of soil tillage by the chisel plow with options of working elements: clutches are fixed in position "flat cutter"; clutches are not fixed and self-mounted in the cross-vertical plane under the action of soil resistance forces transforming the "flat cutter" into the "chisel"; clutches are absent (Figure 1).

Figure 1 *– Chisel plow with options of a working element 1 – the chisel plow of the new generation; 2 – position "flat cutter";3 – position "chisel".*

3. Purpose and methods of research

It is known that the energy consumption for basic soil processing can be around 40% of the total costs on the cultivation of a crop. That is, these studies are to examine the possibility of reducing the traction resistance of a machine, and hence the energy costs of tillage. The reduction of energy inputs is possible with the impact on soil by differently directed movement of working elements when the

layer is destructed along lines of the least links. All possible options (in general type) of working elements for deeper tillage: transforming with full range of change of the mounting angle (0-90^0) of its movable elements (clutches) in the cross-vertical plane as well as the flat-cut (mounting angle of clutches 0^0) and chisel (mounting angle of clutches 90^0 or their absence) are exposed to the comparative analysis on results of agro-technical, energetic and dynamic assessments.

4. Results of researches

The chisel plow effectively carries out the present technological process (Table 1) and corresponds to agro-technical requirements.

The deviation of the depth from given one (2,03-2,16 cm) is in normal range (to 3cm). Some overstated irregularity at depth 19 cm (11% at admitted to 10%) is conditioned to multifocal uptakes of the upper layer of soil. With increasing depth to 26.7-33.8 cm the unevenness is reduced to 8 and 6% respectively and is within the tolerance (10%).

It can also explain the high percentage of ridge from the depth 19cm (28,8%), which however does not exceed the limits (up to 30% agricultural demands).

***Table 1** – Agrotechnical indexes of the chisel plow*

Index title	Value of working element option			
	Clutches are not fixed		Clutches are fixed	Clutches are absent
Technological operation	Subsurface tillage with slight cut of layer in the depth of coverage (chisel plowing)			
Depth of treatment: - average, cm - average square deviation, ± cm - coefficient of variation, %	19,0 2,09 11	26,7 2,14 8	27,0 2,16 8	33,8 2,03 6
Ridging of surface, cm	5,5	5,5	5,4	5,5
Percentage of ridge from the depth, %	28,8	20,6	20,0	16,3
Coverage, m	3,2±1%	3,2±1 %	3,2±1%	3,2±1%
Stubble preservation, %	60…70	60…7 0	60…70	60…70
Degree of weed trimming, %	100	100	100	100
Crumbling of the layer in fractions, mm, %: - above 50 - less 50	35 65	35 65	34 66	40 60
Blocking **%**	8	9	9	8
Sealing and blockage of working elements	not observed			

Ridging with the increase of depth treatment practically is not changed (5,4-5,5 cm). The absolute value of ridging slightly exceeds the norm (to 4 cm), but the relative value determining in percentage from the depth of treatment is within the tolerance. 60-70% of plant residues (stubble) at admitted 60% and more remain on field surface after soil treatment by the chisel plow. Weeds were cut entirely.

The chisel plow provides the stable depth of coverage with irregularity 1% at admitted 2%.

In the treated layer of soil the fractions with diameter up to 50mm (60-66%) with the required 60 or more prevail, and their number with increasing depth decreases slightly. At the maximum depth (33.8 cm) some reduction of content in the treated layer the fractions with diameter up to 50 mm (60%, and on smaller and medium depth of 65 and 66%, respectively) is conditioned to the density of the low soil layers and as well as the method of cultivation of the layer by working elements at a given depth (in the absence of flat-cutting clutches).

Blocking is within normal range, amount of clots in diameter more 100 mm in treated layer does not exceed 8-9% at admitted to 20%.

The fixation of clutches in position “Flat-cutting” does not influence significantly the change of agro-technical indexes characterizing the quality of technological process of the chisel plow. At all models of the working element (fixed, non-fixed and absent clutches) the chisel plow effectively makes the subsurface tillage with slight cut of the layer in coverage and corresponds to agro-technical requirements.

Data of comparative analysis of the structural soil content before and after chisel processing with different models of working elements (Table 2) testify to the increase of agronomically valuable aggregate content in layers 5-15 cm and 15-25 cm on 8,2-8,6% using the working element with non-fixed clutches.

***Table 2** – Data of structural content of soil*

Depth of sampling, cm	Content of fraction in % from absolutely dry soil							<0,25mm	Agronomically valuable aggregates, 0,25-10mm
	>10mm	10-5mm	5-3mm	3-2mm	2-1mm	1-0,5mm	0,5-0,25mm		
Black soils simple weak humus vigorous light-clayey on loess-like clays									
Before treatment									
5-15	17,7	6,7	1,5	8,4	4,6	0,4	10,4	10,3	72,0
15-25	32,9	8,1	6,8	7,5	6,7	3,4	2,4	2,2	64,9
25-35	21,6	7,9	8,8	9,5	0,0	5,2	3,6	3,4	75,0
Clutches are not fixed (depth 27 cm)									
5-15	11,5	17,4	16,7	12,1	16,1	9,5	8,8	7,9	80,6
15-25	21,0	4,0	4,5	8,6	1,2	8,2	6,6	5,9	73,1
25-35	31,3	23,0	12,4	7,5	9,4	6,2	5,4	4,8	63,9
Clutches are missing (depth 34 cm)									
5-15	53,1	9,5	5,6	4,9	8,4	6,7	5,9	5,9	41,0
15-25	25,8	20,6	11,4	7,6	11,1	8,4	7,8	7,3	66,9
25-35	11,8	29,6	19,0	11,0	11,8	6,9	5,1	4,8	83,4

At soil treatment by chisel plow with missing clutches, on the contrary, in the layer of 5-15 cm a sharp decrease in the content of agronomically valuable aggregates (from 72,0 to 41.0%) takes place, in the layer of 15-25 cm – it remains the same (and 64.9 and 66.9%), and increases by 8.4% in the layer of 25-35 cm at the depth of the chisel plow’s passage.

So, it can be marked the increase of amount of agronomically valuable aggregates in layers 5-15 cm and 15-25 cm under treatment by the chisel plow with non-fixed clutches in the layer 25-35 cm – at missing clutches.

Therefore, it is advisable to use the option with missing clutches at the deepest tillage, and to use a chisel plow with non-fixed clutches at the tillage on small and medium depth.

The experimental studies of energy rates of the chisel plow are shown in Table 3, calculated on the basis of experimental values of traction resistance.

The analysis of data testifies to the increase of traction resistance consumed output and specific power intensity with increase of depth treatment [1, 2, 3].

It follows that from the analysis:

– increasing the speed of the aggregate from 6,67km/h (1^{st} gear of the tractor T-150K) to 8,57km/h (3^{rd} gear) traction resistance increases in 1,5 times;

– traction resistance with the increase of depth increases more intensively than with the increase of speed. So, with the increase of soil treatment depth in 1,4 times by the chisel plow with non-fixed clutches the traction resistance increases in 1,7 times.

At soil treatment depth in 27 cm and the option of working on with non-fixed clutches the traction resistance of the chisel plow is close to the nominal traction force of the tractor of traction class 3T, which indicates to the rational consumption of power with specified operation mode.

In the result of researches there was determined that the traction resistance of the chisel plow with non-fixed clutches on the depth in 34 cm with clutches insufficient to the capacity of the tractor T-150K. So, the way of soil treatment with option of a working

element without clutches is rational to use at the deeper tillage (34 cm and more).

On the depth in 19 cm the traction resistance of the chisel plow is quite less than at 27 cm, the consumed power is lower, the speed is 6,67; 7,35 and 8,57km/h on 1, 2 и 3 gears, that corresponds to the norm at maximum traction capacity of the tractor of the traction class 3T.

Based on the foregoing, we can conclude that the traction resistance of the chisel plow satisfactorily is aggregated with the tractor T-150K.

The comparison of energy characteristics of the chisel plow (Table 4) indicates to the decline of traction resistance (by 12.27%) and decrease of specific energy intensity (1.14%) when using the working elements with non-fixed clutches, it supports the hypothesis that the destruction of the layer along the path of the least resistance by self- mounting of clutches at the angle of natural soil cleavage. The increase of traction resistance is conditioned by the increase of pressure of the soil layer on the surface of working elements in the option with fixed clutches [4].

Table 4 *– Comparative assessment of chisel plow energy rates*

Rate title	Value for option of working element	
	non-fixed clutches	fixed clutches
Work rate: - speed, km/h - depth, cm	6,10 27	6,10 27
Traction resistance, kN	32,52±3,2	37,07±3,8
Decrease of traction resistance, %	12,27	–
Specific energy intensity, kWt·h/ha	33,21	37,76
Decrease of specific energy intensity, time	1,14	–

So, the angle of soil deformation on the sides of the chisel plow, under which the clutches are mounted to loosen the layer, is determined by the physico-mechanical properties of the treated medium (humidity, hardness, etc.), we can assume that under other circumstances, the reduction of traction resistance, and, consequently, specific energy consumption in the process is more important than the results of field experiments.

Analyzing the obtained deviation of traction resistance from the average one (Table 3), it follows to note the decrease of irregularity with the increase of treatment depth conditioned by the miter of dynamic influences of the top layer of soil. So the coefficient of variation of traction resistance at the depth of 19 cm in average amounts for 14.06%, at the depth of 27 cm – 10,02%, at the depth of 33-34 cm – 8,67%. In this case the average deviation of traction resistance is not practically changed from speed, depth, and type of a working element of the garden chisel plow and is in the limits of tolerance (in average about ±3 kN).

Despite the fact that the great cut plant residues remain on the surface, the topsoil does not have sufficient erosion resistance, as plant residues are badly crushed, there are areas with large clots of soil, thereby mulch surface I not provided. These disadvantages can be eliminated by means of application in the construction of disk working elements to crumble the plant residues and adjustments to improve the soil crumbling (rollers). It is necessary to apply the compaction of the top treated layer by the roller in arid areas, because the blowing of fertile soil is decreased and moisture is preserved better because of decrease of intensity of convection-diffusion flow of vaporous water, the intensity of which will be higher in loose soil. In combination with disks the rollers create the insulating layer on the soil surface decreasing the moisture evaporation.

On the basis of researches there was worked out the construction of the combined chisel plow presenting the combination of the chisel plow with a roller, whose general form is presented on the fig.2.

The technological process of the chisel plow with a roller is implemented in the following way: during the moving of the aggregate across the field the clutches with a bit cut soil on a given depth, which is crumbled and then is subjected to additional tillage and crumbling of large soil clots by a roller-ripper with simultaneous leveling of surface.

Agro-technical indices of the chisel plow with a roller were obtained [5] at tillage of black soils along stubble of winter wheat. Relief and microrelief of fields are smooth. Humidity and soil solidity on the background 2 is in normal range, the background 1 is characterized by increased solidity and low soil humidity in a treated layer (Report №11-64-12 (1010032) North-Caucasian MIS).

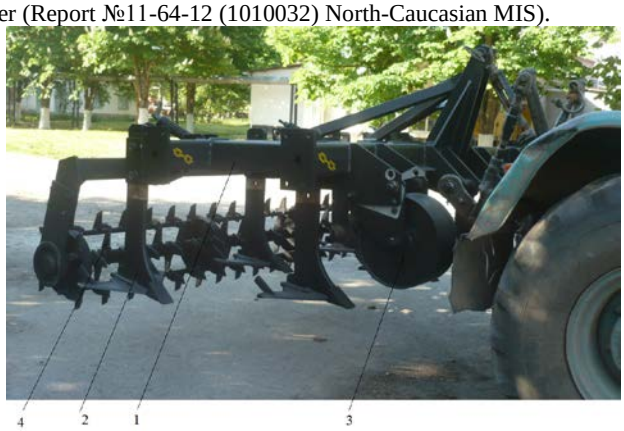

Figure 2 *– Chisel plow with a roller: 1 – frame; 2 – supporting wheel; 3 – working element; 4 – roller-ripper*

Agro-technical indices obtained at working elements with clutches on the depth 13; 20 and 27 cm and without clutches on the depth 27 and 30 cm. The unit runs steadily by the depth of soil treatment (deviation of 1.3...3.0 cm).

Agro-technical indices of the chisel plow with a roller are presented in the Table 1.

Table 5 *– Agro-technical indices of the chisel – plow with a roller*

Rate title	Value of rate for a working element				
	with clutches (background 1)			without clutches (background 2)	
Depth of treatment: -average, cm	12,24	19,10	27,56	26,42	29,49
- deviation, ±cm	1,30	1,76	2,16	1,30	3,00
- coefficient of variation, %	14,79	9,28	7,88	4,92	10,50
Soil crumbling, %: - size of fractions to 50 mm	76,49	63,88	57,51	71,91	61,44
- size of fractions more 50 mm	23,51	36,12	42,49	28,06	38,56
Ridging of soil surface, cm	3,25	4,50	5,03	5,79	5,88
Stubble preservation, %	50,52	47,42	43,30	85,58	85,12
Change of erosion-hazardous soil particles in the layer of 0...5 cm, ±%	- 2,40	- 2,76	- 4,04	- 5,14	- 5,19

The quality of soil crumbling is good, the number of fractions up to 50 mm made of 57.51...76,49%, which meets the agronomic requirements (not less than 25% in fallow field). During almost at all operation modes the number of fractions up to 50 mm accounted for more than 60% with the exception of the variant with clutches on

the depth 27,56 cm (of 57.51%), due to the increased soil hardness in the treated layer on the given background.

Blocking of soil layer amounted for 3,25…5,88 cm, it meets the requirements (not more than 30% from depth of treatment).

The preservation of stubble on the background of normal moisture and solidity meets the agro-technical requirements (not less 85%) and amounted for 85,12…85,88%. However, this rate does not exceed 50,52% on the background of increased solidity and low moisture, as far as the stubble got spilled in the crack between dry soil clots.

After the passage of the aggregate the amount of erosion-hazardous particles in the top soil layer decreased to 2,40…5,19%, it corresponds to agro-technical requirements (it must not increase).

So, at soil tillage by the chisel plow with a roller without options of working elements on all regimes the aggregate's work on all agro-technical characteristic corresponds to requirements excluding the preservation of stubble with increased solidity and low humidity that is connected with arid soil-climatic conditions [5].

The analysis of energetic characteristic testifies to the increase of speed and depth of treatment the traction resistance consumed the capacity and specific power inputs are increased

The most traction resistance 41,7 kN at 6,67 km/h and depth 27 cm is explained by the increased soil solidity of the background 1 and by low soil humidity of treated layers that led to the remultiplex of the layer.

The analysis shows that the chisel plow with a roller due to traction and capacity rates is satisfactorily aggregated with the tractor T-150K.

During the operation of the chisel plow with a roller the soil tillage technological process damages (blockage and sticking) were not noticed on all regimes, it testifies to the stability of technological process operation, the coefficient of reliability is 1,0, and it meets standard requirements (not less 0,99).

5. Conclusion

Researches show that the chisel plow with a roller meets the requirements due to rates of technological process of soil treatment and is recommended to the application in agricultural production on the results of tests on North-Caucasian MIS.

The comparative analysis of agro-technical rates testifies to increase the quality of crumbling and decreasing of height of ridges on the surface of treated soil under functioning the chisel plow with a roller (Table 1 and Table 5), that is the power inputs will slightly increase (Table 3 and Table 6) and are in normal range. From above mentioned we make conclusions on reasonability of the chisel plow modernization.

6. References

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