Multilayered destruction of a soil layer

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Abstract. One of the main tasks of agriculture of the Russian Federation today and for the near future is transition to the modern economically effective technologies demanding the new approach to agriculture with application of modern scientific solutions and a new generation of agricultural machinery. The analysis of scientific research has shown that cultivation of grain crops to 40% of resource potential is for the technological process of processing of soil, and the share of machining of soil, for example, in wheat crop, is 14%. In a context of the previously mentioned, soil processing should be done to receive the necessary quality of processing, to reduce a power consumption, to increase development of cars. Optimum quality destruction of the soils, a demanded turn of a layer etc. is probably provided in advance, forcing a soil layer to move on the set trajectory on ploughshare-mouldboard surfaces, a plough or on ploughshare non-mouldboard tools. Thereupon carrying out profound scientific research of interaction of working bodies with soil for the purpose of modernisation and designing of such working bodies of soil-cultivating tools, which allow receiving the set agrotechnical indicators of processing of soil with the minimum expenses, is actual.

1. Introduction
The agricultural production main tasks of soil preparation under crops and planting of agricultural crops are preservation and increase of fertility of soils. The principal view of works using soil preparation is ploughing. Soil ploughing in agriculture in power-intensive processes frequently does not meet completely the requirements for agricultural technicians. Therefore, in ploughing of soil the general purpose ploughs even in its physical ripeness are on average only 20% of the field corresponding to agro-technical requirements for degree crumbling. By results of field research, it is established that the degree of destruction of a layer of soils in processing fluctuates from 35 to 60%. Thus, it is necessary that ploughing is the most power-intensive operation in plant growing, for its realisation it is necessary to have about 40% of power inputs in soil preparation. In this connection, it replaces other kinds of processing of soil – disking, cultivation, etc. As a result, there is no soil loosening at all the depth of the arable horizon and reconsolidation of underlying layers of earth that breaks an aero-aquatic mode root habitat of a layer of cultural plants is observed.

Soil processing remains the most power-intensive and most important operation in the conditions of modern agriculture. It defines efficiency of use of soil resources, repeated passes across the field of heavy agricultural machinery – one of the main reasons of constant consolidation and degradation of soil fertility, and increases in power inputs on tillage. A change of density of soil by 0.1-0.3 g/cm³ from optimum (1.1-
1.3 g/cm³) productivity decreases by 20-40%. Even at optimum value of average density of arable horizon, the productivity decrease occurs owing to increase in density top root habitat of a layer (12-25 cm).

Also live conditions of soil formation microorganisms worsen; there is a decrease in fertility of soil, the contamination increases and, as consequence, productivity of agricultural cultures decreases.

In this connection, replacement of ploughing by other kinds of processing is unreasonable from a position of agricultural technicians that defines necessity of maintenance of conditions saving energy its performance. A perspective direction of the decision of the given problem is performance of the basic processing of soil, in which the layer turn is provided, the vegetative rests with loosening. Moreover, a turn of the top processed layer of earth for realisation application of working bodies of the plough, which is carried out in the course of processing at first loosening, is offered. The given kind of processing possesses advantages of ploughing and simultaneously satisfies conditions of saving energy.

Processing of soil, technology, means of maintenance of these processes and theoretical solutions in the field of work of cars and mechanisms are constantly in sight of scientific community. We investigated not only separate working bodies, but also units, and technological processes.

Last year questions of moving of a layer of soil on a surface and sailings of ploughs allow drawing correct conclusions on the further perfection as separate working bodies, and whole cars and units are considered in detail.

Klassen J.P. considered a question of branch and moving of a layer of soil on a surface ploughshare. Work is directed at definition of pressure arising in soils and causing it crumbling, and also the sizes of the area of a layer participating in the process. Tangents and the normal pressure arising in a layer of soil were thus considered. It is established that pressure tangents are 4-6 times more than the normal. The analysis of the analytical laws received in work has shown that optimum value of depth of a course of a knife should make 0.11…0.17 m [1].

Mitin A.A. received the construction organic law of ploughshare-moldboard surfaces coulter, presented in the form of directing curve and tangential dependence of movement rectilinear forming on directing, causing minimum of the power consumption of moldboard processing of the top layer of arable horizon. And key parameters of a processed layer are defined: the width of capture coulter is equal to width of capture of the basic working body and 35-40 cm, depth of processing – 12-16 cm [2].

Juhin D.P. offered the combined plough for level-by-level processing of a layer of soil. For level-by-level processing of soil, the parameters of the tool providing its steady work in longitudinal-vertical and horizontal planes at speed of movement – 1.8-2.4 km/s have allowed one to define the analysis of results of research of work of a plough. At depth of processing, tests of a plough of 0.12-0.16 m for level-by-level processing of soil in field conditions have shown full performance of technology tillage. In addition, degree destruction has made 87.2-90.8%; completeness of incorporation weed vegetation and the rests of 87.3-95.7%, uniformity of a surface of a field (soil combing) on the average were 5.3-6.2 % of that meets agro-technical requirements. However, power indicators remained at level of industrial ploughs [3].

Razbezhkin N.P. developed and proved a design of working body a plough, are spent theoretical and experimental researches, the analysis of results that has allowed drawing conclusions that use of the additional regulated crumbler in the top part of a sailing raises quality of the basic processing of soil. Thus, the distance from a field sawn-off shotgun to crumbler should be equal to width of capture of the case. Installation height is average depth of processing of a layer, and its length of 170-200 mm. Analytical dependence for definition of limits of regulation of position of the crumbler according to which regulation of a corner of its installation for all types of soils should be made within 3-27° concerning a furrow bottom is received. Agro-technical indicators of work a plough with an advanced working body are crumbling degree to 75%, lumpiness – no more than 7%, height of crests – no more than 45 mm that corresponds to agro-technical requirements, and leads to increase in productivity of a potato at 6.2 ts/hectares [4].
Rakhimov I.R. is developed mathematical model and analytical dependences for definition of the making forces operating on two- and trihedral wedge, taking into account the normal pressure arising on a platform of contact of a wedge with soil are received. The design of working body with rippers is developed and investigated. It is established, that components of traction resistance for working body with rippers have square-law dependence on depth of processing and speed of movement of the unit. For degree maintenance of crumbling soils within the agro-admission of value of the corners, the characterizing type of working body should be in limits: for the case of a plough – 20-30°, a corner of a solution – 35-45°; for a paw cutter-subsoiler – 27-30°; for gap cutter – 23-27°. For maintenance of a minimum of traction resistance in various working conditions, the value of the corners characterizing the type of working body should be regulated. Parameters of additional crumblers for a paw cutter are established: 30-35° [5].

Pavlushin A.V. investigated work of the four-case plough, equipped experimental working bodies which in comparison with a plough in a serial complete set provides improvement crumbling soils (quantity of soil fractions in the size to 50 mm; the quantity incorporation stubbly increased by 13%). In addition, the vegetative rests have increased by 18.2%. The ploughs equipped with experimental working bodies provided the agro-technical requirements shown to the basic processing of soil. On the power indicators the ploughs equipped with experimental working bodies, in comparison with ploughs in a serial complete set providing decrease in specific power inputs by 9.7 kW/hectares (for a four-case variant) and by 5.8 kW/hectares (for a three-case variant) [6].

Erzamaev M.P. made theoretic research of technological process of soil processing in the analytical expressions proving depth of processing of each circle from demanded depth incorporation of the top layer of earth received. A chisel of the case of the bottom circle investigates the interrelation of height of crests of a bottom of a furrow from arrangement of working bodies in section and a corner of shift of soil. Dependence of traction resistance of working section on constructional parameters of its working elements, physico-mechanical properties of processed layers of earth and speed of the arable unit is established. Dependence of change of traction resistance of working section of the combined plough at the expense of a formation exception «plowsoles» is received. As a result of the experimental research we established: the least power expenses in soil processing are provided with ranges of depths of processing of soil which make: the case of the top circle of 0.12-0.18 m and the general depth of processing of 0.37-0.41m. Thus specific power expenses for processing of the unit of volume of soil make 40.5-46.4 kJ/m³ at a speed of movement of the unit of 1.5-2.5 km/s. In a substantiation of parameters of arrangement of working bodies, it is defined that a plough of 0.05-0.12 m towards a raw surface weeding should be established consistently one after another with lateral displacement of the case of the top circle concerning the case lower tier on size. That provides the least slipping movers of a tractor; the least value of height of crests of a bottom of a furrow of 0.065 m is received at a 30° corner of shift of soil by a chisel in the case of the bottom circle. The combined plough, in soil processing at the speed of 1.5-2.5 km/s, reduces power expenses by 10.6-17.9% in comparison with existing plough PNJ-4-42. It provided crumbling soils of not less than 75% and incorporation of the top layer of earth with the vegetative rests and seeds of weed plants at a depth of 0.18 m. Moreover, stocks of a moisture of soil increase by 20% [7].

Svechnikov P.G. researches and analyses the mechanism of interaction of a wedge with soil established. Research was conducted on the law of formation of a layer of soil on working body. The scientific hypothesis about necessity of allocation in the course of interaction of a wedge with soil of three stages is confirmed: destruction of soil under the influence of a wedge; formation of a layer of soil on a wedge; movement of a layer of soil on a wedge. Dependence of definition of a thickness of a layer on a wedge, which is defined by a corner of cutting of soil, is received. For the first time the concept of a corner of cutting of soil is entered by a trihedral wedge, mathematical formulas for its definition and the dependences connecting in a single whole corners of cutting of soil by a trihedral wedge, introductions of a layer of soil on a wedge and corners, characterizing its parameters are received. The corner of cutting the soil of a tri-
hedral wedge is universal power, and technical characteristics on its work were not used earlier in designing soil tillage of the working bodies allowing more precisely meeting set agro-requirement. Laws of movement of a layer of soil on a flat trihedral wedge are defined. It is established that despite distinctions in resistance to movement of a trihedral wedge, physico-mechanical properties of soil of the characteristic of process of movement of a layer on working bodies (a thickness of a layer on a wedge, a corner destruction a soil layer, the thickness of elements of destruction, etc.) are defined basically by wedge parameters. Dependences of components of speed of movement of soil on axes of the Cartesian coordinates from forward speed of movement of the tool and wedge parameters are defined. The trajectory of movement of soil on a trihedral wedge, proceeding from the analysis of the mechanism of interaction of a wedge with soil that allows one to receive the set result of work of soil-cultivating cars by change of a trajectory of movement of a layer in parameters of working bodies is theoretically defined and experimentally confirmed. The process of movement of soil on flat working bodies not in the pure state (one flat wedge) is investigated. In addition, taking into account office parts of working body – racks, rigidity amplifiers the scheme of formation of roughnesses of a field and break furrows, etc., we defined width in processing of soil by cultivators, cutters, subsoilers. Interrelations of design data of working bodies of soil-cultivating tools with agro-technical requirements to soil processing are opened. The interrelation of swelling and friability of the soil descending from a wedge with size of ruptures in a layer and on a wedge is established.

Theoretically also it is experimentally proved that width of break furrows in work of cultivators, cutters, subsoilers is reduced essentially, having reduced a movement way of particles of soil by change of the form of a boot of working body. The hypothesis about the reasons sticking flat working bodies on damp soils is put forward and confirmed. The technical decision for elimination of sticking flat working bodies is found. The scientific hypothesis about influence of a variable corner of cutting of soil on length of the ploughshare in improvement of crumbling soils is confirmed. We show different values of a variable corner of cutting and in wedge height, it is possible to change a trajectory of movement of a layer on a working surface and by that to receive the set indicators of agro-requirements in soil processing. Dependence for definition of a thickness of a layer on a wedge is received and the reasons of ruptures in the soil arriving on a wedge, swelling and friability of soil after wedge pass are defined. It was a basis for definition of components of speed of movement of soil on axes of the Cartesian co-ordinates in the course of tool movement. That is one of the important factors for perfection of process of interaction of a wedge with soil and modernisation of tillage working bodies [8, 9].

There is a hypothesis on many-tier ploughing of soil transition from the accepted system of processing of cutting of moving on working bodies and the subsequent compression on the system of destruction of a layer on lumps of the set sizes with the subsequent lifting on a sailing and a turn excluding intensive compression. An intensification of processing of the soil provides saving resource, exception of dusty particles, soil processing according to agro-requirements.

2. Materials and methods

According to a hypothesis of many-tier processing of soil, the technique included the following basic questions.

The theoretical decision of a question of movement of a trihedral wedge in soil with definition of a resultant and a point of the appendix are equally effective. We carry out the analysis of the received laws with use of software package MathCAD 15.

It is possible to present a working soil-cultivating working body, consisting of wedges with sharp and stupid corners of occurrence in soil. For a trihedral wedge with a sharp corner of occurrence in soil at the established movement, work is reduced to soil shift aside and to lifting. This process is similar to process
of compression of soil in a file. Normal pressure $N$ of soil upon a wedge varies over a wide a range and
depends on soil consolidation.

For definition of a normal component, we will consider platform deformation $ds$ during its moving on
size $U$. Elementary normal pressure thus can be defined as [10–12]:

$$dN = q ds,$$  \hspace{1cm} (1)

where $q$ – the proportionality factor, which size defines density of soil, speed of moving and geometrical
parameters of the working body.

After integration, normal pressure has become:

$$N = \frac{q \cdot h^3 \cdot (2\cos \gamma - 1)}{3 \cdot \sin \beta \cdot tg^2 \beta \cdot sin 2\gamma \cdot cos \gamma},$$  \hspace{1cm} (2)

where $h$ – depth of a course of the working body, m; $\gamma$ – a corner of a solution of a wing of a wedge, hail-
stones; $\beta$ – a corner of crumbling hailstones.

From expression (2) the normal component of all forces operating on a wedge with a sharp corner of
occurrence follows that it depends on depth of a course in soil in cubic degree, geometrical parameters and
proportionality factor.

If the working body consists of the top and bottom parts with sharp and stupid occurrence corners in
soil, the top part of working body can be presented as the truncated spatial wedge. The normal component
of all forces operating on a wedge cheek can be expressed as a difference of normal components:

$$N_1 = N' - N^* = \frac{q \cdot h^3 \cdot (2\cos \gamma - 1)}{3 \cdot \sin \beta \cdot tg^2 \beta \cdot sin 2\gamma \cdot cos \gamma},$$  \hspace{1cm} (3)

where $N'$ - a normal component of all forces operating on a wedge at depth of a course $h$, m; $N^*$ - a normal
component of all forces operating on a wedge at depth of a course $h_1$, m.

The module of a resultant taking into account (3) makes:

$$R_1 = \frac{2q \cdot h^3 \cdot (2\cos \gamma - 1)}{3 \cdot \sin \beta \cdot tg^2 \beta \cdot sin 2\gamma \cdot cos \gamma \cdot \cos \varphi},$$  \hspace{1cm} (4)

where $\varphi$ – a corner of a friction of soil on a surface of the working body.

The resultant of all forces operating on the bottom part of the working body has become:

$$R_2 = \frac{q \cdot h_2^3 \cdot (2\cos \gamma - 1)}{3 \cdot \sin \beta \cdot tg^2 \beta \cdot sin 2\gamma \cdot cos \varphi},$$

Value of a resultant of all forces can be defined as:

$$R = R_1 + R_2.$$  

Solving the equation $h$ (2) we receive value of a point of the appendix which is 0,118 depths of a
course of the tool.

In substitution of the received expression value of resistance in crumbling a layer, a wedge with a sharp
corner of occurrence in soil is [10]:

$$P = \sum_{i=1}^{3} \frac{q_i \cdot a_i^3 \cdot (2\cos \gamma - 1)}{3 \cdot \sin \beta \cdot tg^2 \beta \cdot sin 2\gamma \cdot cos \gamma} + \varepsilon (a_1 + a_2 + a_3) \cdot (b_1 + b_2 + b_3) \cdot \nu^2$$  \hspace{1cm} (6)

where $P$ – longline plow resistance in ploughing, N; $q_1, q_2, q_3$ – coefficient, soils considering hardness,
N/m$^3$; $a_1, a_2, a_3$ – a thickness of the layer of processed earth of each ploughshare, m; $b_1, b_2, b_3$ – width of
capture of ploughshare, m; $\varepsilon$ – factor considering energy in moving of the destroyed soil layer, (N·s$^2$)/(m$^4$); $\nu$ – speed, m/s.
Thus, use of the present expression (6) gives the chance to define resistance of any soil-cultivating tool. For resistance definition, it is necessary to know geometrical parameters of these working bodies, hardness of soil and layer power at its turn.

3. Results
To check the results of theoretical research, comparisons of results of field tests, we carried out analyses of the received dependences with use of graphic constructions received in software package application in MathCAD. Evident representations of a kind of schedules for resistance of soil are received in passage of an experimental plough with rippers considering theoretical dependences and results of field tests, which are presented in figure 1.

![Figure 1. Dependence of resistance of plough PLN-4-35 $P$ in ploughing on speed of movement $v$: 1 – theoretical curve; 2 – plough PLN-4-35; 3 – plough PLN-4-35 with rippers.](image)

Carrying out theoretical research, the following values have been accepted: depth of a course of the first ripper - 0.08 m; the second ripper - 0.09 m; the general depth of a course of the basic case of a plough - 0.27 m; width of capture both rippers - 0.25 m; width of capture of the basic case - 0.35 m; $\varepsilon$ – factor considering energy on moving of the destroyed layer of soil, 3500 (N∙s$^2$)/(m$^4$); $q_1$, $q_2$, $q_3$ – the factors considering hardness of soil, 1200 N/m$^3$.

The analysis of the received dependences and results of experiment give the chance to draw a conclusion that the technology preliminary decompression soils with simultaneous cutting of a layer of earth yields a positive result not only on quality decompression soils, but also on decrease in expenses of energy in realization of this process. Therefore, a decrease in expenses of energy in use of decompressions saves 0.32-0.36 in comparison with industrial ploughs, and it saves fuel, reduces expenses of work, improves quality of processing of soil. There is a reduction of terms of preparation of soil, reduction in consolidation of soil in the course of its preparation for the subsequent field works, preservation of fertility and improvement of biological and chemical processes proceeding in soil.
4. Conclusion

The analytical dependences were received as a result of the research, full process of decompression of soils and expenses of energy used for ploughing with decompressions. That allows using a tentative estimation of projected soil-cultivating tools.

The offered technology of decompression of soils of a ploughed land, which precedes layer compression, provides a decrease in expenses for processing by 0.32-0.36 in comparison with existing technology and promotes improvement of biological and chemical processes in soil. The combined soil-cultivating tool in which we applied decompressions in the form of tetrahedrons provides a solution of reception of quality of processing of soil within agro-requirements for improvement of all indicators.

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