Theoretical justification of the type of a flat-cutting working body of a ploughshare

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Abstract. The work is dealt with main tillage, namely the theoretical substantiation of the type of a flat-cutting working body of a ploughshare. The article has a research character, which is expressed in the fact that there were given the theoretical analysis of the method of manufacturing working bodies of a similar profile for ploughshares with different widths. Also, there was justified the type of a proposed design, its description and flow of technological process were given. As a result of the work done, there was obtained the theoretical dependence of justification of the shape of a flat-cutting working body of a ploughshare. The conclusions show the main results achieved so far.

There were determined dependence and regularities of influence of individual factors on energy intensity of a process of tillage with various tools in works of scientists Sineokov and Goryachkin. Taking into account these circumstances, it is possible to compile and present a classification of ways to reduce energy consumption for tillage. The working body developed by us for the ploughshare has a number of design features (Figure 1). The location of additional working bodies on the frame of a ploughshare does not lead to a complication of a design. The use of a working body leads to an increase in qualitative and quantitative indicators of an arable unit [1].

The technical result of a proposed design is a flat-cutting working body with an additional angle of attack $\alpha_2$, with reasonable areas of placement over the entire area of slots, ensuring soil adhesion and, as a consequence, reducing traction resistance and soil treatment quality. We showed the completeness of soil cutting and improvement of quality performance across the width of soil tillage to the complete wear of a flat-cutting working body [2].

The above technical result is achieved by the fact that the slots of a flat-cutting working body are located in the area of a working body, taking into account the wear of assemblies in the process of its operation, and the maximum permissible total area of slots, which retains a required structural strength, provides higher stability of an arable unit. Within this technical solution, quantitative and qualitative...
indicators of processing of over-dried soils are improved, and under soil treatment in the condition of optimal ripeness, processing occurs without soil sticking and as a result, traction resistance of an arable unit is reduced [3].

In more detail the essence of design can be explained as follows: boundary surfaces between soil and the surface of working bodies arise under soil treatment by working bodies, and more specifically, between soil and steel, namely, between adjacent to each other soil bodies between a thin layer of soil adhering to a working body and soil layer on the surface of a working body. In general, with such relative displacements there are stresses acting across the surface of the section of two bodies – soil layer on material of a flat-cutting working body, i.e. on steel and soil layer on soil adhering to the surface of a working body. The normal component of this stress causes sliding friction forces, the tangential component, which is the shear stress caused by friction [4].

According to the conclusion of A. Kulen and H. Kuipers, the dependence of soil and material characteristics from the conditions of soil adhering on a working body can be expressed by the expression of the normal component 

\[ \sigma_n = \frac{a-c}{\tan \varphi - \mu}', \tag{1} \]

where, 
- \( a \) – adhesion;
- \( c \) – cohesion;
- \( \varphi \) – angle of inner friction;
- \( \mu' \) – coefficient of soil friction on material of a flat-cutting working body (steel)

Consequently, promotion of soil without sticking will contribute to increase of \( \sigma_n \). Therefore, in this regard, it is advisable to use a flat-cutting working body with slots that increase \( \sigma_n \), since \( \sigma_n = \frac{P_n}{S} \),

where \( S \) – total area of soil contact with surface of a working body of a flat-cutting working body, \( P_n \) – normal component of total tension \( P \).

Soil friction under its sliding along working surface and adhesion – different phenomena but they appear simultaneously. Note that, if friction resistance of sliding does not depend on the area of their contact with each other, i.e. \( F = \mu N \), so resistance to sliding from adhesion depends on area of their contact \( S \). Their total sliding resistance \( T \) is characterized by the following equation [6].

\[ T = F + T_{up} = \mu N + p_0 S + p NS, \tag{2} \]

where \( F \) – resistance to soil sliding on steel (on surface of a flat-cutting working body);
- \( T_{up} \) – resistance to sliding from adhesion;
- \( p_0 \) – coefficient of tangent forces of specific adhesion under absence of normal pressure;
- \( \mu \) – coefficient of sliding friction;
- \( S \) – area of soil contact with surface of a flat-cutting working body;
- \( p \) – coefficient of tangential forces of specific adhesion caused by normal pressure.

Analysis of the expression (2) also shows that total resistance \( T \) can be reduced by decreasing the area of possible adhesion. Therefore, from the point of reducing traction resistance view, it is necessary to increase surface area of slots of a flat-cutting working body and at the same time the limit of increasing the cutout area can only be the preservation of required surface strength of a working body [7].

According to this, you can determine the sharpening angle of a working body and optimal area of slots (see Figure 1).
Figure 1. Type of a present working body

Figure 2. Type of a present working body

The working body has a type of a right-angled triangle (Figure 2). Correspondently we develop a working body \( S_\Delta = \frac{1}{2} mh \) in the program COMPAS on a scale of 1:1. Calculate the contact area of working surface, excluding the cutout sectors I; II; III; IV.

The contact area of working surface is 14050 mm².
Given that the radius of rounding in all sectors is the same, take the area of rounding equal the dependence $\frac{1}{2} \pi r^2$, respectively:

$$S_\Delta = \frac{1}{2} \pi r^2 - (S_I + S_{II} + S_{III} + S_{IV})$$

$$S_I = i_I + r_I + \frac{1}{2} \pi r^2$$

$$S_{II} = i_{II} + r_{II} + \frac{1}{2} \pi r^2$$

$$S_{III} = i_{III} + r_{III} + \frac{1}{2} \pi r^2$$

$$S_{IV} = i_{IV} + r_{IV} + \frac{1}{2} \pi r^2$$

The area of cutout sectors is equal to 2057 mm$^2$.

Since (see Figure 2 slot D-D) flatness $A\parallel B \rightarrow \alpha_p \equiv \alpha_{op}$ respectively the direction of force $\bar{P}_{ns}$ (soil layer) will be constant on the whole area of a flat-cutting working body.

Area of sharpening is equal to

$$S_{ss} = L S_\ell$$

(4)

Since $\alpha_{x_{ssoft}} = \alpha_n = \alpha_s = 90^\circ - \varphi \rightarrow \alpha_s \rightarrow m$, along the whole width of a working body. From the dependence $\alpha_{x_{ssoft}} = \alpha_s = 90^\circ - \varphi$ and theory of soil friction on working it is known that bodies $tg \beta = \mu$, where $\mu$ coefficient of friction on material on flatness. Accordingly, for the optimal operation of flat-cutting working bodies the condition must be met as $\varphi \geq arctg \mu$, we obtain substituting the present condition in dependence (4)

$$\varphi = 90^\circ - (\alpha_s + \alpha_s)$$

$$\alpha_s + \alpha_{x_{ssoft}} = 90^\circ - \varphi$$

$$\alpha_s = 90^\circ - \varphi - \alpha_s$$

$$\alpha_s \geq 90^\circ - arctg \mu - \alpha_s$$

$A\parallel B \rightarrow \alpha_n = \alpha_{sxt}$

$$\alpha_{x_{ssoft}} = \alpha_n = \alpha_s = 90^\circ - \varphi$$

From obtained dependence it is clear that, the sharpening angle of a working body should be in the range of $90^\circ - arctg \mu - \alpha_s$ for optimal operation of a working body. Since $\alpha_s$ is the angle of installation of a flat-cutting working body is constant and samples based on the analysis of theory of flat-cutting working bodies, the sharpening angle can theoretically be in the range of $90^\circ - arctg \mu - \alpha_s \rightarrow$ along the whole width of gripping [8].

Under preservation and observance of this condition, we will get a steady flow of cutting process, and accordingly the quality of tillage.
The important condition is the area of sharpening of a working body $S_{s,n} = L \cdot S_{s,n} + \varphi$, at what $\varphi \to m$ at preservation of the present condition the angle $\delta_{s,n}$ will supply the optimal flow of technological process of cutting.

A number of conclusions can be drawn from the results of the work:

The proposed design based on the results of obtained theoretical data is efficient and ensures the flow of technological process [9]. The location of slots of a flat-cutting working body with recommended geometric parameters will reduce traction resistance of an arable unit, increase its permeability during soil treatment, reduce traction resistance, ensure stable movement of soil layer and cutting weeds across the entire width of processing, that is, ensure the achievement of technical results [10].

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