Parameters of tillage working bodies

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Abstract. This article notes that most of the soil-cutting working bodies wear out their socks a lot, as a result of which their limiting state is reached. Despite the fact that other parts of the working body are still workable and the stock of metal for wear is still sufficient, the working body is completely rejected. In this regard, it is emphasized that increasing the durability of the nose parts leads to an increase in the durability of the entire working body. To determine its parameters, the condition for leveling the resources of socks and other parts of the soil-cutting working bodies is considered. When determining the length of the nose of the bits, an analytical dependence is recommended, taking into account the geometric parameters of the bit and the plowshares welded to it. To obtain self-sharpening in the process of bit nose wear, it is recommended to use a new two-faceted profile. The rational values of the length, the angle of the wedge and the sharpening of the nose are determined, equal to 90 mm, 100 and 350-400, respectively. Based on the condition of rational combinations of strength and self-sharpening characteristics of the toes of bits, the thickness and width of the latter were determined, equal to 22.3 mm and 30 mm, respectively.

1 Introduction

A significant decrease in tractive effort during soil cultivation is possible due to preliminary loosening of the soil in front of the main working body, [1-4] that is, creating an opportunity for the main working body to perform unlocked cutting [5, 6], creating a decompacted zone as well as preliminary loosening of the soil by the working body in front or its nose part, reduces its wear capacity as a result of reducing the contact load of the parts.

The nose parts of the working bodies to one degree or another facilitate the conditions of their work, that is, they loosen the soil and thereby reduce the wear of the adjacent parts of the parts [7]. In this regard, it can be noted that by increasing the durability of the nose parts, the durability of the entire working body can be increased. The nose parts of the working bodies make changes in the wearing capacity of the soil, thereby creating conditions for better and longer performance of the parts of their service functions [8]. The regularities of reducing the wear of the working bodies of soil cultivation machines due to the design action of the nose parts (or individual parts - chisels, socks, handpieces, etc.) require further careful study [8].

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First and foremost, and most quickly, the sock wears out on plowshares and deep rippers [9]. The work of the plow with plowshares, whose socks are worn out, is unacceptable, since it does not penetrate well, plows unevenly in depth, its resistance increases, and, consequently, fuel consumption per hectare of plowing increases and productivity decreases [10].

2 Materials and methods

In soil cultivation machines, to reduce the wear capacity of the soil and facilitate wear conditions, working bodies with special nose parts are used, which increase the wear resistance and durability of the entire working body (Fig. 1) [2]. For deep soil cultivation (loosening and plowing), a significant increase in durability is achieved through the use of chisels that facilitate the wear conditions of the working bodies.

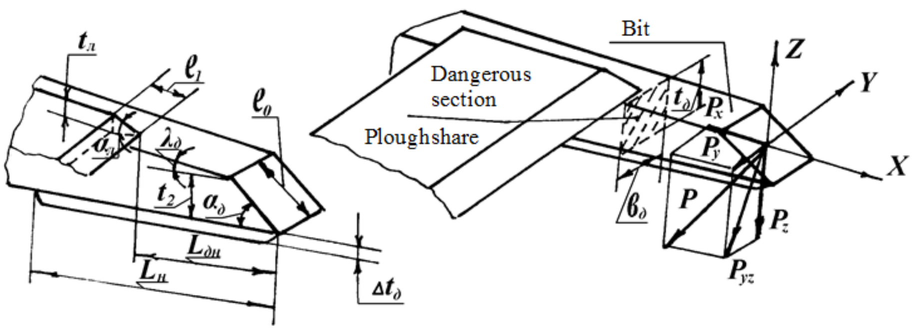

Fig. 1. Design scheme of the toe of the working body.

In cultivator paws, hardfaced with hard alloys, as well as in plow plowshares, the nose first wears out, and so intensively that by the end of the field work season the paw becomes unusable (the cultivator resistance increases, agrotechnical indicators deteriorate, and fuel consumption increases) [10]. At the same time, the wings of the paws wear out more slowly, as a result of which, with a completely worn toe, the width of the surfacing layer on the wings is still quite large [5].

3 Results and discussion

When justifying the parameters of the blades of the working bodies and their socks, it is necessary to strive to ensure that the resources of their blade and socks are the same. Then, when culling, the resources of the blade and the sock must be depleted at the same time. This can be expressed by the condition (1) [1-6]:

$$T_л = T_н \quad (1)$$

where, $T_л$ and $T_н$ - service life of the blade and nose of the working body, ha.

It is known that (2):

$$T_л = h_д / I_л ; \; T_н = L_{дн} / I_н \quad (2)$$

where $I_л$, $I_н$ – intensity of wear of the blade and toe of the working body, mm / ha and $h_д$, $L_{дн}$ – maximum permissible wear of the blade and toe of the working body.

If we connect these equations and transform, then we get (3):

$$L\partial н = (Iн / Il) \times h_\partial \quad (3)$$

The wear of the tip of the chisel occurs more intensively than the wear of the share blade. The soil pressure on the tip of the chisel is several times greater than on the share blade and, accordingly, the wear of the tip is also several times greater than that of the share blade. In the conditions of cotton growing, the wear of the bit nose is 2.5 ... 3.5 times greater than that of the plowshare blade. Therefore: $L_{\partial н}$=(2,5…3,5) h_∂.

Taking into account the fact that the working body is self-sharpening, it is possible to determine the length of the bit surfacing ($L_н$) from the following condition (4):

$$Lн = L\partial н + bл \quad (4)$$

As can be seen from Fig. 1 (5):

$$tg\lambda_\partial = (t_\partial - t_2)/(L_н - \ell_\partial) \quad (5)$$

where, t_2 –thickness of the base layer of the nose at the end of the chamfer of the bit; t_∂ – thickness of the nose of the chisel at the junction of the nose with the blade (dangerous section); and, ℓ_∂ – length of the sharpened part of the sock blade (ℓ_o) in the horizontal plane.

The value ℓ_∂ is determined by the following equation (6):

$$\ell_\partial = t_2 \cdot ctg\alpha_\partial \quad (6)$$

As known (7):

$$t_2 = \frac{\Delta t_\partial \cdot \varepsilon_1 \cdot t_{2o}}{\varepsilon_2 \cdot t_{1o}} \quad (7)$$

With this in mind (8):

$$\ell_\partial = \frac{\Delta t_\partial \cdot \varepsilon_1 \cdot t_{2o}}{tg\alpha_\partial \cdot \varepsilon_2 \cdot t_{1o}} \quad (8)$$

where, Δt_∂ –thickness of the overlay of the tip of the working body; ε_1, ε_2 - coefficients of relative wear resistance of the cutting and base layers; and, t_{1o}, t_{2o} – conventional values of the thickness of the lower and upper "layers" worn out by a stabilized single-layer toe blade.

Then, (9):

$$tg\lambda_\partial = \frac{t_\partial - \frac{\Delta t_\partial \cdot \varepsilon_1 \cdot t_{2o}}{\varepsilon_2 \cdot t_{1o}}}{[(2{,}5 \ldots 3{,}5)h_\partial + b_л] - \frac{\Delta t_\partial \cdot \varepsilon_1 \cdot t_{2o}}{\varepsilon_2 \cdot t_{1o}} \cdot ctg\alpha_\partial} \quad (9)$$

To ensure the equal resource of the plowshare body and the bit nose when the chisel is welded to the field edge of the plowshare, the length of the chisel tip protrusion from the nose of the plowshare frame is performed according to the ratio (10).

$$L_{нд} = \frac{\cos\lambda_\partial}{tg\lambda_\partial}\left\{\ell_0 \sin\alpha_\partial + \right. \tag{10}$$
$$\left. + \sqrt{\ell_0^2 \cdot \sin^2\alpha_\partial - 2\frac{tg\lambda_\partial}{\cos\lambda_\partial}\left[\ell_1 \cdot b_л \cdot \sin\alpha_л - (3{,}4...4{,}7)b_л(t_л + 0{,}07b_л)\right]}\right\}$$

where, λ_∂ – wedge angle; ℓ_o – length of the surface of the front face of the working surface of the bit nosea; ℓ_1 – length of the surface of the chamfer (sharpening) of the share blade; α_∂, $\alpha_л$ – sharpening angles of chisels and plowshares; $b_л$ – width of the hardening strip of the blade part of the share; and, $t_л$ – blade part thickness.

If we consider the solution using the example of a plow share for the following parameter values: Δt_∂=0.8…2.2 mm, ε_1=6.5; ε_2=1; t_{1o}=6.8 mm; Δt_{2o}=15 mm, $b_{\partial л}$=27…30 mm; $b_л$=25…27 mm, α_∂=35…40°; ℓ_o=9.2 mm, ℓ_1=10.8 mm, $t_л$=5.9 mm; and $\alpha_л$=10…15° then we get that the value of the wedge angle should be at least 10° and the length of the bit nose should be at least 90 mm.

The thickness of the toe (t_∂) at the base, or rather in the dangerous section, can be determined by considering the toe as a variable-section beam operating in bending (see Fig. 1).

As shown by theoretical and experimental studies in the field of resistance of materials with a gradual change in the cross-section and the angle of the cone not more than 20°, you can use the formulas obtained for beams of constant cross-section to determine the magnitude of normal stresses. The error in this case usually does not exceed 10% (11).

It is known that in the case of the combined action of oblique bending and tension - compression of a rectangular beam, the strength condition has the form:

$$\left|\pm\frac{P_x}{b_\partial \cdot t_\partial}\right| + \left|\pm M\left(\frac{\sin\phi}{W_y} + \frac{\cos\phi}{W_z}\right)\right| \le [\sigma] \tag{11}$$

where, M – bending moment in dangerous section; W_y, W_z – moments of resistance relative to the y and z axes, respectively (12):

$$W_y = \frac{t_\partial \cdot b_\partial^2}{6}; \quad W_z = \frac{b_\partial \cdot t_\partial^2}{6} \tag{12}$$

where, $[\sigma]$ – permissible tensile (compressive) stress; $0<\varphi<\pi/2$ – angle between y-axis and P_{yz}.

For different values of M, Px, φ, and $[\sigma]$ it is possible to choose an unlimited number of cross sections satisfying condition (11). The rational option is the one that has the minimum area (13):

$$S = b_\partial \cdot t_\partial \tag{13}$$

Consequently, the problem can be reduced to determining the minimum of the function of two variables (13) related by the following equations (14, 15):

$$\frac{P_x}{b_\partial \cdot t_\partial} + \frac{6M}{b_\partial \cdot t_\partial}\left[\frac{\sin\phi}{b_\partial} + \frac{\cos\phi}{t_\partial}\right] = [\sigma] \tag{14}$$

By composing a helper function (15):

$$F(b_\partial, t_\partial, \nu) = b_\partial \cdot t_\partial + \nu\left[\frac{P_x}{b_\partial \cdot t_\partial} + \frac{6M}{b_\partial \cdot t_\partial} - \left(\frac{\sin\phi}{b_\partial} + \frac{\cos\phi}{t_\partial}\right)\right] - [\sigma] \tag{15}$$

By equating to zero its partial derivatives with respect to b_∂, t_∂ and ν, we obtain a system of three equations (16):

$$\left.\begin{aligned} \frac{dF}{\partial b_\partial} &= t_\partial - \nu\left[\frac{P_x}{b_\partial^2 \cdot t_\partial} + 6M\left(\frac{2\sin\phi}{t_\partial \cdot b_\partial^3} + \frac{\cos\phi}{b_\partial^2 \cdot t_\partial^2}\right)\right] = 0 \\ \frac{dF}{\partial b_\partial} &= b_\partial - \nu\left[\frac{P_x}{b_\partial \cdot t_\partial^2} + 6M\left(\frac{\sin\phi}{b_\partial^2 \cdot t_\partial^2} + \frac{2\cos\phi}{t_\partial \cdot b_\partial^3}\right)\right] = 0 \\ \frac{dF}{\partial \nu} &= \frac{P_z}{b_\partial \cdot t_\partial} + 6M\left(\frac{\sin\phi}{t_\partial \cdot b_\partial^2} + \frac{\cos\phi}{b_\partial \cdot t_\partial^2}\right) - [\sigma] = 0 \end{aligned}\right\} \quad (16)$$

from which we find (17):

$$\nu = \frac{2b_\partial^2 \cdot t_\partial^2}{3 \cdot [\sigma] \cdot b_\partial \cdot t_\partial - P_x}; \quad b_\partial = t_\partial \cdot tg\phi \quad (17)$$

and to determine t_∂ we obtain an algebraic equation of the third degree (18):

$$[\sigma] tg\phi t_\partial^3 - P_x t_\partial - 12M\cos\phi = 0 \quad (18)$$

Therefore, based on the Cardano equation (19):

$$t_\partial = \sqrt[3]{-a_1 + \sqrt{a_1^2 + a_2^3}} + \sqrt[3]{-a_1 - \sqrt{a_1^2 + a_2^3}} \quad (19)$$

where, a are found by (20):

$$a_1 = \frac{6M\cos\phi}{[\sigma]tg\phi}; \qquad a_2 = -\frac{P_x}{3[\sigma]tg\phi} \quad (20)$$

For $P_x = 0$, i.e., in the case of oblique bending, formula (19) is simplified.

Beams with cross-sectional dimensions in accordance with (16, 19) satisfy the strength condition (11) and have the smallest mass, i.e. are optimal. Let's consider the solution using the example of a two-tier plow share. We get that t_∂ and b_∂ must be at least 22.3 mm and 30 mm, respectively.

4 Conclusions

Based on the studies carried out, it can be noted that to ensure the equal resource of the bit nose and the plow blade, the wedge angle and the length of the bit nose, respectively, should be at least 10° and 9° mm. Sufficient strength of the toes of chisels during deep tillage is ensured with their thickness and width, respectively, not less than 22.3 and 30 mm.

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