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TO THE DETERMINATION OF THE TRACTION RESISTANCE OF THE EXPERIMENTAL WORKING BODY OF THE CULTIVATOR

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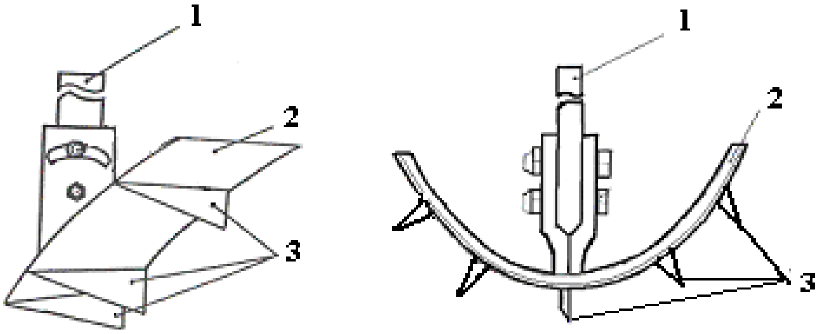
Abstract:
Currently, "classical" working tools are still used for cultivating soil along furrows. The number of razors and rippers installed on one cultivator beam can be from 2 to 4 and from 5 to 7 pieces, respectively, depending on the row spacing of the cotton plant. This leads to an increase in the overall size and weight of the beam. In addition, they do not fully ensure high-quality soil cultivation along furrows

Keywords:

Currently, "classical" working tools are still used for cultivating soil along furrows. The number of razors and rippers installed on one cultivator beam can be from 2 to 4 and from 5 to 7 pieces, respectively, depending on the row spacing of the cotton plant. This leads to an increase in the overall size and weight of the beam. In addition, they do not fully ensure high-quality soil cultivation along furrows.

Based on the literature review and the results of a study of the physical and mechanical properties of the soil in the inter-rows of cotton crops after vegetation irrigation, a prototype of a parabolic cultivator loosening arm was developed and manufactured, which allows cultivating the soil in a furrow and works in conjunction with a deep-throwing arm.

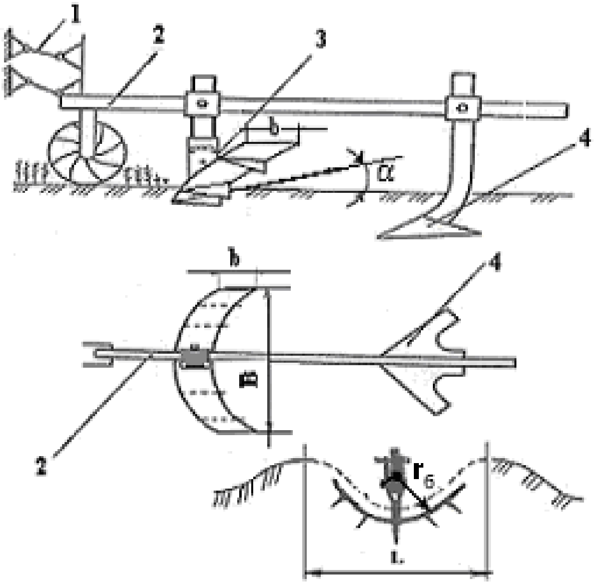
In Fig. 1. shows a diagram of the developed ripping paw in two projections. It consists of a stand 1, a razor 2 with a double-sided blade and soil-cutting knives 3 installed on the underside of the razor. The bracket has a slot for adjusting the angle of entry of the cutting part of the working tool into the soil. The working body has the shape of a furrow in cross section and works in conjunction with a deep-throw paw (Fig. 2).



Rice. 1. Diagram of the experimental cultivator paw: 1-stand, 2-razor, 3-cutting knives.

The ripper paw works as follows. When the unit moves, due to the presence of the entry angle, the paw goes deep into the soil to a depth of 5...6 cm, cuts the roots of weeds present in the rows and ensures its superficial loosening. Knives installed on the underside of the working body deepen the loosened layer, increase the degree of crumbling of the soil, thereby creating good conditions for the operation of the deep-throw cultivator.

The main parameters of the experimental working body that influence its quality and energy performance indicators are: the width of the working body (B), the width of the shelf (h), the number of soil-cutting knives (n), the angle of their entry into the soil ( ), the angle of entry of the working body into the soil ( ), the radius of curvature of the razor blade (rb) and the speed of movement of the unit (V).



Rice. 2. Scheme of arrangement of the experimental working body on the cultivator beam: 1-hitch mechanism; 2-beamer; 3-experimental paw; 4-deep plunger.

The total traction resistance of the experimental working body consists of the resistance of the soil to the movement of its razor and knives.

$$R_0 = R_б + nR_н, \qquad (1)$$

where R_b is the resistance of the soil to the movement of the razor of the working body;
R_N-resistance of the soil to the movement of the soil-cutting knife of the working body;
n -is the number of soil-cutting knives of the working body.

The resistance of the soil to the movement of the razor of the working body is generally described by the expression [1]

$$R_б = R_1 + R_2 + R_3 + R_4, \qquad (2)$$

where R1 is the soil resistance to the penetration of the razor blade of the working body;
R2 - soil resistance to deformation;
R3 - resistance due to the inertia force of the soil;
R4 is the resistance to movement and lifting of soil along the working surface of the working body razor.

The resistance of the soil to the penetration of the razor blade of the working body can be determined by the formula [1,2]

$$R_1 = KT_n t_{лб} \ell_{лб} = K \cdot T_n t_{лб} r_б \cdot \arcsin \frac{0{,}5B}{r_б}, \qquad (3)$$

where K is the coefficient taking into account the shape of the razor blade;
Tp - soil hardness;
B – width of the razor;
tlb - thickness of the razor blade;
- length of the razor blade;
rb - radius of curvature of the working surface of the working body razor

Assuming that the soil layer is destroyed by shear, the soil resistance to deformation can be determined by the formula

$$R_2 = \{\tau_{np} h(2r_б \arcsin \tfrac{0{,}5B}{r_б} + htg\psi_б)[\sin \tfrac{1}{2}(\alpha_\delta + \varphi_1 + \varphi_2) + $$
$$+ f \cos \tfrac{1}{2}(\alpha - \varphi_1 - \varphi_2)\cos\alpha]\} \cdot \cos^{-1} \tfrac{1}{2}(\alpha_\delta + \varphi_1 + \varphi_2), \qquad (4)$$

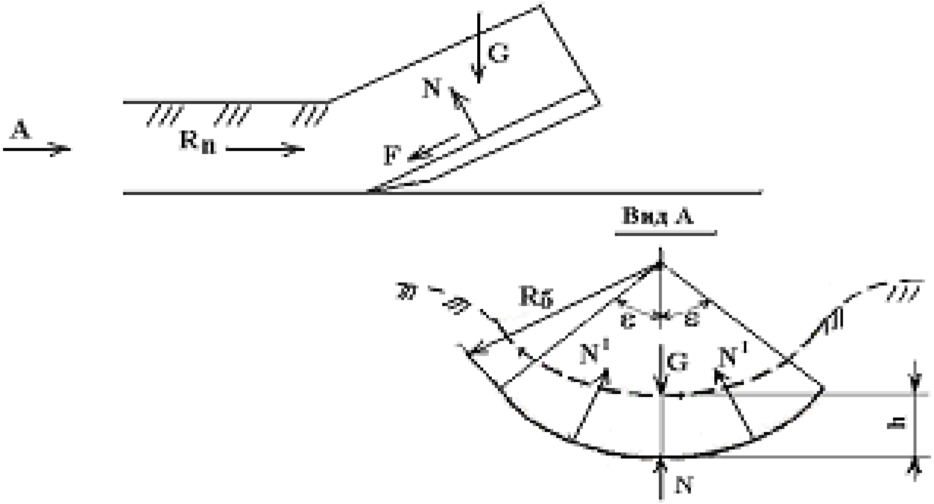
where $\tau_{пр}$ - is the maximum shear stress of the soil;
h - depth of stroke of the working body razor;
$\psi_б$ – angle of lateral soil shearing;
α_δ - angle of entry of the working body razor into the soil;
φ_1, φ_2 – angles of external and internal soil friction;
f - coefficient of soil friction against the material of the working body razor.

The resistance caused by the inertial force of the formation, taking into account the physical and mechanical properties of the soil and the parameters of the razor, is determined by the following expression

$$R_3=(2r_б \arcsin\frac{0,5B}{r_б}+htg\psi_б)h\rho V_n^2\cdot\frac{\sin\alpha\cdot\sin(\alpha+\varphi_1)}{\cos\varphi_1}(1+\frac{W}{100}), \qquad (5)$$

where ρ - soil density;
V_n – speed of movement of the unit;
W – soil moisture.

The resistance to the rise and movement of the soil layer along the working surface of the working body razor is determined using the diagram shown in Fig. 3.



Rice. 2 Scheme for determining the soil resistance to lifting and moving the working body razor along the working surface

The soil moving along the working surface of the razor is affected by its weight force G, the reaction Rn of the undeformed soil located in front of the razor, the normal reaction N and the friction force F of the working surface of the razor. Projecting these forces on the X axis, we have

$$R_4=R_n=N\sin\alpha+F\cos\alpha \qquad (6)$$

From the diagram in Fig. 3

$$N=2N'\cdot\cos\frac{\varepsilon}{2}=G\cdot\cos\alpha\cdot\cos^2\frac{\varepsilon}{2}=G\cdot\cos\alpha\cdot\frac{r_б+\sqrt{r_б^2-0,25B^2}}{2r_б}. \qquad (7)$$

The value of the friction force can be determined by the formula

$$F=Ntg\varphi=G\cos\alpha tg\varphi_1\frac{r_б+\sqrt{r_б^2-0,25B}}{2r_б}. \qquad (8)$$

Substituting the found values of N and F into (6), we obtain

$$R_4=G(\frac{1}{2}\sin 2\alpha+\cos^2\alpha tg\varphi_1)\frac{r_б+\sqrt{r_б^2-0,25B^2}}{2r_б}. \qquad (9)$$

Let us express G through the parameters of the working body and the physical and mechanical properties of the soil.

$$G=2b_n hr_б\rho g(1+\frac{W}{100})\arcsin\frac{0,5B}{r_б}, \qquad (10)$$

where b_n- razor shelf width;
g- is the acceleration of gravity.

Taking into account (3), (4), (5), (9) and (10), expression (2) for determining the resistance of the soil to the movement of the razor of the working body has the following form

$$R_б=\left[2KT_n t_{лб}r_б+b_n h\rho g\left(r_б+\sqrt{r_б^2-0,25B^2}\right)(1+\frac{W}{100})(\frac{1}{2}\sin 2\alpha+\cos^2\alpha tg\varphi)\right]\times$$

$$\times \arcsin\frac{0{,}5B}{r_б} + \left(2r_б \arcsin\frac{0{,}5B}{r_б} + htg\psi_б\right)h\times$$

$$\times\left\{\tau_{np}\left[\sin\frac{1}{2}(\alpha+\varphi_1+\varphi_2)+f\cos\frac{1}{2}(\alpha-\varphi_1-\varphi_2)\cos\alpha\right]\times\right.$$

$$\left.\times\cos^{-1}\frac{1}{2}(\alpha+\varphi_1+\varphi_2)+\rho V_n^2\frac{\sin\alpha\sin(\alpha+\varphi_1)}{\cos\varphi_1}(1+\frac{W}{100})\right\}. \qquad (11)$$

The soil-cutting knife of the working body mainly cuts the soil with the blade and crushes it with the cheeks. Therefore, the resistance of the soil to its movement can be determined by the formula

$$R_н = R_{лн} + R_{щн}, \qquad (12)$$

where $R_{лн}$ - soil resistance caused by cutting it with a knife blade;

$R_{щн}$ - soil resistance due to its crushing by the knife cheeks.

The soil resistance caused by cutting it with a knife blade is determined as above, using the following formula

$$R_{лн} = \frac{KT_n t_{лн} h_н}{\sin\gamma}, \qquad (13)$$

where $t_{лн}$ - knife blade thickness;

$h_н$ - depth of knife stroke.

γ - the angle of installation of the knife to the direction of movement.

The knives have a small thickness and therefore the resistance of the soil to crushing by their cheeks can be considered proportional to the magnitude of the deformation [3]. Taking this into account, the resistance of the soil to the movement of the knife of the working body, due to its crushing by the cheeks of the knife, can be determined by the formula

$$R_{щн} = \frac{1}{4}qt_н^2 h_н(ctg\beta' tg\varphi_1 + 1) \qquad (14)$$

where q – coefficient of volumetric soil compression.

$\beta' = arctg(tg\beta\cdot\sin\gamma);$

t_H- knife thickness

β - design sharpening angle of the knife

Substituting the values of and $R_{лн}$ into (12) we obtain

$$R_H = \left[KT_n t_{лн}\frac{1}{\sin\gamma} + \frac{1}{4}qt_H^2(ctg\beta' tg\varphi_1 + 1)\right]\cdot h_H\cdot \qquad (15)$$

Taking into account (11) and (15), expression (1) for determining the total traction resistance of the working body has the following form

$$R_0 = \left[2KT_n t_{лб} r_б + b_n h\rho(r_б + \sqrt{r_б^2 - 0{,}25B^2})g\left(1+\frac{W}{100}\right)\left(\frac{1}{2}\sin 2\alpha + \cos^2\alpha tg\varphi_1\right)\right]\times$$

$$\times\arcsin\frac{0{,}5B}{r_б} + \left(2r_б\arcsin\frac{0{,}5B}{r_б} + htg\psi_б\right)\cdot h\times$$

$$\times\left\{\tau_{np}\left[\sin\frac{1}{2}(\alpha+\varphi_1+\varphi_2)+f\cos\frac{1}{2}(\alpha-\varphi_1-\varphi_2)\cos\alpha\right]\times\right.$$

$$\times\cos^{-1}\frac{1}{2}(\alpha+\varphi_1+\varphi_2)+\rho V_n^2\frac{\sin\alpha\sin(\alpha+\varphi_1)}{\cos\varphi_1}\left(1+\frac{W}{100}\right)\Bigg\}+$$

$$+n\left[KT_n t_{лн}\frac{1}{\sin\gamma}+\frac{1}{4}qt_H^2(ctg\beta' tg\varphi_1+1)\right]\cdot h_H\ . \qquad (16)$$

From the analysis of this formula it follows that the traction resistance of the working body depends on its parameters ($t_{лб}, t_{лн}, b_n, \alpha, r_б, B, h_H, t_H, \gamma$), physical and mechanical properties of soil ($T_n, \rho, \varphi_1, \varphi_2, W, q$) and the speed of the unit.

Calculations carried out at $t_{лб}$ = 0,001м, $t_{лн}$ = 0,001 м, h =0,05м, b_n =0,08м, α = 10°, $r_б$ = 0,20 м, *B*=0,32м, t_H = 0,005м, h_H = 0,05м, ρ =1300кг/м³, γ =150⁰, q =10⁵Н/м³, β =45°, φ_1 = 30°, φ_2 =40° showed that within the range of movement speeds of 1...2 m/s, the traction resistance of the working element is 674...702 N.

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