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Theoretical Substantiation of the Basic Parameters of a Channel Digger

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ABSTRACT: The main parameters and the shape of the working body of the plow type for cutting temporary sprinklers should be selected taking into account the necessary reasonable dimensions of the cross section of the sprinkler and the minimum possible traction resistance. The process of channel digging consists in cutting and lifting a certain amount (volume) of soil necessary for the formation of a dam with a height that meets agrotechnical requirements, dividing the raised formation into two equal parts while shifting these parts to opposite sides of the channel bore cut.

KEYWORDS: channel digger, sprinkler, furrow-forming bodies, ploughshare, lancet form, working body, traction resistance, layer movement, cross-sectional area, soil density, Cardan's formula.

I. INTRODUCTION.

In the process of research, it turned out that in the well-known works, the parameters of the working bodies of canal diggers were justified without sufficient coordination with the technology of cutting temporary irrigators. In particular, they are justified without taking into account the possibility of reducing the "dead" depth of the irrigation dredging and wedging of the soil in the furrow, which leads to excessive energy consumption of existing channel diggers.

Based on the foregoing, the aim of this work is to reduce water losses in the temporary irrigation zone and the traction resistance of the channel digger by improving its design and parameters.

Taking into account the necessary parameters of the sprinkler, rational parameters of the working body of the channel digger — the height of the body, the angles of the ploughshare and the blade wing to the direction of movement and to the bottom of the furrow, the radius of the guide curve and the law of change of the angles of the deflecting dump surface have been proved.

II. MATERIALS AND METHODS.

When designing the working bodies of plow channel diggers, various methods are used. The most commonly used method is developed by M.E.Matsepuro and R.D. Turetsky.

The working body must raise the soil layer without a turn to a certain height, so that with a further rise the formation turns without jamming between the working body and the slopes of the channel. Therefore, the lower part of the working body is proposed to perform in the form of a flat two-sided wedge (ploughshare). The lancet view of the ploughshare is unsuitable, since it causes additional compression of the formation by the working body and the slope of the channel.

III. RESULTS AND DISCUSSIONS.

The quality of the process of cutting the sprinkler depends on the parameters of the working bodies, which the channel digger (Fig. 1), by analogy with the furrow-forming bodies, are:

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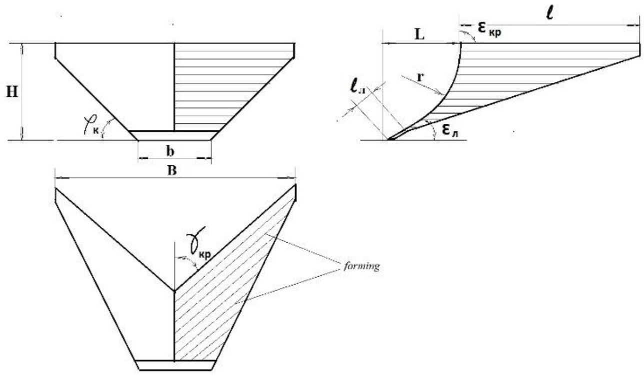

Fig. 1. The main parameters of the working body of the channel digger

as **H -** body height;

r – radius of the guide curve;

B – scope of wings;

Ɛ. - ploughshare installation angle to the bottom of the furrow;

γ. – ploughshare installation angle to the direction of movement;

кр – blade installation angle to the bottom of the furrow;

$\gamma_{кр}$ – blade wing installation angle to the direction of movement**;**

φК – tilt angle to the bottom edge of the blade;

L – guide curve overhang;

L – wing length;

b. – ploughshare width;

l. – ploughshare length;

Justification of the required height of the formation (layer)

The required height of the formation (excluding deformation) is determined from the condition of unobstructed rotation of the layer on the edge of the channel, which is possible (Fig. 2), if

$$AC' \leq AB \quad (1)$$

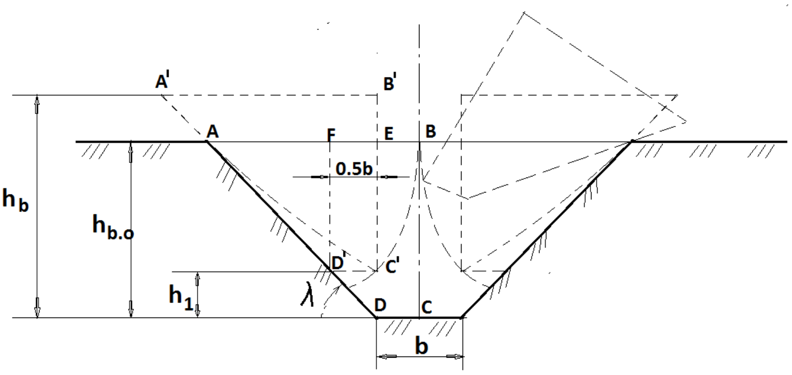

Fig. 2. *Scheme for determining the required height of the lower flat part of the working body*

since in this case, the ABCD layer, raised to the position A[I], B[I], C[I], D[I] to a height h_1 will not be in contact with the layer wrapped on the opposite edge when turning on the edge.

Figure 2 shows that

$$AB = 0{,}5b + h_{b.o}\ \text{ctg}\,\lambda \quad 2)$$

as: b – bottom channel width, m;

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$h_{b.o}$- channel depth into recesses, m;

Figure 2 shows that

$$AC' = \sqrt{(AE)^2 + EC'^2} = \sqrt{(AF + FE)^2 + (B'C' - B'E)^2} =$$

$$= \sqrt{(h_{b.o} - h_1)\,\mathrm{ctg}\,\lambda + 0{,}5b^2 + (h_{b.o} - h_1)^2} \quad (3)$$

Substituting in the equation (1) the values of AC´ and AB from equations (2) and (3), we obtain

$$h_1^2(1+\mathrm{ctg}^2\lambda) - h_1(2h_{b.o}\mathrm{ctg}^2\lambda + b\,\mathrm{ctg}\,\lambda + 2h_{b.o}) + h_{b.o}^2 \geq 0$$

a solution of which gives:

$$h_1 \geq \frac{2h_{b.o}\mathrm{ctg}^2\lambda + b\,\mathrm{ctg}\,\lambda + 2h_{b.o} \pm \sqrt{(2h_{b.o}\mathrm{ctg}^2\lambda + b\,\mathrm{ctg}\,\lambda + 2h_{b.o})^2 - 4h_{b.o}^2(1+\mathrm{ctg}^2\lambda)}}{2(1+\mathrm{ctg}^2\lambda)} \quad (4)$$

Since the smallest possible lift height h_1 is required, inequality with a minus sign is accepted for calculation.

Calculations by formula (4) allowed us to determine the following rational value h_1 :

$h_{b.o}$= 0,15...0,18 м, λ= 45^0 и b= 0,4 м h_1= 0,04...0,06м.

Justification of the angle of installation of the ploughshare to the bottom of the furrow

As already noted in the first chapter, the lower part of the digging body-share should be made in the form of a flat straight ploughshare ($\gamma_л$=90^0).

Studies by a number of authors have shown that for each type of soil, depending on the depth of processing, there is such an optimal value of the angle of the ploughshare installation to the bottom of the furrow, at which the traction resistance of the ploughshare is of the least value.

In the general case, the ploughshare resistance can be represented as:

$$R = R_1 + R_2 + R_3 + R_4, \quad (5)$$

as: R_1 – soil resistance to ploughshare blade penetration;
R_2 – effort, spent on layer deformation;
R_3 – effort, spent on layer movement along ploughshare;
R_4 – effort, spent on lifting layer.

We consider the scheme (Fig. 3) of the layer movement along a flat ploughshare without taking into account.

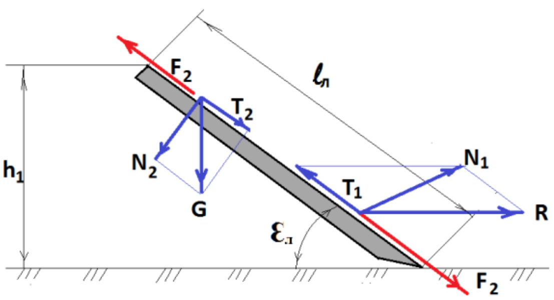

Fig. 3. Scheme of force, acting on a layer of soil and ploughshare

soil resistance to the penetration of the ploughshare blade $\mathbf{R_1}$, formation deformation resistance $\mathbf{R_2}$ and resistance to moving the formation along the ploughshare $\mathbf{R_3}$.

From the ploughshare side in the cutting zone, the normal force $\mathbf{N_1}$ acts on the formation, which can be decomposed into longitudinal **R** and tangent (along the ploughshare) $\mathbf{T_1}$ components. When moving the soil formation

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over the ploughshare, friction force $\mathbf{F_1}$ also appears, which prevents the movement of the layer. The value of the force capable of moving the soil along the share is equal to:

$$P_1 = T_1 - F_1 \qquad (6)$$

It can be seen from Fig. 3 that $R=N_1/\sin$, $T_1= N_1$ ctg и $F_1= N_1$ tg φ. Substituting the values of T_1 и F_1, we obtain:

$$P_1 = R_1 \sin(1- \mathrm{tg}\,\mathrm{tg}\,\varphi)/\mathrm{tg}, \qquad (7)$$

as $\boldsymbol{\varphi}$- soil friction angle for metal.

With the steady motion of the soil through the share, the force $\mathbf{P_1}$ is balanced by the tangent component of the formation weight $\mathbf{T_2}$ and the friction force from the normal component of the weight $\mathbf{N_2}$, i.e.

$$P_1= T_2 +F_2 \qquad (8)$$

Fig. 3 shows that T_2= G sin и F_2= G tg φcos Substituting these values in (8) we obtain:

$$P_1 = G(\sin + \mathrm{tg}\,\varphi\cos), \qquad (9)$$

as **G –** weight of the soil layer on the ploughshare.

The weight of the layer on the ploughshare, can be taken equal:

$$G = F l \gamma_{п} К_{cr} g \qquad (10)$$

or

$$G = F h_1 \gamma_{п} К_{cr} g/\sin , \qquad (11)$$

as $\boldsymbol{F}$ - formation cross-sectional area;

$\boldsymbol{l}$ - ploughshare length;

$\boldsymbol{\gamma_{п}}$ - soil density;

g - acceleration free fall;

$К_{cr}$- loading factor;

$\boldsymbol{h_1}$ – height for lifting layer of soil.

Substituting (10) into (9) we obtain:

$$P_1=F h_1 \gamma_{п} К_{cr} g(\sin + \mathrm{tg}\,\varphi\cos)/\sin \qquad (12)$$

from equality (7) and (9) it follows that:

$$R \sin (1- \mathrm{tg}\,\mathrm{tg}\,\varphi)/\mathrm{tg} =F h_1 \gamma_{п} К_{cr} g(\sin + \mathrm{tg}\,\varphi\cos) / \sin \qquad (13)$$

The decision on R gives the following dependence:

$$R=F h_1 \gamma_{п} К_{cr} g\, \mathrm{tg}\,(+ \varphi)/\sin . \qquad (14)$$

Formation cross-sectional area for our case can be expressed as follows:

$$F=h_{b.o}(b + h_{b.o}\,\mathrm{ctg}\,\lambda)$$

Substituting this expression in (14) we obtain:

$$R=h_{b.o}(b + h_{b.o}\,\mathrm{ctg}\,\lambda)\, h_1 \gamma_{п} К_{cr} g\, \mathrm{tg}\,(+ \varphi)/\sin . \qquad (15)$$

Since the profile of the temporary sprinkler is selected and does not change, and the elevation height remains constant, (2.39) quite realistically reflects the change in traction resistance depending on the angle of ploughshare installation to the bottom of the furrow. Fig. 2.9 shows graphs of this function for various values of the coefficient of friction of soil against steel.

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To determine the extreme value of the angle of the ploughshare to the bottom of the furrow, we determine the first derivative of the function:

$$f(\ )=\mathbf{tg}\,(\ +\varphi)\,/\,\mathbf{sin} \qquad (16)$$

and then it is equated to zero

$$f'(\ )=\ \mathbf{sin}\,/\,\mathbf{cos}^2(\ +\varphi)-\mathbf{cos}\ \mathbf{tg}\,(\ +\varphi)\,/\,\mathbf{sin}^2\ =0 \qquad (17)$$

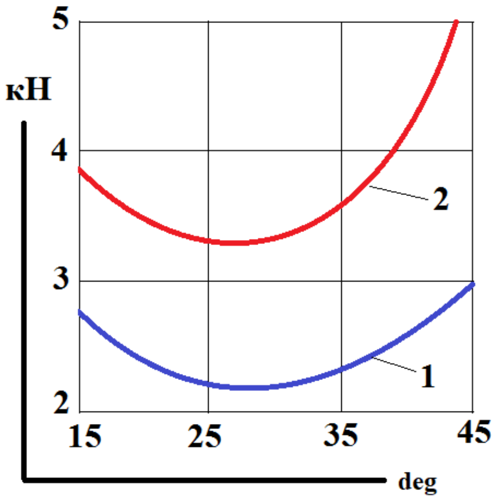

Fig. 4. The dependence of the component of traction resistance on the angle of installation of the share to the bottom of the furrow at: I- φ=20^0; II- φ=30^0;

After transforming equation (17), we obtain:

$$\mathrm{tg}^3\ \mathrm{tg}^2\ \varphi+\mathrm{tg}^3\ \mathrm{tg}\ \varphi\,\mathrm{tg}^2\ +2\mathrm{tg}^2\ -\ \mathrm{tg}\ \varphi=0 \qquad (18)$$

Denoting x= tg , y= $\mathrm{tg}\ \varphi$ has

$$ax^3+bx^2+cx+d=0 \qquad (19)$$

as a= y^2+1, b= y, c=$2y^2$, d=$-$y.

Equation of the third degree (19) has one real solution for the discriminant D= $q^2+p^3>0$

as $q=\frac{b^3}{27a^3}-\frac{bc}{6a^2}+\frac{d}{2a}$; $p=\frac{3ac-b^2}{9a^2}$

A solution to an equation of the third degree can be obtained by reducing equation (2.43) to the form:

$$x^3+3px+2q=0 \qquad (20)$$

as x= z+$\frac{b}{3a}$ and using the Cardan's formula we find the real root of the equation:

$$z=\sqrt[3]{-q+\sqrt{q^2+p^3}}+\sqrt[3]{-q-\sqrt{q^2+p^3}}$$

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Not taking into account the term $\frac{b^3}{27a^3}$ due to its small value, it is possible to determine the quantities; it is possible to determine the quantities p and q by the formulas:

$$q = -\frac{y(5y^2+3)}{6(y^2+1)^2}; \qquad p = \frac{y^2(6y^2+5)}{9(y^2+1)^2}$$

The value of **z** determines the optimal value of the angle of installation of the ploughshare to the bottom of the furrow , which determines the minimum amount of traction:

$$= \text{arctg} \qquad z - \frac{y}{3(y^2+1)} \tag{21}$$

By the formula (21), the values of the angle are calculated. At various angles φ of friction of the soil along the share, the optimal value of the angle of installation of the share to the bottom of the furrow lies within 25…31°.

IV. FINDINGS.

Since the smallest possible lift height h_1 is required, inequality with a minus sign is accepted for calculation.

Calculations by formula (4) allowed us to determine the following rational value h_1 :

$h_{b.o}$= 0,15...0,18 м, λ= 45^0 и b= 0,4 м h_1= 0,04...0,06м.

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