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THEORETICAL PREREQUISITES FOR DETERMINING THE RATIONAL PARAMETERS OF THE CHANNEL DIGGER

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Abstract. Well-known studies on the justification of the parameters of the channel digger were mainly aimed at reducing energy consumption and improving the quality of the formation of temporary irrigation dams. The analysis of well-known works implies the need for theoretical research: substantiation of the basic geometric dimensions of the temporary sprinkler; dependence of the quality of the technological process of cutting the temporary sprinkler on the main parameters of the channel digger. Theoretical prerequisites for determining the rational parameters of the channel digger the shape and geometric dimensions of temporary sprinklers (the width of the bottom of the excavation, the height of the dam, the width of the base of the dam) are substantiated, analytical dependencies for determining the parameters of the channel digger are proposed. Analytical dependences are derived to determine the width of the bottom of the excavation, the width of the base and height of the dam, the width of the occupied strip of the temporary sprinkler, the angle of the ploughshare to the bottom of the furrow, the height of the body, the length of the ploughshare, and other parameters of the working body of the channel digger.

Keywords: *temporary sprinklers, height of the dam, channel digger, width along the bottom, depth of excavation, water flow, width of the dam base, upper edge of the dump, cross-section, height of the reservoir rise, slope angle, angle of installation of the ploughshare, height of the hull.*

Introduction. Currently, the furrow method of irrigation of agricultural plants is mainly used, in which several thousand kilometers of temporary irrigation networks and outlet furrows are cut annually during the growing season of agricultural crops. At the same time, to ensure the necessary command water level, temporary sprinklers are cut in such a way that the bottom of their recess is located below the bottom of the recess of irrigation furrows. This difference in the levels of recesses is usually called "dead" depth because after the termination of irrigation, a certain volume of water remains in the temporary sprinkler, which does not enter the irrigation furrows, is not used by plants and is a net loss. In addition, in this case, after the levelling of the temporary sprinkler in the area of its excavation, increased humidity persists for a long time. This negatively affects the quality of the formation of dams during the re-cutting of temporary sprinklers, which, due to poor crumbling of the soil, are not sufficiently waterproof.

Based on the above, the purpose of this work is to reduce water losses in the temporary sprinkler zone by improving the design of the channel digger and its parameters.

The choice of technical means depends mainly on the purpose of the sprinkler. For cutting temporary sprinklers placed in the sowing zone, the most compact channel digger is selected in an aggregate with a highly maneuverable wheeled tractor [1,2.3,4].

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2024-6.875 ResearchBib IF: 8.848 / 2024
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Materials and methods. It is known that the capacity of temporary sprinklers depends primarily on the area of their cross-section, although its shape is also of great importance. Since the fields where temporary sprinklers are cut have slopes with significant fluctuations, the transverse profile of the sprinkler should be such that it can pass the required amount of water in areas with small and large slopes.

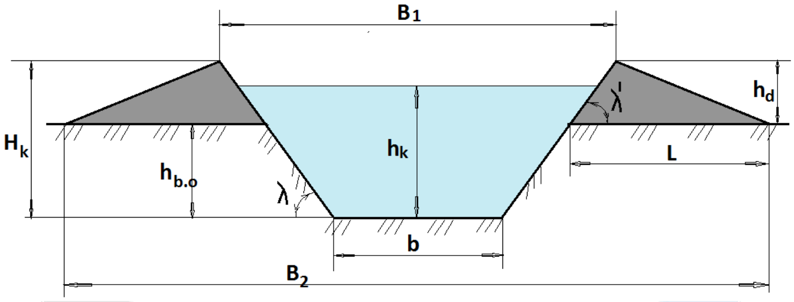

Figure 1. The main parameters of the temporary sprinkler

The main parameters of the temporary sprinkler (Fig.1) are: $\mathbf{h}_{b.o}$ is the depth of the excavation; $\mathbf{h}_\partial$ is the height of the dam; **B** is the width along the bottom.

The water consumption of a temporary sprinkler mainly depends on its width along the bottom, the depth of the excavation and the height of the dam. When watering, to ensure the necessary ($\boldsymbol{Q}$ = 40 ... 70 l/s) water flow, we determine the main parameters of the temporary sprinkler.

According to the purpose of the research and based on the analysis of the state of the issue, the following tasks were set:

- analytical study of the shape and basic dimensions of a water-saving temporary sprinkler.

- theoretically investigate the interaction of the working organ of the channel digger with the soil, depending on the size of the temporary sprinkler and its main parameters.

Results and discussions.

Temporary sprinkler bottom width. As noted above with $\mathbf{h}_{b.o} > \mathbf{h}_{b.b}$ in temporary sprinklers, a "dead" depth $\triangle \boldsymbol{h}$ is formed , determined by the formula:

$$\triangle h = \mathbf{h}_{b.o} - \mathbf{h}_{b.b} \qquad (1)$$

where $\mathbf{h}_{b.b}$ - depth of irrigation furrow excavation.

To exclude the formation of a "dead" depth, the depth of the excavation of the temporary sprinkler should be equal to or less than the depth of the excavation of the irrigation furrows, i.e. $\mathbf{h}_{b.o} \leq \mathbf{h}_{b.b}$. However, on the other hand, the temporary sprinkler must pass the required amount of water.

It is known that the flow rate of water that a temporary sprinkler must pass is determined by the expression.

$\boldsymbol{Q}$ = $\boldsymbol{\omega}$ with $\sqrt{Ri}$,

where $\boldsymbol{Q}$ is the water flow rate in the sprinkler (the volume of liquid flowing through the cross section of the flow per unit time), l/s;

$\boldsymbol{\omega}$ is the area of the " living " section of the sprinkler;

C is the Chezy coefficient (speed coefficient);

ISSN: 2582-4686 SJIF 2021-3.261,SJIF 2022-2.889, 2024-6.875 ResearchBib IF: 8.848 / 2024

R —hydraulic radius, m;

i - the slope of the bottom of the temporary sprinkler.

The hydraulic radius can be determined by the formula of S.A. Girshkan

$$R=O,45\, Q^{0.4} \qquad (2)$$

The flow rate ( ) of water for a temporary sprinkler is 40…70 /l/s /11/, then R= 0.12...0.16 m.

The value of the coefficient **C** at R = 0,12...0,16 m is equal to C = 18,4...19,96.

From Fig.1 with $\lambda = \lambda'$, and given that $h_H = h_{B.o} + h_K$ (where h_K is the command water level), we find:

$\omega = [b + (h_{b.o} + h_k)\,\mathrm{ctg}\,\lambda](h_{b.o} + h_k)$ (2.1)

Taking into account 2.2 and 2.3, formula (2.4) has the following form:

$Q = [b + (h_{b.o} + h_k)\,\mathrm{ctg}\,\lambda](h_{b.o} + h_k)$ with $\sqrt{0{,}45Q^{0{,}4} i}$

From the analysis of this expression it follows that with decreasing $h_{b.o}$ the required water flow, which the temporary sprinkler must pass, can mainly be achieved by increasing the width of the sprinkler along the bottom (2,4,5).

Solving 2.5 with respect to (**b**) we get

$$b = \frac{Q-(h_{b.o}+h_k)^2 c\sqrt{0{,}45Q^{0{,}4} i}\ \mathrm{ctg}\,\lambda}{(h_{b.o}+h_k)\ c\sqrt{0{,}45Q^{0{,}4} i}} \qquad (3)$$

Based on 3, a graph of dependence **b =f (** $h_{b.o}$**) was constructed** (Fig.2).

From the graph (Fig.2) it can be seen that in order to provide the necessary (Q = 40...70 l/s) water flow, the width of the bottom of the excavation at $h_{b.o}$ **= 0.15 m should be** b**= 0.4 ... 0.5 m, and when** $h_{b.o}$ **= 0.18 m -** b**= 0.3 ... 0.4 m** (curves 1 and 2). An increase in the excavation depth of more than 0.18 m will lead to the formation of a “deep” depth. Thus, the width of the bottom of the excavation at $h_{b.o}$= 0.15 ... 0.18 m is equal to b = 0.3 ... 0.5 m, and the average value b_{CP}= 0.4 m.

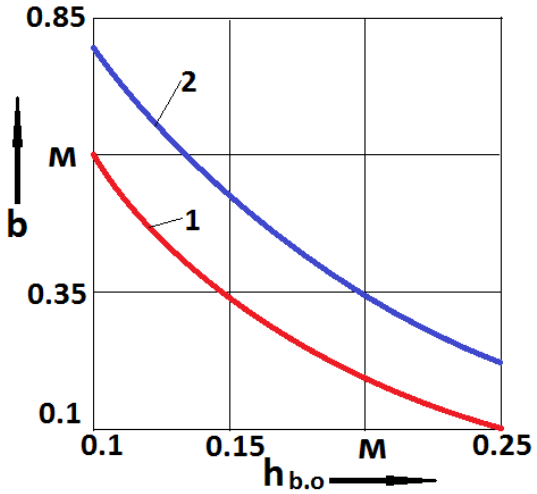

Figure 2. *Dependence graph* ***b =f (*** $h_{b.o}$***)*** *1-at* Q *= 40 l/s; 2-at* Q *= 70l/s.*

Dam Height Determination. It is known /11,16,17/ that the command water level h_K (see Fig.2) in temporary sprinklers for irrigation should be 0.05 ... 0.15 m above the irrigated cutting surface. h_2 (Fig.3) above the command level of the temporary sprinkler should be at least 0.10. Based on this requirement, the height of the dam should be at least 0.2 m / 1.2

ISSN: 2582-4686 SJIF 2021-3.261,SJIF 2022-2.889, 2024-6.875 ResearchBib IF: 8.848 / 2024

Assuming that the excavated soil is distributed equally on both sides of the channel, i.e. **S1 = S2** _ _ write the equation:

$$S = (S_1 + S_2) / K_R \qquad (4)$$

where **S** is the cross-sectional area of the excavation of the temporary sprinkler;

S_1, S_2 - cross-sectional areas of the right and left irrigation dams;

K_P = 1.1 ... 1.3-coefficient of soil loosening.

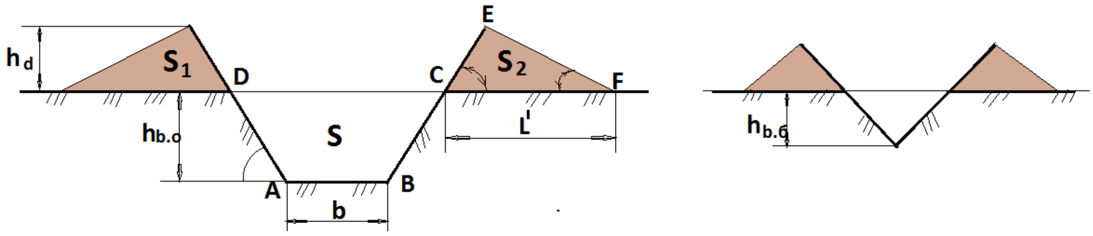

Figure 3. *Scheme for determining the profile and dimensions of a temporary sprinkler*

Fig.3 shows that

$$S = (b + h_{b.o} \operatorname{ctg} \lambda)\, h_{b.o} \qquad (5)$$

from △ CE F

$$S2 = \frac{h_\partial^2}{2} (\operatorname{ctg}\lambda' + \operatorname{ctg}б) \; (2.9)$$

Taking into account (4) and (5), from (6) we have:

$$\mathbf{h}_\partial = \sqrt{\frac{(b+h_{b.o} \operatorname{ctg} \lambda)\, h_{b.o} K_P}{\operatorname{ctg}\lambda' + \operatorname{ctg}б}} \qquad (6)$$

where **δ**= 35 ^{0} ...43 ^{0} is the slope angle of the outer plane of the dam (the angle of natural soil shedding).

From the analysis of formula (6) it follows that the height of the dam depends on the size of the cross section of the excavation, the coefficient of soil loosening (**K_R**) and the angle of the inner (**λ′**) and outer (**δ**) slopes of the dam.

Calculations using formula (6) showed that for $\boldsymbol{h_{b.o}}$ = 0.15...0.18 m, $\boldsymbol{b}$= 0.40m, $\boldsymbol{\lambda}$= $\boldsymbol{\lambda'}$ **= 45** ^{0} , **δ_{CP}** = 39 ^{0} , **Kp** = 1.2 dam height **h_∂** = 0.20...0.23 **m** , i.e. the selected dimensions of the cross-section of the irrigator provide the required height of the dam.

Determining the width of the dam base and the width strip occupied by the sprinkler. The width **L′ of** the base of the dam is one of the important parameters of the temporary irrigation system because it significantly affects the height of the dam and the width of the occupied irrigation strip. It depends on the angle ($\boldsymbol{\gamma_{kr}}$) of the dump wing to the direction of movement and the translational speed ($V_п$) of the channel digger, and it is also affected by the angle ($\boldsymbol{\lambda}$) of the slope and the angle ($\boldsymbol{\lambda'}$) of the inner slope of the dam.

When the channel digger moves, the soil layer is lifted by a plowshare, and then by a dump to the day surface of the field and is dumped from its wings to the side at a certain speed.

The movement of the soil after leaving the dump can be considered as a free flight with an initial *speed* Va

the value V_a can be determined by the well-known formula:

$$V_a = V_p \cos\frac{\gamma_{кр}}{2} \sqrt{2(1 - \cos\gamma_{кр})}, \qquad (7)$$

where $\boldsymbol{V_p}$ - translational speed of the ditcher;

$\boldsymbol{\gamma_{кр}}$- the angle of installation of the blade wing to the direction of movement.

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VOLUME-4, ISSUE-12

We consider that the center of mass (Fig. 4) of the cross section of the reservoir at the moment of leaving the dump is at the cutting heighth_o from the surface of the field, i.e. at the point **M₀** We refer the free movement of the point **M₀** to the fixed coordinate system **y o z** with the origin at the point **O.**

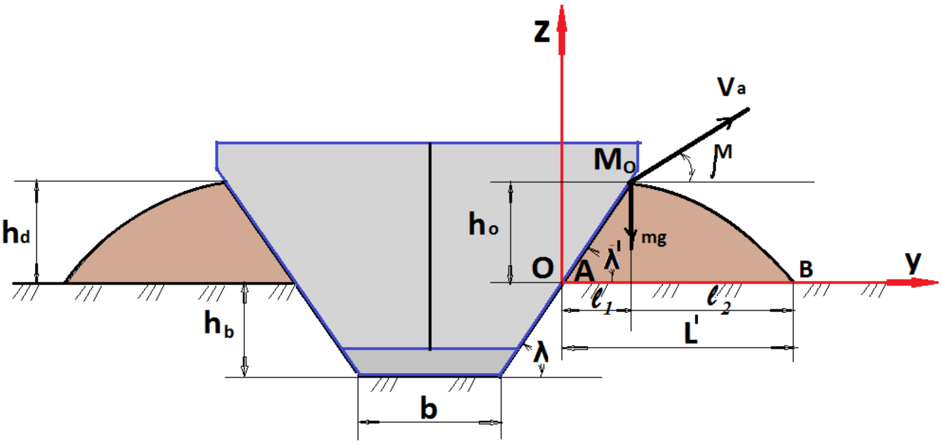

Figure 4. *Scheme for determining the width dam foundations*

Figure 4 shows that

$L' = \ell_1 + \ell_2$ (2.12)

$\ell 1 = h_o \, ctg\lambda'$ (8)

To determine the range l_2 ejection of soil particles, we compose a differential equation of motion of the center of mass (point M_o) of the cross section of the reservoir in the coordinate system **y o z** in the form:

$m\ddot{y} = O, \quad m\dot{z} = -mg$ (9)

Integrating (2.14) twice, taking into account the initial conditions (for t = o, $\dot{y} = V_a \cos\mu$, $z = V_a \sin\mu$, $y = \ell_1$, $z = h_o$, where μ **is** the slope of the vector V_a to the horizon), we get:

$y = \ell_1 + V_a t \cos\mu$ (10)

$z = h_o - gt^2/2 + V_a t \sin\mu$ (11)

From here we find the equation of motion of the point M_o

$z = h_o - g(y - \ell_1)^2/(2V_a^2 \cos^2\mu) + (y - \ell_1)\,tg\mu$ (12)

When $y = \ell_1 + \ell_2$, $z = o$ or

$h_o - g\,\ell_2^2/(2V_a^2 \cos^2\mu) - \ell_2\,tg\mu = o$ (13)

Solving this equation for ℓ_2, we get:

$\ell 2 = \{V_a^2 \cos^2\mu [tg\mu + \sqrt{tg^2\mu + 2gh_o/(V_a^2\cos^2\mu)}]\} / g$ (14)

Substituting the value ℓ_1 and ℓ_2 into equality (13), taking into account (14), we obtain the following expression:

$$L' = h_o\, ctg\lambda' + \frac{2}{g} V_п^2 \left(tg\mu + \sqrt{tg^2\mu + \frac{2gh_o}{V_п^2 \cos^2\frac{\gamma_{кр}}{2}(1-\cos\gamma_{кр})\cos^2\mu}}\right) \times$$

$$\times \cos^2\frac{\gamma_{кр}}{2}(1-\cos\gamma_{кр})\cos^2\mu \quad (15)$$

From the analysis of formula 15 it follows that the width of the base of the dam depends on the speed of movement of the unit and the angle of installation of the blade wing to the direction of movement. In addition, the width of the dam base is influenced by the angle of the internal slope of the dam, the height and angle of the descent of soil particles and the acceleration of their free fall. With an increase in these parameters, the width of the dam base increases and vice versa.

The width (B_2) of the strip occupied by the sprinkler can be determined from the following dependence (see Fig. 4)

$$B_2 = 2(h_{b.o}\,\mathrm{ctg}\,\lambda + L') + b \qquad (16)$$

or taking into account (2.20), we get:

$$B_2 = 2\left[h_{b.o}\,\mathrm{ctg}\,\lambda + h_o \mathrm{ctg}\lambda' + \frac{2}{g}V_п^2\left(\mathrm{tg}\mu + \sqrt{\mathrm{tg}^2\mu + \frac{2gh_o}{V_п^2\cos^2\frac{\gamma_{кр}}{2}(1-\cos\gamma_{кр})\cos^2\mu}}\right)\times\right.$$
$$\left.\times\cos^2\frac{\gamma_{кр}}{2}(1-\cos\gamma_{кр})\cos^2\mu\right] + b \qquad (17)$$

Based on (17) in Fig.5, a graph of the dependence **of B_2** on **V_p** And **$\gamma_{кр}$.**

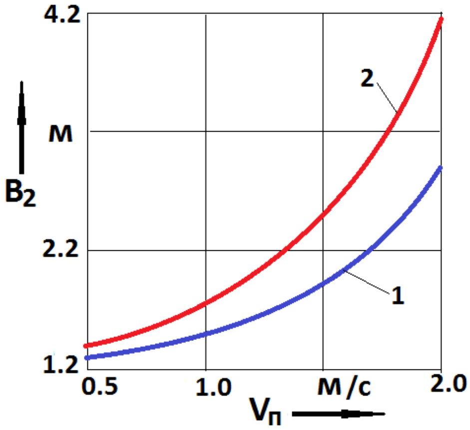

Figure 5. *The dependence of the value of* ***B_2*** *on* ***V_p*****:** *1-at* ***$\gamma_{кр}$****. = 30°; 2-at* ***$\gamma_{кр}$****. 40°*

It can be seen from the graphs that with an increase in the speed of movement and the angle of installation of the wings of the canal digger blade to the direction of movement, the width of the occupied strip increases. However, according to the initial requirements, the width of the strip occupied by the sprinkler should be no more than 2.2 m.

From the graph in Fig.5 it can be seen that this is possible with **V_p** = 1.3 ... 1.63 m / s.

The remaining cross-sectional dimensions of the temporary sprinkler, also necessary to justify the parameters of the working body, can be determined by calculation.

The total (construction) depth **$H_к$** can be determined from the following dependence

$$H_к = h_{b.o} + h_д\,, \qquad (18)$$

Where $h_{b.o} = h_{b.б}$= 0.15...0.18, and according to clause 2.1.2 $h_д$ = 0.2...0.23 m;

Thus, according to (2.23) $H_к$= 0,35...0,41 m.

With B_1 along the top of the dam (see figure 2.1)

$$B_1 = b + 2(h_{b.o}\,\mathrm{ctg}\,\lambda + h_д\,\mathrm{ctg}\lambda') \quad (19)$$

at $\boldsymbol{\lambda} = \boldsymbol{\lambda}'$= 45°, and from clause 2.1.1 ***b***= 0.3 ... 0.5 m.

Taking averages ***b*** and **$h_д$** we get: **B_1** = 1.2 m.

The main parameters and shape of the plow-type working body for cutting temporary sprinklers should be selected considering obtaining the necessary reasonable cross-sectional dimensions of the sprinkler and the minimum possible traction resistance.

ISSN: 2582-4686 SJIF 2021-3.261,SJIF 2022-2.889, 2024-6.875 ResearchBib IF: 8.848 / 2024

The process of operation of a canal digger consists in cutting and lifting a certain amount (volume) of soil necessary to form a dam with a height that meets agrotechnical requirements, dividing the raised layer into two equal parts while simultaneously shifting these parts to opposite sides of the cut to the edge of the channel relative to each other.

Justification of the required reservoir lift height. The working body must raise the soil layer without rotation to a certain height, so that with further lifting, the layer turns without wedging between the working body and the slopes of the channel. Therefore, the bottom part of the working body is proposed to be made in the form of a flat dihedral wedge (ploughshare). The lancet type of the plowshare is unsuitable, as it causes additional compression of the formation by the working body and the slope of the channel.

The required formation lift height (excluding deformation) is determined from the condition of unhindered formation rotation on the crest of the channel, which is possible (Fig.6) if

AC ′ ≤ AB (20)

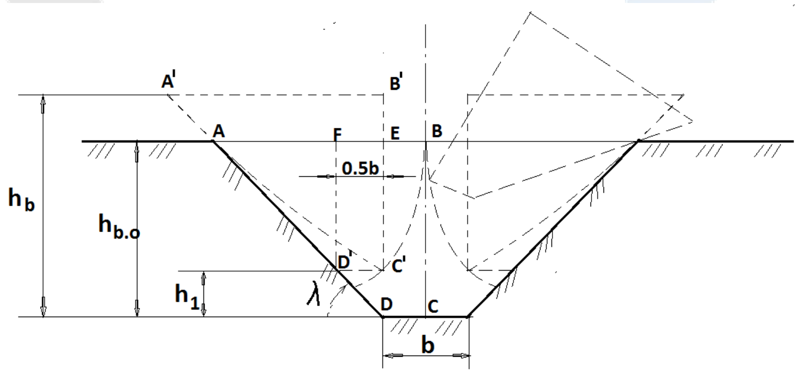

Figure 6. *Scheme for determining the required height of the lower flat part of the working body*

since in this case the ABSD layer, raised to the position A I, B I, C I, D I to a height of h_1, will not be in contact with the layer being turned on the opposite edge when turning on the edge.

Figure 6 shows that

AB = 0,5b+$h_{b.o}$ ctg λ

where: b- channel width along the bottom, m;

$h_{b.o}$- channel depth in excavations, m;

From Figure 6 it can be seen that

$$AC' = \sqrt{(AE)^2 + EC'^2} = \sqrt{(AF + FE)^2 + (B'C' - B'E)^2} =$$
$$= \sqrt{[(h_{b.o} - h_1)\,\mathrm{ctg}\,\lambda + 0{,}5b]^2 + (h_{b.o} - h_1)^2} \quad (21)$$

Substituting into equation (20) the values **AC** ′ and AB from equations (21) and (22), we obtain

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

whose solution will give:

$$h_1 \geq \frac{2h_{b.o}\mathrm{ctg}^2\lambda + \mathrm{b\,ctg}\,\lambda + 2h_{b.o} \pm \sqrt{(2h_{b.o}\mathrm{ctg}^2\lambda + \mathrm{b\,ctg}\,\lambda + 2h_{b.o})^2 - 4h_{b.o}^2(1+\mathrm{ctg}^2\lambda)}}{2(1+\mathrm{ctg}^2\lambda)} \quad (23)$$

Since the smallest possible height is neededh_1 rise of the reservoir, for the calculation take the inequality with a minus sign.

Calculations using formula (23) made it possible to determine the following rational value h_1:

At $h_{b.o}$= 0.15 ... 0.18 m, λ= 45 ^{0} and b= 0.4 m h_1= 0.04 ... 0.06 m.

Justification of the angle of installation of the plowshare to the bottom of the furrow. As already noted in the first chapter, the lower part of the digging share should be made in the form of a flat straight share ($\gamma_{л}$ =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 for the angle of $\varepsilon_{л}$installation of the plowshare to the bottom of the furrow, at which the traction resistance of the plowshare has the smallest value.

In the general case, the resistance of the plowshare can be represented as:

$R = R_1 + R_2 + R_3 + R_4$,

where:

R_1 is the resistance of the soil to the penetration of the plowshare blade;

R_2 is the force expended on the formation deformation;

R_3 - the force expended on moving the layer along the plowshare;

R_4 - the effort expended on the rise of the reservoir.

Consider the scheme (Fig.7) of the movement of the reservoir along a flat share excluding

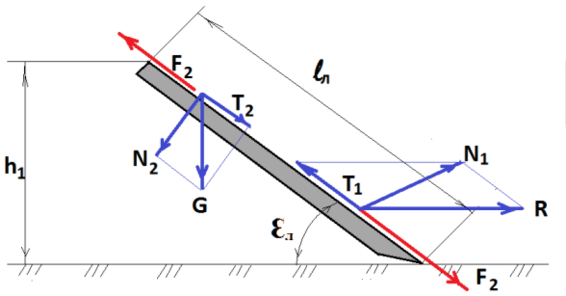

Figure 7. *Scheme of forces acting on the soil layer and the plowshare*

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

$\mathbf{N_1}$ acts on the layer**,** which can be decomposed into a longitudinal **R** and tangent (along the share) $\mathbf{T_1}$ components. When moving the soil layer along the plowshare, a friction force $\mathbf{F_1}$ also appears, which prevents the formation from moving. The magnitude of the force capable of moving the soil along the plowshare is:

$P_1 = T_1 - F_1$ (24)

From Fig.7 it can be seen that $R = N_1 / \sin \varepsilon_{л}$, $T_1 = N_1\,\mathrm{ctg}\varepsilon_{л}$ and $F_1 = N_1\,\mathrm{tg}\,\varphi$. Substituting the values of T_1 and F_1, we get

$P_1 = R_1 \sin \varepsilon_{л}(1 - \mathrm{tg}\varepsilon_{л}\mathrm{tg}\,\varphi) / \mathrm{tg}\varepsilon_{л}$, (25)

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THE MULTIDISCIPLINARY JOURNAL OF SCIENCE AND TECHNOLOGY

VOLUME-4, ISSUE-12

Where **φ-** the angle of friction of the soil on the metal.

With the steady movement of the soil along the plowshare, the force **P $_1$** is balanced by the tangential component of the weight of the reservoir **T $_2$** and the friction force from the normal component of the weight **N $_2$**, i.e.

$P_1 = T_2 + F_2$ (26)

From Fig. 2.8 it can be seen that $T_2 = G \sin Ɛ_л$ and $F_2 = G \,\mathrm{tg}\, \varphi \cos Ɛ_л$ Substituting these values into (26) we get:

$P_1 = G(\sin Ɛ_л + \mathrm{tg}\, \varphi \cos Ɛ_л)$, (27)

Where **G** is the weight of the soil layer on the share.

The weight of the layer on the plowshare can be taken equal to:

$G = F l_л \gamma_п К_{cr} g$ (28)

or

$G = F h_1 \gamma_п К_{cr} g / \sin Ɛ_л$, (29)

where ***F*is** the cross-sectional area of the formation;

$l_л$ - plowshare length;

$\gamma_п$- soil density;

g - free fall acceleration;

$К_{cr}$- loading factor;

h_1 **is** the height of the soil layer.

Substituting (28) into (29) we get:

$P_1 = F h_1 \gamma_п К_{cr} g(\sin Ɛ_л + \mathrm{tg}\, \varphi \cos Ɛ_л) / \sin Ɛ_л$ (30)

from equality (2.31) and (2.33) it follows that

$R \sin Ɛ_л (1 - \mathrm{tg} Ɛ_л \,\mathrm{tg}\, \varphi) / \mathrm{tg} Ɛ_л = F h_1 \gamma_п К_{cr} g(\sin Ɛ_л + \mathrm{tg}\, \varphi \cos Ɛ_л) / \sin Ɛ_л$ (31)

Solution for **R** gives the following relationship:

$R = F h_1 \gamma_п К_{cr} g \,\mathrm{tg}\, (Ɛ_л + \varphi) / \sin Ɛ_л$. (32)

The cross-sectional area of the reservoir for our case can be expressed in terms of in the following form:

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

Substituting this expression into (2.38) we get:

$R = h_{b.o}(b + h_{b.o} \,\mathrm{ctg}\, \lambda)\; h_1 \gamma_п К_{cr} g \,\mathrm{tg}\, (Ɛ_л + \varphi) / \sin Ɛ_л$. (33)

Since the profile of the temporary sprinkler is selected and does not change, and the lifting height remains constant, then (33) quite realistically reflects the change in traction resistance depending on the angle of installation of the plowshare to the bottom of the furrow. Figure 8 shows graphs of this function for various values of the coefficient of friction between soil and steel.

To determine the extreme value of the angle $Ɛ_л$ of installation of the plowshare to the bottom of the furrow, we determine the first derivative of the function:

$f(Ɛ_л) = \mathbf{tg}\, (Ɛ_л + \boldsymbol{\varphi}) / \mathbf{sin} Ɛ_л$ (34)

and equate it to zero

$f'(Ɛ_л) = [\mathbf{sin}\, Ɛ_л / \mathbf{cos}^2 (Ɛ_л + \varphi) - \mathbf{cos} Ɛ_л \,\mathbf{tg}\, (Ɛ_л + \varphi) / \mathbf{sin}^2 Ɛ_л = \mathbf{0}$ (2.41)

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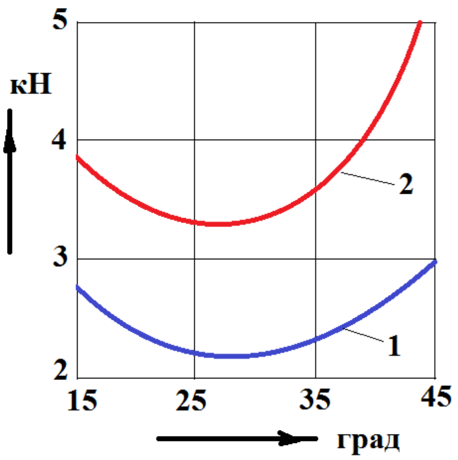

Figure 8. *Graph of the dependence of the component of traction resistance on the angle of installation of the plowshare to the bottom of the furrow at: I - φ=20 ⁰ ; II - φ= 30 ⁰ ;*

After transforming equation (34), we get:

$tg^3 Ɛ_ʌ\, tg^2\, \varphi + tg^3 Ɛ_ʌ\, tg\, \varphi tg^2 Ɛ_ʌ + 2\, tg^2 Ɛ_ʌ - tg\, \varphi = 0$ (35)

Denoting $x = tgƐ_ʌ$, $y = tg\,\varphi$ have

$ax^3 + bx^2 + cx + d = 0$ (36)

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

Equation of the third degree (37) has one real solution for the discriminant $D = q^2 + p^3 > 0$

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

The solution of the equation of the third degree can be obtained by reducing the equation (38) to the form:

$x^3 + 3px + 2q = 0$ (39)

where $x = z + \frac{b}{3a}$ and using the Cordon formula we find the real root of the equation:

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

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

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

The value of **z** determines the optimal value of the angle of installation of the plowshare to the bottom of the furrow $Ɛ_ʌ$, which determines the minimum value of the traction force:

$Ɛ_ʌ = arctg\left[z - \frac{y}{3(y^2+1)}\right]$ (40)

According to the formula (40), the values of the angle are calculated $Ɛ_ʌ$. At various angles $\boldsymbol{\varphi}$ friction of the soil on the plowshare, the optimal value of the angle of installation of the plowshare to the bottom of the furrow lies within 25 ... 31 °.

Determining the height of the body of the worker organ digger. The soil cut by the dredger at the depth of its stroke and raised to the top should not be poured through the body back into the furrow, but should be completely used to form a dam. It follows that the height of the

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VOLUME-4, ISSUE-12

channel digger body must be equal to or greater than the total (construction) depth **H_K** of the channel. Considering the loading of the soil in front of the working body, it is advisable to install it by 20 ... 30% more **H_K**.

With this in mind, the height (**H**) of the body of the working body of the channel digger can be determined by the formula:

$H = K_{cr} \ H_K$, (41)

where **K_{cr}** = 1.2 ... 1.3 - the coefficient of soil loading before the working body.

According to item 2.1.4 $H_K = h_{b.o} + h_\partial$ and considering (42), formula (42) has the form:

$$H = K_{cr}\left[h_{b.o} + \sqrt{\frac{(b+h_{b.o}\,\mathrm{ctg}\,\lambda)h_{b.o}K_p}{\mathrm{ctg}\lambda' + \mathrm{ctg}\delta}}\right] \quad (43)$$

From the analysis of formula (43) it follows that the height of the hull depends on the cross-sectional dimensions of the excavation, the loading coefficients (K_{cr}) and loosening (K_p) and the angles of the inner ($\boldsymbol{\lambda}'$) and outer (δ) slopes of the dam.

Calculations according to formula (43) showed that at $h_{b.o}$= 0.15 .... .0.18 m, b= 0.40m, $\boldsymbol{\lambda} = \boldsymbol{\lambda}'$= 45 ^{0} , δ_{cp}= 39 ^{0} , K_{cr} = 1.3 and K_p= 1.2, height housing H = 0.46 ... 0.51 m.

The height of the body H = 0.5 m was considered, considering the exclusion of spilling the soil back into the furrow.

The remaining necessary parameters of the working body can be selected from the conditions for ensuring rational parameters of the temporary sprinkler and determined by calculation.

For example: the length ($\ell_л$) of the plowshare can be determined by calculation with a known angle$\mathcal{E}_л$ plowshare adjustment to the bottom of the furrow and a known height$\boldsymbol{h_1}$ preliminary lifting of the formation:

$\ell_л = h_1 \ / \ \sin\mathcal{E}_л$ (44)

According to p.2.2.2 $\mathcal{E}_л$= 25...31 $^\circ$ and p.2.2.1 $\boldsymbol{h_1}$= (0.04...0.06) m then $\boldsymbol{\ell}_л$= 0.09...0.12 m.

the width ($\boldsymbol{b_1}$) of the plowshare equal to the average value of the required width of the bottom of the excavation, i.e. $\boldsymbol{b_1} = \boldsymbol{b}_{cp}$= 0.4 m.

Conclusions. Corner $\boldsymbol{\varphi}_к$ the inclination of the lower edge of the wing on the frontal projection should be chosen from the condition of the formation of stable slopes and a dam, i.e. $\boldsymbol{\varphi}_к \leq \boldsymbol{\lambda}_{cp}$**=45** $^\circ$ span **(B)** wings should be no less than the width **(B_1)** along the top of the furrow, i.e. **$B \geq B_1$**= 1.20 m. Corner$\boldsymbol{\gamma}_{кр}$ deviation of the upper edge of the wing to the direction of motion, according to known studies, should be 36 ... 41°. The length $\boldsymbol{\ell}$of the wing can be determined according to Fig.8 according to the following relationship.

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