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JUSTIFICATION OF THE PARAMETERS OF THE COMBINED SECTIONAL CARROT HARVESTER

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Abstract
The article reveals the relevance of vegetable growing in agriculture, the current state of carrot harvesting processes, the types and principles of operation of carrot harvesters, the article provides a diagram of the proposed new carrot harvester and its theoretically justified parameters of the combined digging body and its effectiveness.

Research Method

To determine the effectiveness of the combined digging body of the carrot harvester used theoretical literature, such as the calculation of the working bodies of the root harvester.

Keywords: carrot harvester, digger, digging working body, soils, heap, mass velocity, density.

Introduction

Improving the parameters of the plowshare of the digger is one of the most energy-effective methods in the process of carrots harvesting.
The agricultural construction we propose aimed at improving the digging of carrot shares, i.e. carrot digger, taking into account the physical and mechanical properties of carrot buds and soil.
The Plowshares designed to extract and divide accordingly the necessary part of the carrot buds according to soil parameters like compacting them.
The main parameters of the carrot digger are the installation angle of the plowshare relative to the bottom of the plowshare, i.e. the angle of entry of the plowshare into the soil during cutting, the opening angle of the beak of the plowshare γ and the length L_l and width W_l (Fig. 1.1).

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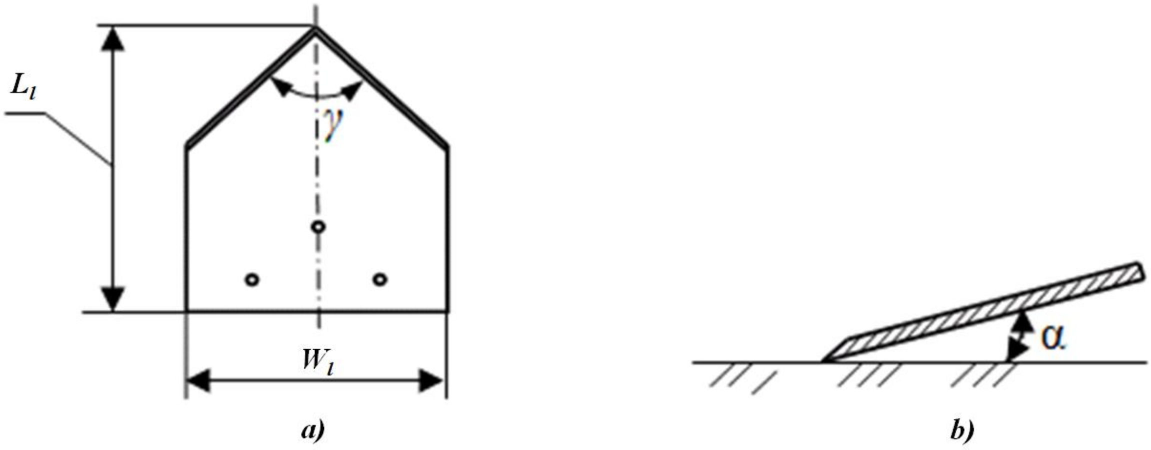
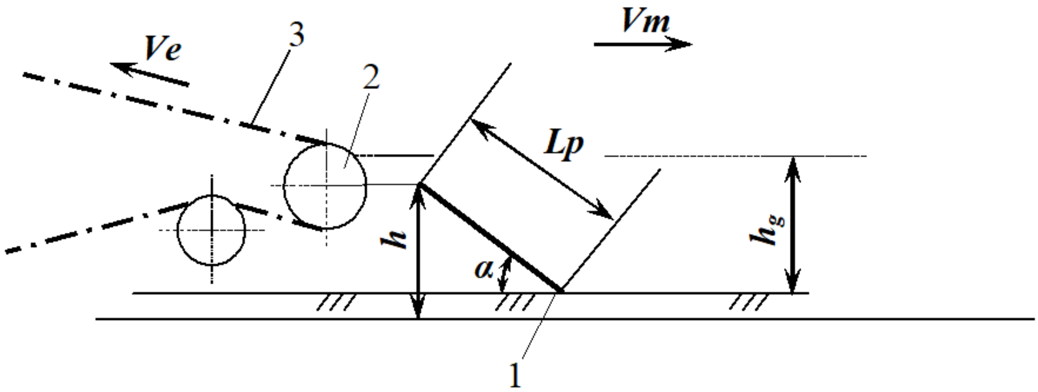


a) - basic plowshare; b) - intermediate plowshare
Figure 1.1. Plowshare scheme of a machine for carrots digging

When digging carrots, the angle of installation of the plowshare along the bottom of the ridge should not exceed 24 degrees to ensure free sliding of the soil slide on the surface of the plowshare.
Based on the foregoing, and taking into account the size of the root crop, the location of carrots in the soil, the depth and physical and mechanical properties of the soil, it is possible to justify the width of the plowshare and its length for the proposed working body.



1 - Sectional share; 2 - Front star of the elevator; 3 - Elevator
Figure 1.2. Scheme for determining the installation angle of the plowshare relative to the horizon

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§ 1.1.1. Justification of the plowshare width and length

The width of the plowshare of the digging working body of the carrot digger selection based on the width of the distance between the disks installed on its two sides. The width of each sectional plowshare is determination by the following expression (3.1):

$$W_l \geq (b_{num} + 3\sigma + c) / b_{size} \qquad (3.1)$$

(3.1) given following expressions:

b_{num}- Average size of a carrot nest;

σ - Standard deviation of a carrot nest

c- Horizontal lateral deviation of the machine;

b_{size}- Smallest diameter of a carrot.

The condition follows from formula (3.1) we determine the value W_l-15 sm.

The total width of the carrot bud cover of sectional shares $W_{gen} < 4W$ is less than or equal to the width of four sectional shares.

According to the analysis of the literatures, the value of the opening angle of the beak-shaped part of the plowshare found according to the following condition

$$\gamma \langle 2(90 - \varphi), \qquad (3.2)$$

In (3.2) γ is the angle of friction of the plant roots relative to the plowshare blade, the γ value is 40-50 degrees.

According to formula (3.2), it can be assume that the average value of the opening angle of the plowshare beak is 90 degrees.

Considering that the value of the opening angle of the plowshare beak in formula (3.2) is higher than or equal to 90 degrees (Fig. 3.2), knowing that the plowshare beak is an equilateral right triangle, the length of the plowshare is determine by the following expression

$$L_l = \frac{h_{mid}}{\sin\alpha}, \qquad (3.3)$$

In (3.3) h_{mid}- average height of carrot bud.

From the known values of α and (3.3) it follows that Ll = 25 cm.

Based on the results of theoretical studies, build an experimental copy of the plowshare (Fig. 1.3).

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Figure 1.3. General view of section plowshares

From the literature that the plowshare of root harvesters considered as a two-sided stalk (Fig. 1.3) and its total resistance to gravity expresses as follows

$$R = R_1 + R_2 + R_3 + R_4, \qquad (3.4)$$

In (3.4) the total resistance of the plowshare; R- resistance caused by cutting the soil with a plowshare knife; R_2- resistance to soil deformation of the plowshare; R_3- resistance to soil movement and elevation along the surface of the plowshare; R_4- resistance formed by the inertial force of the soil.

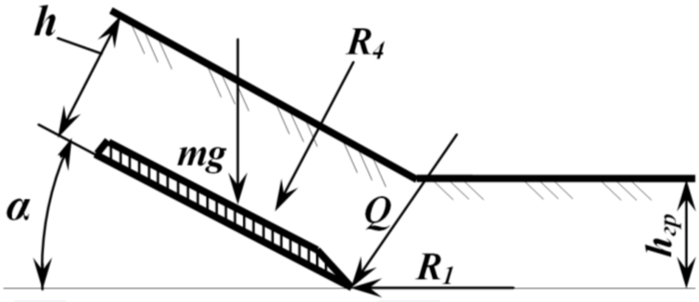

Figure 1.4. Diagram of the forces acting on the plowshare when it crosses the soil layer.

Definitions of the resistance created by cutting the blade of the plowshare, according to the following expression.

$$R_1 = [\sigma] t B_{gen}, \qquad (3.5)$$

Resistance to soil compaction in the horizontal direction;
t is the thickness of the share blade; B_{gen} - the width of the full coverage of the root buds of bush shares.

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The resistance force created by the soil deformation of the working body will be determined according to the scheme shown in Fig. 3.5.
To find R_2 using the circuit shown in fig. 3.5, we project the force Q and the resulting friction force onto the direction of motion.

$$R_2 = Q[\cos\psi + f\sin(\alpha+\psi)\cos\alpha], \qquad (3.6)$$

In (3.6) Q - the resistance of the soil to decomposition;
f- the angle of friction of the soil on the working surface of the plowshare;

$$\psi = \frac{\pi}{2} - \frac{1}{2}(\alpha + \varphi_1 + \varphi_2), \qquad (3.7)$$

where φ_1, φ_2 are the coefficients of external and internal soil friction.
Let us determine the value of Q according to the scheme shown in fig. 3.6, according to the following expression

$$Q_y = [\tau_k]F_{AKCDGB}, \qquad (3.8)$$

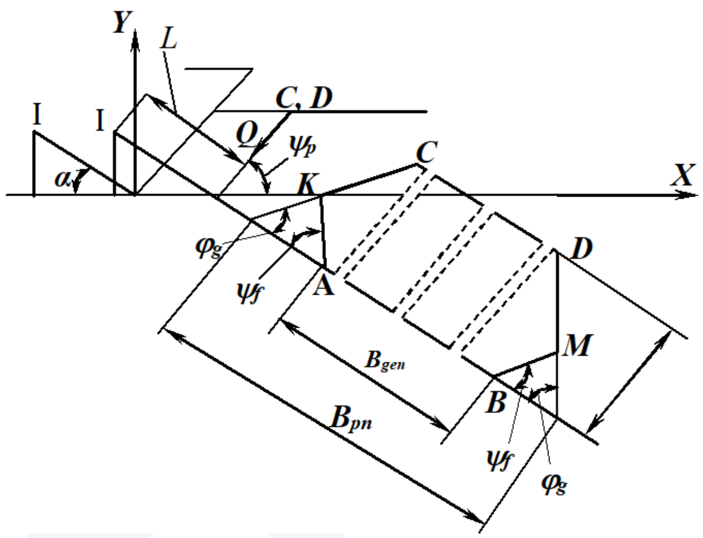

Figure 1.5. Scheme for determining the resistance of a carrot digger to pulling out a sectional plowshare

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In (figure 1.5) $[\tau_k]$ - the limiting value of the applied voltage generated along the decay plane;

F_{AKCDGB} - the face of the AKCDGB fragmentation plane.

According to the scheme shown in figure 1.5 make fallowing mathematic expression

$$F_{AKCDGB} = \left[\left(B_{gen} + \frac{B_{pn} - B_{gen}}{2(ctg\psi_f + ctg\varphi_g)} ctg\psi_{ён}\right) \times \left(\frac{B_{pn} - B_{gen}}{2(ctg\psi_f + ctg\varphi_g)}\right)\right] \times \frac{1}{\sin\psi_f} + \\ + \left[\left(\frac{B_{gen} + в_n}{2} + \frac{B_{pn} - B_{gen}}{2(ctg\psi_f + ctg\varphi_g)} ctg\psi_f\right) \times \left(h_{gen} - \frac{B_{pn} - B_{gen}}{2(ctg\psi_f + ctg\varphi_g)}\right)\right] \times \frac{1}{\sin\psi_p} \quad (3.9)$$

In (3.9) B_{pn} - carrot stem width, [m]; ψ_f - angle of lateral disintegration of soil, [deg];

b_n - the upper base of the carrot stem, m; φ_g - angle of inclination of the pile base, deg.

Substituting the value of F_{AKCDGB} (3.6) into expression (3.5), then this value of Q in (3.4) and taking into account expression (3.8), we obtain the following expression

$$R_2 = [\tau_k] \times \left\{\left[\left(B_{ум} + \frac{B_{pn} - B_{gen}}{2(ctg\psi_f + ctg\varphi_g)} ctg\psi_f\right) \times \left(\frac{B_{pn} - B_{gen}}{2(ctg\psi_f + ctg\varphi_g)}\right)\right] + \right. \\ \left. + \left[\left(\frac{B_{gen} + в_n}{2} + \frac{B_{pn} - B_{gen}}{2(ctg\psi_f + ctg\varphi_g)} ctg\psi_f\right) \times \left(h_{mid} - \frac{B_{pn} - B_{gen}}{2(ctg\psi_f + ctg\varphi_g)}\right)\right]\right\} \times \\ \times \frac{\left(\sin\frac{1}{2}(\alpha + \varphi_1 + \varphi_2) + f\cos\frac{1}{2}(\alpha - \varphi_1 - \varphi_2)\cos\alpha\right)}{\sin\psi_n} \quad (3.10)$$

Taking into account the rise of the soil on the surface of the working body and the resistance forces created by the inertial force, taking into account its moisture content, we determine the following expressions

$$R_G = B_{gen}\left(L - \frac{B_{gen}}{\sin\gamma}\right)hL\rho gtg(\alpha+\varphi_1)\left(1+\frac{W}{100}\right), \qquad (3.11)$$

$$R_{in} = \rho\times\left\{\left[\left(B_{gen} + \frac{B_{pn}-B_{gen}}{2(ctg\psi_f + ctg\varphi_g)}ctg\psi_f\right)\times\left(\frac{B_{pn}-B_{gen}}{2(ctg\psi_f + ctg\varphi_g)}\right)\right]+\right.$$

$$\left.+\left[\left(\frac{B_{gen}+в_{sh}}{2} + \frac{B_{pn}-B_{gen}}{2(ctg\psi_f + ctg\varphi_g)}ctg\psi_f\right)\left(h_{mid} - \frac{B_{pn}-B_{gen}}{2(ctg\psi_f + ctg\varphi_g)}\right)\right]\right\}\times\frac{1}{\sin\psi}$$

$$\times V^2\frac{\sin\alpha\sin(\alpha+\varphi_1)}{\cos\varphi_1\cos^2\frac{1}{2}(\alpha+\varphi_1+\varphi_2)}\left[1+\frac{W}{100}\right), \qquad (3.12)$$

In (3.12) h - the height of the soil rise along the surface of the working body, [m]; ρ - soil density, [kg/m³]; g - free fall acceleration, [m/s²]; W - soil moisture,[%]. Substituting the values (3.6), (3.10), (3.11) and (3.12) for (R-R_1 ...R_4) into expression (3.13), we obtain the following final expression for determining the traction resistance of the working body in the form of a three-sided wedge operating in a closed cutting.

$$R = [\sigma_э]tB_{gen} + [\tau_k]\times\left\{\left[\left(B_{gen} + \frac{B_{pn}-B_{gen}}{2(ctg\psi_f + ctg\varphi_g)}ctg\psi_f\right)\times\left(\frac{B_{pn}-B_{gen}}{2(ctg\psi_f + ctg\varphi_g)}\right)\right]+\right.$$

$$\left.+\left[\left(\frac{B_{gen}+в_n}{2} + \frac{B_{pn}-B_{gen}}{2(ctg\psi_f + ctg\varphi_g)}\right)\left(h_{mid} - \frac{B_{pn}-B_{gen}}{2(ctg\psi_f + ctg\varphi_g)}\right)\right]\right\}\times$$

$$\times\frac{\left(\sin\frac{1}{2}(\alpha+\varphi_1+\varphi_2) + f\cos\frac{1}{2}(\alpha-\varphi_1-\varphi_2)\cos\alpha\right)}{\sin\psi_n} + B_{ум}\left(L - \frac{B_{ум}}{\sin\gamma}\right)hL\rho gtg(\alpha+\varphi_1)\left(1+\frac{W}{100}\right)\times$$

$$+\rho\times\left\{\left[\left(B_{gen} + \frac{B_{pn}-B_{gen}}{2(ctg\psi_f + ctg\varphi_g)}ctg\psi_{ён}\right)\times\left(\frac{B_{pn}-B_{gen}}{2(ctg\psi_f + ctg\varphi_g)}\right)\right]+\right.$$

$$\left.+\left[\left(\frac{B_{gen}+в_n}{2} + \frac{B_{pn}-B_{gen}}{2(ctg\psi_f + ctg\varphi_g)}\right)\times\left(h_{mid} - \frac{B_{pn}-B_{gen}}{2(ctg\psi_f + ctg\varphi_g)}\right)\right]\right\}\times$$

$$\times \frac{V^2}{\sin\psi_f} \times \frac{\sin\alpha \sin(\alpha+\varphi_1)}{\cos\varphi_1 \cos^2 \frac{1}{2}(\alpha+\varphi_1+\varphi_2)}\left[1+\frac{W}{100}\right). \qquad (3.13)$$

According to the analysis of this expression, the gravitational resistance of the plowshare is equal to its parameters (L, t, Bl) plowshare excavation depth (h), physic and mechanic parameters of soil ($[\sigma]$, $[\tau_k]$, φ_1, φ_2, ρ, W, f) all parameters are linked with shape speed of excavation. L=0,25м, t=0,0005м, Bл=0,15м, $[\sigma]=1{,}44\cdot10^6 P$, $[\tau_k]=2\cdot10^4 P$, $\varphi_1=30$, $\varphi_2=40$, ρ=1100 kg/м3, W=15%, f=0,5774, in equalation (13) according to calculation we have following results: optimal speed of soil cutting equal to 1.0 m/sec with 1.08 kN force

Conclusion

According to the results of theoretical studies, the reduction in the mass of soil moved to the machine elevator achieved by installing a combined earth-moving working body on the carrot digger. In this case, optimal parameters of harvesting with minimal energy spending equal to the disk diameter 60 cm, the distance between the lower ends of the disks 57 cm, and angle of inclination of the disk blades relative to the vertical 16 degree.

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