Components of coulter tractive resistance for subsoil throwing about seeds planting

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Abstract. A coulter drills in the stubble of cultivator lancet feet well dug into the hard soil, loose top layer and destroys weeds. However existing studies show that for subsurface broadcasting seeding it is necessary to use the device for the distribution of seeds in subshare space. Uniformity of seeding depth is a major agricultural requirement for planting crops. When the seeds are embedded in the ground with a large spread in depth, shoots are obtained unharmonious, plants are lagging behind in their development, uneven are ripening. From the data of Suleimenov M.K. that the most even shoots in the untreated field were obtained with seed depth of 4.1 ... 5.6 cm. Balanced development of crops requires optimum depth of sowing, which under normal conditions is a grain of 4 to 8 cm seeds should be distributed evenly over the area of nutrition. With increasing depth setting in plants stem escape is formed there has been some increase in the depth setting of the tillering node, individual plants form a second, additional tillering node at the surface. Forming all these additional underground organs, plants are strongly depleted. With the increasing depth of seeding their germination is reduced as well.

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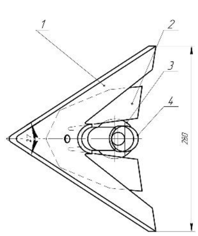
Introduction

To justify the rational parameters of the working body using the studies to determine the laws that establish the relationship between the design parameters and quality performance of the process by seeding width opener, the analysis of technological process was done from the first to the last stage [1]. At each stage areas of feasible solutions are identified, which are represented by analytic functions and their graphical interpretation.

Based on these studies it was found that the required width of the distribution of seeds for the opener width is provided by structural and technological parameters of the delivery tube and the opener: the vertical length of delivery tube 0,2m turns into a curved shape - with a radius of curvature (r) ranging from 0.2 to 0 , 4 pm, the height of the distributor of h = 65-70mm, the base circle radius R = 25-27,5 mm installation height from the bottom of the distributor groove is no more than 23-25mm.



1. Paw 2. Cheek 3. Distributor 4. Feeder

Figure 1 - The opener for subsoil broadcast seeding

Proceeding of the recommended design parameters working body for splash subsurface seeding was taken as a basis (Figure 1).

Working body is a lancet tine opener containing rack portion curved form, with the front, in the direction of enhanced stubble share, the guide of cone-shaped still enshrined in seed distributor, on the bottom of the seed distributor is mounted, the side surfaces of which are in the form of parabola, while the bottom of the rack horizontal metal cheeks are mounted. Meanwhile the layer of soil getting up and stopping on the surface of cheeks, can be laid on the bottom of the seed furrow and thus eliminates clogging the distributor by soil [2, 3].

Installation of additional cheeks helps delay gathering soil layers with coulter opener before laying the seeds to the bottom slot. Extension of the time spent on the surface layer of soil of the coulter opener owing to the installed cheeks and as a consequence of the interaction with the reservoir rack opener can cause the increase of traction resistance of the working body. Therefore there is a need to evaluate the components of the traction resistance developed by a working body.

The results of research

In relation to the working body opener for subsurface splash seeding total traction resistance will consist of traction resistance of the opener and the resistance attributable to rack opener with two horizontal cheeks.

Then the total resistance of the opener for subsurface splash seeding can be represented as:

$$R_x^c = R_x + 2R_c \,, \tag{1}$$

where R_x is the draft of the opener; R_c is the resistance attributable to the rack opener.

Working body opener performs process of tillage of the lancet paw on the analogy with a triangular wedge (Figure 2). In the interaction with the soil wedge horizontal component of the force R, which is a draft of the wedge- R_x is defined as:

$$R_x = \iint dR_x(X,Z) \,, \tag{2}$$

where dR_x is elementary component of traction resistance acting on the selected element surface of the wedge, H.

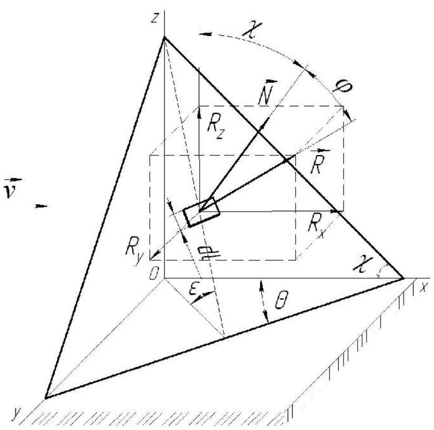


Figure 2 - Forces acting on a triangular wedge

According to [4] the wedge consumes energy for cropping soil layer on the blade, the deformation of the soil layer, as well as the passing the kinetic energy reservoir separated during transport of soil particles. These processes take place simultaneously, and the resistance of the wedge can be seen as the resultant of two component forces:

$$R = k_v R^d + R^K \,, \tag{3}$$

where k_v - is coefficient depending on the rates of processes operating in the soil and place in it [4, 5];

R^d - force spent on pruning and deformation of the soil layer, H;

R^K - the force required to report the kinetic energy of the particles separated during transport to the surface layer of soil coulter opener, H.

Figure 2 draft of the wedge is defined as:

$$R_x = R\,sin(\varphi + \chi), \tag{4}$$

and where χ is the angle of cut triangular wedge ($\chi = arctg(tg\varepsilon \cdot \sin\theta)$).

Taking into account that $R^d = N / cos\,\varphi$ we can express the normal reaction N through the normal tension σ_n, due to the action of the soil at the site of the array [3]:

$$R^d = \frac{\sigma_n \cdot a \cdot b}{sin\,\chi\,cos\,\varphi}, \tag{5}$$

and

where a and b is, respectively, seam thickness and width of the wedge, m.

The tension of the soil in contact with the working surface of the wedge is determined by the dependence [5]:

$$\sigma_n = \frac{1 - sin\tau\,cos\,2\omega_H}{1 + sin\tau\,cos\,2\omega_H}(C\,cos\,\tau + \rho a g), \tag{6}$$

and

where τ - internal friction angle of the soil, hail;

ω_H - angle to the direction of the site of destruction voltage, hail

$(2\omega_H = \pi - 2\alpha + \varphi - arcsin(sin\tau\,sin\varphi)$;

ρ - density of the soil, kg/ m^3;

C - cohesion of the soil, H/m^2;

g - acceleration of gravity, m/c^2.

To determine the strength of R^K the soil through the process of shock element on the front side of the wedge was considered. According to the theorem pulses geometric increment of a system for a period of time equal to the principal vector of the external forces applied to the system: $mv_{disc.} = \int_{t_1}^{t_2} R^K \cdot dt$, where m - mass of the soil elements ; $v_{disc.}$ - soil item drop rate; t_1 and t_2 - the beginning and the end of discarding soil formation.

Taking into account that the weight of the wedge (M) is greater than m, after the transformation, we obtain the resistance required to post speed discarded soil layers:

$$R^K = \gamma_p \cdot v^2 \cdot a \cdot b \cdot \frac{sin\,\chi \cdot cos\,\psi}{sin(\chi + \psi)}, \tag{7}$$

and where a and b - depth and width of the progress of the wedge ; γ_p - the density of the treated soil; $\psi = \pi/2 - (\alpha + \rho + \varphi)/2$ - phase angle of the soil layer. Substituting (5) and (7) in the formula (3) with (4) and after transformations total tractive resistance of the wedge becomes:

$$R_x = ab\,sin(\varphi+\chi)\left(\frac{\sigma_n k_v}{cos\,\chi\,cos\,\varphi} + \gamma_p v^2 \frac{sin\,\chi\,cos\,\psi}{sin(\chi+\psi)}\right). \quad (8)$$

The resulting analytical dependence (8) connects the design parameters of the wedge (wedge angle setting to the bottom groove and ε to the direction of θ, the width of the wedge b) with process parameters (depth of the wedge and progress, the velocity of the wedge v) and soil properties (internal friction coefficient τ, the coefficient of external friction φ, grip of the soil C, soil density γ_p, phase angle ψ).

Figure 3 shows the graphics of force change R_x depending on the speed of the working body opener v. Initial data for the calculation are presented in Table 1.

Table 1. Baseline data for the calculation of traction resistance opener

Parameters items	Symbols	Values	Meanings
Depth of share motion	A	m	0,08
Share width	B	m	0,28
Speed of destruction	v_p	m/c	8,33
Soil density	γ	kg/ m³	1000...1600
Density of loosened area	γ_p	Kg/ m³	900
Grip of the soil	C	N/ m²	3000
Cutting angle of triangular wedge	χ	Degree	30
Angle of internal friction	τ	Degree	28
Angle of external friction	φ	Degree	35
Phase angle, linked soil	ψ	Degree	$\pi/2-(\alpha+\varphi+\tau)/2$
Coulter mounting angle to the furrow bottom	ε	Degree	25
Coulter mounting angle to the direction of the process	θ	Degree	20
Note - $\chi = arctg(tg\varepsilon \cdot \sin\theta)$			

To determine the component of the force R_c let's consider the interaction of the soil element with front side surface opener due the horizontal cheeks (Figure 4).

Dynamic effect of the soil on side opener is characterized by periodic shocks with vibrational distribution of elastic and plastic deformation of waves [6, 7].

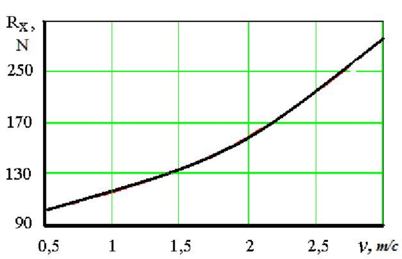


Figure 3 - The dependence of the total resistance R_x opener on the speed v

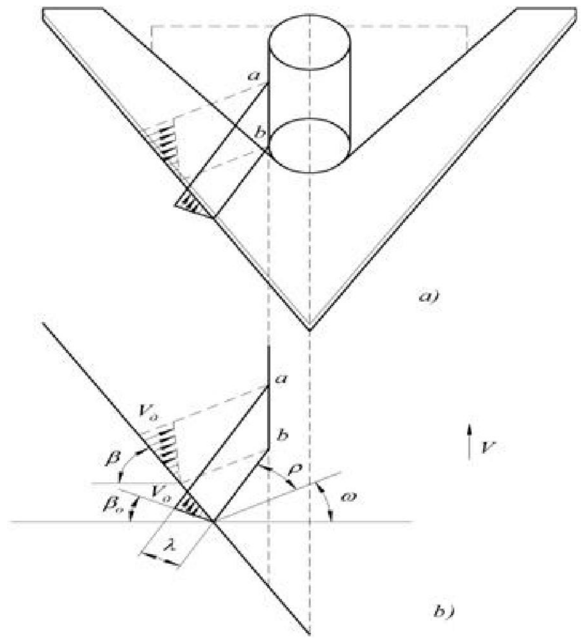


Figure 4 - The working body of the opener (a) and the design scheme, the forces acting on side opener (b)

The fundamental equation of dynamic effect racks opener with the soil, the impulse equation is force [8]:

$$Pdt = d(mv), \quad (9)$$

where m - mass of the soil elements, kg.

The impulse value in the course of which the deformation of the soil ending by the destruction of the internal connections and composed of the sum of elementary pulses produced during the time of impact t, accompanied by the spread of a set of strain waves, one after the other [6], ie $\int_0^t Pdt = mv$. Applied to the side of the rack opener formula can be written as:

$$\int_{t_1}^{t_2} R_c dt = M(v_2 - v_1) + m(v_{disc.} - v_0), \quad (10)$$

where M – mass of the front opener, kg;

v_1, v_2 - speed before and after the impact with the front coulter soil elements in the time interval $t_1 - t_2$, , m / s;

$v_{disc.}$ - velocity dropping soil element, m/s;

v_0- the rate of soil element before impact, m/s;

t_1, t_2 - the beginning and the end of strike, c.

The result of exposure to the side of the rack to the opener on the separated soil are deformations [9, 10]. Every deformation is that part or layer of a deformable body moving at a certain speed relative to another part or another layer. At various points in the array and directions soil deformation speed v_∂ is unequal size. Naturally, the greatest amount of speed v_∂ is towards deformation.

Ideally, the lateral surface of the front opener moves surrounding soil particles relative to the fixed particles in the array at a rate of deformation v_∂ in a direction making an angle ω with the axis OY (Figure 4 a). If we consider that the treated soil is connected, there is a record of the internal friction angle of the soil ρ. Then, according to Figure 4b, deformation rate v_∂ in a direction making an angle ω_0 with the axis OY is defined as:

$$v_\partial = v \cdot \frac{\sin \beta_0}{\sin(\beta_0 + \omega_0 + \rho)}, \tag{11}$$

Available data show that for a variety of soils and loading rates v_∂ value varies from 6 to 15 m/s.

Taking into account that we have: $M >> m$

$$\int_{t_1}^{t_2} R_c dt = m v_{disc.}; \tag{12}$$

$$v_{disc.} = v_\partial(1+k), \tag{13}$$

where k - coefficient of speed restitution after the end of interaction, is the ratio of the shock pulse units for periods of impact.

Substituting (12) in (13), we have:

$$v_{disc.} = \frac{v(1+k)\sin\beta_0}{\sin(\beta_0 + \omega_0 + \rho)}. \tag{14}$$

Given that the strike of the soil element of face cheek opener equal to the period of the soil shear element, we write $t_2 - t_1 = \lambda / v \cdot \sin \beta_0$, where λ - width of the soil on the surface of the side racks opener, m.

Since the formation of the element of soil on the cheek is periodic, and considering its width constant, we can express the value of λ in one of the characteristics of viscosity - dynamic length $\lambda = \mu / \gamma_p \ v$, where μ - dynamic viscosity, kg/ms.

Then substituting (14) in (12) and projecting both sides of the direction of movement of the opener, we find the average value of the force R_c period shift:

$$R_c = \frac{mv^2 \sin\beta_o \sin(\omega_0 + \rho)\cos(\omega_0 + \rho)(1+k)}{\lambda \sin(\beta_0 + \omega_0 + \rho)}. \tag{15}$$

Multiplying the numerator and denominator of (15) into the square $S_{av}=ab/2$ (where b - width opener, m), given the smallness of the coefficient k (due to not fully elastic impact of metal on the ground), and a known volume of the discharge of soil element that is:

$$V = \frac{\lambda S_{av}}{\sin(\omega_0 + \rho)}, \tag{16}$$

we get:

$$\frac{(1+k)m}{\lambda \cdot S_{av} / \sin(\omega_0 + \rho)} = \frac{m}{V} = \gamma_p, \tag{17}$$

where γ_p – the density of the treated soil, kg/m^3;

Hence force R_c,- required to report the kinetic energy of the separated particles during transportation of soil formation from the side of the front opener is defined as:

$$R_c = \gamma_p v^2 ab \frac{\sin\beta_0 \cos(\omega_0 + \rho)}{2\sin(\beta_0 + \omega_0 + \rho)}. \tag{18}$$

Expressing his corner as $\beta_0 = \beta - \rho$ (β where - angle between the blade and the line perpendicular to the direction of movement opener) that:

$$R_c = \gamma_p v^2 ab \frac{\sin(\beta - \rho)\cos(\omega_0 + \rho)}{2\sin(\beta + \omega_0)}. \tag{19}$$

Substituting into (1), the dependencies (8) and (19) that the total resistance of the opener for subsurface broadcast seeding:

$$R_x^c = ab\left\{\left[\sin(\varphi + \chi)\left(\frac{\sigma_n k_v}{\cos\chi\cos\varphi} + \gamma_p v^2 \frac{\sin\chi\cos\psi}{\sin(\chi + \psi)}\right)\right] + \gamma_p v^2 \frac{\sin(\beta - \rho)\cos(\omega_0 + \rho)}{\sin(\beta + \omega_0)}\right\} \tag{20}$$

More visible components of traction resistance opener for subsoil broadcast seeding can imagine, if the formula (20) to the form:

$$R_x^c = ab(K_d + K_k + K_m), \tag{21}$$

where $K_d = \sin(\varphi + \chi)\dfrac{\sigma_n k_v}{\cos\chi\cos\varphi}$

coefficient taking into account the energy cost of the deformation of the soil coulter blade, N/m^2;

$$K_k = \gamma_p v^2 \frac{\sin(\varphi + \chi)\sin\chi\cos\psi}{\sin(\chi + \psi)} -$$

coefficient taking into account the energy cost of the message and change the direction of the velocity of the soil layer shoe, N/m^2;

$$K_m = \gamma_p v^2 \frac{\sin(\beta - \rho)\cos(\omega_0 + \rho)}{2\sin(\beta + \omega_0)}$$

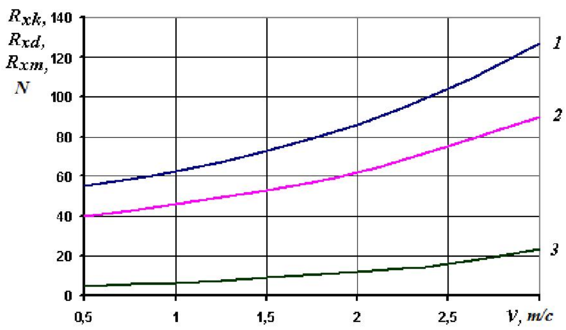
considering the cost of discarding soil layer cheek opener, N/m^2.

To quantify the components of the traction resistance opener (21), it is useful to record as:

$$R_x^c = R_{xd} + R_{xk} + R_{xm}, \tag{22}$$

where $R_{xd} = abK_d$, $R_{xk} = abK_k$, $R_{xm} = abK_m$ respectively, the resistance to overcome the pressure of the soil layer on the blade opener to the message and change the direction of the deformed soil layer shoe to drop and the soil layer cheek opener, N.

Assuming that the opener angle is β =56^0, the angle shift for coherent soil is determined by analogy with the angle $\psi_{,}$, calculated components traction resistance opener by formula 22, the results of which are shown in Figure 5.



1- R_{xk}; 2- R_{xd}; 3 - R_{xm}.

Figure 5 – Dependences of the components of ploughshare traction resistance

If you change the speed of the opener from 0,5 to 3 m/s is the resistance that falls on soil particles drop from the side of the front coulters varies from 4 to 23 H, in comparison with the overall draft of the opener is 5 to 8 %. Components of resistance to deformation of the soil layer and to the change the direction of the ploughshare is far superior the value R_{xm}.

Conclusions

On the basis of theoretical researches the analytical relations for determining the components of the traction resistance of the developed opener were obtained which consist of resistance to overcome the pressure of the soil layer on the blade opener to passing and change the direction of the deformed layer of soil by the opener and dropping the soil layer by side cheek of the opener. It was determined that additional cheeks did not cause an increase of traction resistance of the working body.

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