Scientific Papers. Series A. Agronomy, Vol. LXIV, No. 1, 2021
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

THEORETICAL RESEARCH ON TECHNOLOGICAL PROCESS OF A STUD SEEDER WITH A FURROW-FORMING WORKING BODY

Vasily SHUMAEV, Andrey KALABUSHEV, Julia KULIKOVA, Alfiya GUBANOVA

Penza State Agrarian University, 30 Botanicheskaya Street, 440014, Penza, Russia

Corresponding author email: shumaev.vv@pgau.ru

Abstract

The maximum yield of grain crops with good technological qualities of grain at minimum costs is directly related to the traction resistance of the unit and the exact distribution of seeds in depth and sowing area. The use of cultivator-cultivators for subsoil-spread sowing is more effective than conventional seeders, as it allows evenly distributing seeds over the sowing area, eliminating gaps between individual technological operations, shortens sowing times, better use of the first spring maximum of soil moisture, and compaction of loose soil with wheels of tractors and machines. The working bodies of serially produced seed drills for subsoil-spread stubble sowing do not fully meet the agrotechnical requirements, since their use in production revealed a number of disadvantages that seriously worsen the quality of work, especially with high soil moisture (more than 18%), due to soil sticking to working bodies and its mixing, which leads to roll formation and removal of wet layers to the surface of the field. In this regard, increasing the yield of grain crops and improving the quality indicators of sowing by using a coulter for subsoil-spread sowing is an urgent scientific and technical problem. Based on the research materials, prototypes of seeders with experimental stubble coulters were developed and manufactured. Studies of the developed seeding machines have shown stable performance in sowing grain crops.

Key words: *opener, soil, seeder, ecology, furrow former.*

INTRODUCTION

The development of designs for grain seeders, seeding units and complexes is in the direction of creating units for subsoil-spread sowing, since it allows you to optimally use the area of plant nutrition, improve their growing conditions, reduce sowing time and reduce labor and energy costs. The effectiveness of the use of opener designs for subsoil-spread sowing of agricultural seeds is largely determined by a decrease in the traction resistance of the working bodies to the soil with a simultaneous increase in the quality of sowing (Kalabushev, 2018; Kalabushev, 2019). The existing designs of furrow formers do not fully ensure the quality of the seeders, often have an increased traction resistance, which significantly increases the cost of production and reduces the yield.

MATERIALS AND METHODS

In order to reduce the traction resistance of the units and obtain more uniform crops, domestic and foreign scientists have created a large number of openers of cultivator seeders. In turn, the analysis of the qualitative and quantitative indicators of their work allows us to assert that a wide variety of their designs is not an indicator of perfection, but, on the contrary, the result of insufficient completeness of their study. From the foregoing it follows that the work carried out in the direction of improving the quality indicators of sowing remains relevant (Shumaev, 2020; Kuhmazov, 2020).

To reduce the traction resistance of the seeder-cultivator and increase the uniformity of the distribution of seeds, we propose the design of the combined opener of the seeder-cultivator (Figure 1).

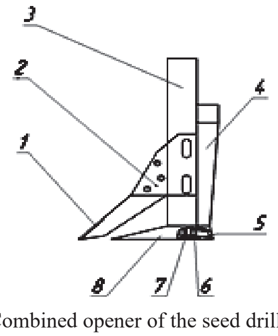

Figure 1. Combined opener of the seed drill-cultivator:
1 - loosening tooth; 2 - bracket; 3 - rack; 4 - seed tube;
5 - seed distributor; 6 - sole; 7 - fastening screw;
8 - lancet paw

The combined opener of the seeder-cultivator contains a stand 3 with a loosening tooth 1, a seed pipe 4 and a lancet paw 8. The loosening tooth 1 is fixed in front of the toe of the lancet paw 8 of the opener by means of a bracket 2 mounted on a stand 3, while the cutting plane of the loosening tooth 1 and a lancet paw 8 are the same. The arrow-shaped paw 8 of the opener is attached to the base of the pillar 3 of the opener by means of the fastening screw 7 and the sole 6, in the rear of which the seed distributor 5 is fixed, two side and one rear surfaces of the distributor 5 are made in the form of a fifth degree polynomial. The rib formed by the side surfaces of the seed distributor is made with a rounding radius to reduce the injury of seeds.

The technological process of the combined opener of the seeder-cultivator is as follows. When the combined coulter moves, loosening tooth 1 enters the stubble layer of the soil, cuts it, forming a gap and loosens the soil. During the movement, the process of constant formation of the soil compaction core on the toe of the loosening tooth 1 takes place, but the soil compaction core on the toe of the lancet paw 8 of the combined coulter does not receive its development and is constantly destroyed, which creates the best conditions for the stability of the movement of the combined coulter in depth, so how the formation of a soil compaction core on the toe of the lancet paw is excluded 8. The soil and plant residues passing along the front working face of the loosening tooth 1 rise and, continuing to slide along the surface of the loosening tooth 1, fall onto the field surface. Pointed share 8 cuts plant roots, loosening the soil and killing weeds, and the sole 6 levels the bottom of the furrow, forming an even, compacted seedbed. At the same time, the seeds from the seed distributor through the seed pipe 4 enter the lateral and rear surfaces of the seed distributor 5 and are laid at the bottom of the furrow, while the seeds that fall on the lateral surfaces of the seed distributor 5 are evenly distributed along the bottom of the furrow to the right and left of the longitudinal-vertical the planes of symmetry of the combined coulter over the entire working width of the lancet paw 8, and the seeds that fall on the rear surface of the seed distributor 5 are distributed in the rear part of the sub-plow space and partially on the sides, which ensures the best uniformity of seed distribution over the sowing area using the maximum capture width of the lancet paw 8 and the creation of better conditions for seed germination and plant development, which leads to an increase in crop yields. A layer of soil coming off the lancet paw covers the sown seeds.

Since the combined opener of a seeder-cultivator of this design was used for the first time during sowing, the task of theoretical research was to study the interaction of its design parameters and the soil.

RESULTS AND DISCUSSIONS

With the theoretical substantiation of the design parameters of the combined opener of the seeder-cultivator, let us consider its traction resistance, the thickness of the loosening tooth (Figure 2), the deformation zone of the loosening tooth and the distance from the nose of the loosening tooth to the toe of the lancet paw in the combined opener.

When cutting bonded and plastic soils, a compacted core of the material being processed is formed in front of the cutting profile, and further cutting is carried out not with a blade, but with this core.

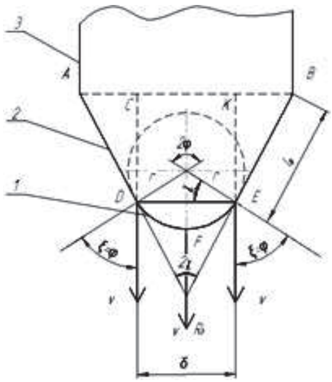

Figure 2. Elements of a loosening tooth: 1 - blade; 2 - chamfer; 3 - skeleton

The required blade width is determined by the chord dc = δ (Figure 2), which is equal to

$$\delta = 2\, r \sin \varphi \qquad (1)$$

where: r is the radius of curvature of the loosening tooth blade, m; φ - angle of friction of the soil against steel, deg.

Considering Figure 2, it can be argued that the width of the loosening tooth will be

$$b = 2(r \cdot \sin\varphi + l_Л \sin\gamma_1), \qquad (2)$$

where 2γ1 is the opening angle of the loosening tooth, deg.

When the loosening tooth moves at a certain depth, the soil chipping would occur in the direction of the action of the resultant force Rl, located at an angle $(\xi_1 + \varphi)$, that is, in the direction nm (Figure 3) of the deformation zone.

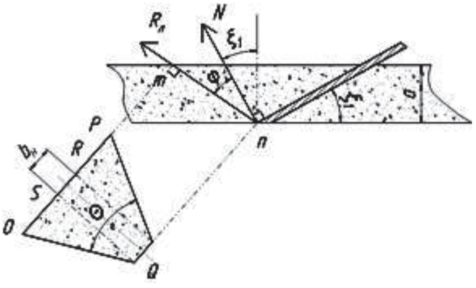

Figure 3. Scheme for determining the soil deformation zone with a loosening tooth: ζ1 - the angle of entry of the paw into the soil; ζ2 - the angle of entry of the paw into the soil; φ2 - angle of friction of the soil along the blade of the paw; a - tillage depth; N - normal lancet paw response; Rl - resultant force; Θ - angle of soil deformation by a loosening tooth, degrees

Dependence of the size of the deformation propagation zone on the size of the soil compaction core on the loosening tooth:

$$b_{Д.Н.} = \frac{2a \cdot tg\frac{\theta}{2}}{\cos(\xi_1 + \varphi)} + 2r \cdot \sin\varphi + 2l_Л \sin\gamma_1, \qquad (3)$$

where: Θ - angle of soil deformation by a loosening tooth, degrees; a - tillage depth, m; ζ1 - angle of entry of the paw into the soil, degrees; ll - blade length, m

In the process of operation of the combined opener of the seeder-cultivator, its paw quickly becomes dull, while the toe of the paw is closed with the width bn. When the paw moves at a depth a, the soil chipping will occur in the direction of action of the resultant paw, Rl which is located at an angle (ζ2 + φ2) (Figure 4), where ζ2 - the angle of entry of the paw into the soil, φ2 is the angle of friction of the soil along the edge of the paw. A loosening tooth is installed in front of the paw, therefore, in order to exclude the influence of soil deformation from the paw on the loosening tooth, the horizontal distance between them should correspond to the segment mp. Therefore, the horizontal distance lg between the toe of the paw and the loosening tooth must satisfy the condition

$$l_г \le lb + mp, \qquad (4)$$

where lb is the overhang of the toe of the loosening tooth, m.

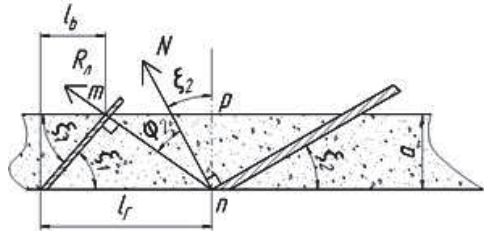

Figure 4. Scheme for determining the distance from the toe of the loosening tooth to the toe of the lancet paw: ζ1 - the angle of entry of the paw into the soil; ζ2 - the angle of entry of the paw into the soil; φ2 - angle of friction of the soil along the blade of the paw; lg - horizontal distance between the toe of the lancet paw and the loosening tooth; a - tillage depth; Rl - resultant force

The maximum horizontal distance between the toes of the lancet paw and the loosening tooth is determined from the expression:

$$l_г \le a \cdot [ctg\zeta 1 + tan(\zeta 2 + \varphi 2)] \qquad (5)$$

To determine the traction resistance of the combined opener of a seeder-cultivator, let us consider its operation, provided that the combined opener moves uniformly, at a constant depth and in a homogeneous environment, and the air resistance is neglected due to its small value.

The total value of the traction resistance of the combined opener of the seeder-cultivator can be represented as the sum of the traction resistance of the loosening tooth and the lancet, that is:

$$RXc = RXз + RXлс, \qquad (6)$$

where RXз, RXлс - traction resistance of the ripper tooth and lancet paw, N.

In this expression, the second component RHls is:

$$RKhls = RKhl - k\,RKhl = RKhl\,(1\text{-}k), \qquad (7)$$

where RXl –traction resistance of the lancet share, N; k– coefficient depending on the size of the deformed soil by the loosening tooth.

The coefficient k depends on the area of the soil deformation zone in the transverse-vertical plane with a loosening tooth and a lancet paw, which is determined by the expression:

$$k = \frac{S_З}{S_Л} = \frac{(b_{Д.Н.} + b) \cdot a}{2 \cdot b_Л \cdot a} = \frac{b_{Д.Н.} + b}{2 \cdot b_Л}, \quad (8)$$

where: Sz, Sl - area of the deformation zone of the loosening tooth and paw in the transverse-vertical plane, m^2; bl - capture width of the lancet paw, m.

Our task is to determine the traction resistance of the loosening tooth and lancet paw when interacting with the soil. It should be noted that each working surface of the loosening tooth and lancet paw is a triangular wedge with angles characterizing the installation of the working surface of the loosening tooth $\alpha_1, \xi_1, \gamma_1$ and lancet paws $\alpha_2, \xi_2, \gamma_2$... Therefore, in what follows we would carry out theoretical calculations, which are based on the theory of the trihedral wedge of V.P. Goryachkin and his followers.

The traction resistance RKhz of the loosening tooth of the combined opener of the seeder-cultivator would consist of the following components:

$$R_{Хз} = 2 \cdot (R_{Хз_G} + R_{Хз_F} + R_{Хз_Д} + R_{Хз_С}, \quad (9)$$

where: $R_{Хз_G} R_{Хз_F} R_{Хз_Д} R_{Хз_С}$ - traction resistance of the loosening tooth, depending on the weight of the seam, the dynamic pressure of the seam, the resistance of the soil to compression by the nape of a blunt blade, the resistance of the soil to deformation, N.

For analogy with expression (9), the traction resistance of the lancet paw would be equal to $R_{Хл}$:

$$R_{Хл} = 2 \cdot (R_{Хл_G} + R_{Хл_F} + R_{Хл_Д} + R_{Хл_С}), \quad (10)$$

where: $R_{Хл_G} R_{Хл_F} R_{Хл_Д} R_{Хл_С}$ - traction resistance of the duckfoot, depending on the weight of the soil layer, the dynamic pressure of the layer, the resistance of the soil to compression by the back of the head of a blunt blade, the resistance of the soil to deformation, N.

Consider the forces acting on the loosening tooth when the soil layer is located on the surface of the loosening tooth. As already noted, the working surface of the loosening tooth is a triangular wedge. Forces would act on the right working surface of the loosening tooth (Figure 5): Nz is the normal reaction to the loosening tooth from the soil, Fz is the friction force of the soil against the working surface of the loosening tooth.

Let us determine the projections of the forces Nz and Fz on the coordinate axes Ox, Oy, Oz. Then the projection of the force Nc on the axis would be:

- on the Ox axis:

$$N_{зx} = N_з \cdot \cos(90 - \zeta_1) \cdot \sin\gamma_1 = N_з \cdot \sin\zeta_1 \cdot \sin\gamma_1, \quad (11)$$

- on the Oy axis:

$$N_{зy} = N_з \cdot \cos(90 - \zeta_1) \cdot \cos\gamma_1 = = N_з \cdot \sin\zeta_1 \cdot \cos\gamma_1, \quad (12)$$

- on the Oz axis:

$$N_{зz} = N_з \cdot \sin(90 - \zeta_1) = N_з \cdot \cos\zeta_1, \quad (13)$$

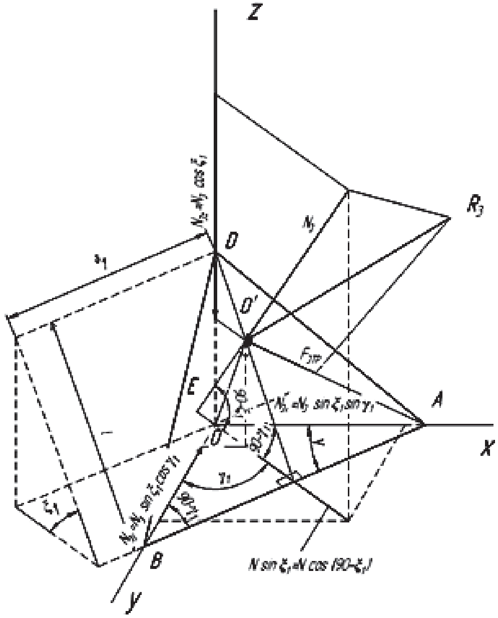

Figure 5. Scheme for the analysis of the work of a trihedral wedge

Since the working surface of the wedge OAB (Figure 6) penetrates into the soil, and the soil particle along this surface moves in the direction OA, it is difficult to determine the projection Fz, then to solve this problem we will decompose the force Fz into two components: Fz1 - parallel to the knife blade AB of the loosening tooth; Fz2 - along the directional perpendicular blade of the knife AB of the loosening tooth.

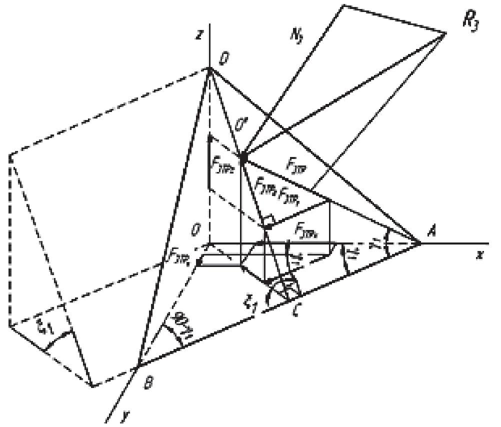

Figure 6. Determination of projections on the coordinate axis of the friction force $F_{3_{TP}}$

The resulting force on the x-axis would be:

$$F_{3_{TPX}} = F_{3_{TP1X}} + F_{3_{TP2X}} = \\ = F_{3_{TP1}} \cdot \cos\gamma_1 + F_{3_{TP2}} \cdot \cos\zeta_1 \cdot \sin\gamma_1 \quad (14)$$

In determining $F_{3_{TP1X}}$ and $F_{3_{TP2X}}$ it should be borne in mind that when the loosening tooth rises to the working surface, the base of the seam, initially occupying the AOC position, goes into AO'S. Therefore, the segment CO is equal to the segment CO ', and the angle OAC = O'AC $= \gamma_1$, hence the angle between the vectors $F_{3_{TP}}$ and $F_{3_{TP1}}$ in the ABD plane will also be equal to γ_1...

Then, respectively, the forces of friction against the tooth $F_{3_{TP1}}$ and $F_{3_{TP2}}$ would be equal:

$$F_{3_{TP1}} = F_{3_{TP}} \cdot cos\gamma_1 \quad (15)$$

$$F_{3_{TP2}} = F_{3_{TP}} \cdot \sin\gamma_1 \quad (16)$$

Substituting formulas (15) and (16) into expression (14), we obtain:

$$F_{3_{TPX}} = F_{3_{TP}} \cdot \cos^2\gamma_1 + F_{3_{TP}} \cdot \cos\zeta_1 \cdot \sin^2\gamma_1$$

or

$$F_{3_{TPX}} = F_{3_{TP}} \cdot (\cos^2\gamma_1 + \cos\zeta_1 \cdot \sin^2\gamma_1)$$

Oy axis: $F_{3_{TP1y}} = F_{3_{TP1}} \cdot \sin\gamma_1$

$$F_{3_{TP2y}} = F_{3_{TP2}} \cdot \cos\zeta_1 \cdot \cos\gamma_1$$

Resultant strength $F_{3_{TPy}}$ per axis Oy will be:

$$F_{3_{TPy}} = F_{3_{TP1y}} - F_{3_{TP2y}} = \\ = F_{3_{TP1}} \cdot \sin\gamma_1 - F_{3_{TP2}} \cdot \cos\zeta_1 \cdot \cos\gamma_1 \quad (17)$$

And taking into account equations (3.27) and (3.28) will take the form:

$$F_{3_{TPy}} = F_{3_{TP}} \cdot \cos\gamma_1 \cdot \sin\gamma_1 - \\ - F_{3_{TP}} \cdot \cos\zeta_1 \cdot \cos\gamma_1 \cdot \sin\gamma_1$$

or

$$F_{3_{TPy}} = F_{3_{TP}} \cdot \cos\gamma_1 \cdot \sin\gamma_1(1 - \cos\zeta_1) \quad (18)$$

Oz axis: $F_{3_{TP1z}} = 0 \qquad F_{3_{TP2z}} = -F_{3_{TP2}} \cdot \sin\zeta_1$

Resultant strength $F_{3_{TPz}}$ per axis Oz will be:

$$F_{3_{TPz}} = F_{3_{TP1z}} - F_{3_{TP2z}} = -F_{3_{TP2}} \cdot \sin\zeta_1 \quad (19)$$

Taking into account formula (15), the equation will take the form:

$$F_{3_{TPz}} = -F_{3_{TP2}} \cdot \sin\zeta_1 \cdot \sin\gamma_1 \quad (20)$$

After the projections of the forces N3 and $F_{3_{TP}}$, we determine the force of static pressure on the surface of the loosening tooth N3G, which is due to the weight of the layer located on the surface of the loosening tooth. In a state of equilibrium, the following forces act on the soil layer: the weight of the soil layer G3 on the loosening tooth; normal reaction of the working surface N3; friction force $F_{3_{TP}}$ soil on the working surface; backing force Q3G from the front of the wedge of untreated soil. The Q3G force will be located in a horizontal plane parallel to the xOy plane (Figure 7).

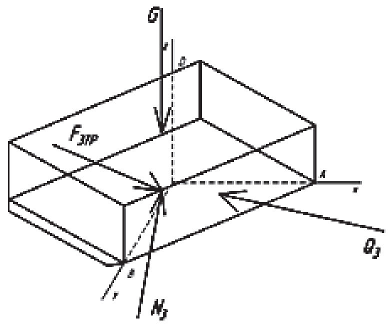

Figure 7. Scheme for determining force N_3

Let's project the forces acting on the soil layer onto the Oz axis:

$$\sum F_{3_z} = 0 \quad -G_3 + N_{3z} - F_{3_{TPz}} = 0 \quad (21)$$

Substituting formulas 3.23 and 3.33 into the resulting expression, we get:

$$-G_3+N_3\cdot cos\zeta_1 - \\ - F_{з_{TP2}}\cdot\sin\zeta_1\cdot\sin\gamma_1 = 0 \quad (22)$$

Then, the weight of the soil layer on the loosening tooth will be determined as: G_3

$$G_3 = N_3\cdot cos\zeta_1 - F_{з_{TP2}}\cdot\sin\zeta_1\cdot\sin\gamma_1 \quad (23)$$

Considering that $F_{з_{TP}} = N_3\cdot f$ we get:

$$G_3 = N_3\cdot cos\zeta_1 - N_з\cdot f\cdot\sin\zeta_1\cdot\sin\gamma_1 = \\ = N_3\cdot(cos\zeta_1 - f\cdot\sin\zeta_1\cdot\sin\gamma_1) \quad (24)$$

Where does the normal reaction come from? N_3:

$$N_{3G} = \frac{G_3}{cos\zeta_1 - f\cdot\sin\zeta_1\cdot\sin\gamma_1} \quad (25)$$

Then the friction force of the soil on the working surface of the loosening tooth $F_{з_{TP}}$ defined by the expression:

$$F_{з_{TP}} = \frac{f\cdot G_3}{cos\zeta_1 - f\cdot\sin\zeta_1\cdot\sin\gamma_1} \quad (26)$$

Respectively:

$$N_{3Gx} = \frac{G\ \cdot\sin\zeta_1\cdot\sin\gamma_1}{cos\zeta_1 - f\cdot\sin\zeta_1\cdot\sin\gamma_1} \quad (27)$$

$$F_{з_{TPGx}} = \frac{f\cdot G\cdot(\cos^2\gamma_1 + \cos\zeta_1\cdot\sin^2\gamma_1)}{cos\zeta_1 - f\cdot\sin\zeta_1\cdot\sin\gamma_1} \quad (28)$$

Formation weight G is defined as:

$$G = V\cdot\gamma_{об}, \quad (29)$$

where V - the volume of the cut soil layer, m^3; $\gamma_{об}$ - volumetric weight of soil, N/m^3.

The volume of the soil layer V is found from its geometric parameters:

$$V = \frac{b\cdot a\cdot l_a}{2\cdot\sin\gamma_1}, \quad (30)$$

where: b is the width of the loosening tooth, m; a - depth of tillage, m; l_a is the length of the blade of the working body at a given depth, m.

Then the weight of the bed G will be equal to:

$$G = \frac{b\cdot a\cdot l_a\cdot\gamma_{об}}{2\cdot\sin\gamma_1}, \quad (31)$$

The value of the component of the traction resistance of the loosening tooth, depending on the weight of the formation:

$$R_{3Gx} = b\cdot a\cdot l_a\cdot\gamma_{об}\cdot \frac{\sin\xi_1 + f\cdot\sin\gamma_1\cdot(ctg^2\gamma_1 + \cos\xi_1)}{2\cdot\cos\xi_1(1 - f\cdot tg\,\xi_1\cdot\sin\gamma_1)}, \quad (32)$$

where is the length of the blade of the working body at a given depth, m; γob l_a –volumetric weight of soil, N/m^3; f is the coefficient of friction of the soil against steel.

The traction resistance of the loosening tooth, depending on the dynamic pressure, will be

$$R_{3Fx} = b\cdot a\cdot v^2\,\frac{\gamma_{об}}{2\cdot g}\cdot \sin^2\gamma_1\cdot\frac{\sin\xi_1 + f\cdot\sin\gamma_1\cdot(ctg^2\gamma_1 + \cos\xi_1)}{ctg\,\xi_1 - f\cdot\sin\gamma_1}, \quad (33)$$

where: v - speed of movement of the combined opener of the seeder-cultivator, m/s; b - bed width, m; g - free fall acceleration, m/s^2.

To determine the resistance of the soil to deformation R3D by a loosening tooth, let us assume that this force is proportional to the cross-sectional area of the formation:

$$R_{x3Д} = k_1\cdot a\ \cdot(r\cdot sin\,\varphi\ \ + l_л\,sin\gamma_1), (13)$$

where k –coefficient taking into account the properties of the soil and the geometric shape of the loosening tooth; a– bed height, m; φ– angle of friction of the soil on the loosening tooth, deg.

Resistance of a loosening tooth, depending on the resistance of the soil to compression by the back of the head of a blunt blade

$$R_{x3C} = \lambda_1\cdot G_м\cdot \sin\gamma_1\cdot\frac{\sin\mu_3 + f\cdot\sin\gamma_1\cdot(ctg^2\gamma_1 + \cos\mu_3)}{\cos\mu_3 - f\cdot sin\,\gamma_1\cdot sin\,\mu_3}, (34)$$

where: λ_1 - coefficient taking into account the pressure of the seeder-cultivator on the loosening tooth; μ_3 - occipital angle, deg.

Thus, the traction resistance of the loosening tooth of the combined opener of the seeder-cultivator can be represented as:

$$R_{X3} = 2\cdot(b\cdot a\cdot l_a\cdot\gamma_{об}\cdot \frac{sin\,\xi_1 + f\cdot sin\,\gamma_1\cdot(ctg^2\gamma_1 + cos\xi_1)}{2\cdot cos\,\xi_1(1 - f\cdot tg\,\xi_1\cdot sin\,\gamma_1)} + b\cdot a\cdot v^2\,\frac{\gamma_{об}}{2\cdot g}\times \\ \times sin^2\gamma_1\cdot\frac{sin\,\xi_1 + f\cdot sin\,\gamma_1\cdot(ctg^2\gamma_1 + cos\xi_1)}{ctg\,\xi_1 - f\cdot sin\,\gamma_1} + k\cdot h\cdot (sin\,\varphi_1\,r + l_л\,sin\gamma_1) + \quad +\lambda_1\cdot \\ G_м\times sin\,\gamma_1\cdot\frac{sin\,\mu_3 + f\cdot sin\,\gamma_1\cdot(ctg^2\gamma_1 + cos\,\mu_3)}{cos\,\mu_3 - f\cdot sin\,\gamma_1\cdot sin\,\mu_3} (35)$$

Making similar calculations with the parameters of the lancet paw, taking into account that the angle of friction of the soil along the loosening tooth φ is equal to the angle of friction of the soil along the lancet paw and their occipital angles are equal, it is possible to obtain a dependence that allows us to estimate the traction resistance of the lancet paw, which looks like: μ_3:

$$R_{Хл} = b_2 \cdot a \cdot l_{2а} \cdot \gamma_{об} \cdot \frac{\sin\xi_2 + f \cdot \sin\gamma_2 \cdot (ctg^2\gamma_2 + \cos\xi_2)}{2 \cdot \cos\xi_2 (1 - f \cdot tg\,\xi_2 \cdot \sin\gamma_2)} + \ +b_2 \cdot a \cdot v^2 \ \frac{\gamma_{об}}{2 \cdot g} \cdot \sin^2\gamma_2 \cdot \frac{\sin\xi_2 + f \cdot \sin\gamma_2 \cdot (ctg^2\gamma_2 + \cos\xi_2)}{ctg\,\xi_2 - f \cdot \sin\gamma_2} + k_2 \cdot a \frac{b_2}{2} + +\lambda_2 \cdot G_м \times \sin\gamma_2 \cdot \frac{\sin\mu_3 + f \cdot \sin\gamma_2 \cdot (ctg^2\gamma_2 + \cos\mu_3)}{\cos\mu_3 - f \cdot \sin\gamma_2 \cdot \sin\mu_3}, \quad (36)$$

where: b_2 - bed width, m; $l_{2а}$ - length of the blade of the working body at a given depth, m; - angle of crumbling of the lancet paw, degrees; $\xi_2\gamma_2$ - wing opening angle of the lancet paw, degrees; k_2 - coefficient taking into account the properties of the soil and the geometric shape of the duckfoot; λ_2 - coefficient taking into account the pressure of the seeder-cultivator on the duckfoot share; μ_3 - occipital angle, deg.

CONCLUSIONS

Calculations have established that the use of a combined opener with a loosening tooth 0.02 m wide, installed at a distance from the toe of the lancet paw to the toe of the loosening tooth 0.07 m and a working depth of 0.06 m, will reduce the traction resistance of the opener from 1.18 to 1 , 13 kN.

REFERENCES

Shumaev, V.V. (2020). Investigation of the grain seeder opener operation for environmental friendly technologies of crops production/ V.V. Shumaev, A.V. Polikanov, Yu.N. Kulikova, A.A. Nuts. *Scientific Papers. Series A.Agronomy*, *63*(1), 527–532.

Kukhmazov, K.Z. (2020). Harvesting flat crops with minimal loss/ K.Z. Kukhmazov, V.V. Shumaev, S. Gubsky, A. Malyshev *Scientific Papers. Series A. Agronomy*, *63*(1), 653–658.

Kalabushev, A.N. (2018). Laboratory research of the combined opener for multilevel sowing of grain crops and fertilization/ A.N. Kalabushev, N.P. Laryushin, V.V. Shumaev. *Science in central Russia*, *3*(33), 21–28.

Kalabushev A.N. (2019). Theoretical calculation of some parameters of the combined coulter/ A.N. Kalabushev, N.P. Laryushin, V.V. Shumaev. *Niva Volga Region*, *1*(50), 151–156.