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Traction resistances of the cotton seeder moulder

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Abstract. The purpose of the study is to determine and analyze the traction resistance of the cotton seeder moulder. The moulder of the cotton seeder consists of a visor, two side dumps and a straight part. The forces acting on the elements of the comb shaper are considered. The basic principles and methods of classical mechanics, mathematical analysis and statistics were used in this study. Analytical dependences for determining the traction resistance of the moulder depending on their design parameters are obtained. It is established that the traction resistance of the moulder movement depends on the physical and mechanical properties of the soil, the depth of its penetration into the soil, the length of the skids, the width of the input edge of the skids and the angles of installation of the side dumps of the moulder. With the optimal parameters of the moulder, the traction resistance of the sowing unit will increase by 0.6-0.8 kN, which practically does not affect the operation of the sowing unit.

1. Introduction

Effective use of the country's soil resources based on the introduction of scientifically based, advanced technologies and new competitive technical means is one of the most promising areas of agricultural development. At the same time, it is important to ensure energy saving in the processes of interaction of working bodies with the soil. The study of the processes of interaction of working bodies with the soil and the determination of their traction resistance was carried out by R.Blevins and W.Frye [1], M.Jamaletdinov [2], G.Sineokov [3], F.Mamatov [4, 5], U.Kodirov [6, 13], A.Engdawork and H.Bork [7], H.Ravshanov [8-9, 13], D.Chuyanov [10], P.Burchenko [11], Fayzullayev Kh [12, 15], N.Aldoshin [14], Sh.Mirzakhodjaev [16] and others. The study of seeders in Uzbekistan was carried out Y.Lobachevski [17], S. Asoegwu [18], K.Astanakulov [19] and others. These studies do not address the energy intensity of the process of forming ridges by the moulder.

The purpose of the study is to determine and analyze the traction resistance of the cotton seeder moulder.

2. Methods

The traction resistance of the moulder (Figure 1) consists of the resistance of its visor, two side dumps and a straight part, that is

$$P_x = R_{1x} + 2R_{3x} + R_{px} + R_{nx} + R_{2x}, \tag{1}$$

where R_{1x} – is the horizontal component of the soil resistance to the visor; R_{3x} – is the horizontal component of the soil resistance on the surface of the side dumps; R_{px} – is the horizontal component of the soil resistance to the front faces of the dump; R_{nx} – is the horizontal component of the soil resistance to the lower faces of the moldboard; R_{2x} – is the horizontal component of the soil resistance to the upper part of the moldboard.
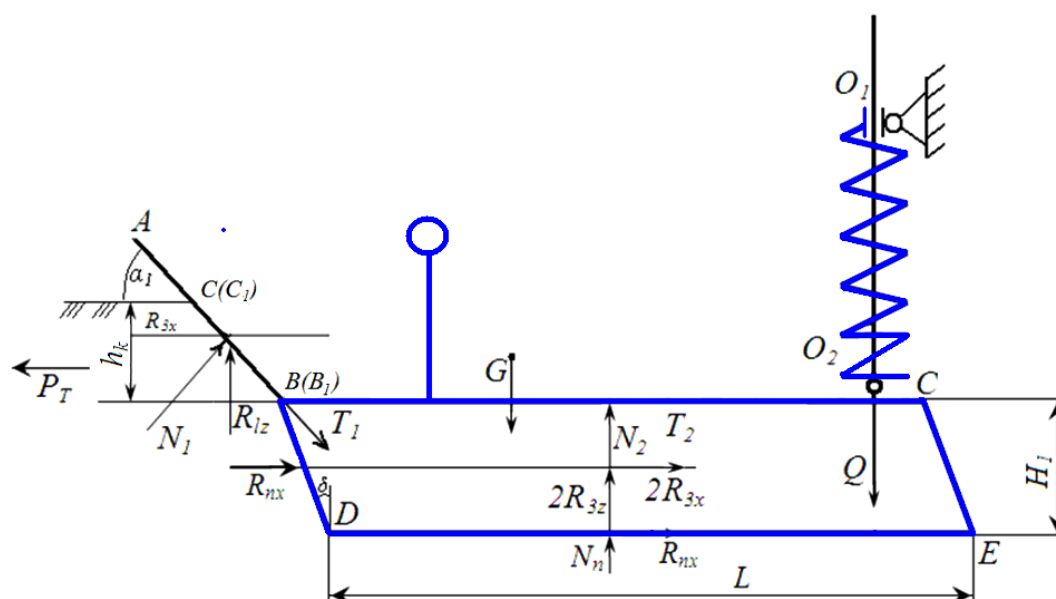

Figure 1. Diagram of forces acting on the moulder in the longitudinal-vertical plane

The molder's visor compacts the soil layer with a height of h_k (Figure 1), resulting in a reactive force R_1. If we assume that the resistance of the soil to crumpling is proportional to the amount of deformation, then the plot of normal soil pressures on the working surface of the visor will have the shape of a triangle. The maximum value of the specific pressure of the soil p at point B. $p = qhk$, where q_0 is the coefficient of static volumetric crumpling of the soil, N/m³; h_k – is the thickness of the soil layer crushed by the visor, m. The resultant of the elementary normal forces of soil resistance on the working surface of the visor

$$N_1 = F_P/2, \tag{2}$$

where F – is the area of the peak; $CC_1B_1B_2$ – is in contact with the soil.

$$F = \frac{h_k \left(B \sin \alpha_1 - h_k ctg \varepsilon \right)}{\sin^2 \alpha_1}, \tag{3}$$

where B – is the width of the base of the visor; α_1 – is the angle of installation of the visor, deg; ε – is the angle of inclination of the side face of the visor to its base, deg.

Substituting the value of F in the expression (3) and $p = qh$ in (2) we get
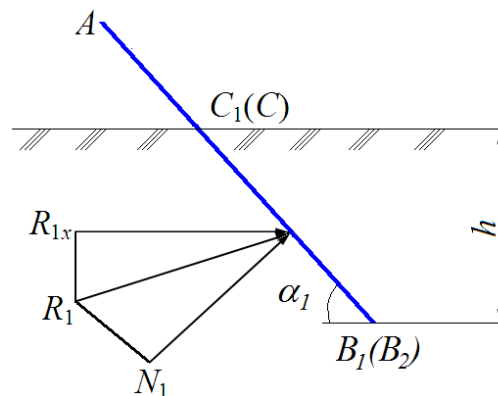
Figure 2. Forces acting on the visor

$$N_1 = \frac{h_k^2 q(B \sin \alpha_1 - h_k ctg\varepsilon)}{2 \sin^2 \alpha_1}, \qquad (4)$$

$$T_1 = fN_1 = N_1 tg\varphi. \qquad (5)$$

The value of the resultant of the normal and tangential forces of soil resistance overcome by the visor R_1, deviated from the normal force N_1 by the angle of friction φ, can be determined by the formula

$$R_1 = \frac{Bh^2 q \sin \alpha_1 - h_k^3 qctg\varepsilon}{2 \sin^2 \alpha_1 \cos \varphi}. \qquad (6)$$

The horizontal R_{1x} component of this force is equal to

$$R_{1x} = \frac{(Bh_k^2 q \sin \alpha_1 - h_k^3 qctg\varepsilon) \sin(\alpha_1 + \varphi)}{2 \sin^2 \alpha_1 \cos \varphi}, \qquad (7)$$

The side dumps of the moulder are compacted by a layer of soil with a height of h_1 (Figure 1), resulting in a reactive force R_3. At the same time, we also assume that the resistance of the soil to crumpling is proportional to the amount of deformation and the plot of normal soil pressures on the working surface of the side dumps of the shaper will have the shape of a triangle. The maximum value of the specific pressure of the soil at the point with $p=qh_1$, where h_1 – is the thickness of the soil layer crushed by the side blade.

Resultant of the elementary normal forces of soil resistance on the working surface of the side moldboard

$$N_3 = F_b p/2, \qquad (8)$$

where F_b – is the area of the side dump.
From Figure 1 we have

$$F_b = \frac{(B-b)H_1}{4 \sin \alpha}. \qquad (9)$$

where B and b – are the width of the input output edge of the moulder, m; H_1 – is the height of the moulder, m.
Substituting the values of F and $p=qh_1$, in (9), we get

$$N_3 = \frac{(B-b)^2 qH_1}{8 \sin \alpha}. \qquad (10)$$

Each side part of the moulder acts on the soil as a three-sided wedge. Therefore, when determining the resultant normal and tangential forces of soil resistance on side dumps, it is advisable to take into account the effect of normal forces and friction forces separately.

Let's define the projection force N_3 on the coordinate axis (Figure 3a):

$$N_{3x} = N_3 \sin \beta_y \sin \alpha = \frac{(B-b)^2}{8} q H_1 \sin \beta_y. \tag{11}$$

To determine the projections on the axes lay the friction force T_3 into two components: T_{3p} – parallel to the bottom face of the blade and T_{3r} – perpendicular to the bottom face of the blade (Figure 3b).

The projection of force T_{3p} on the x-axis is equal to $T_{3p}\cos\delta$, and power T_{3r} equal $T_{3r}\cos\beta_y\sin\delta$, so $T_{3x}= T_{3p}\cos\delta + T_{3r}\cos\beta_y\sin\delta$, $T_{3p} = T_3\cos\delta$, but $T_{3p} = T_3\cos\delta$ и $T_{3r} = T_3\sin\delta$.

Therefore

$$T_{3x}=T_3(\cos^2\delta+\sin^2\delta\cos\beta_y) . \tag{12}$$

Replacing T_3 with fN_3 in these expressions we get

$$T_{3x}= fN_3 (\cos^2\delta+\sin^2\delta\cos\beta_y).$$

Taking into account the above, we will determine the total resistance of the right and left side dumps
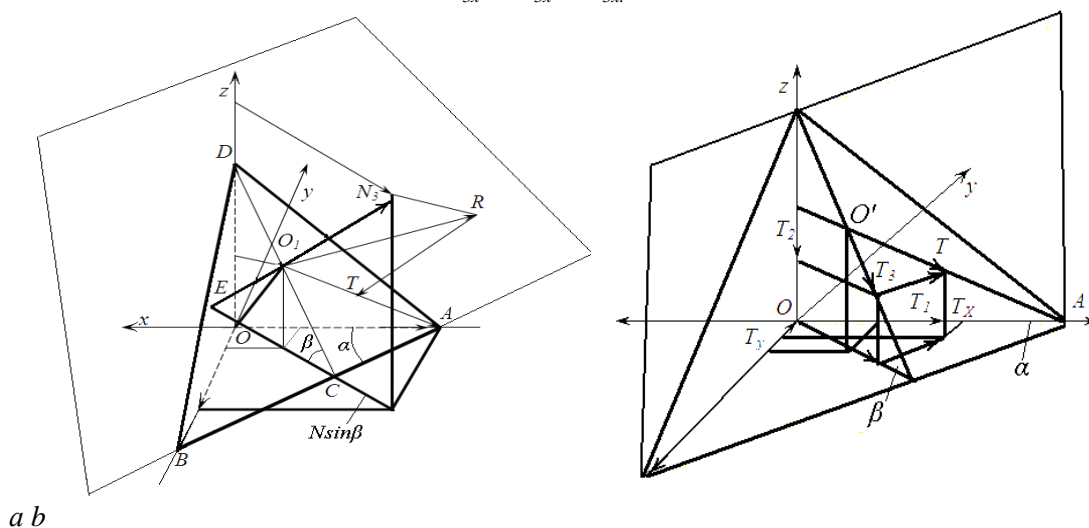
$$R_{3x}=2N_{3x}+2T_{3x}.$$

$a \quad b$

Figure 3. Scheme for determining the projections on the coordinate axis of the force N_3 and N_3

Substituting the value of N_{3x} and T_{3x} in (12) we get

$$R_{3x} = \frac{(B-b)^2}{8} q H_1 (\sin \beta + fctg\alpha \cos \alpha + f \sin \alpha \cos \beta). \tag{13}$$

The value of the resultant normal and tangential forces of soil resistance acting on the front faces of the mold blade can be determined by the following formula

$$R_r = \frac{2ptH_1}{\cos^2 \delta}, \tag{14}$$

where t – is the thickness of the mold blade; δ – is the angle of inclination of the front face of the blade to the vertical.

Since $\delta<\varphi$, the horizontal component of this force is

$$R_{px} = R_p = \frac{2ptH_1}{\cos^2 \delta}. \tag{15}$$

The value of the resultant normal and tangential forces of soil resistance acting on the lower faces of the moldboard can be determined by the following formula

$$R_n = \frac{2N_n}{\cos \varphi} = \frac{2L_1 t_r}{\cos \varphi}, \tag{16}$$

where N_n – is the normal force on the lower face of the blade, $N_n = L_1 t_r$ (17)
The horizontal R_{nx} component of this force is equal to

$$R_{nx} = 2T_n = 2N_n tg\varphi = 2L_1 t_r tg\varphi. \tag{18}$$

The value of the resultant normal and tangential forces of soil resistance acting on the straight part of the mold can be determined by the following formula

$$R_2 = \frac{N_2}{\cos \varphi} = \frac{(B+b)L_1 r}{2\cos \varphi}, \tag{19}$$

where N_2 – is the normal force on the straight part of the shaper.
The horizontal component of this force R_{nx} is equal to

$$R_{2x} = T_2 = N_2 tg\varphi = \frac{(B+b)}{2} L_1 rtg\varphi. \tag{20}$$

Substituting the values of R_{1x}, R_{3x}, R_{nx}, $R_{нx}$ and R_{2x} in (1) we get

$$P_x = \frac{(Bh_k^2 q \sin \alpha - h_k^3 qctg\varepsilon)\cos(\alpha + \varphi)}{2\sin^2 \alpha \cos \varphi} + \frac{(B-b)^2 qH_1(\sin \beta_y + fctg\alpha \cos \alpha + f \sin \alpha \cos \beta_y)}{4} +$$

$$+ \frac{2r_t H_b}{\cos^2 \delta} + 2L_1 t_r tg\varphi + \frac{(B+b)}{2} L_1 rtg\varphi. \tag{21}$$

The influence of the speed of movement on the traction resistance of the moulder can be determined taking into account the following formula [28]

$$q = q_0(1 + K_V V), \tag{22}$$

where q_o – is the coefficient of volumetric crumpling of the soil at a speed of movement close to 1 m/s; K_V – is the coefficient that takes into account the influence of the speed of movement on the coefficient of volumetric crumpling of the soil.
Taking into account (22), the dependence (21) has the following form

$$P_x = \frac{q_o(1 + K_v V)(Bh_k^2 \sin \alpha_1 - h_1^3 ctg\varepsilon)\cos(\alpha_1 + \varphi)}{2\sin^2 \alpha \cos \varphi} +$$

$$+ \frac{(B-b)^2(1 + K_v V)q_0 H_1(\sin \beta_y + fctg\alpha \cos \alpha + f \sin \alpha \cos \beta_y)}{4} + \frac{2rtH_o}{\cos^2 \delta} + \tag{23}$$

$$+ 2L_1 t_r tg\varphi + \frac{(B+b)}{2} L_1 rtg\varphi.$$

From the analysis of this expression, it follows that the traction resistance of the moulder depends on its parameters and the physical and mechanical properties of the soil (q_0, φ, p). Calculations performed according to (23) at B=0.283-0.323 m, H_1=0.1 m, h_k=0.02 m, φ=25^0, α=15^0, K_v=1, V=1.2-1.4 m/s, β_1=22^0, β=42^0, b=0.16m, L=0.21 m, q_0=1.64·10^{3}N/m^3, δ=20^0, ε=45^0, t=0.0025 m showed that the traction resistance of the working body is 160-180 N.

3. Results and Discussion

The traction resistance of the moulder was determined by strain measurement in the soil channel of the Research Institute of Mechanization and Electrification of Agriculture (NIIMESH) Uzbekistan. At the same time, the layout of the moulder with a changing angle of installation of the side dumps was installed on a special load baler.

During the traction tests, the soil moisture and density were 11.2-13.3% and 1.0-1.2 g/cm^3, respectively. The moulder was installed at a stroke depth of 100 mm.

The results of the experiments showed that the increase in the width of the input edge of the slide and the load on it leads to a proportional increase in the traction resistance of the shaper. For example, with an increase in the width of the input edge from 160 mm to 320 mm at a load of 0.05 kN, the traction resistance of the moulder increases 2.5 times, and at a load of 0.2 kN – 2.58 times. With an increase in the load from 0 to 0.2 kN with a width of the input edge of 160 mm, the traction resistance of the moulder increases 3.24 times, and with a width of the input edge of 320 mm, 3.47 times. On average, at the optimal parameters of the moulder, its traction resistance is 0.15-0.20 kN, Therefore, at the optimal parameters of the moulder, the traction resistance of the sowing unit will increase by 0.6-0.8 kN, which practically does not affect the operation of the sowing unit.

4. Conclusions

The obtained analytical dependences showed that the traction resistance of the moulder movement depends on the physical and mechanical properties of the soil, the depth of its penetration into the soil, the length of the skids, the width of the input edge of the skids and the angles of installation of the side dumps of the moulder.

Therefore, with the optimal parameters of the moulder, the traction resistance of the sowing unit will increase by 0.6-0.8 kN, which practically does not affect the operation of the sowing unit.

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