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Ways to Reduce the Negative Effects of the Comparative Resistance of the Soil and the Aggregate Speed of Movement on the Stable Walk of Mounted Plow in Terms of Driving Depth

Rasuljonov Abdurakhmon Ravshanbek ugli
Philosophy of Doctor, s.s.e.

Rasulov Azamat Davranovich
Philosophy of Doctor, docent.

Abstract: The article presents the ways to reduce the negative effects of the comparative resistance of the soil and aggregate speed of movement on the stable walk of mounted plow designed for wheel drive tractors in terms of driving depth. According to the results of the conducted theoretical studies, when the vertical distance between the lower suspension points of the suspension device from the base plane of the plow is 0.65 m, the driving depth is reduced by 0.36-1.52 cm with the increase in the specific resistance of the soil and the speed of aggregate movement. When this distance is 0.80 m, it is reduced by 0.12-0.70 cm, that is, the stability of driving depth is improved.
Keywords: suspension plow, support wheel, the vertical distance between the lower suspension points of the suspension device from the base plane of the plow, the relative resistance of the soil to plowing and the speed of aggregate movement.

INTRODUCTION. It is known from the literature [1-5] that the following condition must be met in order for the suspended plow to sink to a specified depth and run stably (uniformly) at this depth:

$$Q_Z > 0, \qquad (1)$$

where Q_Z – the vertical pressure force exerted on the soil by the support wheel of the plow, kN.

When this condition is met, the base wheel of the plow is constantly pressed against the field surface, as a result, the plow sinks to the specified depth and works without changing the driving depth [6-14].

In addition, the vertical pressure force of the plow support wheel on the soil should have a certain acceptable value [1, 2, 4, 6], i.e.

$$Q_Z = Q_M, \qquad (2)$$

where Q_M – the optimal value of the vertical pressure force applied to the soil by the support wheel of the plow, which ensures the stability of the working (driving) depth, kN.

In the case of $Q_Z < Q_M$, the plow's support wheel cannot adequately adjust to the unevenness of the field surface, and in the case of $Q_Z > Q_M$, too much energy is used to pull the plow. Figure 1 shows a diagram of the forces acting on the suspension plow during operation.

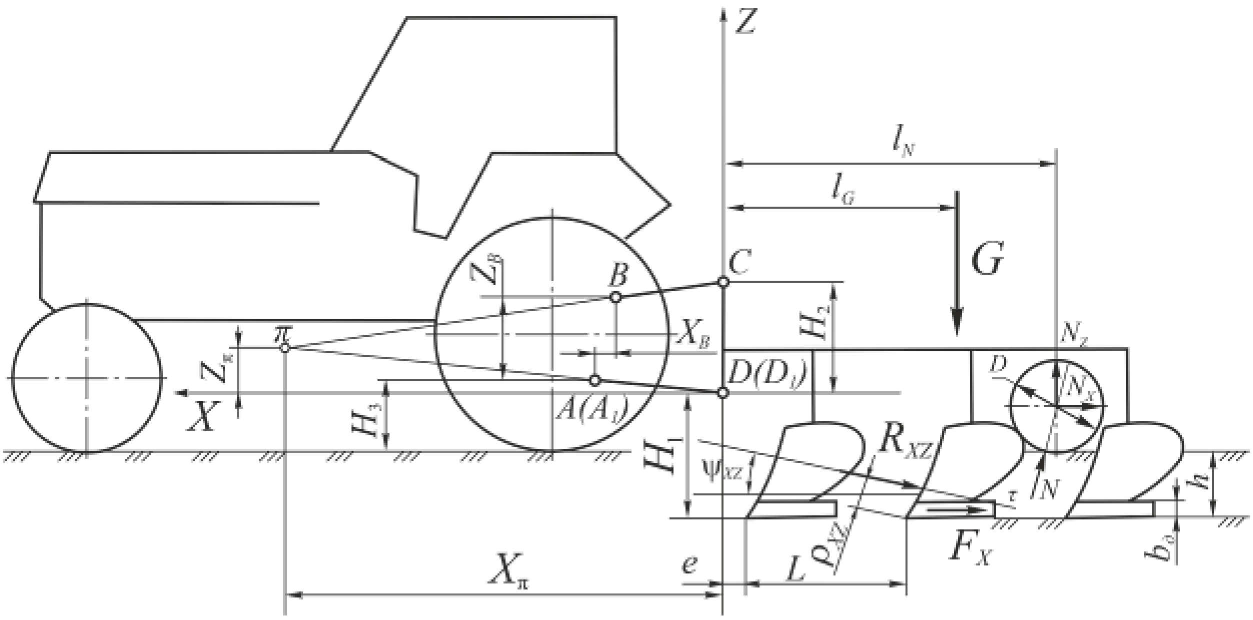

Figure 1. Scheme of the forces acting on the plow during operation

Materials and methods. When condition (2) is satisfied, the actual driving depth of the plow can be expressed as:

$h_x = h + h_0$, (3)

where h_0 –the depth of immersion of the plow support wheel into the ground during work, m.

As it is known from the literature [15], the depth of plow support wheel immersion in the soil during work is determined as follows (Fig. 2):

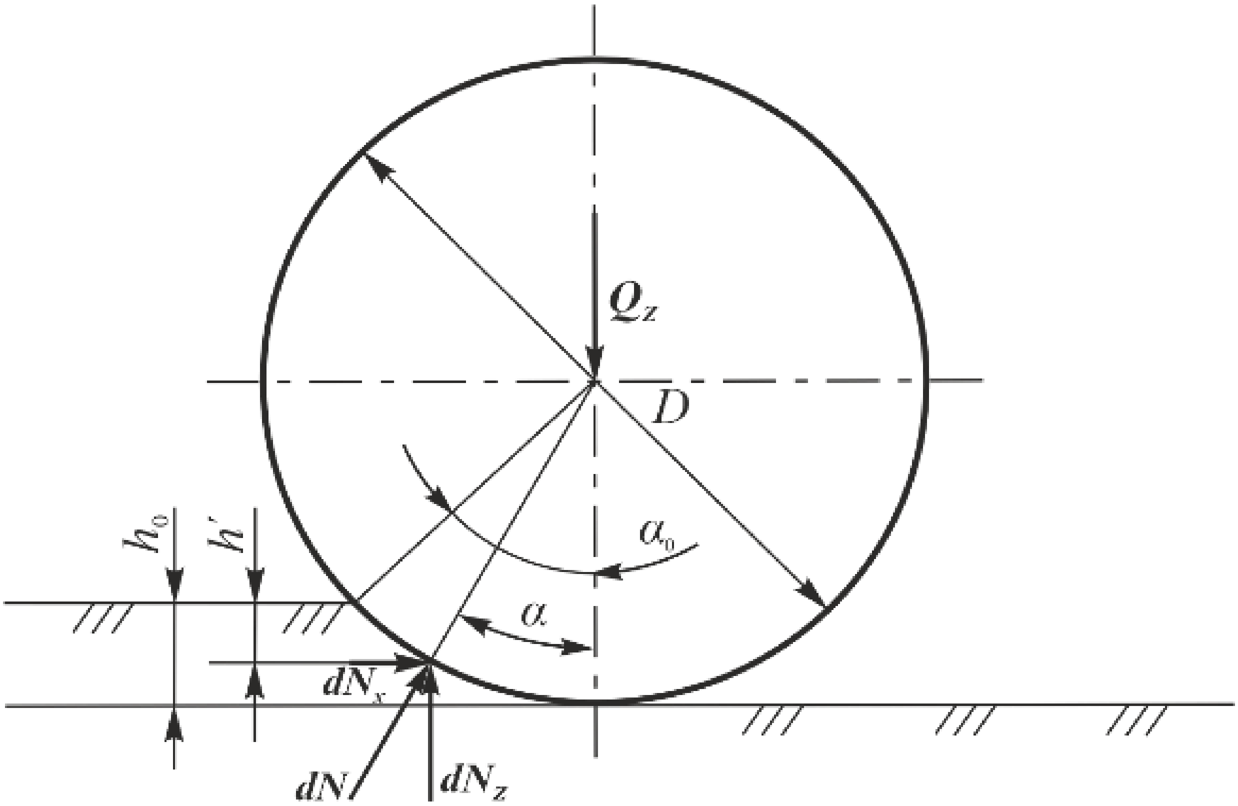

Figure 2. The scheme for determining the depth of immersion of the plow support wheel into the soil

$$h_0 = \left(\frac{9Q_Z^2}{4B_m^2 q_0^2 D} \right)^{\frac{1}{3}}. \qquad (4)$$

where B_m – the width of the axle of the plow support wheel, m; q_0 – static volume compression coefficient of the soil, N/m^3; q_0 – the diameter of the plow support wheel, m.

Taking into account previous theoretical studies [7, 8], expression (4) has the following form:

$$h_0 = \left(\frac{9}{4B_m^2 q_0^2 D} \right)^{\frac{1}{3}} \left\{ \left\{ n \left[m_k g + \left(k + \varepsilon V^2\right) b_k h tg\psi_{XZ} \right] \times \right. \right.$$

$$\times \frac{H_2 \sqrt{l_б^2 - 0,25(l-c)^2 - \left(H_3 + h - H_1\right)^2} \left[\sqrt{l_б^2 - 0,25(l-c)^2 - \left(H_3 + h - H_1\right)^2} - X_B \right]}{\left(H_2 - Z_B\right)\sqrt{l_б^2 - 0,25(l-c)^2 - \left(H_3 + h - H_1\right)^2} - \left(H_3 + h - H_1\right) X_B} -$$

$$-\frac{7}{6}\left(k + \varepsilon V^2\right) n b_k h \frac{H_2\left(H_3 + h - H_1\right)\left[\sqrt{l_б^2 - 0,25(l-c)^2 - \left(H_3 + h - H_1\right)^2} - X_B \right]}{\left(H_2 - Z_B\right)\sqrt{l_б^2 - 0,25(l-c)^2 - \left(H_3 + h - H_1\right)^2} - \left(H_3 + h - H_1\right) X_B} +$$

$$+ n \left\{ m_k g \left(e + \frac{n-1}{2} L \right) + \left(k + \varepsilon V^2\right) b_k h \left[\left(e + \frac{n-1}{2} L + \frac{\rho_{XZ}}{\sin\psi_{XZ}} \right) tg\psi_{XZ} - \frac{7}{6} H_1 + \frac{1}{12} b_д \right] \right\} \right\} :$$

$$: \left\{ \frac{H_2 \sqrt{l_б^2 - 0,25(l-c)^2 - \left(H_3 + h - H_1\right)^2} \left[\sqrt{l_б^2 - 0,25(l-c)^2 - \left(H_3 + h - H_1\right)^2} - X_B \right]}{\left(H_2 - Z_B\right)\sqrt{l_б^2 - 0,25(l-c)^2 - \left(H_3 + h - H_1\right)^2} - \left(H_3 + h - H_1\right) X_B} + \right.$$

$$+ \left[e + (n-1)L \right] + \mu \left\{ H_1 + \frac{H_2\left(H_3 + h - H_1\right)\left[\sqrt{l_б^2 - 0,25(l-c)^2 - \left(H_3 + h - H_1\right)^2} - X_B \right]}{\left(H_2 - Z_B\right)\sqrt{l_б^2 - 0,25(l-c)^2 - \left(H_3 + h - H_1\right)^2} - \left(H_3 + h - H_1\right) X_B} - \right.$$

$$\left. \left. \left. - h - 0,5D \right\} \right\} \right\}^{\frac{2}{3}}, \qquad (5)$$

where n – the number of cases installed on the plow, pcs; m_k – the mass of the plow per one body, kg; g – free fall acceleration, m/s^2; k – relative resistance of the soil to plowing, Pa; ε – coefficient that takes into account the effect of speed on drag, N s^2/m^4; V – the speed of movement of the plow, m/s^2; b_k – the coverage width of the plow housing, m; h – the driving depth of the plow, m; $\psi_{XZ} - R_{XZ}$ (R_{XZ} – equal effector of the forces acting on the ploughshares and tippers in the longitudinal-vertical plane, kN) is the angle of direction of the force relative to the horizontal, °; H_2 – the vertical distance between the lower and upper suspension points of the plow, m; $l_б$ – the length of the lower links of the tractor suspension mechanism, m; l – transverse distance between the lower suspension points of the plow, m; c – the transverse distance between the fixed hinges of the lower longitudinal drawbars of the tractor suspension mechanism, m; H_3 – the vertical distance from the tractor support plane to the fixed hinges $A(A_1)$ of the lower links of the suspension mechanism, m; H_1 – the vertical distance from the base plane of the plow to the lower suspension points, m; X_{π}, Z_{π} – horizontal and vertical distances from the lower suspension points of the plow $D(D_1)$ to its instantaneous center of rotation in the longitudinal-vertical plane, respectively, m; e – the longitudinal distance from the lower suspension points of the plow to the tip of the ploughshare of its first body, m; L – longitudinal distance between the bodies of the plow, m; ρ_{XZ} – the distance from the end of the ploughshare of the middle (conditional middle) body of the plow to the line of action of force R_{XZ}, m; $b_д$ – width (height) of plow field boards, m; μ – the rolling coefficient of the plow support wheel.

Considering the expression (5), (3) takes the following form:

$$h_x = h + \left(\frac{9}{4B_m^2 q_0^2 D} \right)^{\frac{1}{3}} \left\{ \left\{ n \left[m_k g + \left(k + \varepsilon V^2 \right) b_k h tg\psi_{XZ} \right] \times \right. \right.$$

$$\times \frac{H_2 \sqrt{l_б^2 - 0,25(l-c)^2 - \left(H_3 + h - H_1\right)^2} \left[\sqrt{l_б^2 - 0,25(l-c)^2 - \left(H_3 + h - H_1\right)^2} - X_B \right]}{\left(H_2 - Z_B\right) \sqrt{l_б^2 - 0,25(l-c)^2 - \left(H_3 + h - H_1\right)^2} - \left(H_3 + h - H_1\right) X_B} -$$

$$-\frac{7}{6}\left(k + \varepsilon V^2\right) n b_k h \frac{H_2 \left(H_3 + h - H_1\right) \left[\sqrt{l_б^2 - 0,25(l-c)^2 - \left(H_3 + h - H_1\right)^2} - X_B \right]}{\left(H_2 - Z_B\right) \sqrt{l_б^2 - 0,25(l-c)^2 - \left(H_3 + h - H_1\right)^2} - \left(H_3 + h - H_1\right) X_B} +$$

$$\left. \left. + n \left\{ m_k g \left(e + \frac{n-1}{2} L \right) + \left(k + \varepsilon V^2 \right) b_k h \left[\left(e + \frac{n-1}{2} L + \frac{\rho_{XZ}}{\sin\psi_{XZ}} \right) tg\psi_{XZ} - \frac{7}{6} H_1 + \frac{1}{12} b_д \right] \right\} \right\} :$$

$$: \left\{ \frac{H_2 \sqrt{l_б^2 - 0,25(l-c)^2 - \left(H_3 + h - H_1\right)^2} \left[\sqrt{l_б^2 - 0,25(l-c)^2 - \left(H_3 + h - H_1\right)^2} - X_B \right]}{\left(H_2 - Z_B\right) \sqrt{l_б^2 - 0,25(l-c)^2 - \left(H_3 + h - H_1\right)^2} - \left(H_3 + h - H_1\right) X_B} + \right.$$

$$+\left[e+(n-1)L\right]+\mu\left\{H_1+\frac{H_2\left(H_3+h-H_1\right)\left[\sqrt{l_б^2-0,25(l-c)^2-\left(H_3+h-H_1\right)^2}-X_B\right]}{\left(H_2-Z_B\right)\sqrt{l_б^2-0,25(l-c)^2-\left(H_3+h-H_1\right)^2}-\left(H_3+h-H_1\right)X_B}-\right.$$

$$\left.\left.\left.\left.-h-0,5D\right\}\right\}\right\}\right\}^{\frac{2}{3}}. \quad (6)$$

Results and discussion. This expression makes it possible to determine the extent to which the plowing depth and its stability are influenced by the relative resistance of the soil to plowing and the aggregate movement speed.

μ = 0.2; n = 3 dona, m_k = 300 kg/dona, g = 9.81 m/s^2, $k = 0.65\cdot10^5$ Pa, B_m = 0.2 m, $q_0 = 2\cdot10^7$ N/m^3, ε = 1500 Ns^2/m^4, V = 2 m/s, b_k = 0.45 m, h = 0.35 m, ψ_{XZ} = 12º; e = 0.62 m, L = 1.0 m, ρ_{XZ} = 0.15 m, $b_д$ = 0.2 m, D = 0.4 m and For wheel drive tractors of class 3-4, H_2 = 0.9 m, H_3 = 0.6 m, $l_б$ = 0.95 m, l = 1.04 m, c = 0.62 m, X_B = 0.3 m, Z_B = 0.56 m [26; 151-б.] being accepted. According to the expression (6) for the values H_1 = 0.65 m (for existing plows) and H_1 = 0.80 m (according to the results of previous theoretical studies) [7, 8] the change of plowing depth depending on the specific resistance of the soil to plowing and the speed of the aggregate was calculated.

It can be seen from the table that when H_1 = 0.65 m, the driving depth decreased by 0.36-1.52 cm with an increase in the specific resistance of the soil and aggregate movement speed, and by 0.12-0.70 cm when H_1 = 0.80 m decreased, i.e. 2-3 times smaller.

Conclusion. The results of the conducted theoretical studies showed that with an increase in the specific resistance of the soil and the speed of aggregate

Table. Variation of the driving depth depending on the specific resistance of the soil and the speed of aggregate movement

Relative soil resistance to plowing, 10^5 Pa	Driving depth, cm	Aggregate movement speed, m/s	Driving depth, cm
H_1 = 0.65 m		**H_1 = 0.65 m**	
0.4	36.75	1.5	36.32
0.6	36.36	2.0	36.14
0.8	35.89	2.5	36.06
1.0	35.23	3.0	35.96
H_1 = 0.80 m		**H_1 = 0.80 m**	
0.4	37.04	1.5	36.74
0.6	36.82	2.0	36.71
0.8	36.59	2.5	36.67
1.0	36.34	3.0	36.62

movement, the change in driving depth was 2-3 times less when the vertical distance between the lower suspension points of the suspension device from the base plane of the plow was 0.80 m compared to 0.65 m, that is, this distance has improved the stability of the driving depth of 0.80 m.

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