THEORETICAL RESEARCH OF TRACTIVE RESISTANCE OF ROTARY TYPE SEEDERS

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Abstract: *The use of modern methods of conservative farming requires an ever more in-depth study of the design of agricultural machinery, ensuring the high-quality execution of technological operations. The development of seeders for No-till, Mini-till and Strip-till technologies assumes theoretical and experimental studies of the working bodies of the designed seeder. At the same time it is necessary to prepare the feasibility study of its use, which in the conditions of market economy and various forms of land management is very important. This article is devoted to the substantiation of the tractive resistance of the seed drill's seeding section.*
KEYWORDS: ROTARY TYPE SEEDER, ROTARY SEED DRILL, RUNNER, TRACTIVE RESISTANCE, SEEDING SECTION.

Introduction

Conservative technologies are widely spread in the world. Therefore, the idea of protecting the soil by reducing the direct mechanical effects on the soil is more relevant than ever [1].
Modern technologies suppose not only advanced agricultural technology, but also new solutions for the realization of technological operations with minimal production costs and high quality. That is why the construction of agricultural machinery is in permanent improvement. In addition, new machines, new solutions and constructions are being developed.

Conservative technologies No-til, Mini-till, Strip-till etc. involve the use of agricultural machines with rotary disc working organs to perform agricultural work such as soil preparation for sowing, shredding and soil incorporation of vegetal remains and weed control [2]. But, it also applies to sowing machines, the rotary type of which essentially reduces the tractive resistance of the sowing unit.

At the same time, the production experience and long-term tests of row seeders, conducted at the Moldavian State Testing Station, showed that these seeders do not fulfill the requirements of ATR for uniformity of seeding in intervals in a row. The seeders do not reach the normative uniformity of seeding 24...35%. So, with an increase in working speeds the uniformity of seeding is reduced.

A wide use in the agricultural production of energy-saturated and high-speed tractors urgently requires the transfer of seeding technology to high speeds, but the problem of quality cultivation of row crops remains unresolved. At the moment, we need new principles for the technology for seeding row crops and new constructive solutions for the creation of planting technology. Improving the seeding technology and creating the seeding technique able to make the discrete sowing of the row crops at high speeds and with a high degree of planting uniformity at a given planting distance represents an urgent task [3].

Material and method

A promising area for improving technology and technique for sowing row crops is the sowing with rotary seed drills in which discrete seedbed formation with discrete seed laying is coordinated. To perform such sowing, it was developed a pneumatic rotary seed drill [3].

The seed wheel of a rotary seed drill is a support, transport and working element that ensures the implementation of the technological process. In the process, the wheel rotates and rolls due to the force of adhesion of the rim to the soil. The presence of runners on the wheel, creating additional rolling resistance, causes uneven sliding of the wheel rim over the soil.

The forces acting on the sowing wheel due to these factors are shown in Fig.1.

The amount of wheel slip is influenced by: load (G), determined by the mass of the sowing section, wheel radius (R), the length of the hole formers (a) and the physicomechanical properties of the soil. At the same time, assumptions were made: 1) the force Q applied to the tip of the runners is directed perpendicularly to the radius of the wheel on which the runner is located; 2) the depth of the track is insignificant and does not have a significant effect on the rolling process of the sowing wheel.

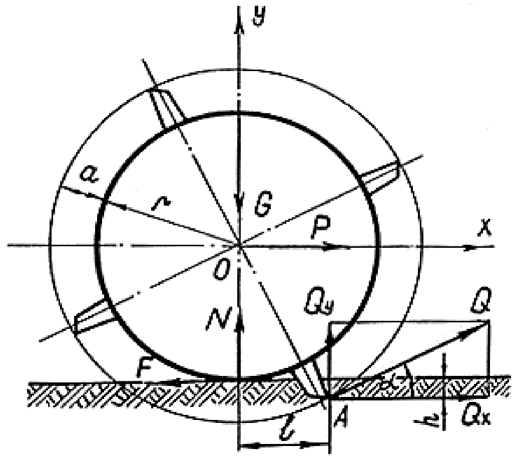

Fig.1. *The diagram of the forces acting on the land wheel of the seeder:*
G is the load on the wheel; N – the reaction of the soil to the wheel; F is the friction force; Q – the reaction of the soil to the runner; P – traction force of the tractor; r – the radius of the land wheel; a – length of the runner; h – the depth of the runner plunging into the soil.

Taking into account the accepted assumptions, the equations of forces and moments applied to the land wheel, at runner's plunging into the soil, are the following:

$$\sum_x = P - F + Q_x = 0 \quad (1)$$

$$\sum_y = N + Q_y - G = 0 \quad (2)$$

$$\sum_{M_o} = F \cdot r - Q(r + a) = 0 \quad (3)$$

The resistance of the rotary seed drill is due to the rolling of the impellers along the soil. The rolling process of the land wheel of the seed drill has two phases: rolling the wheel rim along the soil and rolling the wheel along the soil over the runner.

In the first rolling phase, wheel resistance is determined by the Granvuane-Goryachkin formula[4]:

$$P = 0{,}86\sqrt[3]{\frac{G^4}{k \cdot B \cdot D^2}} = 0{,}86\, k^{-\frac{1}{3}}\sqrt[3]{\frac{G^4}{B \cdot D^2}} \quad (4)$$

In which connection $k = \frac{9}{4}q$,

where: q - coefficient of volumetric soil compression;
G - total wheel load;
B - wheel rim width;
D - wheel diameter.

In the second rolling phase, additional resistance occurs, created by the runner. To determine it, we assume that the resistance consists of two resistances: resistance from pressing the rim into the soil (P_1) and resistance from the introduction of the runner and its movement in the soil (P_2):

$$P = P_1 + P_2. \quad (5)$$

Since these two forces are functionally interconnected, the total load on the land wheel during rolling is appropriately distributed between the rim and the runner.

The scheme of the forces acting on the land wheel remains the same as shown in Fig. 2, but with the replacement of the force P by (P_2) and equation (1) will have the following form:

$$\sum_x = P_2 - F + Q_x = 0 \quad (6)$$

From this equation

$$P_2 = F - Q_x \tag{7}$$

Further, from Fig.1 it follows that

$$Q_x = Qcos\alpha, \tag{8}$$

$$Q_y = Qsin\alpha. \tag{9}$$

where: $cos\alpha = \frac{r+h}{r+a}$, (10) $\sin\alpha = \frac{r+a}{r}$ (11)

Taking into account expression (10) and (11), from the equalities (8) and (3) we define the values of Q_x and F.

$$Q_x = Q\frac{r+h}{r+a} \tag{12}$$

$$Q_y = \frac{r+a}{r} \tag{13}$$

Substituting equations (12 and (13) into equation (6), we obtain:

$$P_2 = Q\frac{(r+a)^2-(r+h)}{r(r+a)} \tag{14}$$

After the transformations, we have:

$$P_2 = Q\frac{\frac{a^2}{r}+2a-h}{r+a} \tag{15}$$

The obtained equation determines the resistance force caused by the runner.

The track formed by the wheel rim is proportional to the force of the reaction N (Figure 1). So, according to equation (2), the load on the rim of the land wheel is expressed by the equation:

$$N = G - Q_e \tag{16}$$

Then using the Granvoyane-Goryachkin equation (4), the rolling resistance of the land wheel rim will be:

$$P_1 = 0{,}86\, k^{-\frac{1}{3}} \sqrt[3]{\frac{(G-Q_y)^4}{4B\cdot r^2}} \tag{17}$$

and taking into account expression (9), it will take the following form:

$$P_1 = 0{,}86\, k^{-\frac{1}{3}} \sqrt[3]{\frac{(G-Qsin\alpha)^4}{4B\cdot r^2}} \tag{18}$$

Thus, the total resistance of the drill's land wheel during rolling is determined by the expression:

$$P=0{,}86\, k^{-\frac{1}{3}} \sqrt[3]{\frac{(G-Qsin\alpha)^4}{4B\cdot r^2}} + Q\frac{\frac{a^2}{r}+2a-h}{r+a} \tag{19}$$

The force Q applied to the runner is determined by the following equation:

$$Q = q\cdot s\cdot h, \tag{20}$$

where: q - coefficient of bulk soil contortion;

s - cross –section area of the runner;

h - depth of the runner's penetration into the soil.

Substituting the equation (20) in equation (19) we get the final form of the equation of rolling resistance of the land wheel:

$$P=0{,}86\, k^{-\frac{1}{3}} \sqrt[3]{\frac{(G-Qsin\alpha)^4}{4B\cdot r^2}} + qsh\frac{\frac{a^2}{r}+2a-h}{r+a} \tag{21}$$

Rezults and discussions

From the obtained equation, it can be seen that, under determined conditions in the rolling phase of the wheel over the runner, rolling resistance varies according to a complex law, depending on the penetration of the runner into the soil.

The limiting values of the resistance force are determined from the condition:

$$0\leq h \leq a$$

$$P_{min}\,|_{h=0} = 0{,}86\, k^{-\frac{1}{3}} \sqrt[3]{\frac{(G-Qsin\alpha)^4}{4B\cdot r^2}} \tag{22}$$

$$P_{max}\,|_{\alpha=90^o}^{h=a} = qsh\frac{\frac{a^2}{r}+2a-h}{r+a} + 0{,}86\, k^{-\frac{1}{3}} \sqrt[3]{\frac{(G-Qsin\alpha)^4}{4B\cdot r^2}} \tag{23}$$

To determine the nature of the change in wheel resistance according to the data from Table 1, graphs of equation (23) are built, shown in Fig.2.

Table 1. *Values for calculating the resistance of the seeding section of a rotary seed drill*

Names of quantities	Symbols	Dimension	Values
Wheel radius	*r*	см	30
Land wheel rim's width	*B*	см	17
Runner's length	*a*	см	8
Cross-sectional area of the runner	*s*	$см^2$	12
Wheel load	*G*	Н	500
Coefficient of soil contortion	*q*	$Н/см^2$	2
Coefficient of the formula	*k*	$Н/см^2$	4,5

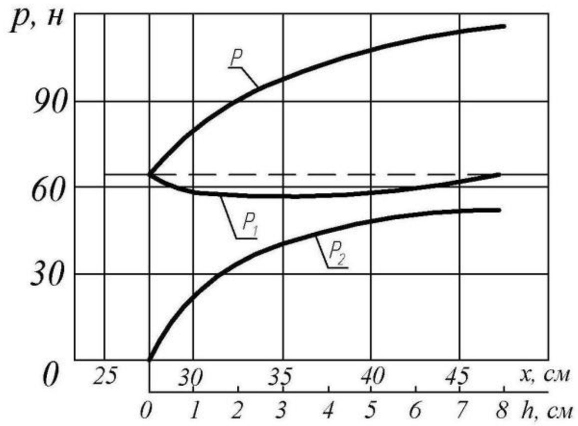

Fig. 2. *Tractive resistance of the section of a rotary seed drill: P_1 – rolling resistance of land wheel rim; P_2 – rolling resistance caused by the runner; P- total rolling resistance of the seed section.*

When building the graphs, it was taken into account that the resistance of the land wheel is simultaneously a function of the wheel displacement (x) and of the depth of the runner's penetration into the soil (h):

$$P = [xf(h)] \tag{24}$$

$$x = r\cdot\varphi \tag{25}$$

where φ - angle of the wheel rotation with respect to the horizontal diameter.

$$h = (r+a)sin\varphi \tag{26}$$

whence

$$\varphi = arcsin\frac{r+h}{r+a} \tag{27}$$

Therefore, the displacement of the land wheel, depending on the depth of the runner's penetration into the soil, is determined by the formula:

$$x = r\cdot arcsin\frac{r+h}{r+a} \tag{28}$$

As the results, the graphs show that the tractive resistance of the rotary seed drill for a complete revolution of the wheel is cyclical.

Conclusions

1. Tractive resistance of the section of a rotary seed drill depends on the mass, diameter and width of the land wheel rim, the length of the runners, the depth of their penetration into the soil and the physical and mechanical properties of the soil.

2. Tractive resistance of the rotary seed drill for a complete revolution of the wheel is cyclical: when rolling the wheel along the rim, the resistance is minimal; when it rolls over the runner, it increases and reaches its maximum value when the runner is completely plunged into the soil.

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