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DETERMINING OF THE PARAMETERS FOR MOVEMENT ON A VACUUM SOWING APPARATUS OF SEEDER SECTION FOR PNEUMATIC PRECISION SEED DRILL

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Abstract

The parameters necessary for driving the working bodies from the sowing section of the precision seed drill are substantiated. With these machines, the seeder disc is mechanically driven. The seeds are retained in its holes on seed disk by the force created by the vacuum. The stepless mechanical drive allows for the realization of different sowing rates (pieces of seeds per decare). The force required to hold the seed to the sowing disc varies to some extent due to differences in weight. In the present work are researched and determined the power for driving the sowing disc and the pneumatic units for creating a vacuum. The obtained results were used to determine the elements of a device for mechatronic control of the operation on a seed section from a precision seed drill.

***Key words**: pneumatic seed drill, power, vacuum, corn.*

INTRODUCTION

In the cultivation of agricultural crops sowing is one of the most responsible operations, as correct the chosen technology, the exact adjustment of the sowing rate depending on the specific soil and climatic conditions, determine future yields (Kuvaytsev et al., 2014; Kuvaytsev et al., 2014**)**.

The growing trend of increasing power worldwide and as a result and the energy saturation of tractors has a detrimental effect on environmental situation (Lovkis et al., 2016). The repeated passing of the equipment in the field during the cultivation of plant production leads to intensive compaction of the arable and subsoil layers of the soil, as a result of which the yields are reduced and the energy consumption during tillage is increased. At the same time, in the case of powerful tractors with an internal combustion engine of 300-350 hp, there is insufficient efficiency in their use due to the impossibility of realizing all their power in the the existing ones drives of the working bodies (PTO, towing from the support wheels, etc.).

The solution to these problems is the development and use of combined tillage and sowing units, combining operations and using machines with active working bodies. One of the ways to increase the efficiency when using the tractor is to apply different types of drives to the working bodies of agricultural machinery - pneumatic, hydraulic, electric or combined. In the case of seed drills, one of the most promising and reliable, with good quality indicators and precise adjustment of the sowing rate, is the mechanical drive of the seed drills by means of reducers or variators.

Currently, one of the most common ways to change the speed of rotation of seed drills is the use of replaceable gears and reducers (Antonov and Laryushin, 2011). Unfortunately, this method has a number of disadvantages that affect sowing and ultimately the harvest. Thus, one of the main disadvantages is the difficulty in regulating the sowing rate due to the abrupt change in gear ratio of the gearbox.

The change of the sowing rate with the help of a reducer has some significant shortcomings, which affect the deterioration of the accuracy of its adjustment, reduce the uniformity of seed distribution, increase the traumatized seeds, which leads to reduced yields and increased seed costs (Kuvaytsev et al., 2014; Kuvaytsev et al., 2014). The operation of seed drills with a variator is the most promising, but is currently poorly studied.

The variator (from Latin variātor) is a device that transmits torque and is able to smoothly change the gear ratio in a certain range of regulation (Nezhizhimov, Kushnarev and Savostina, 2018). The gear ratio is changed automatically, according to a set program or manually. The adjustment range (ratio of the largest to the smallest gear ratio) is usually 3-6 and less often 10-12. The variator is characterized by high reliability and simplicity in its manufacture (Klenin and Sakun, 1994).

At the present time (Kuvaytsev, Laryushin and Mamonov, 2015) in the Penza Agricultural Academy was designed, manufactured and tested hump-lever variator for driving the seed drills. When using it, the following result is obtained - when it is positioned as a driving element of machines and mechanisms, it is possible to set the output shaft virtually any law of motion, as there is a possibility to smoothly adjust the speed of rotation of the output shaft of the variator. its uniformity of rotation, the vibrations in the variator are reduced, the kinematics of the drive is simplified due to the small number of details.

To adjust the sowing rate, the gear ratio in the seed drill system must be precisely determined. An interesting methodology for this offers (Lysy, 2015).

Increasingly, work is being done to replace the mechanical gearbox for driving the shaft of seed drills with electric drives (Gorobey and Tarimov, 2009). In this case (developed stand) the shaft is driven by a stepper motor and a driver for the motor (with modulations up to 200 step pulses in s). It also contains a simulator on the seed drill wheel, powered by an electric motor and a microprocessor control panel. On the model, with the help of specially developed tachometers, the speed of rotation of the seed drill wheel and the speed of rotation of the shaft of the seed drills are measured. The forward speed (respectively the speed of rotation of the wheel) varies from 2.5 to 12 km/h (11.3 to 54 min^{-1}). The stepper motor sets a different speed of rotation of the seed drill shaft and realizes a different gear ratio (from 0 to 70). Studies have shown that with a gear ratio of up to 30, the relationship between the speed of rotation of the wheel and the shaft of the seeders is linear, which is desirable when adjusting the sowing rate.

A frequency converter can be used to drive and adjust electric motors. At low engine speeds, cooling problems occur. At high speeds this problem is not observed, but there is a risk of rapid damage to the bearings. By using special motors designed for operation at different speeds, the above problems are avoided, but the cost of the drive rises. The variator allows asynchronous motors to operate in rated mode. Its disadvantage is its smaller control range (e.g. 6 vs. 10 for a frequency converter).

The introduction of continuously variable transmission at the expense of frequency converters and special motors in the drive of conveyors and other equipment provides the following advantages: the main part of the drive remains and consists of standard mechanisms; the use of a variator allows the application of standard asynchronous motors that will operate in rated mode. It is economically advantageous to use such a drive because the motor life remains the same and the value of the variator is lower than that of the frequency converter and other devices.

When sowing oilseeds, the use is promising (Brichagina, Palvinsky and Orlov, 2017) of sowing apparatus controlled by an electronic system. It was found that for sowing rapeseed and other small-seeded crops, a seeder equipped with an electronic seed metering device meets all agronomic requirements and works much better than those equipped with a mechanical transmission system. Practically does not damage the seeds, allows very precise adjustment of the required sowing rate, ensures sustainable sowing and even distribution of seeds in rows and between them.

MATERIALS AND METHODS

The corn seeds used are of the KC 4568 variety with an average weight per 1000 grains (MKV), 316.1 g (Petrovska and Dimova, 2012).

The sowing disc is green, 30/5 (30 holes with a hole diameter of d = 5 mm) for corn seeds weighing 1000 g and up to 320 g.

The study is in two stages.

The first stage is to determine the required torque to drive the drill seed drill according to the following diagram shown in Figure 1.

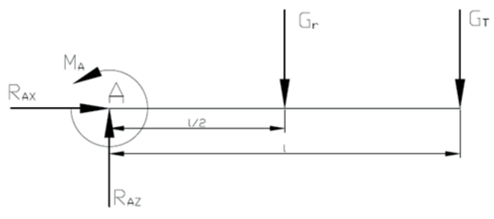

Figure 1. Scheme for determining the torque for driving the seed drill

After weighing the weights G_r and G_T, the moment is calculated by the formula:

$$M = g.\left(G_r.\frac{l}{2} + G_T.l\right) \quad (1)$$

To meet different sowing rates (number of seeds per decare) and sowing step (distance between the seeds in a row) is determined the required range of speed change (n_{SD}) of the seed disc relative to the speed of the seed drill.
The gear ratio of the gear (i_{red}) between the seed disc and the drive shaft of the drill section is determined. The values obtained are used to calculate the range of variation of the speed of the electric drive motor ($n_{el.m}$).
For the calculations of the power (P_1) required to drive the section, the largest (highest) revolutions are taken from the drill ($n_{el.m\ MAX}$).

$$P_1 = M.\omega, [W], \quad (2)$$

where: M [Nm] - torque for driving the sowing disc; ω [rad / s] - angular velocity of the drive shaft of the drill section.
Превръщането от обороти $n_{el.m\ MAX}$ [min^{-1}] в ъглова скорост ω [rad/s] е по следната формула:
The conversion from speed nel.m MAX [min^{-1}] to angular velocity ω, [rad/s] is by the following formula:

$$\omega = \frac{2.\pi.n}{60} \quad (3)$$

To determine the power of the electric drive motor, the power reserve factor (K_3) is selected according to tabular data (Trifonov, 2015) and is calculated by the formula:

$$P_{el.m} = P_1. K_3, W \quad (4)$$

With the obtained results a standard gear motor with electronic speed control (the nearest higher standard value) is selected.
The second stage is to determine the parameters of the vacuum fan. The largest values of the weight of the maize seed with which the sowing disc is intended to work are taken, namely 320 g per 1000 corn seeds. It follows that the mass of 1 seed will be $M_{corn\ grain}$ = 320/ 1000 = 0.32 g.
The disk has 30 holes, 26 of which are under the influence of vacuum.
The mass of the sucked grains is determined:

$$M_a = (M_{corn\ grain} . 26)/1000, kg \quad (5)$$

For subsequent calculations, the kilograms are converted into newtons (1 kg ≈ 10 N):

$$G_a = M_a . 10, N \quad (6)$$

Determination of air consumption Q_B by the formula:

$$Q_B = \frac{G_a}{3600.\mu.\gamma_B}, m^3/s \quad (7)$$

where G_a [N] is the weight of the seeds sucked on the sowing disc; μ - weight concentration of the mixture; γ_B = 12.4 [N/m^3] - bulk density of air.
They are selected from the reference literature (Krasnikov, 1981).
According to calculation data, a standard fan with electronic speed control (the nearest higher standard value) is selected.

RESULTS AND DISCUSSIONS

On an experienced path were established values of G_r = 122 g and G_T = 197 g. According to formula 1, calculate the required torque to drive the seed disc (M).

$$M = 9.81.\left(0.122.\frac{0.615}{2} + 0.197.0.615\right)$$

M = 1.56 Nm

The speed of the input shaft of the sowing section was measured - $n_{input\ shaft}$ = 3.347 (the angle of rotation $\alpha_{input\ shaft}$ = 1205°) with one full rotation of the sowing disc - n_{SD} = 1 (α_{SD} = 360°). The gear ratio between the input shaft and the seeding disc has been determined - i_{red} .

$$i_{red} = \alpha_{input\ shaft}/\alpha_{SD} = 1205/360 = 3.347$$

$$i_{red} = n_{input\ shaft}/n_{SD}$$

$$n_{input\ shaft} = i_{red} . n_{SD} = 3.347 . 1 = 3.347$$

The required sowing step s varies from 12 to 26 cm.

Given that the sowing disc has 30 holes, the distance traveled by seed drill S for 1 revolution (n_{SD} = 1) will depend on the sowing step s.
The linear speed of the seed drill V varies from 4 to 16 (18) km/h. Due to the peculiarities of the field it is limited in the range from 6 to 12 km/h.

For the calculations it is necessary to convert the speed of the seed drill V from km/h to m/min.
After comparing the data for the sowing step s, the seed drill speed V, the gear ratio i_{red} and the number of holes in the seed disc (30 pieces), the range of variation of the input shaft speed is determined. The results are shown in Table 1.

Table 1. Input shaft speed $n_{input\ shaft}$ [min^{-1}] depending on travel speed V and step s

Sowing step **s**		Traveled way from the seed drill **S** for 1 revolution of the seeding disc	Seed drill speed **V**								
			km/h	5	6	7	8	9	10	11	12
			m/min	83.33	100.00	116.67	133.33	150.00	166.67	183.33	200.00
cm	m	m									
12	0.12	3.6		77.48	92.97	108.47	123.96	139.46	154.95	170.45	185.94
13	0.13	3.9		71.52	85.82	100.12	114.43	128.73	143.03	157.34	171.64
14	0.14	4.20		66.41	79.69	92.97	106.25	119.54	132.82	146.10	159.38
15	0.15	4.50		61.98	74.38	86.77	99.17	111.57	123.96	136.36	148.76
16	0.16	4.80		58.11	69.73	81.35	92.97	104.59	116.22	127.84	139.46
17	0.17	5.10		54.69	65.63	76.57	87.50	98.44	109.38	120.32	131.25
18	0.18	5.40		51.65	61.98	72.31	82.64	92.97	103.30	113.63	123.96
19	0.19	5.70		48.93	58.72	68.51	78.29	88.08	97.87	107.65	117.44
20	0.20	6.00		46.49	55.78	65.08	74.38	83.68	92.97	102.27	111.57
21	0.21	6.30		44.27	53.13	61.98	70.84	79.69	88.54	97.40	106.25
22	0.22	6.60		42.26	50.71	59.16	67.62	76.07	84.52	92.97	101.42
23	0.23	6.90		40.42	48.51	56.59	64.68	72.76	80.85	88.93	97.01
24	0.24	7.20		38.74	46.49	54.23	61.98	69.73	77.48	85.22	92.97
25	0.25	7.50		37.19	44.63	52.06	59.50	66.94	74.38	81.82	89.25
26	0.26	7.80		35.76	42.91	50.06	57.21	64.37	71.52	78.67	85.82

From the data given in Table 1 it can be seen that the minimum speed should be 42 ($n_{input\ shaft\ (min)} = 42\ min^{-1}$) and the maximum 186 ($n_{input\ shaft\ (max)} = 186\ min^{-1}$).
The power for driving the sowing section P_1 according to formulas 2 and 3 is determined and the maximum revolutions ($n_{input\ shaft\ (max)} = 186\ min^{-1}$) are taken.

$$\omega = \frac{2 .3,14 .\ 186}{60} = 19.48 \text{ rad/s}$$

$P_1 = 1.56 \ .\ 19.48 = 30.39$ W

(P = 0.03 kW)

According to tabular data the power reserve coefficient $K_3 = 2.0$ is determined. The required power of the electric motor is calculated by formula 4:

$P_{el.m} = 30.39.\ 2.0 = 60.78$ W

($P_{el.m} = 0.061$ kW).

To determine the parameters of the vacuum fan, the weight of the suction grains according to formulas 5 and 6 is calculated:

$M_{corn\ grain} = 0.32$ g

$M_a = (0.32\ .\ 26)/1000 = 8.32\ .\ 10^{-3}$ kg

$G_a = 8.32\ .\ 10^{-3}.\ 10 = 83.2\ .\ 10^{-3}$ N

Necessary flow rate on air Q_B [m^3/s] is calculated by formula 7.

According to tabular data:

γB = 12.4 [N/m^3]; μ =20

$$Q_B = \frac{83.2\,.\,10^{-3}}{3600.\,20.\,12.4} = 0.0932.\,10^{-6}\ \frac{m^3}{s}$$

CONCLUSIONS

On the basis of the above, can be formulating the following conclusions:
The methodology for converting the drive of a drill section for precise sowing from mechanical (group) to electrical (individual) has been developed. The parameters of the driving electric motor are determined - power 0.061 kW and revolutions - from 30 to 190.
The required air flow rate QB for individual supply of the seed drill with vacuum has been calculated.

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