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Determining parameters of an electric drive for sowing apparatus of the Saxonia A200 seed drill

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Abstract. *A methodology has been developed for the selection of an electric motor for the replacement of the mechanical with electric drive of the sowing apparatus of the Saxonia A200 seeder. The gear ratio, angular velocity and torque required to drive the sowing apparatus have been determined. As a result, 22.65 W of motor power is calculated.*

Keywords: seed drills, gear ratio, torque, motor power, Saxonia A200

Introduction

Sowing is a major technological stage in the cultivation of crops. There is a wide variety of machines to perform this operation. Some of them are mechanical and others with electric drive and control of the sowing machines. Is it possible for old, mechanically driven seed drills to be equipped with electric drive and seed drill adjustment? The present study specifies a methodology for selecting an electric motor to drive these bodies on a Saxonia A200 seed drill.

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 injured seeds, which leads to reduced yields and increased seed costs. (Kuvaytsev et al., 2014a, Kuvaytsev et al., 2014b). The operation of seed drills with a variator is the most promising, but is currently poorly studied.

When driving and regulating with electric motors, a frequency converter can be used (Nezhizhimov et al., 2018). 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 sized 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 (for example 6 to 10 for a frequency converter).

The seed drills in the Saxonia A200 drill are driven by the seed wheel of the drill, through a system of chain and gears. The last step in the transmission system is a chain drive.

It is known that power (Portaev et al., 1987) is the product of torque and angular velocity.

The angular velocity of the seed drill shaft can be represented as the product of the angular velocity of the support wheel and the gear ratio in the transmission mechanism of the drill.

An important clarification on the influence of sowing rate on quality is made (Šarauskis et al., 2008). The study shows that when the sowing rate of winter wheat is increased, the uniformity of seed application decreases due to the change in the resistance of the boot. At higher speeds and especially when an obstacle is encountered, the boots are raised and the seeds are spread on the soil surface or introduced into different soil layers.

The authors (Barr et al., 2016) have attempted direct

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sowing at speeds of 8 to 16 km/h with different boots. The results of this field experiment highlight the problems with no-till technologies and provide an attractive solution for higher sowing speeds. Additional studies are needed to optimize the design parameters of the boots.

In 2019, Barr et al. (2019) proved that in no-till sowing of cereals there is an unprecedented opportunity to increase working speeds by 50% without affecting germination or yields. This increase in working speed can improve sowing practices in industry through (1) timeliness of sowing, therefore increasing the potential for grain yield, (2) reducing the total sowing time per season or reducing the required working time per day for the farmer (3) the potential to reduce the width of the machine to minimize investment costs while maintaining a similar speed of operation.

When sowing oil-bearing crops, the use (Brichagina et al., 2017) of sowing machines controlled by an electronic system is promising. It was found that for sowing rapeseed and other small seed crops, a seeder equipped with an electronic seed metering device satisfies all agronomic requirements and works much better than those equipped with a mechanical transmission system. Practically this does not damage the seeds, allows very precise adjustment of the required sowing rate, provides stable sowing and even distribution of seeds in rows and between them.

The gear ratio is presented as a product of the gear ratios of each gear and chain gear in the transmission of the seed drill.

To rotate the drive shaft, it is necessary to apply a torque equal to and opposite to the resistance moment generated by the friction forces in the bearing bodies and between the sowing apparatus and the seed.

The purpose of the present study is to determine the power required for electric drive of the sowing devices of the Saxony A200 planter. To achieve this goal, the moment of resistance generated by the operation of the sowing devices and the maximum angular velocity during their operation must be determined.

Material and methods

The angular velocity of the sowing devices shaft can be represented as the product of the angular velocity of the support wheel and the gear ratio in the transmission mechanism of the drill. The angular velocity of the support wheel is determined using the formula for the peripheral speed (working speed of the drill).

$$V_p = \omega . R \qquad (1)$$

where V_p - operating speed, km/h, ω - angular velocity of the seeder's running wheel, s^{-1}, R - radius of the running wheel, m.

Solving equation 1 with respect to the angular velocity is obtained

$$\omega = \frac{V_p}{R} \qquad (2)$$

According to some authors (Rodichev et al., 1984) when sowing cereals with a "fused" surface, the recommended working speed is from 7 to 12 km/ h. The current study operates at a speed of 12 km/h (3.33 m/s).

The radius of the support wheel of the Saxonia A200 seeder is 0.30 m.

The transmission mechanism of the Saxonia A200 drill includes 3 chain gears and one multistage gear reducer. The gear ratio of the chain gears is defined as divisible by the number of teeth of the drive to the number of teeth of the drive gears.

$$i_{wi} = \frac{z_2}{z_1} \qquad (3)$$

where i_{wi} - gear ratio of chain gear, z_2 - number of driven gear teeth, z_1 - number of driving gear teeth

Due to the lack of technical documentation for the drill, the gear ratio of the gearbox is determined as a quotient of the number of revolutions of the input shaft for 1 revolution of its output shaft.

$$i_p = \frac{n_{wx}}{n_{ix}} \qquad (4)$$

where i_p - transmission ratio of the reducer, n_{wx} - revolutions of the input shaft, n_{ix} - revolutions of the output shaft

The overall gear ratio i_{pm} is the product of the gear ratios of each gear

$$i_{pm} = i_{w1} \cdot i_{w2} \cdot i_p \cdot i_{w3} \qquad (5)$$

To determine the torque, remove the chain and then remove the gear from the drive shaft of the sowing devices. In its place is mounted a shoulder with a length of 0.615 m. Weights are placed one after the other at the end of the arm until the shaft rotates. The torque is composed of 2 components - the first is the moment obtained from the impact of weights, and the second - the moment created by the mass of the arm. The mass of the arm can be considered as an evenly distributed load. Her moment is her mass and half the length of her shoulder.

The moment is determined using the following Figure 1.

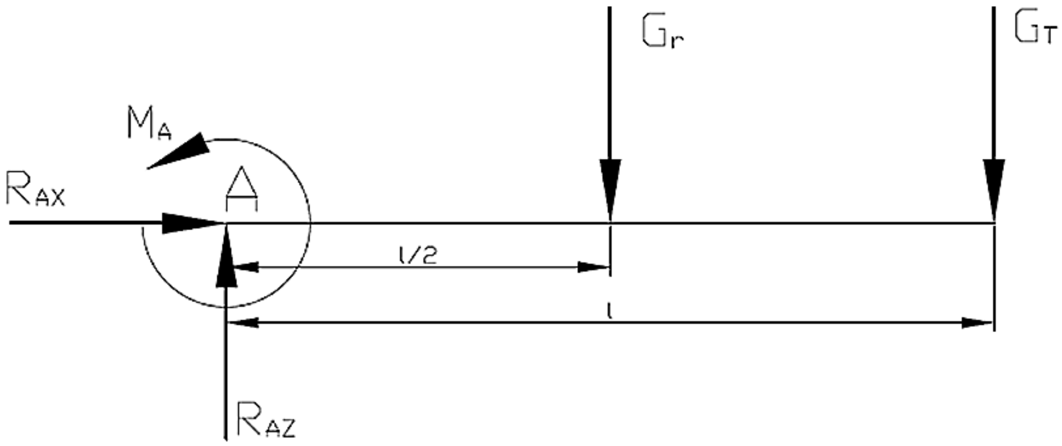

Figure 1. Determining the moment

According to (Stoychev et al., 1980) the moment is:

$$M = 9,81.(Gr.\frac{l}{2} + Gt.l) \quad (6)$$

where M - moment of resistance of the sowing apparatus, Nm, Gr - shoulder mass, kg, Gt - mass of the weights, kg, l - length of the shoulder, m

The transmission of the torque is carried out by the running wheel of the drill through 3 chain and 2 gears. The efficiency of each of them is in the range of 0.95-0.98.

The number of repetitions when measuring the quantities: shoulder weight, mass of weights and gear ratio in the gearbox is determined at a level of significance α = 0.05 and relative error δ = 5% according to the authors' recommendations (Bojanov and Vuchkov, 1983; Mitkov and Minkov, 1989).

The obtained results from the measurements for each quantity are averaged and with these values it is replaced in the formulas listed above for obtaining the required power.

Results and discussion

The number of repetitions for the shoulder mass, the mass of the weights and the gear ratio in the gearbox is determined on the basis of the accepted methodology. For each of the monitored indicators, 3 measurements were performed, after which the average value, the variance and the coefficient of variation were determined. The data from these measurements and their statistical processing are reflected in Table 1.

Table 1. Results of preliminary experiments

Tracked indicators	Experimental results			Results of statistical analysis		
	1	2	3	$\bar{x}$	σ	υ, %
Shoulder mass, kg	0.122	0.121	0.122	0.1217	3.33E-07	0.47
Mass of weights, kg	0.295	0.290	0.295	0.2933	8.33E-06	0.98
Transmission ratio (634)	2	2	2	2	0	0

The obtained values for the coefficient of variation determine the number of repetitions at a significance level α = 0.05 and a relative error δ = 5%. For the respective indicators they are: - shoulder mass - 2; - mass of weights - 2; gear ratio. For greater reliability of the following results, the number of repetitions in determining these indicators is assumed to be 5. After performing the final measurements, the following results were obtained, reflected in Table 2.

Table 2. Values of the monitored indicators

Tracked indicators	**Experimental results**					
	1	**2**	**3**	**4**	**5**	$\bar{x}$
Shoulder mass, kg	0,122	0,121	0,122	0,121	0,122	0,1216
Mass of weights, kg	0,295	0,290	0,295	0,285	0,295	0,292
Transmission ratio (634)	2	2	2	2	2	2

The dependence 6 is used to determine the torque.

$$M = 9,81.\left(0,1216.\frac{0,615}{2} + 0,296.0,615\right) = 2,153\ Nm$$

Taking into account the losses in the transmission, at an efficiency of individual gears of 0.95, the required torque is determined by the following formula:

$$M_b = \frac{M}{0,95^5} = \frac{2,153}{0,774} = 2,782\ Nm$$

According to dependence 2, the angular velocity of the drill drive wheel is:

$$\omega_{wx} = \frac{3,33}{0,3} = 11,1\ s^{-1}$$

To determine the total gear ratio, a diagram (Figure 2) of the transmission mechanism of the drill is drawn. The number of teeth from the sprockets involved in each intermediate gear is determined. The data obtained are shown in Table 3.

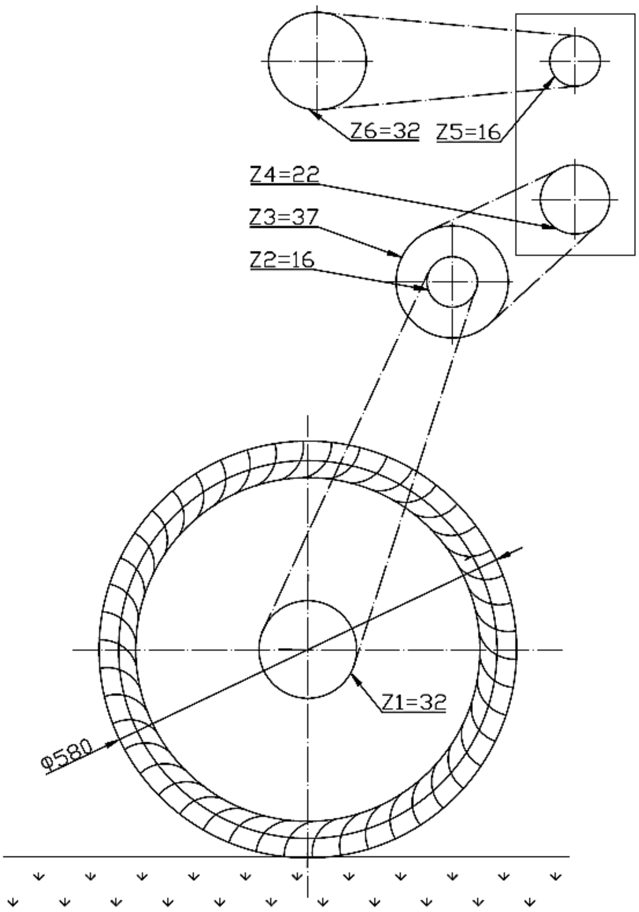

Figure 2. Transmission mechanism

Using the data from Table 3 and Formula 3 for the intermediate gear ratios, the following values are obtained:

- for the gear ratio of the first chain gear

$$i_{w1} = \frac{16}{32} = 0,5\,;$$

- for the gear ratio of the second chain gear

$$i_{w2} = \frac{22}{37} = 0,5946\,;$$

- for the gear ratio of the third chain gear

$$i_{w3} = \frac{32}{36} = 2\,;$$

As already specified, the gear ratio of the gear unit at position 634 of the adjusting mechanism is 2.

The total gear ratio of the transmission is a product of the values of the intermediate and from formula 5 the following is obtained:

$$\mathbf{i_{pm}} = 0,5.0,5946.2.2 = 1,1892$$

It is known that the gear ratio is the quotient of the angular velocity of the input shaft to the angular velocity of the output one. In our case, the input shaft is the shaft of the support (drive) wheel of the drill, and the output shaft is the shaft of the sowing devices.

$$i_{pm} = \frac{\omega_{wx}}{\omega_{ix}} \quad (7)$$

The above expression is solved with respect to the angular velocity of the output shaft and the following is obtained:

$$\omega_{ix} = \frac{\omega_{wx}}{i_{pm}} = \frac{11,1}{1,1892} = 9,334\ s^{-1}$$

With the results thus obtained for torque and angular velocity, the power required to drive the sowing devices is:

$$P = M_b.\omega_{ix} = 2,782.9,334 = 22,65\ W$$

There are many DC and asynchronous motors on the market that can drive the sowing devices. The optimal option must be selected in terms of precision seed dosing, easy and safe process control and last but not least economically justified choice.

Table 3. Number of teeth on the gears of the transmission

Gear wheel	z_1	z_2	z_3	z_4	z_5	z_6
Number of teeth	32	16	37	22	16	32

Conclusion

With the help of the elements used in physics, mechanics and statistical analysis, the torque, angular velocity and the power required to drive the sowing devices of the Saxonia A200 drill have been determined. The listed parameters have the following values:

angular velocity - 9,334 s^{-1};

torque - 2,782 Nm;

power for driving the sowing devices - 22.65 W.

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