Rotary paddle orienting device for planting root crops

V A Ovtov and N S Chirkova
Penza State Agrarian University, 30 Botanicheskaya Street, Penza, 440014, Russia
E-mail: ovtov.v.a@pgau.ru

Abstract. In the total volume of vegetable production, sugar beet takes a leading position. However, the current structure of sugar beet seed production in Russia is not able to meet the needs of agricultural producers with domestic seeds, which leads to a high share of the use of foreign breeding hybrids. Therefore, studies aimed at reducing the cost of manual labor when planting sugar beet mother plants through the development and use of orienting devices for planting machines are relevant. The article presents a three-dimensional model of a rotary paddle orienting device with given design parameters for planting sugar beet mother plants. The power expended on the drive of the rotary paddle orienting device providing the piece-by-piece supply of sugar beet plantings at a planting unit speed of 3.6 km/h has been determined. The kinematic parameters of the operation with the rotary paddle orienting device in conjunction with the landing apparatus of the planting machine have been substantiated. The energy calculation of the drive of the rotary vane orienting device was carried out and the loads acting on it were carried out, as well as the rolling bearings were selected. A chain transmission has been designed and modeled using the KOMPAS 3D computer-aided design system and its main parameters have been determined, which ensure reliable operation of the rotary paddle orienting device.

1. Introduction
In the Russian Federation, sugar beet is the main source of raw materials for sugar production at sugar factories. Sugar beet roots contain up to 20% sucrose. Sugar beet is grown mainly for sugar production, while by-products such as pulp are used for animal feed. Also, molasses obtained from root vegetables, in turn, is used for the production of citric acid, glycerin, alcohol, organic acids and yeast. The efficiency of sugar beet growing depends on many factors, such as weather conditions, adherence to agricultural technology, availability of modern technologies, timely fertilization and the quality of the seeds used. At present, the domestic market of sugar beet seeds shows dependence on supplies of foreign sugar beet seeds, as well as the lack of competitiveness of domestic sugar beet producers with foreign agricultural holdings [1-5].

Currently, breeding work is carried out mainly by state breeding centers, which are part of the system of the Federal Agency for Scientific Institutions. At the same time, the material, technical and technological base of breeding and seed production is outdated, which significantly affects the selection work and the production of high-quality seeds. Therefore, the modernization of production, the development of the necessary seed-growing technology is of current importance.

At the moment, the task of providing a fully mechanized technological chain from the sampling of sugar beet mother plants to their planting has not been fully resolved. An important role in planting sugar beet mother plants is played by an orienting device, the operation of which largely determines the technological process of single-piece feeding of beet plantings into the planting cones of the
planting apparatus, followed by embedding them with a cone downward in the soil and maintaining their original position [4-8].

Therefore, studies aimed at reducing the costs of manual labor when planting sugar beet mother plants by developing and using a rotary paddle orienting device of the planting machine are relevant.

The obtained results of the research carried out make it possible to substantiate the geometrical, kinematic and power parameters of the paddle orienting device, as well as to offer design solutions confirmed by patents for inventions and utility model.

2. Materials and methods
Currently known devices for orienting conical roots are implemented in the used planting machines VPS-2,8A, VPG-4, MV-2,8, 4SAS-62.5 and others, as well as confirmed by patents (AS No. 146241 USSR B.I., 1962, No. 7; AS 244162. USSR, B.I., 1969, No. 7; AS 361934 USSR. B1 1973, No. 2; the Russian Federation patent 2310313. IPC A01C 11/02. Publ. 20.11.2007, bull. No. 32 of 20.11.2007; the Russian Federation patent 2310312. IPC A01C 11/02; 20.11.2007, bull. No. 32 of 20.11.2007; the Russian Federation patent No. 2299548, IPC A01C 11/02, Bulletin No. 15 dated May 27, 2007; the Russian Federation patent No. 2633543, IPC A01C 11/00, Bulletin No. 29 dated October 13, 2017; the Russian Federation patent No. 2738274, Bulletin No. 35 of 11.12.2020, etc.). The disadvantages of these devices are: orientation of root crops. It is provided only when the planting material is divided into two fractions. Damage to root crops is possible due to an increase in the number of stages in orientation of some root crops due to their discharge if orientation is incorrect. Due to the lack of synchronization of the root crops supply, the established planting interval is not provided and damage to the heads of root crops occurs. Low productivity and insufficient reliability of the orienting devices is due to the fact that when root crops come off the feed conveyor, a shock and rebound from the chute is possible. There is damage to root crops by the existing screw winding.

The offered current rotary paddle orienting device is proposed, which improves the uniform supply of sugar beet mother plants to the planting apparatus at different speeds of the planting machine, which increases productivity and reduces manual labor costs during planting.

3. Results and Discussion
According to the patents of the Russian Federation No. 2738276, RF No. 201497 obtained by Penza State Agrarian university a three-dimensional model of a rotary paddle orienting device of the landing machine was developed and designed (Figure 1).

The rotary vane orienting device of the planting machine consists of a frame including stands, two rotors containing shells with slots along the protruding edges in which the blades made of elastic material are fixed, bearing housings screwed to the frame, rotor shafts on which the drive sprockets and a guide tray are fixed.

The proposed rotary paddle (blade) orienting device of the planting machine operates as follows. Root crops 9 are individually captured by one of the rotor blades 4 and, due to the moment from gravity, occupy a horizontal position between adjacent rotor blades, with a long axis along the rotor rotation axis. When the rotor blade is turned from a horizontal position by the value of the rolling friction angle of the root crop, it rolls over the blade surface and takes a stable position between the two combined blades of two rotors, which form a V-shaped groove. With further synchronous rotation of the two rotors, the aligned rotor blades are at a certain distance from each other, while the root crop turns with its tail downward and hangs at the level of the plane of the maximum diameter between the aligned blades of two rotors supported at two points. Orientation of the root crop with the tail part down occurs due to the conical shape of the tail part of the root crop and the moment of gravity arising in the V-shaped groove formed by the combined blades of the rotors, then the root crop is fed through the guide tray 8 into the planting cones of the planting apparatus.
According to agritechnical requirements, the speed of planting machines aggregation when planting sugar beet mother plants varies from 1.8 to 3.6 km/h (0.5 ... 1.0 m/s), and the landing step is 0.6 or 0.7 m [8-9].

The frequency of rotation of the lander, providing a landing step of 0.6 m, at the maximum speed of the lander, is determined by the expression [8-9]:

$$n_{ap} = \frac{60 \cdot V_m}{s \cdot z} = \frac{60 \cdot 1.0}{0.6 \cdot 4} = 25 \text{ min}^{-1},$$

where $V_m$ – speed of the planting machine, m/s; $s$ – planting step of sugar beet seedlings, m; $z$ – number of planting cones with trays, pcs.

The time of one turn of the planting unit will be:

$$t = \frac{2 \cdot \pi}{\omega} = \frac{2 \cdot 3.14}{2.62} = 2.4 \text{ s}$$

where $\omega$ – angular velocity of the planting device, s$^{-1}$.

Depending on the design of the planting device, most of the number of trays ($z$), the planting time per root crop will be:

$$t = \frac{60}{z \cdot n_{ap}} = \frac{60}{4 \cdot 25} = 0.6 \text{ s}.$$

Since the rotor orienting device of the planting machine is driven through a chain transmission from the leading sprocket mounted on the shaft of the planting unit and the driven sprockets 7 of the rotors, the chain transmission ratio should be $i=1$. 

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**Figure 1.** Model of a rotary paddle device: 1 - frame; 2 - racks; 3 - shells; 4 - blades; 5 - bearing housings; 6 - rotor shafts; 7 - sprockets; 8 - receiving tray; 9 - root stock
For design considerations, we accept the number of teeth of the drive sprocket \( z_1 = 25 \), and the number of teeth of the driven sprocket \( z_2 = 25 \) with a transmission ratio of \( u = 1 \).

Our design calculations of chain transmission with the help of CAD-KOMPAS 3D enabled us to select the chain ПР-12.7-9000-1 according to GOST 13568-75 with pitch \( t = 12.7 \text{ mm} \) and breaking load \( F_r = 9000 \text{ N} \), which meets the requirements of wear resistance, strength and longevity.

Reliable operation of the rotary paddle orienting device providing piece-by-piece delivery to the landing apparatus of the planting machine is determined by energy (power) parameters of its drive.

When one of the blades of the rotor captures a root crop, then under the action of its gravity creates a moment of force (Figure 2), which must be overcome by the driving device.

According to the presented scheme (Figure 2) the moment of force created by the gravity force of the root crop would be determined by the formula:

\[
M_r = m \cdot g \cdot a = 1.33 \cdot 9.81 \cdot 0.07 = 0.91 \text{ Nm}
\]

where \( F \) – gravity of the root crop, N; \( a \) – distance from the line of force to the rotor rotation axis, m; \( m \) – weight of one root crop, kg (mass of the uterus from 145 to 1330 g).

The value of torque taking into account the dynamism coefficient \( K_d \) under moderately uneven load would be:

\[
T_r = K_d \cdot M_r = 1.5 \cdot 0.91 = 1.4 \text{ Nm}
\]

The power used to drive the rotor orienting device \( P_r \) is equal to:

\[
P_r = T_r \cdot \omega_{ap} = T_r \cdot \frac{\pi \cdot n_{ap}}{30} = 1.4 \cdot \frac{3.14 \cdot 25}{30} = 3.7 \text{ W}
\]

where \( \omega_{ap} \) – angular velocity of the rotor orienting device, \( \text{s}^{-1} \).

Based on the design parameters of the rotary paddle orienting device selected bearings in accordance with GOST 7242-81 single-row deep groove ball bearings with shields: No. 80104: \( C = 9360 \text{ N} \); \( C_0 = 4500 \text{ N} \).

The required dynamic bearing load capacity was determined by the formula:

\[
C_{req} = F_{equ} \cdot \sqrt{L}
\]

where \( p = 3.0 \) – for ball bearings; \( L \) – required bearing life (service life) in millions of revolutions; \( F_{equ} \) – equivalent load, N;

\[
C_{req} = 77.03 \cdot \sqrt{15.768} = 193.2 \text{ N}
\]

\[
C_{req} = 193.2 \text{ H} < C = 9360 \text{ N}
\]

The calculated dynamic load rating of the bearing is much lower than the standard dynamic load rating for this type of bearing.

![Figure 2. Scheme of forces in a rotary paddle orienting device](image-url)
4. Conclusion
The calculations made it possible to substantiate the kinematic parameters of the designed rotary paddle orienting device, namely, to determine the rotary speed of the rotors, which is $25 \text{ min}^{-1}$, that ensures the planting of sugar beet mother plants with a step of 0.60 m. The power and energy calculation of the drive allows us to conclude that for a given speed of the planting machine, the developed rotary vane orienting device provides the required productivity of the planting machine. The resource of the selected bearings would ensure the reliable operation of the rotary paddle orienting device of the planting machine with the specified durability. Thus, the rotary paddle orienting device of the planting machine provides one-by-one orientation of root crops, regardless of their size and taper.

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