Theoretical substantiation of the design of the opener of the beet seeder

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Abstract. Compliance with the sowing technology is the basis for the cultivation of any agricultural crop, since the yield and product quality, material and monetary costs, the seeding rate, the area of plant nutrition, as well as the design features of the machines used, depend on it. When sowing sugar beet, this issue is most relevant because recently, the sowing of this crop has undergone major changes. Most of the seeds used in Russia are both granulated and single-sprout. The seeding rate is set at the final density and, therefore, a delay in the growth of individual plants is not permissible. In this regard, serious requirements are imposed on the design of the seed sowing apparatus, one of the indicators of which is to ensure the placement of seeds on the loose bottom of the sowing furrow, backfilling it with soil from above with subsequent compaction creates unfavorable conditions for seed germination.

1. Introduction
Sugar beet in the Russian Federation is the main source of sugar production. With the development of agricultural science, the technology of its cultivation is constantly being improved. After mastering the technology of sowing sugar beet at the final density of the plantation, excluding manual labor, the main obstacle in its cultivation is weediness [1, 2]. In 60s – 90s of the XX century, due to the lack of highly effective herbicides for weed control, inter-row cultivation was used at different depths.

With the development of sugar beet production in the northeast of the Central Black Earth Zone of the Russian Federation, in the future, it is possible to conduct research using high-performance wide-cut (24 and 36 row) seeding machines and row cultivators, using foreign growth regulators and highly productive domestic sugar beet hybrids. At the same time, the mechanization of the process of sowing seeds, which ultimately determines the effectiveness of the use of agro-technological measures and the introduction of the required amount of fertilizers, is of great importance for the formation of the yield and increasing the germination rate [3].

The main task of sowing sugar beet is to evenly plant the seeds to a certain depth with their even distribution in the row and ensure the distance between shoots in a row of 16-20 cm. The seed must fall into a prepared bed, located on the border of the wet sedimented and loose upper soil layers. To achieve this goal, a seeding device is proposed in which the seeding disc has a reverse rotation, and the rear wall of the opener is made in the form of a parabola of the corresponding trajectory of the seed movement, thereby ensuring the distribution of seeds in the immediate vicinity of its rear wall, thereby reducing the risk of falling asleep to the furrow bed before the granules get there.
The trajectory of the granule movement directly depends on the angular speed of the seeding disc, which in turn depends on the geometric characteristics of the cells of the seeding disc.

2. Materials and methods

The angular velocity of the disk will be equal to [4]:

\[ \omega_d = \frac{2 \pi \theta_d n_{ob}}{n_p}, \text{ s}^{-1} \]  

(1)

Where: \( \theta_d \) – machine speed, m/s; \( n_p \) is the number of rows on the disk.

Let us consider the movement of seeds in the area AB (figure 2), (the movement of seeds in the cell of the drum, counting the seed of the material point. The arc and the body do not allow seeds to fall out of the cell.)
Depicting the seed in an arbitrary position, figure 2, and the forces acting on it \( P = mg \), \( N \) and \( F \).

\[ F_c = m \omega^2 R \]  

(2)

Where \( R \) – disk radius of the sowing device, \( m \); \( m \) – the mass of the seed; \( \omega \) – angular velocity of the disk, rad/s [5, 6, 7].

The friction force of the seed on the surface of the body is determined by expression 3:

\[ F_{fr} = fN \]  

(3)

The Coriolis inertia force is:

\[ F_k = 2m|\omega||V_h|\sin(\omega, V_h) \]  

(4)

Since the angle between vectors \( \omega \) and \( V_h \) is 90°, and \( V_h = \omega R \), we get:

\[ F_k = 2m\omega^2 R \]  

(5)

To determine \( N \), we project the forces onto the \( y \)-axis \( \sum F_i y = 0 \),

\[ N + F_k - mg\cos\alpha = 0 \]

\[ N = m\cos\alpha - F_k = m\cos\alpha - 2m\omega R = m(g\cos\alpha - 2\omega R) \]  

(6)

Then:

\[ F_{fp} = f(m(g\cos\alpha - 2\omega R)) \]  

(7)

\[
\begin{align*}
\frac{m}{m} \frac{dV_x}{dt} &= F_c - F_{fr} + m\sin\alpha \\
\frac{m}{m} \frac{dV_y}{dt} &= F_k + N - m\cos\alpha
\end{align*}
\]

(8)

or:

\[
\begin{align*}
\frac{m}{m} \frac{dV_r}{dr} &= F_u - F_{fp} + m\sin\alpha \\
\frac{mV_x}{m} \frac{dV_x}{dx} &= F_u - F_{fp} + m\sin\alpha \\
\frac{mV_y}{m} \frac{dV_y}{dy} &= F_k + N - m\cos\alpha
\end{align*}
\]

(9)

Taking into account equations (2), (5), (6), (7) we obtain:

\[
\begin{align*}
\frac{mV_x}{m} \frac{dV_x}{dx} &= \omega^2 R - f\frac{g\cos\alpha - 2\omega R}{m} + m\sin\alpha \\
\frac{mV_y}{m} \frac{dV_y}{dy} &= 2m\omega R + m\frac{g\cos\alpha - 2\omega R}{m} - m\cos\alpha
\end{align*}
\]

(10)

Reducing by \( m \) and transforming we get:

\[
\begin{align*}
V_x \frac{dV_x}{dx} &= \omega^2 R - f\frac{g\cos\alpha}{m} + 2f\omega R + gs\alpha \\
V_y \frac{dV_y}{dy} &= 2\omega R + g\cos\alpha - 2\omega R - g\cos\alpha
\end{align*}
\]

(11)

\[
\begin{align*}
V_x^2 &= 2\omega^2 R x - 2xf \frac{g\cos\alpha}{m} + 4xf \omega R + 2g\sin\alpha + C_1 \\
V_y^2 &= 4x\omega R + 2g\cos\alpha - 4x\omega R - 2g\cos\alpha + C_2
\end{align*}
\]

As a result, the speed of the seed in the disc cell will be determined by the sum of the projections:
\( (x) \left\{ \begin{array}{l} V_x^2 = (2\omega^2R - 2fg \cos \alpha + 4f \omega R + 2gsina)x + C_1 \\
V_y^2 = C_2 \end{array} \right. \) \hspace{1cm} (12)

Let us denote \( A = 2\omega^2R - 2fg \cos \alpha + 4f \omega R + 2gsina \), then the system will take the form:

\[
\left\{ \begin{array}{l}
V_x^2 = Ax + C_1 \\
V_y^2 = C_2 \\
V_x = \sqrt{Ax + C_1} \\
V_y = \sqrt{C_2} \\
\int V_x \, dx = \int \sqrt{Ax + C_1} \\
\int V_y \, dy = \int \sqrt{C_2} \, dy \\
\frac{2\sqrt{(Ax + C_1)^3}}{3A} + C_3 \\
y = C_2y + C_4 \\
x = \frac{2\sqrt{((2\omega^2R - 2fg \cos \alpha + 4f \omega R + 2gsina)x + C_1)^3}}{3(2\omega^2R - 2fg \cos \alpha + 4f \omega R + 2gsina)} + C_3
\end{array} \right. \]

If \( C_4=0, x=0, \alpha=7^\circ, y=0 \).

3. Results and its discussion
Taking into account the main characteristics of the seeder, the trajectory of the granule movement was revealed after exiting the seed meter and before placing it on the bottom of the furrow made by the opener. This, in turn, allows us to further design the design of the opener.

4. Conclusion
Thus, for sowing sugar beets and ensuring uniform seeding of seeds at a certain depth with their uniform distribution in the row, as well as reducing the risks arising from the movement of the granule after leaving the seed meter and before placing it on the bottom of the furrow, a curved opener surface was calculated.

Acknowledgments
The research results presented in the article were obtained as part of the implementation of the Agreement No. 075-11-12019-041 dated November 22, 2019 between the Ministry of Science and Higher Education of the Russian Federation and JSC Millerovoselmash for R&D on the topic “Creation of high-tech production of multifunctional complexes for sowing and cultivation of row crops and vegetable crops in the system of "precision" and "zero" farming based on intelligent mechatronic modules.” R&D is carried out in the organization of the Lead Contractor (FSBEI HE Michurinsky GAU).

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