Modeling of disk sowing apparatus operation process

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Abstract. As foreign and domestic experience in livestock breeding shows, cultivated pastures are highly efficient and are considered to be a reliable source of consistent provision of animals with green feed during the pasture period. Free feeding of animals on pastures is a natural way of feeding them, which is created by nature within the framework of a single ecosystem in which natural grassland vegetation grows. One of the most expensive items in animal breeding is feed production. To exemplify this, when keeping animals on cultural pastures, there is a decrease in the relevant share of expenses for feed production in the structure of aggregate expenses compared to their management in livestock buildings by 2 times (from 60 ... 65% to 30%), and the expenses on purchasing fuels and lubricants by 6 ... 7 times. It has been established that in the North Caucasus region three methods of creating cultural pastures are used: based on existing natural and artificial grasses through their surface improvement (by carrying out cultural work, regulating the water-air regime of the soil, combating weed and poisonous vegetation, sowing grass, fertilizing); radical improvement of natural fodder farmland, i.e. the creation of artificial cultural pastures; using pasture crops of perennial grasses cultivated on strongly eroded slope lands to reduce or eliminate erosion processes. As can be seen from the above, the problem of creating cultural pastures on sloping lands is of great current interest.

1. Introduction

Providing farm animals with complete feed is an important task of feed production [1-7]. In this regard, in the mountainous regions, in order to strengthen the fodder base, the creation of cultural pastures with surface-improved natural or artificial grass stands has shown the greatest efficiency. Artificial cultural pastures are recommended to be created mainly in low mountains, in rare, justified cases, and in the middle mountains, in areas with sufficiently powerful and moistened soils, a leveled relief and degenerated grass stand. The type of pasture is determined by the climatic and economic conditions of the region and, accordingly, they can be annual, short-term (up to 5 ... 6 years) and long-standing, long-term (over 5 ... 6 years). Long-term pastures are most effective in mountain regions, which are explained by low aggregate expenses and a lower degree of danger of the emergence and development of erosion processes.

One of the factors for increasing the yield of forage lands is the use of highly efficient technological processes of sowing and seeding machines. The applied ordinary methods of sowing do not fully meet the characteristics of mountain and piedmont agriculture and do not provide the best conditions for realizing the potential productivity of mountain forage land.
The optimal method of sowing crops is a uniform distribution of seeds over the area of nutrition. Such conditions are ensured by seeding using a disc sowing apparatus.

2. Results and discussion

The proposed device [8-10] (figure 1, a) for seeding grasses consists of a frame 1, support wheels 2 and a technological tank 3 for placing seeds and fertilizers. In the technological tank 3 there is a mechanism 4 for feeding and dosing in accordance with the norms of seeds and fertilizers. The working bodies are centrifugal disks 5, equipped with blades 6. The drive of the working bodies is carried out from hydraulic motors 7 and 8. The fertilizer 9 of the seed and fertilizer flow is placed on top of the centrifugal disks 5 and is fixed. In the upper part, it has a height-adjustable emphasis 10, made in the form of a roller. The position of the stop 10 in height is regulated by a screw mechanism 11. The profile track 12 rests on the limit stop 10, which is rigidly fixed to the metering shutter 13 (figure 1, b), which is installed in the guides 14 and has the ability to move vertically. The elastic elements 15 press it against the limit stop 10.

![Figure 1](image1.png)

**Figure 1.** Devices for seeding by scattering way.

The case of the first hydraulic motor 8 is rigidly mounted on the frame 1, and the case of the second hydraulic motor 7 is at one end with the help of the axis 16 to the frame 1 with the possibility of rotation, and at the other end by a link 17 is pivotally connected to the lever 18, which in turn is pivotally connected to the rod 19 of the hydraulic cylinder 20, connected through oil lines 21 to the spool valve 22 of the hydraulic system of the device.

Spool valve stem 22, by means of roller 23, is supported by cam 24, which is rigidly fixed to slider 25, which passes with a gap through the hole of thrust ring 26 fixedly mounted on the frame 1. Spring 27 is installed between thrust ring 26 and straight cam 24. At the end of slider 25 wheel 28 is fixed, which rolls over the surface of cam 29. Cam 29 is fixed on pusher 30, at one end of which a copy wheel 31 is mounted pivotally, having constant contact with the soil surface. Spring 32 disposed between support washer 33 fixed to plunger 30 and thrust ring 34 fixed on frame 1.

In the process of operation of the device on a flat area (figure 1, a), material from the technological tank 3 is fed to the centrifugal disks 5 with blades 6 using feed mechanism 4 and scattered over the soil surface. In this case, rod 19 (figure 1, b) of hydraulic cylinder 20 occupies the lowest position, holding lever 18 and rod 17 in the position in which the axis of the shafts of hydraulic motors 7 and 8 are located vertically. Spool valve stem 22 in this case is in its lowest position, which corresponds to the maximum stroke of slider 25 to the right.

Needle guide 9 of the material flow above the centrifugal disks 5 is installed in the middle position, as a result of which the same amount of material is supplied to the working bodies. Since guide 9 is installed in the middle position, limit stop 10 is located in the middle of profile track 12. Metering valve
13 is located in the lower position due to elastic elements 15. The rate of application of grass and fertilizer seeds is determined by the position of limit stop 10, adjustable by screw mechanism 11.

When the device is operating on a slope section (figure 1, b), copying wheel 31 with pusher 30 with support washer 33 and cam 29 fixed on it moves upward, which helps compress spring 32, and wheel 28 rolls over the lifting surface of cam 29, moving slider 25 to the left. However, spring 27 is compressed and wheel 23 is rolled over the surface of cam 24 to the axis of slider 25, and the stem of spool valve 22 moves up. As a result, oil from spool valve housing 22 under pressure enters hydraulic cylinder 20, which leads to the retraction of rod 19, as a result of which hydraulic motor 7 with centrifugal disk 5 through lever 18 and rod 17 is rotated by an angle determined by the steepness of the slope.

With decreasing steepness of the slope, the gauge wheel 31 with the associated pusher 30 under the influence of the spring 32 is lowered down. This, in turn, leads to a corresponding decrease in the angle of inclination of the hydraulic motor 7 and the centrifugal disk 5.

The analysis of the results of the study of disk spreaders [10] shows that they require further improvement.

The scheme of the proposed disk working body is shown in figure 2. Drum 1 with a radius rotates on wheels 2, in which rolling bearings are installed. Four droppers 3 with radius \( R \) are rigidly fixed on the drum. Let’s consider the process of movement of a seed after it is separated from the ejector. A diagram of the forces acting on the seed is shown in figure 3.

At any moment in time, when, \( 0 < \varphi < 90^\circ \) i.e., when the seed falls from the ejector, the following equality holds:

\[
P_C = P_1 + N_1,
\]

where \( P_C \) is a centrifugal force; \( P_1 \) and \( N_1 \) are, respectively, the component weights of the seed and the reactions of the ejector, directed towards the axis of rotation.

The condition for separation of the seed from the ejector is \( N_1 = 0 \). Thus, at the time of separation of the seed equality \( P_C = P_1 \) will be true, or, \( m \omega^2 \rho = mg \cos \varphi \), whence:

\[
\cos \varphi = \frac{\omega^2 \rho}{g}.
\]

The formula (2) gives the relationship between the polar coordinates of the seed at the time of separation from the ejector.

![Figure 2. Scheme of the disk working body.](image1)

![Figure 3. Scheme of forces acting on the seed.](image2)
If the sliding of the seed on the surface of the ejector (assuming that the speed of the seed is small compared to the peripheral speed of the point on the surface of the ejector with which the seed is in contact or equal to zero) and the air resistance are neglected, then at the moment of separation the seed has a velocity perpendicular to its radius vector. Like a body in a gravitational field, having speed, the seed after separation from the ejector will move along a parabola. The trajectory of its movement is calculated (figure 4).

![Diagram for calculating the trajectory of seed fall](image)

Figure 4. Diagram for calculating the trajectory of seed fall.

Gravity and air resistance will act on the seed when it leaves the disc. The strength of air resistance is determined using Newton's formula:

\[ R_v = k F_M V_s^2 \frac{\gamma_v}{g}, \]  

where \( k \) is a resistance coefficient determined by the properties of the surface of the seed; \( \gamma_v \) is specific gravity of air; \( k / m^3 \); \( F_M \) is Mid-section, \( m^2 \); \( V_s \) is seed speed relative to air, \( m/s \).

The differential equation of flight of the seed in the direction of the axis \( x \), which coincides with the direction of the initial speed \( V_0 \), is composed:

\[
\begin{align*}
    m \ddot{x} &= -R_v \left( \dot{x} \right)^2 \\
    m \ddot{y} &= -m_g g - R_v \left( \dot{y} \right)^2.
\end{align*}
\]

Given the expression (3) according to the first expression of equation (4) we get:

\[
\ddot{x} = -\frac{k F_M \gamma_v}{m_g g} \left( \dot{x} \right)^2 = -k_p \left( \dot{x} \right)^2,
\]

where \( k_p \) is a coefficient of seed sailing capacity.

Equation (5) is solved using the method of deflation:

\[
\dot{x} = V_t, \quad \ddot{x} = \frac{dV_t}{dt}.
\]

Taking into account expressions (6) from dependence (5) after some transformations we get:

\[
\frac{dV_t}{V_t} = -k_p dx.
\]

Integrating equation (7), we obtain:

\[
\ln V_t = \ln e^{-k_p x} + \ln C_1.
\]

Potentiating expression (8), we have:
\[ V_x = C_1 e^{-k_P x} . \]  \hspace{1cm} (9)

The value \( C_1 \) is set, taking into account the initial conditions: at \( x = 0 \) \( V_x = V_0 \), i.e., \( C_1 = V_0 \). In this case

\[ V_x = V_0 e^{-k_P x} . \]  \hspace{1cm} (10)

In order to establish the seed flight range, expression (10) is integrated over time (previously the variables are separated):

\[ \int \frac{1}{k_P} e^{k_P x} \, dx = V_0 t + C_2 . \]  \hspace{1cm} (11)

The constant of integration is determined taking into account the initial conditions: at \( t = 0 \); \( x = 0 \) \( C_2 = 1/k_P \). With this in mind, expression (11) after some transformations takes the following form:

\[ e^{k_P x} = k_P V_0 t + 1 . \]  \hspace{1cm} (12)

After taking the logarithm of both parts of expression (12) we get:

\[ k_P x = \ln(k_P V_0 t + 1) . \]  \hspace{1cm} (13)

Thus, the equation for calculating the seed flight range as a function of time is as follows:

\[ x_s = \frac{1}{k_P} \ln(k_P V_0 t + 1) . \]  \hspace{1cm} (14)

The equation of the trajectory of the seed is written in the following form:

\[
\begin{align*}
    y &= H_D + \frac{1}{2k_P} \ln\left(g + k_P V_0^2\right) - \frac{1}{2k_P} \ln\left(1 + \tan^2\left(\arctan\left(\frac{1}{g} e^{2k_P H_D - \frac{1}{2k_P} \ln(g + k_P V_0^2)}\right) - 1 - \frac{1}{g} \sqrt{\frac{k_P g}{k_P V_0^2} \left(e^{2k_P H_D} - 1\right)}\right)\right),
\end{align*}
\]  \hspace{1cm} (15)

where \( H_D \) is a height of the seed disc above the surface of the earth, m.

The obtained expressions allow determining the range ability of the seed at a given value of the initial speed or, at a given range, determining its necessary initial speed.

3. Conclusion

The proposed design of the unit allows automatically selecting the angle of inclination of the disk working body in accordance with the steepness of the processed slope, which eliminates the need for it to drive onto the hillside when performing the technological process for planting grass and fertilizing. The result is a stable operation of the unit without the risk of tipping over. The proposed unit can also be used for fertilizing on sloping lands in areas prone to tropic erosion.

The theoretical dependences obtained make it possible to establish rational parameters of the disk sowing apparatus.

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