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DETERMINATION AND SUBSTANTIATION OF PARAMETERS OF THE SELF-CLEANING SOWING DEVICE FOR SEEDING OF THE GRANULATED AND POWDERY MINERAL FERTILIZERS

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Annotation

The self-cleaning sowing device for seeding of the granulated and powdery mineral fertilizers which can also work at increases of their humidity is offered. For this purpose, elastic scrapers are fixed in fillets of the coil. The differential equation of the fourth order which describe the oscillating motion of a scraper is received. Its solution has allowed establishing time dependences of amplitude, frequency and oscillation period of a scraper.

Keywords: fertilizer distributor, scraper, differential equation, amplitude, frequency.

For improvement of fertility of the soil, for the purpose of increase in volume of productivity of production of agriculture, it is necessary to enrich it with mineral fertilizers regularly. In our republic, the technology considering features of a regional soil cover is applied. Within this method, the most effective way of enrichment of the soil is direct and uniform application of mineral fertilizers along with crops. Complexity of this sowing technology is insufficient suitability of sowing cars in case of humidity change, hygroscopicity which cause change in physicomechanical properties of fertilizer [1].

According to M.G.Doganovsky and E.V.Kozlovsky, the majority of mineral fertilizers, especially powdery, with humidity increase become sticky, matching and lose outflowing property. Therefore, in such cases, fertilizers stick to working bodies of the sowing device causing slowdowning of its work. Sticking of damp fertilizers to coil pins because of their increased humidity, leads to full violation of all technological process of seeds and fertilizers application.

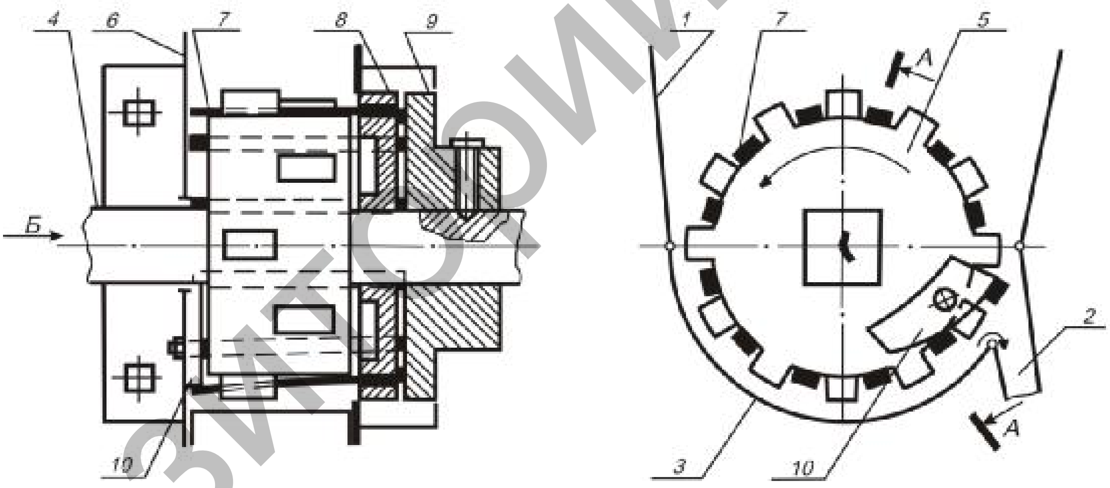
In connection with the above-stated problem, carrying out of research works in the field of designing of the sowing devices intended for uniform and steady seeding of fertilizers, is one of the major directions in development of the newest and effective sowing machines.

Research works and experiments have shown that damp fertilizers stick on sowing coils, and they turn to smooth rollers losing the transporting abilities. Part of fertilizer turn into lumps when they dry out. They mass up at sowing windows and form the arches which block the uniform intake of fertilizer in the sowing bodies [2, 3, 4].

The solution to the problem in

seeding system needs the finest theoretical and experimental substantiation of construction which would provide a fine crushing of clods of different formations for uniform distribution of mineral fertilizers in bodies of the sowing device. As a result of the conducted analytical research, self-cleaning pin-based fertilizer application device is proposed, as represented in Figure 1. It consists of the bunker 1, at sowing windows, in the basis 3 of which the pin coil 5 rotates on longitudinal shaft in a box 6 . On a surface of the coil along its generatrices, scrapers 7 made of a spring material are located. Scrapers are motionlessly fixed to a disk 8 by means of a fixer 9 with one end, and the second ends are free and can make oscillative motions in a radial direction. The cam gear 10 is attached to a box. At rotation (together with the coil), scrapers bend around it. Curvature of the cam gear is such that in a capture and moving zone of fertilizer, scrapers rotate together with the coil in the pressed condition, and in the outflow zone they depart from a coil surface in a radial direction. After the outflow zone, scrapers again nestle on the coil.

As it has been noted, at increase of humidity, fertilizer stick in inter-pin intervals, and coils turn to smooth rollers. In the considered device at the expense of an oscillating motion of scrapers, integrity of the stuck fertilizer is broken, and it lags behind a coil surface. As a result, the process of seeding won't stop, and the reliability of operation of the device will increase.



1-bunker; 2-fertilizer funnel; 3-basis (bottom); 4-shaft; 5- pinned coil; 6-box; 7-scraper; 8-disk; 9-fixer; 10-cam gear.

Figure 1 - Self-cleaning fertilizer and seeding device

For a substantiation of the basic constructive dependences of the proposed fertilizer and seeding device, we will conduct its theoretical research. The major problem is the establishment of the scaraper movement pattern. For its resolution we will present a scraper in the form of the elastic shaft jammed by one end. In Figure 2 the elastic shaft with a length l , on which force P is applied, is represented. Thus the point κ of the shaft has moved to κ_1. Co-ordinates of κ_1 are x, y. If y is taken as a value of the first order of smallness , it is obvious that Δx is the value of the second order of smallness. Such statement is fair if the shaft is considered not to be extensible. Here Δx is the difference between abscissas of points κ and κ_1. The accepted statement allows to neglect value of Δx and to consider that during fluctuations the abscissa of κ remains constant. Thus

$$\dot{x} = 0. \tag{1}$$

The size of the second co-ordinate *y* depends on position of κ on a shaft and from time *t*, i.e. $y = y(x,t)$.

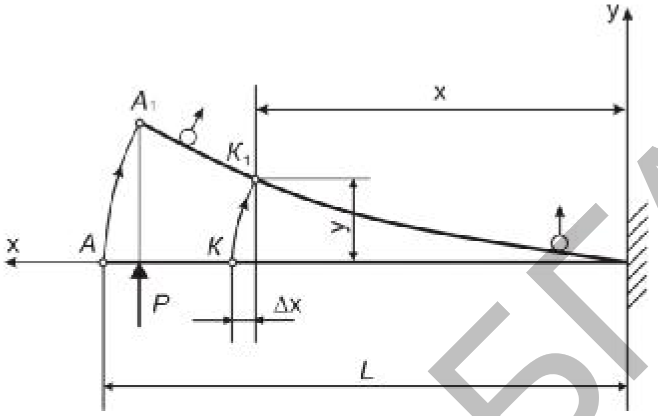


Figure 2 - Scheme of scrapers work

For drawing up the differential equation of fixing fluctuations of the elastic midstream fixed by one end, it is possible to use the principle of Hamilton–Ostrogradsky. Thus it is necessary to define the so-called action *S* of Hamilton [4]:

$$S = \int_{t_1}^{t_2} L\,dt, \tag{2}$$

Where: *L* = T - P – Langrangian;
T - kinetic energy of a point (system);
P - potential energy of a point (system).

Kinetic energy of an elastic shaft can be calculated by means of definite integral:

$$T = \frac{1}{2}\rho\int_0^l V^2 dx, \tag{3}$$

Where: ρ - density of a material of a shaft;
V - speed of a point of a shaft.

B (3) speed of a point of a shaft is obviously equal to: $V^2 = \dot{x}^2 + \dot{y}^2$.

However taking into account (1) it is: $V^2 = \dot{y}^2$.

Thus kinetic energy is calculated by the formula:

$$T = \frac{1}{2}\rho\int_0^l \dot{y}^2 dx. \tag{4}$$

Potential energy of elastic deformation of a bend of a shaft is calculated by the formula [5]:

$$\Pi = \frac{EJ}{2}\int_0^l \left(\frac{\partial^2 y}{\partial x^2}\right)^2 dx, \tag{5}$$

Where: E - the module of elasticity of a material of a shaft;

J - the moment of inertia of the area of cross-section of a shaft.

Let's define Langrangian:

$$L = \frac{1}{2}\int_0^l \left(\rho \dot{y}^2 - EJ y''^2\right) dx, \tag{6}$$

Where $y'' = \frac{\partial^2 y}{\partial x^2}$.

Using (6) and (2) define action across of Hamilton:

$$S = \frac{1}{2}\int_{t_1}^{t_2} dt \int_0^l \left(\rho \dot{y}^2 - EJ y''^2\right) dx. \tag{7}$$

Thus the variation of action S is calculated as:

$$\delta S = \int_{t_1}^{t_2} dt \int_0^l \left(\rho \dot{y}\,\delta \dot{y} - EJ y''\,\delta y''\right) dx. \tag{8}$$

The principle of Hamilton-Ostrogradsky assumes that the variation task of searching dependence $y = y(x, t)$ is reduced to definition of such function y, at which action S is permanent, i.e. such at which the first variation of action is equal to zero, i.e. $\delta S = 0$.

Also it is necessary to keep in mind that required function $y = y(x, t)$ should be continuous and have partial derivatives on x and t, and its variations during the initial and final moments of time (t_1, t_2) should be equal to zero. The last means that "straight line" and "roundabout" ways on the interval ends $\Delta t = t_2 - t_1$ incorporate, i.e.:

$$\delta y(x, t_1) = 0, \qquad \delta y(x, t_2) = 0. \tag{9}$$

Thus from (8) it is:

$$\int_{t_1}^{t_2} dt \int_0^l \left(\rho \dot{y}\,\delta \dot{y} - EJ y''\,\delta y''\right) dx = 0. \tag{10}$$

Conducting a number of transformations of composing members in (10):

$$\delta \dot{y} = \frac{d}{dt}\delta y; \quad \delta y'' = \frac{\partial}{\partial x}\delta y';$$

$$\dot{y}\frac{d}{dt}\delta y = \frac{d}{dt}\left(\dot{y}\,\delta y\right) - \ddot{y}\,\delta y,$$

$$y''\frac{\partial}{\partial x}\delta y' = \frac{\partial}{\partial x}\left(y''\delta y'\right) - y'''\delta y' \tag{11}$$

$$y'''\delta y' = y'''\frac{\partial}{\partial x}\delta y = \frac{\partial}{\partial x}\left(y'''\delta y\right) - y''''\delta y,$$

Taking into account transformations (11) from (10), it is possible to receive:

$$\int_{t_1}^{t_2} dt \int_0^l \left[\rho\frac{d}{dt}\left(\dot{y}\delta y\right) - \rho\ddot{y}\delta y + EJ\frac{\partial}{\partial x}\left(y'''\delta y - y''\delta y'\right) - EJy''''\delta y\right]dx = 0.$$

Last expression will be copied in form more convenient for integration:

$$\rho\int_{t_1}^{t_2} dt \int_0^l \frac{d}{dt}\left(\dot{y}\delta y\right)dx - \int_{t_1}^{t_2} dt \int_0^l \left(\rho\ddot{y} + EJ\,y''''\right)\delta y\,dx +$$
$$+ EJ\int_{t_1}^{t_2} dt \int_0^l \frac{\partial}{\partial x}\left(y'''\delta y - y''\delta y'\right)dx = 0. \tag{12}$$

Examine the first member of the equation (12):

$$\rho\int_{t_1}^{t_2} dt \int_0^l \frac{d}{dt}\left(\dot{y}\delta y\right)dx = \rho\int_0^l dx \int_{t_1}^{t_2} d\left(\dot{y}\delta y\right) =$$
$$\rho\int_0^l \left[\dot{y}\left(x,t_2\right)\delta y\left(x,t_2\right) - \dot{y}\left(x,t_1\right)\delta y\left(x,t_1\right)\right]dx$$

With the account of (9) from last expression, it is received:

$$\rho\int_{t_1}^{t_2} dt \int_0^l \frac{d}{dt}\left(\dot{y}\delta y\right)dx = 0. \tag{13}$$

Examine the second integral of the third member of the equation (12). At $x = 0$, the shaft has no movement. Therefore $\delta\left(0,t\right) = 0, \quad \delta y'\left(0,t\right) = 0.$

In this case, the last integrated expression will become:

$$\int_0^l \frac{\partial}{\partial x}\left(y'''\delta y - y''\delta y'\right)dx = y'''\left(l,t\right)\delta y\left(l,t\right) - y''\left(l,t\right)\delta y'\left(l,t\right). \tag{14}$$

The received results in (13) and (14) are introduced in the initial equation (12):

$$EJ\int_{t_1}^{t_2}\left[y'''\left(l,t\right)\delta y(l,t) - y''\left(l,t\right)\delta y'\left(l,t\right)\right]dt - \int_{t_1}^{t_2} dt \int_0^l \left(\rho\ddot{y} + EJy''''\right)\delta y\,dx = 0. \tag{15}$$

As values of variations in last equation are free, calculation is made, based on the basic lemma of variation problems [6, 7]:

$$\begin{cases} \rho \ddot{y} + EJy'''' = 0 \\ y''(l, t) = 0 \\ y'''(l, t) = 0 \end{cases} \tag{16}$$

In system of the equations (16) the first expression represents the differential equation in private derivative fluctuations of any point of the elastic shaft jammed by one end. The second and third equations in (16) are the equations of a point *A* of the shaft.

For solution of the equation (16) we accept a designation: $a^2 = \frac{E \cdot J}{\rho}$.

Thus in (16) it is possible to present the first expression in the form:

$$\frac{\ddot{y}}{a^2} + y^{(IV)} = 0 \tag{17}$$

Solution of the equation (17) is found in the form:

$$y = T(t) \cdot X(x). \tag{18}$$

Having substituted the last expression in (17) and having divided variables, we will receive:

$$\ddot{T} + a^2 \lambda^4 T = 0. \tag{19}$$

$$X^{(IV)} - \lambda^4 X = 0, \tag{20}$$

Where $\frac{\ddot{T}}{a^2 T} = -\frac{X^{(IV)}}{X} = -\lambda^4$.

The solution of the characteristic equation $\kappa^2 + a^2 \lambda^4 = 0$. For (19) gives:

$$T(t) = C_2 \sin a\lambda^2 t. \tag{21}$$

The solution of the characteristic equation $\kappa^4 - \lambda^4 = (\kappa^2 - \lambda^2)(\kappa^2 + \lambda^2)$ for (20) gives:

$$X(x) = C_6 \left(\frac{e^{\lambda x} - e^{-\lambda x}}{2} + \sin \lambda x \right) \tag{22}$$

Having substituted (21) and (22) in (18) the equation of movement is received of any point of the elastic shaft with one end fixed motionlessly:

$$y = y_m \sin(a\lambda^2 t + 2\pi) \cdot \frac{Sh\lambda x + \sin \lambda x}{Sh\lambda l + \sin \lambda l}, \tag{23}$$

Where: $C_2 \cdot C_6 = C$; $C = \frac{y_m}{Sh\lambda l + \sin\lambda l}$; $\frac{e^{\lambda x} - e^{-\lambda x}}{2} = Sh\lambda x$.

y_m - the maximum amplitude, design data.

$a = \sqrt{\frac{1}{\rho}EJ}$, $\omega = a\lambda^2$; $\lambda = \sqrt{\frac{\omega}{a}}$; ω - frequency of fluctuations.

The solution of the differential equation of the fourth order submitted in (23) connects all the main structural and technological parameters of a scraper of the self-cleaning fertilizer distributing machine [8, 9, 10]. These include amplitude, frequency,time and period of free oscillations of an arbitrary point of an elastic rod. Therefore, asking the current time, it is possible to determine the specified parameters of a scraper. With their help it is easy to justify the eccentric's parameters.

To analyze the motion of an elastic rod of the self-cleaning fertilizer distributing device for sowing of mineral fertilizers the obtained equation is calculated using Microsoft Excel program and is formed three kinds of major dependencies. The accepted measurements: $E = 2 \times 10^5$ *МПа*; J = 5,2 см^4; ℓ = 40 мм; n = 30 об/мин. Changes in amplitude oscillations of an elastic rod points with respect to the distance (x) from the fixing point and the oscillation period (t) are shown in Fig. 3. As shown in Figure oscillation amplitude of an arbitrary point of an elastic rod increases from zero at the period beginning.

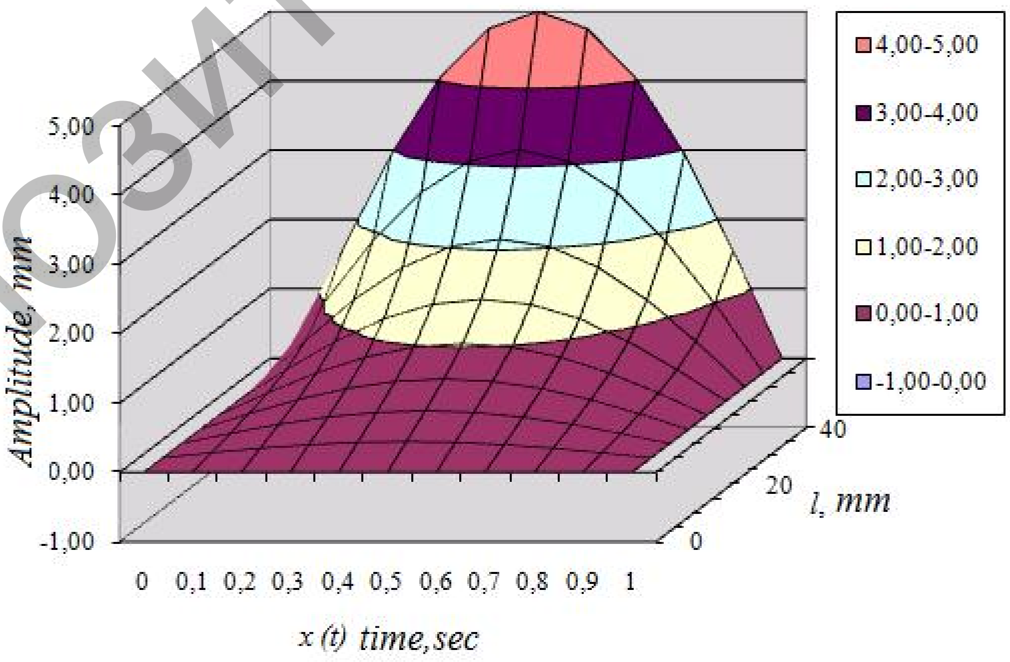


Figure 3 - Changes in the oscillations amplitude of the rod points relative to the distance from the fixing point and the oscillation period

Then in 0,5 seconds goes down and at the end of the period falls to a zero mark. Change of amplitude doesn't consist in direct dependence on change of time. Initial and final phases of amplitude during oscillatory process are less intensive in comparison with amplitude in a middle phase. At the same time theoretical and experimental dependence on time of amplitude and the period of oscillations of a scraper is established.

For the purpose of experimental confirmation of the received theoretical dependence special installation has been made. In it there is a LED lamp guiding thin beams to scraper which are established between coil grooves. On the shaft is mounted the power source. It provides the lamp with electric current. Upon actuation of pin into motion the scraper and the lamp on the guide surface of the eccentric moves in the radial direction. The process of movement of the scrapers with 0.04 seconds interval was recorded on a digital camera that operates at high speed. After processing of shots at a slow rate the parameters of the oscillations scrapers have been calculated. The experimental results have been approximated by five regression lines: linear, logarithmic, polynomial, sedate, exponential. The analysis of the received approximation coefficients, have shown that the most exact description of the studied process gives the polynomial equation:

$$y = -7{,}1165x^2 - 6{,}34x + 5{,}0, \qquad (24)$$

where, x - oscillation period, y - oscillation amplitude. To this equation there corresponds the correlation coefficient $R^2 = 0.9892$.

On the figure - 3 has been checked compliance of this equation with theoretical dependence (23) which describes the movement of an elastic core with the fixed end. What it shows that the experimental and polynomial dependence (24) correlated to 98.9%. In turn, the polynomial equation adequately describes the theoretical hyperbolic function characterizing the elastic behavior of the scraper

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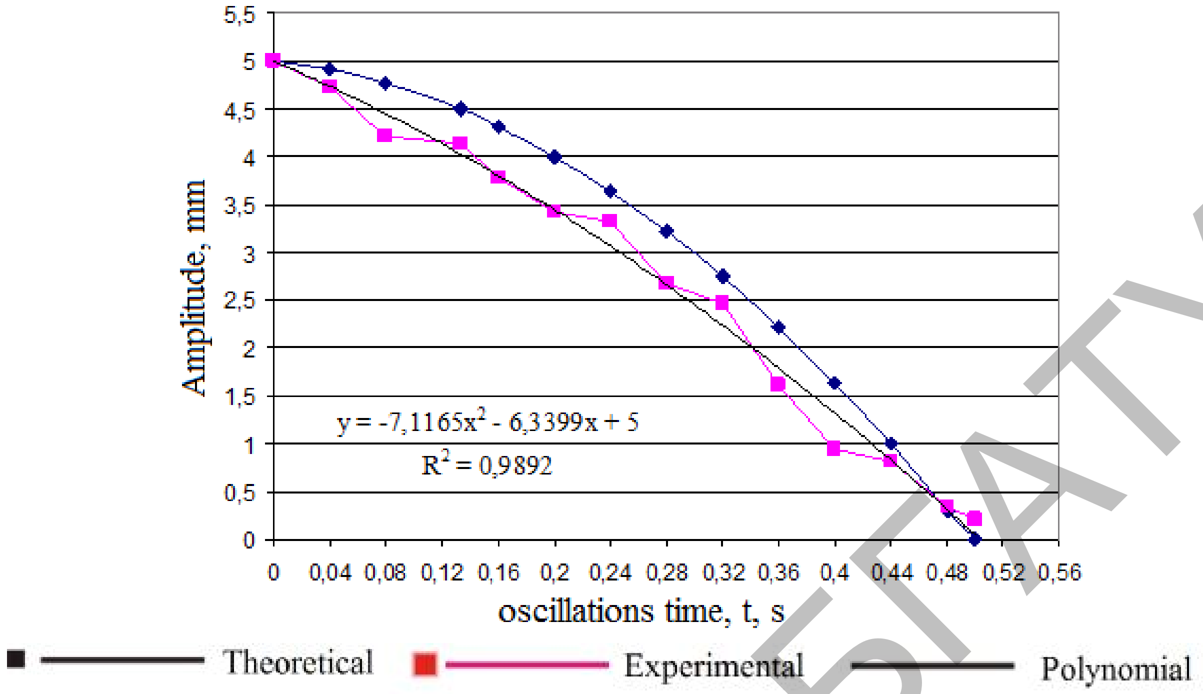

Figure 3 - Theoretical and experimental dependences of the amplitude and the oscillation period

Conclusion

On the basis of the analysis of the famous constructive decisions the sowing device for introduction granulated and powdery fertilizer in which are established the elastic scrapers in the coil grooves is offered. The solution of the differential equation of the fourth order, describing an oscillatory motion of the scraper has allowed to establish dependences of its amplitude, frequency and period on time. On the basis of the graphic analysis of the received hyperbolic function and laboratory experiments on real installation the optimal values of design and technological parameters of the self-cleaning sowing device are established: seeded hole d= 6,4 mm; amplitude A= 5,0 mm; frequency K= 34 rpm. Laboratory experiments with these parameters have shown that the process of seeding process is not violated at the humidity of mineral fertilizers up to 18%, at a stable non-uniformity no more than 7.9%.

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Түйін

Ауылшаруашылық дақылдарының өнімділігін арттыру мақсатында топырақтардың құнарлылығын көтеру үшін, оны минералды тыңайтқыштармен үнемі қоректендіріп отыру қажет. Минералды тыңайтқышты енгізудің тиімділігін сипаттайтын негізгі көрсеткіш – оның тұқым тарайтын топырақ қабатына сіңіру біркелкілігі. Топырақ қабатына тыңайтқыш біркелкі сіңірілген сайын, оның тиімділігі де арта түседі.

Түйіршіктелген және ұнтақталған минералды тыңайтқыштарды себуге арналған өзі тазаланатын себу аппараты ұсынылады. Ол үшін шарғының жолағына тазалағыш орнатылған. Аппарат ылғалдылығы жоғары тыңайтқыштарды да себе алады. Тазалағыштың қозғалысын сыйпаттайтын төртінші реттегі теңдеу алынған. Оның шешімі тазалағыш тербелісі амплитудасының, жиілігінің, оралымының уақытқа байланысын анықтауға мүмкіндік береді.

Резюме

Для восстановления и повышения плодородия почвы, следовательно, урожайности сельскохозяйственных культур необходимо регулярное внесение минеральных удобрений. Оно особенно эффективно, если совмещается посев с внутрипочвенным внесением основной или стартовой дозы туков за один проход машины.

Предложен самочищающийся высевающий аппарат для высева гранулированных и порошковидных минеральных удобрений, который может работать и при повышений их влажности. Для этого в желобки катушки установлены упругие чистики. Получено дифференциальное уравнение четвертого порядка описывающее колебательное движение чистика. Его решение позволило установить зависимости амплитуды, частоты и периода колебенйи чистика от времени.

Summary

To improve soil fertility and to increase the yield of agricultural products soil should be regularly enriched with mineral fertilizers. One of the key indicators of the effectiveness of application of solid fertilizers is nonuniformity of their distribution over the field surface with surface application and over the root layer with intrasoil application.

The proposed self-cleaning sowing machine for application of granular and powdered fertilizers can operate with increased humidity. For this purpose, elastic scrapers were installed into the coil grooves. The differential equation of the fourth order describing the oscillational motion of scraper is derived. Its solution has allowed to set the dependencies of amplitude, frequency, and the oscillation period of scraper on time.