THE CENTRIFUGAL TYPE MINERAL FERTILIZERS SPREADER

The scientific foundations of justification of technological parameters for centrifugal type mineral fertilizers spreaders.

It is founded out one of the possible reasons of the uneven dispersion of fertilizers by centrifugal type spreader. Simplified for engineering application formulas are derived, making it possible to justify the construction of fertilizer spreader disk that is guaranteed improves dispersion. Technical means are created and implemented into production.

Key words: fertilizing, fertilizers, allocation quality, effectiveness of machines, spreader parameters, working modes.

Introduction. The uneven distribution of nutrients by surface of fields affects crop yields. The development of fertilizers favorable primarily in a direction of improving the efficiency of fertilizing by improving the quality of their distribution by soil surface. More than 90% of modern fertilizers are equipped with spreading centrifugal working bodies that successfully applies granular and crystalline fertilizers and chemical ameliorants. Fertilizers must apply them accurately (evenly). Nowadays some parameters of fertilizing are too big, so uneveness by working width with machines of domestic production reaches 60-80%, what reduces the efficiency of fertilizers. Thus, the justification and design parameters of the centrifugal working body for fertilizers is an actual task [3-5].

Literature data analysis. P. Vasilenko was recognized as founder of the centrifugal type spreaders theory by law. Later theoretical studies were conducted by V. V. Adamchuk, E. V. Kozlovsky, Dohonovskyy M. G., M. K. Shtukov, R. M. Hilis, V. F. Yaroshenko, S. I. Nazarov. Among the latest fundamental analytical research attracts the attention works of V. V. Adamchuk, V. M. Bulgakov, P. M. Zaika, S. F. Pylypaky.

An important contribution to science in sphere of the development and implementation of centrifugal type mineral fertilizers was made by S. I. Volosnykov, S. F. Babaryka, V. N. Dyadya, L. I. Letkovskyy and others.

Analytical research of centrifugal spreaders working body sowing process. The process of granules distribution by surface of a field has multifactorial probabilistic nature. It is influenced by: normal distribution coefficient of windage, logarithmic law of dependance of on flight distance from windage coefficient, translational motion of the unit law as a whole. Superposition of these laws gives the final picture of the distribution of fertilizers by the surface. In general, the law can not be normal. But if a sufficiently large number of options for starting coming-off of granules from the surface is provided, from the point of view of probability theory, this law will be closer to normal.

Graphical interpretation of this provision is shown on Fig.1.
As seen from the above, the usual amount of 1 single distribution laws allows to receive areas 2 close to the normal distribution. Therefore, it is necessary to provide coming-off of multiple streams of granules with different initial velocities, preventing flow crossing during flight.

As analysis of the process of fertilizing showed [1,8-10], centrifugal type spreaders can provide more dense sowing by the edges of coverage. To improve eveness, construction diagram is proposed (Fig. 1), which provides various initial conditions for granules escape from each of three edges placed on four bladed disk.

In accordance with the accepted disk construction, scattering scheme provides that the width of the treated area, where fertilizers apply, divided into three parts. Each edge on the blade should apply fertilizer on the territory assigned to it. In order for this happens, it is necessary to determine the length of each edge, and the it position on the blade. Let us assume that goal will be achieved if the granules on the middle edge will gain escaping velocity enough for sowing area with width 2/3B, and with short edge - 1/3B. Velocity addition theorem is used to determine the escaping velocity of fertilizer from edge, which starts at an arbitrary distance $a$ from the center of disk.

$$
\vec{V} = \vec{V}_r + \vec{V}_e,
$$

where $\vec{V}_r$ - the relative velocity along the guiding edge; $\vec{V}_e$ - transient velocity, which for escaping from disk fertilizer determined by known angular velocity $\omega$ of disk and edge length $l$ as

$$
\vec{V}_e = \omega \cdot \sqrt{l^2 \cos^2 \alpha + a^2}.
$$

The relative speed can be found by the theorem of changing of kinetic energy in relative motion from formula [6]

$$
\frac{mV_r^2}{2} - \frac{mV_0^2}{2} = A(F_e) + A(F_{\text{int}}) + A(F_{\text{fric}}) + A(P),
$$

where $A(F_e)$ - work of transient force of inertia $F_e$ on moving along the edge; $A(F_{\text{fric}})$ - work of the friction force that occurs on the surface of the blade because of force action $F_e$ and fertilizer weight $P$; $A(F_{\text{int}})$ - work of the friction force that occurs on surface of the vertical edge from the Coriolis force of inertia $F_e$ and transient force $F_{\text{fric}}$; $A(P)$ - work of weight force; $V_0$ - initial relative velocity.

Work of transient inertial forces on movement defines as

$$
A(F_e^m) = \frac{1}{2} m \omega^2 (R_e^2 - a^2).
$$

Friction force on the surface of blade $F_{\text{fric}}$ determined through the normal reaction $N_1$, which is due fertilizer weight $P$ and transient inertial force $F_e^m$

$$
N_1 = P \cos \alpha + F_e^m \sin \psi \sin \alpha.
$$
Than $F_{mx} = f \left( mg \cos \alpha + m\omega^2 r \cdot \frac{x}{r} \cos \alpha \sin \alpha \right) = fm \left( g \cos \alpha + \omega^2 x \cos \alpha \sin \alpha \right)$.

Where $\tau$- friction coefficient.

Work of the friction force on the surface of blade $A(F_{mx})$ defines as

$$A(F_{mx}) = f m g \sqrt{R_e^2 - a^2} - f m \omega^2 \cdot \frac{1}{2} \left(R_e^2 - a^2\right) \sin \alpha / \cos \alpha.$$  \hspace{1cm} (4)

Friction force on the edge surface is defined as

$$F_{mp} = f \left(2m\omega V, \cos \alpha - m\omega^2 a\right).$$  \hspace{1cm} (5)

Work of this force is defined as

$$A(F_{mp}) = -\int_0^1 f m \omega V_1 \cos \alpha dx + \int_1^2 f m \omega^2 adx.$$  \hspace{1cm} (6)

Assuming that initial relative velocity $V_0 = \omega a \cos \alpha$ for $A(F_{mp})$ we will get

$$A(F_{mp}) = -f m \omega (a \omega \cos \alpha + V) \sqrt{R_e^2 - a^2} + f m \omega^2 a \sqrt{R_e^2 - a^2} / \cos \alpha.$$  \hspace{1cm} (7)

Work of weight force $P$ defines as

$$A(P) = -mg \sin \alpha.$$  \hspace{1cm} (8)

Substituting expressions (3), (4), (7), (8) into formula (2) we will get

$$\frac{mV^2}{2} - \frac{mV_0^2}{2} = \frac{1}{2} m \omega^2 \left(R_e^2 - a^2\right) - f m g \sqrt{R_e^2 - a^2} - \frac{1}{2} f m \omega^2 \left(R_e^2 - a^2\right) \sin \alpha / \cos \alpha -$$

$$- f m \omega (a \omega \cos \alpha + V) \sqrt{R_e^2 - a^2} + f m \omega^2 a \sqrt{R_e^2 - a^2} / \cos \alpha -$$

$$mV_0^2 - \frac{mV_0^2}{2} = \frac{1}{2} m \omega^2 \left(R_e^2 - a^2\right) - f m g \sqrt{R_e^2 - a^2} - \frac{1}{2} f m \omega^2 \left(R_e^2 - a^2\right) \sin \alpha / \cos \alpha -$$

$$mV_0^2 - \frac{mV_0^2}{2} = \frac{1}{2} m \omega^2 \left(R_e^2 - a^2\right) - f m g \sqrt{R_e^2 - a^2} - \frac{1}{2} f m \omega^2 \left(R_e^2 - a^2\right) \sin \alpha / \cos \alpha -$$

$$- f m \omega^2 \cos \alpha \sqrt{R_e^2 - a^2} - f m V \sqrt{R_e^2 - a^2} + f m \omega^2 a \sqrt{R_e^2 - a^2} / \cos \alpha - mgl \sin \alpha.$$  \hspace{1cm} (9)

If into the last expression substitute distance from center to the first edge $(a = a_1)$, we will get

$$\frac{mV^2}{2} - \frac{mV_0^2}{2} = \frac{1}{2} m \omega^2 \left(R_e^2 - a_1^2\right) - f m g \sqrt{R_e^2 - a_1^2} - \frac{1}{2} f m \omega^2 \left(R_e^2 - a_1^2\right) \sin \alpha / \cos \alpha -$$

$$- f m \omega \cos \alpha \sqrt{R_e^2 - a_1^2} - f m V \sqrt{R_e^2 - a_1^2} + f m \omega^2 a_1 \sqrt{R_e^2 - a_1^2} / \cos \alpha - - mgl \sin \alpha.$$  \hspace{1cm} (9)

Where for the relative velocity on escaping from the long edge you can get

$$V = c_1 + \sqrt{c_2^2 + c_1^2},$$  \hspace{1cm} (10)

where $c_1 = f \omega \sqrt{R_e^2 - a_2^2}$,

$c_2 = \omega^2 a_1 \cos \alpha \left(a_1 \cos \alpha - 2 f \sqrt{R_e^2 - a_2^2} + \omega^2 \left(R_e^2 - a_2^2\right)\right) (1 - f \sin \alpha / \cos \alpha) -$  

$$- 2 f g \sqrt{R_e^2 - a_2^2} + 2 f \omega^2 a_1 \sqrt{R_e^2 - a_2^2} / \cos \alpha - 2 gl_\alpha \sin \alpha.$$

Then definition of absolute velocity is:

$$V_a = \sqrt{V_a \cos \alpha_0^2 + (V_r \sin \alpha)^2},$$  \hspace{1cm} (11)

where $\alpha_0$ – angle of fertilizer escaping; $V_0 \cos \alpha_0$ – projection of escaping velocity on a horizontal plane; $V_0 \sin \alpha_0$ – projection of escaping velocity on a vertical plane.

Than for escaping angle we can get

$$\alpha_0 = \arccos \sqrt{(V_r \cos \alpha_0)^2 + V_e^2 + 2V_e V_r \cos \alpha \cos \gamma} / V_a.$$  \hspace{1cm} (12)

These formulas allow to justify some constructional characteristics of the spreader.

Analysis of possible options of constructions of centrifugal working body for fertilizing allowed to accept spreader scheme, construction of which involves formation arrangement of granule flows when loading. To perform the task working body scheme is proposed – Fig.1.

Spreader consists of disk 17, four blades
(sectors 11–14), each of which is formed by two blades whose side walls are formed by vertical edges and bottoms are inclined at angles $\alpha_1$ and $\alpha_2$ to horizontal disk surface. Each edge (1–3) is perpendicular to the common line of intersection blades bottoms and disk plane (at Fig.1 directions of each edge marked with angles $\gamma_1$, $\gamma_2$, $\gamma_3$ accordingly). In the center of the disc there is a conical feeder 4, interior space of which is divided onto separate sectors by radial vertical plates (6–10). Each plate at the bottom part goes beyond the feeder on edge height and by bottom part attached to horizontal central part of the disk. The lateral end of protruding from the feeder part (conical) is connected to the curvilinear section of the edge 2, which is placed on the horizontal plane of the disk.

In the same way edge 3 is connected to the protruding side end of the plate 8, and edge 1 – with 9. In each quarter of the centrifugal working body where the working blade is, feeder divided into four sectors by plates. Three of them workable, through two blades fertilizer fall on upper disk, and on the second sector accounts 53.6% amount of fertilizer from first, and onto the last – third – the least 11.24% of the same amount. From this sector fertilizer falls onto disk 15, which is situated lower on 60 mm from the upper which is provided by cup 5, on which are placed perpendicular one to each other guiding edges 16. One of feeder sectors closed from above (fig.1, shaded). Sectors areas are assigned proportional to the expenditure of material which falls on each edge. The material getting into the sectors falls on the horizontal surface of the disc from which, moves between the curved portions of edges gets to the inclined blades.

**Fig.1. Constructive and technological scheme of the centrifugal working body for fertilization**

At fig.2 there is a scheme, which qualitatively describes the distribution of granules by simultaneous dispersion with three edges.

**Fig. 2. Distribution of three streams**

As we can see, areas are limited by intensity distribution curve, on each of the three units of bandwidth capture approximately the same, so on each lane approximately the same number of granules. Relatively to uneven distribution of granules within a lane, we can note that above-mentioned situation is idealized and includes: all granules flies on the same distance during work of one of the edges. The reality is that the granules are not identical in shape and capacity. They have different aerodynamic characteristics, providing a different range of flight and improves uniformity of distribution which can be tested experimentally.

**Conclusions.** In this paper, the scientific and appliance problem of efficiency improvement of mechanical application of solid fertilizers is solved through improvement of quality of their distribution by the surface of soil and increasing of machine productivity.

1. New construction of spreader is proposed, which can realize better uniform dispersion, in condition of ensuring of individual supply of each of three streams of granules, which are escaping from disc.

2. Fairly simple formulas for engineering application are derived, which gives the possibility to justify the construction of disk fertilizers spreader, which improves dispersion guaranteed.

3. The resulting formula can determine the absolute velocity of fertilizer escaping from the disc and the angle of escaping that are necessary to
дetermine the operation width of spreader.

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Information about the authors

Kobets A.S. – doctor of public administration, professor of the department of agricultural machines of Dnipro national agrarian-economic university (St.S.Efremova, 25, Dnipro, Ukraine, 49000)

Naumenko N.N. – candidate of technical sciences, professor of the department of theoretic mechanic and material recovery of Dnipro national agrarian-economic university (St.S.Efremova, 25, Dnipro, Ukraine, 49000, e-mail: nnitf@ukr.net)

Ponomarenko N.A – candidate of technical sciences, assistant professor of the department of expuationation machinery-tractor park of Dnipro national agrarian-economic university (St.S.Efremova, 25, Dnipro, Ukraine, 49000, e-mail: nanagieva@ukr.net)

Yaropud V.M. – candidate of technical sciences, senior lecturer of the department of agricultural machines of Vinnytsia national agrarian university (St.Soniachna, 3, Vinnytsia, Ukraine, 21008, e-mail: yaropud77@gmail.com)

Кобець Анатолій Степанович – доктор з державного управління, професор кафедри сільськогосподарських машин Дніпровського державного аграрно-економічного університету (ул. Сергія Ефремова, 25, м. Дніпро, Україна, 49000)

Науменко Микола Миколайович – кандидат технічних наук, професор кафедри теоретичної механіки та опору матеріалів Дніпровського державного аграрно-економічного університету (ул. Сергія Ефремова, 25, м. Дніпро, Україна, 49000, e-mail: nnitf@ukr.net)

Пономаренко Наталія Олексandrівна – кандидат технічних наук, доцент кафедри експлуатації машинно-тракторного парку Дніпровського державного аграрно-економічного університету (ул. Сергія Ефремова, 25, м. Дніпро, Україна, 49000, e-mail: nanagieva@ukr.net)

Яропуд Віталій Миколайович – кандидат технічних наук, старший викладач кафедри сільськогосподарських машин Вінницького національного аграрного університету (ул. Сонячна, 3, м. Вінниця, Україна, 21008, e-mail: yaropud77@gmail.com)