RESEARCH OF DESCENT OF MINERAL FERTILISER PARTICLE FROM DISC INCLINED AT ANGLE TO HORIZON

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Abstract. Application of mineral fertilisers is an important operation, providing not only a high yield, but also a uniformity of the obtained crop over the field area. Currently, most of the mineral fertilisers are applied by the surface method, using machines equipped with centrifugal spreaders. One of possible solutions how to improve the mineral fertiliser spreaders in the direction of the uniform distribution of fertilisers on the field surface is to use centrifugal spreading tools, the rotation axes of which are inclined at an angle to the horizontal plane. We carried out theoretical studies and obtained a new equation describing the movement of a material fertiliser particle along the blade of a centrifugal spreader, taking into account the angle of inclination of the spreading disc, and its solution is given in a closed form. New theoretical dependencies were established to determine the absolute velocity of the mineral fertiliser particles at the moment of their escape from the spreader disk, depending on the place of the outlet of the flow of mineral fertilisers from the hopper. The use of the obtained analytical dependences and their subsequent numerical solution on the PC made it possible to establish the impact of the structural and kinematic parameters, the operating conditions of the inclined centrifugal spreader of mineral fertilisers, in particular, the absolute velocity of the fertiliser particles escaping from the distribution disk, and their acceleration angle. By using the centrifugal scattering working tool with an inclined axis of rotation, it is possible to increase the range of dispersion of ammonium nitrate particles over the surface of soil by 3-5 m. Based on the obtained data, a design of a centrifugal scattering working tool with an inclined axis of rotation has been developed.

Keywords: mineral fertilisers, spreading, disc, inclination.

Introductio

Despite the active introduction of organic farming in the main areas of crops, fertilizers are introduced to increase soil fertility [1-2]. Most of the mineral fertilisers are applied by a superficial method, using machines equipped with centrifugal spreaders [2-3]. At present, increasing the efficiency of the aggregates for applying mineral fertilisers because of an increase in the working speed of their movement and the utilisation rate of the variable time, has been exhausted, the only way to increase efficiency is to increase the working width of the grip.

It is generally known that the working width of machines for spreading mineral fertilisers depends on the magnitude of the absolute rate V_{AC} of descent of fertiliser particles from the centrifugal scattering working tool and the angle α_{AC} between the vector of the last and horizontal plane. Value V_{AC} depends on the geometric parameters and kinematic modes of operation of the centrifugal scattering working tool, and the physical-mechanical properties of mineral fertilisers [4-5].

As a result of our previously conducted investigations, we optimised the geometric parameters and operating modes of the centrifugal scattering working tool, taking into account the physical-mechanical properties of the mineral fertilizers, and found that the increase in the kinematic mode of operation of the centrifugal scattering working tool is limited by the strength of the fertiliser granules [6].

Thus, at this stage, with the available structural materials for manufacturing a centrifugal scattering working body and strength of the granules of mineral fertilisers, the possibility of increasing the working width of the spreaders due to the increase in the speed V_{AC} has been exhausted. Due to this, increasing the working width of the spreaders is possible only by achieving rational values of the indicated angle α_{AC} (between the absolute velocity vector V_{AC} of the descent of the fertiliser particles from the centrifugal scattering working tool and the horizontal plane).

The author of [7] has found that increasing the working width of grip of the mineral fertilisers by a centrifugal scattering working tool is possible by achieving rational values of the angle α_{AC}. The obtained results of the investigation indicate that rational values of α_{AC} are within the range 30¯35°. At

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the same time, the author of the work [8] has established that the existing centrifugal scattering working tools can ensure the achievement of a value of α_{AC} not more than 15.7º. The centrifugal scattering working tools with an inclined axis of rotation ensure achievement of rational values of α_{AC} [7].

A methodology is known, by using which it is possible to determine the absolute rate of descent of a fertiliser particle from the centrifugal scattering working tool, the axis of rotation of which is vertical [9]. And another methodology is known, by using which it is possible to determine the absolute rate of descent of a fertilizer particle from a centrifugal scattering working tool, the rotation axis of which is horizontal [5]. Unfortunately, they do not consider methods for determining the absolute rate of descent of a fertiliser particle from a centrifugal scattering working tool, the axis of rotation of which is placed inclined to the horizontal plane.

The purpose of the research is to determine the maximum width of the dispersion of particles of mineral fertilisers (saltpetre), based on analytical and experimental studies and calculations on a PC.

Materials and methods

Theoretical research was carried out on the basis of theoretical mechanics, higher mathematics, as well as numerical calculations on a PC [10]. To study the descent of a particle of the mineral fertiliser from the scattering disk, inclined at angle α to the horizon, at first it is necessary to determine the absolute velocity of the particle (Fig. 2). When determining the absolute rate of descent of the particles of mineral fertilisers from the disk (i.e., from the end of the blade), inclined at angle α to the horizon, the following should be noted. Obviously, the rate of descent $\bar{V}_{GO}$ of the fertiliser particle at any moment time t is the sum of vectors of the previously determined relative velocity $\bar{V}_{BC}$ of the particle along the blade at its end and the transfer velocity $\bar{V}_{NC}$ of the blade during rotation of the disk. Since the velocity vector $\bar{V}_{BC}$ lies in the plane of the disk and is directed along the radius of the disk, and the velocity vector $\bar{V}_{NC}$ also lies in the plane of the disk and has a direction along the tangent to the disk, the velocity vector $\bar{V}_{GO}$ also lies in the plane of the disk and represents the vector sum of two vectors lying in the plane of the disk. However, the main difficulty is that the angle between the velocity vector $\bar{V}_{GO}$ and the horizontal plane will be variable at any given time t. And, if we take into account the forward movement of the spreading working tool, the task is much more complicated. Therefore, in this case it is not possible to apply the usual properties of vector addition by the parallelogram rule and the cosine theorem to determine the modules of these vectors. It is much simpler and more convenient to perform the addition of vectors, determining their modules and the necessary angles between the vectors, to represent these vectors through their projections in the Cartesian coordinate system. In this case, it is simple enough to determine also the scalar and vector products of the vectors.

It is necessary to choose a Cartesian coordinate system so that the projections of the necessary vectors are determined in an obvious way at an arbitrary point in time t. Since we need ultimately to determine the angle between the absolute velocity vector $\bar{V}_a$ of a particle of the mineral fertiliser at the moment of its descent from the end of the blade, taking into account the forward movement of the aggregate and the horizontal plane, we first choose a Cartesian coordinate system $xOyz$, the origin of which (point O) is located in the centre of the rotating disk; axis Oy lies in the horizontal plane and is directed opposite to the direction of the forward movement of the aggregate; axis Ox also lies in the horizontal plane and is directed perpendicular to axis Oy to the right of the indicated axis (to the left of the direction of forward movement of the aggregate); axis Oz is directed vertically upward.

Since the disk is inclined at angle α to the horizon, we choose another Cartesian coordinate system $x_1Oy_1z_1$, which is formed as a result of rotation of the coordinate system $xOyz$ around point O by angle (the angle of inclination of the disk to the horizontal) in a vertical plane yOz counter-clockwise. Besides, the horizontal plane xOy will turn out to be in the plane of the disk, forming plane x_1Oy_1 of the Cartesian coordinate system $x_1Oy_1z_1$, axis Oz will turn by angle α, forming axis Oz_1 that will be perpendicular to the plane of the disk (Fig. 2), which will be perpendicular to the plane of the disc (Fig. 1).

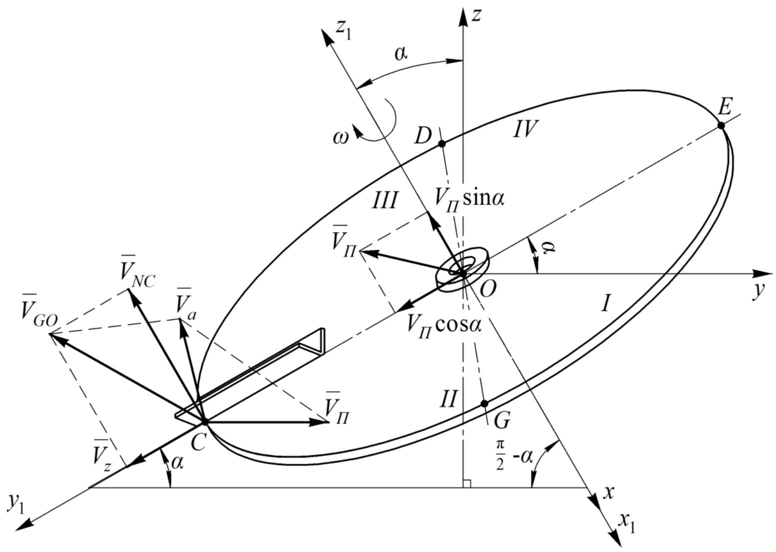

Fig. 1. **Kinematic diagram of the particle velocities of the mineral fertiliser, leaving the end of the blade**

Thus, it will turn out that the disk rotates around an axis that coincides with axis $Oz_1$with a constant angular velocity ω in a clockwise direction. The movement of the fertiliser particle along the disk will be effected in plane x_1Oy_1; therefore, it will not be difficult to determine the projection of the velocity vectors of the this particle in the specified coordinate system $x_1Oy_1z_1$. In the coordinate system $x_1Oy_1z_1$, the relative velocity $\bar{V}_{BC}$ of the movement of a particle along the plane of the disk (along the blade) at the time of being on the edge of the disk may be represented by the following vector:

$$\bar{V}_{BC} = \left\{ V_{BC} \sin \omega t, \quad V_{BC} \cos \omega t, \quad 0 \right\}. \tag{1}$$

The transfer (circular) velocity $\bar{V}_{NC}$ of the particle may be represented by the following vector:

$$\bar{V}_{NC} = \left\{ V_{NC} \cos \omega t, \quad -V_{NC} \sin \omega t, \quad 0 \right\}. \tag{2}$$

Then the total rate $\bar{V}_{GO}$ of descent of the fertiliser particle from the spreading disk is:

$$\bar{V}_{GO} = \bar{V}_{BC} + \bar{V}_{NC}, \tag{3}$$

or, taking into account (1) and (2), we obtain that the speed $\bar{V}_{GO}$ will be equal to such a vector:

$$\bar{V}_{GO} = \left\{ V_{BC} \sin \omega t + V_{NC} \cos \omega t, \quad V_{BC} \cos \omega t - V_{NC} \sin \omega t, \quad 0 \right\}. \tag{4}$$

The velocity vector $\bar{V}_\Pi$ of the forward movement of the aggregate in the coordinate system $x_1Oy_1z_1$ is equal to:

$$\bar{V}_\Pi = \left\{ 0, \quad -V_\Pi \cos \alpha, \quad V_\Pi \sin \alpha \right\}. \tag{5}$$

The vector of the absolute velocity $\bar{V}_a$ of the fertiliser particle during its descent from the disk, taking into account the dooryard movement of the aggregate, is equal to:

$$\bar{V}_a = \bar{V}_{GO} + \bar{V}_\Pi, \tag{6}$$

or, taking into account expressions (4) and (5), we obtain:

$$\bar{V}_a = \left\{ V_{BC} \sin \omega t + V_{NC} \cos \omega t, \quad V_{BC} \cos \omega t - V_{NC} \sin \omega t - V_\Pi \cos \alpha, \quad V_\Pi \sin \alpha \right\}. \tag{7}$$

The modulus of the vector $\bar{V}_a$ (i.e. the value of the absolute velocity) will be equal to:

$$V_a = \Big[\left(V_{BC} \sin \omega t + V_{NC} \cos \omega t\right)^2 + \left(V_{BC} \cos \omega t - V_{NC} \sin \omega t - V_{\Pi} \cos \alpha\right)^2 + + \left(V_{\Pi} \sin \alpha\right)^2 \Big]^{\frac{1}{2}} . \tag{8}$$

The angle of inclination of the vector of the absolute velocity $\bar{V}_a$ of the descent of the fertiliser particle from the disk to the horizontal plane (or the field surface) can be defined as the angle between the indicated vector $\bar{V}_a$ and its projection on the horizontal plane at an arbitrary point in time t. However, the projections of the vector $\bar{V}_a$ are defined in the coordinate system $x_1Oy_1z_1$ (expression 7), the axes of which Oz_1 are Oy_1 deviated from axes Oz and Oy of the coordinate system $xOyz$ by angle α, respectively (Fig. 1). In addition, the axes Ox_1 and Ox coincide. Therefore, first of all, it is necessary to determine the projection of the vector $\bar{V}_a$ in the coordinate system $xOyz$, using the transformations of the Cartesian coordinate system, when it is turned by angle α around the origin of the coordinates. In this case, as already noted above, the coordinate system $xOyz$ was turned counter-clockwise by angle α, resulting in the coordinate system $x_1Oy_1z_1$. If we take as the initial coordinate system the system $x_1Oy_1z_1$in which the projections of vector $\bar{V}_a$ are defined, then the coordinate system $xOyz$ will be obtained by returning the coordinate system $x_1Oy_1z_1$ by angle -α (angle α in a clockwise direction). Since turning of the coordinate system $x_1Oy_1z_1$ by angle -α is made around axis Ox_1, the coordinate x_1 of any point during this turning is preserved, that is, $x = x_1$. Regarding the coordinates y_1 and z_1 of any point, it should be noted that they are converted in accordance with the following expressions when turning counter-clockwise by angle α [1].

$$\left.\begin{aligned} y &= y_1 \cos \alpha + z_1 \sin \alpha, \\ z &= -y_1 \sin \alpha + z_1 \cos \alpha. \end{aligned}\right\} \tag{9}$$

Since in this case turning takes place by angle $-\alpha$, then, replacing in expressions (9) α by -α, we obtain:

$$\left.\begin{aligned} y &= y_1 \cos \alpha - z_1 \sin \alpha, \\ z &= y_1 \sin \alpha + z_1 \cos \alpha. \end{aligned}\right\} \tag{10}$$

However, transformations (10) relate to the transformations of the coordinates of a point. These transformations take place also when transforming the coordinates of a vector. Using expression (10) considering (7), we obtain the value of the vector $\bar{V}_a$ of the absolute velocity of descent of the fertiliser particle from the disk in the Cartesian coordinate system $xOyz$ through its coordinates in the system $x_1Oy_1z_1$:

$$\bar{V}_a = \Big\{ V_{BC} \sin \omega t + V_{NC} \cos \omega t, \quad \left(V_{BC} \cos \omega t - V_{NC} \sin \omega t - V_{\Pi} \cos \alpha\right) \cos \alpha - -V_{\Pi} \sin^2 \alpha, \quad \left(V_{BC} \cos \omega t - V_{NC} \sin \omega t - V_{\Pi} \cos \alpha\right) \sin \alpha + V_{\Pi} \sin \alpha \cdot \cos \alpha \Big\}. \tag{11}$$

The projection $\bar{V}_{anp}$ of the vector $\bar{V}_a$ onto the horizontal plane $xOyz$ can be represented as follows:

$$V_{a\,np.} = \Big\{ V_{BC} \sin \omega t + V_{NC} \cos \omega t, \quad \left(V_{BC} \cos \omega t - V_{NC} \sin \omega t - V_{\Pi} \cos \alpha\right) \times \times \cos \alpha - V_{\Pi} \sin^2 \alpha, \quad 0 \Big\}. \tag{12}$$

Then the cosine of the angle φ = ($\bar{V}_a$, $\bar{V}_{anp}$) between the vector $\bar{V}_a$ and the horizontal plane xOy at an arbitrary point in time t will be equal to:

$$\cos \varphi = \frac{\bar{V}_a \cdot \bar{V}_{a\,np.}}{V_a \cdot V_{a\,np.}}, \tag{13}$$

where $\bar{V}_a \cdot \bar{V}_{anp}$ – scalar product of vectors $\bar{V}_a$ and $\bar{V}_{anp}$;
$\bar{V}_a$ *and* $\bar{V}_{anp}$ – modules of vectors $\bar{V}_a$ and $\bar{V}_{anp}$, respectively.

We define the scalar product of vectors $\bar{V}_a$ and $\bar{V}_{anp}$.

$$\bar{V}_a \cdot \bar{V}_{a\,np.} = \left(V_{BC}\sin\omega t + V_{NC}\cos\omega t\right)^2 + \\ +\left[\left(V_{BC}\cos\omega t - V_{NC}\sin\omega t - V_{\Pi}\cos\alpha\right)\cos\alpha - V_{\Pi}\sin^2\alpha\right]^2. \tag{14}$$

Next, we define the module of the vector $\bar{V}_a$ and the module of the vector $\bar{V}_{anp}$.

The module of the vector $\bar{V}_a$ will be equal to:

$$V_a = \Big\{\left(V_{BC}\sin\omega t + V_{NC}\cos\omega t\right)^2 + \left[\left(V_{BC}\cos\omega t - V_{NC}\sin\omega t - V_{\Pi}\cos\alpha\right)\times \\ \times\cos\alpha - V_{\Pi}\sin^2\alpha\right]^2 + \left[\left(V_{BC}\cos\omega t - V_{NC}\sin\omega t - V_{\Pi}\cos\alpha\right)\sin\alpha + \\ +V_{\Pi}\sin\alpha\cdot\cos\alpha\right]^2\Big\}^{\frac{1}{2}}. \tag{15}$$

The module of the vector $\bar{V}_{anp}$ will be equal to:

$$\bar{V}_{a\,np.} = \Big\{\left(V_{BC}\sin\omega t + V_{NC}\cos\omega t\right)^2 + \left[\left(V_{BC}\cos\omega t - V_{NC}\sin\omega t - \\ -V_{\Pi}\cos\alpha\right)\cos\alpha - V_{\Pi}\sin^2\alpha\right]^2\Big\}^{\frac{1}{2}}. \tag{16}$$

Results and discussions

Substituting (14), (15) and (16) into (13), we obtain:

$$\cos\varphi = \Big\{\left(V_{BC}\sin\omega t + V_{NC}\cos\omega t\right)^2 + \left[\left(V_{BC}\cos\omega t - V_{NC}\sin\omega t - \\ -V_{\Pi}\cos\alpha\right)\cos\alpha - V_{\Pi}\sin^2\alpha\right]^2\Big\}\cdot\Big\{\left(V_{BC}\sin\omega t + V_{NC}\cos\omega t\right)^2 + \\ +\left[\left(V_{BC}\cos\omega t - V_{NC}\sin\omega t - V_{\Pi}\cos\alpha\right)\cos\alpha - V_{\Pi}\sin^2\alpha\right]^2 + \\ +\left[\left(V_{BC}\cos\omega t - V_{NC}\sin\omega t - V_{\Pi}\cos\alpha\right)\sin\alpha + V_{\Pi}\sin\alpha\cdot\cos\alpha\right]^2\Big\}^{-\frac{1}{2}}\times \\ \times\Big\{\left(V_{BC}\sin\omega t + V_{NC}\cos\omega t\right)^2 + \left[\left(V_{BC}\cos\omega t - V_{NC}\sin\omega t - \\ -V_{\Pi}\cos\alpha\right)\cos\alpha - V_{\Pi}\sin^2\alpha\right]^2\Big\}^{-\frac{1}{2}}. \tag{17}$$

From expression 17 we obtain the value of the angle between the vector $\bar{V}_a$ and the horizontal plane xOy at an arbitrary point in time t:

$$\varphi = \arccos\Bigg\{\ \Big\{\left(V_{BC}\sin\omega t + V_{NC}\cos\omega t\right)^2 + \left[\left(V_{BC}\cos\omega t - V_{NC}\sin\omega t - \\ -V_{\Pi}\cos\alpha\right)\cos\alpha - V_{\Pi}\sin^2\alpha\right]^2\Big\}\cdot\Big\{\left(V_{BC}\sin\omega t + V_{NC}\cos\omega t\right)^2 + \\ +\left[\left(V_{BC}\cos\omega t - V_{NC}\sin\omega t - V_{\Pi}\cos\alpha\right)\cos\alpha - V_{\Pi}\sin^2\alpha\right]^2 + \\ +\left[\left(V_{BC}\cos\omega t - V_{NC}\sin\omega t - V_{\Pi}\cos\alpha\right)\sin\alpha + V_{\Pi}\sin\alpha\cdot\cos\alpha\right]^2\Big\}^{-\frac{1}{2}}\times \\ \times\Big\{\left(V_{BC}\sin\omega t + V_{NC}\cos\omega t\right)^2 + \left[\left(V_{BC}\cos\omega t - V_{NC}\sin\omega t - V_{\Pi}\cos\alpha\right)\times \\ \times\cos\alpha - V_{\Pi}\sin^2\alpha\right]^2\Big\}^{-\frac{1}{2}}\ \Bigg\}. \tag{18}$$

The speed of the aggregate will significantly affect the above properties of the particle moving around the disk. There are two options possible for the location of the scattering disk in relation to the direction of the movement of the aggregate: the first is an inclined disk, parallel to the direction of the movement of the aggregate; the second – the inclined disk makes angle α to the direction of the movement of the aggregate. Fig. 2 shows graphs of the angle of descent of the particle from a disk according to the second option, provided that the velocity of the aggregate is $V_a = 2.4$ m·s^{-1}. Increasing the speed of the aggregate, some particles will leave the disk at an angle greater than the angle of inclination of the disk itself.

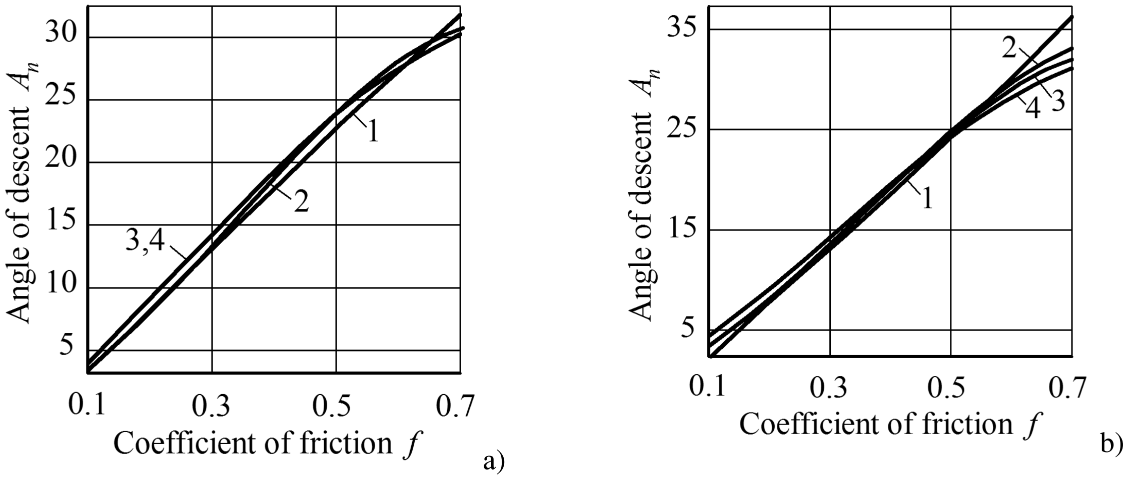

Fig. 2. **Dependences of the angle of descent A_n of a particle from the disk depending on the coefficient of friction f and angular velocity ω (1 – ω = 30 s^{-1}; 2 – ω = 60 s^{-1}; 3 – ω = 90 s^{-1}; 4 – ω = 120 s^{-1}):** a – at $V_a = 2$ m·s^{-1}; b – at $V_a = 4$ m·s^{-1}

Using the well-known methodology [10], a graphical dependence was constructed of the scattering distance of the ammonium nitrate particles of various granulometric size from the centrifugal scattering working tool upon the value of their descent angle α_{AC} from the centrifugal scattering working tool (Fig. 3).

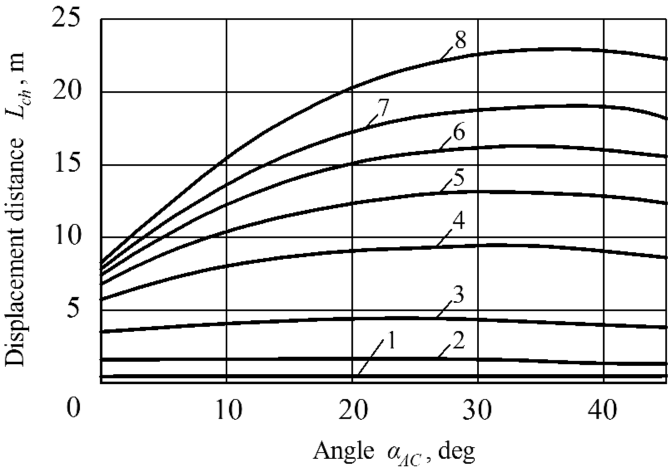

Fig. 3. **Dependence of the distance L_{ch} at which the particles of ammonium nitrate are scattered from the centrifugal scattering working tool upon the value of the angle of descent α_{AC}, with the following average diameters:** 1 – 0.25 mm; 2 – 0.50 mm; 3 – 1.00 mm; – 2.00 mm; 5 – 3.00 mm; 6 – 4.00 mm; 7 – 5.00 mm; 8 – 7.00 mm

Considering the percentage of each of the fertiliser fractions, it can be predicted that the maximum increase in the working width of the machine will be achieved at the values of angle α_{AC} within the range of 30-35°. From the known dependence between the value of the angle of inclination α_{LD} of the generatrix of the cone to the horizontal plane and the angle of descent α_{AC} of the fertiliser particles from the centrifugal scattering working tool, it follows that the maximum values of angle α_{AC} for the particles are: ammonium nitrate 15.7° at $\alpha_{LD} = 40°$, potassium salt 11.9° at $\alpha_{LD} = 35°$. The centrifugal scattering working tools, the design of which includes a conical disk, directed with the top down, cannot provide the most suitable values of angle α_{AC}, which, on the other hand, makes it impossible to significantly increase the working width of the spreader of mineral fertilizers.

It is known that the value of the relative rate V_{BC} of descent of the particles of mineral fertilisers from the centrifugal scattering working tool is about a fifth of the speed V_{AC}. That is, the value of the transfer velocity V_{PC} of descent of particles of mineral fertilisers from a centrifugal scattering working tool has the greatest impact upon the value V_{AC}. In known designs of mineral fertiliser spreaders the velocity vector V_{PC} is directed parallel to the horizontal plane. Hence, it follows that by increasing the value of the angle α_{PC} between the vector V_{PC} and the horizontal plane more beneficial values of the angle α_{AC} can be achieved. It is possible to obtain the values of the angle α_{AC} within the range 30-35° by increasing the angle α_{PC}, using a centrifugal scattering working tool, which includes a flat disk with blades mounted on its working surface, cinematically connected to the drive mechanism in rotational movement. Thus, the axis of rotation of such a centrifugal scattering working tool will be placed inclined to the horizontal plane. Since the value of angle α_V between the inclined axis of rotation of this centrifugal scattering working tool and the vertical plane is equal to the value of angle α_{PC}, by increasing the angle α_V it is possible to achieve the desired angle α_{PC}.

Using the well-known formulas, an analytical dependence of the value of angle α_{AC} upon the value of angle α_{PC} was obtained (Fig. 4). Besides, the constant parameters of the centrifugal scattering working tool were as follows: the angular velocity ω = 120 rad·s^{-1}; the radius of the centrifugal scattering working body R = 0.34 m; the radius of mineral fertiliser supply r_0 = 0.14 m.

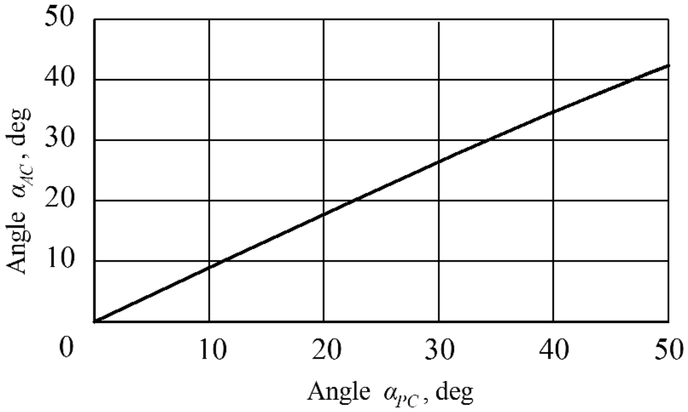

Fig. 4. **Dependence of angle α_{AC} upon the change of angle α_{PC}**

Using the obtained graphical dependence (Fig. 5), the values of angle α_{PC} are determined, at which the most useful values of angle α_{LD} are achieved, which are within the range of 30-35°. The mentioned values of angle α_{PC} are within 35-40°.

For a comparative assessment of the spreading distance of fertilisers by the new centrifugal scattering working tool, the axis of which is placed inclined to the horizon, and the conventional centrifugal scattering working tool, which is equipped with a conical disk, graphical dependencies were constructed for a series-produced centrifugal scattering apparatus (Fig. 5) and for a centrifugal scattering apparatus developed by us with an axis inclined to the horizon (Fig. 6).

As it is evident from Fig. 7, the use of a centrifugal scattering working tool with an inclined axis of rotation provides an increase in the dispersion range of ammonium nitrate over the soil surface, namely: for the particles with a diameter of 0.5 mm – by 1 m; the particles with a diameter of 1 mm – by 2 m; the particles with a diameter of 2 mm – by 3 m; the particles with a diameter of 3 mm – by 4 m; the particles with a diameter of 4 mm – by 5 m; the particles with a diameter of 7 mm – by 10 m.

Consequently, in the distributors for spreading mineral fertilisers it is advisable to use centrifugal scattering working tools with an inclined axis of rotation, which provide the greatest range of spreading of mineral fertilisers across the soil surface at the values of the angle between the velocity vector V_{AC} and the horizontal plane within the range of 35-40°.

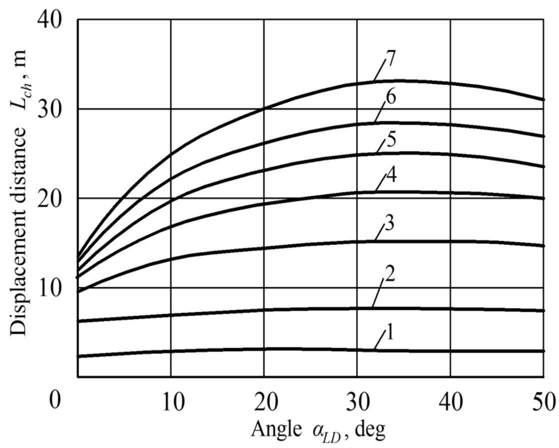

Fig. 5. **Dependence of the range of scattering L_{ch} of the particles of ammonium nitrate from the conventional centrifugal working tool upon the angle of inclination α_{LD} of the generatrix of the cone to the horizontal plane, with the following average particle diameters:** 1 – 0.50 mm; 2 – 1.00 mm; 3 – 2.00 mm; 4 – 3.00 mm; 4 – 4.00 mm; 6 – 5.00 mm; 7 – 7.00 mm

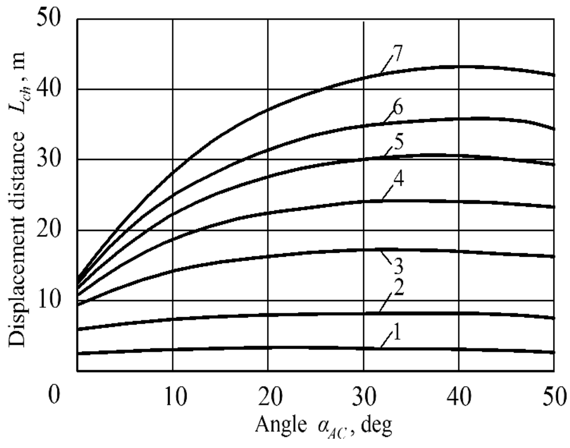

Fig. 6. **Dependence of the range of scattering L_{ch} of the particles of ammonium nitrate from the centrifugal scattering working tool, developed by us, upon the angle α_{AC} between the vector V_{AC} of the descent of the fertiliser particles, and the horizontal plane, with the following average particle diameters:** 1 – 0.50 mm; 2 – 1.00 mm; 3 – 2.00 mm; 4 – 3.00 mm; 4 – 4.00 mm; 6 – 5.00 mm; 7 – 7.00 mm

Based on the obtained data, a design of a centrifugal scattering working tool with an inclined axis of rotation has been developed, which includes a flat disk, cinematically connected to the drive mechanism in a rotational movement with blades, radially mounted on its working surface (Fig. 7). In addition, the rotation axis of the centrifugal scattering working tool is placed at angle α to the horizontal plane. The limitations of the scope of this article do not allow us to consider the experimental material obtained later on the discussed topic (confirming the correctness of theoretical calculations) - it will be presented in our next work.

Fig. 7. **Mineral spreader with scattering discs, inclined at an angle to the horizon**

Conclusions

1. There are theoretically defined expressions for choosing the optimal location of the centrifugal scattering working tool with an inclined axis of rotation. An equation is obtained that describes the movement of a material fertiliser particle along the blade of the centrifugal spreader, taking into account the angle of inclination of the spreading disc, and its solution is given in closed form.
2. The greatest range of the fertiliser spreading over the soil surface is at the values of the angle between the velocity vector V_{AC} and the horizontal plane within 35-40°.

3. By using the centrifugal scattering working tool with an inclined axis of rotation, it is possible to increase the range of dispersion of ammonium nitrate particles over the surface of soil by 3-5 m.

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