Technological working process of the centrifugal pneumatic apparatus for spraying mineral fertilizers and their mixtures

B Khudayarov1*, A Mambetsheripova2, and B Sarimsakov1

1Department of Agricultural Machinery, Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, 100000 Tashkent, Uzbekistan
2Department of Industrial Technology, Karakalpak State University named after Berdakh, 230112 Nukus, Karakalpak

*Email: krone0688@mail.ru

Abstract. The object of research is the process of centrifugal disk pneumomechanical apparatus for smooth application of mineral fertilizers and their mixtures on the field surface. When mineral fertilizers or their mixtures are sown in the field, the process of separation of grains into fractions is observed. This process takes place after they are thrown from the apparatus, that is, in space motion. This means that the quality control of mineral fertilizers is a factor independent of the technological process of the centrifugal disk apparatus. A pneumomechanical hardware scheme was developed using the method of analysis of technological processes of centrifugal devices in existing and patent information materials and the combination of structural elements for high-quality spraying of fertilizer mixtures in them. The pneumomechanical apparatus consists of a horizontal disc with a diameter of 600 mm, 4 logarithmic coil-shaped blades on the disc, and 4 additional air-generating devices under each disc under the disc. The centrifugal pneumomechanical device has two functions at the same time, the first is to spray mineral fertilizers, and the second is to create an additional air flow and direct it behind the discarded fertilizer grains, which ensures even spraying of component fertilizers of different sizes, shapes and densities.

1. Introduction
The object of research is the process of centrifugal disk pneumomechanical apparatus for smooth application of mineral fertilizers and their mixtures on the field surface. When mineral fertilizers are spread on the field surface, the process of fractionation of grains is observed. This process occurs during their movement in space after being thrown from the apparatus. This means that the quality control of mineral fertilizers is a factor independent of the technological process of the centrifugal disk apparatus.

Therefore, the issue of improving the technological process of centrifugal disk hardware represents the relevance of the study. In world practice, for the mass application of mineral fertilizers on the field surface have been developed disk work pieces of various types of centrifugal type [1, 2-12]. However, they are designed to sprinkle granular simple or complex fertilizers. It is recognized that this type of work piece does not meet the agrotechnical requirements when spraying mixtures consisting of several simple mineral fertilizers, the granules of which vary in shape, density and size [1-3, 13].

Based on the above, the purpose of the study is to improve the quality of spraying of mineral fertilizers and their mixtures with different grain sizes with a centrifugal apparatus.

The task of the study was to improve the design and technological process of centrifugal apparatus for
spraying mineral fertilizers and their mixtures, to ensure their even application on the field surface.

2. Method

It was conducted on the basis of 40 years of research and analysis of patent information and research on the design and technological process of centrifugal disk apparatus for all types of spraying of mineral fertilizers and their mixtures around the world. In this case, the shape of the blades in the centrifugal apparatus for high-quality spraying of mineral fertilizers and their mixtures of different shapes, sizes and densities and their placement on the disk, the necessary elements for the authors in the design of additional air generating devices were selected and assembled.

3. Results and Discussions

Many years of theoretical and experimental research have shown that the main reason for the uneven application of mineral fertilizers and their mixtures across the field surface, which vary in shape, size and density, is the separation of mineral fertilizer grains into fractions during their movement in air. As a result, fertilizer grains with low volatility, i.e. sails, fall farther, and those with high volatility fall to the ground at closer distances. It is understandable that the aggregate is spreading small-sized fertilizers in the center and large-sized fertilizers on the outside. This means that if the mixture contains a large amount of large-scale fertilizer, the amount of fertilizer at the edge of the aggregate working width is denser than at the center, creating a basis for uneven spraying of the mixture on the components. It follows that it is possible to solve the scientific and technical problem by ensuring that the volatile grains with high volatility coefficients travel longer distances and by this method ensure that the landing distances of different volatile fertilizer grains in the mixture are close or uniform [1-3]. According to the research conducted by the authors, it is possible to direct the additional air flow behind the fertilizer grains with a large volatility coefficient and ensure that they are thrown over longer distances [2-3]. This requires that the technological work of the centrifugal apparatus should not be limited to the disposal of mineral fertilizers, but also be able to generate additional air flow at once. As a technical solution to these problems, an improved centrifugal apparatus was developed (Figure 1), [2-3]. The advanced centrifugal pneumomechanical apparatus consists of a flat horizontal disk 1 and logarithmic coil-shaped blades 2 mounted on its upper side and a device 3 generating additional airflow mounted on the lower side of the disk (Figure 1). The advanced centrifugal pneumomechanical apparatus consists of a flat horizontal disk 1 and logarithmic coil-shaped blades 2 mounted on its upper side and a device 3 generating additional airflow mounted on the lower side of the disk (Figure 1). Figure 2 highlights the computer graphics view of the advanced centrifugal pneumomechanical fertilizer.

Figure 1. Scheme of advanced centrifugal pneumomechanical fertilizer

![Diagram a) top view diagram of a centrifugal pneumomechanical apparatus; b) the scheme of movement of manure grains and additional air on the bucket; c) installation scheme.](image-url)
Figure 2. Computer graphics view of the advanced centrifugal pneumomechanical fertilizer: 1-flat disc; 2-shovels; 3.4-Air inlet and outlet holes of the device in accordance with the number of paddles made in the form of a logarithmic package in the apparatus is four, as in practice. The diameter of disk 1 is 600 mm. The height of the paddles is 50 mm. At the bottom of the disc 1 is placed a device that creates one additional air in accordance with each paddle 2 (Figure 1 a, b, c).

The technological process of pneumomechanical apparatus is carried out as follows (Figure 1, b.): mineral fertilizers or a mixture thereof are applied on a rotating disc 1 with a number of revolutions of 700-750 rpm. They continue their motion along the line connecting the disc 1 and the paddles 2, under the influence of centrifugal force, and are thrown at an initial $v_0$ speed. In general, it can be assumed that the yield rate of all fertilizer grains is the same.

In the rotation of the air disk, the inlet of the device enters through the ABSD and the outlet exits through the absd (Figure 1, b, c). Due to the fact that the surface of the outlet hole is $\lambda$ (8-10) times smaller than the inlet, the velocity of the outgoing air flow increases by about 5-8 times. The grains of the fertilizer mixture move along with the additional airflow generated after the disc 1 is discarded. This is because the additional air flow and the absolute velocities of the fertilizer grains are directed in the same direction. The same orientation of the absolute velocities is the product of the fact that the blades 2 are in the form of a logarithmic coil. After a certain time $t$, the rate of additional air flow is equal to that of the fertilizer grain, and then drops to the minimum value. During this time, the volatility coefficient is large, and the grain size is close to or equal to that of large fertilizer grains in space. This is because the effect of additional airflow on large-sized fertilizer grains is negligible. As a result, a uniform application of large and small amounts of fertilizer grains to the unit-sized field surface is ensured while maintaining a mixed ratio.

The air outlet of the device is adjustable and is placed at an angle $\gamma$ relative to the horizontal in the initial position. This allows you to adjust the direction of the absolute speed of the extra air. Output angle of the proposed centrifugal pneumomechanical apparatus $\beta$, is a direct indicator of the uneven distribution of fertilizers. This indicator is the distance of fertilizer application to the disk $r_0$, shovel length $S$ and the angle of the disk $\omega$ depending on the velocities (Figure 3) [11].

Figure 3. Scheme for determining the angles of dispersal and scattering of mineral fertilizers from the centrifugal pneumomechanical apparatus.
It is known that mineral fertilizer grains are from the center of the disc, not the beginning of the spatula \( r_0 \), distance \( r_1 \) the initial radius of the blade in the form of a logarithmic coil, i.e., the radius of the pole (Figure 4). [11]. As you can see from the picture \( r_0 \) \( r_1 \).

**Figure 4.** The scheme for determining the length of the paddle through which the fertilizer grains pass

Logarithmic coil-shaped spatula \( MM_i \). The length of the arc can be determined by the following expression [14].

\[
L = \frac{r_1 - r_0}{\cos \psi}
\]

(1)

where \( r_1 \) - the initial radius of the blade, м;

\( \psi \) - the angle between the impact and radius vector transferred to the desired point of the blade, degrees.

(1) The effect of the indicators in the expression on the path length of the fertilizer grains along the paddle is shown in the graphs.

The graphic disk radius shown in Figure 5 was constructed at \( R = 0.3 \) м, \( r_1 = 0.05 \) м, and \( r_0 = 0.11 \) м.

**Figure 5.** The length of the paddle \( \psi \) graph of change depending on the angle

As can be seen from the graph shown in Figure 5, \( \psi \) as the angle increases, the length of the paddle increases according to the law of the curve. The length increases with the logarithmic winding shrinking the radius of curvature. In this case, the time of movement of the fertilizer grains along the paddle increases. This allows the fertilizer grains to be broken down into fractions. In this regard, the length of the shovel \( \psi \approx 30-35^\circ \) and 0.22-0.23 м corresponding to the angle was taken.

The length of the spatula in Figure 6 \( r_0 \) a graph of change depending on the fertilizer application distance is given.
Figure 6. Graph of change in the length of the bucket $r_0$ depending on the fertilizer distance.

The radius of the graphic disk shown in Figure 6 $R = 0.3$ m, $r_1 = 0.05$ m and $\psi = 30^\circ$ values. As can be seen from the graph in Figure 6, as the fertilizer application radius increases, the length of the bucket in which the fertilizer grains move moves in a straight line. As the fertilizer radius increases, the disc radius approaches the length.

Based on the results of previous and experimental studies conducted by us, the radius of fertilization $0.100-0.125$ m accepted in the interval. The results obtained directly affect the exit and scattering angles of the mineral fertilizer grains from the centrifugal apparatus and ultimately their uneven distribution.

The angle of exit of fertilizer grains from the centrifugal apparatus

$$\beta = \omega t$$

(2) where $t$- when the fertilizer grains are moved across the paddle, sec.

(2) expression $t$ ra subtracting the relative and putting the values of the expressions in it, and then performing mathematical operations, we obtain the following,

$$t = \frac{\ln (L_\alpha - m)(P_1 - P_2)}{-P_2(r_0 - m)}$$

(3) in the expression $t$ (2) then do the math,

$$\beta = \ln \left[ \frac{(L_\alpha - m)(P_1 - P_2)}{r_0 - m} \right] \left( -f + \sqrt{f^2 + \frac{a(a + f)}{1 + a^2}} \right)$$

(4) expression $R=0.3$ m, $r_1=0.05$, $\psi=30^\circ$, $L_\alpha=0.144$ m, $m=0.00082$ m, $t=0.0019$ c calculated on the values.

Figure 7. The angle of application of fertilizers from the bucket $\psi$ graph of change depending on the angle: 1.$f=0.3$; 2.$f=0.4$; 3.$f=0.5$
Shovel fertilizer out $\beta$ angle $\psi$ a graph of change depending on the angle is given in Figure 7. The radius of the graphic disk $R=0.3m$, $r_1=0.05m$ at $r_2=0.11m$ values.

As can be seen from the graph shown in Figure 7, $\psi$ as the angle increases, the exit angle $\beta$ increases according to the law of the curve. $\psi$ the increase in the angle is explained by an increase in the length of the paddle in the opposite direction to the direction of rotation of the apparatus, i.e. at this distance the fertilizer grains move and are thrown out of the apparatus, which requires a large angle of rotation. For example, $\psi=30^\circ$ exit angle when $\beta=95^\circ$ if $\psi=42^\circ$ exit angle when $120^\circ$ is equal to. Where $\psi$ angle 12° the exit angle doubles as it increases $25^\circ$ showed an increase.

Taking into account the results of theoretical calculations carried out by the authors and other researchers [15-19] and the design of fertilizer machines, the outlet angle $\beta$=95-105° accepted in the interval. Because, $\psi$ increasing the angle by $30–35^\circ$ causes the logarithmic winding to further reduce its radius of curvature, but to increase its length. Eventually, the duration of the movement of the fertilizer grains on the paddle increases, allowing for the process of segregation [14]. Thus, the proposed centrifugal pneumomechanical device is designed to simultaneously perform two functions, namely - the application of mineral fertilizers, the second - to create an additional air flow and direct it behind the discarded fertilizer grains, which differs from the existing technological process.

4. Conclusions

Based on the results of the research, the following conclusions were made:

1. Research and analysis of the literature and patent information materials mineral fertilizers with centrifugal devices of fertilizer spreader and improved the fertilizing apparatus, which ensured the reduction of uneven spraying of their mixtures along the field surface;
2. The installation of logarithmic coil-shaped paddles on the upper side of the existing centrifugal hardware disc, and a device that creates additional airflow on the lower side, allows to increase the quality of spraying mineral fertilizers and their mixtures on the field surface of different sizes, shapes and densities.
3. The diameter of the centrifugal pneumomechanical apparatus disk is 600 mm, the number of logarithmic coil-shaped blades is 4, their height is 50 mm, 4 devices are placed under the disk according to each blade.

References

[1] Khudayarov BM 1988 Increasing the uniformity of the application of mineral fertilizers and their mixtures by centrifugal disc devices, Candidate of Science Dissertation, Minsk.
[2] Khudayarov BM, Mambetsheripova A 2018 European Science Review 9(10) 235-237.
[3] Khudayarov BM, Mambetsheripova A 2018 ACTA TTPU 3 63-65.
[4] Chernovolov V, Vinnik A, Lyashenko T, Polevik V, Lurye V 1976 Discoveries Inventions Industrial Designs Trademarks 5 1955392.
[5] Skolzayev V, Chernovolov A, Zabrodin V, Lyashenko T 1983 Discoveries Inventions Industrial Designs Trademarks 43 3463794.
[6] Fedotov N, Grigorochuk G, Polevik V, Dovgan A 1983 Discoveries Inventions Industrial Designs Trademarks 5 3352992.
[7] Fedotov N, Grigorochuk G, Shemelinskiy V, Polevik V, Dovgan A, Nesterovskiy V, Chernovolov V, Grigorov S, Kayushnikov Yu 1983 Discoveries Inventions Industrial Designs Trademarks 21 3384106.
[8] Chernovolov V, Polevik V, Lyashenko T, Kurilov A, Plotnikov E, Lure V, Dokuchayev A 1983 Discoveries Inventions Industrial Designs Trademarks.
[9] Vinnik A 1975 Discoveries Inventions Industrial Designs Trademarks 24 19533998.
[10] Chernovolov V, Melnikov B, Lyashenko T 1991 Discoveries Inventions Industrial Designs Trademarks 41 3328236.
[11] Skolzayev V, Fedotov N, Chernovolov V 1975 Discoveries Inventions Industrial Designs Trademarks 6 1657861.
[12] Chernovolov V, Volkov V, Kazachkov I 1998 Working body of the fertilizer spreader, Registered in the State Register of Inventions of the Russian Federation, Moscow.
[13] Patent 3652019 (USA) 1973 CL 239682,896-Published in official, Gas materials of the US Patent Office, pp 6-7.
[14] Malonosov N, Temofeeva L 1976 Proceedings of NIUIF, Moscow.
[15] Khudayarov B, Kuziyev U, Sarimsakov B 2019 International journal for innovative Research in Multidisciplinary Field 5(9) 121-125.
[16] Khudayarov B, Kuziyev U, Sarimsakov B 2019 International Journal of Research Culture Society 3(10) 111-116.
[17] Khudayarov B, Kuziyev U, Sarimsakov B, Khudaykulov R 2020 IOP Conf. Ser.: Mater. Sci. Eng. 883 012110.
[18] Mamatov F, Mirzaev B, Batirov Z, Toshtemirov S, Tursunov O, Bobojonov L 2020 IOP Conf. Ser.: Mater. Sci. Eng. 883 012165.
[19] Mirzaev B, Mamatov F, Tursunov O 2019 E3S Web of Conferences 97 05035.