RESEARCH IN MINERAL FERTILISER PARTICLE THROWING DISTANCE FROM NEW CENTRIFUGAL FERTILIZER SPREADER WORKING TOOL

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Abstract. The produced mineral fertiliser spreaders have the working width and productivity that do not satisfy today's requirements in high-technology agricultural production. It refers also to the distance the mineral fertiliser particle can reach. We have developed a new centrifugal fertilizer spreading working tool with an inclined axis of rotation. It allows for increased distance of mineral particles at centrifugal spreading. The aim of the present research is to determine the throwing distance of the mineral particle from the spreading disc inclined to the horizon. The analytical research has been performed using the methods of modeling, mechanics and mathematics, as well as methods of calculation and computer modeling. In the result of the theoretical research differential equations were obtained describing throwing of the mineral fertiliser particles from the blades and their further distance after leaving the working tool. In the result of calculations new graphical dependences have been obtained of the throwing time from the blades and the distance the particles of different mineral fertilisers can reach, in particular ammonium nitrate, depending on the frequency of the disc rotation, angles of inclination to the horizontal plane, radius of feeding the mineral fertiliser particles, coefficient of friction along the surface of the disc etc. The obatined new analytical expressions and the developed graphical dependences allowed for determination of the working tool parameters that ensure maximal distance of mineral fertiliser particles at centrifugal spreading. The performed experimental investigations proved the correctness of the theoretical research and showed increased throwing distance at the used improved parameters of the new centrifugal working tool.

Keywords: fertilisers, particles, centrifugal spreading, disc, differential equations, numerical calculations.

Introduction

Application of mineral fertilisers in accordance with the recommendations of agricultural sciences is a necessary condition for increasing the productivity of agricultural crops. It is especially topical in relation to introduction of industrial technologies for growing of agricultural crops as spreading of mineral fertilisers on the surface of the soil is an important technological operation. For this operation machines equipped with centrifugal spreading operation parts are used. Still, the existing centrifugal spreaders do not satisfy the modern requirements because of low productivity and quality of mineral fertiliser spreading. The speed of the aggregate and coefficient of exchangeable time for increasing the productivity have already been used. For this reason, it is possible to increase productivity only by increasing the working width of the machine, that is the distance the mineral particles can reach. It requires development of new constructions of the operation parts for spreading of mineral fertiliser particles. We have developed a new construction of a mineral fertiliser spreader with an inclined axis of rotation with the aim to increase the angle between the vector of absolute speed of mineral particles leaving the disc of the working tool and the horizontal plane that gave a possibility to increase the throwing distance of the particles, and with this, also the working width of the machine. The present research deals with solving this problem.

Many scientists have studied determination of the fertiliser particle throwing distance by the fertilizer spreading working tool [1-6]. Still, their solutions did not find practical application as they were obtained with definite simplifications. For a long time, the distance of spreading was determined using the methodology developed by Volkov V. A. [7]. Based on the methodological approaches by Volkov V. A., at definite simplifications some solutions were obtained that could be applied practically [8-10], still with using PC they are not topical.

In the process of machine operation for spreading fertilisers the wind can influence the particles from the working tool moving along the surface of the soil. Many scientists have tried to obtain mathematical dependences in a theoretical way to describe the trajectory of movement of a particle of technological material considering the speed characteristics, physical-mechanical properties and the influence of the wind. The research results on material particle movement are most widely described in

[11; 12]. In [11] the system of differential equations was obtained of particle movement in projections on the coordinate axis for a general case of its movement.

These solutions were developed and made more precise in [13; 14] as differential equations of mineral fertiliser particle movement in relation to the general case of its movement, i.e. considering the speed characteristics of the particles leaving the fertilizer spreading working tool, physical-mechanical properties of fertilisers considering the speed of the air movement (wind) and the direction relative to the vector of absolute speed of the mineral fertiliser particle from the fertilizer spreader.

Based on the above mentioned, we can make a conclusion: the results are known of theoretical investigations for determination of the distance of spreading a separate particle of mineral fertilisers in conditions of windy weather and without wind. In relation to determination of the distance of spreading fertilisers at fan spreading, such results of investigations were obtained for definite fertilizer spreading operation parts only experimentally.

All the above mentioned publications describe centrifugal fertilizer spreading operation parts with a vertical axis of rotation. As the distance of the particle movement depends not only on the value of the absolute speed from the spreading disc, but also on the angle between the vector of absolute speed and the horizontal plane, we offer a new construction of the working tool with an inclined axis of rotation that allows for essential increasing of the mentioned angle. It requires the necessary theoretical and experimental research in the throwing distance of mineral fertiliser particles from the disc of the new construction offered by the authors.

Materials and methods

Using the mentioned methods and programming [15], the influence of the inclined disc to the horizontal plane of the working tool on the throwing distance of spreading mineral fertilisers was theoretically investigated. The research was performed using ammonium nitrate the granules of which had close to round shape. The speed characteristics of the fertiliser granules at the moment leaving the blades were determined using the mathematical models of particle movement along the disc and blades of the inclined working tool obtained in the result of our research.

With the aim to prove the adequacy of the theoretical dependences obtained in the result of mathematical modeling of the mineral fertiliser spreading process experimental research was performed in the influence of the disc inclination to the horizontal plane on the distance of spreading ammonium nitrate granules from the working tool of the experimental device developed by the authors. The general view and construction sheme of the device are shown in Fig. 1 and Fig. 2.

Fig. 1. **General view of the experimental device** (turning frame and tank removed)

The construction of the experimental device (Fig. 2) included the basic frame 14 on two wheels 15 and a support leg. A handle 1was attached to the basic frame for moving the device on the wheels 15 to the experimental site. On top of the basic frame the electric motor 2, chain variator 4 and conical reductor 10 were installed which were kinematically connected through a connecting overrunning clutch 13. The conical reductor was fastened to the frame by supports 11 and 12 by which the angle to the horizontal

plane could be regulated. On the outlet shaft of the conical reductor the inclined working tool 9 was installed that consisted of a disc on the surface of which four grooved blades were fastened radially.

The outer ends of the blades were outside the disc. A movable frame 3 was installed on the basic frame 14 for movement regulation. On the movable frame 3 a turning frame 5 was mounted for turning to the horizontal plane and a tank 7 was installed on it. At its bottom there was an opening for spreading with a flap 8, which served to adjust the area of the open section of the indicated hole.

It was possible to regulate the frequency of the disc rotation, as well as the angle of inclination to the horizontal plane.

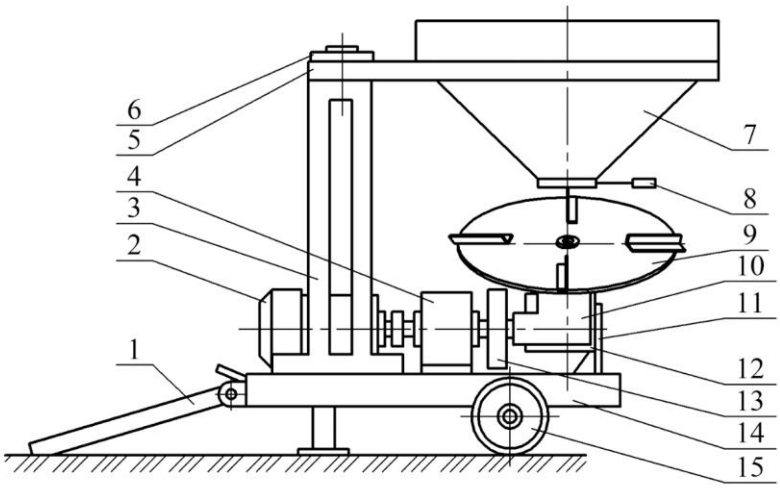

Fig. 2. **Scheme of the experimental device:** 1 – handle; 2 – electric motor; 3, 5 – movable and turning frames; 4 – chain variator; 6 – hinge for turning the frame; 7 – tank; 8 – flap; 9 – inclined working tool; 10 – conical reductor; 11, 12 – supports; 13 – overrunning clutch; 14 – basic frame; 15 – support wheel

The operation process of the experimental device was as follows. The torque from the electric motor 2 through the connecting clutch was transfered to the inlet shaft of the chain variator 4 which changed the rotation frequency, the outlet shaft transfered rotation movement to the shaft of the conical reductor 10. In the result the outlet shaft of the reductor 10 on which the inclined working tool was installed started to rotate. Fertilisers from the tank 7 through the spreading opening due to gravitation force were spread in dosed qualities to the working tool blades that were installed on the rotating disc. On the blades fertilisers spread moving by centrifugal force along the blades in the direction from the centre of the disc to its sides. Reaching the ends of the blades the fertilisers due to kinetic energy were moving in the air in a definite trajectory in the direction from the working tool to the surface of the soil.

Results and discussion

It was stated (Fig. 3) that increasing the angle of the disc inclination to the horizontal surface from 0^o to 10^o the distance of spreading granules of ammonium nitrate of all fractions increases. This increase depends on the granule diameter, for instance, spreading granules with the diameter 1 mm, it increases by 6.25%, 2 mm – 55.56%, 3 mm – 72.73, 4 mm – 91.67, 5 mm – 112.0%.

It means that with increasing the fertiliser granule diameter the intensity of increasing the throwing distance is growing. Analoguous dependence is found at increasing the inclination of the disc to the horizontal plane from 10° to 20°. The distance of spreading granules with the diameter 1 mm increased by 3.75%, 2 mm –19.43, 3 mm – 21.33, 4 mm – 22.74, 5 mm – 24.52%.

Increasing the disc inclination angle to the horizontal plane from 20° to 30° and from 30° to 40° also increases the distance of spreading particles, but the intensity decreases with increasing the angle.

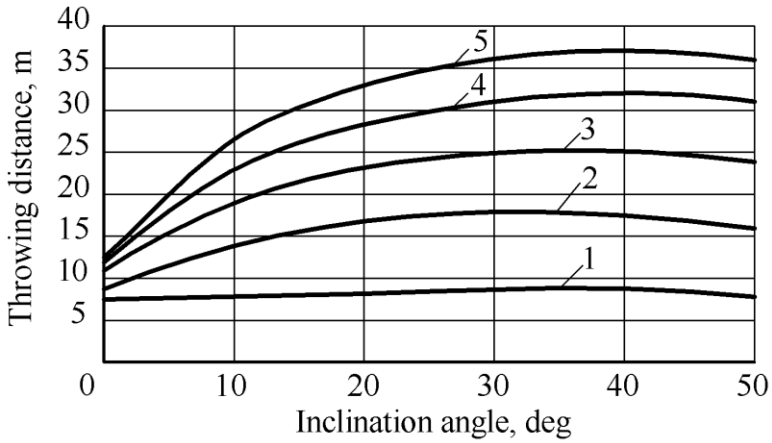

Fig. 3. **Dependence of throwing distance of ammonium nitrate granules on the angle of the disc inclination to the horizontal plane:** 1, 2, 3, 4, 5 – granule diameter equals 1, 2, 3, 4, 5 mm

That is, increasing the disc inclination angle to the horizontal plane from 30° to 40°, the distance did not increase essentially, but at the angles more than 40° it decreases for all sizes of fertiliser granules.

So, increasing the inclination angle of the disc to the horizontal plane increases the throwing distance for all mineral fertiliser granules. Granules with a larger diameter are more sensitive to the changes of the disc inclination angle. Increasing the angle to the horizontal plane from 0° to 10° results in more increased throwing distance of all mineral fertiliser granule sizes. Increasing the angle further also gives increased throwing distance, but the intensity of increasing is less, but at the angles more than 40° the throwing distance of all ammonium nitrate granules decreases.

Based on the obtained results a conclusion can be made that increasing of the disc inclination angle to the horizontal plane increases the spreading distance of mineral fertilisers. Rational meaning of the angle to the horizontal plane is within 20° to 30°.

Considering the spreading of a particle with a diameter of 1 mm, the angle does not have great influence on the throwing distance, so, it can be concluded: usage of the inclined working tool in machines for spreading chemical ameliorants will not ensure essential increase of the working width.

Below the experimental dependences are shown that were obtained in the result of the performed experiments on the mentioned device (Fig. 4).

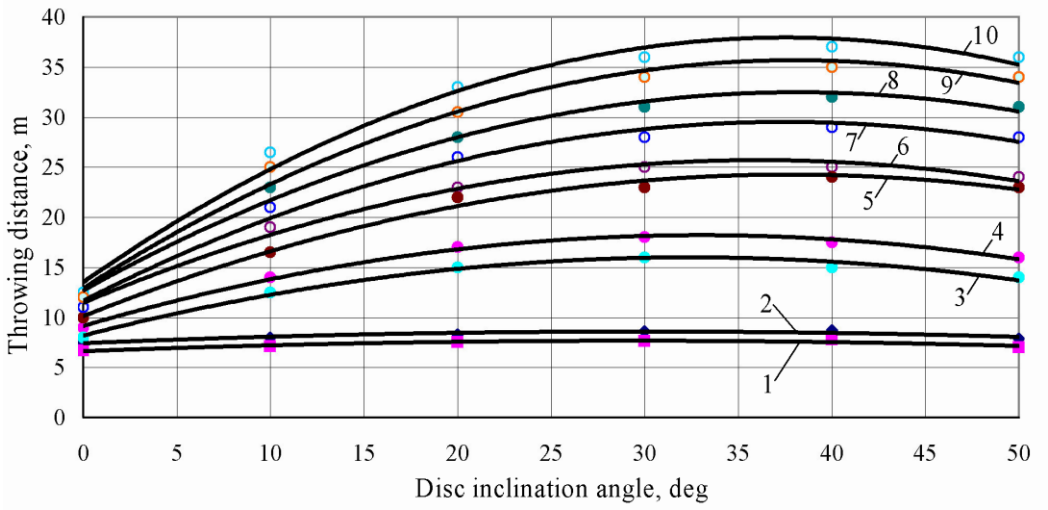

Fig. **4. Dependence of the throwing distance of ammonium nitrate granules on the angle of the disc inclination to the horizontal plane:** 1, 3, 5, 7, 9 – experimental curves, fertiliser particle diameter equals 1, 2, 3, 4, 5 mm; 2, 4, 6, 8, 10 – theoretical curves, fertiliser particle diameter equals 1, 2, 3, 4, 5 mm

According to the experimental research results it was stated that at increasing the disc inclination angle to the horizontal plane from 0° to 40° the throwing distance of ammonium nitrate granules increases (Fig. 4, curves 1, 3, 5, 7, 9). At further increasing of the disc incline angle the throwing distance gradually decreases. Similar trends can be observed at different fertiliser particle sizes.

In publication [16] it is proved that a way to get more uniform spreading of particles on the surface of the working tool with the aim to get more uniform throwing is forced vibrations. The basis for determination and evaluation of the technological process depending on vibrations can be found in publications [17; 18].

It can be concluded that the results of the theoretical research on determination of the absolute speed of granules leaving the inclined working tool and the angle between the vector of the speed and horizontal plane that were used for determination of the throwing distance of ammonium nitrate are adequate to the results obtained experimentally. It should be mentioned that the theoretical curves in Fig. 4 are the same as in Fig. 3.

Conclusions

1. Increasing of the disc inclination angle to the horizontal plane increases the throwing distance of fertiliser granules of all sizes. The granules with a larger diameter are more sensitive to the changes of the angle.
2. Increasing the disc inclination angle to the horizontal plane from 0° to 10° increases the granule throwing distance more intensively. At further increasing of the angle also the distance of throwing increaes, but the intensity of increasing is less. At the angles larger than 40^{o} the throwing distance of granules of all sizes decreases.
3. Rational disc inclination angle to the horizontal plane values are within 20° to 30°.
4. The results of the theoretical research on determination of the absolute speed of granules leaving the inclined working tool and the angle between the vector of the speed and horizontal plane that were used for determination of the throwing distance of ammonium nitrate are adequate to the results obtained experimentally.
5. Usage of the inclined fertilizer spreading working tool on machines for spreading chemical ameliorants the diameter of the granules of which is less or 1 mm will not essentially increase the working width.

Author contributions

All the authors have contributed equally to creation of this article. All authors have read and agreed to the published version of the manuscript.

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