Artículo de investigación

Rational parameter calculation method for devices with horizontal rotation axis to disseminate mineral fertilizers and seeds

Método de cálculo de parámetros racionales para dispositivos con eje de rotación horizontal para diseminar fertilizantes minerales y semillas

Método de cálculo de parâmetros racionais para dispositivos com eixo de rotação horizontal para disseminar fertilizantes minerais e sementes

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Abstract

The article proposes the modeling technique for the uniform distribution of particles by a throwing unit. The material is devoted to the substantiation of rational parameters and operating modes of vertical throwing units to distribute the particles of fertilizers and seeds.

Keywords: mineral fertilizers, vertical throwing vehicles, combined machines, probabilistic modeling, uniform distribution of particles, calculation of throwing vehicle parameters.

Resumen

El artículo propone la técnica de modelado para la distribución uniforme de partículas por una unidad de lanzamiento. El material está dedicado a la fundamentación de parámetros racionales y modos de operación de unidades de lanzamiento vertical para distribuir las partículas de fertilizantes y semillas.

Palabras clave: fertilizantes minerales, vehículos de lanzamiento vertical, máquinas combinadas, modelos probabilísticos, distribución uniforme de partículas, cálculo de los parámetros del vehículo de lanzamiento.

Resumo

O artigo propõe a técnica de modelagem para a distribuição uniforme de partículas por uma unidade de arremesso. O material é dedicado à comprovação de parâmetros racionais e modos de operação de unidades de arremesso vertical para distribuir as partículas de fertilizantes e sementes.

Palavras-chave: fertilizantes minerais, veículos de arremesso vertical, máquinas combinadas, modelagem probabilística, distribuição uniforme de partículas, cálculo dos parâmetros do veículo lançador.

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Introduction

The introduction of high technologies is one of the reserves to increase yields and gross grain harvest. The peculiarity of high technology is the use of a large amount of fertilizers, plant protection products and the exact observance of the norms, terms and methods of their introduction, as well as the rational distribution of seeds (Khizhnyak & Yatsenko, 2017) and fertilizers over field area.

Mineral fertilizers, especially nitrogen fertilizers, or the seeds must be embedded in soil immediately after sowing, therefore, the development of combined machines with simultaneous processing of soil and the sowing of fertilizers or seeds is urgent. LEHNER company produces "Super Vario" seed drill, which is attached to the front hitch of a tractor and works in the aggregate with a tillage machine, for example, as a disc tool. The most suitable is a vertical throwing device to distribute fertilizer particles and seeds for a combined tillage sowing machine.

Vertical throwing devices have several advantages. Their drive is carried out without the use of bevel gear speed reducers, since the shafts of the rotors are horizontal and parallel to the power shaft. The flight paths of fertilizer or seed particles ejected at negative angles to the horizon are shorter than those of horizontal vehicles. This reduces the effect of wind on sieving uniformity. The coverage width of the tillage aggregate is limited by the tractor traction capabilities, so it is important that a fertilizer and a seed applicator ensure uniform sieving of fertilizers and seeds across the tillage width (Morozova, 2018; Morozova, 2016; Zhokhova, 2015).

In this regard, the purpose of the presented research is to develop the method of rational parameter and operating mode calculation for throwing machines of a combined tillage sowing machine.

Research Methodology

The study is based on the method of probabilistic modeling (Chernovolov & Sherstov, 2016a), which uses deterministic and random factors. The response function is the uniformity of fertilizer and seed sowing when the condition for a given width and application rate is satisfied.

The operation scheme of the vertical throwing apparatus is shown on Figure 1. The particles ejected at the angle γ are distributed over the field with the probability density f(X, Y/γ). The change of the angle γ causes the change of the sieving zone position. With the increase of γ up to 30 ... 350, the zone moves away from the device, and with its further increase it approaches the device, sowing the same platforms again.

After the dropping of all particles from the blade as the result of multiple overlaps of conditional distributions f(X, Y/γ), the field area will be sown bounded by the f(X, Y) line.

Two-dimensional probability density f(X, Y) of area X, Y coordinates characterizes the intensity of particle introduction in different points of the sieving zone at Vm = 0.

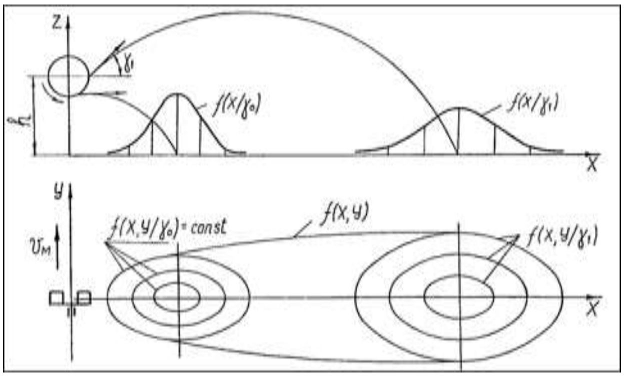


Fig. 1. Diagram of particle distribution process by the vertical apparatus

The intensity of particle introduction on the site dF at Vm = 0 can be found by the integration of conditional densities f(X, Y/γ) over the angle γ, taking into account their mass f(γ) and by the multiplication of the result by the flow rate Q.

In order to analyze the transverse distribution only, the following dependence was obtained (Chernovolov & Sherstov, 2016a)

$$q_F(X) = \frac{Q}{V_M}\int_{\gamma_{min}}^{\gamma_{max}} f(\gamma) f(X/\gamma) d\gamma .$$

where V_M – the unit speed, m/s;
Q – particle consumption, kg/s;
γ – throw angle, grades;
f(X, γ) – probability density function, m-1.

Further, they considered the design of the apparatus for the work in a combined tillage unit. The unit consists of a disc tool with the coverage width of 10 m and a mounted spreader of fertilizers and seeds. It is required to coordinate the effective sieving width of fertilizers (using carbamide) and the seeds with the tool coverage width.

In order to obtain the parameters and the modes of throwing apparatus operation, it is necessary to conduct the study of three most significant factors (Table 1). The results of a multifactorial experiment are used for the calculations of rational parameters and operation modes.

Table 1. Variation factors, levels and ranges

Factors, levels	Blade inclination angle to the initial radius	Rotor speed	Transverse coordinate of particle guide
Natural designation	Ψ, grades	n, min^{-1}	x_3,mm
Lower level	-40	400	-20
Zero level	-30	600	0
Upper level	-20	800	+20
Coded designation	X_1	X_2	X_3
Lower level	-1	-1	-1
Zero level	0	0	0
Upper level	+1	+1	+1

Calculation procedure

In order to determine the range of the particle throwing at the horizontal ejection with a given effective sieving width, it is necessary to use the ratio between an effective sieving width and the throwing range using the following source data as an example: fertilizer type - granulated carbamide of grade B; introduction dose - 200 kg/ha (kg/m2); sail ratio - 0.22 m-1; unit speed - m/s; an effective sieving width - Ve = 10 m; the number of rotors - 2; allowable irregularity - 10%.

It is known that Bэ/Mx(0) = 3, therefore, at Bэ = 10 m let's calculate Mx(0) = 10/3 = 3.33 m.

Let's give the algorithm to determine the parameters and the modes of a throwing device operation.

1. To determine the speed of particle throwing to obtain a given range. To do this, you need to use the program Mx1(y) (Figure 2, a). We set the initial speed v0 at the beginning of the program and display the result. We change speed prior to the desired range obtaining.

2. In order to determine the vector of angle Г throwing and to calculate the range of throwing corresponding to each value of the angle Г (Figure 2, b).

3. To interpolate the values of the VГ1 vector (Figure 3).

4. To calculate the values of dose vectors (Chernovolov & Sherstov, 2016b) at various input parameters (Figure 4).

```
Mx1(γ) := | Vo ← 10
          | Vox ← Vo·cos(γ)
          | Voy ← Vo·sin(γ)
          | v(vx, vy) ← √(vx² + vy²)
          | xo ← 0
          | Ho ← 0.8
          | kp ← 0.22
          | g ← 9.81
          | yo ← (xo, Vox, Ho, Voy)
          | D(t, yo) ← (yo1, −kp·v(yo1, yo3)·yo1, yo3, −g − kp·v(yo1, yo3)·yo3)
          | To ← 0
          | Tk ← 2
          | L ← Rkadapt(yo, To, Tk, 1000, D)
          | M ← | n ← 1000
          |     | for i ∈ 0..n
          |     |     | I ← i  if (L⟨3⟩)_i ≥ 0
          |     |     | break  otherwise
          |     | M ← (L⟨1⟩)_I
          | (L⟨1⟩)_I

Mx1(0) = 3.109
```

Fig. 2,a. Carbamide particle flight range calculation program at $K_p = 0{,}22$ m[-1].

```
i := 0..13
Γ_i := i·0.25 − 1.6
VΓ1_i := Mx1(Γ_i)
```

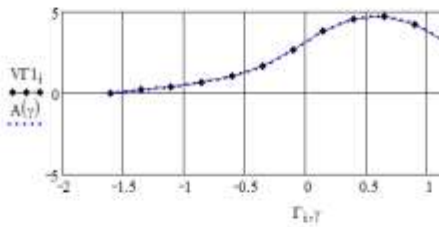
Γ =

	0
0	-1.6
1	-1.35
2	-1.1
3	-0.85
4	-0.6
5	-0.35
6	-0.1
7	0.15
8	0.4
9	0.65
10	0.9
11	1.15
12	1.4

VΓ1

Figure 2,6 – The results of carbamide particle flight range calculation at $K_p = 0{,}22$ m[-1].

```
KSI := cspline(Γ, VΓ1)    γ := −1.6, −1.5 .. 1.6    A(γ) := σx(γ)
i := 0..20
```




```
A(0) = 3.104
```

Figure 3. Interpolation of VΓ1 vector values

```
Mγ := 0      σγ := 0.3      i := 0..10      X1_i := i
γmin := Mγ − 3·σγ      γmax := Mγ + 3·σγ      Q := 0.18      Vm :=
Q1f(Mγ, σγ, X1) := Q/Vm · ∫_γmin^γmax dnorm(γ, Mγ, σγ)·dnorm(X1, A(γ)
Q1f(0.1, 0.3, 3) = 0.023        i := 0..10
```

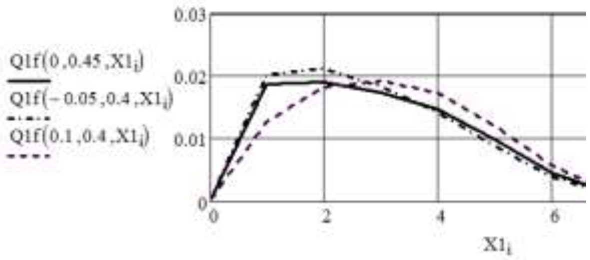


Fig. 4. Carbamide dose introduction schedules

3. The second option is rational, we select it and create the vector of doses Vd4, taking into account the operation of two rotors. In this case, let's assume that Q1f(X) = Q1f(-X). Next, using F4(n)

program, we perform the summation of doses on the overlap areas and calculate the non-uniformity of sieving taking into account the overlap (Figure 5). In the F4(n) program, the number of overlaps on each side is n + 1.

4.

3. According to Figure 5, the optimal sieving width is 10 meters with the non-uniformity of 6.06%. According to the task, the sieving width should be equal to 10 meters and the sifting unevenness should not exceed 10 percent. They performed the requirements of the task on width and dissemination uniformity.

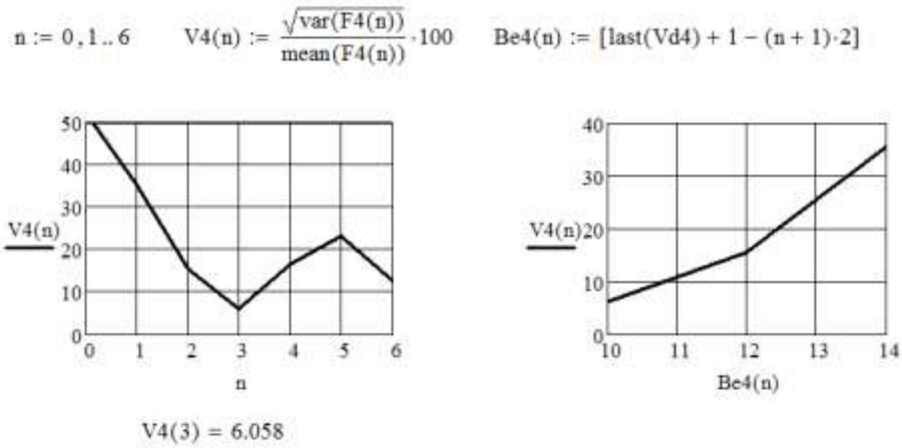


Fig. 5. The calculation of non-uniformity and the optimal width of particle dissemination

4. Let's determine the rotor speed. From the structural reasoning, the rotor diameter is assumed to be 0.25 mm, therefore

$$n = \frac{V}{2\pi R}, \text{ c}^{-1}, \qquad (2)$$

where n is the rotational speed, s^{-1};

V – throwing speed, m/s;

R – rotor radius, m.

At the throwing speed of 10 m/s, we get $n = 12{,}74c^{-1}$ (764 min^{-1}).

Using the data in Table 1 according to coding formulas, we get

$$X_2 = \frac{764 - 600}{200} = 0{,}82.$$

5. Then they determine the blade inclination angle and the coordinates of the particle guide tray. In the calculation we use the regression equations for the numerical characteristics of the throwing angle (Chernovolov & Sherstov, 2017).

$$Ym = -12{,}3 + 6{,}44X_1 + 6{,}909X_2 + 11{,}78X_3 + 0{,}512X_1X_3 - 1{,}5X_2^2 + 0{,}843X_3^{\ 2}. \qquad (3)$$

$$Y\sigma = 19{,}974 + 0{,}235X_1 + 2{,}305X_2 + 0{,}414X_3. \qquad (4)$$

where X_1, X_2, X_3 are the factors; $X_1 = \frac{\psi + 30}{10}$; $X_2 = \frac{n - 600}{200}$; $X_3 = \frac{x_3}{20}$.

At X2=0,82 the equations are the following ones:

$$Ym = -7{,}644 + 6{,}44X_1 + 11{,}78X_3 + 0{,}512X_1X_3 + 0{,}843X_3^{\ 2}. \qquad (5)$$

$$Y\sigma = 21{,}864 + 0{,}238X_1 + 0{,}414X_3. \qquad (6)$$

According to the simulation results, it is necessary to obtain $Ym = -0{,}05$рад (2,87°) и $Y\sigma = 0{,}4$ рад (22,9°). The solution of the equations (5) and (6) does not give a result, since this system of equations is incompatible. A compromise problem will be solved by the imposition of function graph $Ym = -0{,}05$ рад (2,87°) and $Y\sigma = 22$. The coordinates of the intersection point are considered to be the rational values of the factor X_1 and X_3. They obtained $X_1 = -0{,}69$; $X_3 = 0{,}765$. The check of solution correctness is performed by the substitution of these values into the regression equations. The following results are obtained:

$$Ym(-0{,}69;0{,}765) = -2{,}853; \qquad Y\sigma(-0{,}69;0{,}765) = 22{,}016.$$

The values of natural factors are found by coding formulas.

The blade inclination angle is 36.9°, the transverse coordinate of the particle guide makes x_3 = 15.3 mm.

The device can work with a switchgear if the width of the tillage machine is about five meters. At the coverage width of ten meters it is necessary to use two devices for a uniform distribution of particles (Chernovolov & Sherstov, 2013; Chernovolov & Sherstov, 2014; Chernovolov & Sherstov, 2015).

Conclusions

Thus, they obtained the method to determine the rational parameters of a vertical throwing apparatus with a longitudinal horizontal rotation axis for the surface application of mineral fertilizers and seeds. The calculation is performed on the basis of sieving width and uniformity, as provided by the technical task. After the proposed algorithm implementation, they determine the inclination angle, the rotational speed of the rotor, the position of the particle guide, the optimal width and the minimum irregularity of fertilizer and seed sowing.

Reference

Khizhnyak, V. I., Yatsenko, P. L. (2017). The slotted pneumatic seeding apparatus of excess pressure. *Bulletin of Agrarian Science of Don. Special edition issue, 1*(37.1).

Chernovolov, V. A., Sherstov, S. A. (2016a). The simulation of fertilizer distribution with a vertical throwing device. *Bulletin of the Stavropol region AI, 1* (21), 44-49

Chernovolov, V. A., Sherstov, S. A. (2016b). Calculation of fertilizer dose introduction by vertical throwing apparatus with the horizontal rotation axis. *The certificate of computer program state registration*, №20166106674.

Chernovolov, V. A., Sherstov, S. A. (2017). Experimental study of vertical rotary apparatuses for mineral fertilizer dissemination. *Michurinsky agronomical bulletin, 2*, 103-111.

Chernovolov, V. A., Sherstov, S. A. (2013). The development of an algorithm to optimize the parameters of a switchgear for a throwing device with horizontal rotation axis. The improvement of crop production technical means. *Interuniversity collection of scientific papers.* - Zernograd: FSBEI HVE ACHSAA, 121.

Chernovolov, V. A., Sherstov, S. A. (2014). The use of similarity methods during the calculation of throwing apparatus. *The improvement of technical means in crop production: interuniversity collection of scientific papers.* - Zernograd: FSBEI HVE ACHSAA, 123.

Chernovolov, V. A., Sherstov, S. A. (2015). The calculation of switchgear parameters for a throwing device with the horizontal rotation axis. *The certificate of computer program state registration,* №2015610250.

Morozova, N. (2018). *Search for a model for training specialists for the innovative development of a system of consumer cooperation in the conditions of a post-industrial society.* Fundamental and applied research of the cooperative sector of the economy, 1: 24-27 (In Russian, Fundamental'nye i prikladnye issledovaniya kooperativnogo sektora ehkonomiki)

Morozova, N. (2016). Quality of life of the population: economic nature, determinants and directions of assessment. *Modern Economy: Problems and Solutions, 6*(78), 128-134.

Zhokhova, V.V. (2015). Social entrepreneurship: essence and concept [Text], Proceedings of Far Eastern Federal University (FEFU). *Economics and management, 1,* 85-98.