

Design of the Construction and Parameters Justification of Stud-Belt Seeding Machine for Application of the Main Dose of Mineral Fertilizer

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ABSTRACT

As a result of the performed analytical and experimental work, a studded belt mineral fertilizer feeder has been developed and manufactured. It can ensure applying a greater fertilizer portion on a wide area. Due to avoidance of batch feeding, it ensures uniform fertilizer distribution in the soil. Uniform fertilizer distribution on the belt conveyor, as well as in the soil, depends on the stud arrangement pattern on the belt surface. The article provides a rationale for the optimal parameters of the stud arrangement on the running belt, its optimum angle in the longitudinal vertical plane, and the longitudinal stud arrangement parameters. We have also developed the fertilizer feeder's structural design and provided a rationale for it, theoretically determined the main functional dependencies between its parameters. We have tested the capability of the experimental fertilizer feeder of mineral fertilizer feeding at an increased rate and determined its main parameters in laboratory conditions. Laboratory experiments confirmed the development prospects and a distribution irregularity reduction to 5.7%-8.4%.

KEYWORDS

Mineral fertilizer application;
studded belt conveyor; seeding machine;
metering; stud line.

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Introduction

One of the most important ways to increase the crop yield in the region of Northern Kazakhstan is to improve soil fertility. With the annual use of the same areas, every crop takes out nutrients from the soil. As a result, the soil becomes infertile. The main method to improve soil fertility is rational and effective application of mineral fertilizers.

The crop quantity and quality farmers receive on processed agricultural plots depend, first of all, on their fertility, secondly, on the agriculture efficiency, and thirdly, on the mineral fertilizer application rates. Many variables impact on the application rate. These include: the availability of various nutrients in the soil; whether the crop is released or not; the climatic conditions for its growth; and finally, the state and adaptability of the application device.

Methods of mineral fertilizer application are distinguished by the terms of application and the technological manner and are divided into: presowing broadcast dressing; main seedbed dressing (at the time of seed sowing), and post-sowing dressing (mainly for row crops, this is applied during inter-row cultivation).

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The main device widely used in the area under study is GUN-4. It provides banding mineral fertilizers in the soil to a depth of 16–30 cm. However, it has a significant drawback: its metering unit cannot comply with the stability requirements of the set application rate and cannot ensure applying an increased portion of 400 kg/ha.

Among the existing mineral fertilizer application systems, the most common are roller, centrifugal, and pneumatic feeders (Muller & Köller, 1996; Sommer & Köller, 1989; Yuan et al., 2010; Cakmak et al., 2010; Powlson et al., 1985; Lal, 2003; Meyer & Mamerling, 1963). There are also many other designs of metering devices (Crowe et al., 1998; Tsirkunov a& Panfilov, 1994; Nukeshev, 2008; 2009). However, the main drawback of all these devices is the irregular material feeding to the fertilizer funnel. At the same time, more uniform fertilizer distribution ensures optimum nutrition of each plant and increases the overall yield due to the increased intraspecific competitiveness (Heege, 1993; Sogaard & Kierkegaard, 1994; Onal, 1995; Aykas et al., 1990; 2005). In this view, there is a need for further research intensification aimed at the design development, justification of parameters and operating modes of fertilizer feeders for the application of the main portion of mineral fertilizers.

The object of this study is the studded belt fertilizer feeder designed in the Kazakh AgroTechnical university, Kazakhstan (Eskhozhin et al., 2013; Nukeshev 2013).

Materials and Methods

In order to facilitate the study of fertilizer feeders, the Technical Mechanics Department of the S.Seifullin Kazakh AgroTechnical University designed and constructed a laboratory device (figure 1). The laboratory device consists of frame 1, on which fragment of bin 2 of SZS-2,0, conveyor fertilizer feeder 3, and running belt 4 are mounted. Fertilizer feeders are driven by stand 5 (STEU-40M-1000-GOSNITD), which enables stepless variation of the rotation rate and has a device for measuring its value. The running closed loop belt is driven by a separate drive. In laboratory experiments, the fertilizer feeder shaft rotation rate was measured with the SK tachometer; the time was measured with a stopwatch; and the fertilizer weight was measured with VLKT-500M scales.

We determined the quality indicators of the studded belt fertilizer feeder through experimental studies, the results of which were the identified structural and technological parameters and their values.

For the purposes of the experimental study, studded belt conveyors with three types of studs were made: diamond-shaped, square, and cylindrical (figure 2), which showed the best results in the course of establishment experiments.

The stud height was 10 mm, the cross-section area was 100 mm². The laboratory unit allows infinite variation of the following: the conveyor speed between 0.05 and 0.3 m/s, the bin gate opening value between 5.0 and 20.0 mm, and the conveyor inclination angle between 1.0 and 12.0 degrees. The experiments were conducted with granulated superphosphate. The experiments targeted determining the following: application irregularity (deviation from the average weighted along the row) and application instability (deviation from the average weighted between the rows). The deviations were estimated with the variation coefficient. Fertilizer consumption was maintained at 200±11 g/s, which corresponds to the increased application rate of 400 kg/ha. The weighing precision was 0.01 g (Dospekhov, 1972).

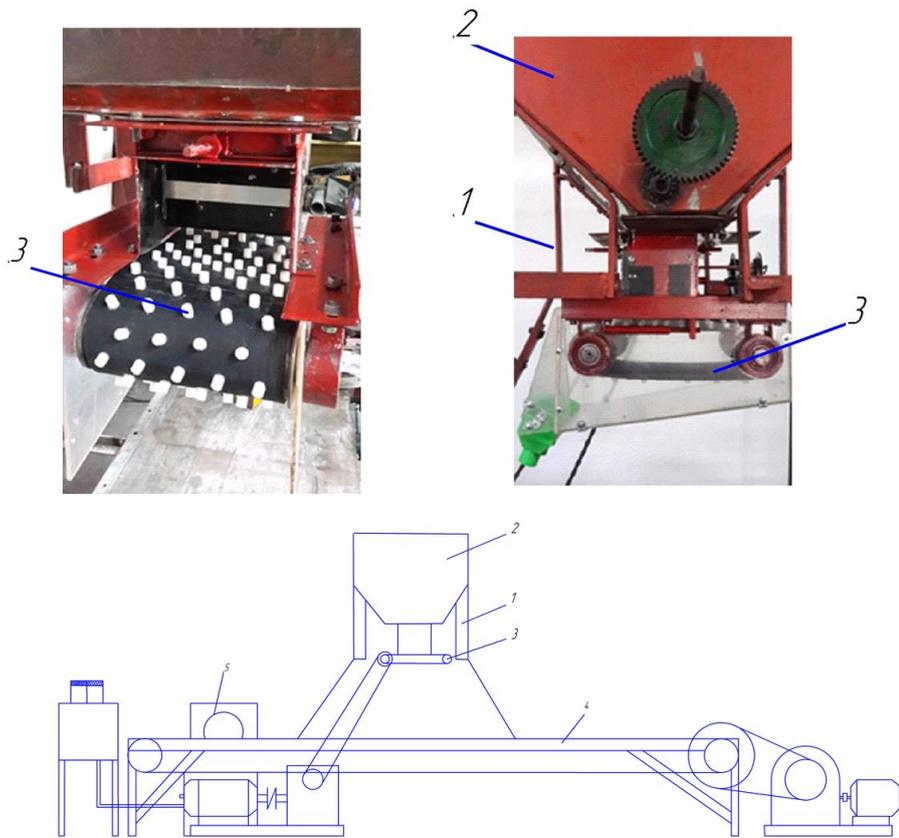


Figure 1. Laboratory device

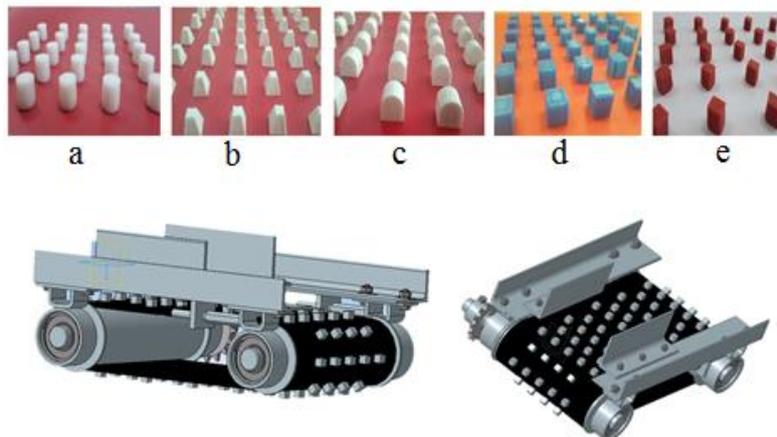


Figure 2. Studded belt fertilizer feeder and stud shapes: a) cylindrical b) pyramidal c) semi-cylindrical d) square e) rhomboid

The experiments were carried out by the usual fertilizer feeder research technique using mineral fertilizer granules (GOST 28714-2007).

The duration of each experiment was 60 seconds. After application, we determined the weight of fed mineral granular fertilizers in sections. The results of

the observations were recorded in the observation log. The laboratory experiments were conducted in triplicate. We determined the application irregularity and instability of the fertilizer feeders equipped with diamond-shaped, square, and cylindrical studs.

Based on the mathematical experiment planning (Spiridonov, 1981; Adler et al., 1976), we analyzed basic levels of factors affecting the model. We found that a full factorial experiment is required and we determined its matrix. The planned number of each experiment repetitions is at least three (Spiridonov, 1981; Adler et al., 1976; Ushakov et al., 2002).

The factors to study are: gate opening; shaft rotation rate; conveyor inclination angle. Establishment research has shown that the fertilizer bin filling level has little effect on the fertilizer feeder performance. Therefore, in laboratory studies the fertilizer bin filling factor remained at 60%. Thus, the full factorial experiment will contain three research factors and three levels of natural values.

Results and Discussion

To determine the stud location on the conveyor surface, we select a quadrangular portion of the conveyor belt with width B and height H . Next, we draw straight stud line AD at certain angle α to the ground and divide it into equal segments of length d . In segment AB , we need to build a non-isosceles triangle, so that segments $A_1 > 1C$ or $A_1 < 1C$. The fact is that if $\triangle ABC$ is isosceles, rhombus BB_1C_1C will also be isosceles. In this case, studs located on the upper and lower rhombus vertices will follow each other. Therefore, it is necessary to form non-isosceles rhombuses. It is possible if triangles ABC are non-isosceles.

The number of stud traces within step t can be determined based on the following considerations. If at step t the number of stud lines $Z_{pl} = 1$, the number of traces is equal to N . In this case, when $Z_{pl} = 2$, the number of traces is equal to $2N$. Therefore, when the number of stud lines $Z_{pl} = N$, the number of traces equals to:

$$Z_{nt} = Z_{pl} \cdot N. \quad (1)$$

In this case, the distance between the stud traces can be determined:

$$\delta = \frac{t}{Z_{nt}} = \frac{t}{Z_{pl} \cdot N}. \quad (2)$$

Studs disposed successively on a right-facing helical curve shift the occurring fertilizer granules to the right, and studs disposed successively on the left-facing helical curve shift these granules to the left. As a result of such alternating shift and due to the studs' own oscillation along with the conveyor, fertilizer is distributed uniformly on the conveyor surface. To provide alternating shift of granules, we need to determine the stud line inclination angle.

Let's assume that the conveyor moves towards v_t and consider several studs disposed on the conveyor surface (figure 3). As noted in (Eskhozhin et al., 2015b), the studs' shape can vary and be rectangular, square, diamond-shaped, cylindrical, etc. For theoretical considerations, we initially take the stud shape to be square.

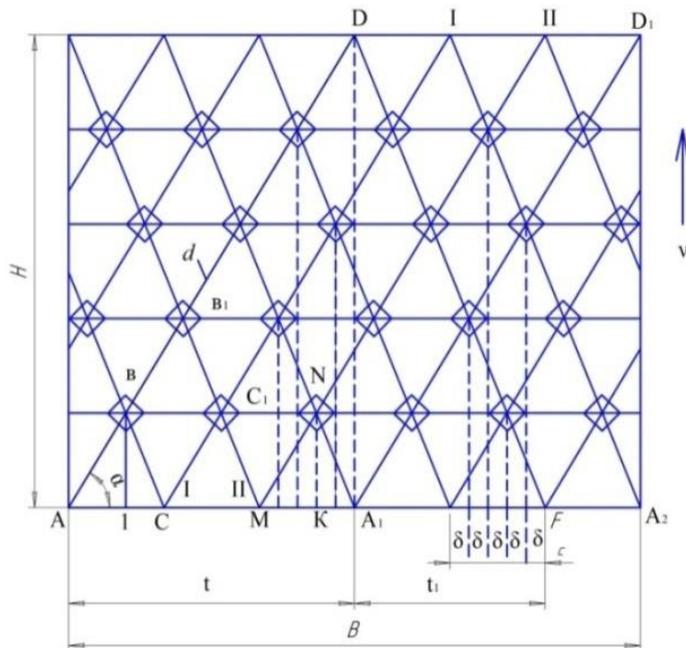


Figure 3. Stud arrangement on the conveyor surface

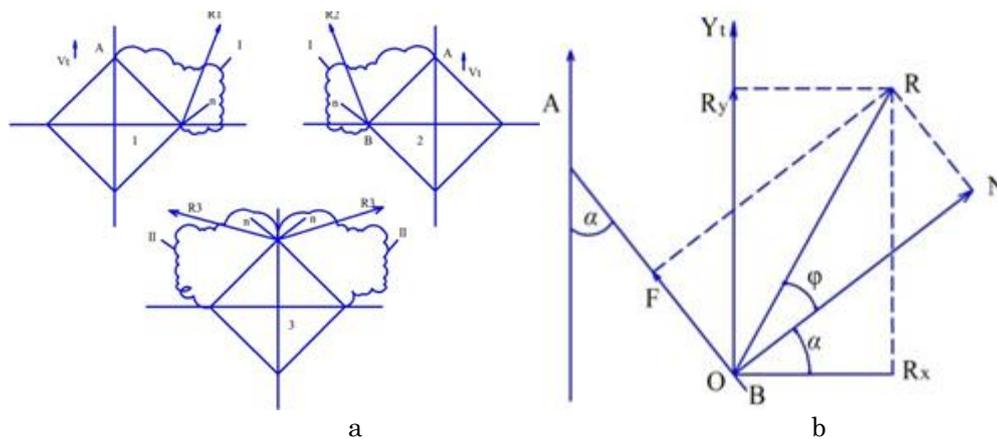


Figure 4. Transporting stud operation scheme

As you can see on the figure 3, the first and second studs impact the fertilizer in directions R_1 and R_2 and shift its granules to the center, cluster I. The third stud acts in direction R_3 and shifts the fertilizer granules that have passed studs 1 and 2 without being touched to the sides, cluster II. This movement to the center and to the sides results in even distribution of the fertilizer granules on the conveyor surface (Eskhozhin et al., 2015a).

Figure 4b shows the edge of stud AB. The following forces are applied to point O of the granule, which has faced the stud edge:

- N — normal response of the stud surface;
- F — the friction force between the surface of the stud and the granule;
- R — resultant force affecting granule O;

From the equilibrium of forces applied to the stud, we find:

$$\operatorname{tg}(\alpha + \varphi) = \frac{\sin \alpha + f \cos \alpha}{\cos \alpha - f \sin \alpha}. \quad (3)$$

where: v_t —is the belt speed vector; α —is the angle between the stud surface and the belt travel direction; φ — is the fertilizer-to-metal friction angle;

As you can see in (3), an increase in angle α causes an increase in angle $(\alpha + \varphi)$, which tends to $\frac{\pi}{2}$. In this case, granules cease sliding on the stud surface. The stud acts as a scraper. This occurs in case of the following condition:

$$\cos \alpha_m - f \sin \alpha_m = 0; f = \operatorname{ctg} \alpha_m.$$

The last equation makes it possible to determine the following:

$$\operatorname{tg} \varphi = \operatorname{tg} \left(\frac{\pi}{2} - \alpha_m \right); \varphi = \frac{\pi}{2} - \alpha_m, \alpha_m \leq \frac{\pi}{2} - \varphi. \quad (4)$$

As seen from (4), relative motion of granules is provided in case if the angle between the stud surface and the direction of belt travel is less than: $(\frac{\pi}{2} - \varphi)$.

In order to justify the longitudinal stud arrangement, we will consider edge CD disposed at angle γ to the motion speed v direction, Figure 5. After period t , in the absence of relative motion particle C takes position C_1 . However, if there is relative motion, this particle sliding along the edge will move to point D_1 .

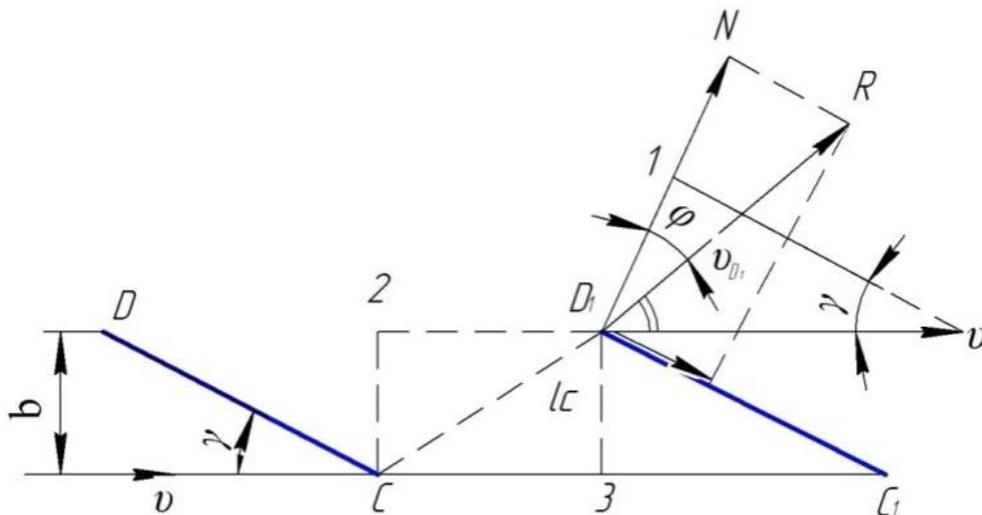


Figure 5. To the longitudinal stud arrangement rationale

Normal response N applies to the particle. Due to friction force F , resultant force R is diverged from it at angle γ . The absolute speed of particle C coincides with direction R .

The figure shows that the stud path together with the conveyor consists of two parts:

$$l = CC_1 = C_1C_2 + C_2C_3;$$

$$l = b \left[\tan(\gamma + \varphi) + \frac{1}{\tan \gamma} \right] \quad (5)$$

Formula (5) shows the minimum distance between adjacent studs in a longitudinal row, which depends on the half width of the stud and the span and friction angles. With a smaller distance between studs, material pileup can occur in front of the stud edge.

As seen in Figure 5, material that was in triangle DCD moves along the speed vector v_a and sliding on edge D_1C_1 disengages with it at point D_1 . Material that disengages with edge CD will be replaced with other material from triangle CD_1C_1 . The area of triangle DCD_1 depends on angle γ . Obviously, we need to find such value γ , with which the area under consideration will be as small as possible, so that a smaller area would not allow redistribution of material, since the studs will have a minimal effect on it.

Obviously, the weight of material before edge CD is equal to:

$$mg = w\rho,$$

where: w is the material volume in front of edge CD; ρ is the volumetric weight of the material.

From the previous expression, we have:

$$m = \frac{1}{q} w\rho. \quad (6)$$

Substituting values in (6), we find:

$$m = \frac{1}{2q} \left[\tan(\gamma + \varphi) + \frac{1}{\tan \gamma} \right] \cdot b^2 \cdot h \cdot \rho. \quad (7)$$

where: h is the height of the conveyor bins' layer; q is the acceleration of gravity.

In (7) b , h , ρ and φ are independent from γ ; they are constant for this design and process conditions. It is necessary to determine the minimum of function $m(\gamma)$. To do this, we need to equate the first derivative of the function to zero:

$$\frac{dm}{d\gamma} = \frac{b^2 h \rho}{2q} \left[\frac{1}{\cos^2(\gamma + \varphi)} - \frac{1}{\sin^2 \gamma} \right] = 0.$$

In this equation, the first term cannot be equal to zero. Consequently:

$$\frac{1}{\cos^2(\gamma + \varphi)} - \frac{1}{\sin^2 \gamma} = 0$$

$$\gamma_{\min} \geq \frac{1}{2} \left(\frac{\pi}{2} - \varphi \right). \quad (8)$$



Equation (8) proves that the span angle of the front stud edge cannot be less than the specified value.

Resulting dependencies 8 were used in the design and calculation of the studded belt fertilizer feeder.

Rationale for the optimal parameters of the fertilizer feeder. The optimal design and technological parameters of the studded belt fertilizer feeder were found as a result of full factorial experiments performed within the program of central composite rotatable second-order planning. Based on single factor experiments, we accepted three variable factors, including the conveyor inclination angle, the bin gate opening value, and the device shaft rpm, as well as two optimization parameters, including the distribution irregularity and instability. Additionally, the planning matrix was generated (Table 1). As a result of the mathematical processing of the experimental data, we determined the regression equations for:

the application irregularity:

$$b^0 = 3.11 \quad b^1 = 0.952 \quad b^2 = -0.582 \quad b^3 = 0.178;$$

$$b^{12} = -0.76 \quad b^{13} = 0.27 \quad b^{23} = 0.235 \quad b^{123} = 0.182;$$

$$b^{11} = 0.427 \quad b^{22} = 0.576 \quad b^{33} = 0.459.$$

the application instability between different devices:

$$b''^0 = 3.19 \quad b''^1 = 0.758 \quad b''^2 = -0.646 \quad b''^3 = 0.345;$$

$$b''^{12} = -0.887 \quad b''^{13} = 0.512 \quad b''^{23} = 0.762 \quad b''^{123} = 0.187;$$

$$b''^{11} = 0.860 \quad b''^{22} = 0.993 \quad b''^{33} = 0.524.$$

Since the absolute values of coefficients b'_{123} и b''_{123} are less than the corresponding confidence intervals, they can be treated as statistically valid and excluded from the regression equations.

In this case, the regression equations are as follows:

For the application irregularity:

$$Y_1 = 3.14 + 0.952x_1 - 0.582x_2 + 0.178x_3 - 0.76x_1x_2 + 0.27x_1x_3 + 0.235x_2x_3 + 0.427x_1^2 + 0.576x_2^2 + 0.459x_3^2. \quad (9)$$

For the application instability:

$$Y_2 = 3.2 + 0.758x_1 - 0.646x_2 + 0.345x_3 - 0.887x_1x_2 + 0.512x_1x_3 + 0.762x_2x_3 + 0.857x_1^2 + 0.99x_2^2 + 0.521x_3^2. \quad (10)$$

Second-degree equations (9) and (10) are hard to analyze; therefore, in order to understand the geometric shape of the response function, we brought the dependencies correspondent to them through transformations to the canonical form:

for the application irregularity:

$$Y_1 - 5.58 = 0.53x_1^2 + 0.03x_2^2 + 0.88x_3^2. \quad (11)$$

for the application instability:

$$Y_2 - 4.41 = 1.39x_1^2 + 0.04x_2^2 + 0.928x_3^2. \quad (12)$$

Examining the application irregularity equations in the canonical form, we need to note that the response surface is a rotational ellipsoid and have a minimum at the ellipsoid center. The extremum is in the study area, which confirms the

correctness of the choice of variable factor variation limits. The figure center coordinates are:

$$\text{for irregularity: } x_{1_s} = 2.918; \quad x_{2_s} = 1.641; \quad x_{3_s} = -1.085;$$

$$\text{for instability: } x_{1_s} = -0.604; \quad x_{2_s} = -1.167; \quad x_{3_s} = 1.482;$$

Table 1. Planning matrix and experiment results

Studded belt fertilizer feeder		Input factors			Optimization parameters	
Natural	Conveyor inclination angle α , degrees	Bin gate opening value s , mm	Fertilizer feeder shaft revolution rate n , s^{-1}	H1, % Application irregularity	H2, % Application instability between feeders	
Coded	x_1	x_2	x_3	Y_1	Y_2	
Factor	+1	7	15	0.66	-	
varying	0	5	12	0.5	-	
levels	-1	3	9	0.33	-	
	-1.682	1.6	6.957	0.22	-	
Variation interval		2	3	0.16	-	
	1	+	+	+	4.13	4.9
	2	-	+	+	3.08	5.2
	3	+	-	+	6.92	7.5
	4	-	-	+	2.1	3.5
	5	+	+	-	4.5	3.1
	6	-	+	-	3.8	4.7
	7	+	-	-	7.5	8
	8	-	-	-	4.49	6.8
Experiment numbers and conditions	9	+1.682	0	0	5.36	7.9
	10	-1.682	0	0	3.32	3.7
	11	0	+1.682	0	4.03	5.9
	12	0	-1.682	0	5.49	6.45
	13	0	0	+1.682	2.5	3
	14	0	0	-1.682	6.36	6.7
	15	0	0	0	2.78	3.1
	16	0	0	0	3.18	2.2
	17	0	0	0	3.03	3.7
	18	0	0	0	3.5	3.1
	19	0	0	0	3.05	3.9
	20	0	0	0	3.17	3.2

When decoding coordinates of the singular point for U_1 , we found the following natural values of factors: conveyor inclination angle – 10.8°; gate opening value – 16.9 mm; fertilizer feeder shaft rotation rate – 0.32 s^{-1} ; the application irregularity in this case is equal to 5.58%.

Having also considered equations for Y_2 , we find the following natural values of factors in the experiment center: $\alpha = 3.8^\circ$; $s = 8.5$ mm; $n = 0.73$ s^{-1} . In the figure center, the application instability is equal to 4.41%.

As a result of the performed study, we built the response surfaces, derived from regression equations by equating one of the factors to zero, in order to determine the impact of variable factors on the application irregularity and instability. Their analysis was performed with two-dimensional cross-sections.

The influence of the bin gate opening and the rotation rate was studied for irregularity and instability of the fertilizer application at $x_1=0$. As a result, equations (9) and (10) take the following forms:

for the application irregularity:

$$Y_1 = 3.14 - 0.582x_2 + 0.178x_3 + 0.235x_2x_3 + 0.576x_2^2 + 0.459x_3^2. \quad (13)$$

for the application instability:

$$Y_2 = 3.2 - 0.646x_2 + 0.345x_3 + 0.762x_2x_3 + 0.99x_2^2 + 0.521x_3^2. \quad (14)$$

Figure 6 shows the response surfaces describing the dependency of the application irregularity and instability on the gate opening value and conveyor shaft rotation rate.

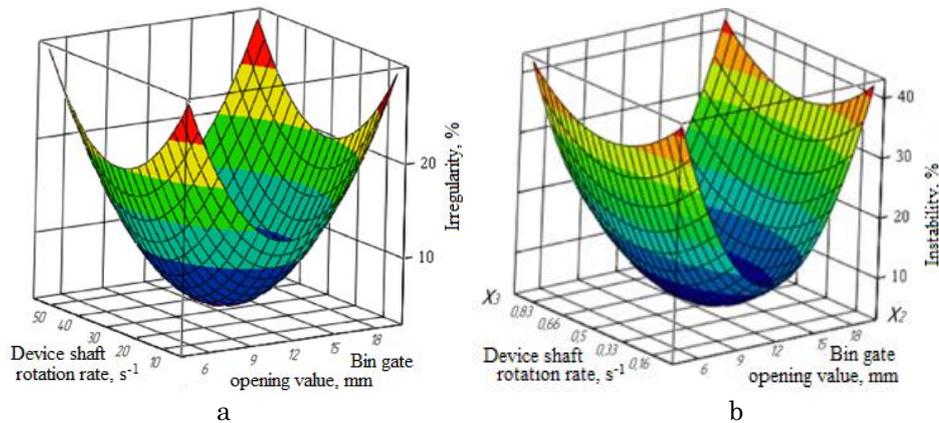


Figure 6. Response surfaces at $x_1 = 0$: a - irregularity coefficient H , %; b - instability coefficient H , %.

Two-dimensional cross-sections of the response surfaces are isolevel lines projected on plane x_2 and x_3 (Figure 7).

Visual representations of the response surfaces and their two-dimensional cross-sections allow determining the minimum values of application irregularity and instability and the values of factors that can provide them.

We found the optimal area of the factors under study through the analysis of the resulting response surfaces. The minimum irregularity values are observed at the following values of the factors under study: the rotation rate of the fertilizer feeder shaft is $n=0.42-0.58 \text{ s}^{-1}$; the bin gate opening value is $S=11-13 \text{ mm}$. We can also define the factor values for instability (Figure 7b).

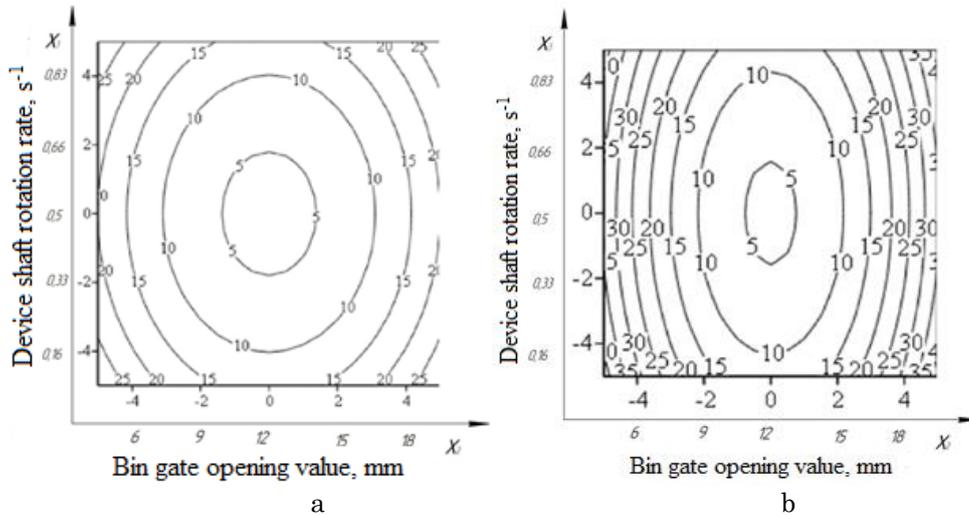


Figure 7. Two-dimensional cross-section of the response surface $x_1=0$: a – the application irregularity; b – the application instability.

In a similar manner, response surfaces and two-dimensional cross-sections were built at $x_2=0$ and $x_3=0$.

To establish the process conditions, which would ensure the least irregularity and instability of application, we used the graphical-analytical method, based on the consideration of two-dimensional cross-sections of surface Y_1 combined with two-dimensional sections of surface Y_2 and choosing conditional extremums.

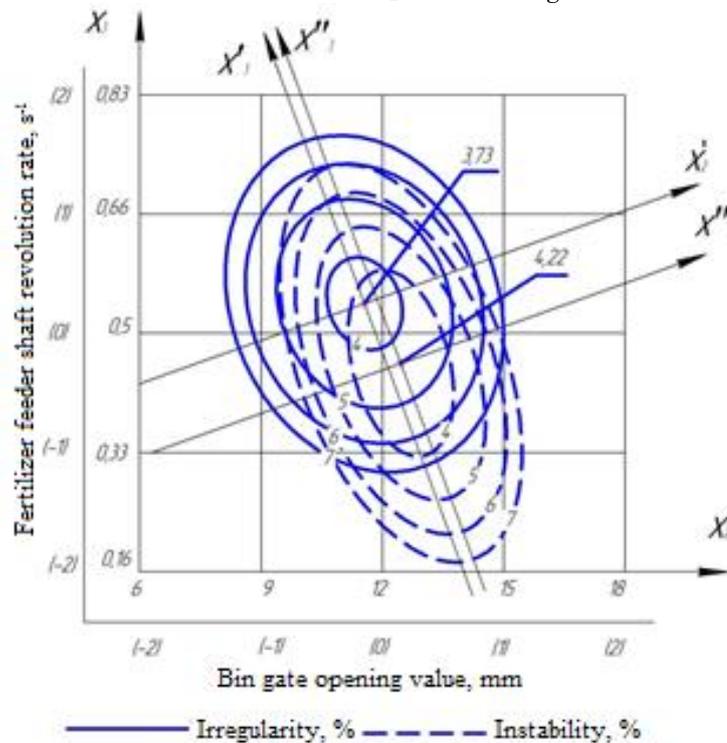


Figure 8a. Combined two-dimensional cross-sections of response surfaces, characterizing the application irregularity and instability (when $x_1=0$).

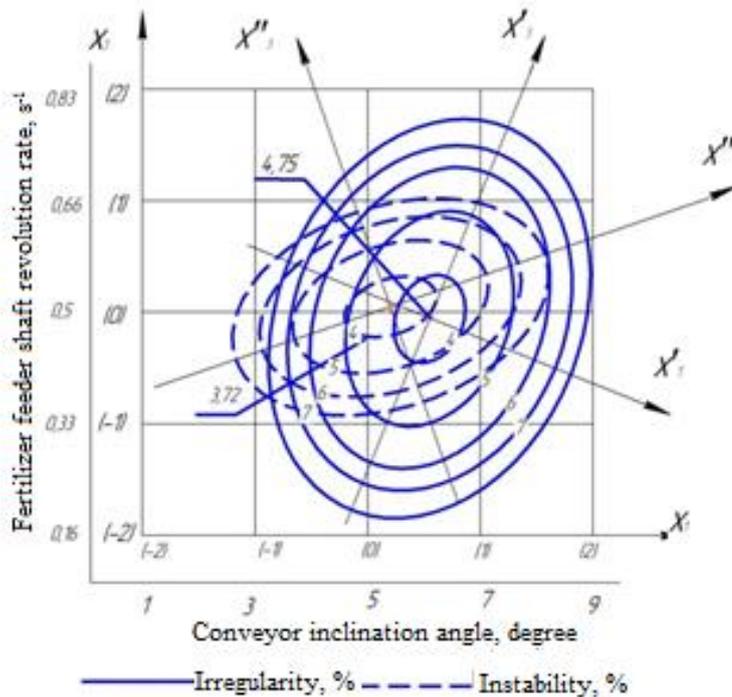


Figure 8b. Combined two-dimensional cross-sections of response surfaces, characterizing the application irregularity and instability (when $x_2=0$).

Taking different values of irregularity and instability between different devices in equations (11) and (12), we obtained equations of corresponding contour curves that collectively represent a family of conjugate ellipses, i.e. isolevel lines of the application instability and irregularity index (Figure 8).

The effects of the shaft rotation rate, the bin gate opening value, and the inclination angle of the conveyor of the studded belt fertilizer feeder on the application irregularity and instability at $x_1=0$ are shown in Figure 8. The figure allows determining the optimal values of variable factors that provide minimum values of the application irregularity and instability. They are: $x_3=0.47-0.58 \text{ s}^{-1}$, $x_2=11.2-12.8 \text{ mm}$, $x_1=5.3-6.1$. They correspond to irregularity of 3.73% and instability of 4.22%.

Thus, we combined two-dimensional sections of response surfaces at $x_3=0$. In this case, we obtain the optimal values of variable factors: $\alpha=6^\circ$; $S=12 \text{ mm}$; $n=0.5 \text{ s}^{-1}$.

Conclusion

As a result of the work performed, we can conclude that the studded belt mineral fertilizer feeder can provide a higher rate of fertilizer application with the application irregularity of 5.58% and application instability of 4.41%. They corresponded to the following technological parameter values:

Fertilizer feeder shaft revolution rate; $n = 0.5 \text{ s}^{-1}$.

Bin gate opening value; $S = 12 \text{ mm}$.

Conveyor inclination angle; $\alpha=6^\circ$.

The conveyor travel speed in this case equaled to 0.13 m/s.

Disclosure statement

No potential conflict of interest was reported by the authors.

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References

- Adler, Yu.P., Markova, E.V., Granovskii, Yu.V. (1976). Planning an experiment in the search for optimal conditions. Moscow: Nauka.
- Aykas, E., Uz, E., Onal, I., (1990). A Research on the seed broadcasting machines. 4th International congress on mechanization and Energy in Agriculture. Adana.
- Aykas, E., Yalcin, H., Cakir, E. (2005). Conservation Tillage Methods and Direct Seeding. The Journal of Agricultural Faculty Ege University, 42 (3), 69-74.
- Cakmak, B., Aykas, E., Onal, I., Cakir, E. (2010). The performance of developed rotary tiller fitted with pneumatic seeder. *Bulgarian Journal of Agricultural Science*, 16 (6), 801-810.
- Crowe, C.T., Sommerfeld, M., Tsuji, Y. (1998). The performance of developed rotary tiller fitted with pneumatic seeder. London: CRC Press.
- Dospikhov, B.A. (1972). Planning a field experiment and statistical processing of its data. Moscow: Kolos.
- Eskhozhin, D., Karaivanov, D., Zhaksylykova, Z. (2015a). Belt conveyor for mineral fertilizer applying machine. Jubilee Scientific Conference with International Participation traditions and challenges facing agricultural education, science and business. Plovdiv.
- Eskhozhin, D., Nukeshev, S., Akhmetov, E., Zhaksylykova, Z., Balabekova, A. (2013). Technical problems of intra-soil applying of mineral fertilizers and their solution. Proceedings of the Innovation Convent "Kuzbass: Education, Sciences, Innovations", 2, 27-31.
- Eskhozhin, D.Z., Nukeshev, S.O., Zhaksylykova, Z.S., Akhmetov, E.S., Eskhozhin, K.D. (2015b). Justification of the design parameters of a studded conveyor fertilizer feeder for mineral fertilizer application. Proceedings of the International Scientific and Practical Conference. Volgograd.
- GOST 28714 -2007. Devices for solid fertilizer application. Test methods. Moscow: Standartinform.
- Heege, H.J., (1993). Seeding methods performance for cereals, rape, and beans. *Trans. of ASAE*, 36 (3), 653-661.
- Lal, R., (2003). Soil erosion and the global carbon budget. *Environment International*, 29, 437- 450.
- Meyer, J. D., Mamerling, J. V. (1963). Crop Residues as Surface Mulches for Controlling Erosion on Sloping Land Under Intensive Cropping. *Trans. of ASAE*, 16(4), 322-323.
- Muller, J., Köller, K., 1996. Improvement of seed spacing for seed drills. AgEng'96 Conference on Agricultural Engineering, Madrid, Report No. 96A-030.
- Nukeshev, S.O., (2013). Patent BY 9706 U 2013.12.30 MPK A01S 15/00 (2006.01). Fertilizer Feeder.
- Nukeshev, S. O. (2008). Patent 19007 RK. Bulk material distributing device.
- Nukeshev, S.O., (2009). Technical solution of the problem of uniform distribution of bulk material. Proceedings of the Z. AldamzharKostanay Socially-Technical University, 1, 141-146.
- Sogaard, H.T., Kierkegaard, P. (1994). Yield reduction resulting from uneven fertilizer distribution. *Trans. of ASAE*, 37 (6), 1749-1752.
- Sommer, C., Köller, K. (1989). Brenndörfer Einching von Bodenbearbeitungs und Bestellverfahren Bodenbearbeitungs und Bestellsysteme in der Diskussion. KTBL Arbeitspaper, 130, 8-16.



- Spiridonov, A.A. (1981). Planning an experiment in the study of technological processes. Moscow: Mashinostroenie, 1981.
- Tsirkunov, Y.M., Panfilov, S.V. (1994). Dusty gas flow around bodies: effects of non-elastic reflection of particles. Abstracts of Papers of 2nd European Fluid Mechanics Conference. Warsaw.
- Ushakov, L.S., Ryabchuk, S.A., Kotylev, Yu.E. (2002). Active factorial experiment. Mathematical planning, organization and statistical analysis of the results: Study Guide. Orel: Orel State Technical University.
- Yuan, J., Liu, C.-L., Li, Y.-M., Zeng, Q., Zha, X.F. (2010). Gaussian processes based bivariate control parameters optimization of variable-rate granular fertilizer applicator. *Computers and Electronics in Agriculture*, 70, 33-41.