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Polish Academy of Sciences Branch in Lublin
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Polish Academy of Sciences Branch in Lublin
Pałac Czartoryskich, Plac Litewski 2, 20-080 Lublin, Poland
e-mail: eugeniusz.krasowski@up.lublin.pl

Publishing Office address
Ivan Rogovskii
National University of Life and Environmental Sciences of Ukraine
Str. Heroiv Obrony, 15, Kyiv, Ukraine, e-mail: irogovskii@gmail.com

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Investigation of Movement of Grains in Drum Dryer with Ir-Energy Supply on Sloping, Ruled Minimum Surface

Valeriy Voytyuk, Sergiy Pylypaka, Roman Kalinichenko, Mykola Mukvich

National University of Life and Environmental Sciences of Ukraine.
E-mail: rkalinichenko@ukr.net

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Summary. Storage in the dry state is the most common way of preserving plant materials. Energy costs for drying grain, seed and feed materials can be up to 50% of the total costs for the production of the finished product. Universal drum-type dryers are widely used in farms, since they allow dehydration of various loose wet materials. But for a number of performance indicators (specific energy costs, automation level, environmental requirements, and others), these dryers do not fully meet the modern requirements for the production of agricultural and processing industries. The solution of optimization problems, in terms of productivity and energy consumption of drum units, is possible only if adequate mathematical models of processes are available. Therefore, the aim of the research was to develop a mathematical apparatus for substantiating the geometric parameters of a sloped shelf in a drying drum to ensure a guaranteed gravitational movement of the grain material along it with a minimum speed for maximum exposure of the radiation exposure to the grain. The obtained equations can be used to analyze the process of grain moving in the drying drum and to optimize the regime parameters of heat treatment at known values of the design parameters of the dryer.

Key words: drying drum, minimal surface, gravel movement, coefficient of friction.

INTRODUCTION

The problem of energy consumption reduction during thermal drying wet grain is extremely relevant for farmers, especially in small farms. Thermal drying to be 40% of the harvested grain, and in some years - 80%. This energy for drying can reach 50% of the production of the final product. In small farms most used technical tools are unified and universal saving material costs for their purchase. Therefore the use of drum dryers is appropriate in terms of versatility for the type of grain raw material and heat treatment [1].

For the purposes of agroindustrial production are developed, produced and operated drum dryers of various types and brands [2], the most common SZSB, CFSP type BNv which can be implemented in different versions (direct-flow, reverse flow, with the blade, pie, blade-pie system of movement and combined nozzles, an angle unit of 10 to 40, etc. [3]) Figure 1, but they have a significant disadvantage compared with other types of dryers, realizing convection type drying - too high specific energy.

Ways to reduce energy consumption for drying is supplying radiation energy to heat the grain raw material directly inside the drum to reduce the amount of coolant supply and, consequently, reduce heat costs spent drying agent in the environment.

But the use of this method of thermal drying process is constrained not feasible way to move grain and mixing the material in the areas of local radiation drum dryers with infrared enerhopidvedennyam.

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

In literature, sufficient material on the movement of material [5-10] and calculation processes of convective heat and mass transfer [6, 11-21] in the settings drum drying of agricultural and food materials.

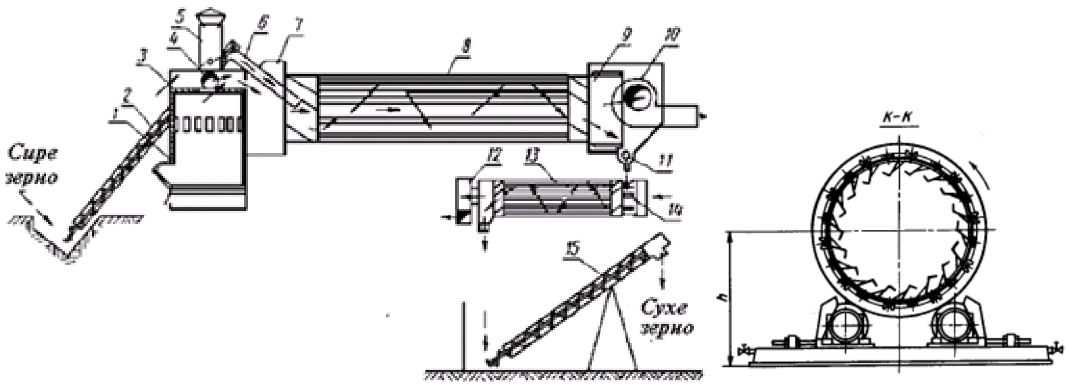
In [1, 7] proved the efficacy of termoradiation - IR drying drums.

The main advantage of such schemes drying process is more efficient and intensive heat transfer to the material and the ability to influence the temperature distribution of the material along the length of the drum.

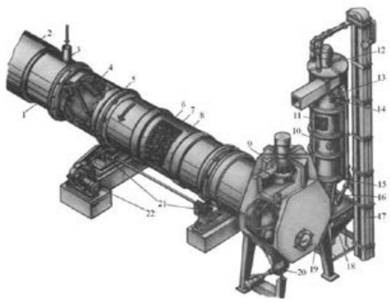
However, in certain papers [5, 6, 7] to move the grain material inside the drum is not considered changing the coefficient of friction depending on humidity grain.

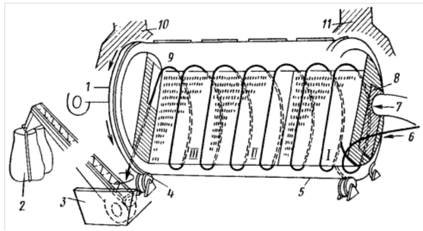
OBJECTIVE

Development of mathematical tools to study the geometric parameters pitched shelves in a drying drum to ensure guaranteed gravitational movement on it grain material with a minimum speed for maximum exposure to radiation grains.



a)





b) c)

Fig. 1. Drum dryers (a - flowsheet CFSP, b - exterior SZSB in - system Mueller [4]).

THE MAIN RESULTS OF THE RESEARCH

To ensure immediate supply of radiation energy from infrared heaters to grain material in the drum dryer is proposed to place pitched shelves of one of them placed IR heaters, Figure 2.

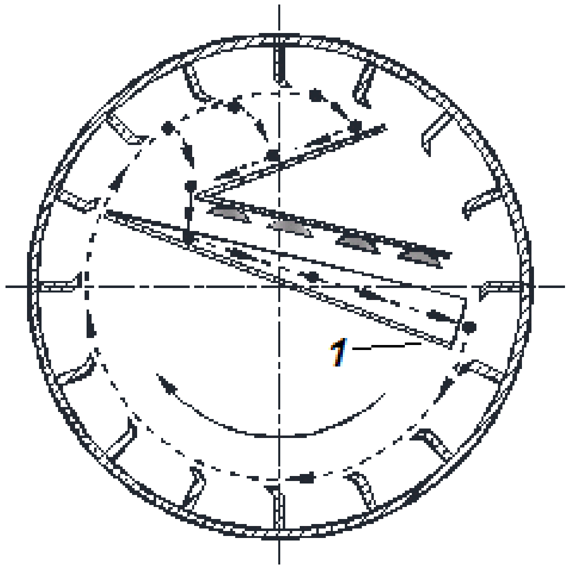


Fig. 2. Front scheme drum dryer (1 - Inclined roof shelf).

To maximize the radiation energy to supply grain material period (radiation exposure) stay grain material on sloping shelf 1 must be maximized.

To determine the patterns of movement of grains on the shelf pitched consider the forces acting on the grains in the gravity driving on rough surface, Figure 3.

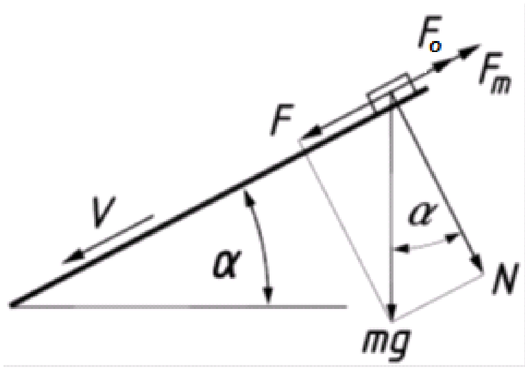


Fig. 3. The scheme forces acting on the grains in the gravity driving on rough surface.

Differential equations of gravity of a particle in a straight rough surface can be written as:

$$m\ddot{x} = mg \cdot \sin\alpha - f \cdot mg \cdot \cos\alpha - F_o \quad (1)$$

where: m - mass of grains, kg, $\ddot{x}$ - acceleration, m / s2, α - the angle of the surface, f - friction coefficient, Fo - resistance force protection, N.

The power of resistance of the medium (air) can be determined by Stokes' law - the resistance is proportional to the velocity of the grains:

$$F_0 = k \cdot v = k \cdot \frac{ds}{dt}.$$

Where k - coefficient of proportionality for particles in the form of balls is defined as:

$$k = 6 \cdot \pi \cdot \mu \cdot R_e$$

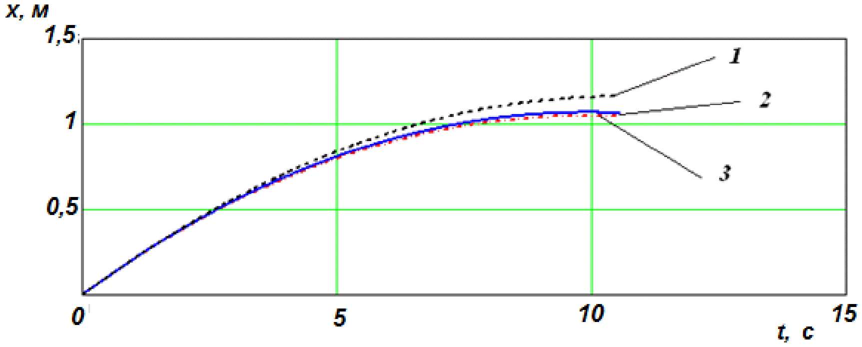


Fig. 4. Dependencies move on rough surface grains (1 - without support medium 2 - resisting the law Stokes 3 - resistance by Newton's law).

Or by law Nyutona-resistance force proportional to the square of the velocity of the grains:

$$F_0 = k_n \cdot \upsilon^2 = k_n \cdot \left(\frac{ds}{dt}\right)^2 .$$

Where KP - coefficient of sails is determined to speed greetings grains.

Figure 4 graphs the results of numerical solution of equation (1), with the support and protection without.

The results of the numerical calculations in equation (1) at different initial parameters (initial velocity, coefficient of friction), the maximum difference grains moving shelves at the end of ramp length of 1m under different laws calculating the resistance of the medium and without his consideration was - 7%.

Therefore, to further simplify the analytical calculations take into account environmental resistance will not, but when calculating the length of the shelf will increase by 10%, rising to guarantee the grains of it.

To maximize long weevil was on the shelf under the influence of infrared heaters need to determine the angle at which the shelf velocity decreases weevil on it in motion and end shelves zero. Define the first initial velocity of grains on the shelf.

Grains falling from the blades and zero Homepage speed (υ0 = 0), begins a free fall. Time to fall from shelves depending find:

$$t_n = \sqrt{\frac{2\cdot h}{g}} \qquad (3)$$

where: h - height of free fall (to the shelves), g - acceleration of gravity, m / s2.

The speed at the end of fall determines the relationship:

$$\dot{x} = \upsilon(t) = \upsilon_0 + g \cdot t_{ї} \qquad (4)$$

Substituting (3) (4) obtain a final rate of fall grains:

$$\upsilon_{кп} = g \cdot \sqrt{\frac{2\cdot h}{g}} = \sqrt{2\cdot g\cdot h} \qquad (5)$$

Given that the shelf is inclined at an angle α to the horizon is the initial velocity of the grains on the shelf will be determined from the relationship:

$$\upsilon_0 = \upsilon_{кп} \cdot \sin\alpha = \sqrt{2\cdot g\cdot h} \cdot \sin\alpha \qquad (6)$$

Consider moving without the resistance of the environment (air), then the equation (1) can be rewritten as:

$$m\ddot{x} = mg \cdot \sin\alpha - f \cdot mg \cdot \cos\alpha ,$$

$$\ddot{x} = g \cdot (\sin\alpha - f \cdot \cos\alpha), \qquad (7)$$

where: f - coefficient of friction, $f = tg\rho$, P - angle of friction.

Equation (7) rewrite as:

$$\ddot{x} = \frac{g \cdot \sin(\alpha - \rho)}{\cos\rho} . \qquad (8)$$

At the end of shelf speed should be close to zero, $\upsilon_n = 0$.

Then the equations (4), (6), (8) we find the movement to stop:

$$t = -\frac{\upsilon_0}{\ddot{x}} = -\frac{\sqrt{2\cdot g\cdot h}\cdot\sin\alpha}{\frac{g\cdot\sin(\alpha-\rho)}{\cos\rho}} = \qquad (9)$$

$$= -\frac{\sqrt{2\cdot g\cdot h}\sin\alpha\cdot\cos\rho}{g\cdot\sin(\alpha-\rho)}$$

Integrate equation (4) and substitute it (9), (8), (6) we obtain the path will be to stop the weevil:

$$x_з = -\frac{h\cdot\cos\rho\cdot\sin^2\alpha}{\sin(\alpha-\rho)} . \qquad (10)$$

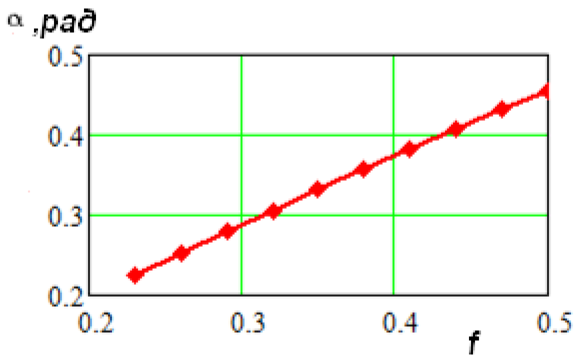


Fig. 4. Dependence angle shelf width x = 1 m, the coefficient of friction.

When given h, ρ, Xz (width shelves) find **α** from equation (10), then the equation (9) determined to move the shelf, Figure 5, Figure 6.

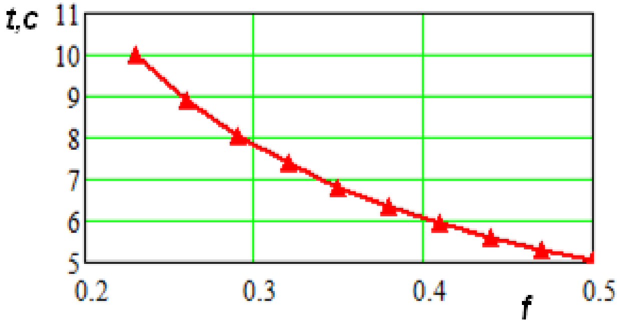
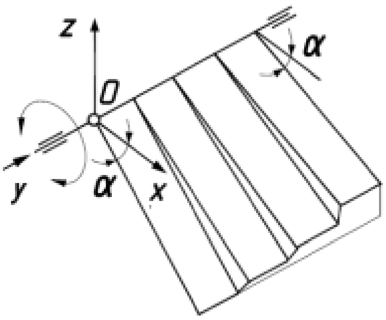
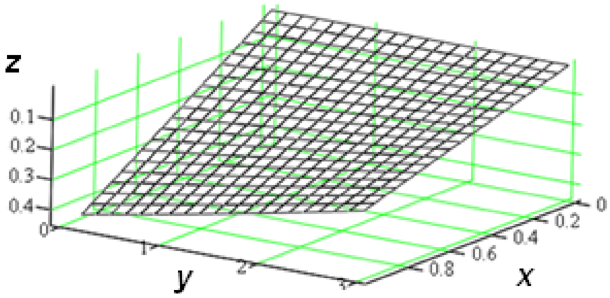


Fig. 5. Dependence time spent grains on the shelf width x = 1 m, the coefficient of friction and therefore determined α.

Coefficient of friction in the dryer varies from a maximum value at wettest grain at the entrance to the dryer to dry grain at minimum output of the dryer. [8] Accordingly, the angle α will vary from maximum to minimum, Figure 6. If the angle α will vary linearly, for projecting shelf ramp can use minimal compartment ruled surface screw conoid (or direct closed helicoid) [9] Figure 6 b. However, in this case, the trajectory of the particle may not coincide with the rectilinear generators but this is typical for a big difference angles α. In this case, the difference is small, so we assume that the particle moves down along straight generatrix surface.



a



b

Fig. 6. Minimum ruled surface pitched shelves.

In Figure 6, would be built compartment screw conoid surface (or direct closed helicoid) [9], parametric equations which are as follows:

$$\begin{aligned} X(u,v) &= u\cdot\cos v, \\ Y(u,v) &= \frac{L}{\alpha_\kappa-\alpha_0}(v+\alpha_0), \\ Z(u,v) &= u\cdot\sin v, \end{aligned} \tag{11}$$

where: α0 - shelf angle determined from (10) to the angle of friction wettest grain dryer inlet, αk - angle shelves for dry grain at the outlet of the dryer, L - length of shelves, m,

$$u\in[0,\dots,\ L],\ v\in[\alpha_0,\dots,\alpha_\kappa].$$

Expressions coefficients of the first quadratic form [9] surface (11) pitched shelves are equal:

$$E=1,\ \ F=0,\ \ G=u^2+\left(\frac{L}{\alpha_\kappa-\alpha_0}\right)^2. \tag{12}$$

Expressions coefficients of the second quadratic form [9] surface (11) pitched shelves are equal:

$$L=0,\ \ M=\frac{L}{\sqrt{1+u^2\cdot(\alpha_\kappa-\alpha_0)^2}},\ \ N=0. \tag{13}$$

The coefficients of the first and second quadratic forms constructed surface (11) transforming the expression of the average curvature [9]

$$H=\frac{E\cdot N-2\cdot F\cdot M+G\cdot L}{2(E\cdot G-F^2)}$$

to zero, so the surface is minimal ramp shelves.

In thermal drying to reduce the energy consumption required to ensure maximum grains stay on the shelf, according to the time of dependence (9) depends on variables - shelf angle and height of fall grains.

Numerically define variables in which α and (9) will receive maximum value. To simplify the calculations will conduct these algebraic transformation.

Domnozhymo numerator and denominator of the equation (9) $h\cdot sin\,\alpha$, We get:

$$\begin{aligned} t &= -\frac{\sqrt{2\cdot g\cdot h}\sin\alpha\cdot\cos\rho}{g\cdot\sin(\alpha-\rho)}\cdot\frac{h\cdot\sin\alpha}{h\cdot\sin\alpha}= \\ &= \frac{\sqrt{2\cdot g\cdot h}}{g\cdot h\cdot\sin\alpha}\cdot\left[-\frac{h\cdot\cos\rho\cdot\sin^2\alpha}{\sin(\alpha-\rho)}\right] \end{aligned} \tag{14}$$

In equation (12) expression in brackets represents the movement to stop by the formula (10), ie:

$$t_з=\frac{\sqrt{2\cdot g\cdot h}}{g\cdot h\cdot sin\,\alpha}\cdot s_з \tag{15}$$

where, s - way weevil equal width pitched shelves.

The results of numerous studies on the movement of grains sloping shelf dependencies (10), (15) in a mathematical environment Mathcad fragment presented on screen in Figure 7.

The results of numerical experiments in the greatest possible range of variables determined that the longest stay on the shelf grains provided at least fall from height (regardless of the coefficient of friction) and angle α that is defined from (10).

формула для визначення часу руху по поличці - $t(\alpha,h) := \frac{\sqrt{2\cdot g\cdot h}}{g\cdot h\cdot \sin(\alpha)}\cdot S$

початкові значення відліку - $\alpha := 0.3$ $h := 0.08$

Given

$0.7\cdot\rho \le \alpha \le 1.2\rho$ -діапазон значень кута нахилу полички

$0.05 \le h \le 0.1$ -діапазон значень висоти з якої падає зерно на поличку

$S = \frac{-h\cdot\cos(\rho)\cdot(\sin(\alpha))^2}{\sin(\alpha-\rho)}$ -умова досягення зернівкою краю полички

$P := \mathrm{Maximize}(t,\alpha,h) = \begin{pmatrix} 0.279 \\ 0.05 \end{pmatrix}$ значення кута і висоти при яких час руху по пиличці буде максимальним

$P = \begin{pmatrix} 0.279 \\ 0.05 \end{pmatrix}$

$T := t(P_0, P_1) = 8.068$ час руху зернівки по поличці

Fig. 7. Screen fragment numerical study on extreme environments in the mathematical Mathcad.

CONCLUSIONS

1. The mathematical apparatus allows to determine parameters pitched shelves depending on the parameters of the grain size of the material and the drum to ensure the minimum speed of the grain of the material on it.

2. Optimization studies numerical methods Analytical dependences allows to prove the options pitched shelves in a drying drum for the specific conditions of the process.

REFERENCES

1. **Kalinichenko R. A., 2017.** Mathematical model of drying of vegetative raw material into a rotary drum for a combined supply of energy. Scientific Bulletin of Nulesu. Series: electronics and energetics, agriculture. Vol. 261. 217-225.

2. **Kalinichenko R. A., 2017.** Energy efficient operation modes of machinery for high-intensity heat treatment of grain materials. Nizhyn. Publishing center NDU Gogol. 261.

3. **Koryagin A. A. 1988.** A drying apparatus. Directory. Fifth edition, revised and enlarged. Publishing house "ANTIIMPERIAL". Moscow. 74.

4. **Malta V. M. 1979.** Sushilnye install for agricultural purposes. Moscow. Engineering. 525.

5. **Pershin V. F. 2009.** Processing of granular materials in drum-type machines. Moscow. Engineering. 220.

6. **Antipov S. T. 2001.** Heat and mass transfer during drying in the apparatus with a rotating drum. Voronezh. 308.

7. **Nesvitski I. V. 2010.** Justification of parameters of drying drums with thermogradient energoprodukt drying agent in drying chicory roots. Materials of V international scientific-practical conference "Modern problems of sustainable natural resource management" PDATA. Kamenetz-Podolsk. 170-172.

8. **Kalinichenko R. A., 2017.** Mathematical modelling of the displacement of grains during heat treatment. Innovations in selskom economy. No. 4 (29). 50-58.

9. **Abdul M. M. 2007.** Justification of parameters of the separator with inclined air channel for separation of grain mixtures. Autorepair. dis. Cand. tech. Sciences. Kharkiv, HANTUSH them. P. Vasilenko. 20.

10. **Kotov B. I., Kalinichenko R. A., Stepanenko S. P., Swida V. A., Lisiecki V. A. 2017.** Modeling of technological processes in the model objects post-harvest processing and grain storage (separation, drying, aeration, cooling)]. Nizhyn. Publisher PE Lysenko. M. 552.

11. **Stepanenko S. P., Kotov B. I., Spirin A. V. 2017.** To the question of the mathematical description of the movement of the threshed seeds in the annular channel of variable cross section. Mechanization of agricultural production. Bulletin INTOSH behalf Peter Vasilenko. Kharkov. Vol. 180. 330-339.

12. **Stepanenko S. P., Kotov B. I., Swida V. A., Koval Y. G. 2009.** The theory of separation of grain in the air stream. Design, production and operation of agricultural machinery. Vol. 39. Kirovograd. KNTU. 54-62.

13. **Adamchuk V. V. 2014.** The concept of the prospects of a comprehensive solution to the problem of post-harvest handling and storage of grain in the agricultural enterprises of Ukraine. Mechanization and

electrification of agriculture. Glevaha. Vol. 99. Vol. 1. 40-56.

14. **Voronkov O. A., Rogovskii I. L. 2017.** Alignment of adjacent transport and technological operations of transportation of grain and crop products. Bulletin of East Ukrainian National University named after Volodymyr Dahl. No. 3. 36-43.

15. **Voronkov O. A., Rogovskii I. L. 2017.** General principles of creation of control systems of transport streams transport grain bread. Scientific Herald of National University of Life and Environmental Science of Ukraine. Series: Technique and energy of APK. Kiev. Vol. 258. 390-399.

16. **Voronkov O. A., Rogovskii I. L. 2017.** Options of structural solutions of the system of management of transport flows transport grain bread. Scientific Herald of National University of Life and Environmental Science of Ukraine. Series: Technique and energy of APK. Kiev. Vol. 262. 361-367.

17. **Shevchuk R. S., Krupych R. 2015.** Manual vibro-impact fruit shaker/ MOTROL Commission of motorization and energetics in agriculture. – Lublin-Rzeszow, Vol. 17, №4., 153-159.

18. **Sydorchuk O., Triguba A., Makarchuk O. 2012.** Optimization of the life cycle of integrated programs for harvesting grain crops. MOTROL Commission of motorization and energetics in agriculture. Lublin, Vol. 14, №4. 131-140.

19. **Sydorchuk O., Ivasjuk I., Syatkovskyy A. 2012.** Influence subject to conditions terms of tillage, planting summer-autumn period. MOTROL Commission of motorization and energetics in agriculture. – Lublin, – Vol.14, №4. 16-20.

20. **Sydorchuk A., Ivasiuk I., Ukraynecz V. 2013.** Harmonization of the components of the technological system of soil cultivation and sowing of winter crops. MOTROL. Commission of motorization and energetics in agriculture. Lublin-Rzeszow, Vol. 15, №4. 180-186.

21. **Rogovskii Ivan. 2016.** Graph-modeling when the response and recovery of agricultural machinery. Motrol : Motorization and power industry in agriculture. Lublin. T. 18. №3. 155-164.

22. **Rogovskii I. L. 2016.** Analysis of model of recovery of agricultural machines and interpretation of results of numerical experiment. Scientific Herald of National University of Life and Environmental Science of Ukraine. Series: Technique and energy of APK. Kyiv. No 254. 424-431.

23. **Rogovskii I. L. 2017.** Probability of preventing loss of efficiency of agricultural machinery during exploitation. Scientific Herald of National University of Life and Environmental Science of Ukraine. Series: Technique and energy of APK. Kyiv. No 258. 399-407.

24. **Rogovskii I. L. 2017.** Conceptual framework of management system of failures of agricultural machinery. Scientific Herald of National University of Life and Environmental Science of Ukraine. Series: Technique and energy of APK. Kyiv. No 262. 403-411.

25. **Rogovskii Ivan. 2017.** Choice of model class and method of modeling the resilience of agricultural machinery. TEKA. An International Quarterly Journal on Motorization, Vehicle Operation, Energy Efficiency and Mechanical Engineering. Lublin–Rzeszów. Vol. 17. No 3. 101-114.

26. **Kalinichenko Dmytro, Rogovskii Ivan. 2018.** Method for Determining Time of next Maintenance of Combine Harvesters. TEKA. An International Quarterly Journal on Motorization, Vehicle Operation, Energy Efficiency and Mechanical Engineering. Lublin–Rzeszów. Vol. 18. No 1. 105-115.

ИССЛЕДОВАНИЕ ДВИЖЕНИЯ ЗЕРНОВКИ В БАРАБАННОЙ СУШИЛКЕ С ИК-ЭНЕРГОПОДВОДОМ ПО СКАТНОЙ ЛИНЕЙЧАТОЙ МИНИМАЛЬНОЙ ПОВЕРХНОСТИ

Аннотация. Хранение в сухом состоянии - наиболее распространенный способ консервирования растительных материалов. Энергозатраты на сушку зерновых, семенных и кормовых материалов могут составлять до 50% от суммарных затрат на производство готового продукта. Универсальные сушилки барабанного типа широко используются в хозяйствах, поскольку, позволяют проводить обезвоживания различных сыпучих влажных материалов. Но по ряду показателей работы (удельные затраты энергии, уровень автоматизации, выполнения экологических требований, и другие) эти сушилки не полностью отвечают современным требованиям производства сельскохозяйственной и перерабатывающей отраслей. Решение задач оптимизации, по производительности и энергозатратах барабанных агрегатов, возможно только при наличии адекватных математических моделей процессов. Поэтому целью исследований было разработка математического аппарата для обоснования геометрических параметров скатной полочки в сушильном барабане для обеспечения гарантированного гравитационного движения по ней зернового материала с минимальной скоростью для максимальной экспозиции радиационного облучения зерновки. Полученные уравнения можно использовать для анализа процесса перемещения зерновки в сушильном барабане и оптимизации режимных параметров термообработки при известных значениях конструктивных параметров сушилки.

Ключевые слова: сушильный барабан, минимальная поверхность, движение зерновки, коэффициент трения.

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Analysis of Multi-Channel System of Mass Service with Installed and Uninstalled Operating Modes

Oleksandr Nadtochiy, Lyudmila Titova

National University of Life and Environmental Sciences of Ukraine.
E-mail: o.nad@ukr.net

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Summary. The article defines the total aggregate losses for the maintenance of groups of combines with a threshing capacity of more than 9 kg / s and various seasonal loads. It is established that the minimum cost is about 800 ha per harvester per season. The optimal number of maintenance links for small (150 ha) and large (> 900 ha) developments for a combine harvester is more than doubled compared to all the ZK in groups.

Analysis and comparison of SMO characteristics for stable and unstable operating modes has shown that the mutual transition for the ZK group lasts from 4 hours (20 combines) and up to 8 hours (1-5 combines). Taking into account the SMO model and the proposed method will allow obtaining more accurate characteristics of the QMS: waiting time in the queue, queue length and the like. The value of the total total losses at 1 hour of operation differs by a factor of almost 5 in comparison with the steady-state regime.

Key words: optimization, mass maintenance system, grain harvester, periodicity of maintenance.

INTRODUCTION

It is known that annual losses from late harvesting grain farms Ukraine for an estimated amount to more than 10% of the harvest [2]. This is despite the current yield is about 7 mil tons. Reducing losses of grain depends on a high level of logistics and proper organization of customer service. It should also be borne in mind that the low solvency of agricultural enterprises and small investments prevented timely upgrading of logistics. This led to an aging fleet.Significantly increased cost of funds for maintenance and repair of harvesting, especially in small farms, including farms. Agooptimization of the Technical service combine harvesters with different load and their annual harvest number in the squad is today one of the urgent tasks.

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

For the analysis used data obtained by collecting, cultivation of mathematical statistics and mathematical modeling [1, 2].

Ukrainian farmers today have little or no repair and servicing base. Thus, according to UAAN equipped repair-technological equipment of peasant (farm) is only 15...25%. Farms sometimes exceed the relevant standards for large farms on average 3.2 times. However, despite this, they performed no more than 30% of the field of mechanized operations in optimal agronomic terms. This is the harvest work. The reason is very poor repair and servicing facilities. And the result is not long to wait makes. Timing of harvest stretching a month and seasonal operating time ranges from 150 to 1,000 hectares harvester [7].

OBJECTIVE

The aim of the study - specification model optimization of technical service of combine harvesters based on queuing theory for mode and depending on seasonal workload harvester.

THE MAIN RESULTS OF THE RESEARCH

The most effective and failure recovery HCC during harvesting can be described queuing theory [1]. The process occurring in the system can have the form (Figure 1). Random character stream applications leads to what happens in the QS some random process. If Markov random process, the operation of the QS system can be described by differential equations, and in the extreme case - a system of linear algebraic equations solution are determined by the characteristics of the QS. The article [1] and the authors considered it marginal state of the system when the flow of orders is set and unchanging. However, this phenomenon is rather "artificial" to simplify the mathematical model calculations. In real terms harvest work units inherent unsustainable modes of queuing system (QS) [8]. That such regimes that depend on time. This will SMO probabilistic characteristics that depend on time, for example, for some of its range. Then the intensity of the input and output streams for each state will be balanced, but taking into account the probability of derivatives. It is such a system and invited to consider in this article.

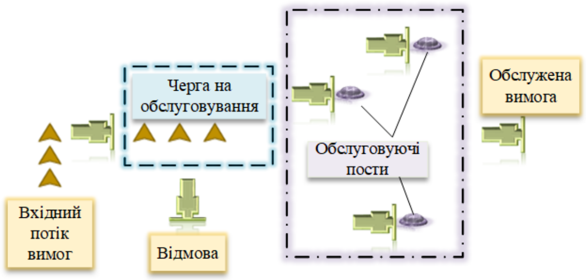

Fig. 1. Queuing system (QS).

In queuing systems flow requirements accidental. Random and maintenance. Work QS runs irregularly, it formed a queue for service, there is downtime service stations. The task queuing theory - an optimal set (with a minimum of downtime) the nature of the relationship between flow requirements, the number of posts and their performance (service time), the rules of the system maintenance.

Most often as a criterion - performance of queuing systems - using the average waiting time requirements early service, the average size of the queue for service, the likelihood that the system will be a certain amount of service requirements, the average number of posts occupied or free services, and others. However, the most appropriate to use economic indicators for assessing the efficiency of queuing systems that provide a generalized description of the manufacturing process. In this case, the performance criteria selected by the QS total cash costs associated with downtime waiting combines service and costs of establishing and operating positions (service units) [4, 6].

In order to identify the most efficient system maintenance calculations of the total cost of maintenance of combine harvesters. Thus considered various options for usage in households combine harvestersKyiv and Cherkasy regionsAnd at a certain (optimal) variations in the number of service channels system.

For example, use the previous data [1] of bringing some data (Table 1).

According to the table. 1 calculated flux density and intensity requirements λ μ service for households with different loads One year HCC and combines different number in the household. We decided that the percentage of failures (1 and 2 groups of difficulty), eliminated by visiting the units, about 70% [3, 4]. The very same multichannel queuing system selected. In the multichannel queuing system must distinguish between two cases:

- including requirements n, received in less number of service channels N, ie they are in serving 0 <n <N,
- including requirements n, which came in greater than or equal to the number of service channels N, N requirements that are served and the rest waiting in line (k = 1,2, ... m - N).

To begin, consider the QS simplified with steady state of the system when the main probabilistic characteristics of its constant in time, for example, for an hour. Then the intensity of the input and output streams for each state are balanced. These balances are as follows:

In the case of

Table 1. Flux density requirements λ and intensity of maintenance for years of operation and annual operating time.

Years acc. combo.	Kiel-bone, units.	Annual operating time, ha (intervals and their middle)						μ 1 / h.
		150-180	470-500	630-660	780-810	840-870	1000-1030	
		165	485	645	795	855	1015	
		λ 1 / h.						
5 years	3	0.236	.193	.196	.189	.193	.170	.4256
	5	.393	.323	.327	0,315	.323	.283	
	10	.787	.646	.654	.630	.646	.567	
	15	1,181	.969	0.982	.945	.969	.850	
	20	1,575	1,292	1.309	1,260	1,292	1,134	

$$0 \le n < N: \; P_0 m\lambda = P_1\mu,$$
$$P_1(\mu + (m-1)\lambda) = P_0 m\lambda + P_2 2\mu,$$
$$P_2(2\mu + (m-2)\lambda) = P_1(m-1)\lambda + P_3 3\mu$$
$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (1)$$
$$P_n(n\mu + (m-n)\lambda) = P_{n-1}(m-(n-1))\lambda + P_{n+1}(n+1)\mu$$

In the case of $N \le n \le m$:

$$P_n(N\mu + (m-n)\lambda) = P_{n-1}(m-(n-1))\lambda + P_{n+1}N\mu$$
$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$
$$P_{m-1}\lambda = P_m N\mu$$

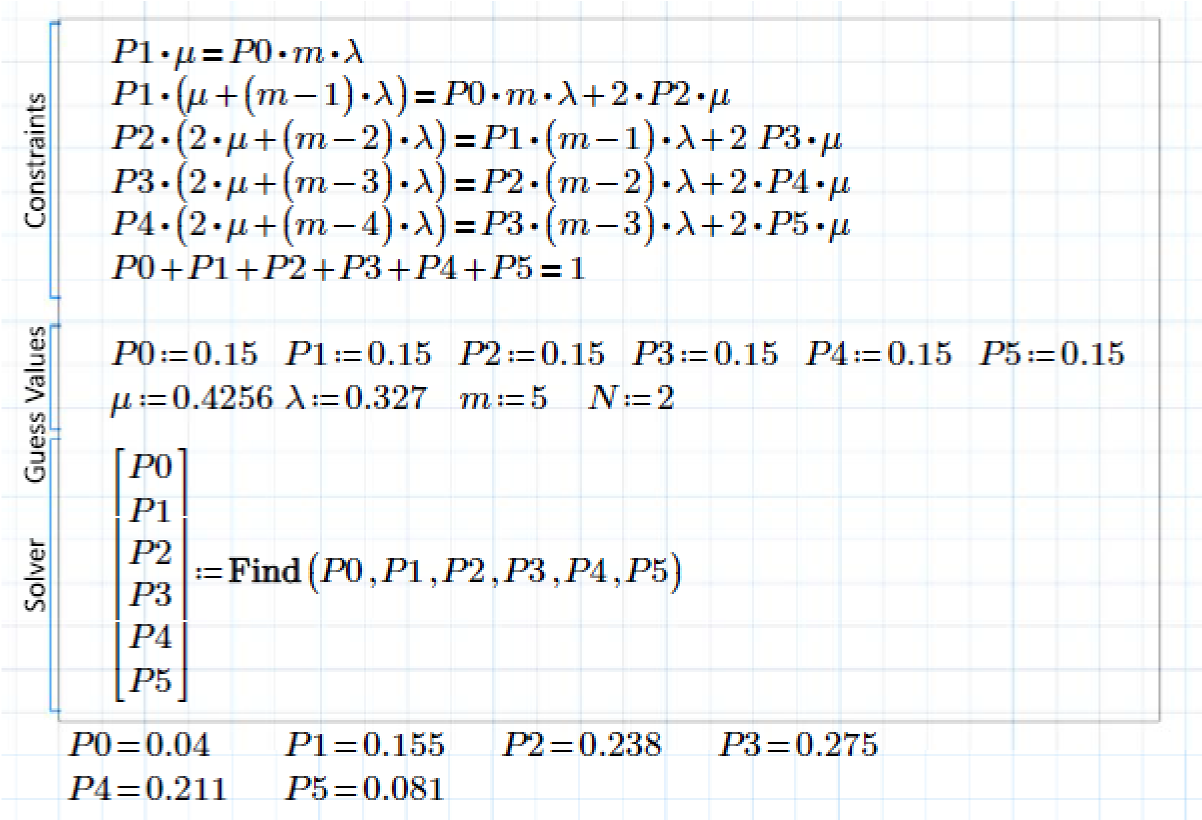

Fig. 2. QS to calculate steady state (PTC Mathcad Prime 4.0).

Suppose that our system has two channels of service N = 2. Intensity of receipt of a claim for maintenance $\lambda = 0.327$ times an hour. The intensity of service requirements $\mu = 0.4256$. Number of serviced vehicles is 5 m (Table 1., Selection). It is necessary to determine the probability of a different number of requirements on the system.

To make use of these probabilities System PTC Mathcad Prime 4.0 (Figure 2).

To solve the problem we use the block function Find. When using it is necessary to set the desired initial approximation values:

$$P0 := 0.15,$$

$$P1 := 0.15,$$

$$P2 := 0.15,$$

$$P3 := 0.15,$$

$$P4 := 0.15,$$

$$P5 := 0.15.$$

Apparently probability values are constant and unchanging appearance from the time around which we analyze the system.

That is, at the beginning of the 1st hours and 4 time change this value constant. In fact in the life course as processes do not occur.

Failures HCC are completely arbitrary and depend on time.

So first approximation to assume that the system is in a steady state may, however interesting (realistic) is an approach that will make it possible to calculate the probability characteristics given time. That flimsy mode LC group.

Consider just a flimsy QS mode when its main probabilistic characteristics depend on time, for example, for some of its range.

Then the intensity of the input and output streams for each state will be balanced, but taking into account the probability of derivatives.

So we have a system of ordinary differential equations describing the operation of multi-channel closed-loop system at unsustainable mode:

The preparation of the above system of equations describing the operation of the QS Puassonovskym flow, there mnemonic rule:

• derivative $\frac{dP(t)}{dt}$ the probability of system stay in state n is the algebraic sum of several members,

• the number of members of this amount equals the number of arrows on a graph of the system, connecting with other state n,

• if the arrow is directed in the analyzed state → n, then the member is taken with the sign "plus",

• if the arrow directed ← the state of n, then a member of the set with the sign "minus",

• each member of the amount equal to the product of the probability state, which aimed an arrow at the intensity of the flow of events that puts the system on this arrow. According to the graph labeled conditions [(Fig. 1)], the system of ordinary differential equations would be:

In the case of $0 \le n < N$:

$$\begin{cases} \dfrac{dP_0(t)}{dt} = P_1(t)\mu - P_0(t)m\lambda \\ \dfrac{dP_1(t)}{dt} = P_0(t)m\lambda + P_2(t)2\mu - P_1(t)(\mu + (m-1)\lambda) \\ \dfrac{dP_2(t)}{dt} = P_1(t)(m-1)\lambda + P_3(t)3\mu - P_2(t)(2\mu + (m-2)\lambda) \\ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \\ \dfrac{dP_n(t)}{dt} = P_{n-1}(t)(m-(n-1))\lambda + P_{n+1}(t)(n+1)\mu - P_n(t)(n\mu + (m-n)\lambda) \end{cases} \tag{2}$$

In the case of $N \le n \le m$:

$$\begin{cases} \dfrac{dP_n(t)}{dt} = P_{n-1}(t)(m-(n-1))\lambda + P_{n+1}(t)N\mu - P_n(t)(N\mu + (m-n)\lambda) \\ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \\ \dfrac{dP_m(t)}{dt} = P_{m-1}\lambda - P_m N\mu \end{cases} \tag{3}$$

Constraints

$$\frac{d}{dt}P_0(t) = -P_0(t)\cdot 5\cdot\lambda + P_1(t)\cdot\mu$$
$$\frac{d}{dt}P_1(t) = P_0(t)\cdot 5\cdot\lambda + P_2(t)\cdot 2\cdot\mu - P_1(t)\cdot(\mu + 4\cdot\lambda)$$
$$\frac{d}{dt}P_2(t) = P_1(t)\cdot 4\cdot\lambda + P_3(t)\cdot 2\cdot\mu - P_2(t)\cdot(2\cdot\mu + 3\cdot\lambda)$$
$$\frac{d}{dt}P_3(t) = P_2(t)\cdot 3\cdot\lambda + P_4(t)\cdot 2\cdot\mu - P_3(t)\cdot(2\cdot\mu + 2\cdot\lambda)$$
$$\frac{d}{dt}P_4(t) = P_3(t)\cdot 2\cdot\lambda + P_5(t)\cdot 2\cdot\mu - P_4(t)\cdot(2\cdot\mu + 1\cdot\lambda)$$
$$\frac{d}{dt}P_5(t) = P_4(t)\cdot 1\cdot\lambda - P_5(t)\cdot 2\cdot\mu$$

$\mu := 0.4256$ $\lambda := 0.327$ $m := 5$ $N := 2$

$$D(t,P) := \begin{bmatrix} -P_0\cdot 5\cdot\lambda + P_1\cdot\mu \\ P_0\cdot 5\cdot\lambda + P_2\cdot 2\cdot\mu - P_1\cdot(\mu + 4\cdot\lambda) \\ P_1\cdot 4\cdot\lambda + P_3\cdot 2\cdot\mu - P_2\cdot(2\cdot\mu + 3\cdot\lambda) \\ P_2\cdot 3\cdot\lambda + P_4\cdot 2\cdot\mu - P_3\cdot(2\cdot\mu + 2\cdot\lambda) \\ P_3\cdot 2\cdot\lambda + P_5\cdot 2\cdot\mu - P_4\cdot(2\cdot\mu + 1\cdot\lambda) \\ P_4\cdot 1\cdot\lambda - P_5\cdot 2\cdot\mu \end{bmatrix} \qquad P := \begin{bmatrix} 1 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

$t0 := 0$ $t1 := 8$ $N := 1000$

$S := \mathrm{rkfixed}(P, t0, t1, N, D)$

$t := S^{\langle 0\rangle}$ $P0 := S^{\langle 1\rangle}$ $P1 := S^{\langle 2\rangle}$ $P2 := S^{\langle 3\rangle}$ $P3 := S^{\langle 4\rangle}$ $P4 := S^{\langle 5\rangle}$ $P5 := S^{\langle 6\rangle}$

Fig. 3. QS with unsteady calculation mode.

The system (1 and 2) describes the process of multi-functioning closed queuing system at unsustainable mode.

To resolve make use of the initial data of the previous solution, $\lambda = 0.327$, $\mu = 0.4256$.

To use the built-in solution rkfixed (P, to, tl, N, D), which implements the Runge-Kutta method with fixed step.

To begin to form a feature vector deviation values, which is essentially a system right parts corresponding differential equations $D(t, P)$ and the vector of initial values P.

Next, define additional options for solving a system of differential equations: initial and final time interval study the system and the number of steps of iteration.

During the initial condition (Figure 3) were taken intervals from 0 to 8 hours.

This is done intentionally to try to see how long the system will start to move in the incoming data values in a steady state during the change.

The result of the calculation system of equations presented in Figure 4.

As can be seen from Figure 4, during the change of the system and does not enter steady state.

This proves that better estimates for spending at unsustainable QS mode.

By comparing the value P0 first tasks equal to 0.04 on any period of time and for the second value P0 (Figure 4, blue curve), it is clear that here lies the common mistake.

If further calculations using a single (average) value P0, the probability of correct decision will be somewhat questionable.

Further modeling and graphical analysis of dependencies showed that at time t1 increased to 20 hours for the system to undertake the same condition as at 9 o'clock. It can be argued that the transition to a sustainable state when data $\lambda = 0.327$, $\mu = 0.4256$ occurs after 8 hours and further changes. The value is equal probabilities are given the task queuing system at steady state (Figure 2):

$P0 = 0.04,$

$P1 = 0.155,$

$P2 = 0.238,$

$P3 = 0.275,$

$P4 = 0.211,$

$P5 = 0.081.$

All other features of the QS can define the following dependencies (Table 2).

To further compare the two modes of QS sustainable and unsustainable dependencies and subsequent calculation table. 2 identified the following data (Table 3).

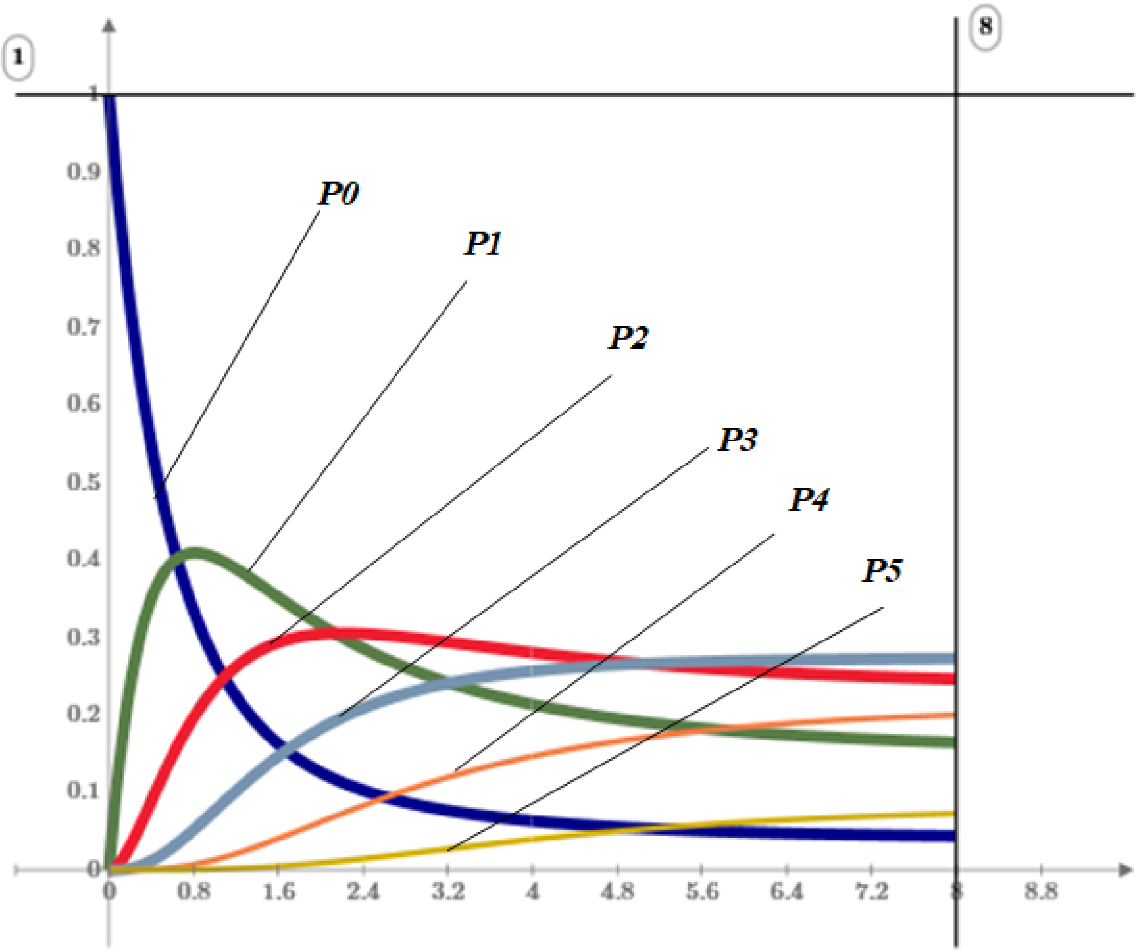

Fig. 4. Graphic system of differential equations for QS with transient mode.

Table 2. Characteristics of CMOs and major dependence.

The average length of the queue	$L_1 = \sum_{k=n}^{m} (k-n) P^k$
The average number of claims that are served	$L_2 = \sum_{k=1}^{m} k P_k$
The average number of free service channels	$L_3 = \sum_{k=0}^{n-1} (n-k) P_k$
The utilization of orders	$K_2 = 1 - \frac{L_2}{m}$
Waiting time	$MQ = \frac{1-K_2}{\lambda K_2} - \frac{1}{\mu}$
Upper secondary losses from downtime requirements in line and do not load feed	$\varphi(n) = C_1 \cdot L_1 + C_2 \cdot L_3$

Table 3. The characteristics of QS sustainable and unsustainable modes.

Time t1, h	Probabilities for the unsteady regime QS						L_1	L_3	MQ	$\varphi(n)$
	P0	P1	P2	P3	P4	P5				
0.5	.481	.379	.119	0.02	0,002	0.00006	0,024	.379	-1.864	854.7
1	.271	.403	0,235	0,075	0,013	0.00095	.104	.403	-1.431	1221.4
1.5	.175	.361	.288	0,136	0,035	0.00388	0.218	.361	-1.034	1592.6
2	0,126	.316	.304	0,182	0,062	0.00913	0.333	.316	-0.683	1965.6
3	.082	.251	.297	0,235	.111	0,024	0.7	.251	.471	3302
8	0,044	.165	.246	.273	0.2	.0726	0.94	0.155	1.255	4070

Table 1 is the largest interval. We were taken to analyze the range [0 ... 0.5], [0.5 ... 1], [1 ... 1.5], [1,5 ... 2], [2 ... 3] and [4 ... 8]. All other parameters (P0, P5 ...) and others designed specifically for this value t1. It should draw attention to the importance MQ. That only after 2.5 hours.

Combine squad is positive. Physical value of this variable is the time waiting in line.

That is nearly three o'clock likelihood of queues absent. Only after 2.5 hours is the probability of the queue.

If you use SMO at steady state the probability of downtime in the queue will just equal to 1.255 hours.

As a result of the cultivation of mathematical initial data plotted total cost of service groups combines seasonal operating time and the number of service units N (Fig. 5).

From Fig. 5 follows the following to complete the minimum total losses for all service groups harvester thresher with a capacity of more than 9 kg / s responsible operating time of 800 hectares on a combine for the season.

The optimal number of units is the maintenance of small and large operating time for HCC is increasing more than twice compared to all groups of HCC quantities.

Production capacity of the maintenance of the existing farms in low maintenance units at low average annual load on a combine harvester. In this regard, useful in small farms (5 HCC) have compact multifunction units maintenance.

Transient mode characteristic group of HCC lasts 4 hours (20 combines) and up to 8 hours (1-5 harvesting).

Considering the QS model and the proposed method will allow for a more precise characteristics QS: waiting time, queue length, and so on.

The value of total comprehensive loss for 1 hours compared to the steady differ in size by almost 5 times.

CONCLUSIONS

1. Complete total loss of cash from simple in line and HCC service channels depend on the annual operating time machines. These developments at an annual minimum of 600-700 hectares.
2. Number of units in the maintenance sector defined annual load at dean number and combine harvesters link harvesting and transport sector.
3. In small farms advisable to have a compact multifunction units maintenance.
4. Using a calculation model QS with unsustainable mode of operation on any time interval changes will make it possible to more accurately plan the costs of technical services combine forces.

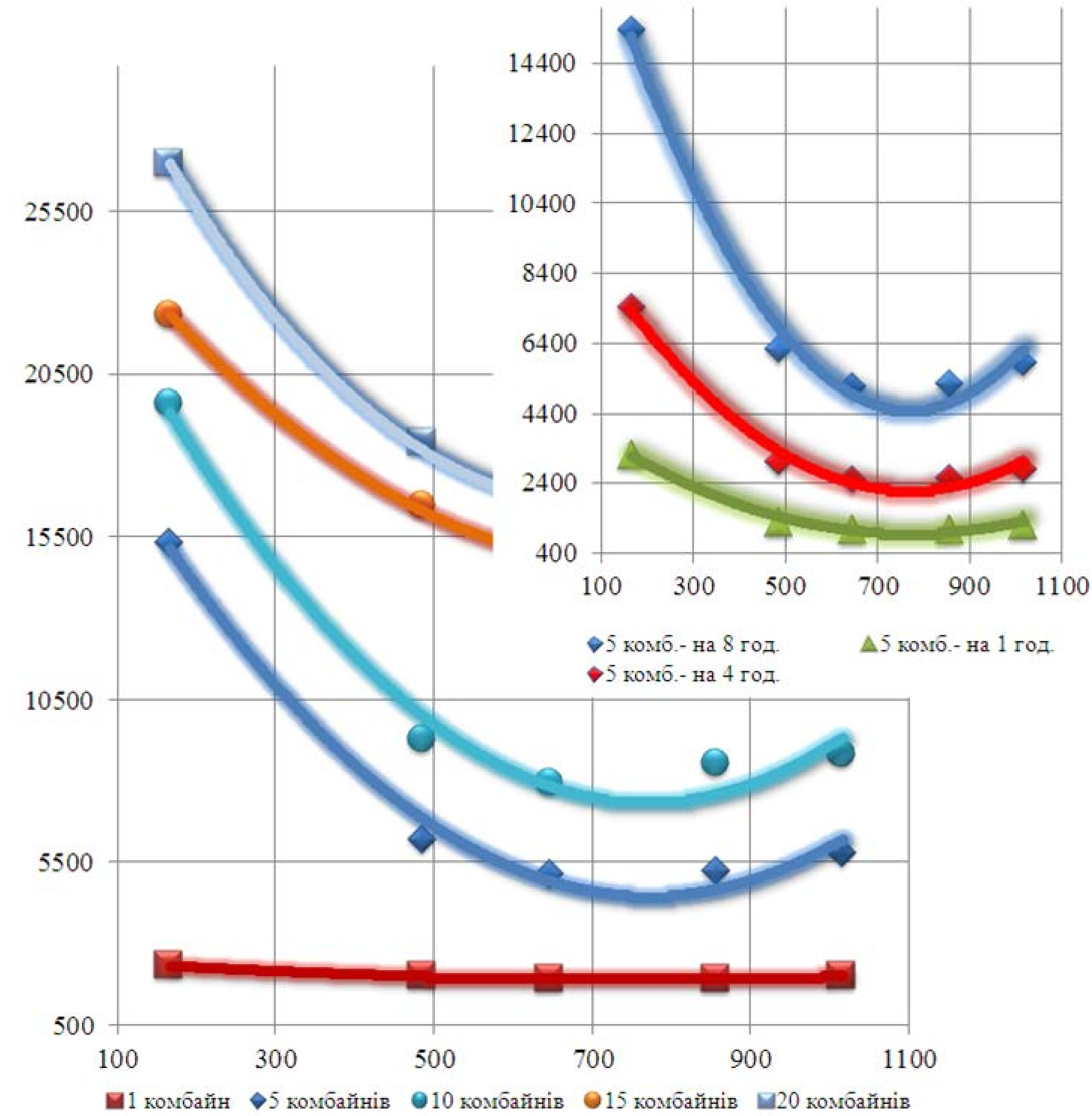

Fig. 5. Dependence of total comprehensive loss $\varphi(n)$ to service combines groups of their annual operating time and the loss of a group of 5 to unsustainable harvesting mode (1st, 4th and 8th -ma hours).

REFERENCES

1. **Nadtochii O., Titova L., Rogovskii I. 2016.** Analysis of the dynamics of the combine market of Ukraine. Techno-technological aspects of development and testing of new technology and technologies for agriculture in Ukraine. Vol 20. 254-262.

2. **Voronkov O. A., Rogovskii I. L. 2016.** Analysis of the role of road transport in the transport-technological support of agriculture. A collection of abstracts of II-nd International scientific-practical conference "Modern technologies of agricultural production" (9-10 November 2016). Kiev. 215-216.

3. **Voronkov O. A., Rogovskii I. L. 2017.** Adaptation of vehicle use in technology of harvesting grain crops. Abstracts of the International scientific-practical conference "Modern technologies of grain production 2017" within the framework of VI International exhibition of innovative solutions in grain farming "Grain technologies 2017" (February 16, 2017). Kiev. 2017. 28-29.

4. **Voronkov O. A., Rogovskii I. L. 2017.** Classification features of vehicles in transport-technological processes in agricultural production. Abstracts of the II all-Ukrainian scientific-theoretical conference "the Problems with traffic flows and the ways of their solution" national University "Lviv Polytechnic (16-18 March 2017). Lions. 17-19.

5. **Voronkov O. A., Rogovskii I. L. 2017.** Analysis of current state of problem of optimization of transport and technological support AIC. The book of abstracts XI International scientific-practical conference "Obukhov" read (March 21, 2017). Kiev. 92-93.

6. **Voronkov O. A., Rogovskii I. L. 2017.** In-line transport technology of transportation of grain bread. Problems of development of transport and logistics. Collection of scientific works on materials of VII-th International scientific-practical conference, Severodonetsk, Odesa, April 26-28 2017 –

Severodonetsk, Ukraine: publishing house VNU named after Volodymyr Dahl. 15-17.

7. **Voronkov O. A., Rogovskii I. L. 2017.** Methodology of experimental research of the traction characteristics of vehicles. The book of abstracts of the XVII international conference of scientific and pedagogical workers, scientific employees and graduate students "Problems and prospects of development of technical and bio-energy systems of environmental management" (20-24 March 2017). Kiev. 122-123.

8. **Voronkov O. A., Rogovskii I. L. 2017.** Analytical prerequisites to transport and technological systems of transportation of production of crop production. Theses of International Scientific Conference "Globalization of scientific and educational space. innovations of transport. problems, experience, prospects" (3-12 May 2017) / Dresden (Germany) Paris (France). 47-50.

9. **Voronkov O. A., Rogovskii I. L. 2017.** Ways to reduce energy consumption in transportation and technological support for weight of transported grain crops. A collection of abstracts of the XIII International scientific conference "the Rational use of energy in technology. TechEnergy 2017" (17-19 may 2017). Kiev. 72-74.

10. **Voronkov O. A., Rogovskii I. L. 2017.** Analytical model for energy estimation of transport technological process of transportation of grain and crop products. Journal of mechanical engineering and transport. Vinnitsa: VNTU. Vol. 1. 21-28.

11. **Voronkov O. A., Rogovskii I. L. 2017.** Approach to solving the problem of management of transport system for transporting of the grain harvest. The book of abstracts of V-th international scientific conference "Innovative maintenance of organic production in agriculture" in the framework of the XXI International agricultural exhibition "AGRO 2017" (05-06 June 2017). Kiev. 44-46.

12. **Voronkov O. A., Rogovskii I. L. 2017.** Automation operators for the monitoring of vehicles for the carriage of grain bread Automatic – 2017: international conference on automatic control, Kiev, Ukraine, 13-15 September 2017: proceedings of the conference. Kiev. 181-182.

13. **Voronkov O. A., Rogovskii I. L. 2017.** Alignment of adjacent transport and technological operations of transportation of grain and crop products. Bulletin of East Ukrainian national University named after Volodymyr Dahl. No. 3. 36-43.

14. **Voronkov O. A., Rogovskii I. L. 2017.** General principles of creation of control systems of transport streams transport grain bread. Scientific Herald of National University of Life and Environmental Science of Ukraine. Series: Technique and energy of APK. Kiev. Vol. 258. 390-399.

15. **Voronkov O. A., Rogovskii I. L. 2017.** Options of structural solutions of the system of management of transport flows transport grain bread. Scientific Herald of National University of Life and Environmental Science of Ukraine. Series: Technique and energy of APK. Kiev. Vol. 262. 361-367.

16. **Shevchuk R. S., Krupych R. 2015.** Manual vibro-impact fruit shaker/ MOTROL Commission of motorization and energetics in agriculture. – Lublin-Rzeszow, Vol. 17, №4., 153-159.

17. **Sydorchuk O., Triguba A., Makarchuk O. 2012.** Optimization of the life cycle of integrated programs for harvesting grain crops. MOTROL Commission of motorization and energetics in agriculture. Lublin, Vol. 14, №4. 131-140.

18. **Sydorchuk O., Ivasjuk I., Syatkovskyy A. 2012.** Influence subject to conditions terms of tillage, planting summer-autumn period. MOTROL Commission of motorization and energetics in agriculture. – Lublin, – Vol.14, №4. 16-20.

19. **Sydorchuk A., Ivasiuk I., Ukraynecz V. 2013.** Harmonization of the components of the technological system of soil cultivation and sowing of winter crops. MOTROL Commission of motorization and energetics in agriculture. Lublin-Rzeszow, Vol. 15, №4. 180-186.

20. **Rogovskii Ivan. 2016.** Graph-modeling when the response and recovery of agricultural machinery. Motrol : Motorization and power industry in agriculture. Lublin. T. 18. №3. 155-164.

21. **Rogovskii I. L. 2017.** Probability of preventing loss of efficiency of agricultural machinery during exploitation. Scientific Herald of National University of Life and Environmental Science of Ukraine. Series: Technique and energy of APK. Kyiv. No 258. 399-407.

22. **Rogovskii I. L. 2017.** Conceptual framework of management system of failures of agricultural machinery. Scientific Herald of National University of Life and Environmental Science of Ukraine. Series: Technique and energy of APK. Kyiv. No 262. 403-411.

АНАЛИЗ МНОГОКАНАЛЬНОЙ СИСТЕМЫ МАССОВОГО ОБСЛУЖИВАНИЯ ПРИ ПОСТОЯННОМ И НЕ ПОСТОЯННОМ РЕЖИМАХ РАБОТЫ

Аннотация. В статье определены полные суммарные потери на обслуживание групп комбайнов с пропускной способностью молотилки более 9 кг/с и различным сезонным нагрузкам. Установлено, что минимум затрат приходится на наработка около 800 га на один комбайн за сезон. Оптимальное же количество звеньев технического обслуживания для малых (150 га) и больших (>900 га) наработок на зерноуборочный комбайн возрастает более чем в два раза, по сравнению для всех количеств ЗК в группах.

Анализ и сравнение характеристик СМО для устойчивого и неустойчивого режимов работы показал, что взаимный переход для группы ЗК длится от 4 часов (20 комбайнов) и до 8 часов (1-5 комбайнов). Учета модели СМО и предложенного метода позволит получить точнее характеристики СМО: время ожидания в очереди, длина очереди, и тому подобное. Величина полных суммарных потерь на 1 часу работы в сравнении с постоянным режимом отличается по величине почти в 5 раз.

Ключевые слова: оптимизация, система массового обслуживания, зерноуборочный комбайн, периодичность ТО.

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Determination of Influence of Modes of Storage Products in its Condition

Volodymyr Moozychenko
National Scientific Centre «Institute for Agricultural Engineering and Electrification» National Academy of Agrarian Sciences of Ukraine.
E-mail: moozychenko.va@gmal.com

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Summary. We analyzed the levels of consumption of fruit and vegetable products and its losses.

It proposed to use information from a storage facility on its condition to determine the effect of storage conditions on the condition.

Analyzed ways of obtaining information from crop production on her condition.

The necessity of providing information on the status of the storage facility, depending on the condition of the storage conditions, as well as the impact on the duration of storage modes in an analytical form.

The necessity for the use of storage efficiency as the optimization and simulation mathematical modeling of the impact of external influences on the stored product.

The analytical description of the production condition depending on the storage conditions allowing to determine one of modes of storage, depending on the planned storage efficiency remaining under fixed conditions.

In the example according to the redox potential of plant raw material with succulent tissues of storage time the technique its exponential approximation.

The dependence of the efficiency of its storage mode, which can serve as an objective function in the optimization of these regimes.

The prerequisites for simulation of the effect of external influences on the storage efficiency and optimize storage by the criterion of minimum loss mode if the controlled variables are the length of storage, and the temperature and humidity in the warehouse.

Mathematical models of processes of storage make it possible to adjust the modes during storage and predict the state of the stored object.

Key words: agricultural production, storage, efficiency, modes, mathematical modeling.

INTRODUCTION

Ensure an adequate level of food consumption remains relevant. His may be improved by reducing the loss during storage, which is more advantageous as compared to the expansion of production. The same applies to animal feed.

Further work on improving the loss reduction require analytical description of the storage process.

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

In 1980 he founded the annual rate of consumption per person in the Soviet Union was considered 146 kg vegetables and 120 kg fruit [1]. In 1989 this, but recommended, is the norm in Ukraine161 kg vegetables [2]. In fact, in the Soviet Union in 1982 the consumption of vegetables was 101, and the fruit 42 kg human [3]. According to [2] in 1985, every resident of Ukraine consumes133 kg vegetables.

At the same time state leaders recognized that the storage is lost at least one third of production. [4] Gross harvest of fruits and vegetables while approaching the standards of consumption, but the actual consumption of the losses was not enough. In 2000, losses of fruits and vegetables and other plant products with rich fabrics in storage was estimated at 30-50% [5].

However, according to [6] in Ukraine produced 6.195 million tons of vegetables and melons, and their losses in 2000 amounted to 177,000 tons, or only 2.857%. In 2016 it produced 9.998 million tons of vegetables and melons, and their losses amounted to 1.195 million tons, or 11.95%.

In such negligible losses sustainment level vegetables and foodstuffs in melons 2016 the declared at the level of 101.6%, and fruits, berries and grapes -84.9%.

With cording to other publications modern volume of consumption of fresh vegetables, potatoes and fruits in Ukraine is 50-60% of the physiological norm. [7]

Potero in storage potatoes, vegetables and fruit make up 20-30% annually. [8]

Investing in storage products is 2-3 times more efficient than in the expansion of its production.

Investigation of product storage process and the development of new ways it requires an analytical description of the state of the product, depending on the storage conditions and storage process modeling.

Asked to assess and optimize the quality of agricultural products depending on the conditions of its cultivation [9-11].

Some growing conditions influence possible. This dose and timing of fertilizer application [12], agricultural practices, and the like. Basically the same growing conditions - it's climate and weather indicators that influence is not possible, but they are most dependent on timing of field work. Of these, the quality of the crops most significantly affected by harvesting time. Therefore, to study the effect on product quality growing conditions appropriate to use simulation techniques.

In contrast to the growing conditions in the storage modes can be influenced to optimize these regimes. This raises the question of the choice of optimization criteria: the minimization of losses (from disease, weight, nutrition), or minimizing the cost of production at the end of the retention period.

In any case, the optimization of the process is necessary to have quality products depending on the storage conditions in the analytical form. However, the results of studying the effect of storage conditions (as, indeed, and growing conditions) in the analytic form are practically absent, e.g., [13-15]

The [16, 17] background laid analytical description of the state of the plant product with succulent tissues, depending on its processing and storage conditions.

Such a description requires information from the storage facility.

For plant products with rich fabrics receive the information requested by measuring the redox potential (ORP) [18-20].

Research change ORP plant products with rich fabrics during storage give reason to use it as an indicator of the quality of products

An exponential dependence on the duration of storage of AFP with a correlation coefficient of 0.997 [21].

Simultaneously experimentally proved matching ORP changes real loss [22].

For plant material, having a lower humidity, an indicator to be determined.

Compliance dynamics ORP plant products with rich fabrics exponential dependence, as well as its compliance with the magnitude of losses [22] provides a basis to use the dynamics of ORP for predicting plant products with rich fabrics.

AFP is not the only indicator of the properties of plant products. Only plant products with succulent tissues resistance measurement can be used [23], the dielectric properties [24] technique [25-27].

Assessment of the status and quality of food products is carried out by drawing the regression equations. The dependences of the potential on growing conditions. Developed corresponding monogram [28-30].

OBJECTIVE

When storing any product it is important to be aware of its ability to store and the deadline within which it will have a sufficient level of consumer qualities, to know which of the batches of products under the identity of all the indicators ability to store longer and what to send to the implementation or processing Firstly. Modern methods of predicting the state of the stored products do not provide the ability to track the dynamics of indicators of the quality of stored products.

The object of research is an analytical description of the effect of storage conditions on its efficiency, enabling the use of mathematical modeling to improve product preservation. Mathematical modeling, in turn, will make it possible to evaluate the effect of storage conditions on the state of the storage facility, as far as possible in a timely manner to change these regimes, or to predict the potential products, and therefore have information about whether to continue storing it.

THE MAIN RESULTS OF THE RESEARCH

Theoretical analysis of the impact of external influences on biological objects may be based on the physical nature of the processes occurring in the object and the parameters of these effects.

An example of such an analysis is given in [31].

Establish a connection of biological indicators of vegetable raw state with the physical storage performance modes are not yet represented analytically possible.

It is therefore proposed to consider the storage process as a black box on which input information on storage conditions, and the output - the indicators characterizing the state of the storage facility.

According to this principle serves to change the ORP example vegetable raw materials with rich fabrics during storage to give an analytical description of the product according to the state of storage modes, and to be able to determine the storage efficiency depending on the factors that affect this efficiency.

At the subsequent discussion we will proceed from the fact that ORP stored object corresponds to the energy of the object.

$$dP = k_1 dQ, \tag{1}$$

where: P - measure the energy state stored object;

k_{one} - proportionality factor;

Q - current value of ORP stored object.

The time variation of the energy state during storage is proportional to the difference between the current value of AFP and its steady value, which is the object after its storage for an indefinite time.

$$dP = k_2 (Q - Q_\infty) dt, \tag{2}$$

where: k2 - coefficient of proportionality;

Q_∞ - steady ORP value of the object,

t - duration of storage.

From (1) and (2) we have:

$$k_1 dQ = k_2 (Q - Q_\infty) dt. \tag{3}$$

designating

$$\frac{k_2}{k_1} = -\tau \tag{4}$$

where: τ - permanent storage duration.

After separation of variables we obtain the differential equation:

$$\frac{dQ}{Q - Q_\infty} = -\frac{dt}{\tau}. \tag{5}$$

After its integration we have:

$$\ln(Q - Q_\infty) = -\frac{t}{\tau} + \ln C. \tag{6}$$

or

$$(Q - Q_\infty) = Ce^{-\frac{t}{\tau}}. \tag{7}$$

Before the start of the storage, namely, when t = 0, the coefficient of the constant of integration is equal to one, since any number to the zero power is equal to unity, the integration constant will correspond to the expression:

$$\tilde{N} = Q_0 - Q_\infty . \qquad (8)$$

where: Q0 - ORP value prior to storage.

In view of the above, we obtain the relationship AFP storage facility on the duration of storage, a constant storage time, as well as on the initial and steady ORP values [32].

$$Q = Q_\infty \left(1 - e^{-\frac{t}{\tau}}\right) + Q_0 e^{-\frac{t}{\tau}} . \qquad (9)$$

Ptinuous duration of storage corresponds to the rate of change of production condition during storage, and thus is a measure of its ability to storage. It is important to note that it is obtained as the ratio of the coefficients of proportionality, which gives the relationship between ORP stored object and its energy state.

Comes the ORP value can provide information about the status of the storage facility at equality of his other indicators. The potential ability to be stored in those products, set a higher ORP.

Storage efficiency is defined as the ratio of the difference between the steady-state current value and ORP of the stored object to a difference between the steady-state and its initial value.

$$Y^t = \frac{Q_\infty - Q}{Q_\infty - Q_0} . \qquad (10)$$

where: Yt - storage efficiency for time changes
ORP from its initial value to
steady.

From (9) and (10) have storage efficiency dependence on its duration and potential production capacity for storage, expressed by a constant storage time:

$$Y^t = e^{-\frac{t}{\tau}} . \qquad (11)$$

For calculation of the duration of storage of products having potential lozhkost, defines a constant storage time, when a predetermined storage efficiency have

$$t = -\tau \ln Y^t . \qquad (12)$$

Equation (9) has two unknowns that must be determined.

Steady function value (in this case the AFP) can be determined from the measured values of its four

$$Q_\infty = \frac{Q_2 Q_3 - Q_1 Q_4}{Q_2 + Q_3 - Q_1 - Q_4} . \qquad (13)$$

or of three values

$$Q_\infty = \frac{Q_2^2 - Q_1 Q_3}{2Q_2 - Q_1 - Q_3} . \qquad (14)$$

When three dimensions get exhibitors who exactly runs through all three of these points. For interpolation is enough. When calculations using four exhibitor measurements accurately pass through only one data point, but more will be fully taken into account the measurement error, the whole process will be described more precisely as required for extrapolation, and one of the goals of this work has predict the state of the stored products.

Steady function value should also be constant for the calculation of the length exponent storage having a certain initial value.

This technique requires that the interval between observations. If, during the experiment, this condition was not met, to determine the desired point, you can use an interpolation method.

The next step will be to determine the difference between the established and the current value of the function

$$\Delta Q = Q_\infty - Q . \qquad (15)$$

The exponential dependence of the difference in duration from the process or from any other argument:

$$\Delta Q = \lambda e^{\mu t} . \qquad (16)$$

where: λ μ- and approximating rates.

Subsequently we define a constant duration of storage, or any other process [33].

$$\tau = -\frac{1}{\mu} \qquad (17)$$

Coefficients and correlation coefficient for the exponential dependence of AFP on the storage duration correspond to the formulas

$$\mu = \frac{\sum_{i=1}^{n} t_i \ln Q - \frac{1}{n}\sum_{i=1}^{n} t_i \sum_{i=1}^{n} \ln Q}{\sum_{i=1}^{n} t_i^2 - \frac{1}{n}\left(\sum_i t_i\right)^2}; \qquad (18)$$

$$\lambda = \exp\left[\frac{1}{n}\left(\sum_{i=1}^{n} \ln Q - \mu \sum_{i=1}^{n} t_i\right)\right]; \qquad (19)$$

$$r^2 = \frac{\left[\sum_{i=1}^{n} t_i \ln Q - \frac{1}{n}\sum_{i=1}^{n} t_i \sum_{i=1}^{n} \ln Q\right]^2}{\left[\sum_{i=1}^{n} t_i^2 - \frac{1}{n}\left(\sum_{i=1}^{n} t_i\right)^2\right]\left[\sum_{i=1}^{n} (\ln Q)^2 - \frac{1}{n}\left(\sum_{i=1}^{n} \ln Q\right)^2\right]} . \qquad (20)$$

Experimental verification of the relationship (9) showed that the observation for 19 days ORP changes apples gave the following results: Q0 = 264,3 mV, Q∞ = 371,4 mV, τ = days. According to these data promoted calculation AFP after 54 days of storage, the result - 346.5 mV. Result respective measuring - 354.0 mV. The difference between the estimated value and the actual ORP was 2.88%, which is quite satisfactory considering three-fold excess of storage time over the measurement duration period [21].

Permanent storage time and is an indirect measure of the ability of products to storage.

The expression (9) takes into account the effect on the storage efficiency only its duration. To investigate the influence of other factors on storage process is necessary to determine the influence of these factors in a fixed storage time. All of them were taken into account is impossible, and for each type of product they are different and well-known, but the shelf life is always crucial.

Typically, products with high moisture content greatest influence temperature and low - humidity environment.

On products is influenced by other factors, such as the gas composition of the medium, aeration regimes and m. P.

In general, the storage efficiency is described by the dependence

$$Y = f\left(x_1, x_2, x_3 ... x_n\right). \quad (21)$$

where: $x_1, x_2, x_3...x_n$ - indicators of factors affecting on storage efficiency.

The dependence of the efficiency of the storage of its duration, defined based on ORP measurements, gives reason to use this method to obtain analytical relations storage efficiency of other factors.

This entails the need for the approximation of the existing table data corresponding dependencies. The next assumption is that it should be an exhibitor, as the dependence of the most relevant processes occurring in biological objects.

Then for storage efficiency depending on the duration, temperature and ambient humidity

$$Y^{t,\theta,W} = f\left(t, \theta, W\right). \quad (22)$$

where: θ - ambient temperature;

W- ambient humidity,

we have

$$Y^{t,\theta,W} = 1 - e^{-\frac{W}{w}} - e^{-\frac{\theta}{\vartheta}} - e^{-\frac{t}{\tau}} + e^{-\frac{W}{w}} e^{-\frac{\theta}{\vartheta}} + \\ + e^{-\frac{W}{w}} e^{-\frac{t}{\tau}} + e^{-\frac{\theta}{\vartheta}} e^{-\frac{t}{\tau}} - e^{-\frac{W}{w}} e^{-\frac{\theta}{\vartheta}} e^{-\frac{t}{\tau}} . \quad (23)$$

where: ϑ - constant temperature change influence environment;

w - constant humidity changes influence environment.

Similar dependencies can be obtained from a larger number of factors influencing the efficiency of storage.

The dependence (23) allows specifying the desired storage efficiency and temperature and humidity in storage to determine the allowable storage time provided that based on the condition of your products from temperature and humidity correspond to the exponent.

$$t = -\tau \ln\left(1 - \frac{Y^{t,\theta,w}}{1 - e^{-\frac{\theta}{\vartheta}} - e^{-\frac{W}{w}} + e^{-\frac{W}{w}} e^{-\frac{\theta}{\vartheta}}}\right). \quad (24)$$

Similarly obtained the valid values of humidity and temperature.

$$\theta = -\vartheta \ln\left(1 - \frac{Y^{t,\theta,w}}{1 - e^{-\frac{W}{w}} - e^{-\frac{t}{\tau}} + e^{-\frac{W}{w}} e^{-\frac{t}{\tau}}}\right). \quad (25)$$

$$W = -w \ln\left(1 - \frac{Y^{t,\theta,w}}{1 - e^{-\frac{t}{\tau}} - e^{-\frac{\theta}{\vartheta}} + e^{-\frac{t}{\tau}} e^{-\frac{\theta}{\vartheta}}}\right). \quad (26)$$

According to (23-26) can be used for simulation of the influence of external factors on efficiency of storage.

Using exponents to approximate the results of a study of the influence of designer factors on the efficiency of storage is not the only possible one. The main argument in favor of using one or another form of addiction has its highest correlation ratio.

The dependence of storage efciency on the temperature and humidity are more consistent with the parabolas, since they most often have an optimum (extremum). However, the principle of using three or more exponential dependencies suitable for determining the effectiveness of the storage and modelling of the process, with other factors influencing this effectiveness.

A parabolic dependence of storage efficiency on temperature

$$Y^{\theta} = a_1\theta^2 + a_2\theta + a_3, \quad (27)$$

where: a1, a2 and a3 – experimental factors, gives the possibility by equating its first derivative to zero to determine the optimal storage temperature

$$\theta_{opt} = -\frac{a_2}{2a_1}. \quad (28)$$

In this case, the storage efficiency may be determined by any known method, including the measurement of ORP.

A similar dependence of storage efciency from humidity

$$Y^{W} = m_1W^2 + m_2W + m_3. \quad (29)$$

where: m1, m2 and m3 – experimental coefficients.

Accordingly, the optimum moisture content in the repository

$$W_{opt} = -\frac{m_2}{2m_1}. \quad (30)$$

In the study of the influence of one factor on efficiency of storage the other factors should remain unchanged.

To determine the dependence of storage efciency from two factors, for example, the temperature and humidity in the vault, you need to determine according to the experimental factors included in the expression (27) from moisture, namely:

$$a_1 = b_1W^2 + b_2W + b_3, \quad (31)$$

$$a_2 = c_1W^2 + c_2W + c_3, \quad (32)$$

$$a_3 = d_1W^2 + d_2W + d_3 \quad (33)$$

where: b-b3, c1-c3 and d1-d3 – experimental coefficients.

The dependence of storage efficiency on temperature and humidity

$$Y^{\theta,W} = b_1W^2 + b_2W + b\theta^2 + c_1W^2 + \\ + c_2W + c_3\theta + d_1W^2 + d_2W + d_3 . \quad (34)$$

This dependence is also easy to be differentiation with the aim of determining an optimum one of the parameters of the environment.

According to (27-34) give the relationship between efficiency of storage, temperature and humidity in the vault, either separately or together.

Thus, the preconditions for storage optimization process, under controlled temperature and humidity storage.

To do this optimization criterion defined with (minimum losses during storage or minimum cost storage process), and to determine the maximum permissible boundary values of adjustable parameters and to develop an algorithm corresponding calculations.

However, along with the parameters of the medium must also be considered and duration of storage.

Permanent storage duration carries information about the potential ability of an object to storage. The first is biological properties of the object. However, because the duration of storage is largely dependent on the temperature and humidity, these factors should affect the permanent storage duration.

Effect of temperature on a permanent storage duration will correspond expression

$$\tau = g_1\theta^2 + g_2\theta + g_3 . \qquad (35)$$

where: g1, g2 and g3 - the experimental factors.

Then the dependence of the efficiency of its storage duration and storage temperature will be

$$Y^{t,\theta} = e^{-\frac{t}{g_1\theta^2 + g_2\theta + g_3}} . \qquad (36)$$

where we have the dependence of the duration of storage of the temperature in the storage and storage efficiency

$$t = -\left(g_1\theta^2 + g_2\theta + g_3\right)\ln Y^{t,\theta} . \qquad (20)$$

Effect of humidity on the permanent storage duration will correspond expression

$$\tau = q_1W^2 + q_2W + q_3 \qquad (37)$$

where: q1, q2 and q3 - experimental factors.

Similarly, the dependence of the efficiency of storage of its duration and the humidity in storage will

$$Y^{t,W} = e^{-\frac{t}{q_1W^2 + q_2W + q_3}} . \qquad (38)$$

where we have the dependence of the duration of storage of the temperature in the storage and storage efficiency, namely:

$$t = -\left(q_1W^2 + q_2W + q_3\right)\ln Y^{t,W} . \qquad (39)$$

Based on (27, 29, 31-33, 35 and 37) obtained on the basis of direct measurements of losses during storage. The corresponding dependence of the storage efficiency obtained by measuring the ORP or other indicators of the object state storage will be the following:

the dependence of storage efficiency that is ego duration and temperature in the vault

$$Y^{t,\theta} = \frac{Q_\infty - Q_\infty\left(1 - e^{-\frac{t}{g_1\theta + g_2\theta + g_3}}\right) + Q_0 e^{-\frac{t}{g_1\theta + g_2\theta + g_3}}}{Q_\infty - Q_0}, \qquad (40)$$

and the dependence of storage efciency that is ego duration and humidity in the vault

$$Y^{t,W} = \frac{Q_\infty - Q_\infty\left(1 - e^{-\frac{t}{q_1W + q_2W + q_3}}\right) + Q_0 e^{-\frac{t}{q_1W + q_2W + q_3}}}{Q_\infty - Q_0}. \qquad (41)$$

The expression (35-41) can be used to simulate the storage process vegetable raw materials with rich fabrics. They give the relationship between the three parameters of the four: effectiveness and duration of storage, as well as humidity and temperature in storage, which is sufficient for simulation.

The foregoing is valid at any combination of factors affecting the process and storage can be used to study the process of storing any product.

The abundance of experimental factors explained by the fact that modeling is required to be based on the results of previous studies.

The object is to obtain further analytical work efficiency dependence storage on three factors, namely its duration, as well as temperature and humidity, or any other gaseous medium in the storage.

Experience studies the impact of external influences on the state of the storage object shows that it is these factors have the most significant impact. However, not excluded the need to study the simultaneous effect on the storage facility is four or more factors.

CONCLUSIONS

1. Consumption of vegetables and fruits in Ukraine lags behind the rational norms.
2. Most cheap way to increase consumption of this product - reducing its losses, primarily due to the optimization of storage modes.
3. Despite the abundance of descriptions of the impact of various factors on the effectiveness of the storage process, the analytical expressions, which should be an integral part of mathematical models of this process are unknown.
4. To predict the state of the storage facility and adjustment modes of storage in the course of his proposed analytical relationships that let you create optimization and simulation models of the storage process.
5. The analytical curves were obtained thanks to the state information storage object obtained during the storage process itself.

REFERENCES

1. **Andrest B. V., Bazarova V. S., Walking I. L. and others 1980.** The Handbook of commodity food products. M.: Economics. Vol. 1. 416.

2. **Koltunov V. A., Chepurny, N. S. 1989.** Reserves to reduce losses of vegetables. K.: Vintage, 264.

3. **USSR in figures in 1982. 1983.** M.: Finance and statistics, 237.

4. **Subbotina E. S. 1989.** Storage for farm products. Mechanization and electrification of agriculture. No. 8. 46-50.

5. **Starchevsky I. P. 2000.** The issue of safety crops on the basis of the biological agriculture and Energogarant products. Mechanization and electrification of villages. hoz.-VA. K.: Hey-Bi-Si, Vol. 83. 77-79.

6. **Balances** and consumption of basic foodstuffs population of Ukraine. The statistical compilation. **2017.** Kiev. 49.

7. **Turbin, V. A. 2004.** Scientific substantiation of the technology of keeping and ensuring the quality of basic fruits and vegetables. Abstract. Diss. ... doctor. tech. Sciences. 05.18.03 primary processing and storage of crop products. Kherson. 38.

8. Bases of storage of crop production. Agribusiness In Ukraine. URL: agrobiznes.org.ua/node/297

9. **Bald A.V., Stadnyk. S. 2013.** Theoretical and methodological approaches to the assessment of the quality of farm products. MOTROL. Commission of Motorization and Energetics in Agriculture. Vol. 15. No. 4. 120-125.

10. **Andrushko, G. P., Bald, A. V. 2017.** Assessment of the quality of farm products. Abstracts. All-Ukrainian scientific-practical. Conf. Sustainable development of the country in the framework of European integration. Zhytomyr, GGTU. 122-123.

11. **Bald Medic A. A.-B. 2013.** Assessment of the

quality of farm products and choose the optimal variant. Bulletin of Lviv national agrarian University. Agricultural studies No. 17. 103-110. URL: http://nbuv.gov.ua/UJRN/Vlnau_agr_2013_17_19

12. **Olga Lysa, Igor Medyk. 2014.** Problematic aspects of assessing the quality of farm products. Measuring technique and Metrology. No. 75. 60-63.

13. **Bober V. A., Skubala A. V. 2010.** The change in the quality of barley grain depending on conditions and duration of storage. Scientific reports Nulesu URL: http://www.nbuv.gov.ua/e-journals/Nd/2010_5/10 bavcds.pdf.

14. **Podpryatov A., Rozhko V. S., Skaletska L. F. 2014.** Technology of storage and processing of crop production. K.: Agricultural education, 393.

15. **Koltunov V. A., Blynskaya E. V. 2014.** The technology of storage of food products. K.: Center for studies. l-ry, 138.

16. **Muzychenko V. A., Bondarenko S. B. 2013.** Determinate electrobraid plant products from lush fabrics. Mechanization and electrification of agriculture. Vol. 97, vol. 2. Glevaha. NSC "IMESH".194-201.

17. **Muzychenko V. A. 2014.** The modeling of juicy plant raw material during processing and storage. Scientific-technical progress in agricultural production: proceedings of the international. Scientific.-tech. Conf. RUE "SPC NAS of Belarus for agriculture mechanization". Minsk. 229-233.

18. **Inozemtsev G. B., Okushko V. A. 2011.** A method for predicting the keeping quality of fruits and vegetables. The patent for useful model 56552 IPC A23L 3/32, G01N 33/02.

19. **Savchenko V. V. 2010.** The effect of electromagnetic processing of potatoes. Scientific Bulletin of Nulesu. Series "technology and energy agriculture". No. 153. 138-145.

20. **Korchemny N. A. Muzychenko, V. A., A. Sinyavsky, Y. 1996.** A method of storing plant materials with rich fabrics. Pat. 10574A MPK5 A23L 3/32.

21. **Martynenko S. S., Linnik N. K., Muzychenko V. A. 2006.** Defining the potential for storage and processing of vegetable raw materials with rich fabrics. Proceedings of the 5th International scientific.-tech. Conf. 16-17 may 2006 energy saving technologies in crop production and cell energy. Moscow: GNU vieskh, Part 2. P. 185-193.

22. **Muzychenko V. A. 2004.** Optimization of single aeroionic processing. Electrification and automation of agriculture. No. 4. 24-29.

23. **Kozhanova N. S. 1992.** A method for predicting the shelf life of root crops of carrots and beets 1729327 A. S. of the USSR, МКИ5 A01F 25/00.

24. **Romanovsky S. A., Koltunov V. A. 1992.** A method for predicting the keeping quality of fruits and vegetables 1729326 A. S. of the USSR, МКИ5 A01F 25/00. G 01N 35/02.

25. **Feitelberg Blanc, V. G., Bykova E. V., Orlova A. V. Ostapenko, L. G., Averbukh A. G., Stepanenko V. A. 1979.** Improve the safety of potatoes and onions with ionized air. Journal of farm Sciences. No. 4. 110-112.

26. **Feitelberg Blanc, V. G., Bykova E. V., Orlova A. V. 1979.** The influence of the neutral component of ionized air on the metabolism of potato tubers. Journal of farm Sciences. No. 2. 15-17.

27. **Pilipenko L. M., Danilova A. S., Pilipenko V. S, Soloviev D. K. 2014.** Biosensors in food quality control. The scientific works. Odessa national Academy of food technologies. Vol. 42. Vol. 2. 251-255.

28. **Koltunov V. A. 2004.** The quality of food products and technology of its storage. Part 1. Quality and storage of potato and vegetables. K.: KNTEU, 568 p. (in Ukraine).

29. **Koltunov V. A. 2004.** The quality of food products and technology of its storage. Part 2. The quality and storage of fruits and berries. K.: KNTEU. 249.

30. **Koltunov V. A. 2002.** Prediction of quality of food products. K.: KNTEU. 199.

31. **Muntean V. A., Koval D. M. 2014.** A theoretical analysis of the interaction of low-energy electromagnetic radiation with biological objects. Energy and automation. No. 3. 102-106.

32. **Muzychenko V. A. 2003.** Use biopotential to control the state of plant products. Proceedings of the IV International scientific-technical conference. MOTROL. 21-23 may 2003 the Lublin–Kijów. Mechanization and power engineering of agriculture. 352-356.

33. **Martynenko A. S., Muzychenko V. A. 1999.** The method of determining modes of aeroionic processing. Bulletin of agricultural science. No. 3. 47-50.

ОПРЕДЕЛЕНИЕ ВЛИЯНИЯ РЕЖИМОВ ХРАНЕНИЯ ПРОДУКЦИИ НА ЕЁ СОСТОЯНИЕ

Аннотация. Проанализированы уровни потребления плодоовощной продукции и её потерь.

Предложено использовать информацию от объекта хранения о его состоянии для определения влияния условий хранения на это состояние.

Проанализированы способы получения информации от продукции растениеводства о её состоянии.

Обоснована необходимость предоставления информации о состоянии объекта хранения, зависимости этого состояния от режимов хранения, а также влияния режимов хранения на его продолжительность в аналитическом виде.

Обоснована необходимость использования для повышения эффективности хранения как оптимизационное, так и имитационное математическое моделирование влияния внешних воздействий на хранящуюся продукцию.

Получено аналитическое описание зависимости состояния продукции от режимов хранения, позволяющие определять один из режимов хранения в зависимости от плановой эффективности хранения при фиксированных остальных режимах.

На примере зависимости окислительно-восстановительного потенциала растительного сырья с сочными тканями от продолжительности хранения изложена методика её аппроксимации экспонентой.

Получена зависимость эффективности хранения от её режимов, которая может служить целевой функцией при оптимизации этих режимов.

Созданы предпосылки для имитационного моделирования влияния внешних воздействий на

эффективность хранения и оптимизации режимов хранения по критерию минимума потерь, если регулируемыми переменными являются продолжительность хранения, а также температура и влажность воздуха в хранилище.

Математические модели процессов хранения дают возможность корректировать режимы в процессе хранения и прогнозировать состояние хранящихся объектов.

Ключевые слова: сельскохозяйственная продукция, хранение, эффективность, режимы, математическое моделирование.

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Structure of Project Values for Creation of Family Dairy Farms and Feed Supply Cooperatives and their Risks

Oleh Boyarchuk
Lviv National Agrarian University.
E-mail: boyarchuko@mail.ua

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Summary. The analysis of the state production of milk raw materials in Ukraine and the peculiarities of forming quality and operational requirements. The need for development in separate territorial communities on the basis of systematical implementation for the creation of family dairy farms and feed supply cooperatives projects is substantiated. The unresolved scientific and applied task is designated to develop tools to control the system of creation of family dairy farms of feed supply. The analysis of relationships between the creation of family dairy farms and feed supply cooperatives projects. The structural scheme of value formation from project implementation for the creation of family dairy farms and feed supply cooperatives is substantiated. The risk for stakeholders interested in projects of creation family dairy farms and feed supply cooperatives for is established as to its affiliation to values. Substantiated that projects of the creation of feed supply cooperatives for family dairy farms are derivative in relation to the projects of the creation of these farms, but without the implementation of the first, it is impossible to achieve their maximum systemic value.

The scheme of interconnections between the components of the values for creation of family dairy farms and feed supply cooperatives projects is substantiated. It is established that between them there is a causal link. Changing these connections can achieve a maximum value from the implementation of the project for the creation of family dairy farms and feed supply cooperatives is regarding the data of such projects. Changing the characteristics of data for this project determine the risk values for the creation of family dairy farms and feed supply cooperatives projects. It is proved, that the components of values for creation for the creation of family dairy farms and feed supply cooperatives projects has its benefits for stakeholders who are at risk. The affiliation of the components of the values to the stakeholders of the creation of family dairy farms and feed supply cooperatives projects and their risks is substantiated. They make the basis of the development of tools for planning, considering these risk-taking projects.

Key words: structure, value, project, risk, feed supply, family dairy farm.

INTRODUCTION

The problem of state food security is still unresolved nowadays in Ukraine. With the accession of our state to the World Trade Organization, this problem became more escalated as the majority of the milk raw materials falls short of international standards of EU legislation [1, 2].

In the structure of milk raw materials providers, more than 80% is occupied by households that cannot ensure its quality [3-5].

Strengthening of the EU requirements and our state to the quality of the milk raw materials impact the households that produce milk raw materials to unite through the implementation for the creation of family dairy farms projects (FDF). The implementation of such projects makes it possible to provide the FDF with all the necessary resources (industrial premises, machines, and equipment, performers, etc.), which significantly increases the quality of milk raw materials, and accordingly their value. As for this, the government has adopted a number of legislative documents and has developed programs which contribute to such growth of milk producers [6-8].

At the same time, scientific and applied problems of creating systems of feed supply FDF remain unresolved, due to the implementation of relevant projects, which also has a significant impact on the quality of milk raw materials production and the value of an FDF. However, for the development of individual territorial communities despite the implementation of projects of the creation of FDF it is necessary to implement the creative projects of feed supply cooperatives (FC) of these farms.

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

The analysis of existing scientific and methodological bases, methods and models of project management in various applications, indicates that they do not take into account the need for risk assessment for the interest of stakeholders. This greatly impacts on projects of creation FDF and FC [3-7]. However, the developed methodology P2M [9-12], which deals with project management and development programs of the organizations, although considers the project as a mean of value creation, however, it cannot be fully used for the project management of FDF and FC. Projects for the creation FDF and FC differ from other types of projects as features of the values creation and its variable project development environment determine their risks. In other words, for the management of the project FDF and FC methodological basis, methods, models and algorithms, which will take into account the interrelationships between the components of the value and peculiarities of their formation, should be researched and developed. These values are inherent with the risk, which determine its variable project environment.

OBJECTIVE

To substantiate the structure of project value for the creation of family dairy farms and feed supply cooperatives and their risks.

THE MAIN RESULTS OF THE RESEARCH

Under the value of creation of projects FC imply benefits which receive the parties concerned (stakeholders) from their received product [7].

The formation of values of the creation of projects FC is going systematically with the formation of values of projects of creation FDF.

Thus the bases of creating of these values are benefits for stakeholders of these projects. To determine the value of the implementation FC, firstly, it should be noted the components of the projects and their interrelation with the projects of creation FDF and the project environment (Fig. 1).

The creation of project FC – it is a unique and temporary action, that executed at the limited resources and are aimed to increase the value of the product (organization of feed supply FDF) in variable project development environment that's determine their risks.

The product of project creation - FC is the organization which provides manufacture and feed supply for FDF.

The creation of project FDF - it is a unique and temporary action, that executed at the limited resources and are aimed to increase the value of the product (FDF) in variable project development environment that's determine their risks.

The product of project creation FDF – it is FDF, which provides production of high-quality raw milk. All creation of projects of FC can be classified according to three classification criteria: scales, investments, functional and technological characteristics of the product.

On a scale creation of projects FC are divided into public (at the level of the individual territorial communities) and territorial (at the level of separate administrative regions).

To attract investment to the creation of projects FC they are divided into those that need to attract investment from the budgets of individual territories and the state, also from business structures and membership fees.

According to the functional and technological features of the product creation of projects FC they are divided into those that provide: production and feed supply, production, procurement, storage and delivery of feed to individual FDF.

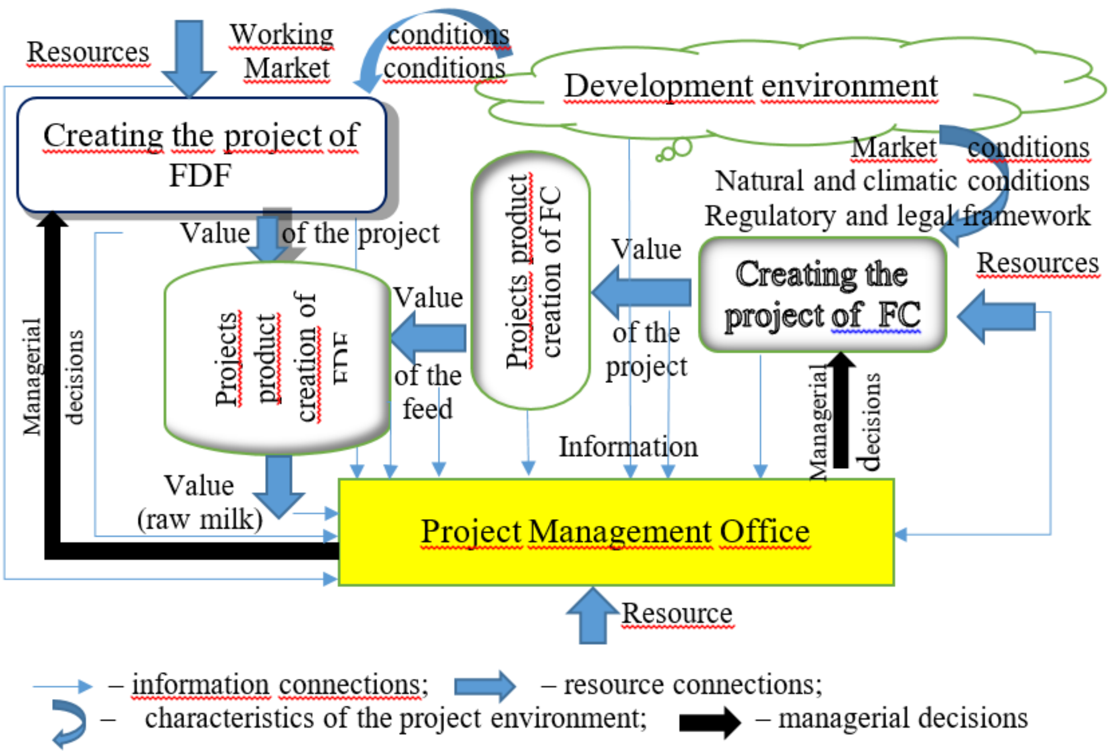

Fig. 1. Structural scheme of forming the values of creation the projects FDF and FC

Project environment for the creation of projects FC includes external and internal components, which have variable things, energetic and informational connections and are the basis of risks creations of these projects. External project environment is an environment for the creation of projects FC, thus such similar changing connections effect on its implementation.

Internal project environment includes individual components (elements) which also change its material, energetic and information connections.

The allocation of external and internal components of the FC project environment is conditional, as depending on the level of consideration of these projects, some of them can move from the external to the internal components and vice versa. In addition, some components of FC creation projects can simultaneously participate in several projects on the same stage (technical support, project team etc.) [13-16].

These projects and their components are linked by the various connections. In particular, there are four kinds of relationships that reflect: 1) the flow of information (informational), 2) provide resources (resourceful), 3) the impact of the project environment (informational), 4) management‘s decisions (informational) [17-21].

Most of the connections are observed in the management office of FDF and FC creation projects. They are connected by informational links with each of the projects‘ components of creation FDF and FC. Information about their condition is transmitted to the project management office, where it is processed by present resources (project managers, office computer equipment, management tools, etc.) and on its basis, management decisions are made on the peculiarities of implementation FDF and FC creation projects. In relation to resource links, each of the components of these projects requires the use of different types of resources. In particular, for realization creating of FDF and FC projects requires material, technical, human, natural (fields for feed crops) and financial resources.

By changing the noted connections (volumes, deadlines, timeliness, etc.) it is possible to achieve a maximum value from the project’s implementation regarding data on this project. With the variable environment of the project, the risk of value FC and FDF creation of projects can be determined. The FC projects are variations of the creation of FDF projects, but without the implementation of the first, it is impossible to achieve the maximum value from the implementation of other.

The value of system implementation should be noted in the creation of projects FDF and FC. In particular, it is based on the value of managerial decision-making, which is obtained with the temporary functioning of office management of these projects. It has two components – the value of V^{m}_{FDF} management decisions on creating of projects FDF and the value of V^{m}_{FC} management decisions on creating of projects FC. The derivatives of these values are the value of action V^{a}_{FDF} and V^{a}_{FC} which are performed in each of these projects, which in turn, determine the value of products of the respective projects – V^{p}_{FDF} , V^{p}_{FC}. Thanks to the product of FDF and FC creation projects receive the values of their intended use – respectively V^{r}_{FDF} and V^{r}_{FC}. However, the value of V^{r}_{FC} has a great impact on many values V^{r}_{FDF}. The ultimate values in these projects are the values V^{r}_{FDF}, that are created by the functioning of products creation of projects FDF and they relate to the received milk raw material of specified quantity and quality.

The interrelation between the mentioned values creation of projects FDF and FC and their products can be described by the following chain, as shown in fig. 2.

In projects, FDF and FC values V^{m}_{FDF} and V^{m}_{FC} management decisions determine all other components of values within the chains of their formation in these projects. All others values have a consistent impact on previous values on the following, only the value of using a product creation of project FC (feed production for FDF) has an impact on the value of product creation projects FDF on the territory of the community and its intended use (operational activity).

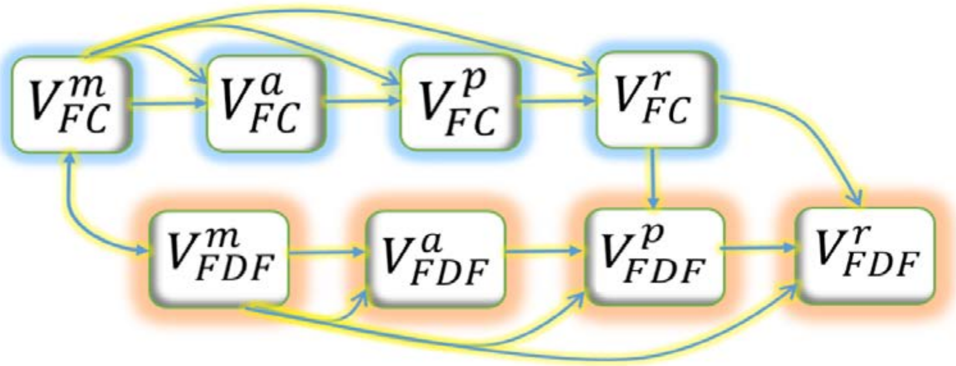

Fig. 1. The scheme of interrelations between the component values of creation the projects FDF and FC: V^{m}_{FDF} , V^{m}_{FC} – the value of managerial decisions on the implementation in the creation of projects FDF and FC, V^{a}_{FDF} , V^{a}_{FC} – the value of the actions in the creation of projects FDF and FC, V^{p}_{FDF} , V^{p}_{FC} – product value of creation the projects FDF and FC, V^{r}_{FDF} , V^{r}_{FC} – the values of their intended use - respectively FDF and FC.

Table. The affiliation of the values to the stakeholder's creation of projects FC and their risks.

The stakeholder	The components of risk values			
	V_{FC}^{m}	V_{FC}^{a}	V_{FC}^{p}	V_{FC}^{r}
State	Regulatory and legal framework	Marketplace	State support	Feed price
Community	The allocation of land resources	Social demands	Social safeguards	Preservation of natural resources. Taxes
FDF	The basic configuration of FDF	Reconfiguration of FDF	Compliance with requirements	Volume, quality, and cost of feed
Business structure	Investments	Stages and amount of financing	Compliance with needs	Profit
Contractor	Execution of the work	Timeless, quality and cost of the work performed	Quality of executed works	–
Project manager	Quality of managerial decision-making	The coherence of resources with configuration, content and timing of actions	Results of projects	–

Each of the noted components of values (fig.1) is characterized by its benefits for stakeholders. The stakeholders for the FC creation project are the state, community, business structures, executives, project managers. We formulated the affiliation of the components of the values to the stakeholders and their risks (tab l.).

Each of the stakeholders wants to get their value from the implementation of FC creation projects, which are mostly various-directional. Without the intervention of a single project office implementation FDF and FC creation project it is impossible to get the declared product – the creation of FDF and FC with the maximum value for each stakeholder. The project management office provides regulatory influence on the formation of values system for stakeholders. In addition, the state ensures coordination of the stakeholders interests in the FDF and FC creation projects, through the establishment of legislative documents for regulating their activity and application of motivational letters for them, that greatly affects the risk of the implementation of these projects.

Risk management of each of the designated values of FDF and FC creation projects requires consideration on its features. For this purpose, it is necessary to develop an algorithm for their evaluation and justification of the reactions to them. At the core of such algorithm are patterns of value formation. The risk of values relating to the stakeholders on the same level systematically affects the risk of the values received by stakeholders at other levels of the project.

In addition, risk-based values in the FC creation projects is the configuration of their product and project environment. The configuration of the products from these projects is characterized by their form (producer cooperatives, which are created by businesses for profit or cooperatives that are created by the share of the resources of FDF) and equipment (premises, technical and technological support, etc.), that affects the structure of the values of stakeholders. Accordingly, they affect the types of risk values and management features.

The configuration of the project environment of FC, which has two components (internal and external) that determines types of risk values, especially their impact on these projects and numerical values.

Methods and models should be developed for the creation of FC project planning on the territory of individual communities, which will take into account the changing features of their implementation and changeable characteristics of the project environment, which determine the structure of values of these projects and the presence of risk. Consequently, the mentioned changing components greatly impact on the quality of managerial project plan creation of FC and their effectiveness.

CONCLUSIONS

1. The analysis of the subject area (dairy cattle husbandry) indicates that remain unresolved scientific and applied problems for creation system of family dairy farms and feed supply cooperatives. However, the development of individual territorial communities is possible under the condition of a system implementation for the creation of family dairy farms and feed supply cooperatives projects.

2. The structural scheme of the formation of their values is substantiated on the basis of the analysis of interconnections between the creation of family dairy farms and feed supply cooperatives projects. This gave the opportunity to establish that the creation of family dairy farms and feed supply cooperatives projects are derivative in relation to the projects of the creation of these farms, but without the implementation of the first, it is impossible to achieve their maximum systemic value.

3. The scheme of interconnections between the components of project values is substantiated on the creation of family dairy farms and feed supply cooperatives indicates that between them there is a causal link, but changing these relations (volumes, timings and timeliness etc.) is possible to achieve a maximum value from the projects implementation regarding to data this

project, that determines the risk values of the projects creation.

4. Each of the component values of the projects creation family dairy farms and feed supply cooperatives is characterized by its benefits for stakeholders which are at risk. Substantiated that the affiliation of the components of the values to the stakeholders for the creation of family dairy farms and feed supply cooperatives projects are the basis of the development of tools for planning these projects a risk-based.

5. A further study should be conducted in relation to the development of methods and models of the creation of family dairy farms and feed supply cooperatives projects taking into account the risk of their value.

REFERENCES

1. **Regulation EU 882/2004. 2004.** About official control,carried out in order to ensure compliance checks on legislation concerning food and feed,and the rules for the health and welfare of animals. Approved. from 29.04.2004.

2. **DSTU 3662:2015. 2017.** Milk-raw cow. Specifications / NAT. standard of Ukraine. Vyd. ofic. – [Uvedeno vpershe, chynnyj vid 2017-01-01]. Kyiv. 14.

3. **Tryhuba A. 2015.** Modeling of the technological system of forage feeding of dairy farms with the participation of service cooperatives. Visnyk Ljvivsjkogho nacionaljnogho aghrarnogho universytetu: aghroinzhenerni doslidzhennja. No 19. 3-7.

4. **Tryhuba A. 2015.** Kombinaciji proektiv u proghramakh kormozabezpechennja molochnykh ferm za uchastju obslughovujuchykh. Mekhanizacija ta elektryfikacija siljsjkogho ghospodarstva : mizhvid. temat. nauk. zb. Ghlevakha, Vyp. 2(101). 329-337.

5. **Tryhuba A., Bojarchuk O. 2018.** Osoblyvosti doslidzhennja proektiv kooperovanogho vyrobnyctva kormiv na pidstavi jikh modeljuvannja. Importozaminni tekhnologhiji vyroshhuvannja, zberighannja i pererobky produkciji sadivnyctva ta roslynnyctva : Materialy IV mizhnarodnoji naukovo-praktychnoji konferenciji. Umanj. 109-110.

6. **Tryhuba A. 2014.** Argumentation of the parameters of the system of purveyance of milk collected from the private farm-steads within a single administratinve district / A. Tryhuba // Econtechhod : An international quarterly journal on economics in technology, new technologies and modelling processes/ – Lublin-Rzeszów. No 4 (3). 23-27.

7. **Tryhuba A.N. 2017.** Systemno-proektni osnovy upravlinnia rozvytkom tekhnolohichnykh struktur vyrobnytstva molochnoi produktsii : avtoref.dys. na zdobuttia nauk. stupenia doktor. tekhn. nauk 05.13.22. Odesa. 48.

8. **Tryhuba A. M., Sholud'ko P. V., Sydorchuk L.L., Boyarchuk O. V. 2016.** System-valued principles of management of integrated milking development programs on the basis of modeling. Bulletin of the National Technical University "Kharkiv Polytechnic Institute". Collection of scientific works. Kharkiv. No 2 (1174). 103-107.

9. **ISO 21500. 2012.** Guidance on project management, http://www.projectprofy.ru/.

10. **A Guide** to the Project Management Body of Knowledge. **2008.** PMBOK Guide. Fifth Edition. URL: http://www.pmi.org.

11. **GOST R 54869-011. 2011.** Proyektnyj menedzhment. Trebovaniya k upravleniyu proyektom». Moskva. Standartinform. 34.

12. **PRIENCE2. 2009.** Managing successful project with PRIENCE2. TSO Blackwell and other accredited agents. 315.

13. **Buslenko N.P. 1978.** Modelirovaniye slozhnykh sistem. Moscow. Nauka. 400.

14. **Sovetov B.Ya., Yakovlev S.A. 1985.** Modelirovaniye sistem. Moscow. Vysshaya shkola. 271.

15. **Sydorchuk O., Tryhuba A., Sydorchuk L. 2016.** Engineering of cooperative production of dairy products: system-design basis. Nizhyn. 352.

16. **Bushuev S.D. 2009.** Guide to the management of innovative projects and programs P2M. Kyiv. 173.

17. **Krasowski E., Sydorchuk O., Sydorchuk L. 2015.** Modeling and Management of the Technical and Technological Potential in Agricultural Production. Teka : An international quarterly journal on economics in technology, new technologies and modelling processes, Lublin-Rzeszow, No 15 (4). 79-84.

18. **Tryhuba A., Sydorchuk L., Shelega O., Sy`vakovska E. 2015.** Upravleny`e cennost`yu proektov texny`ko-texnololgy`chesky`x obsluzhy`vayushhy`x kooperaty`v. Motrol. Commission of Motorization and Energetics in Agriculture.– Lublin-Rzeszów. No 17 (3). 161-167.

19. **Tryhuba A., Sharybura O. 2011.** Protsesy upravlinnia intehrovanymy proektamy ahrarnoho vyrobnytstva. Motrol. Commission of Motorization and Energetics in Agriculture. – Lublin-Rzeszów. No 13D. 37-42.

20. **Sydorchuk O., Tryhuba A., Chaban A., Kovalyshyn S., Paniura Ya., Malanchuk O. 2012.** Orhanizatsiini varianty konfihuratsii proektiv. Motrol. Commission of Motorization and Energetics in Agriculture. – Lublin-Rzeszów. No 14 (4). 70-74.

21. **Sydorchuk O., Tryhuba A., Makarchuk O. 2013.** Otsenka tsennostei servysnыkh prohramm ahrarnoho proyzvodstva. Motrol. Commission of Motorization and Energetics in Agriculture. – Lublin-Rzeszów. No 15 (4). 147-152.

СТРУКТУРА ЦЕННОСТЕЙ ПРОЕКТОВ СОЗДАНИЯ КООПЕРАТИВОВ КОРМООБЕСПЕЧЕНИЯ СЕМЕЙНЫХ МОЛОЧНЫХ ФЕРМ И ИХ РИСКИ

Аннотация. Выполнен анализ состояния производства молока-сырья в Украине, особенностей формирования его качества и действующих требований к ней. Обоснована необходимость развития отдельных территориальных общин на основании системной реализации проектов создания семейных молочных ферм и кооперативов кормопроизводства. Обоснована нерешенная научно-прикладная задача разработки инструментария для управления проектами создания систем кормообеспечения семейных молочных ферм.

Выполнен анализ взаимосвязей между проектами создания семейных молочных ферм и кооперативов с их кормообеспечения. Обоснованно структурную схему формирования ценности от реализации проектов создания семейных молочных ферм и кооперативов с их кормообеспечения. Установлена принадлежность рисков ценностей к заинтересованным сторонам проектов создания кооперативов с кормообеспечения семейных молочных ферм. Обосновано, что проекты создания кооперативов с кормообеспечения семейных молочных ферм являются производными по отношению к проектам создания этих ферм, но без реализации первых невозможно достичь максимальной системной их ценности.

Обоснованно схему взаимосвязей между составляющими ценностей проектов создания семейных молочных ферм и кооперативов с их кормообеспечения. Установлено, что между ними существуют причинно-следственные связи. Эти связи проявляются через объемы, сроки и своевременность ресурсного обеспечения. Изменением указанных связей можно добиться создания максимальной ценности от реализации проектов создания кооперативов с кормообеспечения семейных молочных ферм при заданной проектной среде. Меняющиеся характеристики проектного среды обусловливают риск ценностей проектов создания кооперативов с кормообеспечения семейных молочных ферм.

Доказано, что составляющие ценностей проектов создания семейных молочных ферм и кооперативов с их кормообеспечения характеризуется своими выгодами относительно заинтересованных сторон, которые имеют риск. Обоснована принадлежность составляющих ценностей к заинтересованным сторонам проектов создания кооперативов с кормообеспечения семейных молочных ферм и их риск. Они лежат в основе разработки инструментария для планирования этих проектов с учетом риска.

Ключевые слова: структура, ценность, проект, риск, кормообеспечение, семейная молочная ферма.

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Analysis of Forced Vibrations of Elastic Elements (Ropes) Hoisting Machines Cranes: Analytical Approach, Discrete – Continuous Model

Yuri Chovnyuk, Igor Sivak

National University of Life and Environmental Sciences of Ukraine.
E-mail: ychovnyuk@ukr.net

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Summary. The substantiated method and discrete - continuum model for the analysis of forced oscillations of elastic elements (ropes) of lifting mechanisms of cranes at arbitrary and time - harmonic laws of the change of external forces. The proposed criterion of the quality of the rope movement of the lifting mechanism of the crane, which, when implemented, permits the establishment of such modes of motion of elastic elements, which minimize the stresses in the latter. Realization of the purpose of this study allows to determine the dynamics coefficients in different sections of ropes and specify the methods / directions that lead to their minimization in the transition areas of the functioning of these mechanisms lifting cargo cranes.

The solution of the corresponding differential equations, which is a mathematical model of the problem, is carried out by decomposition in a series of eigenfunctions of the desired solutions of the indicated equations (in partial derivatives in spatial and temporal coordinates). For the external load, a generalized law of change in space and time is chosen. Conditions for resonance / antiresonance are found in the case of harmonic excitatory external force for various endpoints (boundary conditions for fixing an elastic element (rope).

Key words: analysis, forced oscillations, elasticity, ropes, load-lifting mechanisms, valves, analytical approach, discrete-continuum model.

INTRODUCTION

To implement analytical approach in the analysis of forced oscillations of elastic elements (ropes) cranes lifting mechanisms (within discrete - continual models) can use two basic methods of solving initial - boundary problem. It all depends on the nature of forced forces that act on the system with the distributed nature (ie cable). If the external force is forced harmonic excitation, then find a convenient solution to the problem fixed, which corresponds forced oscillations (after the transition) occurring with a frequency excitation method of separation of variables (Fourier method).

If an external force is forced to arbitrarily set excitation time should exercise schedule desired solution in a series of its own spatial (and temporal) function, which correspond to its own (free) vibrations of elastic elements (ropes) for the relevant boundary conditions of fixed.

The latter approach is particularly necessary to analyze transients (start, braking, etc.) in hoisting cranes and defining factors dynamic in different sections of the cables to prevent tearing and damage the latter, as well as to improve reliability and long - dovichnosti work, both the elastic elements, and mechanisms for lifting cranes in general.

The authors of this paper, the existing methods of analysis of forced oscillations crane lifting mechanisms require further refinement and improvement, particularly with regard to optimize their modes of motion, which will be for transitional areas in the operation of the above mechanisms are minimized coefficient of dynamic ropes.

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

The basic approaches and methods of analysis of forced oscillations in systems with distributed parameters set forth in [1,9]. The authors of these studies used mainly known model discrete - continual systems - namely flexible deformable models (in the longitudinal direction, ie along the axis of the straight) rods.

However, the use of such models and approaches elastic elements (rope) crane hoisting devices virtually no scientific literature relevant area of research.

It should be noted that the results of [4, 8, 9] will be partly used in this study.

OBJECTIVE

The purpose of the work justification is discrete - continuum model and analytical approach to the analysis of forced oscillations of elastic elements

(Rope) crane lifting mechanisms for different boundary conditions of said fixing elements (ropes) for different character internally forces. Implementation of the objectives of this study to set the dynamic factors in the different sections of rope and specify methods / trends that lead to their transition areas to minimize these mechanisms functioning lifting cranes.

THE MAIN RESULTS OF THE RESEARCH

1. The longitudinal vibrations of ropes (flexible rods) at harmonic excitation.

Let us at this point and subsequently used as a model rope lifting mechanism valve - straight model flexible rod that is able to maintain in its longitudinal vibrations excited outside. It is not'll take into account dissipative processes that occur during the forced longitudinal oscillations of the rod.

So, consider the case where the rod / rope under the influence of a centered longitudinal force that varies according to the harmonic law:

$$P = P_o \cdot sin\omega t \, , \tag{1}$$

where: Po - amplitude, ω - angular frequency of the external force P, t - time.

Stationary forced oscillations occur with a frequency ω excitement and accordingly must be described by law:

$$u(x, t) = U(x) \cdot sin\omega t \, , \tag{2}$$

where: U (x) - the function of abscissa x (a form of forced oscillations), which should be determined using boundary conditions and the type of wave equation [8]:

$$c^2 \cdot \frac{\partial^2 u}{\partial x^2} = \frac{\partial^2 u}{\partial t^2} \tag{3}$$

where: $u = u(x, t)$ - Move longitudinal section of arbitrary type rod when it forced vibrations,

$c^2 = \frac{E}{\rho}$, C - velocity of longitudinal waves in a rope / rod,

E- Young's modulus, ρ - density / density core material.

Substituting in (3) the expression (2), according to the method of Fourier come to the ordinary differential equation for the function U (x):

$$U'' + \frac{\omega^2 U}{c} = 0 \tag{4}$$

which touches at the function U (x) means the differentiation of the coordinate x. Solution (4) is written as:

$$U(x) = A \cdot \sin\left(\frac{\omega x}{c}\right) + D \cdot \cos\left(\frac{\omega x}{c}\right) \tag{5}$$

Constant C and D must be determined from the boundary conditions, which are formed as follows.

1) Pinned end of the rod. In this case, n = 0 in all - which t.

So, in this section shall be implemented equation U = 0.

2) By the end of the rod applied force that corresponds to the equation (1).

It should be equal longitudinal force (N) in the final section.

For N we have:

$$N = E \cdot S \cdot \frac{\partial u}{\partial x} = ES \cdot U' \cdot sin\omega t \, . \tag{6}$$

In (6) E - Young's modulus of the core material, S - area of its cross section

$$U'(x) = \frac{dU(x)}{dx} \, .$$

Equating (1) to (6), have:

$$U' = \frac{P_o}{(E \cdot S)} \tag{7}$$

3) The end of the rod is free from stress. According to (7) $U' = 0$.

At the end of the rod there is concentrated mass mo. The force of inertia, which it develops

$$\left(-m_o \ddot{u}_o\right) = m_o \omega^2 \cdot U_o \cdot sin\omega t \, ,$$

$$\ddot{u}_o = \frac{d^2 u_o(t)}{d t^2}$$

(Uo and Uo - values that relate to the point of securing mass mo), longitudinal force must be equal to:

$$N_o = E \cdot S \cdot \frac{\partial u}{\partial x} = ES \cdot U'_o \cdot sin\omega t \, .$$

So,

$$\frac{m_o \cdot \omega^2 \cdot U_o}{(ES)} = U'_o \tag{8}$$

Consider some typical problems lifting mechanisms when these mechanisms are influenced by external harmonic excitation.

A. Define the vibration amplitude rod / rope to which the applied force $P(t) = P_o \cdot sin\omega t$. (In section x = 0), a rod at the other end there is concentrated mass mo (in section x = l).

So, we have:

$$U' = \frac{P_o}{(ES)}$$

at x = 0 and

$$\frac{m_o \cdot \omega^2 \cdot U}{(ES)} = U'_o$$

at x = l.

With these boundary conditions we obtain for this case form factors spatial fluctuations (5)

$$A = \frac{c \cdot P_o}{ES \cdot \omega} \, ,$$

$$D = \frac{c \cdot P_o}{ES \cdot \omega} \cdot \left\{ \frac{\frac{1}{c} \cdot \cos\left(\frac{\omega l}{c}\right) - \frac{m_o \cdot \omega}{ES} \cdot \sin\left(\frac{\omega l}{c}\right)}{\frac{1}{c} \cdot \sin\left(\frac{\omega l}{c}\right) + \frac{m_o \omega}{ES} \cdot \cos\left(\frac{\omega l}{c}\right)} \right\} \tag{9}$$

Thus, the amplitude of the rod end (x = l) has the form:

$$U(l)=\frac{P_o\cdot c}{ES\cdot\omega}\cdot\left\{\frac{1}{\sin\left(\frac{\omega l}{c}\right)+\frac{m_o\cdot\omega\cdot c}{ES}\cdot\cos\left(\frac{\omega l}{c}\right)}\right\} \quad (10)$$

If the frequency of forced force applied to the rope in the section (x = 0) corresponds solving transcendental equation:

$$tg\left(\frac{\omega l}{c}\right)=-\frac{m_o\cdot\omega\cdot c}{E\cdot S}, \quad (11)$$

then rope $U(l)\rightarrow\infty$ There is a response.

(This corresponds to the situation resonant longitudinal swinging cargo mass mo, when the upper rope (x = 0), there are exciting harmonic force (that is, in fact, at the point of suspension to the rope drum drive mechanism is harmonic vibrations)).

Clearly, equation (11) has many solutions ω_n, N = 1,2,3 ....

B. Determine the amplitude of oscillation end of the rod / rope, which in cross section (x = l) harmonic force $P(t)=P_o\cdot sin\omega t$ and the other end (x = 0) is fixed (stationary).

Then we have the following boundary conditions: $U=0$ at $x=0$, $U'=\frac{P_o}{ES}$ at x = l. For spatial form factors vibrations rope $U(x)$ (5) we have:

$$A=\frac{(P_o\cdot c)}{\left(ES\cdot\omega\cdot\cos\left(\frac{\omega l}{c}\right)\right)}, \ D = 0. \quad (12)$$

Accordingly, the amplitude end of the rod / rope:

$$U(l)=\frac{P_o\cdot c\cdot tg\left(\frac{\omega l}{c}\right)}{(ES\omega)}. \quad (13)$$

Provided:

$$\frac{\omega\cdot l}{c}=(2n-1)\cdot\frac{\pi}{2}, \ N = 1, 2, 3, ..., \quad (14)$$

Amplitude $U(l)\rightarrow\infty$. Corresponding to resonance, and $\omega_1=\frac{\pi}{2}\cdot\frac{c}{l}$ is the lowest natural frequency:

Provided:

$$\frac{\widetilde{w}\cdot l}{c}=m\cdot\pi, \ M = 1,2,3, ..., \quad (15)$$

final section (x = l) Fixed, there is the so-called antiresonance. Its lowest natural frequency $\widetilde{w}_1=\frac{\pi\cdot c}{l}$.

Table 1 shows the lowest resonant natural frequencies, $\left(\omega_1=\frac{\pi c}{2l}\right)$ and antiresonance natural oscillations rope / rod for different lengths l.

As a material selected steel ropes (c = 5 · 103m / c).

Table 1. Frequency dependence and the length of the rope l, c = 5 · 103m / c.$w_1\widetilde{w}_1$

l, м	"Резонанс", $\omega_1=\frac{\pi\cdot c}{2l}$, c $^{-1}$	"Антирезонанс", $\widetilde{\omega}_1=\frac{\pi\cdot c}{l}$
10	785,4	1570,8
20	392,7	785,4
30	261,8	523,6
50	157,1	314,2
100	78,5	157
200	39,3	78,6
500	15,7	31,4
1000	7,9	15,8

C. Define the amplitude of oscillation end of the rod to which the force is applied $P=P_o\cdot sin\omega t$, and to this end (x = l) is also concentrated mass mo (load) and the other end (x = 0) is fixed (stationary).

In this case, the boundary conditions:

$$U=0 \text{ at x = 0, } U'=\frac{\left(P_o+m_o\omega^2\cdot U\right)}{(ES)} \text{ at x = l.} \quad (16)$$

The second boundary condition expresses essentially equal longitudinal forces on the right end of the rod / channel amount of forced harmonic forces and the forces of inertia final mass.

From (16) to form spatial fluctuations rope (5) we have:

$$A=\frac{P_o}{\left[\frac{ES\omega}{c}\cdot\cos\left(\frac{\omega l}{c}\right)-m_o\omega^2\cdot\sin\left(\frac{\omega l}{c}\right)\right]}, \ D=0. \quad (17)$$

The amplitude of the end of the rod / rope (x = l):

$$U(l)=P_o\cdot\frac{\sin\left(\frac{\omega l}{c}\right)}{\left[\frac{ES}{c}\cdot\omega\cdot\cos\left(\frac{\omega l}{c}\right)-m_o\cdot\omega^2\cdot\sin\left(\frac{\omega l}{c}\right)\right]} \quad (18)$$

Responses in this case, which leads to $U(l)\rightarrow\infty$, There is provided:

$$tg\left(\frac{\omega l}{c}\right)=\frac{ES}{c\cdot m_o\cdot\omega}. \quad (19)$$

2. Longitudinal vibrations of ropes (flexible rods) for an arbitrary distribution of load length and a function of time.

Let the external load randomly distributed along the length and have any - what function of time t: $q=q(x,t)$. In particular, the load may vary over time according to the law, common to all points (rope):

$$q=q_o(x)\cdot H(t). \quad (20)$$

Given the basic external load $q\cdot dx$ in the preparation of the differential equation of wave type for war, will have at $ES=const$. [8]

$$E\cdot S\cdot\frac{\partial^2 u}{\partial x^2}-\rho\cdot S\cdot\frac{\partial^2 u}{\partial t^2}=q(x,t). \quad (21)$$

These load $q(x,t)$ and moving $u(x,t)$ can be represented as a series in the eigenfunctions corresponding problem about free oscillations:

$$q(x,t) = X_1(x)\cdot S_1(t) + X_2(x)\cdot S_2(t) + ...; \quad (22)$$

$$u(x,t) = X_1(x)\cdot T_1(t) + X_2(x)\cdot T_2(t) + ... \quad (23)$$

To determine the function of time $S_i(t)$ multiply both sides of equation (22) to $X_i(x)$ and integrate the result over the entire length of the rod / rope.

When integrating the right side disappear all the ingredients, except the first, and (because of their orthogonal functions), and for $S_i(t)$ will have the formula:

$$S_i(t) = \frac{\left[\int_o^{\kappa} q(x,t)\cdot X_i(x)\,\mathrm{d}x\right]}{\left[\int_o^{l} X_i^2(x)\,\mathrm{d}x\right]} \quad (24)$$

If the load changes the law (20), while

$$S_i(t) = H(t)\cdot\frac{\left[\int_0^{l} q_o(x)\cdot X_i(x)\,\mathrm{d}x\right]}{\left[\int_o^{l} X_i^2(x)\,\mathrm{d}x\right]}, \quad (25)$$

that function $S_i(t)$ for all the numbers (i) differ only in scale.

If the load is carried by lumped $P_a(t)$, $P_b(t)$ ... in the section with abscissa a, b ..., then the formula (24) takes the form:

$$S_i(t) = \frac{\left[P_a(t)\cdot X_i(a) + P_b(t)\cdot X_i(b) + ...\right]}{\left[\int_o^{l} X_i^2(x)\,\mathrm{d}x\right]}, \quad (26)$$

Defining functions $T_i(t)$ based on the circumstance that each component in (22) causes a movement defined by the respective component (23). Therefore, the equation (21) can be substituted:

$$q(x,t) = X_i(x)\cdot S_i(t);\ u(x,t) = X_i(x)\cdot T_i(t). \quad (27)$$

Then we will have the equation:

$$ES\cdot X_i''\cdot T_i - \rho\cdot S\cdot X_i\cdot \ddot{T}_i = X_i\cdot S_i, \quad (28)$$

or after division by $\rho S\cdot X_i\cdot T_i$:

$$c^2\cdot\frac{X_i''}{X_i} = \frac{\ddot{T}_i}{T_i} + \frac{S_i}{(\rho\cdot S\cdot T_i)}. \quad (29)$$

The left side of the resulting equation (29) is constant and equal $-p_i^2$ [8] where p_i - natural frequency of free oscillations rope. Accordingly, the same value $i_a -p_i^2$ and the right side is thus:

$$\ddot{T}_i + p_i^2 T_i = -\frac{S_i}{(\rho\cdot S)}. \quad (30)$$

This formula also solves the problem, as it enables to form the sum (23) for the solution according inhomogeneous differential equation (30) we have:

$$T_i(t) = -\frac{1}{\rho S\cdot p_i}\cdot\int_o^t S_i(\tau)\cdot\sin\left[p_i(t-\tau)\right]\mathrm{d}\tau. \quad (31)$$

In the most general case, $S_i(t)$ from (24) it is possible to $T_i(t)$ by (31) write:

$$T_i(t) = -\frac{\int_o^l\int_o^t q(x,\tau)\cdot X_i(x)\cdot\sin\left[p_i\cdot(t-\tau)\right]dx\mathrm{d}\tau}{\rho S\cdot p_i\cdot\int_o^b X_i^2\mathrm{d}x} \quad (32)$$

If the load complies with the law (20), while taking into account the expression (25) we can write:

$$T_i(t) = -\frac{\int_o^l q_o(x)\cdot X_i(x)\,\mathrm{d}x}{\rho S\cdot p_i\cdot\int_o^l X_i^2(x)\,\mathrm{d}x}\cdot\int_o^t H(\tau)\cdot\sin\left[p_i(t-\tau)\right]\mathrm{d}\tau. \quad (33)$$

It should be noted that the functions $X_i(x)$ defined boundary conditions specific problem is the solution of the wave equation with zero right side (3). Regarding the expression (26) indicate that external forces are applied concentrated, usually by the end of the rope, ie the sections x = 0 and x = l. Therefore, the analysis of forced vibrations of ropes of cranes lifting mechanisms are:

$$S_i(t) = \frac{\left[P_o(t)\cdot X_i(0) + P_l(t)\cdot X_i(l)\right]}{\left[\int_o^l X_i^2(x)\,\mathrm{d}x\right]}. \quad (34)$$

General solution (21) takes the form:

$$u(x,t) = \sum_{i=1}^{\infty} X_i(x)\cdot T_i(t). \quad (35)$$

It should be noted that (35) defines only forced vibrations rod / rope and ignores his own free oscillations that occur even in the absence of external influences and are determined solely by the initial conditions of the problem and boundary.

Calculate optimal modes of starting / braking crane lifting mechanism should be in a way that satisfied the following criteria as the movement of discrete - continual systems:

$$\left[\frac{1}{t_s}\int_o^{t_s} ES\cdot\left\{\frac{\partial u(x,t)}{\partial x}\right\}^2\mathrm{d}t\right]^{\frac{1}{2}} \to \min. \quad (36)$$

The physical meaning of (36) is as follows. It allows to realize optimal motion of a discrete - continuum of "drive mechanism with a drum - rope - load" on which minimizes the mean force acting on the rope during acceleration / braking (duration t_s) When lifting / lowering cargo.

It is clear that the implementation of the criterion (36) depends on the location of a particular section ropes, ie from x ($0 \le x \le l$). This problem disappears when averaging the expression under the sign of integral t (36) also on the x on the entire length of the rope, ie:

$$\left\{ \frac{1}{l \cdot t_s} \int_o^l \int_o^{t_s} \left[E \cdot S' \cdot \frac{\partial u(x,t)}{\partial x} \right]^2 \mathrm{d}t\mathrm{d}x \right\}^{\frac{1}{2}} \Rightarrow \min. \quad (37)$$

CONCLUSIONS

1. Reasonable discrete - continuum model for implementing analytical approach in the analysis of forced oscillations of elastic elements (Rope) crane lifting mechanisms for arbitrary and harmonic laws of time t changes in external forces.
2. The proposed criterion of the quality movement rope crane lifting mechanism, which in its implementation allows the following modes of motion of elastic elements that minimize stress in the past.
3. The obtained results in the future may be used to improve and clarify the existing engineering calculation methods lifting mechanisms and their elements as the stages of design / construction and real operation.

REFERENCES

1. **Komarov M. S. 1969.** Dynamics of lifting machines. Moscow. Engineering. 206.
2. **Kazak, S. A. 1968.** Dynamics of bridge cranes. Moscow. Engineering. 331.
3. **Gokhberg M. M. 1969.** Metal constructions of lifting – transport machines. Moscow. Engineering. 520.
4. **Lobov N. A. 1987.** Dynamics of load-lifting cranes. Moscow. Engineering. 160.
5. **Gaydamaka V. F. 1989.** Lifting – transport machines. Kiev. High school. 328.
6. **Loveikin V. S. 2004.** Modeling of dynamics of mechanisms of hoisting machines. Nikolaev. RVV NGAU. 286.
7. S**cheffler M., Dresig H., Kurt F. 1981.** Lifting – transport cranes. Moscow. Engineering. 287.
8. **Panovko J. G. 1990.** Fundamentals of applied theory of vibrations and shock. Leningrad. Polytechnic. 272.
9. **Panovko J. G. 1991.** Introduction to the theory of mechanical vibrations. Moscow. Science. 256.
10. **Loveykin V. S., Garnec V. M., Pochka K. I. 2004.** Patent of Ukraine for an invention № 67091A. Installation for formation of products from concrete mixes, № u2003076371 it is stated 08.07.2003, it is published 15.06.2004, Bulletin №6.
11. **Loveykin V. S., Pochka K. I. 2004.** The dynamic analysis of roller forming installation with the rekuperativ drive. Dynamics, durability and reliability of farm vehicles: *Works of the First International scientific and technical conference (DSR AM-I)*, on October 4-7, 2004, Ternopil (Ukraine), 507-514.
12. **Loveykin V. S., Pochka K. I. 2005.** The analysis of unevenness of the movement of roller forming installation with the rekuperative drive. *Scientific and technical and production magazine «Hoisting-and-transport equipment*», 2005, No 4, 19-33.
13. **Loveykin V. S., Pochka K. I., Palamarchuk D. A. 2004.** Optimization of design data of the driving mechanism of roller forming installation with the rekuperative drive. *Scientific and technical magazine «Technology of construction*», Kyiv, 2004, No 15, 40-48.
14. **Loveykin V. S., Pochka K. I. 2010.** The analysis of unevenness of the movement of roller forming installation with energetically balanced drive. V*ibrations in the equipment and technologies*, 2010, No 4 (60), 20-29.
15. **Loveykin V. S., Pochka K. I. 2010.** Optimization of design data of roller forming installation with energetically balanced drive. *MOTROL*. Motorization and power industry in agriculture, Lublin, 2010, Tom 12 B, 9-18.
16. **Loveykin V. S., Pochka K. I. 2004.** The analysis of the movement of roller forming installation with the balanced drive. *Bulletin of the Kharkiv national automobile and road university*, 2004, No 27, 95-101.
17. **Loveykin V. S., Pochka K. I. 2005.** The power analysis of roller forming installation with the balanced drive. S*cientific bulletin of National agricultural university*, 2005, No 80, 346-356.
18. **Loveykin V. S. 1989.** Assessment of the movement of mechanisms and cars. *Hoisting-and-transport equipment*, Kyiv, Tehnika, 16-18 (in Russian).
19. **Lovejkin V. S., Shumilov G. V. 2011.** Optimization of the mode of change of a departure of the tower crane behind single kinematic criteria. *MOTROL*. Motorization and power industry in agriculture, Lublin, 2011, Tom 13 B, 167-174.
20. **Loveykin V. S., Pochka K. I. 2015.** The analysis of unevenness of the movement of roller forming installation with the balanced drive. *MOTROL*. Commission of Motorization and Energetics in Agriculture, Lublin-Rzeszow, 2015, Vol. 17, No 3, 17-27.
21. **Loveykin V. S., Pochka K. I. 2016.** Analysis of dynamic equilibration by the drive of cars of roller formation. *MOTROL*. Commission of Motorization and Energetics in Agriculture, Lublin-Rzeszow, 2016, Vol. 18, No 3, 41-52.

АНАЛИЗ ВЫНУЖДЕННЫХ КОЛЕБАНИЙ УПРУГИХ ЭЛЕМЕНТОВ (КАНАТОВ) ГРУЗОПОДЪЕМНЫХ МЕХАНИЗМОВ КРАНОВ: АНАЛИТИЧЕСКИЙ ПОДХОД, ДИСКРЕТНО – КОНТИНУАЛЬНАЯ МОДЕЛЬ

Аннотация. Обоснован метод и дискретно - континуальная модель для анализа вынужденных колебаний упругих элементов (канатов) грузоподъемных механизмов кранов при произвольном и гармоничном от времени законов изменения внешних сил. Предложенный критерий качества движения канатов грузоподъемного механизма крана, при его реализации позволяет устанавливать такие режимы движения упругих элементов, которые минимизируют напряжение в последних. Реализация цели данного исследования позволяет установить коэффициенты динамичности в разных сечениях канатов и указать методы / направления, которые ведут к минимизации на переходных участках функционирования указанных механизмов подъема груза кранов.

Решение соответствующих дифференциальных уравнений, является математической моделью задачи, осуществлен путем разложения в ряд по собственным функциям искомых решений указанных уравнений (в частных производных по пространственной и временной координатам). Для внешней нагрузки выбран обобщенный закон изменения в пространстве и времени. Найдены условия резонанса / антирезонанса в случае гармоничной возбуждающей внешней силы для различных конечных (граничных условий закрепления упругого элемента (каната).

Ключевые слова: анализ, вынужденные колебания, упругость, канаты, грузоподъемные механизмы, краны, аналитический подход, дискретно – континуальная модель.

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Simulation Models of Agricultural Processes

Oleksandr Nadtochiy, Lyudmila Titova

National University of Life and Environmental Sciences of Ukraine.
E-mail: o.nad@ukr.net

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Summary. In the article the simulation of a closed two-factor multi-queuing system. According to the model adopted by the process of harvesting a group of five combine harvesters served a certain number of vehicles. The optimum number of cars, which was 6 cars. Optimality criterion is the appearance of the queue for downloading. Lack queue indicates combines simple, which is unacceptable.

The most optimal yields for harvesting capacity of 6 m^3 hopper was 5 t / ha. A simulation model to determine the optimal yield to any harvesting and combinations thereof.

Key words: queuing system, combine harvester, optimization, simulation, GPSS World.

INTRODUCTION

In the article was considered an error of simulation compared with the analytical model equations for the different distribution of the random variable. We studied two queuing system (QS) multi refusal and single-channel queue. In general, the least common error appeared equation for exponential distribution and Veybula.

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

Combine efficiency of the process is largely determined by the level of its transport service characterized by a large volume of traffic in the short term, particularly efficient operation of vehicles [1-11]. The high level of seasonality, short collection, poor technical condition of most vehicles pose big problems with transporting grain from the combine to the granary. To ensure efficient management of transport processes in the transportation of grain, should use the scientific principles of optimizing traffic flow, determination of reserves to reduce costs in the "field - transport - granary", taking into account the dynamic processes occurring and outgoing information [12-16].

Continuing the theme of simulation in the second part of the article we construct a model unit to ensure vehicles combine harvesters [17-21]. The question of the optimal number of transport is very important. Ensuring the smooth operation unit combines reduces terms of harvest and get rid of this crop losses from shattering. On the other hand surplus vehicles will lead to inefficient use, reduced productivity and increased cost tons of grain.

OBJECTIVE

The aim of the study - development of two-factor simulation model System "Transporting grain" Field - tick - box ". Determination by the model number of vehicles optimal service for groups of 5 combine harvesters. Identify change the characteristics of a closed queuing system (QS) by changing the yield and distance transportation.

THE MAIN RESULTS OF THE RESEARCH

Consider the following production problems. On the same time a team of five combine harvesters. It is a kind of multiphase multichannel queuing system with unlimited latency requirements and Poisson flow of orders. As the car back in, we have closed production system. Each of the requirements is two phases: loading and unloading. So our system is a closed two-phase multi-channel service. For this system, the following restrictions:

– receipt of a claim (in the car boot) the system does not depend on other income requirements (no consequences),

– the system simultaneously receives two or more claims. Among the requirements is the interval (ordinary flow requirements),

– the likelihood of the request depends on the length of follow-up (720 hv.- change), that is stationary flow requirements.

It is necessary to determine the optimal number of vehicles to certain conditions (distance transportation, productivity). This Busy all service channels not release the car and turn it continues to be the release of any channel. And after the service moves to the place of discharge, which again can be formed queue (with a large number of cars in the system), the release of which the car is moving unit (TIK) where it is unloaded and returned to the beginning.

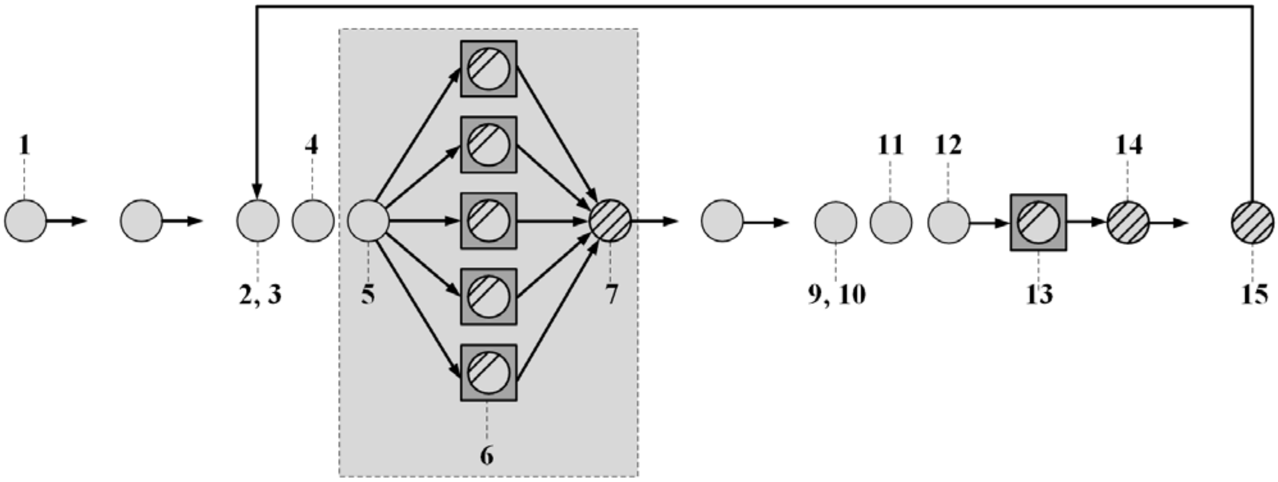

Fig. 1. Functional diagram of "Transportation of grain" Field - tick - box ".

That system is a closed loop and after passing TRANSACT not leave the system and continue to be in it.

Functional scheme's represent graphically five channel closed queuing system (first phase) and one channel (second phase) closed queuing system (Figure 1).

Figure 1. The basic events that occur when the system "Transporting grain" Field - tick - box ". Briefly characterize each event simulation model:

1. Generate income requirements (car) system (GENERATE).
2. Sign in turn download (ENTER).
3. Setting the queue to download (QUEUE).
4. Transmission requirements for loading into one of the available channels (TRANSFER).
5. Trying to take one of the free channels (SEIZE).
6. The delay time for car maintenance channel (ADVANCE).
7. The release service channel (RELEASE).
8. Discharge channel loading (LEAVE).
9. The delay time for movement of the vehicle with the load (ADVANCE).
10. Setting the queue for unloading (QUEUE)
11. Leaving the stage to discharge (DEPART).
12. Take the place of unloading (SEIZE)
13. Delay time unloading car (ADVANCE).
14. Releasing the place of discharge (RELEASE).
15. Return system requirements with regard to moving (ADVANCE, TRANSFER).

Overall this is a very simplified scheme. In the simulation model of combine harvesters work periodically interrupted by simulating failure, and is locked at the time of removal of failure. This car that took the channel to load continues to be a channel recovery device (combine). All time periods to simulate a real situation generated randomly exponentially distribution.

The program of the simulation model can be presented in seven sectors. The first sector is determined by the capacity of the system (5 harvesters). Do it by using the STORAGE. In our example it would look like this:

ZAVANTAG STORAGE 6

The second sector is modeled flow requirements for the system and its maintenance. The operator GENERATE used to form the number of vehicles serviced download queue (ZAVANTAG). This mode is used assumes that the fields A, B, C remain empty, and operand D affix the number of cars. This uses a variable X $ AUTO for further modeling:

GENERATE ,,, X $ AUTO

Then the flow of cars entering the queue to download and channels (HCC). If a free car service channel frees all and becomes a service (upload) to combine. The residence time in the channel consists of two periods: the period of time filling hopper and discharge hopper. On average, this time is respectively 38 and 54 minutes. If the employment of all 5 channels, a car awaits the release of one of the channels. Employment service channel is defined by the operator ADVANCE by exponentially distribution medium size service Exponential (1,0, X $ BUNKER). BUNKER variable X $ is the time for loading + unloading the combine hopper. Overall service block will look like:

SEIZE KOMBAIN
DEPART ZAVANTAG
ADVANCE (Exponential (1,0, X $ BUNKER))
RELEASE KOMBAIN

After the service vehicle (loaded) leaves the download queue and moves to queue for unloading ADVANCE (Exponential (1,5, X $ VANTAG)). Simulation of vehicle movement with load and without considered time change movement.

The fifth car sector enters the queue for unloading. Further verified employment channel for discharging (unloading place–THRESHING FLOOR). When dealing TRANSACT release device (car) and unloaded. After discharge, he frees the service channel (RELEASE TIK) and returned to the system for a jump the queue to download:

TRANSFER, AUTOMOBIL

Thus, after unloading cars returning the system to service (cycle repeats). Back in the car system runs until the time will not exceed the simulation system. For our system this time is 720 minutes. (12 hour shift). Timing simulation is defined in the last seventh sector. This time is determined by a simple timing model:

GENERATE 720
TERMINATE 1
START 1

The model would not be complete without probable failures combine harvesters at work. For this purpose, we modeled delay in another sector, sixth. Delays HCC combine this failure simulation, which is a random variable and has a period of 300 minutes refusal. At the same time restoring the status combine to take 20 minutes. Failures and eliminate failures are random variables anda Poisson distribution. Imitation rejection and elimination is carried out by operators to lock and unlock the device (FUNAVAIL, FAVAIL).

The code looks like a simulation model (Figure 2) is presented below.

To solve this problem of production had initially calculated the following variable data (Table 1).

```
*******************************************
*Моделювання двофазної замкнутої СМО транспортування зерна від комбайну
*******************************************
          INITIAL   X$AUTO,6                          ;Кількість автомобілів
          INITIAL   X$BUNKER,42                       ;Час завантаження бункера і авто
          INITIAL   X$VANTAG,30                       ;Час на рух до току з вантажем
          INITIAL   X$NOVANT,22                       ;Час на рух до комбайнів без вант.
          INITIAL   X$ROZVANT,12                      ;Час розвантаження на зернотоку
          INITIAL   X$PERVIDMOVA,312                  ;Частота відмов комбайна, хв
          INITIAL   X$USUNVIDMOVA,20                  ;Час на усунення відмови, хв
ZAVANTAG  STORAGE 6
          GENERATE  ,,,X$AUTO                         ;Число авто які працюють у системі
AUTOMOBIL ENTER     ZAVANTAG                          ;Вхід в чергу на завантаження
          QUEUE     ZAVANTAG                          ;Постановка в чергу на завантаження
          TRANSFER  ALL,k1,k5,5                       ;Передача по каналу к1...к5
k1        SEIZE     KOMBAIN1
          DEPART    ZAVANTAG                          ;Вихід з черги на завантаження
          ADVANCE   (Exponential(1,0,X$BUNKER))       ;Імітація завантаження авто
          RELEASE   KOMBAIN1                          ;Канал обслуговування звільнено
          TRANSFER  ,out
          ...
          ...
out       LEAVE     ZAVANTAG
          ADVANCE   (Exponential(1,5,X$VANTAG))       ;Імітація руху на розвантаження
*******************************************
          QUEUE     ROZVANTAG                         ;Постановка авто в чергу розвант.
          SEIZE     TOK                               ;Зайнятість розвантаження
          DEPART    ROZVANTAG                         ;Вихід з черги розвантаження
          ADVANCE   (Exponential(1,0,X$ROZVANT))      ;Час розвантаження
          RELEASE   TOK                               ;Звільнення місця розвантаження
          ADVANCE   (Exponential(1,0,X$NOVANT))       ;Затримка на повернення
          TRANSFER  ,AUTOMOBIL                        ;Перехід на початок черги
***ЗУПИНКА НА УСУНЕННЯ НЕПОЛАДКИ 1 комбайна
          GENERATE  (EXPONENTIAL(3,0,X$PERVIDMOVA)) ;Генерація відмов
          FUNAVAIL  KOMBAIN1                          ;Блокування комбайну 1
          ADVANCE   (EXPONENTIAL(3,0,X$USUNVIDMOVA))  ;Час ремонту 30 хв.
          ...
          ...
          GENERATE  720
          TERMINATE 1
          START     1
```

Fig. 2. The text of the two closed factor simulation model QS.

Table 1. Input two factorial design multichannel queuing system.

Vintageness t / ha	Hourly productivityness, ha / year.	Time to fill the hopper and loading the car, min.	The transportation of grain			
			5 km		10 km	
			Moveme nt	Movement without load	Moveme nt	Movement without load
3	2.89	45	15	12	30	22
5	1.94	42	15	12	30	22
7	1.45	40	15	12	30	22
9	1.12	39	15	12	30	22

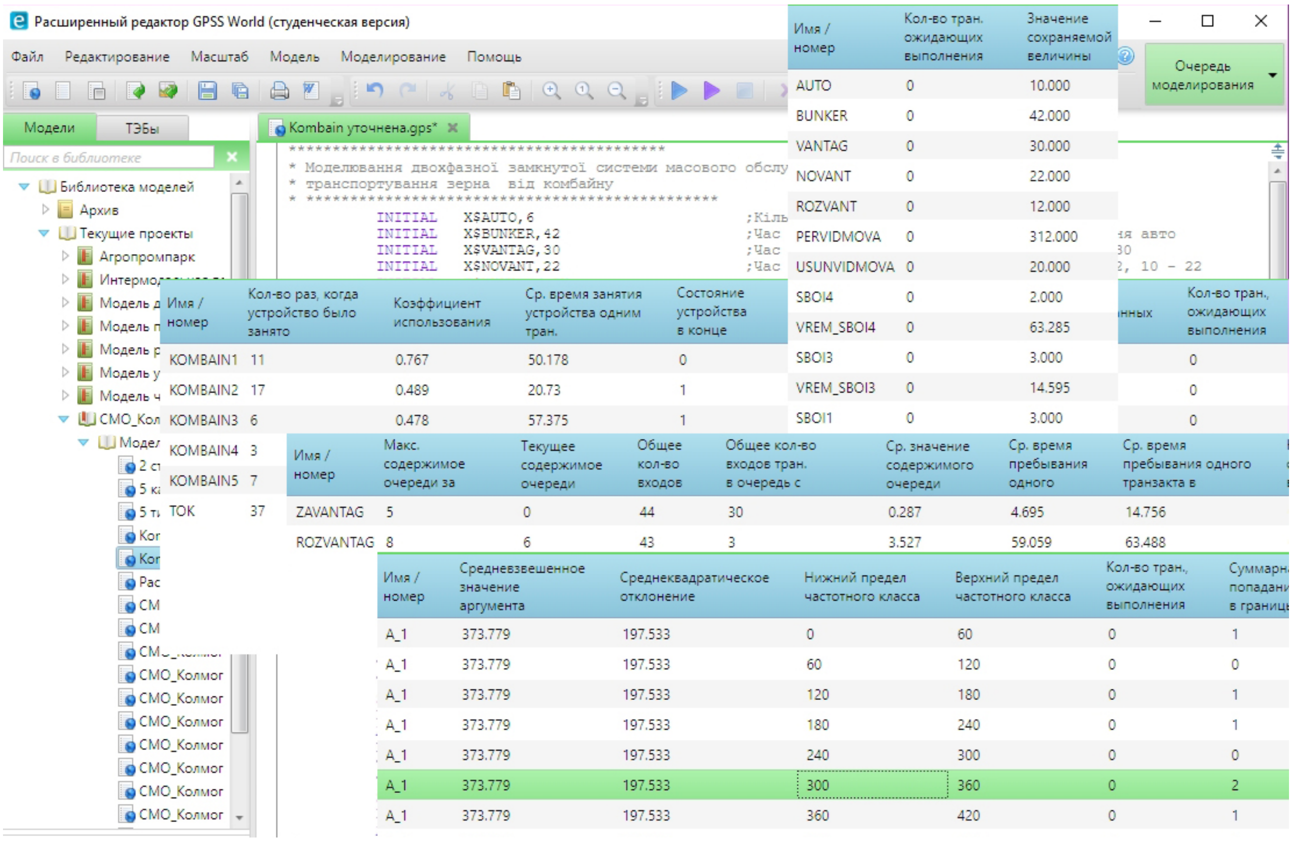

Fig. 3. Simulation results of the simulation model in GPSS World Editor.

Additionally, the model adopted unchanged following parameters: the number of vehicles 5-10, the average frequency rejection combine 312 min. Average time to eliminate failure 20 minutes. To solve the problem used GPSS World editor (Figure 3).

The object of the simulation was to determine the first phase of the optimal number of cars for the average yield of 5 t / ha and 10 km distance transportation. In the second stage, to explore changing the basic parameters of the system when changing: yield and average grain transportation distance determined in relation to the first stage, the optimal number of transport.

In the simulation results were obtained characteristics queues for loading and unloading vehicles (Fig. 4).

Chart 3 shows the result of simulation systems for different numbers of vehicles, such as 5, 6 and 7. Increase the number was not necessary, as the performance of the group deteriorated.

Analyzing the present schedule can be concluded that the optimal number of cars under given conditions is 6 cars (average histogram).

Here the best (lowest) is a queue for relief, but the main stage is the emergence download.

To turn auto download missing (equal to 0).

This shows that the most expensive cost units– HCC idle awaiting discharge, which is in production unacceptable.

For 6 cars idle in line for loading and unloading was respectively 0.176 and 3.577 min. The total average downtime same car in both queues per cycle is equal to 3,753 minutes. (225 C).

General characteristics of multichannel queuing system (Fig. 5) of the number of failures in servicing accounts for 1 processor. Of course it is conditional (Harvester be beloved by phone). This is because once the queue TRANSACT enters the combine 1 and Busy attempts to take a second channel and so on until the fifth.

Analyzing the histogram data, the number of failures in service for 7 cars is 6-12, 3-13 to 6, respectively, and for 5 cars –2 to 12 failures. For the "Product"– TIK these values are respectively 39, 37 and 27.

Fig. 4. Histogram medium size queues at the system.

Fig. 5. The number of failures in service 5 cars Combine harvesters (download) and 1 channel (unloading).

Fig. 6. Frequency realization employment multichannel queuing system.

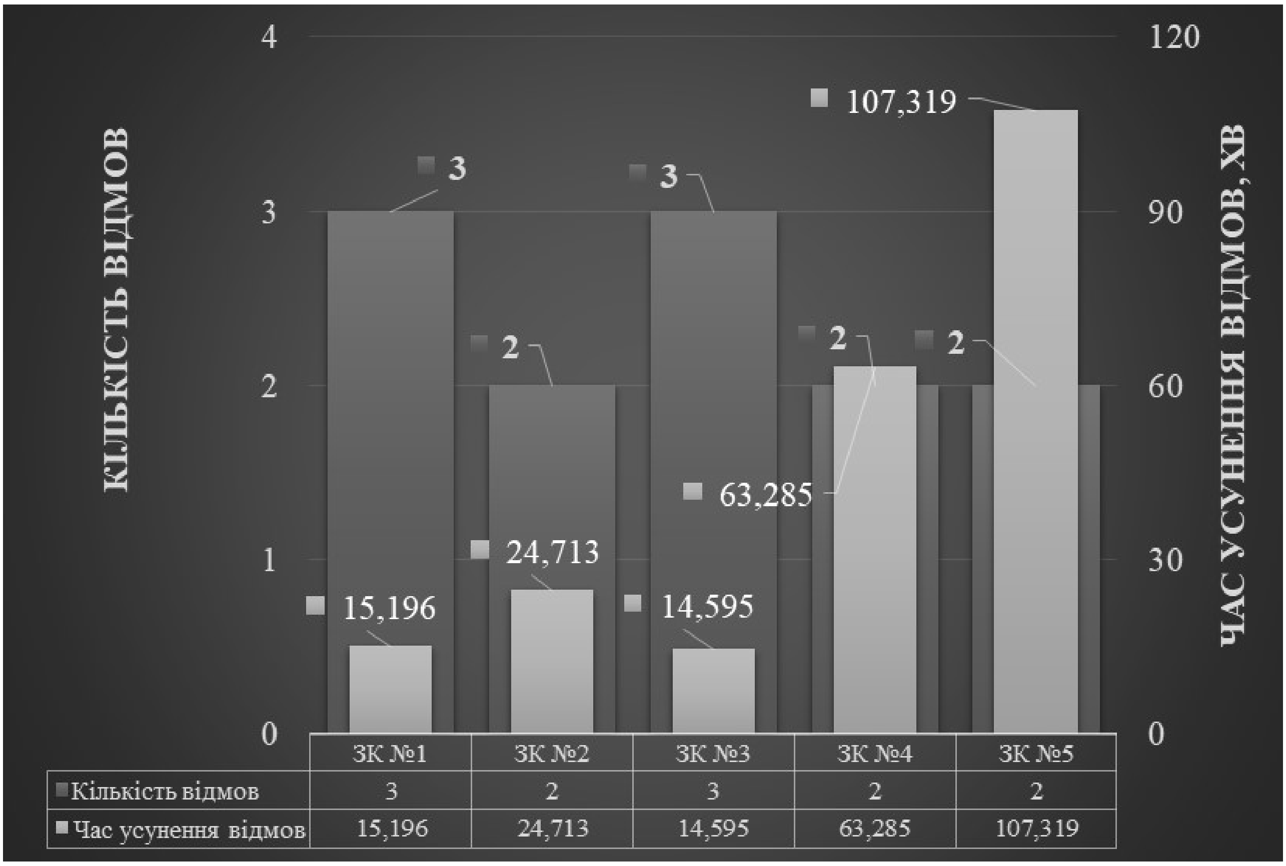

Fig. 7. Poisson flow of failures of service channels.

Table 2. Estimated characteristics of a closed queuing system, queues and handling.

On-dal km	Urozh., T / ha	Characteristics QS		Max's turn		Mean values			
						Retrieve.		Offloading facilities.	
		Employment	Conv. usage	Retrieve.	Offloading facilities.	Employ ment	Time line	Employ ment	Time line
5	3	2.553	.426	1	5	0,041	.736	1,085	19.528
	5	2.968	0,495	1	3	0,035	.521	.365	6.116
	7	2.724	.454	2	4	0,065	.953	.488	7.987
	9	2.554	.426	2	4	0,063	.962	.666	11.154
10	3	2,559	.427	1	3	0,011	.208	.263	5.923
	5	2.2	.367	1	2	0.01	.176	.184	3.577
	7	2.19	.365	1	2	0.01	.172	.327	6.546
	9	2.286	.381	1	2	0,009	.176	.344	7.084

Fig. 8. Characteristics channel loading with different yields and distance.

Graphical display of the time spent in queues for loading and unloading are shown in Fig. 8, 9.

More advanced features of the system are generated frequency tables employment service channels over time (Fig. 6) and dependent failures generated by a Poisson distribution (Fig. 7). To generate a frequency distribution (Fig. 6) is an interval of time (60 minutes). The graph shows that at any given time total employment vehicle systems ranging from 2 to 6, and employment separate channel service ranged from 0 to 2.

Interesting data were failures HCC. Poisson probability distribution simulates a real life situation. Number of failures generated for the channel was 2 - 3 failure, and a removal (with an average of 20 minutes) ranging from 15.196 to 107.319 minutes.

Further simulation was conducted only for the number of vehicles equal to 6. This changed yield and distance transportation. Simulation results are given in Table 2.

Analyzing the data of Table 2 and histograms (Fig. 8, 9) can be marked complete consistency of the data, which indicates the adequacy of the model. With increasing time on transportation (speed of 10 km) for loading and unloading increases. For transportation distance of 5 km that time increased respectively by 1.84 and 3.19 times. For speed, this increase was 1.2 and 1.98 times.

The most optimal regardless of vehicle speed for this brand combine harvesters (DON-1500B) with a volume of 6 m3 hopper yield is 5 t / ha.

Charts show that any fluctuations in yields at any direction leads to increased time spent in the queue for the channel to load and discharge channel.

CONCLUSIONS

1. Developed two-factor simulation model multichannel queuing system can successfully solve production problems by determining the optimal number of vehicles for the smooth operation Combine complex.

Fig. 9. Characteristics of the discharge channel at different yields and distance

2. The first stage of the simulation allowed us to determine the optimal number of vehicles under certain conditions. For our problem, this number was 6 cars. For a given set number appears on the stage of discharge, indicating a lack of simple combine harvesters. For 6 cars idle in line for loading and unloading was respectively 0.176 and 3.577 min. The total average downtime of vehicles in both queues per cycle is equal to 3,753 minutes. (225 C).

3. The most optimal yields for harvesting capacity of 6 m^3 hopper was 5 t / ha. A simulation model to determine the optimal yield to any harvesting and combinations thereof.

4. Summarizing it can be argued that the use of simulation with a minimum of effort really allows to evaluate agricultural production processes relating to the execution of the cycle work.

REFERENCES

1. **Nadtochii O., Titova L., Rogovskii I. 2016.** Analysis of the dynamics of the combine market of Ukraine. Techno-technological aspects of development and testing of new technology and technologies for agriculture in Ukraine. Vol 20. 254-262.

2. **Voronkov O. A., Rogovskii I. L. 2016.** Analysis of the role of road transport in the transport-technological support of agriculture. A collection of abstracts of II-nd International scientific-practical conference "Modern technologies of agricultural production" (9-10 November 2016). Kiev. 215-216.

3. **Voronkov O. A., Rogovskii I. L. 2017.** Adaptation of vehicle use in technology of harvesting grain crops. Abstracts of the International scientific-practical conference "Modern technologies of grain production 2017" within the framework of VI International exhibition of innovative solutions in grain farming "Grain technologies 2017" (February 16, 2017). Kiev. 2017. 28-29.

4. **Voronkov O. A., Rogovskii I. L. 2017.** Classification features of vehicles in transport-technological processes in agricultural production. Abstracts of the II all-Ukrainian scientific-theoretical conference "the Problems with traffic flows and the ways of their solution" national University "Lviv Polytechnic (16-18 March 2017). Lions. 17-19.

5. **Voronkov O. A., Rogovskii I. L. 2017.** Analysis of current state of problem of optimization of transport and technological support AIC. The book of abstracts XI International scientific-practical conference "Obukhov" read (March 21, 2017). Kiev. 92-93.

6. **Voronkov O. A., Rogovskii I. L. 2017.** In-line transport technology of transportation of grain bread. Problems of development of transport and logistics. Collection of scientific works on materials of VII-th International scientific-practical conference, Severodonetsk, Odesa, April 26-28 2017 – Severodonetsk, Ukraine: publishing house VNU named after Volodymyr Dahl. 15-17.

7. **Voronkov O. A., Rogovskii I. L. 2017.** Methodology of experimental research of the traction characteristics of vehicles. The book of abstracts of the XVII international conference of scientific and pedagogical workers, scientific employees and graduate students "Problems and prospects of development of technical and bio-energy systems of environmental management" (20-24 March 2017). Kiev. 122-123.

8. **Voronkov O. A., Rogovskii I. L. 2017.** Analytical prerequisites to transport and technological systems of transportation of production of crop production. Theses of International Scientific Conference "Globalization of scientific and educational space. innovations of transport.

problems, experience, prospects" (3-12 May 2017) / Dresden (Germany) Paris (France). 47-50.

9. **Voronkov O. A., Rogovskii I. L. 2017.** Ways to reduce energy consumption in transportation and technological support for weight of transported grain crops. A collection of abstracts of the XIII International scientific conference "the Rational use of energy in technology. TechEnergy 2017" (17-19 may 2017). Kiev. 72-74.

10. **Voronkov O. A., Rogovskii I. L. 2017.** Analytical model for energy estimation of transport technological process of transportation of grain and crop products. Journal of mechanical engineering and transport. Vinnitsa: VNTU. Vol. 1. 21-28.

11. **Voronkov O. A., Rogovskii I. L. 2017.** Approach to solving the problem of management of transport system for transporting of the grain harvest. The book of abstracts of V-th international scientific conference "Innovative maintenance of organic production in agriculture" in the framework of the XXI International agricultural exhibition "AGRO 2017" (05-06 June 2017). Kiev. 44-46.

12. **Voronkov O. A., Rogovskii I. L. 2017.** Automation operators for the monitoring of vehicles for the carriage of grain bread Automatic – 2017: international conference on automatic control, Kiev, Ukraine, 13-15 September 2017: proceedings of the conference. Kiev. 181-182.

13. 12. **Voronkov O. A., Rogovskii I. L. 2017.** Alignment of adjacent transport and technological operations of transportation of grain and crop products. Bulletin of East Ukrainian national University named after Volodymyr Dahl. No. 3. 36-43.

14. **Voronkov O. A., Rogovskii I. L. 2017.** General principles of creation of control systems of transport streams transport grain bread. Scientific Herald of National University of Life and Environmental Science of Ukraine. Series: Technique and energy of APK. Kiev. Vol. 258. 390-399.

15. **Voronkov O. A., Rogovskii I. L. 2017.** Options of structural solutions of the system of management of transport flows transport grain bread. Scientific Herald of National University of Life and Environmental Science of Ukraine. Series: Technique and energy of APK. Kiev. Vol. 262. 361-367.

16. **Shevchuk R. S., Krupych R. 2015.** Manual vibro-impact fruit shaker/ MOTROL Commission of motorization and energetics in agriculture. – Lublin-Rzeszow, Vol. 17, №4., 153-159.

17. **Sydorchuk O., Triguba A., Makarchuk O. 2012.** Optimization of the life cycle of integrated programs for harvesting grain crops. MOTROL Commission of motorization and energetics in agriculture. Lublin, Vol. 14, №4. 131-140.

18. **Sydorchuk O., Ivasjuk I., Syatkovskyy A. 2012.** Influence subject to conditions terms of tillage, planting summer-autumn period. MOTROL Commission of motorization and energetics in agriculture. – Lublin, – Vol.14, №4. 16-20.

19. **Sydorchuk A., Ivasiuk I., Ukraynecz V. 2013.** Harmonization of the components of the technological system of soil cultivation and sowing of winter crops. MOTROL Commission of motorization and energetics in agriculture. Lublin-Rzeszow, Vol. 15, №4. 180-186.

20. **Rogovskii Ivan. 2016.** Graph-modeling when the response and recovery of agricultural machinery. Motrol : Motorization and power industry in agriculture. Lublin. T. 18. №3. 155-164.

21. **Rogovskii I. L. 2016.** Analysis of model of recovery of agricultural machines and interpretation of results of numerical experiment. Scientific Herald of National University of Life and Environmental Science of Ukraine. Series: Technique and energy of APK. Kyiv. No 254. 424-431.

22. **Rogovskii I. L. 2017.** Probability of preventing loss of efficiency of agricultural machinery during exploitation. Scientific Herald of National University of Life and Environmental Science of Ukraine. Series: Technique and energy of APK. Kyiv. No 258. 399-407.

23. **Rogovskii I. L. 2017.** Conceptual framework of management system of failures of agricultural machinery. Scientific Herald of National University of Life and Environmental Science of Ukraine. Series: Technique and energy of APK. Kyiv. No 262. 403-411.

ИМИТАЦИОННОЕ МОДЕЛИРОВАНИЕ СЕЛЬСКОХОЗЯЙСТВЕННЫХ ПРОЦЕССОВ

Аннотация. В статье проведено имитационное моделирование многоканальной системы массового обслуживания с отказом и одноканальной очереди. промоделированы различные уравнения распределения случайной величины. найдено погрешности результатов имитационного моделирования по сравнению с аналитическими моделями.

Полученные результаты показали минимальные погрешности для экспоненциального распределения (*Exponential – 10,71%*) и распределения вейбула (*Weibull – 9,58%*).

Использование других законов распределения для решения уравнений колмогорова — чепмена приводит к большим расхождениям результатов. их использование без дополнительной проверки вызывают большое сомнение. проверка же за аналитическими моделями теряет смысл имитационного моделирования.

Ключевые слова: система массового обслуживания, оптимизация, имитационное моделирование, GPSS World.

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Theoretical Research of Separation Process Grain Mixtures

Sergiy Stepanenko[1], Boris Kotov[2]

[1]National Scientific Center "Institute of Mechanization and Electrification of Agriculture".
[2]Podolsky State Agricultural and Technical University.
E-mail: stepanenko_s@ukr.net

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Summary. Theoretical researches of the technological process of pneumoviral separation of grain mixtures on the pneumatic flow center separators of new generation grains, aimed at increasing the efficiency and quality of the phased separation of grain mixtures.

The analysis of the results of the well-known studies presented in the scientific and technical literature on the issues of pneumatic and centrifugal and pneumatic separation of grain mixtures was carried out by analytical and deductive methods, on the basis of which the parameters of the investigated operations of the technological process of the motion of the grain mixture in the pneumoviral separating device were substantiated by theoretical methods.

The theoretical researches of the technological process of pneumoviral separation of grain mixtures have been made, which makes it possible to determine the structural-kinematic and technological parameters of the grain-cleaning air-solenoid pneumatic-centrifugal unit with productivity from 25-50 t / h on primary purification of wheat grain with the provision of qualitative indicators in accordance with DSTU 3768: 2010 and seed quality of seeds respectively PH-1-3 ДСТУ 2240-93 at productivity from 10-20 t / h.

It is established that the application of the process of pneumatic separation of cereal mixtures when used in the construction of a pneumatic centrifugal separator has the potential to increase its productivity by 1,5-2 times compared with the performance of known industrial separators and on its basis create a new generation of universal centrifugal centrifugal separators with productivity of 50, 100 and 200 t / h

Key words: theoretical dependence, grain mix, dosage, separation, distribution, efficiency, productivity, quality.

INTRODUCTION

Extremely widespread in Ukraine and in other countries of the world, there are air-grate grain separators with gravitational working bodies such as flat oscillating, cylindrical rotating sieve and vertical or inclined pneumatic separation channels, which are characterized by limited severity of separation, which greatly complicates the creation on their basis of high-performance separators for cleaning and sorting grain materials.

The prospect of the development and application of modern high-tech technical equipment in agricultural production [1-5] and the prospect of a comprehensive solution to the problem of post-harvest processing and preservation of grain in Ukrainian farms [1, 3, 6] is the creation of modern refrigeration and drying-storage complexes that provide direct-flow processing of crops with bringing to the norms of basic conditions in accordance with DSTU on concrete grain crops, which, in turn, requires the creation of high-performance universal grain separators (machines for primary cleaning of grain) with productivity from 25 - 200 t / h.

Scientific researches of the motion of grain mixtures using centrifugal forces of inertia as the most effective ones allowed the creation and introduction into production of universal grain separators with productivity from 15 to 100 t / h [12-15], which became the basis for mastering the machine-building production of the family of universal vibrocentric separators of the type BCS .

In the indicated separators, the integration of working bodies and the joint use of air and grid separating devices in the form of autonomous grain cleaning units are used. The design and technological scheme of the pneumatic separating device was developed on the basis of conducted scientific research [1-6], which does not allow to increase the productivity of the machine with the necessary quality of primary cleaning of grain.

In connection with the foregoing, the problem of the development of technical means and the theoretical and mechano-technological substantiation of the technological process of pneumoviral separation in the machines of primary purification of the new generation of grain is relevant, and its solution will provide such a new, higher level.

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

In the known universal grain separators of the type BCS used pneumatic centrifugal devices [1-6, 10, 11], while the separation process does not allow to provide significant increase in the efficiency and quality of separation [5, 6]. The authors [7, 8, 9] note that the increase in productivity at non-changing quality indices is directly or indirectly related to the design features of dosing devices, rotary scatterers and the organization of air separation channels.

The research of [10, 11, 12] of the disk grain distributor for a pneumatic system with a vertical ring aspiration channel (an analogue of the grain cleaning unit BCC) achieved some increase in the efficiency of grain purification by a vibration centrifugal separator, by developing a pneumatic separating channel with a vertical annular aspiration channel separated by partitions [13, 14] . Increased productivity with this development has not been achieved.

Studies [7, 15-17], aimed at increasing the separation efficiency in pneumatic centrifugal devices, achieved some improvement in the quality of separation of grain mixtures. However, the results of these studies did not confirm the feasibility of using the proposed designs of air-cooled devices on centrifugal separators.

As a result of the research, the design and technological scheme of the grain separator has been developed, which provides an increase in the separation efficiency due to the following factors: the combination of the rotational spreader and the bounding walls of the circular air-separating channel with vortex upward airflow [15, 16], the design of the dosing device and its co-positioning relative to the rotational grain mixer spreader [16], use of vortex upward airflow [5], use of new design of rotational spreader [5].

OBJECTIVE

Theoretical studies of the technological process of pneumoviral separation of grain mixtures on the new generation of grain centrifugal separators of grain mills, aimed at increasing the efficiency and quality of phased separation of grain mixtures.

THE MAIN RESULTS OF THE RESEARCH

Using mechano-mathematical methods [6, 10, 12, 18, 20, 22], developments and studies [2-7, 16-21] have been carried out, which allowed to substantiate the design and technological scheme of the grain-cleaning module of the universal grain separator of the new generation and to substantiate the pneumoviral the method and design of a device for separating cereal mixtures, which provides the necessary controlled loading (productivity) of the module and the uniform distribution of the grain mixture in the pneumatic air flow due to the new design of the rotary spreader.

As a result of the research [5, 6, 7] the design of the pneumoviral device was created, the principal scheme of which is presented in Fig. 1. The essence of the technological process is as follows: the grain mixture through the loading grain lines 1 when the squirrels of the dispensing device 2 are opened by gravity on the center of the rotational spreader 3, which is fixed to the shaft 7 of the rotor of the separator rotating with the optimum (for the lattice system) speed ω.

The rotary scatterer 3 supplies the grain mixture with a uniform layer of a given thickness, which is determined by the amount of its flow through the window of the dispensing device 2, into the air separation channel limited by the outer wall 4. The air in the window of the louver 5 and the conical 6 walls is in the direction of rotation of the rotary spreader 3 of the cereal mixture , which creates an air rising vortex flow.

As a result of the interaction of the particles of the grain mixture with the air flow, the mixture is divided: the lungs are carried out beyond the air channel, and heavy (full grain of the main crop) is reflected from the wall of the 4 pneumatic channels and is directed to the surface of the louvre cone 5, which performs a dual function: the foundation of the pneumoviral flow air and aerodynamic transport of heavy fractions to the center.

The linear velocity of the grain mixture and the angles of the direction of its introduction into the pneumoviral channel relative to the axes of the cylindrical coordinate system 0ρθz are determined by calculations when solving the system of differential equations [5].

The separation of the air flow of the grain mixture on the light and heavy fraction is carried out by means of the interaction of particles of this mixture introduced into the air stream with velocity v and air flow, the intensity of which is determined by adjusting the aspiration system, and its direction is measured experimentally: the measurement of the angle of incidence is measured by dynamic pressure tubes to the axis of the cylindrical coordinate system 0ρθz, which allows you to calculate the components of the air velocity vBR, vBES, and vBz in the direction of the coordinates, determine the air resistance forces the environment of the particles of the cereal mixture in the direction of the indicated axes of coordinates, using the known formula $R = mk_n v^2$, where k_n- particle coefficient of sailing.

In the general case, the Navier-Stokes equation [5, 7, 9] is used to describe the flow of air in the working zone of the vortex chamber. In accordance with the Prandtlian hypothesis [9, 12, 18, 22] the voltages in the turbulent flow are equal:

$$\tau_{xy} = \rho \varepsilon dV/dy \quad (1)$$

where ε – coefficient of kinematic viscosity of air flow, which depends on the trajectory of shear l [5, 9, 22] $\varepsilon = l^2 dV/dy$.

Taking into account the dependence on the displacement trajectory and velocity [9]:

$$\varepsilon = l^2 \partial/\partial r (V_\varphi/r) \quad (2)$$

where $l = f(r)$, r – the value of the radius of the vortex chamber at the time t, m;

V_φ – circular air velocity, m/s.

In this case, the coefficient of the kinematic viscosity of the air flow is replaced by the turbulent viscosity coefficient e. With this approach, it is possible to obtain an analytical solution of these equations in the following form [9, 18]:

$$V_\varphi = \frac{V_{\varphi_1}R_1 - V_{\varphi_2}R_2}{R_1^{Re+2} - R_2^{Re+2}} r^{Re+1} + \frac{V_{\varphi_2}R_2R_1^{Re+2} - V_{\varphi_1}R_1R_2^{Re+2}}{R_1^{Re+2} - R_2^{Re+2}} r^{-1} \quad (3)$$

where V_{φ_1}, V_{φ_2} – Circular velocity of air, respectively, in radii R_1, R_2, m/s;

R_1 – the radius of the arrangement of tangential cracks for introducing airflow on the conical portion of the vortex chamber, m;

R_2 – the radius of the aspiration channel for removing the airflow from the vortex chamber, m;

Re – number of Reynolds.

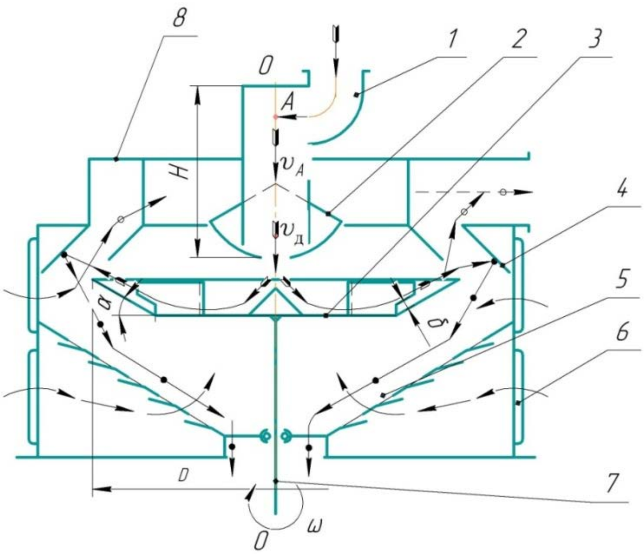

Fig. 1. Principal scheme of pneumoviral device [15, 16]: 1 - loading grain lines; 2 - dosing device; 3 - rotary spreader of grain mixture; 4 - the wall of the air channel; 5 - louver cone; 6 - louver cylindrical wall; 7 - separator rotor shaft; 8 is a casing.

Theoretical studies are aimed at determining the analytical dependence, in which, when taking into account the boundary conditions for air flow only at the entrance to the vortex chamber, one can obtain the basic geometric dimensions of this vortex chamber and determine the values of the velocity of the vortex upward air flow and the particles of the grain mixture at any distance per radius of the vortex chamber:

$$\begin{cases} V_r\frac{\partial V_r}{\partial r}+\frac{V_\varphi}{r}\frac{\partial V_r}{\partial \varphi}+V_z\frac{\partial V_z}{\partial z}-\frac{V_\varphi^2}{r}=-\frac{1}{\rho}\frac{\partial P}{\partial r}+ \\ +\varepsilon\left(\frac{\partial^2 V_r}{\partial r^2}+\frac{1}{r^2}\frac{\partial^2 V_r}{\partial \varphi^2}+\frac{\partial^2 V_r}{\partial z^2}+\frac{1}{r}\frac{\partial V_r}{\partial r}-\frac{2}{r^2}\frac{\partial V_\varphi}{\partial \varphi}-\frac{V_r}{r^2}\right) \\ V_r\frac{\partial V_\varphi}{\partial r}+\frac{V_\varphi}{r}\frac{\partial V_\varphi}{\partial \varphi}+V_z\frac{\partial V_z}{\partial z}+\frac{V_r V_\varphi}{r}=-\frac{1}{\rho r}\frac{\partial P}{\partial \varphi}+ \\ +\varepsilon\left(\frac{\partial^2 V_\varphi}{\partial r^2}+\frac{1}{r^2}\frac{\partial^2 V_\varphi}{\partial \varphi^2}+\frac{\partial^2 V_\varphi}{\partial z^2}+\frac{1}{r}\frac{\partial V_\varphi}{\partial r}+\frac{2}{r^2}\frac{\partial V_r}{\partial \varphi}-\frac{V_\varphi}{r^2}\right), \\ V_r\frac{\partial V_z}{\partial r}+\frac{V_\varphi}{r}\frac{\partial V_z}{\partial \varphi}+V_z\frac{\partial V_z}{\partial z}=-\frac{1}{\rho}\frac{\partial P}{\partial r}+ \\ +\varepsilon\left(\frac{\partial^2 V_z}{\partial r^2}+\frac{1}{r^2}\frac{\partial^2 V_z}{\partial \varphi^2}+\frac{\partial^2 V_z}{\partial z^2}+\frac{1}{r}\frac{\partial V_z}{\partial r}\right) \\ \frac{\partial V_r}{\partial r}+\frac{1}{r}\frac{\partial V_\varphi}{\partial \varphi}+\frac{\partial V_z}{\partial z}+\frac{V_r}{r}=0 \end{cases} \quad (4)$$

where V_r – radial air velocity, m/s;

V_φ – circular air velocity, m/s;

V_z – axial air velocity, m/s;

P – full pressure in the vortex chamber, Pa;

ε – coefficient of viscosity of the turbulent flow;

ρ – grain mix density, kg/m^3.

To do this, we assume that the flow of air in the vortex chamber is asymmetric, for the solution of this problem we use the Navier-Stokes equation in a cylindrical coordinate system (4).

Assuming that the vortex airflow in the chamber is asymmetric, and its motion becomes flat, then mathematical assumptions can be written as follows:

$$\frac{\partial}{\partial \varphi}=0;\ \frac{\partial}{\partial z}=0;\ V_z=0.$$

Under these conditions, the Navier-Stokes equation system (4) is written as:

$$\begin{cases} V_r(r)\left(\frac{d}{dr}V_\varphi(r)\right)+\frac{V_r(r)V_\varphi(r)}{r}= \\ =\varepsilon\left(\frac{d}{dr}\left(\frac{d}{dr}V_\varphi(r)\right)+\frac{\frac{d}{dr}V_\varphi(r)}{r}-\frac{V_\varphi}{r^2}\right) \\ V_r\left(\frac{d}{dr}V_r(r)\right)-\frac{V_\varphi(r)^2}{r}=\frac{\frac{d}{dr}P(r)}{\rho} \\ \frac{d}{dr}V_r(r)+\frac{V_r(r)}{r}=0 \end{cases} \quad (5)$$

From the third equation of the system (5), the radial component of the air velocity depends only on the radius, and also this equation is a differential equation in the complete derivatives, therefore its solution becomes the following form:

$$V_r(r)=\frac{C_1}{r} \quad (6)$$

Permanent integration of : C_1 is possible to determine from the condition if, on radius R_1, we know the value of the radial component of the air flow.

The value of this speed will be written as follows:

$$V_{r1}=\frac{Q_g}{2\pi R_1 H} \quad (7)$$

where Q_g - volumetric flow rate of air;

H – height of the vortex chamber, m

Consequently, constant integration is determined from the relation:

$$C_1=V_{r1}R_1 \quad (8)$$

and the equation for determining the radial component of the air flow velocity will take the following form:

$$V_r=\frac{V_{r1}R_1}{r} \quad (9)$$

After the transformations from the first equation of system (5) one can obtain the theoretical dependence by which the quantity of the air velocity in the radius of the vortex chamber is determined quantitatively. This equation is a differential equation of the second degree with constant coefficients, but some simplifications have led to the dependence on one variable, which is the radius of the vortex chamber. Twice about integrating this differential equation, we obtain an analytic dependence in which there are two constant integrals:

$$V_\varphi(r)=\frac{C_2}{r}+C_3 r^{\left(\frac{V_{r1}R_1+\varepsilon}{\varepsilon}\right)} \quad (10)$$

If the first derivative from the received dependence of the velocity of the air flow at a radius near a point with radius R_1 is 0, the analytical expression for this derivative has the form:

$$\frac{d}{dr}V_\varphi(r)=-\frac{C_2}{r^2}+\frac{C_3 r^{\left(\frac{V_{r1}R_1+\varepsilon}{\varepsilon}\right)}(V_{r1}R_1+\varepsilon)}{\varepsilon r} \quad (11)$$

then the second condition that will determine the second constant integration, will be the equality of the velocity component of the air flow rate, the velocity of air flow from the input tangential cracks located on the radius R_1.

$$V_{r1}=\frac{Q_g}{h_щ n_щ H} \quad (12)$$

where $h_щ$ – width of tangential gap, m;

$n_щ$ – number of tangential cracks, pcs.

After the substitution, we obtain a system of two equations with two unknowns:

$$\begin{cases} 0 = -\frac{C_2}{R_1^2} + \frac{C_3 R_1^{\left(\frac{V_{r1}R_1+\varepsilon}{\varepsilon}\right)}(V_{r1}+\varepsilon)}{R_1\varepsilon} \\ V_{\varphi 1} = \frac{C_2}{R_1} + C_3 R_1^{\left(\frac{V_{r1}R_1+\varepsilon}{\varepsilon}\right)} \end{cases} \quad (13)$$

The solution of this system of equations (13) is the analytic equations for constant integration:

$$\begin{cases} C_2 = \frac{V_{\varphi 1}R_1(V_{r1}R_1+\varepsilon)}{2\varepsilon+V_{r1}R_1} \\ C_3 = \frac{\varepsilon V_{\varphi 1} R_1^{\left(-\frac{V_{r1}R_1+\varepsilon}{\varepsilon}\right)}}{2\varepsilon+V_{r1}R_1} \end{cases} \quad (14)$$

Consequently, we obtained an analytical expression by which we can quantitatively determine the value of the velocity of the airflow along the radius of the vortex chamber. To do this, you must specify the boundary conditions. In our case, such conditions are quantitative data of the velocity of the airflow within a radius equal to the radius of the arrangement of the tangential cracks for introducing air into the vortex aspiration chamber. After adding the values of the constants obtained as a result of the solution of the differential equation, the dependence for determining the velocity velocity of the vortex airflow along the radius of the vortex chamber will be as follows:

$$V_\varphi(r) = \frac{V_{\varphi 1}R_1(V_{r1}R_1+\varepsilon)}{(2\varepsilon+V_{r1}R_1)r} + \frac{\varepsilon V_{\varphi 1} R_1^{\left(-\frac{V_{r1}R_1+\varepsilon}{\varepsilon}\right)} r^{\left(\frac{V_{r1}R_1+\varepsilon}{\varepsilon}\right)}}{2\varepsilon+V_{r1}R_1}. \quad (15)$$

To solve this mathematical dependence (15) and to facilitate its analysis, we will write this expression in the following form:

$$V_\varphi(r) = \frac{1}{(2\varepsilon+V_{r1}R_1)r}\left(V_{\varphi 1}\left(R_1^2 V_{r1} + R_1\varepsilon + \varepsilon R_1^{\left(-\frac{V_{r1}R_1+\varepsilon}{\varepsilon}\right)} r^{\left(\frac{V_{r1}R_1+2\varepsilon}{\varepsilon}\right)}\right)\right). \quad (16)$$

The analysis of the equations of the system (4-16) shows that the parasitic coefficient and the coefficient of kinematic viscosity, which is different for particles with different characteristics, is of paramount importance in the nature of the motion of the grain mixture particles in all directions of the vortex stream. In the radial direction, the movement of particles of the grain mixture is slowing down, and in the tangential direction it is accelerated, which provides the movement of heavy particles along the curvilinear trajectories with the approach to the axis of the vortex stream while simultaneously slowing down their fall. For light particles it promotes accelerated removal of them from the separation zone beyond the separating channel.

Compare the obtained dependence (16) with the results of calculations, for example, the ideal flow of air. It is known that in order to determine the velocity in a perfect airflow (without taking into account the viscosity), it is possible to obtain dependence on the conservation law of the moment of the number of rotational motion, which has the following known expression:

$$m_i \frac{d}{dt}\left(rV_\varphi\right) = 0 \quad (17)$$

where m_i – mass i – th volume of air.

Considering this mathematical dependence on the condition, that $m_i \neq 0$ and $dt \neq 0$, we obtain the following condition:

$$d\left(rV_\varphi\right) = 0 \quad (18)$$

Considering this equation, taking into account that the value r is a variable, we obtain a differential equation of the form:

$$V_\varphi(r) + r\left(\frac{d}{dr}V_\varphi(r)\right) = 0 \quad (19)$$

the solution of which will be as follows:

$$V_\varphi(r) = \frac{C_1}{r} \quad (20)$$

The constant integration of C_1 can be determined from the boundary conditions at the entrance to the vortex aspiration chamber. That is, when $r = R_1$, we assume that the velocity will be determined and exactly $V_\varphi = V_{\varphi 1}$. Consequently, under such conditions, constant integration will be determined by the following dependence:

$$C_1 = V_{\varphi 1}R_1. \quad (21)$$

Consequently, the analytical equation for determining the velocity in the ideal flow of air (without taking into account the viscosity) will take the following form:

$$V_\varphi(r) = \frac{V_{\varphi 1}R_1}{r}. \quad (22)$$

Let's consider in our example how the dependences (16) differ in determining the velocity of the viscous vortex airflow and the dependence (22), which determines the value of the velocity of the ideal airflow.

In these research, we take a vortex aspiration chamber with a radius of location of the tangential cracks $R_1 = 0{,}5\ m$, the value of the radial component of the full air flow velocity on the given radius $V_{r1} = 5\ m/s$,, the value of the velocity component at the same radius of the vortex chamber $V_{\varphi 1} = 17\ m/s$. We restrict the area along the radius of the vortex aspiration chamber, the radius of the aspiration canal to remove contaminated air from the vortex chamber, $R_2 = 0{,}15\ m$.

In Figure 2. Graphic dependencies are presented that clearly compare the calculations of the velocity of the ideal air flow and the viscous vortex air flow within the limits of the above dimensions of the vortex chamber and the specified boundary conditions.

Analyzing the obtained graphic dependences, we arrive at the conclusion that there is a significant decrease in the value of the velocity of the viscous vortex airflow relative to the velocity of the ideal airflow. This discrepancy is also confirmed by other investigators [23] for diverting the designs of aspiration chambers.

CONCLUSIONS

1. The conducted research confirm the possibility intensification of the separation of the grain mixture in the pneumatic separating device, and theoretical reserch and mechano-technological substantiation of operations allow to determine the technological, kinematic and structural elements of such devices.

2. Taking into account the constructional possibilities of extending the perimeter of the pipeline and the intensification of its technological process, it is possible to create a grain-cleaning air-rack pneumatic center-flow block (module) with a high degree of unification and using the modular principle of constructing a separator structure with productivity up to 200 t / h. The analysis of the operations of the pneumoviral device shows his dear opportunities, which involves reducing of grain and seeds.

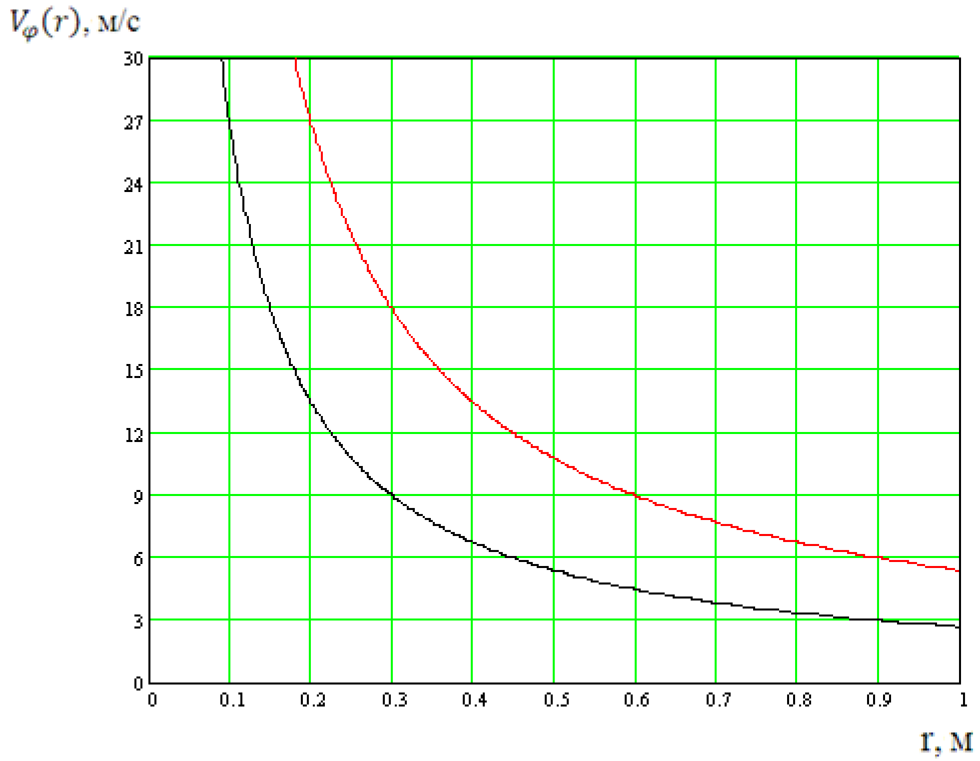

Fig. 2. Graphic dependencies of the velocity of the airflow along the radius of the vortex aspiration chamber (the upper line is for an ideal air flow; the bottom line is for a viscous vortex air stream).

REFERENCES

1. **Burkov A. M. 2000.** Grain-cleaning machines. Design, research, calculation and testing. Kirov. In niiskh Severo-East. 258.

2. **Stepanenko S. P. 2017.** Analysis of the development of structures pneumoseparation systems separators. Mechanization and electrification of agriculture. Vol. No. 5 (104). Glevaha. 132-142.

3. **Kotov B. I. 2017.** Conceptual bases of creation of technical means of processing of the grain in farms APK. Design, production and operation of agricultural machinery. Kropiwnicki. CSTS. Vol. 47. Part 1. 105-114.

4. **Gievskaya A. M. 2016.** The efficiency universal air-sieve grain cleaning machines: author. dis. ... doctor. tech. Sciences: 05.20.01. Voronezh. 40.

5. **Kotov B. I. 2016.** The increase of the separation efficiency of seeds using prototechno feed material in a horizontal air flow. Technology, energy, transport, agriculture. Vol. 3(95). Vinnitsa. 121-125.

6. **Ermak V. P. 2004.** Ways to increase the efficiency of seed separation in the horizontal air stream. ZB. Sciences. works. Lnau. Vol. 42. 66-72.

7. **Abdul M. M. 2007.** Justification of parameters of the separator with inclined air channel for separation of grain mixtures. Autorepair. dis. Cand. tech. Sciences. Kharkiv, HANTUSH them. P. Vasilenko. 20.

8. **Kotov B. I., Kalinichenko, G. A., Stepanenko S. P., Swida V. A., Lisiecki V. A. 2017.** Modeling of technological processes in the model objects post-harvest processing and grain storage (separation, drying, aeration, cooling)]. Nizhyn. Publisher PE Lysenko. M. 552.

9. **Stepanenko S. P., Kotov B. I., Spirin A. V. 2017.** To the question of the mathematical description of the movement of the threshed seeds in the annular channel of variable cross section. Mechanization of agricultural production. Bulletin INTOSH behalf Peter Vasilenko. Kharkov. Vol. 180. 330-339.

10. **Stepanenko S. P., Kotov B. I., Swida V. A., Koval Y. G. 2009.** The theory of separation of grain in the air stream. Design, production and operation of agricultural machinery. Vol. 39. Kirovograd. KNTU. 54-62.

11. **Adamchuk V. V. 2014.** The concept of the prospects of a comprehensive solution to the problem of post-harvest handling and storage of grain in the agricultural enterprises of Ukraine. Mechanization and electrification of agriculture. Glevaha. Vol. 99. Vol. 1. 40-56.

12. **Voronkov O. A., Rogovskii I. L. 2017.** Analytical prerequisites to transport and technological systems of transportation of production of crop production. Theses of International Scientific Conference "Globalization of scientific and educational space. innovations of transport. problems, experience, prospects" (3-12 May 2017) / Dresden (Germany) Paris (France). 47-50.

13. **Voronkov O. A., Rogovskii I. L. 2017.** Ways to reduce energy consumption in transportation and technological support for weight of transported grain crops. A collection of abstracts of the XIII International scientific conference "the Rational use of energy in technology. TechEnergy 2017" (17-19 may 2017). Kiev. 72-74.

14. **Voronkov O. A., Rogovskii I. L. 2017.** Analytical model for energy estimation of transport technological process of transportation of grain and crop

products. Journal of mechanical engineering and transport. Vinnitsa: VNTU. Vol. 1. 21-28.

15. **Voronkov O. A., Rogovskii I. L. 2017.** Approach to solving the problem of management of transport system for transporting of the grain harvest. The book of abstracts of V-th international scientific conference "Innovative maintenance of organic production in agriculture" in the framework of the XXI International agricultural exhibition "AGRO 2017" (05-06 June 2017). Kiev. 44-46.

16. **Voronkov O. A., Rogovskii I. L. 2017.** Automation operators for the monitoring of vehicles for the carriage of grain bread Automatic – 2017: international conference on automatic control, Kiev, Ukraine, 13-15 September 2017: proceedings of the conference. Kiev. 181-182.

17. **Voronkov O. A., Rogovskii I. L. 2017.** Alignment of adjacent transport and technological operations of transportation of grain and crop products. Bulletin of East Ukrainian national University named after Volodymyr Dahl. No. 3. 36-43.

18. **Voronkov O. A., Rogovskii I. L. 2017.** General principles of creation of control systems of transport streams transport grain bread. Scientific Herald of National University of Life and Environmental Science of Ukraine. Series: Technique and energy of APK. Kiev. Vol. 258. 390-399.

19. **Voronkov O. A., Rogovskii I. L. 2017.** Options of structural solutions of the system of management of transport flows transport grain bread. Scientific Herald of National University of Life and Environmental Science of Ukraine. Series: Technique and energy of APK. Kiev. Vol. 262. 361-367.

20. **Shevchuk R. S., Krupych R. 2015.** Manual vibro-impact fruit shaker/ MOTROL Commission of motorization and energetics in agriculture. – Lublin-Rzeszow, Vol. 17, №4., 153-159.

21. **Sydorchuk O., Triguba A., Makarchuk O. 2012.** Optimization of the life cycle of integrated programs for harvesting grain crops. MOTROL Commission of motorization and energetics in agriculture. Lublin, Vol. 14, №4. 131-140.

22. **Sydorchuk O., Ivasjuk I., Syatkovskyy A. 2012.** Influence subject to conditions terms of tillage, planting summer-autumn period. MOTROL Commission of motorization and energetics in agriculture. – Lublin, – Vol.14, №4. 16-20.

23. **Sydorchuk A., Ivasiuk I., Ukraynecz V. 2013.** Harmonization of the components of the technological system of soil cultivation and sowing of winter crops. MOTROL. Commission of motorization and energetics in agriculture. Lublin-Rzeszow, Vol. 15, №4. 180-186.

24. **Rogovskii Ivan. 2016.** Graph-modeling when the response and recovery of agricultural machinery. Motrol : Motorization and power industry in agriculture. Lublin. T. 18. №3. 155-164.

25. **Rogovskii I. L. 2016.** Analysis of model of recovery of agricultural machines and interpretation of results of numerical experiment. Scientific Herald of National University of Life and Environmental Science of Ukraine. Series: Technique and energy of APK. Kyiv. No 254. 424-431.

26. **Rogovskii I. L. 2017.** Probability of preventing loss of efficiency of agricultural machinery during exploitation. Scientific Herald of National University of Life and Environmental Science of Ukraine. Series: Technique and energy of APK. Kyiv. No 258. 399-407.

27. **Rogovskii I. L. 2017.** Conceptual framework of management system of failures of agricultural machinery. Scientific Herald of National University of Life and Environmental Science of Ukraine. Series: Technique and energy of APK. Kyiv. No 262. 403-411.

28. **Rogovskii Ivan. 2017.** Choice of model class and method of modeling the resilience of agricultural machinery. TEKA. An International Quarterly Journal on Motorization, Vehicle Operation, Energy Efficiency and Mechanical Engineering. Lublin–Rzeszów. Vol. 17. No 3. 101-114.

29. **Kalinichenko Dmytro, Rogovskii Ivan. 2018.** Method for Determining Time of next Maintenance of Combine Harvesters. TEKA. An International Quarterly Journal on Motorization, Vehicle Operation, Energy Efficiency and Mechanical Engineering. Lublin–Rzeszów. Vol. 18. No 1. 105-115.

ТЕОРЕТИЧЕСКОЕ ИССЛЕДОВАНИЕ ПРОЦЕССА РАЗДЕЛЕНИЯ ЗЕРНОВЫХ СМЕСЕЙ

Аннотация. В работе приведены результаты теоретического исследования взаимодействия частиц компонентов зернового материала при противоточной подаче материала в воздушный поток и при переменных эпюрах скорости потока вдоль осей координат. Установлено, что использование переменной скорости увеличивает величину расщепления траекторий движения и эффективность разделения.

Анализируя полученные результаты математического моделирования баллистики частиц компонентов зернового материала можно определить, что увеличение величины расщепления (ветвления) траекторий движения частиц при использовании переменной скорости воздушного потока по координатам. Увеличение величины расщепления траекторий однозначно характеризует увеличение эффективности разделения компонентов зернового материала на фракции по аэродинамическим свойствам, которые как известно плотно коррелируют с качественными показателями зернового материала.

Полученные результаты исследований процесса инерционного фракционирования свидетельствуют о реальной возможности повышения эффективности разделения материала на фракции по аэродинамическим свойствам. Эффект эпюры скорости воздуха в воздушном канале может быть использовано для управления процессами разделения материала на фракции.

Ключевые слова: теоретическая зависимость, зерновая смесь, дозировка, выделения, распределения, эффективность, производительность, качество.

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Methodical Principles of Modeling of Subject-Agrometeorological Events in Technological Processes Growing of Grain Crops

Rostyslav Kudrynetskyi, Viktor Dnes, Volodymyr Skibchyk

National Scientific Center «Institute for Agriculture Engineering and Electrification». E-mail: rostkud@gmail.com, vik31@ua.fm, scibczyk05@gmail.com

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Summary. The article identifies and classifies subject-agrometeorological events in the technological processes of cultivating grain crops. The analysis of these events made it possible to classify them according to the periodicity of their appearance, as well as to indicate the content of the influence of each of them on the course of these processes, which made it possible to develop appropriate algorithms for modeling the time of occurrence of these events.

The distribution of the time of occurrence of subject-agrometeorological events in technological processes of growing of grain crops, in particular: the time of restoration of spring vegetation, the completion of the autumn vegetation period of winter grain crops, the time of reaching their characteristic predecessors, and the patterns of change in the duration of soil warming have been established. The obtained regularities allow to predict (generate) the onset of phases of development of plants and time constraints for the implementation of mechanized operations in the technological processes of cultivating grain crops for different natural and production conditions.

The developed scientific and methodical principles of modeling of subject-agrometeorological events in the technological processes of cultivating grain crops underlie the creation of their computer models. The practical use of these models will allow you to predict the time constraints for performing mechanized operations and the characteristics of the flow of orders for their execution.

The methods of analysis and synthesis, system-factor and system-event approaches to the study of technological processes of cultivating grain crops were used in the work. To develop algorithms for modeling these technological processes, a discrete-event approach was used.

Key words: cultivation, grain crops, subject-agrometeorological events, technological processes, mechanized operations, modeling.

INTRODUCTION

The high level of technology of agricultural production, technical complexity and high technology costs require a high level of management of the technical base of agricultural producers, the search for ways to reduce material and energy costs. The search for rational solutions during the acquisition and use of machine-tractor fleet of agricultural producers is one of the most difficult tasks of mechanization of agricultural production. To solve it, it is necessary to consider a large number of factors, some of which are unmanaged and probabilistic. At present, there is no general system approach to the modeling of subject-agrometeorological events in the technological processes of cultivating grain crops, which underlies the creation of simulation models of these processes and prediction of time constraints for the implementation of technological operations in them.

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

Many research and methodological works [1 - 19] are devoted to the study of the tendencies of occurrence and influence of subject-agrometeorological events on the flows of requirements for the implementation of mechanized operations in the technological processes of cultivating grain crops. In particular, the causative and consequential connections between events and mechanized operations of partial soil cultivation processes [1, 2], integrated soil cultivation and winter crop sowing [3, 4], protection of plants by spraying [5], collection and after-harvest treatment of crop crops [6-19].

OBJECTIVE

The purpose of this study is to reveal the methodological principles of modeling the time of occurrence of subject-agrometeorological events in the technological processes of cultivating grain crops, which will enable to increase the efficiency of planning these processes by taking into account the stochastic influence of these events.

THE MAIN RESULTS OF THE RESEARCH

Analysis of agrotechnological requirements for the cultivation of grain crops made it possible to indicate two main periods of operations and works in the technological processes of cultivating grain crops - spring-summer and summer-autumn [12]. In the spring-summer period technological processes are considered: soil cultivation, sowing of spring crops, care of crops (chemical protection of plants). In the summer-autumn period - harvesting of predecessor, pre-planting of soil, winter wheat seed production.

The peculiarity of the technological processes of cultivating grain crops is that the probabilistic nature of the occurrence of subject-agrometeorological events during their course of time determines the possibility and feasibility of their implementation. Without a thorough analysis of these events it is not possible to ensure the harmonization of technological processes and their effective implementation. Creation and use of computer models of occurrence of subject-agrometeorological events in technological processes will allow to predict the time constraints of the characteristics of flow of orders for their execution.

Subject-agrometeorological events that affect the flow of technological processes of growing crops can be divided into two groups: the first - events that determine the timing of their implementation, the second is the events that cause the suspension and restoration of their execution. Under the influence of these events, funds are formed for the implementation of these processes. The probabilistic nature of the occurrence of agrometeorological events determines the variability in the duration of mechanized operations of the technological processes of growing these crops, both within one year for different regions and within the same region in different years.

The analysis of subject-agrometeorological events in the technological processes of cultivating grain crops (Table 1) shows the following. For the spring-summer period of the implementation of technological processes of cultivating grain crops, there are eight main events, and for the summer-autumn six. Each of the subject-agrometeorological events reflects the action of a limited set of factors that influence the performance of these technological processes. In addition, the content of the effect on the course of technological processes of growing crops of each of the indicated events is different. It should be noted that the frequency of the occurrence of events in these processes, they can be divided into seasonal, which are characterized by a single appearance in a separate season and daily - arise (may arise) every day of the season.

In order to take into account the probabilistic nature of the subject-agrometeorological events of the spring-summer and summer-autumn periods, as well as their influence on the course of technological processes of growing of grain crops, it is expedient to use a statistical simulation modeling of these processes. In particular, in this case, a discrete-event approach to modeling can be used [11].

For this purpose, generalized algorithms for the modeling of subject-agrometeorological events in the process of functioning of arable technological processes in the spring-summer (Figure 1) and summer-autumn (Figure 4) periods have been developed.

Table 1. Analysis of subject-agrometeorological events in the technological processes

№	Period of implementation of mechanized operations of technological processes	Event name	Displays the effect of factors *	Content of influence on the course of technological processes	Classification the periodicity of occurrence in the technological processes
1	2	3	4	5	6
1	Spring-summer period	The onset of physical maturation of the soil	Am, Pp, Tl	Determines the beginning of mechanized soil cultivation operations	Seasonal
2		Heat the soil to the temperature of the sowing	Am, Pp, Tl	Determines the beginning of the implementation of sowing of spring cereal crops	Seasonal
3		The onset of phenological phases of plant development	Am, Pp, Tl	Identify the beginnings of works on chemical protection of plants	Seasonal
4		Precipitation fall	Am, Pp, Tn	Determines the possibility of mechanized operations	Daily

Continuation of Table 1

1	2	3	4	5	6
5	Spring-summer period	The onset and completion of the light period of the day	Am, Tn	Determines the possibility of performing mechanized chemical protection plant operations	Daily
6		Excess air temperature 25^{o}C	Am, Pp, Tl		Daily
7		The dew disappear	Am, Pp, Tl		Daily
8		Excess wind speed 5 m/s	Am, Pp, Tl		Daily
9	Summer-autumn period	Ripening of the predecessor	Am, Pp	Specifies the start of collecting a predecessor on a given field	Seasonal
10		Completion of harvesting predecessor	Pp, Tn	Determines the possibility of pre-planting soil cultivation	Seasonal
11		Precipitation fall	Am, Pp, Tn	Determine the possibility of performing soil-sowing operations	Daily
12		Completion of pre-planting soil cultivation	Pp, Tn	Determine the possibility of seeding winter crops	Seasonal
13		Completion (predicted) set of cultures of the required amount of active daily average temperatures	Am, Pp, Tl	Determine the time when sowing winter crops needs	Seasonal
14		Completion of time fund tilling winter crops	Am, Pp	Determine the deadlines for the sowing of winter crops, in which the continuation of works is economically inexpedient	Seasonal

* - Am, Pr, Tl, Tn - respectively agrometeorological, subject,, technological and technical groups of factors [13].

In the first stage (Figure 1) the simulation of the time of occurrence of subject-agrometeorological events substantiates the number of implementations of the computer model to ensure its required accuracy and specifies the characteristics of the natural-production conditions (geographical location and characteristics of the production plan) of agricultural producers (AP).

At the second stage (Figure 1), the time of occurrence of physical soil maturity (PMS) (τ_{pms}) is generated. In particular, for the conditions of the L'viv region of Ukraine, the time distribution of the physical soil maturity is consistent with the normal distribution law by an adjusted polynomial, the main statistical characteristics of which are: $\bar{M}[\tau_{pms}]$ = 85,6 days, $\bar{\sigma}[\tau_{pms}]$ = 13.4 days [1]. At the third stage (Fig. 1), the time for the restoration of spring vegetation (τ_{rsv}) of winter cereal crops is generated.

Based on the statistical processing of the retrospective data on the time of restoration of spring vegetation (τ_{rsv}) of winter crops in Ukraine, we have established that their distributions are consistent with the normal law and are described by different equations of distribution density (Figure 2). At stage 6 (Figure 1), the duration of the weathered and subtropical intervals of time in the interval from the moment of physical soil maturity to the time of the end of the sowing of heat-loving grain crops is generated.

At the seventh step (Figure 1), the actual timeframe is determined for pre-sowing tillage and sowing of spring cereal crops. For example, the estimation of the mathematical expectation of the time of restoration of spring vegetation of winter grain crops for the conditions of the Lviv region of Ukraine $\bar{M}[\tau_{rsv}] = 90,32\,\text{days}$, and the mean square deviation $\bar{\sigma}[\tau_{rsv}]=14,23$days (Fig. 2, a). For the conditions of the Kherson region Ukraine: $\bar{M}[\tau_{rsv}]=91,37$days, $\bar{\sigma}[\tau_{rsv}]=6,99$ days (Fig. 2, b).

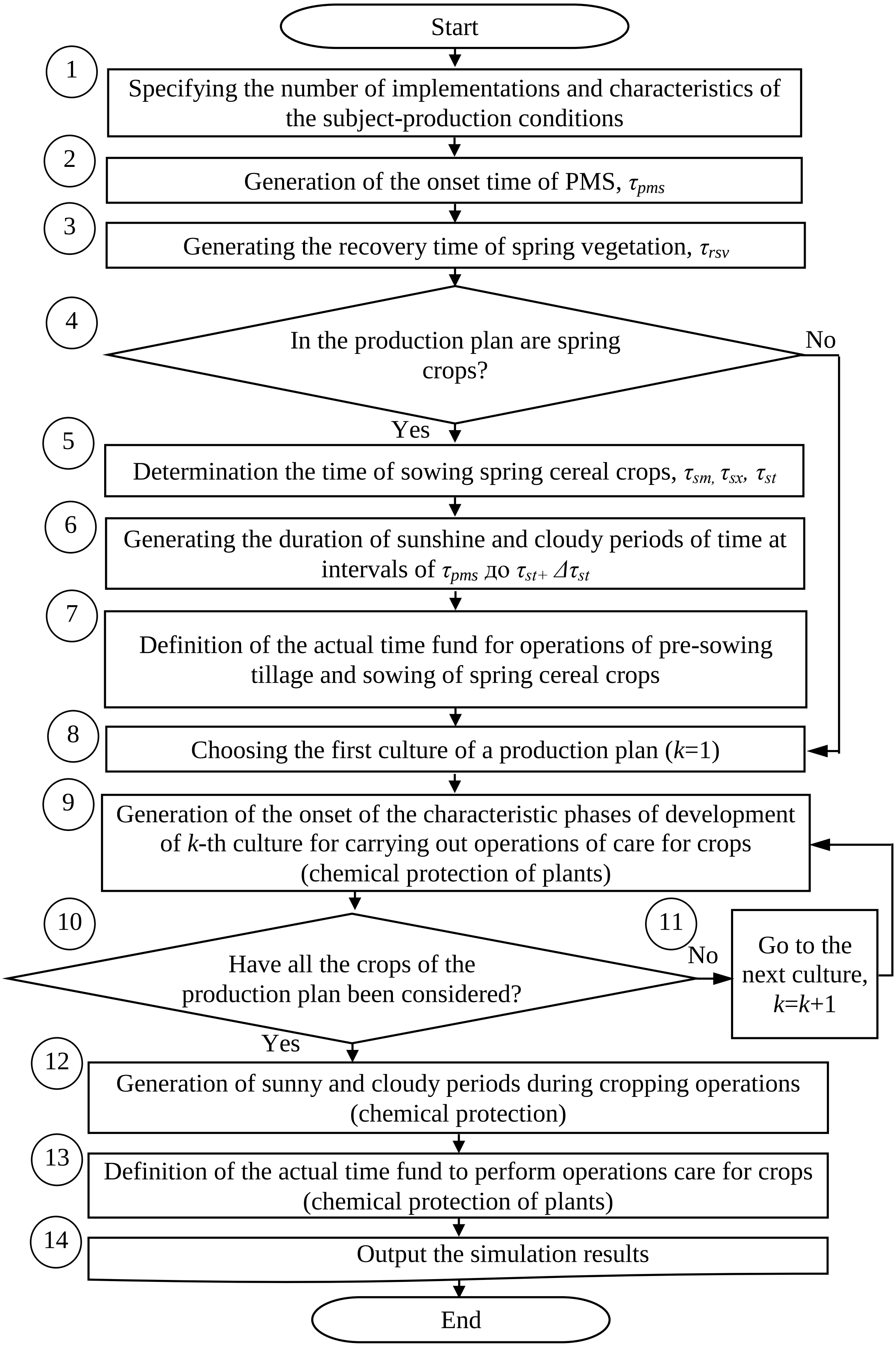
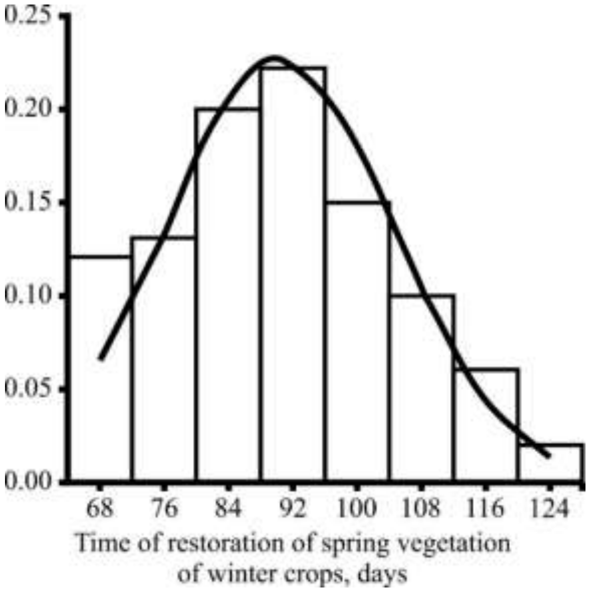


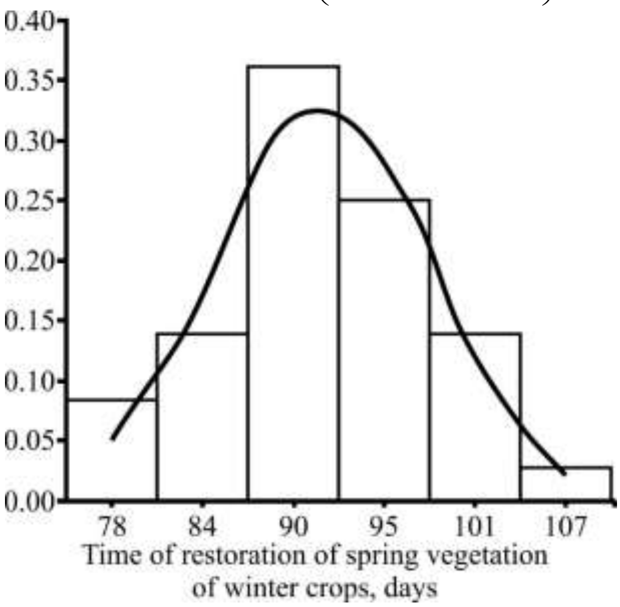
Fig. 1. A generalized algorithm for modeling the occurrence of subject-agrometeorological events in mechanized processes of arable farming in the spring-summer period

$$f\left(\tau_{rsv}\right)=0,03\times\exp\left(-\frac{\left(\tau_{rsv}-90,32\right)^2}{202,6}\right)$$



a)

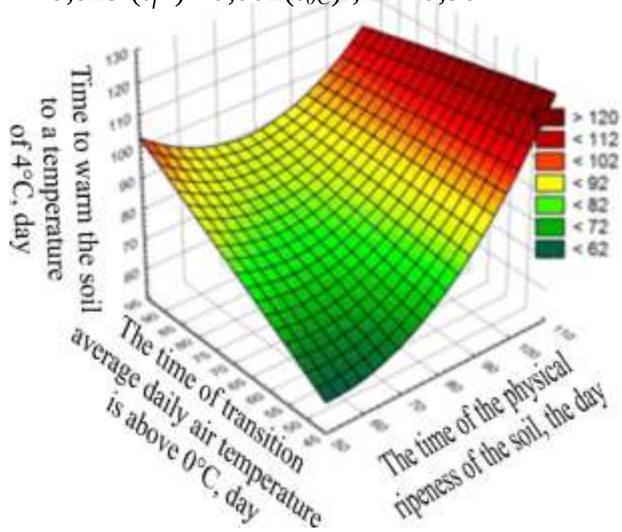
$$f\left(\tau_{rsv}\right)=0,04\times\exp\left(-\frac{\left(\tau_{rsv}-87,27\right)^2}{126,37}\right)$$



b)

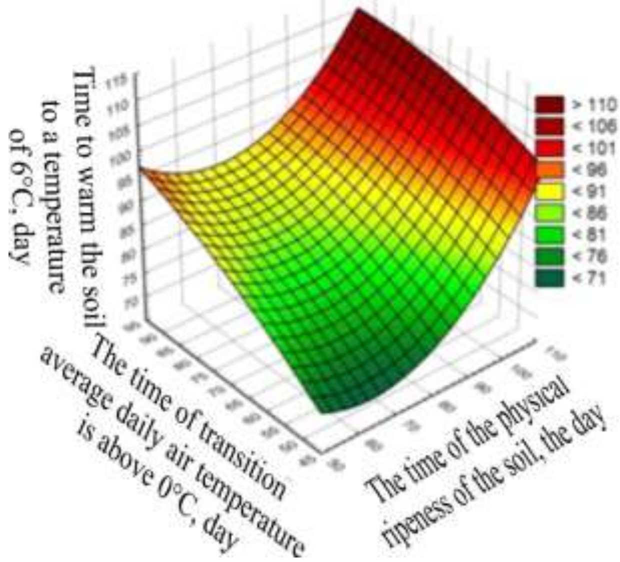
Fig. 2. Distribution of the time of restoration of spring vegetation of winter grains in agrometeorological conditions of L'viv (a) and Kherson (b) regions of Ukraine.

$$\tau_{4C} = 26,58 -1,07\, \tau_f^{\,n} + 1,88\, \tau_{0C} -0,019\, \tau_{0C}\cdot\tau_f^{\,n} +0,019\, (\tau_f^{\,n})^2 -0,001(\tau_{0C})^2;\ R^2=0,96$$



a)

$$\tau_{6C} = 78,05 +1,51\, \tau_f^{\,n} + 1,21\, \tau_{0C} -0,005\, \tau_{0C}\, \tau_f^{\,n} +0,014\, (\tau_f^{\,n})^2 -0,004(\tau_{0C})^2;\ R^2=0,87$$



b)

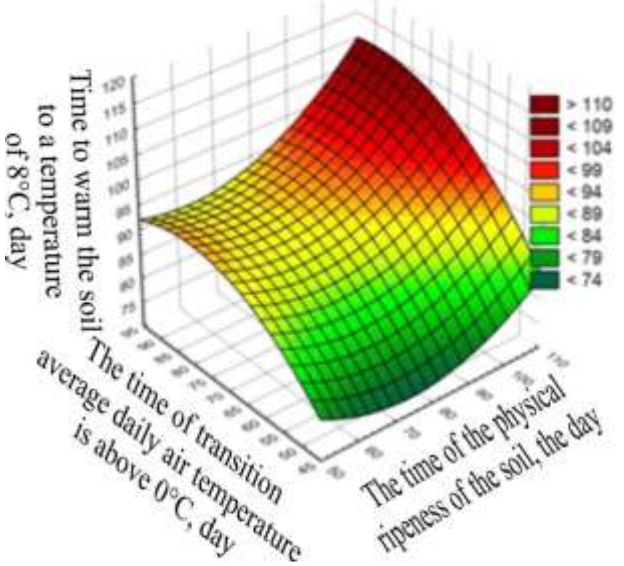
Fig. 3. Change in the duration of soil warming at a depth of 10 cm from the time of its physical maturity and the time of transition of the average daily temperature of air above 0°C in the spring to the temperature:

a) 4°C,

b) 6°C,

c) 8°C (for the conditions of the Lviv region of Ukraine)

$$\tau_{8C} = 68,44 - 1,46\,\tau_f^{\,n} + 1,87\,\tau_{0C} - 0,004\,\tau_{0C}\cdot\tau_f^{\,n} + 0,009\,(\tau_f^{\,n})^2 - 0,013(\tau_{0C})^2;\; R^2 = 0,57$$



c)

Fig. 3. Change in the duration of soil warming at a depth of 10 cm from the time of its physical maturity and the time of transition of the average daily temperature of air above 0°C in the spring to the temperature

In the fourth stage (Figure 1), the presence of spring cereal crops in the production plan of the AP is checked. If spring crops are available, then proceed to stage 5, if not - go to step 8.

The fifth stage (Figure 1) provides for the calculation of the time of sowing of spring crops, which depends on the time of soil warming at a depth of 10 cm to the required temperature of crop sowing.

For its forecasting, regularities of the change in the duration of soil warming at 10 cm depth from the time of its physical maturity and the time of transition of the average daily temperature of air above 0 ° C in the spring period to temperatures of 4 ° C (possibility of sowing frost-resistant crops) were established, 6°C (possibility of sowing cold-resistant crops) and 8°C (possibility of sowing thermophilic cultures) for different regions of the state.

In particular, for the agro-meteorological conditions of the L'viv region of Ukraine, the indicated dependencies presented in Figure 3.

Next (stage 8) the first grain crop is selected from the given production plan of agricultural commodity producers, for which the time onset of phenological phases of development of plants is generated (step 9).

The dependence of the onset of the phenological phases of the development of spring and winter grains on, respectively, the time of their sowing and the restoration of spring vegetation (for the conditions the L'viv region of Ukraine) is disclosed in the paper [5].

At the tenth stage (Fig. 1) the condition is checked whether all crops of the production plan are considered. If not for all cultures, the time of the onset of the phenological phases of the development of plants is generated, the transition to the next culture (step 11) and the return to the stage 9 are carried out. If for all - we pass to the stage 12, on which (Figure 1) the appearance and duration of the algae and low season periods based on statistical regularities of their appearance and duration in the process of performing cropping operations (chemical protection of plants) for agrometeorological conditions of a given region of agricultural commodity producers [2, 10, 12].

The final stages of modeling the occurrence of subject-agrometeorological events in the technological processes of cultivation grain crops in the spring-summer period (Figure 1) is the definition of the actual time fund for the implementation of cropping operations (chemical protection of plants) (stage 13) and the output of the simulation results (stage 14).

The analysis of the technological processes of cultivation grain crops of summer-autumn period makes it possible to assert that the time constraints on their implementation depend on the timeliness of implementation of mechanized processes in the spring and summer period. In particular, the probabilistic nature of the timing of reaching winter crop precursors and the timeliness of harvesting their crops (spring-summer period) determine the need for pre-planting of the soil (summer-autumn period). The time for the pre-sowing cultivation of the soil is due to the need to sow winter crops. In turn, the need to sow winter cereals is determined by the conditions of their autumn vegetation.

Winter cereals are recommended to sow so that, before the beginning of winter, provide a set of plants with the required amount of effective daily average temperatures. Under such conditions, the crop manages to develop into the phase of planting and undergo quenching by the action of low temperatures, which is an important prerequisite for its wintering and productive development in the next spring vegetation [1, 4, 13].

The time interval between the completion of harvesting of the predecessor and the time of emergence of winter crop sowing needs is characterized by the timeframe for pre-sowing tillage in the summer-autumn period.

The influence of subject-agrometeorological events in the technological processes of cultivation grain crops the summer-autumn period cultivation on the formation of time-based funds for the implementation of individual operations of these processes has been taken into account and reflected in the algorithm for simulating the occurrence of these events in a separate day and during the season (Figure 4).

In the first stage (Figure 4), the simulation of occurrence subject-agrometeorological events in the technological processes of the summer-autumn period justifies the number of implementations of the computer model to provide the necessary accuracy of the output data, as well as the characteristics of the natural and production conditions (geographical location and characteristics of the production plan of AP).

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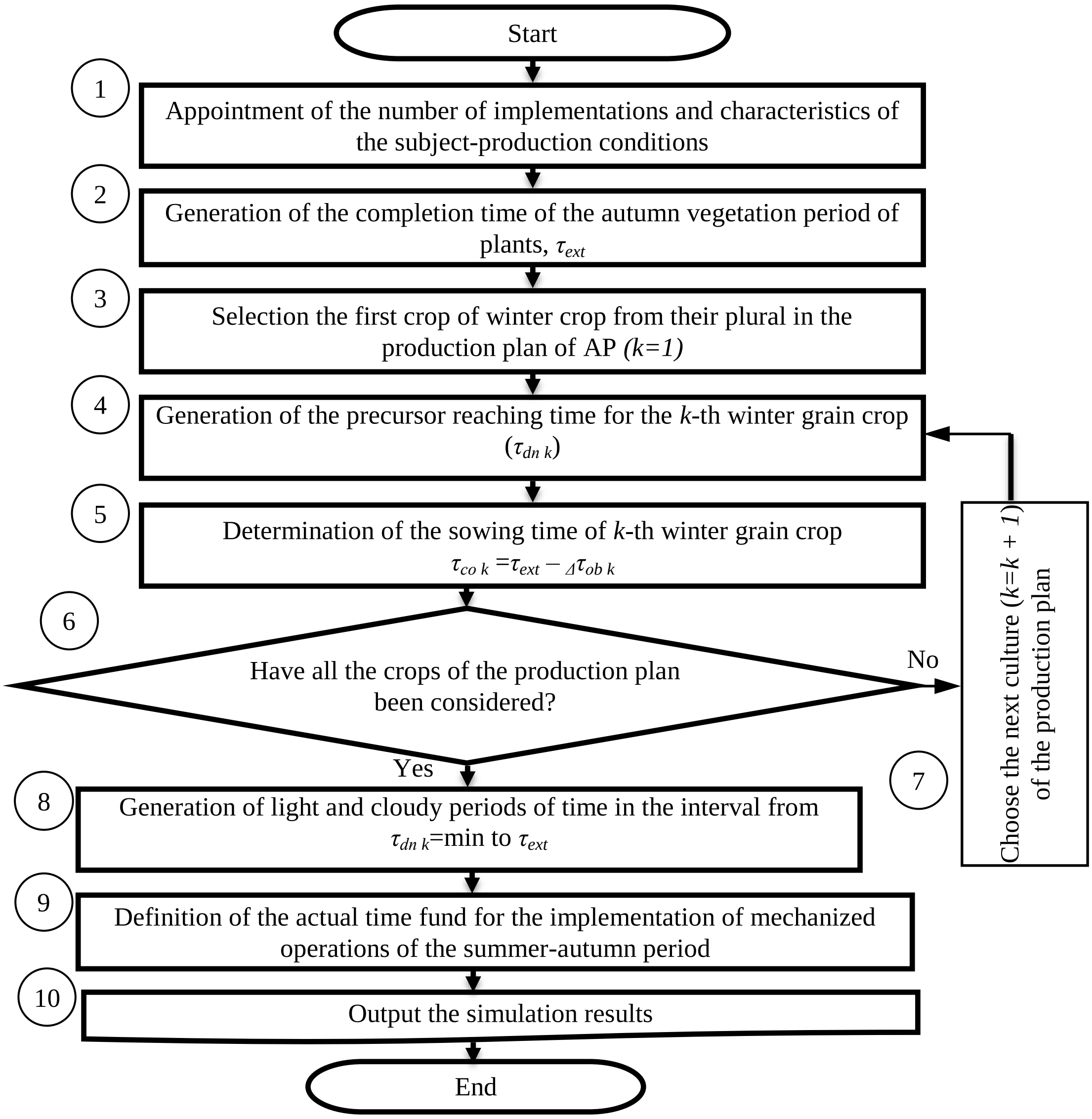

Fig. 4. A generalized algorithm for modeling the occurrence of subject-agrometeorological events in the technological processes of cultivation grain crops the summer-autumn period.

$$f(\tau_{ext}) = 0,075\left(\frac{\tau_{ext}-285}{25,131}\right)^{0,887}\exp\left[-\left(\frac{\tau_{ext}-285}{25,131}\right)^{1,887}\right]$$

$$f(\tau_{ext}) = 0,064\left(\frac{\tau_{ext}-294}{23,967}\right)^{0,545}\exp\left[-\left(\frac{\tau_{ext}-294}{23,967}\right)^{1,545}\right]$$

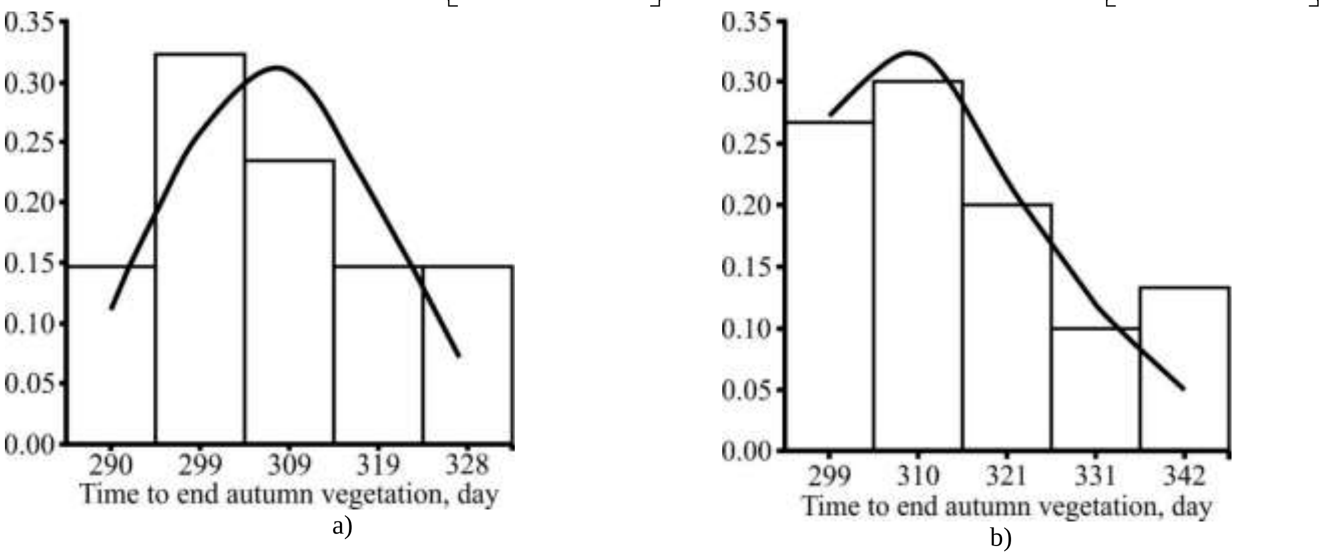

Fig. 5. Distribution of the time of completion of the autumn vegetation of winter grains in the agro-meteorological conditions of the Lviv (a) and Kherson (b) regions of Ukraine.

Table 2. Statistical characteristics of the time distribution of the achievement of characteristic predecessors of winter cereal crops.

Indexes	Distribution density function	M[t], day	σ[t], day
L'viv region			
Date of the set of 1200°C of active temperatures (roughly, reaching the winter barley, winter rye)	$f\left(t_{1200}\right)=0,05\times\exp\left(-\frac{\left(t_{1200}-180,7\right)^2}{109,52}\right)$	180,7	7,4
Date of the set of 1500°C of active temperatures (roughly, reaching the potatoes)	$f\left(t_{1500}\right)=0,01\times\exp\left(-\frac{\left(t_{1500}-197,2\right)^2}{100,6}\right)$	197,2	7,1
Date of the set of 1700°C of active temperatures (roughly, reaching the oats)	$f\left(t_{1700}\right)=0,05\times\exp\left(-\frac{\left(t_{1700}-208,2\right)^2}{115,52}\right)$	208,2	7,6
Date of the set of 2200°C of active temperatures (roughly, reaching the corn for silage)	$f\left(t_{2200}\right)=0,01\times\exp\left(-\frac{\left(t_{2200}-235,2\right)^2}{182}\right)$	235,3	9,0
Kherson region			
Date of the set of 1200°C of active temperatures (roughly, reaching the winter barley, winter rye)	$f\left(t_{1200}\right)=0,08\times\exp\left(-\frac{\left(t_{1200}-167,7\right)^2}{56,18}\right)$	167,7	5,3
Date of the set of 1500°C of active temperatures (roughly, reaching the potatoes)	$f\left(t_{1500}\right)=0,08\times\exp\left(-\frac{\left(t_{1500}-182,3\right)^2}{54,8}\right)$	182,3	5,2
Date of the set of 1700°C of active temperatures (roughly, reaching the oats)	$f\left(t_{1700}\right)=0,07\times\exp\left(-\frac{\left(t_{1700}-191,2\right)^2}{58,32}\right)$	191,2	5,4
Date of the set of 2200°C of active temperatures (roughly, reaching the corn for silage)	$f\left(t_{2200}\right)=0,06\times\exp\left(-\frac{\left(t_{2200}-212,2\right)^2}{83,1}\right)$	212,6	6,5

The next step (stage 2 of figure 4) is the generation of the end time of the autumn winter growth of winter crops. For this purpose, the distributions of the time of completion of the autumn winter vegetation period of winter crops in the agro-meteorological conditions of all regions of Ukraine were constructed and their statistical characteristics were determined. It was established that the distribution of the time of completion of the autumn vegetation period of winter grain crops is consistent with the theoretical law of the distribution of Weibull (Figure 5).

For example, an estimation of the mathematical expectation of the completion time of the autumn vegetation duration for the conditions of the Lviv region of Ukraine $\bar{M}[\tau_{ext}]=307,3\text{days}$, and the mean square deviation $\bar{\sigma}[\tau_{ext}]=12,2\text{days}$ (Figure 5, a). For conditions of the Kherson region of Ukraine $\bar{M}[\tau_{ext}]=315,6\text{days}$, $\bar{\sigma}[\tau_{ext}]=14,1\text{days}$ (figure 5, b).

The third stage (Figure 4) assumes the choice of the first winter crop (k = 1) from the given production plan of the agricultural producer, and the next (stage 4) generates the time of reaching the predecessor ($\tau_{dn\,k}$) for the k winter crop. For this purpose, the statistical characteristics of the time distribution of the achievement of characteristic predecessors of winter grain crops in agrometeorological conditions of all regions of Ukraine were determined. For comparison, the statistical characteristics of the time distribution of the characteristic predecessors of winter cereal crops in the agro-meteorological conditions of the L'viv and Kherson regions of Ukraine shown in Table. 2

At stage 5 (Figure 4), the time of sowing of the k-th winter grain crop ($\tau_{co\,k}$) is determined, taking into account the condition of its recruitment of the required amount of active temperatures until the end of autumn vegetation:

$$\tau_{co\,k}=\tau_{ext}-\Delta\tau_{ob\,k}\,, \tag{1}$$

where: $\Delta\tau_{ob\,k}$ – the term for which the winter culture will collect the required amount of active temperatures.

At stage 6 (Figure 4), an examination is made of whether all winter crops of the farmer's production plan are considered. If so, go to the next stage 8, if not - select the next culture (stage 7) and return to stage 4.

The eighth stage (Figure 4) provides for the generation of weathered and cloudy periods of time during a period of time from reaching predecessor of a given winter crop until the end of the autumn vegetation period of the given winter crop.

These intervals are generated on the basis of statistical regularities of their appearance and duration in the specified period for the conditions of a given region [2, 10, 12].

At stage 9 (figure 4), based on the information received earlier, the actual time frame for performing mechanized operations for each crop is determined, as well as the tense periods of their implementation. Finally, the output of the obtained simulation results is performed (stage 10, figure 4).

Thus, the developed scientific and methodological principles of modeling of subject-agrometeorological events in the technological processes cultivation grain crops fully take into account the peculiarities of the course of these processes in the spring-summer and summer-autumn periods, the regularities of the appearance of subject-agrometeorological events and their influence on the formation of funds for the time of mechanized operations.

CONCLUSIONS

1. The analysis of subject-agrometeorological events in the technological processes cultivation grain crops made it possible to classify them in terms periodicity of appearance, as well as to indicate the content of the influence of each of them on the course of these processes, which made possible the development of algorithms for simulating the occurrence of these events in these processes.

2. The statistical characteristics of the distribution of the time of the restoration of spring vegetation, the completion of the autumn winter vegetation period of winter crops, the time to reach their characteristic predecessors, as well as the regularities of the change in the duration of soil warming in different agrometeorological conditions of the regions of Ukraine, make it possible to predict (generate) the onset of phases of plant development and time Restrictions on the implementation of mechanized operations in the technological processes cultivation grain crops in the specified natural and production conditions of individual agricultural of the commodity producers.

3. The developed scientific and methodological principles of modeling of subject-agrometeorological events in the technological processes cultivation grain crops are the basis for the creation of their computer models, the practical use of which will enable to predict time limits for the implementation of technological processes and the characteristics of orders flows for their implementation.

REFERENCES

1. **Sydorchuk O., Lub P. 2004.** Naturally allowed time for spring soil preparation to sow. Herald of L'viv State Agrarian University: Agroengineering research. L'viv. No. 8 9-16.

2. **Sydorchuk O. V., Senchuk S. R., Lub P. V. Kabar V. V. 2004.** Stochastic phenomena in models of mechanized cultivation and harvesting of cereals. Mechanization and electrification of agriculture. Glevaha Issue 85. 265-269.

3. **Sydorchuk O., Lub P., Ivasiuk I., Ukrainets V. 2009.** Identification of events in soil cultivation and crop sowing. Herald of L'viv National Agrarian University. Agroengineering research. L'viv. No. 13. Volume 2. 13-21.

4. **Lub P. M., Dnes V. I., Ukrainets V. A., Ivasiuk I. P. 2010.** Features of production and technological risk management in soil cultivation and crop sowing projects. East European Magazine of Advanced Technology. No. 1 (43). 58-60.

5. **Sydorchuk O. V., Tryhuba A. M., Paniura Ya. Yo., Sholudko P. V. 2010.** Peculiarities of situational management of content and time of execution of works in integrated projects of agrarian production. East European Journal of Advanced Technology. No. 1/2 (43). 46-48.

6. **Sydorchuk O. V., Lub P. V., Spichak V. S. 2009.** Agrometeorological component of basic events in the project of centralized harvesting of sugar beet. Herald of L'viv National Agrarian University. Agroengineering research. L'viv. No. 13, vol. 1. 8-12.

7. **Sydorchuk O. V., Dnes V. I., Skibchyk V. I. 2011.** A number of major events and the peculiarities of their planning in harvesting early grain crops. Mechanization and electrification of agriculture. Inter-departmental thematic scientific collection. Glevakha. Issue 95. 375-384.

8. **Sydorchuk O. V., Dnes V. I., Skibchyk V. I. 2011.** Analysis of research methods and case models in projects at different stages of early grain harvest planning. Computer-integrated technologies. Education, science, production. Scientific journal of Lutsk National Technical University. Lutsk. No. 7. 141 - 144.

9. **Sydorchuk O. V., Skibchyk V. I. 2012.** Forecasting the basic events of the internal environment of harvesting early grain, oilseed and legume crops. Computer-integrated technologies. Education, science, production. Scientific journal of Lutsk National Technical University. Lutsk. No. 10. 232-237.

10. **Sydorchuk O. V., Dnes V. I., Skibchyk V. I. 2016.** Analysis of the process of forming a daily organizationally-adjusted working time fund for post-harvest grain processing. Prospects and tendencies of development of structures and technical service of agricultural machines and tools. Abstracts of the II All-Ukrainian Scientific and Practical Conference of the Zhytomyr Agro-technical College. Zhytomyr. 61-64.

11. **Sydorchuk O. V., Dnes V. I., Skibchyk V. I. 2016.** An approaching approach to the modeling of agrometeorological conditions during the harvesting of early grain crops. Mathematical and simulation systems simulation. MODS 2016. theses of the endings of the Eleventh International Scientific and Practical Conference (Zhukin, June 27 - July 1, 2016). Chernigov. 59-63.

12. **Kudrynetskyi R. B., Hrytsyshyn M. I. 2015.** Substantiation of effective technological complexes of machines for the production of crop production in agricultural enterprises. Mechanization and electrification of agriculture. Inter-departmental thematic scientific collection. Glevakha. Issue 1 (100). 250-259.

13. **Adamchuk V. V., Sydorchuk O. V., Lub P. V. 2014.** Planning of agricultural crop projects on the basis of statistical simulation: monograph. Nizhyn 223 c.

14. **Kudrynetskyi R. B. 2014.** Deterministic model of planning of mechanized works in agrarian enterprises of Ukraine. Mathematical and simulation systems simulation. MODES 2014: thesis of reports of the Ninth International Scientific and Practical Conference (Kyiv-Zhukin, June 23-27, 2014). Chernigov. 112-115.

15. **Kudrynetskyy R. 2017.** Rationale of parameters of technical support crop production. International scientific journal "Mechanization in agriculture & conserving of the resources". Sofia, Bulgaria. Issue 1. 18-21.

16. **Kudrynetskyy R., Dnes, V., Skibchyk V. 2017.** Methodical bases for selecting parameters of post-harvest grain processing points based on statistical simulation. International scientific conference "Concerving soils and water" 30.08-02.09.2017. Burgas, Bulgaria. Scientific technical union of mechanical engineering "INDUSTRY 4.0" year 1. Issue 1 (1). September 2017. 109-112.

17. **Kudrynetskyi R. B. 2017.** Concerning the scientific and methodological principles of determining the technical and operational indices of machine-tractor aggregates. Mechanization and electrification of agriculture. Inter-departmental thematic scientific collection. Glevakha. Issue 6 (105). 216-226.

18. **Kudrynetskyi R. B. 2007.** Substantiation of technological complexes of machines for crop production. National inter-departmental thematic scientific collection. Design, manufacture and operation of agricultural machines. KNTU. Issue 37(1). 240-244.

19. **Kudrynetskyi R. B. 2006.** Optimization of expenses of material and technical and energy resources in the production of grain crops. Herald of L'viv National Agrarian University. Agroengineering research. L'viv. No.10. 81-86.

20. **Rogovskii Ivan. 2017.** Choice of model class and method of modeling the resilience of agricultural machinery. TEKA. An International Quarterly Journal on Motorization, Vehicle Operation, Energy Efficiency and Mechanical Engineering. Lublin–Rzeszów. Vol. 17. No 3. 101-114.

21. **Kalinichenko Dmytro, Rogovskii Ivan. 2018.** Method for Determining Time of next Maintenance of Combine Harvesters. TEKA. An International Quarterly Journal on Motorization, Vehicle Operation, Energy Efficiency and Mechanical Engineering. Lublin–Rzeszów. Vol. 18. No 1. 105-115.

МЕТОДИЧЕСКИЕ ОСНОВЫ МОДЕЛИРОВАНИЯ ПРЕДМЕТНО-АГРОМЕТЕОРОЛОГИЧЕСКИХ СОБЫТИЙ В ТЕХНОЛОГИЧЕСКИХ ПРОЦЕССАХ НА ВЫРАЩИВАНИИ ЗЕРНОВЫХ КУЛЬТУР

Аннотация. В статье отмечено и классифицированы предметно-агрометеорологические события в технологических процессах на выращивании зерновых культур, установлено статистические характеристики распределений времени возникновения и продолжительности этих событий, раскрыто методические основы и разработаны алгоритмы их моделирования. Во время исследований были использованы методы анализа и синтеза, системно-факторных и системно-событиевых подходов к исследованию технологических процессов при выращивании зерновых культур. Для разработки алгоритмов моделирования этих технологических процессов были использованы дискретно-событиевый подход. Проведенный анализ предметно-агрометеорологических событий в технологических процессах при выращивании зерновых культур позволил классифицировать их по времени и периодичностью появления, а также обозначить содержание влияния каждой из них на ход этих процессов, что позволило разработки алгоритмов моделирования возникновения указанных событий в вышеуказанных технологических процессах. Установлены статистические характеристики распределений времени возобновления весенней вегетации, завершение продолжительности осенней вегетации озимых зерновых культур, времени созревания их характерных предшественников, а также закономерности изменения продолжительности прогрева почвы в различных агрометеорологических условиях регионов Украины позволяют прогнозировать (генерировать) наступления фаз развития растений и временные ограничения на выполнения механизированных операций в технологических процессах полеводства при заданных природно-производственных условий отдельных сельхозтоваропроизводителей. Разработанные научно-методические основы моделирования предметно-агрометеорологических событий в технологических процессах полеводства лежат в основе создания их компьютерных моделей в технологических процессах полеводства, практическое использование которых позволит прогнозировать временные ограничения выполнения механизированных операций и характеристики потоков заказов на их выполнение.

Ключевые слова: предметно-агрометеорологические события, технологические процессы земледелия, механизированные операции, моделирование.

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Methodology of Experimental Research of Hydroseeding Process of Gemitated Grain

Stanislav Deyneka[1], Leonid Aniskevich[1], Serhii Kushnarov[2], Olexander Kovalov[3]

[1]National University of Life and Environmental Science of Ukraine.
E-mail: deyneka5555@ukr.net, L-anisk@meta.ua
[2]Nizhyn Agrotechnical Institute.
E-mail: alekstdaty1979@gmail.com
[3]Tavria State Agrotechnologigal University.
E-mail: alekstdaty1979@gmail.com

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Summary. The population of Ukraine is not provided with a sufficient number of vegetables. Insufficient amount of moisture in spring needs to improve the technology of vegetable crops sowing.

The work is devoted to the experimental study of the possibility to seed sprouted vegetable grain together with liquid. The article deals with the process of hydroseeding of germinated grain in which the most effective working parameters of the hydroseeder are realized. A new technological scheme for mixing of the seed mixture without traumatization of sprouters with the help of a mixing chamber of aerodynamic action is studied.

The proposed designs of hydroseeders and sowing machines due to their imperfections did not find implementation into production. The analysis of existing structures indicates that the degree of their introduction is the result of low evenness of seeding and high damaging of sprouts.

The experimental research program includes determination of the even distribution of seeds in the mixing chamber in the conditions of various air pressures and water levels in the chamber, determination of the evenness of seeding depending on the number of seeds in the mixing chamber, determination the seed lifting speed depending on the size characteristics, determination of the optimal loss rate of the water and seed mixture in the hydroseeding process.

The article deals with the materials of laboratory tests of the stationary experimental model of the hydroseeding apparatus. The research was conducted in the stationary mode with the use of modern equipment and methods of conducting scientific studies with the help of computer technologies. The purpose of experiments includes the definition of empirical coefficients that are determined by the test results. On the base of the conclusions on the article materials it is possible to develop of an optimal field research plan which can confirm the scientific hypothesis of the dependence of the evenness of seeding of germinated grain on the evenness of their distribution in the mixing chamber.

The interconnection of the structural and technological parameters of the seeding process of the hydromixture with the efficiency of the technological process is experimentally proved.

Key words: experiment, plan of the experiment, installation, factor randomization, empirical coefficients.

INTRODUCTION

The programme of experimental research includes determination of the even distribution of seeds in the mixing chamber in the conditions of various air pressures and water levels in the chamber, determination of the evenness of seeding which depends on the number of seeds in the mixing chamber, determination the seed lifting rate depending on the size characteristics, determination of the optimal flow rate of the water and seed mixture in the hydroseeding process.

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

The scientific researches [1-21] are devoted to the design of the hydroseeding apparatus, which would allow the seeding of germinated seeds with simultaneously irrigation in small doses of water.

Uninvestigated parts of general matters defining. V.F. Pashchenko and other authors proposed a method of seeds placing into the soil and a device for its implementation, which transports the seeds to the coulter by a liquid flow under pressure from the hydraulic pump. The disadvantage of this process is inability to plant the germinated seeds.

A well-known hydraulic seeding machine of such authors as M.F. Olkhovskyi and S.V. Halimonenko includes a tank with an agitator placed in it (the tank has an outlet which is equipped with a locking device installed in the distribution chamber), a control system that is installed in direct brackets with the possibility of vertical displacement of a spring loaded container. The disadvantages of these hydroseeder is an unstable regulatory effect on the pouring of water and seeds mixture. This sowing machine is unsatisfactory in open ground.

The patent search and the review of literary sources allowed revealing other models of hydroseeders. However, the proposed designs of hydroseeders and sowing machines due to their imperfections did not find implementation into production. The analysis of existing models indicates that the degree of their introduction is the result of low evenness of seeding and high damaging of sprouts.

OBJECTIVE

Purpose of the article is theoretical investigation of the hydroseeding process of fine vegetable germinated seeds.

THE MAIN RESULTS OF THE RESEARCH

The experimental research program includes determination of the even distribution of seeds in the mixing chamber in the conditions of various air pressures (α) and water levels in the chamber (β), determination of the evenness of seeding depending on the number of seeds in the mixing chamber, determination the seed lifting speed depending on the size characteristics, determination of the optimal loss rate of the water and seed mixture in the hydroseeding process.

To determine the even distribution of seeds in the volume of liquid under the action of air bubbles, we need to know their relative position with respect to each other.

The information on the theoretical and experimental determination of the distances between the seeds relative to the X, Y, Z axes and the effect on their values of the air pressure parameters and the liquid level in the chamber (α and β) was not found in special publications. For an analytical solution of the equation of kinematics of seeds in a liquid, we need to determine experimentally the nature of the movement of seeds in the liquid under the influence of air pressure, velocity, and the trajectory of their ascent.

To determine the trajectory and the ascending speed depending on the air pressure delivered through the perforated bottom of the chamber, we developed a laboratory-field unit that meets the following requirements:

1. The unit is provided with pressure control and the control of the size of the holes in the perforated bottom of the mixing chamber (the size of the holes A in the range 1-2 mm and the air pressure B in the range 0.1-0.6 atm.).

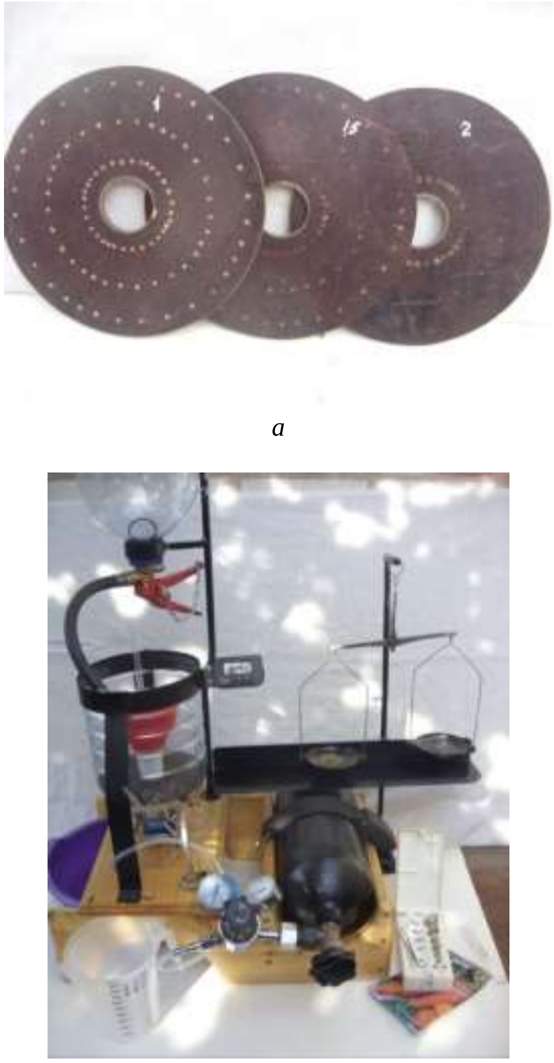
2. In the course of the experiment it is provided:

- the measurement of seed ascending speed (measurement error is 0.1 s),
- the measurement of the density of the liquid,
- the measurement of travelling speed v_n unit,
- the measurement of the process of seed distribution in the volume of the liquid.

3. Registration of information is carried out using a laptop with software for further information processing.

To install various perforated discs and maintain air pressure, the design of the unit has been constructed, providing the necessary range of factors A and B (Fig. 1).

To measure the lifting speed of seeds a measurable bulb with photodetectors was made. The photodetectors record the time of seeds lifting in the range of 0,8-20 Hz to within 5%.



a

b

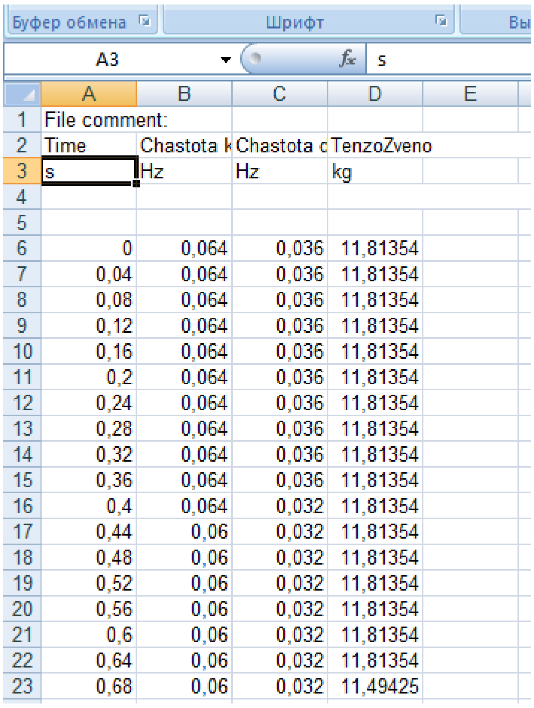
Fig. 1. The design concept of the unit a - the replacement of perforated discs of the bottom of the mixing chamber b- the regularity of the air pressure β.

Fig. 2. Installation of WEB-cameras.

For a visual observation of the process of interaction of seeds with air bubbles on a frame, the Microsoft Life Cam VX-70 webcam is rigidly mounted (Fig. 2)

All information from the sensors is translated into a digital code using the digital amplifier and converter Spider 8, then recorded and stored in the memory of the Omnibook-600 laptop computer (Fig. 3).

a



	A	B	C	D	E
1	File comment:				
2	Time	Chastota k	Chastota c	TenzoZveno	
3	s	Hz	Hz	kg	
4					
5					
6	0	0,064	0,036	11,81354	
7	0,04	0,064	0,036	11,81354	
8	0,08	0,064	0,036	11,81354	
9	0,12	0,064	0,036	11,81354	
10	0,16	0,064	0,036	11,81354	
11	0,2	0,064	0,036	11,81354	
12	0,24	0,064	0,036	11,81354	
13	0,28	0,064	0,036	11,81354	
14	0,32	0,064	0,036	11,81354	
15	0,36	0,064	0,036	11,81354	
16	0,4	0,064	0,032	11,81354	
17	0,44	0,06	0,032	11,81354	
18	0,48	0,06	0,032	11,81354	
19	0,52	0,06	0,032	11,81354	
20	0,56	0,06	0,032	11,81354	
21	0,6	0,06	0,032	11,81354	
22	0,64	0,06	0,032	11,81354	
23	0,68	0,06	0,032	11,49425	

b

Fig. 3. Conducting a field experiment: a - measuring complex, b - registration of information on a laptop.

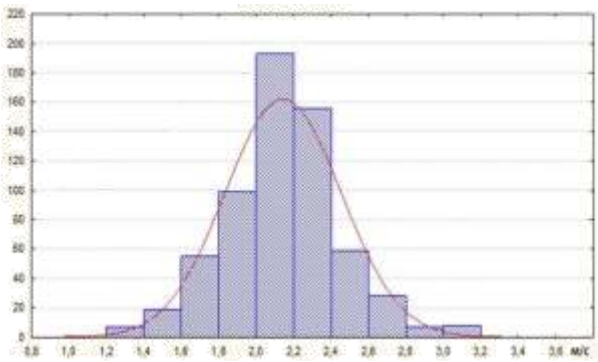
In column *A* the time of seeds lifting is fixed, in column *B* the bubble separation frequency is fixed,, in column *C* the frequency of operation of the photodetector is fixed, and in column *D* the value of height of the liquid column above the seed catcher is fixed. The data is recorded with a frequency of 25 data per second. Further data processing is done using Statistica 6.0 software.

The methodology of experimental studies to determine the even distribution of seeds in the seedbed depends on the diameter of the seed catcher α and the height of the water and seed mixture over the level of the funnel β.

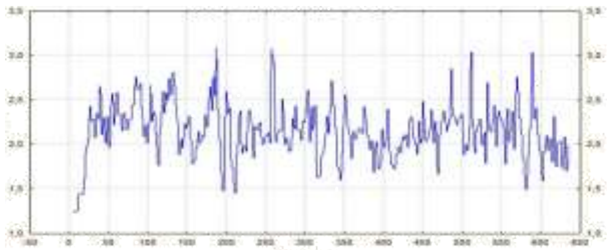
The experimental research is based on the methodology of the multifactorial experiment.

To organize and conduct multifactorial experiments it is necessary to perform the following stages of work: preliminary study of the research object, choice of factors and plan of experiments, factors coding, developing a matrix for planning experiments, randomization of experimental studies, conducting experiments, analysis and processing of the results, determination of regression coefficients, estimation of significant regression coefficients, constructing of a polynomial model and checking it for adequacy [7].

Preliminary evaluation of available research results and analysis of the process of interaction of air bubbles with seeds in a liquid medium allow to advance the hypothesis that the even distribution of seeds above the level of the funnel is nonlinear functions of air pressure α, the diameter of the openings of the perforated chamber bottom of the mixer β discs, as well as the level of the mixture over the catcher. At the first solving of the problem, a three-factor experiment is wanted. But the research experiments under field conditions made us certain that it was impossible to fix a "progressive speed" at a given level. The large speed range on the histogram practically covers the entire range of possible level variations from 0.5 to 1.5 m/s (Fig. 4).



a

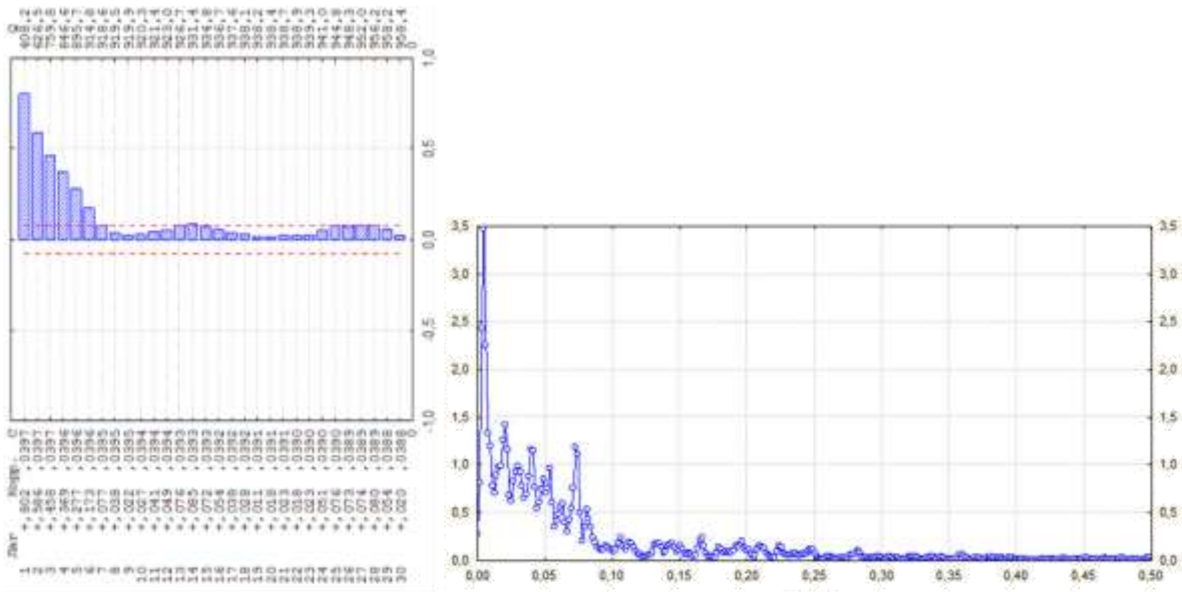


b

Fig. 4. Diagram of the unit speed measurements in time (a) and histogram of the unit speed (b).

The nature of the autocorrelation function and the spectral plane (Fig. 4) proved that under field conditions the unit speed can act as a controllable factor in multifactorial experiments (Fig. 5).

Thus, this raises the challenge to conduct a two-factor experiment of the second order. New studies on the theory of a multifactorial experiment show that used in practice orthogonal central composite plans (OCCP) and other plans for constructing of polynomial models of the second order are redundant in both the number of experimental points and the number of levels of factors variation.



a *b*

Fig. 5. Correlation function (a) and spectral density of the unit (b).

For example, for four factors the number of experimental points in the OCCP is 25, and the number of unknown coefficients in the complete model of the second order is 15. Therefore, to check the adequacy of the model there are 10 degrees of freedom.

For a number of factors greater than or equal to three, the number of levels of variation in the OCCP is five, at the same time, for the construction of the models of the second order three levels of variation of factors are enough. Hence, the OCCP is redundant both in the number of experimental points, and in the number of levels of factors variation.

The number of experimental points in the matrix of the OCCP is calculated by the formula:

$$N = 2^n + 2n + 1 \quad (1)$$

where N is the number of experimental points, n is the number of factors.

The process model in the two-factor experiment of the second order is in the following form:

$$y = b_0 + b_1x_1 + b_2x_2 + b_{11}x_1^2 + b_{22}x_2^2 + b_{12}x_1x_2 \quad (2)$$

where y is the investigated factor, x_1 and x_2 - variable factors, b_0, b_1, b_2, b_{11}, b_{22}, b_{12} - empirical coefficients that need to be determined by the results of a multivariate experiment.

There is a large variety of plans for two-factor experiments of the second order. They are almost equivalent as for reflection of the reality of the described processes, but differ in the scope of experimental work [4].

As an alternative, consider the three most common points of the plan:

1. The central composite rotatable plan of the second order for two factors.

For realization of this plan it is necessary to conduct 13 experiments, if necessary, to identify 6 unknowns. Provision of parameters of the regulated factor at star points in values of +1.414 and -1.414 is sometimes very problematic.

2. Central noncomposite plan of the second order. For realization of this plan it is necessary to conduct ten variants of the experiment. It is very difficult to provide x_2 parameters at levels +0.866 and -0.866.

3. The two-factor orthogonal central composite plan (OCCP) of the second order has recently been used in engineering practice due to a number of advantages over other plans. The feature of the task is that the object of the study is not the process itself, but statistical indicators that characterize this process in a steady state. In this case, the initial value is determined almost without error (due to a large number of measurements), and the result of each experiment is accurately reproduced in its repetition, if there are no random emissions.

Hence, there is no need to check the uniformity of sampling variances of reproducibility, in the conduct of randomization and duplication of experiments. At the same time, it is difficult to assess the significance of the coefficients and to check the adequacy of the mathematical model in the form of a polynomial.

The verification of the adequacy of approximating expressions on F-criteria and the significance of the coefficients on t-criteria in this case is inappropriate, since the sampling variance of reproducibility in determining the values of y according to the graph is practically zero. At the same time, all the coefficients, even slightly different from zero, will be significant, and any deviations of the calculated by polynomial value y from the values $\tilde{y}$ (taken from the characteristic) formally make the model inadequate. A similar problem of adequacy and significance of coefficients arises also when studying the mathematical model of an object on a computer.

In this case, the following ways are acceptable: consider all the coefficients significant, since the variance of experiments is practically absent (due to its lower significance), the estimation should be made on the basis of the accepted level of approximation accuracy, which is connected with the artificial introduction of the variance of reproducibility. Taking the value of the error of experiment for the initial parameter, the verification of the model adequacy can be made according to the F-criterion.

However, the correspondence of the approximating polynomial of an approximating curve or their family can be determined by the maximum absolute deviation of the values of the initial parameter calculated by polynomial from the values determined by the statistical characteristic.

The last way inferior to the mathematical rigor of the first two. However, considering the graphic description of the statistical properties of the object, this way is quite acceptable under the approximation of statistical characteristics [1].

The special features of experimental methods for mathematical representation of statistical characteristics include the fact that in this case the experiment (defining initial parameter values using the diagram) does not require a lot of time and resources. The experiment is not expensive. Therefore, the question of minimizing of the number of necessary experiments is not as acute as when planning an industrial experiment. In the general case, there is no need for the consistent nature of the experiment, since the character of the statistical characteristics is already known. For example, if the statistical characteristic shows that the connection $y = f(x_1 x_2)$ is non-linear, then, as a rule, there is no need to use more simple models [5].

Because of some difficulty of estimating the adequacy of the model, it seems appropriate to use nonlinear plans even in the cases where the nonlinearity of statistical characteristics is hardly noticeable. The degree of nonlinearity can be inferred by the value of the coefficients under the quadratic terms of the polynomial. Nonlinear plans are more versatile.

Enter the next range of air pressures and the levels of the mixture over the seed catcher:

$\alpha_{min} = 1$ атм., $\alpha_{max} = 6$ атм., $\beta_{min} = 1$ мм,
$\beta_{max} = 5$ мм.

For multi-factorial experiment the second-order OCC-plan for two factors is used. It is presented in the table 1.

Table 1. OCC - plan of the second order for two factors.

Number of Experiments	x_1	x_2
1	-1	-1
2	-1	+1
3	+1	+1
4	+1	-1
5	+1	0
6	-1	0
7	0	+1
8	0	-1
9	0	0

Factors vary in the next range (table 2).

Thus, the features of this plan are 1) the smallest number of variants of research experiments from the existing (9 variants), 2) there are only three factors, which are studied and the results of the experiments are rounded up to a whole number (+1, 0, -1), 3) particularity of imagination of a priori information.

Table 2. Factors in the natural size.

$x_{1.} = \alpha$	x_1= 0,5 мм	-1
	x_1= 1 мм	0
	x_1= 1,5 мм	+1
$x_2 = \beta$	x_2= 0,1 атм.	-1
	x_2= 0,3 атм.	0
	x_2= 0,6 атм.	+1

CONCLUSIONS

1. The scientific fundamentals of principles of action and design of a hydroseeder for seeding of fine vegetable germinated seeds are examined.
2. The mathematical models of some processes are proposed. The using of them allows dividing the general process of designing the hydrseeding apparatus into the following phases:
   -the process of bubbling,
   -the process of mixing seeds in a liquid,
   -the process of water and seed mixture pouring.
3. The application of a set of physical processes makes it possible to achieve the high quality of the process of hydroseeding of sprouted seeds without traumatization of sprouters
4. The conducted theoretical studies of the hydroseeding process give the opportunity to form the main directions of experimental researches of both individual processes and the general process. Optimization of operating modes of these processes allows solving the question of the hydroseeder design. Thus, it is possible to shorten the period of having harvest of vegetable crops by reducing the period of sprouts emergence.

REFERENCES

1. **Baraschuk V. 1984.** Planning of the experiment in the technique. Kyiv. Technics. 240.
2. **Bakhtin A. V., Chalyi V. D. 1999.** Improving the efficiency of the use of the STCP. Scientific session of MIFI. Moscow. 124.
3. **Voznesenskyi V. A. 1973.** Statistical methods of planning of an experiment in technical and technological studies. Moscow. 224.
4. **Dospekhov B. A. 1985.** Field experiment technique (with basics of statistical processing of research results). (5th ed., rev. and enl.). Moscow. Agropromizdat. 128.
5. **Kalaida V. T. 1997.** Planning of an experiment. Methods of processing of the results of the experiment and the basis of the mathematical theory of experiment planning. Tomsk, Edition of Tomsk University. 320.
6. **Klymenko M. O., Feshchenko V. P., Vozniuk N. M. 2010.** Fundamentals and methodology of

scientific research: teaching. manual. Kyiv. Agrarian Education. 208.

7. **Montgomery D. K. 1980.** Experiment planning and data analysis. Leningrad. Shipbuilding. 302.

8. **Solodov V. S. 1980.** Use, construction of mathematical models and static characteristics of energy complexes of industrial vessels. Dvigatelestroenie. Draft Building, No. 5. 5.

9. **Stepanenko S. P., Kotov B. I., Spirin A. V. 2017.** To the question of the mathematical description of the movement of the threshed seeds in the annular channel of variable cross section. Mechanization of agricultural production. Bulletin INTOSH behalf Peter Vasilenko. Kharkov. Vol. 180. 330-339.

10. **Stepanenko S. P., Kotov B. I., Swida V. A., Koval Y. G. 2009.** The theory of separation of grain in the air stream. Design, production and operation of agricultural machinery. Vol. 39. Kirovograd. KNTU. 54-62.

11. **Adamchuk V. V. 2014.** The concept of the prospects of a comprehensive solution to the problem of post-harvest handling and storage of grain in the agricultural enterprises of Ukraine. Mechanization and electrification of agriculture. Glevaha. Vol. 99. Vol. 1. 40-56.

12. **Voronkov O. A., Rogovskii I. L. 2017.** Analytical prerequisites to transport and technological systems of transportation of production of crop production. Theses of International Scientific Conference "Globalization of scientific and educational space. innovations of transport. problems, experience, prospects" (3-12 May 2017) / Dresden (Germany) Paris (France). 47-50.

13. **Voronkov O. A., Rogovskii I. L. 2017.** Ways to reduce energy consumption in transportation and technological support for weight of transported grain crops. A collection of abstracts of the XIII International scientific conference "the Rational use of energy in technology. TechEnergy 2017" (17-19 may 2017). Kiev. 72-74.

14. **Voronkov O. A., Rogovskii I. L. 2017.** Analytical model for energy estimation of transport technological process of transportation of grain and crop products. Journal of mechanical engineering and transport. Vinnitsa: VNTU. Vol. 1. 21-28.

15. **Voronkov O. A., Rogovskii I. L. 2017.** Approach to solving the problem of management of transport system for transporting of the grain harvest. The book of abstracts of V-th international scientific conference "Innovative maintenance of organic production in agriculture" in the framework of the XXI International agricultural exhibition "AGRO 2017" (05-06 June 2017). Kiev. 44-46.

16. **Voronkov O. A., Rogovskii I. L. 2017.** Automation operators for the monitoring of vehicles for the carriage of grain bread Automatic – 2017: international conference on automatic control, Kiev, Ukraine, 13-15 September 2017: proceedings of the conference. Kiev. 181-182.

17. **Voronkov O. A., Rogovskii I. L. 2017.** Alignment of adjacent transport and technological operations of transportation of grain and crop products. Bulletin of East Ukrainian national University named after Volodymyr Dahl. No. 3. 36-43.

18. **Voronkov O. A., Rogovskii I. L. 2017.** General principles of creation of control systems of transport streams transport grain bread. Scientific Herald of National University of Life and Environmental Science of Ukraine. Series: Technique and energy of APK. Kiev. Vol. 258. 390-399.

19. **Voronkov O. A., Rogovskii I. L. 2017.** Options of structural solutions of the system of management of transport flows transport grain bread. Scientific Herald of National University of Life and Environmental Science of Ukraine. Series: Technique and energy of APK. Kiev. Vol. 262. 361-367.

20. **Shevchuk R. S., Krupych R. 2015.** Manual vibro-impact fruit shaker/ MOTROL Commission of motorization and energetics in agriculture. – Lublin-Rzeszow, Vol. 17, №4., 153-159.

21. **Sydorchuk O., Triguba A., Makarchuk O. 2012.** Optimization of the life cycle of integrated programs for harvesting grain crops. MOTROL Commission of motorization and energetics in agriculture. Lublin, Vol. 14, №4. 131-140.

22. **Sydorchuk O., Ivasjuk I., Syatkovskyy A. 2012.** Influence subject to conditions terms of tillage, planting summer-autumn period. MOTROL Commission of motorization and energetics in agriculture. – Lublin, – Vol.14, №4. 16-20.

23. **Sydorchuk A., Ivasiuk I., Ukraynecz V. 2013.** Harmonization of the components of the technological system of soil cultivation and sowing of winter crops. MOTROL. Commission of motorization and energetics in agriculture. Lublin-Rzeszow, Vol. 15, №4. 180-186.

24. **Rogovskii Ivan. 2016.** Graph-modeling when the response and recovery of agricultural machinery. Motrol : Motorization and power industry in agriculture. Lublin. T. 18. №3. 155-164.

25. **Rogovskii I. L. 2016.** Analysis of model of recovery of agricultural machines and interpretation of results of numerical experiment. Scientific Herald of National University of Life and Environmental Science of Ukraine. Series: Technique and energy of APK. Kyiv. No 254. 424-431.

26. **Rogovskii I. L. 2017.** Probability of preventing loss of efficiency of agricultural machinery during exploitation. Scientific Herald of National University of Life and Environmental Science of Ukraine. Series: Technique and energy of APK. Kyiv. No 258. 399-407.

27. **Rogovskii I. L. 2017.** Conceptual framework of management system of failures of agricultural machinery. Scientific Herald of National University of Life and Environmental Science of Ukraine. Series: Technique and energy of APK. Kyiv. No 262. 403-411.

28. **Rogovskii Ivan. 2017.** Choice of model class and method of modeling the resilience of agricultural machinery. TEKA. An International Quarterly Journal on Motorization, Vehicle Operation, Energy Efficiency and Mechanical Engineering. Lublin–Rzeszów. Vol. 17. No 3. 101-114.

29. **Kalinichenko Dmytro, Rogovskii Ivan. 2018.** Method for Determining Time of next Maintenance of Combine Harvesters. TEKA. An International Quarterly Journal on Motorization, Vehicle Operation, Energy

Efficiency and Mechanical Engineering. Lublin–Rzeszów. Vol. 18. No 1. 105-115.

МЕТОДИКА ЭКСПЕРИМЕНТАЛЬНЫХ ИССЛЕДОВАНИЙ ГИДРОПОСЕВА ПРОРОЩЕНЫХ СЕМЯН

Население Украины не обеспечивается достаточным количеством овощей собственного производства. Из-за недостаточного количество влаги весной необходимо совершенствовать технологии посева овощных культур.

Работа посвящена экспериментальному исследованию возможности посева пророщенных семян овощных культур вместе с жидкостью, обоснованию процесса гидропосева пророщенных семян, в котором реализуются наиболее эффективные рабочие параметры гидросеялки, исследованию новой технологической схемы перемешивания посевной смеси без травмирования ростков семян за счет внедрения смесительной камеры аэродинамического действия .

Предложеные конструкции гидросеялок и высевных аппаратов из-за их неэффективности не были массово внедрены в производство. Анализ существующих конструкций свидетельствует, что степень их внедрения есть результатом низкой равномерности посева и высокого травмирования ростков.

Программой экспериментальных исследований предусмотрено: определение равномерности распределения семян в смесительной камере при разных значениях давления воздуха и уровнях жидкости в камере, определение равномерности посева семян в зависимости от количества семян в смесительной камере, определение скорости подъёма семян в зависимости от размерных характеристик, определение оптимального использования водосеменной смеси в процессе гидропосева.

В статье представлены материалы лабораторных исследований стационарной экспериментальной установки гидровысевного аппарата. Исследования проводились в стационарном режиме с использованием современного оборудования и методик проведения научных экспериментов с помощью компьютерных технологий. Цель экспериментов включает определение эмпирических коэффициентов, определяющихся по результатах исследований. Выводы из материалов статьи дают возможность разработать оптимальный план полевых исследований, которые могут подтвердить научную гипотезу зависимости равномерности посева пророщенных семян от равномерности их распределения в смесительной камере.

Экспериментально определена взаимосвязь конструктивных и технологических параметров процесса высева гидросмеси с эффективностью исполнения технологического процесса.

Ключевые слова: эксперимент, план эксперимента, установка, рандомизация факторов, эмпирические коэффициенты.

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Model of Trajectory of Falling Seed When Sowing Sugar Beet by Pneumatic Seeder

Mykola Volokha

Institute of Bioenergy Crops and Sugar Beet.
E-mail: volmp@i.ua

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Summary. In the paper, during analyzes of scientific studies the main factors of increasing the yield of sugar beets are highlighted. The process of sowing sugar beet seeds with the help of pneumatic sowing apparatus was considered. The equations (mathematical model) of the trajectory of the seeds, separated from the disc of the sowing apparatus of the pneumatic type seeder, were obtained in two ways. This model allows to ensure the quality of sowing by setting the desired process parameters and the selection of sugar beet seeds. The application of a new device was considered for seed preparation, which allows sorting seeds by weight within one fraction so that their flight path after separation from the seed disc is the same. When preparing seeds for sowing, it is expedient to carry out sorting not only in size but also in weight within the same fraction.

Key words: pneumatic seeder, sowing device, mathematical modeling, seeds, mass, speed, force, trajectory, equations.

INTRODUCTION

When sowing sugar beet in accordance with the standards of agrotechnical requirements, seeds should be placed in a pre-prepared soil of a certain structure, moisture and hardness, on a compacted sowing bed at a given sowing depth and, most importantly, with a uniform (within a given tolerance) pitch along the line. This requires the perfection of seeding machines seeder, since it has a positive effect on the level of field germination of the seed and simultaneity of germination, which in general increases the yield of the crop.

Over the past 10-15 years, the most common domestic beet seeder with mechanical sowing devices SST-12V has been actively supplanted by pneumatic type seeders such as Western European ones ("Multicorn" by Franz Kleine, "Aeromat PV-12" - Becker, "Monoair-80 "- Acord, Germany," "Pneumosem"- Naude Guzhy, France, etc.) and domestic production (SU-12 - "Orizon-pribor", Smila of Cherkasy region, UPS-12 - OS "Chervona Zirka", Kropyvnytskyi). It is worth noting that the SU-12 and UPS-12 pneumatic seeders are slightly inferior to the “reference” German “Multikorn” seeder according to the coefficient of variation of V intervals between sprouted plants. The results of state tests in 1996-1998. at UkrNDIPVT (Doslidnitske, Vasilkovsky district, Kiev region) showed that the coefficient V of the mentioned seeders averages 48,6%, 53,9% and 41,9%, respectively [1]. A significant decrease in the coefficient of variation (V <10%) requires a study of the sowing technological process and is associated with the improvement of the sowing device. This article is dedicated to solving this problem.

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

According to the agrotechnical requirements (Tab. 1) in high-cultivated fields for high-quality soil preparation and sufficient moisture, the depth of wrapping of the seed is 2-3 cm. Deviation from the specified depth should be no more than ± 0,5 cm. Under conditions of unstable and insufficient moisture it increases to 3-4 cm [1].

Increase the depth of seeds incorporation negatively affects the field germination, which happens at a later time cultivation. So that seeds get into a wet layer, they incorporate them to a depth of 4 and more centimeters, but wrapping at such depth leads to decrease in field germination, which decreases in comparison with the optimal depth (2,5-3,5 cm) on the 6- 11%, and crop yields - by 2,5-3 t/ha [2-6].

The depth of seeds embedment decreases also with the increase in the speed of the sowing machines above the recommended (Fig. 1) and the uniform distribution of the seed along the length of the line deteriorates, as proved in the work [7].

Table 1. Agrotechnical requirements for the implementation of the technological process of sowing.

Indicators	Requirements
Sowing dates	Start the beet seeding, when the average daily temperature of the soil at a depth of 8-10 cm reaches 5-6 ° C, after the pre-planting of the soil and finish it in one field for 1-1,5 working days *
Depth of seeds embedment	Depending on the soil and weather conditions of the beet seeding zones, the seeds should be embedment to a depth of 2-4 cm.

Continues Table 1

Indicators	Requirements
Depth of seeds embedment	The deviation of the average depth of seeding of the seed from the given should not exceed 0,5 cm
Density of the seedbed, g/cm^3	1,2–1,3
Density of the soil over the seeds, g/cm^3	1,0–1,2
The uniform distribution of seeds along the length of the line	The number of seeds sown with a deviation of 20% of the specified interval for the line length should not exceed 40%
Number of seeds sown on 1m row	Deviations from the set norm of seeding are allowed not more than 14%
Width between the rows	The width of the row within the seizer of seeder must be 45 cm, with a deflection not more than 1 cm, and the width of the joint row spacings - 50 cm, with a deflection not more than 5 cm
Straightness of sowing	The deflection of the axial line on the length of the row of 50 m should not exceed 5 cm
The presence of grains between the rows	Not allowed
Field alignment after sowing	After the passage of the drill on the axial line of rows, a ground crest should be formed up to 5 cm high, and from the left and the right side of it - furrows depth up to 3 cm
Width of swivel bands	The width of the headland at the ends of the rut should be equal to three - four captures seeder

* Being late for sowing on one day, compared with the optimal period, reduces the yield of root crops by 5-7 centners per hectare, on 5-6 days – by 25-40 c/ha.

Seeds do not germinate when sown in a dry and very loosened soil layer, as a prerequisite for high field germination is the close contact of seeds with moist soil. It is important to sow the seeds on a packed bed with an intact capillary system. Under such conditions, even in dry weather, access of soil moisture to the seeds is provided. The loosened topsoil should not be too thick (2-4 cm) so that oxygen from the air and heat can easily flow through it [8–13].

Field germination at the same time reaches 80-90% or more. This has a positive effect both on the level of field germination of seeds, and on the simultaneity of germination, which generally increases the initial development of plants and, as a result, crop yield.

Numerous studies of scientists IBSiB and All-Russian Scientific Research Institute of sugar beet and sugar (town Ramon, Voronezh region) since the 80s and now proved that one of the main factors increasing the yield is the uniformity of sowing seeds along the length of the line [14-22].

Palamarchuk V. I. found that with a decrease in the coefficient of variation of the intervals between plants, the yield of beets is 0,12-0,25 t/ha and its sugar content increases by 1% [23].

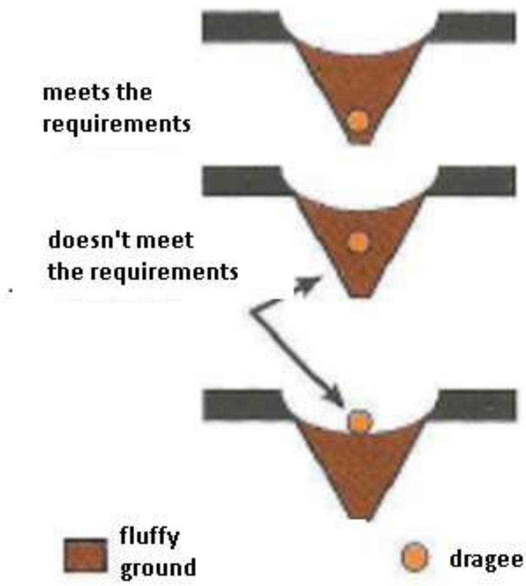

Fig. 1. The location of seeds in the soil, depending on the operating speed of the seeder.

According to V. M. Sinchenko, who experimentally proved on model crops that with an average interval between plants of 20-25 cm and decrease in the coefficient of variation from 50% to 25%, the yield of root crops before harvest is 4,7-5,3 t/ha [24].

The pneumatic sowing apparatus of domestic seeders, for example, the UPS-12, like Western European ones, works on the principle of air dilution created in its chambers by a fan, which is driven from the tractor's PTO. Seeds that are in the area of the intake chamber of the sowing disc, passing through the vacuum zone, sticking to his cell. The derailer, which is equipped with an adjustment mechanism, removes excess seeds, leaving only one per each cell of the disk. The disk transfers the seed to the zone of atmospheric pressure, where it, separated from the cell, flies in the air along a certain curve and falls into the wedge-shaped furrow created in the soil by the opener [25-28].

OBJECTIVE

The purpose of the article is to study the trajectory of falling seeds, sowing with seeder of the pneumatic type and obtain an analytical dependence (model) of the trajectory of its movement.

THE MAIN RESULTS OF THE RESEARCH

The seed, taken as the material point of mass *m*, is separated from the disk, which rotates in the direction of movement of the sowing device (counterclockwise in the pattern plane) with a constant angular velocity, flies in the air along a certain curve (Fig. 2). In this case, all the sowing device performs uniform translational motion along the X-axis.

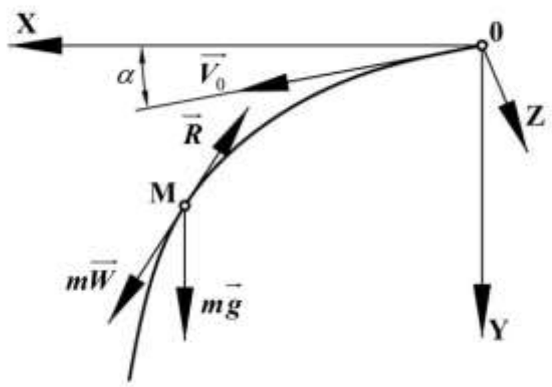

Fig. 2. Scheme of the trajectory of the falling seed.

Let us determine the law of motion and the equation of the trajectory of point *m* with the initial velocity $\vec{V}_0$, directed at an angle α to the horizon. We assume that the force of resistance of motion is proportional to the speed of a point $\vec{V}$:

$$\vec{R} = -\mu m\vec{V}, \qquad (1)$$

Introduce the coordinate system 0*xy*, the start of which coincides with the initial position of the point [6]. Initial conditions: $t=0$, $x_0 = 0$, $y_0 = 0$, $\dot{x}_0 = V_0 \cos\alpha$, $\dot{y}_0 = V_0 \sin\alpha$. In the current position *M*, the point is acted upon by the force of gravity $m\vec{g}$ and the force of resistance $\vec{R}$, which are directed opposite to the direction of movement (velocity vector). Based on the basic equation of dynamics and the law of independence of the action of forces [29], we can write:

$$m\vec{W} = m\vec{g} + \vec{R}. \qquad (2)$$

Let's define the projections of the vector equation (1) on the coordinate axes:

$$mW_x = -\mu mV_x,\ mW_y = mg - \mu mVy.$$

Given that $W_x = \ddot{x}$, $W_y = \ddot{y}$, and $V_x = \dot{x}$, but $V_y = \dot{y}$, and by reducing the expressions on *m*, we obtain a system of two equations:

$$\begin{cases} \ddot{x} = -\mu\dot{x} \\ \ddot{y} = g - \mu\dot{y} \end{cases} \qquad (3)$$

To integrate the first equation of system (3) we replace $\ddot{x}$ to $\frac{d\dot{x}}{dt}$ and divide the variables: $\frac{d\dot{x}}{\dot{x}} = -\mu\, dt$. The first integral will look like:

$$\ln\dot{x} = -\mu t + C_1. \qquad (4)$$

Substituting in (4) the corresponding initial conditions ($t = 0$, $\dot{x}_0 = V_0 \cos\alpha$), we obtain: $C_1 = \ln V_0 \cos\alpha$. Let's add the value of C_1 to equation (4):

$$\ln\dot{x} = -\mu t + \ln V_0 \cos\alpha$$

or the same

$$\ln\frac{\dot{x}}{V_0\cos\alpha} = -\mu t.$$

From where:

$$\dot{x} = V_0 e^{-\mu t}\cos\alpha. \qquad (5)$$

Having replaced the equation (5) $\ddot{x}$ with $\frac{d\dot{x}}{dt}$ and dividing the variables, after integrating we find the second integral of the first equation of system (3):

$$x = -\frac{V_0}{\mu}e^{-\mu t}\cos\alpha + C_2. \qquad (6)$$

Substituting the initial conditions (t = 0, $x = 0$), we obtain: $C_2 = -\frac{V_0}{\mu}\cos\alpha$. By taking advantage of this value, we obtain from (5) the equation of the trajectory of the point's motion in the projection on the x-axis:

$$x = \frac{V_0}{\mu}(1 - e^{-\mu t})\cos\alpha \qquad (7)$$

To integrate the second equation of system (3) we replace $\ddot{y}$ with $\frac{d\dot{y}}{dt}$ and divide the variables: $\frac{d\dot{y}}{-g + \mu\dot{y}} = -dt$.

The first integral of the resulting differential equation has the form:

$$\ln(-g + \mu\dot{y}) = -\mu t + C_3. \qquad (8)$$

Substituting in (8) the initial conditions – $t = 0$, $\dot{y}_0 = V_0 \sin\alpha$ we obtain: $C_3 = \ln(-g + \mu V_0 \sin\alpha$. Having introduced this value in (8), we obtain:

$$\ln\frac{g - \mu\dot{y}}{g - \mu V_0 \sin\alpha} = -\mu t \qquad (9)$$

From where:

$$\frac{g - \mu\dot{y}}{g - \mu V_0 \sin\alpha} = e^{-\mu t} \qquad (10)$$

Having solved the equation (10) relative to $\dot{y}$, we get:

$$\dot{y} = -\frac{1}{\mu}(g - \mu V_0 \sin\alpha)e^{-\mu t} + \frac{g}{\mu} \qquad (11)$$

Replacing the equation (11) $\dot{y}$ with $\frac{dy}{dt}$ and dividing the variables, we integrate it:

$$y = \frac{1}{\mu^2}(g - \mu V_0 \sin\alpha)e^{-\mu t} + \frac{g}{\mu}t + C_4 \qquad (12)$$

Substituting in (12) the initial conditions ($t = 0$, $y = 0$), we obtain: $C_4 = \frac{1}{\mu^2}(g - \mu V_0 \sin\alpha)$. As a result, we obtain the equation of the trajectory of the point's motion in the projection on the y-axis:

$$y = \frac{1}{\mu^2}(g - \mu V_0 \sin\alpha)(1 - e^{-\mu t}) + \frac{g}{\mu}t \quad (13)$$

The equations of the point trajectory in the projections on the x and y axis - dependences (7) and (13) - are given in a parametric form, where *t* is the time parameter. After the exclusion of the parameter *t* from these equations and the corresponding transformations, the desired equation of the trajectory of the point (seed) will look like:

$$y = \frac{1}{\mu}\frac{g - \mu V_0 \sin\alpha}{V_0 \cos\alpha}x + \frac{g}{\mu^2}\ln\left(1 - \frac{\mu}{V_0 \cos\alpha}x\right) \quad (14)$$

If the system of equations (3) is written in the form:

$$\begin{cases} \ddot{x} + \mu\dot{x} = 0 \\ \ddot{y} + \mu\dot{y} = g \end{cases}, \quad (15)$$

Then it can be solved as a system of ordinary differential equations. The solution of the first equation of the system (15) is written as a general solution of a homogeneous differential equation in the form:

$$x = C_1 e^{-\mu t} + C_2, \quad (16)$$

where: μ – one of the roots $b_1 = 0$ and $b_2 = -\mu$ of the characteristic equation:

$$b^2 + \mu b = 0. \quad (17)$$

From there $C_3 = -C_5 = -\frac{V_0}{\mu}\sin\alpha - \frac{g}{\mu^2}$.

Then the equation of the trajectory of the point motion at the coordinate y will have the following form:

$$y = \frac{1}{\mu^2}(g - \mu V_0 \sin\alpha)(1 - e^{-\mu t}) + \frac{g}{\mu}t \quad (18)$$

The final equation of the trajectory of the point movement (seed) has the form:

$$y = \frac{1}{\mu}\frac{g - \mu V_0 \sin\alpha}{V_0 \cos\alpha}x + \frac{g}{\mu^2}\ln\left(1 - \frac{\mu}{V_0 \cos\alpha}x\right) \quad (19)$$

It's easy to see that the obtained dependence (19) completely coincides with the dependence (14), which confirms the correctness of mathematical calculations.

Graphical interpretation of numerical calculations of the obtained model (14, 19) is shown in Fig. 3 and Fig. 4:

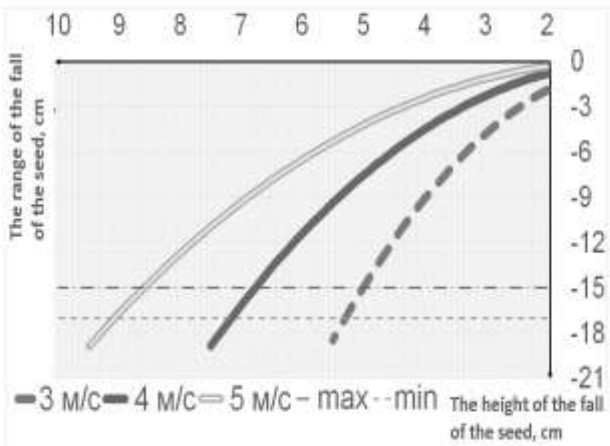

Fig. 3. Influence of the initial velocity on the trajectory of the falling seed.

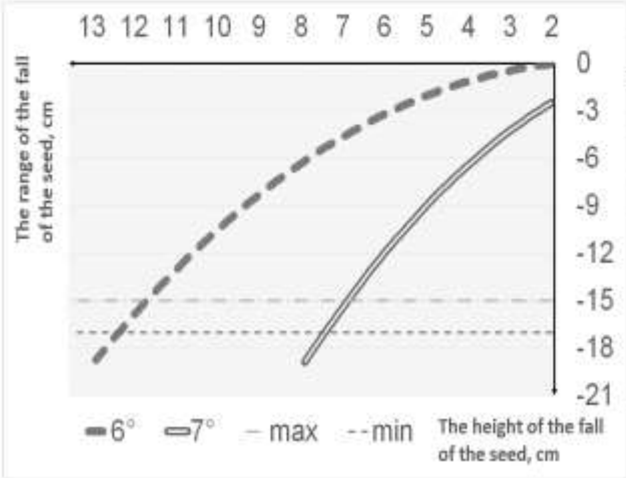

Fig. 4. Influence of the angle of inclination of the initial velocity to the horizon on the trajectory of the falling seed.

Consequently, the range of fall of a separate seed that falls apart from the cell of the seeding disk of the pneumatic seeder drill depends directly on the initial velocity of the fall and inverted - from the angle α of the inclination of its vector to the horizon. This allows to determine the accuracy of the seeding (the length of the intervals between seeds) and evaluate the technological process and are the initial conditions for determining the optimal parameters of the sowing device.

The range of fall of the flying seed separating from the sowing disk of the seeding machine of the pneumatic type directly depends on the initial velocity and inversely - from the angle of inclination of its vector to the horizon. The weight of the seed affects indirectly the range of its fall. Let's consider the process of sorting seeds before sowing.

Under the current production conditions for preparing seeds for sowing, both ordinary inlaid (encapsulated) and drageed seeds are purchased from plants and supplied to farms not by mass, but by sowing units. One sowing unit contains 100,000 seeds, so when sowing on one hectare of one sowing unit, there are 10 seeds per 1 m2 of field, and 4-5 seeds per one meter of row length. Therefore, in the production of sugar beet 1,2-1,5 sowing units are sown, and sometimes more, depending on the conditions of a particular field [30, 31].

Our experiments to determine the mass of inlaid and drageed seeds of various varieties by weighing it, found that the average weight, for example, of drageed seed of the Matador variety 3,25–4,25 mm, is 27,34 mg (02734×10^{-3} g) with deviations ranging from 19,05 to 43,30 mg, which is 22% for the coefficient of variation. As a result, even with such an insignificant fluctuation of an insignificant mass of the seed, the trajectories of fall of individual seeds and, accordingly, the intervals between them when reaching the bottom of the furrow, will also be different. This conclusion is confirmed by experiments with the sowing of seeds on the adhesive tape, which moved evenly, and a slow stroboscopic survey [7, 26].

In order to improve the coefficient of variation of seed placement along the row, a new device [26] was developed for seed preparation (material points of different mass), which allows sorting seeds by weight within one fraction so that their flight path after separation from the seed disc is the same. The task of improving the well-known analogue, which contains disk *1* and plowshare *2* arranged behind each other, is solved by installing a sectional conveyor with built-in containers *3*, after the plowshare, which fix the seeds of a certain mass (Fig. 5).

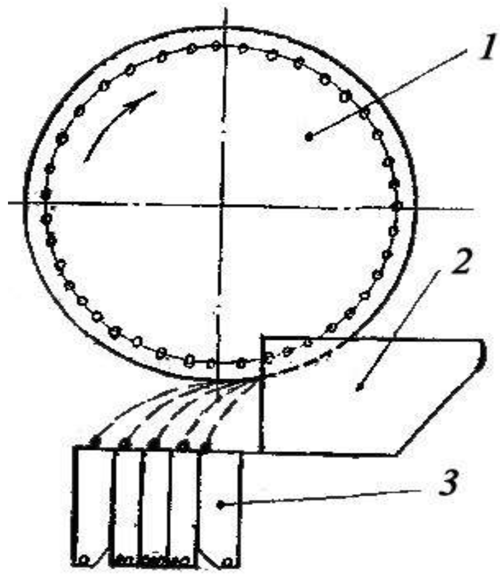

Fig. 5. Schema of the device for sorting seeds by weight.

The device is the main part of the sowing section of the seeder with the sowing disk *1*, the plowshare *2* and the conveyor *3* with built-in tanks for fixing the falling seeds. When the disk *1* rotates, the seeds one in each hole moves to the plowshare 2 zone, after which, depending on their weight, they enter different capacities of the conveyor *3* moving in the direction of the axis of rotation of the disk *1*. Thus, the seeds are packed in each section of the conveyor separately for sowing. Since all sorted seeds belong to the same size fraction, the quality of sowing with this distribution obviously increases.

CONCLUSIONS

1. The range of fall of the flying seed which was separated from the sowing disk of the sowing device of the pneumatic seeder to the bottom of the furrow directly depends on the initial velocity and inversely - from the angle of inclination of its vector to the horizon.

2. The weight of the seed affects indirectly the range of its fall.

3. When preparing seeds for sowing, it is expedient to carry out sorting not only in size but also in weight within the same fraction.

REFERENCES

1. Garnec V. M. 1991. The progressive the forming units and complexes of concrete. Kyiv, 1991, 144.

2. Kuzin V. N. 1981. Technology of roller formation of flat articles from fine-grained concrete: The abstract of the thesis for a degree of the candidate of science, Moscow, 1981, 20.

3. Rjushin V. T. 1986. Research of working process and development of a method of calculation of cars of roller formation of concrete mixes. The thesis for a degree of Candidate of Technical Sciences, Kyiv, 1986, 186.

4. Loveykin V. S., Garnec V. M., Pochka K. I. 2004. Patent of Ukraine for an invention № 67091A. Installation for formation of products from concrete mixes, № u2003076371 it is stated 08.07.2003, it is published 15.06.2004, Bulletin №6.

5. Loveykin V. S., Pochka K. I. 2004. The dynamic analysis of roller forming installation with the rekuperativ drive. Dynamics, durability and reliability of farm vehicles: *Works of the First International scientific and technical conference (DSR AM-I)*, on October 4-7, 2004, Ternopil (Ukraine), 507-514.

6. Loveykin V. S., Pochka K. I., 2003. The power analysis of roller forming installation with the rekuperativ drive. *Scientific and technical magazine «Technology of construction»*, Kyiv, 2003, No 14, 27-37.

7. Loveykin V. S., Pochka K. I. 2005. The analysis of unevenness of the movement of roller forming installation with the rekuperative drive. *Scientific and technical and production magazine «Hoisting-and-transport equipment»*, 2005, No 4, 19-33.

8. Loveykin V. S., Pochka K. I., Palamarchuk D. A. 2004. Optimization of design data of the driving mechanism of roller forming installation with the rekuperative drive. *Scientific and technical magazine «Technology of construction»*, Kyiv, 2004, No 15, 40-48.

9. Pochka K. I. 2008. Development and the analysis of roller forming installation with the rekuperativ drive. The abstract of the thesis for a degree of Candidate of Technical Sciences, Kyiv, KNUCA, 2008, 24.

10. Loveykin V. S., Kovbasa V. P., Pochka K. I. 2010. The dynamic analysis of roller forming installation with energetically balanced drive. *Scientific Herald of National University of Life and Environmental Science of Ukraine. Series: Technique and energy of APC*, Kyiv, 2010, No 144, part 5, 338-344.

11. Loveykin V. S., Kovbasa V. P., Pochka K. I. 2011. The power analysis of roller forming installation with energetically balanced drive. *Scientific bulletin of the Tavriysky State Agro Technological University*, Melitopol, 2011, No 1, Tom 2, 16-23.

12. Loveykin V. S., Pochka K. I. 2010. The analysis of unevenness of the movement of roller forming installation with energetically balanced drive. V*ibrations in the equipment and technologies*, 2010, No 4 (60), 20-29.

13. Loveykin V. S., Pochka K. I. 2010. Optimization of design data of roller forming installation with energetically balanced drive. *MOTROL*. Motorization and power industry in agriculture, Lublin, 2010, Tom 12 B, 9-18.

14. Loveykin V. S., Pochka K. I. 2004. The analysis of the movement of roller forming installation with the balanced drive. *Bulletin of the Kharkiv national automobile and road university*, 2004, No 27, 95-101.

15. Loveykin V. S., Pochka K. I. 2005. The power analysis of roller forming installation with the balanced drive. S*cientific bulletin of National agricultural university*, 2005, No 80, 346-356.

16. Loveykin V. S. 1989. Assessment of the movement of mechanisms and cars. *Hoisting-and-transport equipment*, Kyiv, Tehnika, 16-18 (in Russian).

17. Lovejkin V. S., Shumilov G. V. 2011. Optimization of the mode of change of a departure of the tower crane behind single kinematic criteria. *MOTROL*. Motorization and power industry in agriculture, Lublin, 2011, Том 13 B, 167-174.

18. Loveykin V. S., Pochka K. I. 2015. The analysis of unevenness of the movement of roller forming installation with the balanced drive. *MOTROL*. Commission of Motorization and Energetics in Agriculture, Lublin-Rzeszow, 2015, Vol. 17, No 3, 17-27.

19. Loveykin V. S., Pochka K. I. 2016. Analysis of dynamic equilibration by the drive of cars of roller formation. *MOTROL*. Commission of Motorization and Energetics in Agriculture, Lublin-Rzeszow, 2016, Vol. 18, No 3, 41-52.

20. Loveykin V. S., Pochka K. I. 2015. Dynamic optimization of the mode of reversal of roller forming installation. *Collection of scientific tinders «Mechanical engineering»*, Harkiv, Ukrainian engineering and pedagogical academy, 2015, No 15, 76-86.

21. Loveykin V. S., Pochka K. I. 2015. Optimization of the breakthrough mode of reversal of roller forming installation. *Scientific Herald of National University of Life and Environmental Science of Ukraine. Series: Technique and energy of APK*, Kyiv, 2015, No 212, part 1, 186-197.

22. Loveykin V. S., Pochka K. I. 2015. Optimization of the mode of reversal of roller forming installation on acceleration of the third order. *Bulletin of the Donbass state machine-building academy*: collection of scientific works, Kramatorsk, 2015, No 3 (36), 16-26.

23. Loveykin V. S., Pochka K. I. 2017. Synthesis of camshaft driving mechanism in roller molding installation with combined motion mode according to acceleration of third order. Science & Technique, Minsk, BNTU, 2017, No 16(3), 206-214. DOI:10.21122/2227-1031-2017-16-3-206-214.

24. Loveykin V. S. 1990. Calculations of the optimum modes of the movement of mechanisms and cars. Manual, Kyiv, UMK VO, 168.

25. Lovejkin V. S., Pochka K. I., Chovnjuk Ju. V., Dikteruk M. G. 2014. Patent of Ukraine for an invention № 105744. Installation for formation of products from concrete mixes. № a201309305 it is stated 25.07.2013, it is published 10.06.2014, Bulletin № 11.

26. Voronkov O. A., Rogovskii I. L. 2017. Options of structural solutions of the system of management of transport flows transport grain bread. Scientific Herald of National University of Life and Environmental Science of Ukraine. Series: Technique and energy of APK. Kiev. Vol. 262. 361-367.

27. Sydorchuk O., Triguba A., Makarchuk O. 2012. Optimization of the life cycle of integrated programs for harvesting grain crops. MOTROL Commission of motorization and energetics in agriculture. Lublin, Vol. 14, №4. 131-140.

28. Sydorchuk O., Ivasjuk I., Syatkovskyy A. 2012. Influence subject to conditions terms of tillage, planting summer-autumn period. MOTROL Commission of motorization and energetics in agriculture. – Lublin, – Vol.14, №4. 16-20.

29. Sydorchuk A., Ivasiuk I., Ukraynecz V. 2013. Harmonization of the components of the technological system of soil cultivation and sowing of winter crops. MOTROL. Commission of motorization and energetics in agriculture. Lublin-Rzeszow, Vol. 15, №4. 180-186.

30. Rogovskii Ivan. 2017. Choice of model class and method of modeling the resilience of agricultural machinery. TEKA. An International Quarterly Journal on Motorization, Vehicle Operation, Energy Efficiency and Mechanical Engineering. Lublin–Rzeszów. Vol. 17. No 3. 101-114.

31. Kalinichenko Dmytro, Rogovskii Ivan. 2018. Method for Determining Time of next Maintenance of Combine Harvesters. TEKA. An International Quarterly Journal on Motorization, Vehicle Operation, Energy Efficiency and Mechanical Engineering. Lublin–Rzeszów. Vol. 18. No 1. 105-115.

МОДЕЛЬ ТРАЕКТОРИИ ПАДЕНИЯ СЕМЯН ПРИ ПОСЕВЕ САХАРНОЙ СВЕКЛЫ НА ПНЕВМАТИЧЕСКОЙ СЕЯЛКИ

Аннотация. В статье, в ходе анализа научных исследований основных факторов повышения урожайности сахарной свеклы выделяются. Был рассмотрен процесс посева семян сахарной свеклы с помощью пневматического высевающего аппарата. Уравнения (математическая модель) траектории движения семян, отделенных от диска высевающего аппарата пневматической сеялки типа, были получены двумя способами. Эта модель позволяет обеспечить качество сева, установив нужные параметры и отбора семян сахарной свеклы. Применение нового устройства для подготовки семенного материала, который позволяет сортировать семена по весу в пределах одной фракции, так что их траектории полета после отделения от высевающего диска одинаковы. При подготовке семян к посеву целесообразно проводить сортировку не только по размеру, но также по весу в пределах одной фракции.

Ключевые слова: пневматическая сеялка, высевающий аппарат, математическое моделирование, семена, масса, скорость, сила, траектория, уравнения.

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Method of Determining the Technical Parameters of Machines for Poultry Farming when no Parametric Information

Victor Rebenko, Ivan Rogovskii

National University of Life and Environmental Sciences of Ukraine.
E-mail: vicnb@ukr.net

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Summary. The article summarizes the existing domestic, European and North American methodological requirements to test set of machines for poultry.

Characterized that the method of comparing the values of indicators in the subject of complex regulatory requirements and with relevant indicators for complex analog.

It is also established that the results of mathematical processing of measurement data used for comparison with the required values of technical specifications with the state acceptance tests (technical terms, if state periodic testing) for a decision on the conformity of the test complex technical requirements to technical specifications). There are two possible cases.

Also, for comparison of parameters obtained in the prototype testing of complex equipment and complex analog calculate the significance of differences in means.

Recommendations from the results of testing complex take on the basis of results of comparison of values of indicators of the test of complex equipment technical requirements for supply, zootechnical requirements and values for complex analog.

Key words: methodology, requirement, test, complex, machine for poultry.

INTRODUCTION

In order to accelerate scientific and technological progress decision is provided to improve the system for evaluating the technical and economic level of developed and manufactured cars, including for livestock.

The efficiency of livestock production depends largely on the degree of perfection of applied technologies, machinery and equipment. Increasing production efficiency possible for a rational management of scientific and technological progress, scientific substantiation of directions of development and improvement techniques.

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

The main characteristic of the degree of perfection of machinery and equipment is the level of quality [1, 2]. Assess the level of quality for:

1) certification of machines [3],
2) select the best option [4],
3) improve the quality level of planning [5],
4) decision on statement on the production or removal from the production machine [6],
5) The quality of the machine control [7].

The quality of cars or technologies evaluated uniquely determined by a complex index, which is called the index of technical and economic level [8, 9].

Under the technical and economic level (TEU) understand the relative quantitative characterization of the degree of perfection of the machine, based on a comparison of its technical performance and economic indicators to the base case [10, 11]. This definition is consistent [12, 13] with regulatory accepted general methodological instructions and national standard.

However, these regulations dissect machine concept of quality for the following types: 1) the technical level (technical primarily constructive perfection and novelty) [14], 2) the level of quality of manufacture [15], 3) the quality level of the consumer (in operation) [16]. This approach leads to the fact that the quality level of the same machine is estimated in different ways, which is caused by the barriers between organizations, to develop, produce and use machines [17]. This is contrary to the requirements of modern scientific and technological progress, set out in the decisions of the CPSU and the Government, in particular, the Food Program for the period until 2020, which states the need to develop and implement a comprehensive program of machines for the standardization of agricultural production [18].

The main goal in determining the feasibility of the art is to improve the outcome - the production of agricultural products [19].

This Recommendation establishes methods for determining the TEU technologies, machines and components for farm animals, with which you can generate independent information and opinion for decision-making about the production of machinery for the production and the continuation of research and development work on the new development [20].

From the standpoint of the concept of TEU for machinery and equipment can be divided into two stages of their development and use of: I) this solution is made on the level of ideas or the experimental sample that is reliable indicators of the technical-operational and economic performance are not available [21]. The aim is to give an objective opinion on the need for further research and engineering design of the machine, or on the termination of further work, 2) Vehicle information is available on its technical and operational and economic performance obtained. result of industrial or state tests. The aim is to give an objective assessment of the degree of perfection of the machine, I specify the possible directions of work on quality improvement [22].

Due to the different data used for each stage applies its method of determining TEU.

OBJECTIVE

The following are the methods for determining the TEU technologies, machines and components for animal husbandry in relation to the two stages of the development and use.

THE MAIN RESULTS OF THE RESEARCH

1. Definition TEU machines for which no parametric information. Developed for machines for which no parametric information as an indicator of the proposed TEU applies fullness factor. Last characterizes the potential technical and economic level of the developed machines and is defined as:

$$\Phi = \frac{b}{B} = \frac{\sum_{i=1}^{m} j_{\text{ок}}}{\sum_{i=1}^{m} j_{\text{ок}}^{max}}\,. \quad \text{(q)}$$

where b - the amount of the final j_{ok} estimates, which are assigned to this proposal by comparing it with a general identification key. (GOT), B - the maximum amount of the final estimates $j^{max}{}_{ok}$ all the characteristics of GOT.

In order to determine the fullness factor, develop a GEI, which summarizes the requirements for the car of the future from the standpoint of present-day conditions. In accordance with the terminology of the Committee of scientific and technical terminology, the Academy of Sciences of the GOT - is a system of weighted characteristics of the object of forecasting, which allows to transform it into a qualitative description of a generalized quantitative assessment. GOT includes features for which correlated information sources - the objects for which the determined TEU. Each characteristic is decomposed into sub-goals, characteristics that differentiate. With the help of expert determine absolute values of significance (from 0 to 1) characteristics. The number of characteristics must be between 6-9. Expert number upper limit is not limited, but should be at least 10. Preparation and processing of expert information produced in accordance with accepted methods. At the same time take into account that the value of the significance of characteristics φ reflects the subjective opinion of a broad range of specialists (in other ways to prove the significance can not be). Consequently, the expert estimates are stochastic variables that are grouped around an unknown mathematical expectation M). Since the true value of M (φ) can not be determined, using its evaluation: which are grouped around an unknown mathematical expectation M). Since the true value of M (φ) can not be determined, using its evaluation: which are grouped around an unknown mathematical expectation M). Since the true value of M (φ) can not be determined, using its evaluation:

the average

$$M(\varphi) = \int_{-\infty}^{+\infty} \varphi\, f(\varphi) d\varphi. \quad (2)$$

and the variance

$$\sigma^2 = \int_{-\infty}^{+\infty} [\varphi - M(\varphi)]^2 f(\varphi) d\varphi$$

where f (φ) - the probability density function c_p.

Typically, at processing expert information limited calculation of mean, variance, and a coefficient of variation of concordance (consistency), and their values is taken as the average value of significance. However, the results thus estimates M(φ) can be displaced and inconsistent, particularly when a small number of experts. Therefore, the completeness and the coefficients c_p, calculated by (1), will be displaced, which leads to errors in the recommendations for decision-making.

Process described below for obtaining and processing expert information and a method for calculating the fullness factor allows to obtain unbiased estimates Φ. It is based on: 1) using a Bayesian approach in determining the characteristics and significance 2) calculating values of completeness not point coefficient (coefficient and TEU) and its confidence interval with a predetermined probability.

Bayesian approach in determining the significance of the characteristics of GOT.

General identification key developed by a group of researchers (forecasters), taking into account policy decisions, orders and other documents. For each type of equipment comprise a list of characteristics and their significance are predetermined based on the requirements that are put forward scientific-technical progress.

It should be noted that the value of (sometimes called a weight) reflects the characteristics of the demands made at the present time to the developed machines. Thus, the reduction of labor costs and money, improve the quality of the work in creating machines for the period of the most significant until 2000. If GEI developed at the end of the XIX century for the evaluation of cars with electric drive, it would be no less important requirement of electrical safety than the reduction of labor costs and money, since at the time of electrical issues were not resolved. Currently created equipment which if properly exploited virtually eliminates trauma to humans and animals, and therefore the importance of characteristics reflecting the working conditions, less than demand reduction of labor costs and money. (Note here that such means are available, such as cranes,

Due to the fact that the value of φ is in the range 0 ... 1, the probability density function φ describes a beta distribution. For information about the importance of some characteristics assigned forecasters said to be a priori, and the function f (φ) is called a priori probability density function. It can be designated P (φ) and takes the form:

$$P(a_1, b_1) = [1/B(a_1, b_1)]\varphi^{a_1-1}(1-\varphi)^{b_1-1}\,. \quad (4)$$

where a_1 and b_1 - priori parameters of φ, B (a1, b1) - normalizing constant (beta), expressed in terms of the gamma function

B (a1, b1) = D (a1) r (b1) / T (a1 + b1).

Note. For convenience, an index indicating the characteristics of a room, is omitted here.

Parameters (4) are in accordance with known methods.

Since forecasters (as well as experts) is difficult to "feel" the physical meaning of the parameters a and b, the values are initially set φ, then the parameters for (4) is calculated as follows:

$$a_1 = \varphi_{\text{cp}} \left[\frac{\varphi_{\text{cp}} - (1-\varphi_{\text{cp}})}{S^2} - 1\right]. \quad (5)$$

$$b_1 = (1-\varphi_{\text{cp}}) \left[\frac{\varphi_{\text{cp}} - (1-\varphi_{\text{cp}})}{S^2} - 1\right]. \quad (6)$$

φsr wherein - the sample mean, S2 - sample variance determined from the expression:

$$\varphi_{\text{cp}} = (1/n) \sum_{i=1}^{m} \varphi_i .$$

$$S^2 = (1/(n-1)) \sum_{i=1}^{m} (\varphi_i - \varphi_{\text{cp}})^2 .$$

Here m - number of predictors, φi - significance of this characteristic, and said i-th forecaster. Note that the number of predictors is not limited, and may be equal to one, then the sample variance of (8) vanishes,

In the compilation of a list of characteristics of individual columns indicate their a priori importance and sending experts to specify their magnitude of importance. If the examiner agrees with the estimates of forecasters, he only signs the form, otherwise indicate its estimates. This approach has the advantage over other methods. On the one hand, experts have different understandings of absolute importance (the relative importance of getting characteristics when including a 6 undesirable because expert is unable to decompose the objective unit 6 or more different sizes), and their estimates may be very different. On the other hand, if the forecasters have significant experience in the preparation of GOT, it is vital to take into account their knowledge in determining the characteristics of significance.

Resulting from the evaluation experts treated. According to the results of the examination determines the probability density function, which is the likelihood function. We denote it by P (φ | a2, b2). Since the likelihood function also applies to the beta-distribution, then:

$$P(\varphi|a_2, b_2) = K_2 \varphi^{a_2 - 1} (1-\varphi)^{b_2 - 1}. \quad (7)$$

where K2 - normalizing constant.

Parameters (7) a2 and b2, are defined by (5) and (6).

By Bayes' theorem posterior (joint) probability density function P (a, b | φ) can be obtained based on a priori association function (4) and the likelihood function (7):

$$P(a, b|\varphi) = \frac{P(a_1, b_1) P(\varphi|a2, b2)}{P(\varphi)}. \quad (8)$$

where P (φ) - normalizing constant:

$$P(\varphi) = \int_{-\infty}^{+\infty} P(\theta)\, P(\varphi|\theta) d\theta. \quad (9)$$

Here P (θ) - a vector of parameters of a random distribution.

Then:

$$P(a, b|\varphi) \sim P(a_1, b_1) P(\varphi|a2, b2). \quad (10)$$

where the sign ~ denotes proportionality.

Under conventional operations on c probability distribution functions of the function (10) takes the form:

$$P(a, b|\varphi) \sim K_0 \varphi^{a_1 + a_2 - 2} (1-\varphi)^{b_1 + b_2 - 2}. \quad (11)$$

Function (11) refers to beta-distribution with parameters a = a1 + a2-1 and b = b1 + b2-2. Normalizing constant for (11) is equal to:

T K0 = (a + b) / G (a) D (b). (12)

Having calculated from the function (11) the parameters of the received information, determine the parameters: evaluation of expectation, variance and the confidence interval for the significance of the characteristics. Evaluation of mathematical expectation is equal to:.

$$M(\varphi) = a/(a+b). \quad (13)$$

and variance:

$$D = ab/(a+b)^2(a+b+1) . \quad (14)$$

Next, determine the confidence interval with a probability of P (typically P = 0.95) for the expectation:

$$\varphi = M(\varphi) \pm t_\alpha \sqrt{D}/\sqrt{n}. \quad (15)$$

where tα - t-statistics for a probability P = 1-d,

n - the number of experts who participated in the assessment of the significance of this characteristic.

We illustrate forth in this Example section. According to one characteristic of predictors (in an amount of 3 persons) established following estimates of significance: 0.90, 0.95, 0.85, then the mean value φ = 0,90, dispersion S2 = 0,00167. We define the parameters for the prior distribution (5) and (6):

a1 = 0.90 ((0.90 (1 - 0.90) / .00167) - 1) = 47.702,

b1 = (1 - 0.90) ((0.90 (1 - 0.90) / 0.00167) -1) = = 5.300.

24 experts were rated. Processing them showed that the Expert Opinions mainly aligned (concordance coefficient is 0.47 and is not different from zero at the 0.05 level). Mean value is 0.909, the dispersion is 0.086. likelihood function parameters are: a2 = 9,265, b2 = 0,927.

Substituting in (11) obtained parameters can be calculated (by the method of numerical integration) for any probability φ. But we are interested in the confidence interval for M (φ) probability P = 0.95. Therefore, first we calculate the parameters of the posterior distribution.

a = a1 + a2 - 1 = 47.702 + 9.265 - 1 = 55.967,

b = b1 + b2 - 1 = 5.300 + 0.927 - 1 = 5.227.

Then estimate the posterior of the expectation of (13) is equal to:

M (φ) = 55.967 / (55.967 + 5.227) = 0.914,

and the variance of (14) will be:

D = 55.967 * 5.227 / (55.967 +5.227) 2 (55.967 + +5,227-1) = 0.01256.

For the calculation of (15) of the confidence interval at n = 24 and P = 0.95 by / 13 / have: tα = 2,07. Substituting in (15), the numerical values, we obtain:

φ = 0.914 ± 2.07 √0,01256 / √24 = 0.914 ± 0.015.

Thus, the average value of the significance of this characteristic is 0.914, and the confidence interval with a probability of P = 0.95 is M (φ) = 0,899 ... 0,929.

In determining the coefficient of fullness of the formula (1) produce not only calculating the mean values M (φ), but also for their deviations: first, for minimum and then for the maximum. The numerator is summed only the average value M (φ). This facilitates the calculation of the coefficient of fullness, which is to obtain its three estimates: the mean, minimum (in the denominator substituted greatest values B, calculated from (15)), and the maximum value (in the denominator of (1) substituted lowest values B).

Table 1. GOT characteristics of significance when assessing the technical means for the preparation and distribution of feed.

number specifications	*φsr* M = (φ)	**σ** = √D	confidence interval at P = 0.95
1	0.909	0.089	0.881 ... 0.937
2	0.836	0.122	0.798 ... 0.874
3	0.941	0,080	0.916 ... 0.966
4	0.746	0.164	0.695 ... 0.797
5	0,900	0.106	0.867 ... 0.933
6	0.527	0.244	0.458 ... 0.596
7	0.523	0.219	0.455 ... 0.591
8	0.623	0.189	0.564 ... 0.681

We show in this example for GOT developed. The final evaluation of the positions of GOT are defined as follows:

$$jok\ \varphi sr = m = m\ M\ (\varphi). \tag{16}$$

where m - the item number (baseline assessment).

Thus, the first position estimate equal importance characteristics.

To assess the means of preparation and feed distribution characteristics obtained significance and their statistical evaluation are listed in Table 1.Note. To obtain estimates shown in Table 1, we used data from 24 experts.

The denominator of (1) The value expresses the maximum amount of the final importance ratings. Since the number of positions on all the characteristics equal to 7, the average value of B is equal to:

$$\bar{B} = \sum_{i=1}^{8} 7\bar{\varphi}_i = 42{,}035. \tag{17}$$

minimum value

$$B_{min} = \sum_{i=1}^{8} 7\varphi_{min,i} = 39{,}438. \tag{18}$$

and the maximum value

$$B_{max} = \sum_{i=1}^{8} 7\varphi_{max,i} = 44{,}625. \tag{19}$$

We define the ratio of completeness mobile feeder (Inventor's Certificate №665867), wherein the unloading device has a screw, which contributes to the accuracy of the feed dosage. When comparing this proposal GOT annexed 1 revealed the structural formula: 33353446. Each digit of structural formula represents a baseline assessment for all characteristics of the first to eighth which deserves the proposal. Comparison with the GOT produce forecasters with the involvement of specialists with experience in the development and research of this type of technology. From the expression (16) we have:

b = 3 * 0.909 + 3 * 0.836 + 3 * 0.941 + 5 * 0.746 + 4 * 0.527 + 4 * 0.523 + 6 * 0.623 = 22.645.

Using (17) - (19) calculate on (1) the coefficient of fullness of:

F = 22.645: 42.035 = 0.539,

$Fmin$ = 22.645: 44.625 = 0.507,

$Fmax$ = 22.645: 39.438 = 0.576.

fullness factor may be normalized with the value of coefficient K TEU:

$$K = F + 0.8. \tag{20}$$

and submit to the generalized indicator of technical and economic level. Scale categories for P and K.

By comparing the obtained values of the coefficient of completeness of the above proposals for the distribution of feed we can see that this proposal relates to unpromising. This is due to the fact that for the first three and the fifth characteristics of the proposal received low scores. should have in the development of devices to make novelty not only to improve the quality of work, but also for increasing productivity and reliability.

The second example. Distributor-mixer for cattle farms has a structural formula of GOT 45354546. fullness factor F = 0.58 ... 0.74, and TEU coefficient K = 1,38 ... 1,54, which makes the device a promising, however further work on this machine must seek to further reduce labor costs (for the third characteristic low score).

Thus, for determining the coefficient TEU and its analysis, the following steps should be performed.

1. Create GOT for this type of art. You can use the GOT provided in Appendix 1. If there are any doubts about the importance of performance assessment, they can improve (specify) by applying a Bayesian approach. For this purpose given in these guidelines statistical evaluation of the significance used as parameters a priori function, and received by any way of new information to construct the likelihood function.

2. Compare the analyte bid with GOT, calculate TEU factor (K factor).

3. Resolve To the scale categories.

4. Formulate proposals for decisions on the technical proposal.

Coefficient TEU machinery and equipment, for which there is information about their technical performance and economic indicators, defined as the sum of the relative changes in performance compared to the base model, divided by the sum of the importance of all parameters:

$$K = \frac{\sum_{i=1}^{m} g_i \varphi_i}{\sum_{i=1}^{m} \varphi_i}. \tag{21}$$

where gi - the relative change in the i-th index, φi - the importance of the i-th index, m - number of indicators.

From (21) it is seen that the coefficient TEU is a complex dimensionless exponent investigated machines perfection from baseline.

TEU coefficient determination process includes the following steps:

1. to identify a list of indicators,
2. definition of relevant indicators,
3. collect data on the machine,
4. selection of the base sample and the collection of data concerning him,
5. TEU calculation coefficient,
6. Analysis TEU ratio and its components, to prepare recommendations for a decision.

TEU coefficient determined for all types of machinery and equipment used on livestock farms.

Table 2. Features and values, which is determined by the TEU machines for livestock.

name specifications	list of indicators
1. Improving the quality of work	Quality of the process
2. Reduction of material consumption	consumption of materials
3. Reduction of energy consumption	Energy intensity
4. Increase the unification	coefficient of applicability
5. Reducing the cost of installation, maintenance and technological service * (increase maintainability)	1. Montazheprigodnost 2. Specific complexity of maintenance
6. Increased reliability	1. availability factor 2. The coefficient of process reliability
7. Improving the working conditions	level indicators: 1) dust, 2) noise, 3) vibration, 4) temperature, 5) the concentration of harmful substances
8. Reduced labor costs	Unit labor costs
9. Reducing the cost of funds	Specific indicators: 1) investment 2) operating costs, 3) reduced costs

* The indicator "specific complexity of repair" is a measure of reliability - "uptime".

Conditionally possible to allocate for this purpose following techniques:

1. design and technology of the farm as a whole,
2. a set of equipment on the farm,
3. Kit preparation center equipment,
4. Crushers of food,
5. granulators,
6. feed dispensers,
7. food mixers,
8. feeders,
9. Milking installation,
10. preprocessing means milk,
11. means watering animals,
12. means manure,
13. storage facilities and manure,
14. a leash,
15. machining equipment.

Identify a list of indicators indicators are used to determine TEU machines that defined the applicable regulations. However GOST 4.57-79 provides, if necessary, to supplement the existing list of indicators.

Typically, indicators are combined in groups and in the calculation TEU set relevance indicators each group. Conducted in studies have shown that more advisable to combine all indicators in these groups, whose contents meet the specific requirements of scientific and technological progress, and each group express the characteristics of scientific and technical progress. In this case, it becomes possible to objectively evaluate the significance of the characteristics, and, consequently, groups of indicators. At the same violations GOST 4.57-79 happens. To determine TEU machines used in animal husbandry, all indicators can be combined into 9 groups, which correspond to the characteristics given in Table 2.

Significance is determined by the characteristics of Defect. For this purpose any examination procedure. It is useful to take advantage of the recommendations, which are described in Section 2 of these guidelines, namely developers priori set the value and importance of reporting them to the experts, obtained from the evaluation experts and process them according to the method. Using a Bayesian approach averages calculated significances, which is used in subsequent calculations.

To verify the above estimates, proceed as follows. Assess the significance of the application 6 is presented as a priori information, and new estimates obtained are used to construct the likelihood function. Then Bayes' theorem combine both functions and acquire new revised estimates.

To determine the coefficient TEU are required for machine all evaluated parameters noted in Table 2, if, of course, they are inherent in the machine. For their preparation used regulated methods and procedures laid down in the relevant national and industry standards. Here we mention briefly some features of reception of input data.

The quality of the machines and kits used in livestock, expressed quality indicators, which are inherent in this type of equipment needed in the performance of the manufacturing operation. For example, the quality of the uneven dispensing feeder evaluated (in%) and the feed losses (in%).

Material-Ku.m GOST 14.202-73 defined as the ratio M of the machine to its mass productivity W:

$$К_{у.м} = {}^{М}/_{W}, \frac{kg}{t/h} \tag{22}$$

For those of machinery and equipment that is not defined performance (for example, machine tool equipment), material consumption is expressed in units of mass in the head:

$$К_{у.м} = {}^{М}/_{N}, \frac{kg}{h} \tag{23}$$

where N - served population.

Energy intensity E is defined as the process of the specific energy consumption:

$$Э = {}^{P}/_{W}, \frac{kW\cdot h}{t/h} \quad \text{or} \quad Э = {}^{P}/_{N}, \frac{kW\cdot h}{h} \tag{24}$$

where P - power expended on the drive.

Unification of the new machine in accordance with GOST 22851-77 expressed by the coefficient of applicability:

$$К_{пр} = \frac{n-n_0}{n}, \quad (25)$$

where n - total number of standard sizes of the main parts of the machine,

n_0 - the number of sizes of original components.

It follows from calculations on (25) should be deleted in accordance with the fasteners, screws, plugs, dowels, gaskets, small tools, and other similar items.

Maintainability expressed montazheprigodnostyu, complexity of maintenance and repair.

Coefficient Km:

$$К_м = \frac{Q_0}{Q_0+Q_м}, \quad (26)$$

where Q_0 - the wholesale price of the equipment, rubles,

Qm - installation of the equipment cost, rubles.

The complexity of maintenance is determined according to GOST 13377-75 specific maintenance complexity:

$$К_{то} = \frac{Т_р}{Т_т+Т_р}, \quad (27)$$

where K_{TO} - coefficient maintenance complexity,

T_t - total labor costs for maintenance during the test period,

Tr - the total time during the same test period.

There do not include component repairs complexity, since in accordance with the GOST 13377-75 availability factor (see below.) Describe various properties simultaneously two machines - its reliability and maintainability.

Reliability GOST 13377-75 expressed: availability factor

$$К_г = \frac{Т_о}{Т_о+Т_в}, \quad (28)$$

where T0 - MTBF,

tv - mean time to repair,

and process reliability coefficient

$$К_{тп} = \frac{Т}{Т \quad +Т_{ун}}, \quad (29)$$

where T - time net work over the testing period,

Thun - the time spent on the elimination of violations of the process.

Working conditions indicators in accordance with GOST 16456-70 and GOST 12.1.005-76 are defined as follows. The following parameters determine if necessary: the level of dust in the workplace (mg / m^3), component noise in the workplace (dB), figure vibration in the workplace (dB), temperature level indicator in the workplace and unprotected parts of the machine heated ° C), indicator of the concentration of hazardous substances in the workplace (mg / m^3).

Definition of economic indicators, unit labor costs (person-hours / ton, people · h / bird.), investments (RUR / t, € / goal), operating costs (RUR / t, rubles / goal), reduced costs (RUR / t, rubles / finish) is carried out in accordance with existing methods.

All raw data obtained are entered in a table form on application 7.

In the preparation of the initial data for the calculation should take into account two features.

The first feature. Indicators of the car and especially the performance of which is included as a derivative in almost all indicators, is a random variable. Normative materials to determine TEU recommended to take this into account.

The second feature. Researcher who determines the TEU, has, as a rule, several (more than one) sources of information about the performance of this machine: the machine test reports on MIS, departmental protocols or hardware testing.

The first feature is treated as follows. For each indicator accept not only its mean value, but also the confidence interval with a predetermined probability. For this purpose, the information embedded in the original sources or the use known statistical methods, including regulatory. Thus, the confidence limits for the random variable with a normal distribution are determined by the formulas:

upper bound

$$x_в = \bar{x} + t_\alpha S/\sqrt{n} \quad (30)$$

bottom line

$$x_н = \bar{x} - t_\alpha S/\sqrt{n} \quad (31)$$

where $\bar{x}$- the average value of the index,

S - standard deviation

n - number of measurements,

tα - t-Student statistics with n-1 degrees of freedom and a probability P = 1-α.

The second feature allows for the use of the Bayesian approach. Section 2 describes the main provisions of the Bayesian approach. Here we mention a method of its application to the raw data obtained on the machines from different sources.

Let the results obtained testing machine metric values, the results are processed, whereby each indicator detected by the likelihood function - the probability density function F (x / θ) for a random observation vector x and the parameter vector θ. Under the parameters θ understand the parameters of the distribution, for example, for a normal distribution are the parameters: expectation m and variance σp2. Information obtained previously from other sources (MIS reports, economic test) is used to construct a priori probability density function, which is denoted by P (θ). The joint (posterior) probability density function takes the form:

$$P(\theta / x) \sim P(\theta)\, P(x / \theta). \quad (32)$$

If the function is a priori, and likelihood are normally distributed, they are written as follows. Priori function for the value m:

$$P(m) = (\sqrt{2\pi}\sigma_а)^{-1} exp[-(2\sigma_а^2)^{-1}(m - m_а)]. \quad (33)$$

where ma - priori expectation σa2 - priori variance.

The likelihood function for the unknown parameter m for a given sample n, value x becomes:

$$P(x|m, \sigma_n^2) = (2\pi\sigma_n^2)^{-n/2} exp\left[-\frac{1}{2\sigma_n^2}\sum_{i=1}^{n}(x_i - -m)^2\right]. (34)$$

where σn_2, - known variance for a given sample.

Then, in accordance with (32) function to obtain the a posteriori parameter m:

$$P(m|x, \sigma_n^2) \sim exp\left\{-\frac{1}{2}\left[\frac{(m-m_а)^2}{\sigma_а^2} + \frac{n}{\sigma_n^2}(m-\bar{x})^2\right]\right\}. (35)$$

From (35) we see that the parameter m is also normally distributed with expectation:

$$M(m) = \frac{x\sigma_а^2 + m_а\sigma_n^2/n}{\sigma_а^2+\sigma_n^2/n}. \quad (36)$$

and variance:

$$D(m) = \frac{\sigma_a^2 \sigma_n^2 / n}{\sigma_a^2 + \sigma_n^2 / n}. \quad (37)$$

Expression (36) shows that the posterior expectation is a weighted average sample average of the test results and a priori mathematical expectation, combined with weights to reverse.$\bar{x}\sigma_n^2 / n\sigma_a^2$

The above example will explain. In the study of the following a priori information of the mixer was set at P-economic conditions 30: mixer performance W = 14.0 m / h = ma (a priori expectation), and the a priori variance for W is = 8.5. Tests of this mixer into VNIIMOZH the results of 40 measurements showed that the sample average productivity W = 15,20 t / h = and = sample variance is 1.20. Combining function priori likelihood function by the formula (36) we calculate the expectation for a posteriori performance of the mixer:$\sigma_a^2 \bar{x} \sigma_n^2$

$$M(W) = \frac{15.2*8.3+14.0*1.2/40}{8.3+1.2/40} = 15.19 \text{ T / h.}$$

Posteriori variance of (37) will be:

$$D(W) = \frac{8.3*1.2/40}{8.3+1.2/40} = 0.03.$$

Define a confidence interval for W by the formulas (30) and (31), taking into account that tα = 2,02

at P = 0.95, and n = 40:

W = 15,19 ± 2,02 * 0,173 / √40 = 15,13 ... 15,25 t / h.

If you do not use a Bayesian approach is based on the results confidence interval is:

W = 15,20 ± 2,02 * 1.095 / √40 = 14,15 ... 15,55 t / h.

As seen from this example, a Bayesian approach to reduce the confidence interval, i.e. to obtain more accurate data.

Base sample for comparative evaluation of performance when calculating TEU coefficient is selected in accordance with the instructions. He shall be chosen from a group of machines that are similar in purpose, production and operating conditions. The basic model can serve as a machine manufactured in abroad, technical and economic indicators which at the time of assessment to meet the highest requirements and is most effective in operation. Using obsolete and technically inefficient samples leads to distortion unreasonably high coefficient TEU.

Not allowed the use as a base sample of hypothetical samples, not the past, at the time the TEU, scientific and engineering work.

A set of basic values indicators should characterize optimal performance TEU at a given period.

Obtaining basic indicators of the sample must be performed by the same methods as that of being assessed to ensure their comparability.

Selection of basic models produce industrial research institutes, central and head of SKB, headaches and basic standards organizations. These organizations are establishing collection, analysis and synthesis of materials on the performance of domestic and foreign cars, establish their validity and timely supply interested companies and organizations.

TEU factor is the generalized indicator of the estimated degree of perfection of the machine and is calculated as follows:

$$K = \sum_{i=1}^{m} g_i \varphi_i \, / \sum_{i=1}^{m} \varphi_i \quad (38)$$

where gi - the relative change in the estimated machine compared with the base, φi - importance (weighing) i-th index, the total number of which is m.

The relative change of a single parameter is determined by the formulas:

$$g_i = \begin{cases} \frac{S_{\delta i} - \beta_i}{S_i - \beta_i}, S_i \to \beta \neq 0 \\ \frac{S_i}{S_{\delta i}}, S_i \to max \\ \frac{S_{\delta i}}{S_i}, S_{\delta i} \to min \end{cases} \quad (39, 40, 41)$$

where Sδi, Si - index values, respectively and the base of the machine being evaluated, βi - known reasonable limit change indicator.

If this characteristic is determined several unit figures, the generalized value gi for the group of indicators is calculated by the formula:

$$g_i = \sqrt[e]{\prod_{k=1}^{e} g_{ki}}, \text{ k = 1,2, ..., e} \quad (42)$$

where e - the number of indicators of this group corresponding to the i-th characteristic.

Depending on how the must, in accordance with the technical progress indicator change, apply a particular formula for determining gi.

If the formula (39) used in accordance with the technical progress indicator should be increased and the known index achieve reasonable limit (e.g., availability factor for which β = 1), and this limit has not yet been achieved for either the base or to the estimated machine.

If the limit of variation of the unknown or zero, or made known limit nonzero, apply the formula (40) or (41). Thus, if the exponent must be incremented formula (40) used in accordance with the technological progress, and if technical progress to the reduction index, formula (41) is used.

Examples explain the calculation of the relative change.

Example 1: The availability of the conveyor for cleaning manure TSN-160 kg = 0.98 ... 0.99. Basic machine (TSN-3,0B transporter) is Cg = 0.94 ... 0.96. (4 According machines test protocols 10 IIA). Tensile index change β = 1. From (39) we have:

$$g_{i\,max} = \frac{0{,}94-1}{0{,}99-1} = 6.$$

$$g_{i\,min} = \frac{0{,}96-1}{0{,}98-1} = 2.$$

Then: gi = 2 ... 6. As can be seen, for the calculation of the maximum relative change gi accept the most favorable conditions for the comparison of the machine: from the base index of the smallest, while the estimated - the greatest. The minimum value is determined for the adverse conditions: at the base of the machine indicator largest, while being evaluated is the smallest.

Example 2. The coefficient of process reliability in the estimated machine - continuous feed mixer CH-100M Rmn = 1.0. At the base of the machine - Mixer C-30 Rmn = 0.98 ... 0.99. Since the estimated machine reached the limit indicator, use the formula (40),

$$g_i = \frac{1{,}0}{0{,}98 \ldots 0{,}99} = 1{,}01 \ldots 1{,}02.$$

Example 3. We calculate the relative change in the power consumption of the mixer CH-100M (power P = 6,5 kW, Wδ = 30 ... 35 m / h) as compared with mixer C-30 (p = 5.5 kW, Wδ = 15.13 ... 15.25 t / h). To do this, first determine the energy consumption of machines:

$$Э_i = \frac{6{,}5}{30 \ldots 35} = 0{,}185 \ldots 0{,}217 \text{ kWh / t,}$$

$$Э_i = \frac{5{,}5}{15{,}13 \ldots 15{,}25} = 0{,}361 \ldots 0{,}364 \text{ kWh / ton.}$$

Then the limits of the relative change in energy intensity according to the formula (41) are equal to:

$$g_{i\,max} = \frac{0,364}{0,185} = 1,97.$$

$$g_{i\,min} = \frac{0,361}{0,217} = 1,66.$$

Thus, for this indicator gi = 1,66 ... 1,97.

Substituting into equation (38) the calculated values gi, TEU coefficient determined, not only the mean value but also the confidence interval.

Here is an example of determining the coefficient TEU Autodrinking group ACG-12. Base installation serves drinker PCA-4A and troughs "Richie" firm Catley-Masta (USA). Input data and calculation results are shown in Tables 3 and 4. Note that the indicators of working conditions by using drinkers are not changed. Due to the fact that the estimated troughs 400 serves to livestock fattening at the sites, and base - to 100 heads, calculations are made for 400 head of livestock. Coefficient TEU ACG-drinkers 12 is 1.71 ... 2.00, which can be attributed to its very promising equipment. Also applies to prospective drinker evaluated and compared to the best foreign models.

Analysis TEU coefficient start with comparing it with values for an application-level categories ascertain 5. Further, for some parameters achieved a significant increase gi and on which there is no increase of relative change or it slightly. Analysis of all the indicators are exposed. If there is an opportunity to improve individual performance, it is reflected in the conclusion.

Especially analyze the quality of performance indicators. If they do not conform to zootechnical requirements, regardless of the value of the coefficient TEU, the car is not recommended for use. Also check compliance with working conditions. If these figures are estimated machine worse than normative (permissible), the car is not recommended to be used to address this shortcoming.

Materials TEU coefficient calculations provide a basis for drafting the technical level of the card, which is filled in accordance with the GOST 2.116-71.

The results of calculating the coefficient of TEU and the technical level of the card are transferred to the relevant departments, organizations and institutions for decision-making. These same materials are attached to the zootechnical requirements on the machine or equipment.

Table 3. Determination coefficient TEU watering system cattle in feedlots with ACS-12 application group drinkers.

Name specifications	indicator	U rev.	Limit	significance			***gi (1)***	***gi (2)***
				Evaluated ACG-12 equipment	compares			
					PCA-4A	"Richie"		
1. Increase the quality of work	Water pollution	g / l	0	0,27-0,30	0,42-0,45	0,27-0,30	1.40-1.67	one
2. Decrease consumption of materials	consumption of materials	kg / head	-	0.31	0.55	0.31	1.77	one
3.Snizhenie energy intensity	Energy intensity	kWh / head	-	0,0210-0,0215	0,0306-0,0308	0,0210-0,0215	1,42-1,47	one
4.Povyshenie unification	coefficient of applicability	-	one	0.7	one	0.42	0.7	1.67
5.Povyshenie maintainability	1) Ratio montazheprigodnosti 2) Coefficient maintenance laboriousness	- -	- -	0.6 0,999	0,325 0,89-0,90	0.62 0,999	1.85 1,12-1,11	0.97 one
6.Povyshenie reliability	1) availability factor 2 Coefficient of process reliability	- -	one one	0.98-0.99 one	0.98-0.99 0.99	0,999 one	10-20 1.01	one one
7. Indicators of working conditions do not change								
8.Snizhenie labor costs	Unit labor costs in the year	man-hours / goal		0,0035-0,0037	0,0058-0,0060	0,0035-0,0037	1.57-1.72	one
9.Snizhenie means costs	1) Investments 2) Annual operating costs 3) The annual costs given	p / head p / head p / head	- - -	9.35 1,45-1,47 2,85-2,87	14.04 2,20-2,22 4,31-4,33	13.87 2,15-2,17 4,23-4,25	1.50 1,50-1,53 1,50-1,53	1.48 1,02-1,03 1,48-1,50

Note: gi (1) - basic equipment AGK-4A, gi (2) - basic equipment "Richie".

Table 4. Calculation of the coefficient TEU.

number specifications	significance *φi*	Basic - PCA-4A		Basic - "Richie"	
		gi (1)*min φi*	***gi (1)****max φi*	***gi (2)****min φi*	***gi (2)****max φi*
one	0.95	1.33	1.59	0.95	0.95
2	0.86	1.52	1.52	0.86	0.86
3	0.50	0.71	0.74	0.50	0.50
four	0.56	0.39	0.39	0.94	0.94
five	0.64	0.92	0.92	0.63	0.63
6	0.96	3.05	4.31	0.96	0.96
eight	0.76	1.19	1.36	0.76	0.76
9	0.83	1.25	1.26	1.09	1.10
Σ	6.06	10.36	12.09	6.69	6.70

CONCLUSIONS

1. Note: relative change in characteristics 5, 6 and 8 were calculated by the formula (40).
2. TEU coefficient compared to domestic equipment: K1 = (10.36 ... 12.09) / 6,06 = 1,71 ... 2,00.
3. TEU coefficient compared with foreign equipment K2 = (6.69 ... 6.70) / 6,06 = 1,10 ... 1,11.

REFERENCES

1. **J. Liua M. Abdalbasit, A. Gasmallaa, P. Lia, R. Yang. 2016.** Enzyme-assisted extraction processing from oilseeds: Principle, processing and application. Innovative Food Science & Emerging Technologies. Vol. 35. 184-193.
2. **Th. A. McKeon, D. L. Brandon, X. He. 2016.** Improved method for extraction of castor seed for toxin determination. Biocatalysis and Agricultural Biotechnology. Vol. 5. 56-57.
3. **Novitsky A. V. 2015.** Assessment of the reliability of funds for the preparation and distribution of feed, depending on conditions and modes of operation. Scientific Bulletin of National University of life and environmental Sciences of Ukraine. Series: electronics and energetics, agriculture. Kiev. Vol. 212. 141-147.
4. **Modern methods for the preparation and distribution of feed. 2018.** Available at: http://www.propozitsiya.com.
5. **Verkhovna Rada of Ukraine. 1994.** The Law of Ukraine "On ensuring the sanitary and epidemic well-being of the population", Vidomosti Verkhovnoi Rady Ukrainy. Vol. 27. 218.
6. **Ministry of Health Protection of Ukraine. 1996.** Order "On Approval of State Sanitary Rules and Norms", available at: http://zakon2.rada.gov.ua/laws/show/z0488-96 (Accessed 16 Jan 2017).
7. **Lukin V. A. 2011.** New sanitary norms and rules: first impressions. Wireless Ukraine, vol. 7(1). 18-21, Available at: http://www.wireless.ua/templates/new_template/images/wu6.pdf (Accessed 16 Jan 2017).
8. conf.rd.asu.lt/index.php/rd/article/download/151/34.html.
9. **Rogovskii I. L. 2015.** Recovery Assembly units of agricultural machines. Bulletin of Kharkov National Technical University of Agriculture named Peter Vasilenko. Kharkov. Vol. 159. 224-232.
10. **Rogovskii I. L. 2015.** Methodologist technological operations recovery of agricultural machines with limited resources. Scientific Herald of National University of Life and Enviromental Science of Ukraine. Series: Technique and energy of APK. Kyiv. Vol. 212.
Part 1. 314-322.
11. **Rogovskii I. L., Melnyk V. I. 2016.** Model of parametric synthesis rehabilitation agricultural machines. Scientific Herald of National University of Life and Enviromental Science of Ukraine. Series: Technique and energy of APK. Kyiv. Vol. 241. 387-395.
12. **Rogovskii I. L., Melnyk V. I. 2016.** Analyticity of spatial requirements for maintenance of agricultural machinery. Scientific Herald of National University of Life and Enviromental Science of Ukraine. Series: Technique and energy of APK. Kyiv. Vol. 251. 400-407.
13. **Rogovskii I. L. 2016.** Analysis of model of recovery of agricultural machines and interpretation of results of numerical experiment. Scientific Herald of National University of Life and Enviromental Science of Ukraine. Series: Technique and energy of APK. Kyiv. Vol. 254. 424-431.
14. **Voytyuk V. D., Rublyov V. I., Rogovskii I. L. 2016.** System guidelines for quality assurance of technical service of agricultural machinery. Kiev. NULESU. 360.
15. **Rebenko V. I., Rogovskii I. L. 2017.** Methodological requirements to test set of machines for poultry. Scientific Herald of National University of Life and Enviromental Science of Ukraine. Series: Technique and energy of APK. Kyiv. Vol. 275. 311-325.
16. **Rebenko V. I., Rogovskii I. L. 2018.** Basic methodological requirements to test set of machines for poultry. Scientific Herald of National University of Life and Environmental Science of Ukraine. Series: Technique and energy of APK. Kyiv. Vol. 282. 339-350.
17. **Rogovskii Ivan. 2014.** Stochastic models ensure the efficiency of agricultural machines. *MOTROL*. Lublin. 2014. Vol. 16. No 3. 296-302.
18. **Rogovskii Ivan. 2016.** Graph-modeling when the response and recovery of agricultural machinery. *MOTROL*. Lublin. Vol. 18. No 3. 155-164.
19. **Rogovskii Ivan. 2017.** Analytical provision of regular preventive maintenance of agricultural machinery and system implementation. *MOTROL*. Lublin. Vol. 19. No 3. P. 185-191.
20. **Rogovskii Ivan. 2017.** Choice of model class and method of modeling the resilience of agricultural machinery. *TEKA*. Lublin–Rzeszów. 2017. Vol. 17. No 3. 101-114.

21. **Rogovskii Ivan, Eugeniusz Krasowski. 2018.** Entropy Conditional Subjective Preferences for Alternative Functions Defined in Conditions at Early Diagnosis of Internal Diseases of Cattle. TEKA. An International Quarterly Journal on Motorization, Vehicle Operation, Energy Efficiency and Mechanical Engineering. Lublin–Rzeszów. Vol. 18. No 1. 95-104.

22. **Victor Rebenko, Rogovskii Ivan. 2018.** Technological Basis for Process Control of Production of Poultry Production. TEKA. An International Quarterly Journal on Motorization, Vehicle Operation, Energy Efficiency and Mechanical Engineering. Lublin–Rzeszów. Vol. 18. No 1. 79-86.

МЕТОДИКА ОПРЕДЕЛЕНИЯ ТЕХНИЧЕСКИХ ПАРАМЕТРОВ МАШИН ДЛЯ ПТИЦЕВОДСТВА ПРИ ОТСУТСТВИИ ПАРАМЕТРИЧЕСКОЙ ИНФОРМАЦИИ

Аннотация. В статье обобщены существующие отечественные, европейские и североамериканские методические требования к испытаниям комплекса машин для содержания птицы. Охарактеризовано, что методика сравнения значений показателей по испытуемому комплексу с требованиями нормативной документации и с соответствующими показателями по комплексу-аналогу.

Также установлено, что результаты математической обработки данных измерений используют при сравнении их с требуемыми величинами технического задания при государственных приемочных испытаниях (технических условий при государственных периодических испытаниях) для принятия решения о соответствии испытываемого комплекса требованиям технического задания технических условий). При этом возможны два случая. Также для сравнения показателей, полученных при испытаниях опытного образца комплекса оборудования и комплекса-аналога подсчитывают значимость разницы средних показателей.

Рекомендации из результатов испытаний комплекса принимают на основании результатов сравнения значений показателей испытуемого комплекса оборудования требованиям технических условий на поставку, зоотехническим требованиям и значениями показателей по комплексу-аналога.

Ключевые слова: методика, требование, испытание, комплекс, машина для содержания птицы.

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INTEGRATED APPROACH ORGANIZING TRANSPORTATION WORK TRANSPORTATION OF CEREAL GRAIN

Oleksiy Voronkov[1], Ivan Rogovskii[1], Eugeniusz Krasowski[2]

[1]National University of Life and Environmental Sciences of Ukraine.
E-mail: irogovskii@gmail.com
[2]Polish Academy of Sciences in Lublin.
E-mail: eugeniusz.krasowski@up.lublin.pl

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Summary. A feature of the transport security of the rural economy reveals a significant role of motor vehicles in the development of enterprises producing agricultural products. More than 90 percent of the volume of internal transportation made production, and also delivering it to the implementation is carried out by motor transport. Wide range of transported goods at low partiinost for each of them determine the uncertainty in the structure of the fleet of agricultural units and is the reason for the low employment of trucks during the annual period due to seasonality of production and creates a problem in the efficient use of rolling stock.

If you change the conditions of production in agricultural enterprises during the years of perestroika centralized since the time of formation of a socialist society, the transport system of the agricultural sector has been unable to effectively provide shipping and cargo in the appropriate conditions. The price disparity has created a difficult financial situation at the enterprises of agrarian sphere, which in turn did not allow to adapt the structure of their vehicle fleet to change their areas of specialization and under the environmental conditions of agricultural production.

At present, the transport capacity of the agro-industrial complex of the country, despite its significant reduction in the post-perestroika period is still high and its quite large. However, to reveal them completely is not yet possible, and the utilization of the Park APK leave much to be desired.

Transport technologies in agriculture are based on the classical theory of transport of goods. At the present stage of agricultural development requires new methods of evaluating the efficiency of transport technologies.

Transport subcomplex retooled. Developed new types of vehicles for agriculture, covering the whole necessary range of capacity, up to small trucks for smallholders. Today, however, almost 60% of the park district operated more than 20 years. Parks as components of their cars are not adapted to the local conditions of transport of goods, with the consequence that the cost of operation leave much to be desired.

Most methods for building parks based on the methods of linear programming without considering such an important factor as mileage significantly affecting the operation cost. They are adequate only in a certain point or a very narrow period of time. Therefore, optimization or formation of car parks these methods will not give the desired results.

In agriculture technological indicator of the bulk cargo from minimum to maximum changes 30 times. Therefore, this factor in industry should be considered as variables. Operation in agricultural production is most often considered for annual period, due to which this factor has significant impact on final performance of transport.

Key words: method, assessment, adaptation, transport, technology, transportation, grain harvest, operating, condition, vehicle.

INTRODUCTION

More efficient use of road transport in agriculture caused by economic expediency. The most urgent problem of agriculture today is to reduce the cost of production and increase the profitability of agricultural enterprises.

Transport and cargo handling operations in general complex agricultural operations constitute 1/3 of all expenses for the cultivation of crops and transportation costs in the production costs - from 15 to 40%.

In the transport process of agricultural production particularly significant role covers auto transport, whose share in the total traffic of approximately 70%.

The most responsible and stressful period for vehicle transportation of agricultural products is at harvest. Feature of traffic in this period is the need to implement them quickly.

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

Transportation of grain harvesters to the floor and the elevators is the most time-consuming and complicated process operation, so the supply of vehicles, their technical condition and organization of transport depends on overall performance cleaning technique [1-3].

More efficient use of harvesting machinery, vehicles and manpower SG enterprises in transport work is achieved through the use of appropriate types of equipment in those areas where they achieved the highest performance [4-6]. The current place is the interaction of vehicles with agricultural machinery [7-9].

These recommendations will be useful to those skilled engineers trucking companies in the organization of rational use of vehicles for the carriage of grain, sugar beets, potatoes, vegetables, and green mass at harvest [10-13].

The intensification of agricultural production continuously accompanied by increased volume of transport operations. For example in the fields where there is no black soil, per hectare of seed grain has an average of 10-20 tons of organic fertilizer, 0.5 - 1 ton of seeds and fertilizer, 1-3 tons of grain, 3.4 tons of straw, 2-3 t technical goods, which include transportation of oil and trailed machines, aggregates [14-16]. Each hectare of cultivation of grain transport accounts for an average of 20 to 30 tons of cargo [17-19].

When grown potatoes, beets and vegetables volume of traffic per hectare reaches 55-85 tonnes of which the transportation of organic fertilizers is 30-40 tons, production yield 20-40 tons of seeds and fertilizers 1-3 tons of technical cargo transportation, including trailer cars - up to 3 tons [20-22].

When hay traffic volume per 1 hectare is 3.7 tonnes and with growing and harvesting silage crops - up to 80 tons per hectare [23].

Information on the volume of traffic during the cultivation of crops indicate that today, without the use of an innovative computerized machinery, vehicles and technologies impossible the effective functioning of the agricultural enterprises, the implementation of its internal and external communications [24].

OBJECTIVE

The aim of this work is intensification of use of the vehicle fleet of the agro-industrial complex by improving their technological adaptability to local conditions of agricultural production.

THE MAIN RESULTS OF THE RESEARCH

One of the main features of the vehicle in the farms are seasonal transport of goods, due to the sharp ahrostrokamy and implementation of traffic on the dirt road and off-road.

Transportation of goods for agricultural enterprises carried out a relatively low level of mechanization handling, especially in transporting potatoes and vegetables, organic fertilizers.

Considerable difficulties arise in farms unloading cargoes delivered by rail. Most of these operations are performed with long idle cars.

All agricultural goods depending zovnishnohospodarskyh farm and transport, can be divided into 3 groups. For each of these groups characterized by certain types of goods, household goods, conditions, terms of traffic.

The first group includes goods delivered from farms on public procurement stations, railway stations, ports. These goods combines agricultural products - corn, sugar beets, potatoes, vegetables.

The second group includes goods delivered to farms with railway stations, ports, depots, warehouses, industrial, construction and commercial enterprises. They combine the concept of industrial goods for agricultural purposes.

The third group consists of goods and technology assembly-type distribution, transportation are made within households. These combined transport concept farm traffic.

Among farm transport should provide technology that include transportation of seed crops, silage, grain from the fields to the floor and corn in warehouses farms, organic and mineral fertilizers, chemicals from warehouses in fields and plantations, fuel, spare parts for tractors and agricultural machinery, construction materials, water between the estates, offices and teams, transport of feed on farms, containers for vegetables and potatoes, etc.

Transportation of cargo in the first part and the third group (delivery from the fields of agricultural products for current and storage facilities) necessitate annual involvement in the countryside for 3-4 months, hundreds of thousands of cars of different departmental affiliation of cities and industrial regions.

This requires agricultural specialists pay special attention to the organization and improvement of road transport in the economy.

The second group of transported goods in scope than the first group of more than 2 times. The group is dominated by transportation of building materials (about 38% of the traffic of the group) for the needs of agricultural production, road and home construction. Loads of this group also include feed, seed, pulp, fuel, fertilizer, machinery, agricultural machinery, spare parts and other goods that are essential to production.

A characteristic feature of the transport of goods is the second group of relative stability during the year, broken only in periods of sharp deterioration in road conditions.

Delivery of cargo a large part of this group may be distributed in time based savings early in their farms to a tense period to ensure smooth operation of vehicles and units for construction and livestock.

Loads third group of production process on the farms and their transport carried out only within the industry. Despite the fact that these relate to transport farm, their massive participation in them thousands of cars from different sectors of the economy and the importance of transport for the country as a whole put forward a number of major transportation problems facing the road.

In households direction of the grain during harvesting is carried by trucks and 70% of the annual volume of traffic. This creates a tense traffic balance, resulting in an annual gathering attracted to more than 600 thousand.

Cars from various organizations cities and industrial areas of the country, which in turn raises the construction industry in the difficult conditions of transport provision.

At the same time, a number of research institutes and advanced machine experience shows that improving the technology of harvesting grain haulage the floor and on procuring points can significantly improve the performance of vehicles and reduce the overall need for agriculture to transport.

In recent years, science and practice proposed a number of new, more effective ways of transportation of agricultural products, that reduce the need for vehicles This mixed motor transport (kombitreylerni), the use of mobile and stationary silos, storage, centralized units, the only transport management, scheduling , harvesting-transport complex and others.

The work of harvesting and transport unit pilot manufacturing sector showed that the discharge hoppers regardless of the degree of filling allows for direct transport to reduce downtime combines awaiting transport to 64% and the total loss of time for unloading and waiting - by 34%, while just a car pending load decreased by 32.5%.

Coordinated work combines and cars with direct transport can be achieved by installing additional bins. For example, machine equipped with the Zaporozhye region combine theirSC-4 bunkers taken from decommissioned combines IC 3 and IC-4. As a result of establishing additional silos with capacity of 1,8m3 allowed many people combine variable output increase by 1.5 times, and comparative industrial tests have shown that a simple dvobunkernyh unloading grain harvesting through reduced almost 2-fold.

Compared with individual fixing cars at harvesting combines expedient of forming integrated teams traffic. The efficiency of harvesting and transport crews to direct traffic confirm data obtainedVolgograd region economy. When using integrated teams need a car in this sector decreased by 33%, combines productivity increased by 35%, reduced harvesting times for 6 days. If the introduction of harvesting and transport crews simply harvesting the farm accounted for 28% of the time change, when their creation time loss dropped to 7.1%.

According to averaged data MSG Ukraine normal group combines the use of 20% of their time increases 1.7 times to reduce wasted time troubleshooting by 20% reduces the need for vehicles.

The estimated data on the number of cars GAZ-53, for service groups 4, 5 and 6 combines SC-4 and SC-5, recommended are shown in Tables 1 and 2.

If brigade method, two or three groups of harvesters are combined into one production team. This method combines group work and vehicles are fixed by them impersonal. Brigadier work combines used where large tracts bread and have the opportunity to work together to organize at least four combines in one to two days.

When harvesting and transporting crops created complex teams and centralized units for automobiles.

Integrated teams created to organize collective work in the collection and harvesting of agricultural products new harvest.

Cleaning crews throughout the complex created from harvesting at farms Krasnodar region, Voronezh and Rostov areas. Usually they are equipped with machines of the same type. And in many places technology focused no matter what team or department it belongs.

For a more complete use of technical capabilities cars and creating favorable conditions for them to work with trailers Kazakhstan developed and widely used kombitreylerna transport system whereby grain from combines collected and transported in a trailer or semi-trailer (trailer) towed by tractors in the fields, and roads - cars.

The positive effect of giving complete harvesting and transport crews using kombitreylernyh transportation of grain harvesting schemes harvester - car - a tractor with a trailer or a harvester - car - propelled bunker - Drives that were created as part of combine, tractor drivers and

In households of Kazakhstan kombitreylernu grain transportation system combines use of 300 teams. For example, the introduction of a system area was freed 390 cars for other needs of the economy. Performance cars while significantly increased.

Table 1. Number of vehicles for service group combines SK-5.

Number harvesting SC-5 group	The need for cars at yield kg / ha														
	16					25					40				
	Distance transport, km														
	2	4	6	8	10	2	4	6	8	10	2	4	6	8	10
4	22	2	2	3	3	2	2	3	3	3	2	2	3	3	4
5	22	22	3	3	4	2	2	3	4	4	2	3	3	4	4
6	22	23	3	4	4	2	3	4	5	5	3	3	4	5	5

Table 2. Number of vehicles for service group combines SK-4.

Number harvesting SC-4 group	The need for vehicles at yield kg / ha														
	16					25					40				
	Distance transport, km														
	2	4	6	8	10	2	4	6	8	10	2	4	6	8	10
4	2	2	2	3	3	2	2	2	2	3	2	2	3	3	3
5	2	3	3	3	4	2	3	3	3	4	2	3	3	4	4
6	2	3	4	4	4	3	3	4	4	5	3	3	4	5	5

To reduce the time spent in the fields of vehicles, as well as when they are not enough to ensure the smooth operation of combines, in recent years, receiving application-propelled or stationary silos storage capacity 8-15t that are loaded directly from the processor or by delivery to they harvesting grain on tractors with trailers.

Vehicles are loaded from storage hopper regardless of cycles and time of harvesting, so there is no need to provide coordinated work harvesting equipment and vehicles, as torn "hard link" combines with cars and liquidated combines simple and cars for reasons untimely car to combine and waiting filling hopper of the combine. Application farms Kokchetav region hundred storage hopper in combination with other vehicles made about the economic effect 120 thousand. Rubles. Experience of transport grain harvesters using storage hopper received the most prevalent region, employing between 2,000 collection bins drives. If brigade method transport service can be as single cars and mixed automobile and tractor trains on kombitreylerniy transport system.

In group work combines the smallest car simple and combines reached in the case:

- number of harvesters in the group is the number of bins placed in the body of one of the assigned vehicles,
- real-time delivery of grain to the floor the car matches the duty cycle harvester (process execution of two operations: namolotu full grain bin and unloading grain in the vehicle).

Actual delivery of grain cars to the floor depends mainly on the distance of transportation. The smaller the difference between the actual and optimal distances calculated for time namolotu grain silo and the number of cars assigned to the group combines the less easy vehicles during loading. Knowing the working cycle and the actual distance transportation, we can choose the most appropriate combination of the number of cars in their combines group work (Tables 3, 4, 5).

Table 3. Number of vehiclesrequired for grain combines 4.

The working cycle combines, min.	The need for transportation vehicles, the distance in km													
	2	3	5	8	10	12	15	18	20	22	24	26	28	30
15	2	3	4	5	5	6	7	7	8	8	9	9	9	9
20	2	3	3	4	4	4	5	6	6	6	7	7	7	8
25	2	2	3	3	3	4	4	5	5	5	6	6	6	6
30	2	2	2	3	3	3	4	4	4	5	5	5	5	6
35	2	2	2	2	3	3	3	4	4	4	4	4	5	5
40	1	2	2	2	2	3	3	3	3	4	4	4	4	4
45	1	1	2	2	2	2	3	3	3	4	4	4	4	4
50	1	1	2	2	2	2	3	3	3	3	3	3	4	4
65	1	1	1	2	2	2	2	2	2	2	3	3	3	3

Table 4. Number of vehicles required for grain harvesting 3.

The working cycle combines, min.	The need for transportation vehicles, the distance in km													
	2	3	5	8	10	12	15	18	20	22	24	26	28	30
15	2	3	4	4	5	5	6	7	7	8	8	8	9	9
20	2	2	3	4	4	4	5	5	6	6	7	7	7	8
25	1	2	2	3	3	4	4	4	5	5	5	6	6	6
30	1	2	2	3	3	3	4	4	4	4	5	5	5	5
35	1	2	2	2	2	3	3	3	4	4	4	4	5	5
40	1	1	2	2	2	2	3	3	3	3	4	4	4	4
45	1	1	2	2	2	2	3	3	3	3	3	3	4	4
50	1	1	1	2	2	2	2	3	3	3	3	3	3	3
65	1	1	1	1	2	2	2	2	2	2	3	3	3	3

Table 5. Number of vehicles required for grain harvesting 2.

The working cycle combines, min.	The need for transportation vehicles, the distance in km													
	2	3	5	8	10	12	15	18	20	22	24	26	28	30
15	2	3	4	4	4	5	6	7	7	8	8	8	8	9
20	2	2	3	3	3	4	5	5	6	6	7	7	7	8
25	2	2	2	3	3	3	4	4	5	5	6	6	6	7
30	1	2	2	2	2	3	3	4	4	4	5	5	6	6
35	1	1	2	2	2	2	3	3	4	4	4	4	5	5
40	1	1	2	2	2	2	3	3	3	3	4	4	4	4
45	1	1	1	2	2	2	2	3	3	3	3	4	4	4
50	1	1	1	2	2	2	2	2	3	3	3	3	4	4
65	1	1	1	1	2	2	2	2	2	2	3	3	3	3

Table 6. Vehicles in the grain transportation system.

Distance transportation, km	Number of vehicles in integrated teams, depending on the distance of transportation vehicles.		
	Trailer carrying capacity 4t	Car 3 t	additional car 5t
3-5	b	I	-
8	6	I	-
10	6	1	I
12	8	1.5	-
15	8	1.5	I
20	8	2	-
25	10	2.5	-

The tables are proven by experience combination of vehicles and combines depending on the duty cycle combines, cars and transport distance.

The use of a method of Brigadier harvesting and transport operations will improve the efficiency of cars to 25% compared with the group method.

The most highly used harvesting and transport equipment reached at brigade method of harvesting using kombitreylernoyi transportation system. With the use of this system of grain harvesting bins are collected and transported in a trailer or semi-trailer towed by fields tractors on the roads - cars.

In this case the tractor moves with one or two automobile trailers from the combine harvester to download to their grain. After filling trailers transported to the nearest field area of the road or the end unit. During this time the car is loaded with grain. The driver drives the car trailer, touches and moves them into the floor.

In the absence of grain train going in empty trailer negotiable.

When using semi-tractors equipped with movable carts and car-tractor truck must have device. In this case, completely excluded mileage by fields.

Application system provides for the allocation to each team one tractor "Belarus". Number of trailers and vehicles allocated team depends on the distance of transportation (tab. 6).

In team can be arranged with the grain harvesters trailers without towing them across the field a tractor or car. You need to cut troops long enough to fill the hopper grain harvester ended at the end or near prokoshuvannya units where there are trailers, which are discharged directly from grain harvesters.

At harvest interval conveyor-tech field with small distances should be used Tractor transport. Group of engineers developed scheme of transporting grain from the floor combines specialized trailers.

The novelty of this scheme is as follows. The usual method of group work for six combines, the direct collection at yield 10 kg / ha highlighted three tractor "Belarus" with two trailers. The proposed method is characterized in that one of the tractor trailers are constantly being in the paddock fills them with a grain of combines. With the filling of trailers, collecting tractor trailers delivering to the edge of the field and vidchiplyuye them and empty prychiplyaye and returns to harvesters. Two other tractor transporting grain on the floor.

This excludes mere vehicles and minimized downtime harvesters.

on the farm Dobrinsky district of Lipetsk region grain from combines group work when they were taken to the floortractor K-700. Which was granted on 8 trailer 4t lifting capacity each. Trailers were placed on the field so that they were convenient to unload grain from silos machines. Four tractor trailer filled transported to the floor, and during this time loaded others. This method of transporting grain adopted many farms in the region.

In households where there was K-700 used tractors "BelarusFor which fixed two trailers. At night, when not working combines, tractor train at a small distance used to transport grain to the elevator is current.

When working harvesting and transport unit (group) must first of all decide on its composition, that is, to determine the optimal number of vehicles (units) for the service specified number of harvesters. In this case, more convenient to use the method of calculation for transport services combine units proposedVoronezh Agricultural Institute. Let the group work method combines odnomarochnyh m. Daily tc duration of their work hours. The rate of output in the given conditions Wch, hectares per hour. Grain yield U quintals per 1 hectare. The whole group combines a day collecting Ωk kg of grain. Weight of grain from combines is given by:

$$\Omega_к = U \cdot W_ч \cdot t_c \cdot m \qquad \text{kg / day (1)}$$

This grain during the same time period tc hours must carry off the floor.

Assume that the transportation of grain from the floor combines employed n the same transport units with a nominal total capacity Qt. Suppose that for each unit tc daily hours of K again carry grain harvesting from the floor (do K or flight cycles). Then the total daily operation of all vehicles Ωt will be equal to:

$$\Omega_т = 10 \cdot Q \cdot \varphi \cdot k \cdot n \qquad \text{,kg / day(2)}$$

where 10 - the number of quintals in tonnes,

φ - nominal capacity utilization of the transport unit.

For smooth harvesters and vehicles must comply with a condition $\Omega_к = \Omega_т$:

$$U \cdot W_ч \cdot t_c \cdot m = 10 \cdot Q \cdot \varphi \cdot к \cdot n \qquad (3)$$

Solving this equation for m or n, can determine this or these values for a given value of one of them.

Determine the number of transport units:

$$n = \frac{U \cdot W \cdot t_c \cdot m}{10 \cdot Q \cdot \varphi \cdot к} \qquad \text{transport units} \quad (4)$$

The number of flights (cycles) of the transport unit per day equals:

$$к = \frac{t_c \cdot \tau}{t_ц} \quad , \qquad \textit{cycles / day} \ (5)$$

where t_c - cycle time (flight) in hours,

τ- utilization of time, taking into account the loss of driver time to rest and daily maintenance of the unit. The coefficient is the ratio of work time to the time change.τ

The duration of the cycle time is the sum of TA time traffic load off the floor and back unloading time TA and TR.

$$t_ц = t_п + t_Д + t_р \qquad \textit{h / cycle} \ (6)$$

If the grain is transported by tractor train, the term should include time to balance the field empty trailers and time to collect and coupling loaded tractor trailers. $t_п$

Moving time is determined by the formula

$$t_д = \frac{2 \cdot l}{v_c} \ , \qquad \text{hour / cycle} \ (7)$$

where l - the average distance from the field to the threshing km,

v_c - the average speed of traffic, km / h

Formula (4) can be presented now as follows:

$$n = \frac{U \cdot W_ч \cdot m \cdot \left(t_п + \frac{2 \cdot l}{v_c} + t_р\right)}{10 \cdot Q \cdot \varphi \cdot \tau} \quad \text{transport units} \ (8)$$

All right values of equality and is subjected to the calculation to determine the total number of vehicles required for the given conditions.

Rated load tractor-vehicle unit is

$$Q = b \cdot G_T \qquad (9)$$

where b - the number of tractor-trailers to transport the unit,

G_T- the weight of cargo in a trailer, Vol.

Number of trailers in the unit will be

$$b = \frac{P_{крн}}{f_n \cdot (G_T + G_n) \cdot 10^3} \qquad (10)$$

where $P_{крн}$- nominal thrust on this tractor transmission kgs,

f_n - coefficient of rolling the trailer is (0,10-0,12),

G_n-Weight empty trailer, Vol.

The utilization of the nominal traction tractor

$$\varepsilon_{цс} = \frac{R}{P_{крн}} = \frac{10^3 \cdot (G_T + G_n) \cdot f_n}{P_{крн}}, \qquad (11)$$

where R - pulling the load on the tractor (traction resistance trailers imposed on aggregate)

$$\varepsilon_{ЦС=0,85 \div 0,95}$$

Cargo weight in volume trailer body

$$G = g \cdot w = g \cdot a \cdot l \cdot h \qquad (12)$$

where g - grain volume weight, t / m3,

w - the volume of body m3,

a, l, h - in accordance with the length, width, height body, m.

Calculation of trailers formula (10) should be carried out at different tractor gears except first (backup). The answer should be expressed as fractions. If the result will contain an integer you should select a different transmission or increase body sides trailer.

Transmission choices depends on the number of available trailers and road conditions affecting the speed of the unit.

For continuous operation, assembly-vehicle unit must ensure not only equal the number of daily harvesting and transport units (formula 3), but equality containers for storage of grain and its export.

For one cycle of the vehicles they carry grain off the floor:

$$w_{тц} = \frac{Q \cdot \varphi \cdot n}{g} \qquad \text{m}^3 \text{ / cycle} \qquad (13)$$

The same amount of grain in the same period of time must gather the whole group working machines.

$$w_{кц} = \frac{U \cdot W_ч \cdot t_ц \cdot m}{10 g} \qquad (14)$$

Drives that amount of grain harvesting is a bunker and additional capacity - trailers to tractors or cars that serve the harvesting machine. Trailers field position at the end of the road and poured them with grain bins combines the return transport.

Define any additional capacity wg trailers (containers)

$$w_g = w_{кц} - w_к \cdot m = \frac{U \cdot W_ч \cdot t_ц \cdot m}{10 g} - w_к \cdot m \qquad \text{m}^3 \ (15)$$

Find additional amount trailers

$$b_g = \frac{w_К}{w_T} \qquad (16)$$

where $w_К$- capacity hopper combine m^3,

w_t - capacity one trailer m3.

Total number of trailers in harvesting and transport detachment equal

$$b_c = n \cdot b + b_g \qquad (17)$$

To load currents applied to corn grain loaders continuous, adjustable-propelled -Runway-60 and propelled loaders APP-125 capacity respectively 60 and 80 t / h.

In households with no special handling facilities can be used converted stacker sleep-0.5, which mounted on a tractor "Belarus.

Maximum performance is achieved unloaders Guara-15 and PGA-25M when unloading grain from single cars through tailgate.

Therefore, the rolling stock for the transport of agricultural products should be chosen taking into account the presence and types of handling equipment on public collection points, as well as farms.

The steady growth of grain production and procurement requires clear and coordinated work of all parts of harvesting and transport conveyor, including its final element - Cereal.

Studies in recent years, research on the reception of grain to grain enterprises of Ukraine showed that sustainability is essential for the flow of grain from farms. Therefore, the process of the grain Cereal should be part of a single process of harvesting and transport, which provides a clear relationship of three parts: tick - Road transport - Cereal.

The most progressive system of interconnection links is the rhythmic delivery of grain to grain company for timetables.

Time schedule is a document that binds a single technological process of loading operation of agricultural production on farms and their transport by road, receiving and unloading at public collection points.

The graphics consist of the light in traffic performance of agricultural products from every sector, departments and teams, currents and warehouses in terms that preclude damage to the crop in storage after harvest.

Charts agree farms in order to fully utilize their existing handling facilities and provide a uniform work during the day the whole period of transportation. They agree with elevators, mills. This takes into account the type and capacity of laboratory analysis of grain farming and weight handling equipment with the expectation of even the most complete and their use to prevent accumulation of rolling stock in anticipation of unloading, etc. On the basis of each train or car, each driver is and is given to variable-day tasks.

Experience advanced economies, Ukraine shows that car delivery teams to grain elevator then by time schedule provides upbeat and productive work vehicles and road trains of various departmental affiliation, the possibility of operational management and control of shipments and timely take necessary measures according to changes in traffic conditions.

When the complex system of grain transportation by road interdepartmental agencies created a single operational management of vehicles regardless of their subordination. The only operational management of transport in this period the central republican, regional operational group of executives transportation, agricultural, procurement, travel organizations and enterprises.

Working bodies of these groups is under the central, regional and district control department of motor transport organizations. Working together members of task forces and the ability of each within its jurisdiction and granted the right to decide and implement measures depending on the particular situation makes it possible to quickly and smoothly to decide on timely and quality traffic.

The direct operational management and monitoring of compliance schedules rolling exercise control stations and dispatcher positions, subordinate district team. With information about the situation in the area of their activities and relationship with farms and elevators, mills, operational groups, harvesting and transport teams and automotive units and control point positions quickly maneuvering vehicles in time to submit information on the traffic.

Thus the only comprehensive approach organization of harvesting and transport operations include: Calculating the number of vehicles for transporting grain and harvesting machinery, the distribution volume of traffic, creating complex mechanized brigades for grain off the floor, the organization of operational management, online monitoring and quality control traffic, the use of innovative methods of use of vehicles and their interactions.

Implementation of this system will maximize the performance of vehicles and significantly reduce the harvest period, which in turn will lead to improved economic performance assembly-transport sector as a whole.

CONCLUSIONS

1. Transport technologies in agriculture are based on the classical theory of transport of goods. At the present stage of agricultural development requires new methods of evaluating the efficiency of transport technologies.

2. Transport subcomplex retooled. Developed new types of vehicles for agriculture, covering the whole necessary range of capacity, up to small trucks for smallholders. Today, however, almost 60% of the park district operated more than 20 years. Parks as components of their cars are not adapted to the local conditions of transport of goods, with the consequence that the cost of operation leave much to be desired.

3. Most methods for building parks based on the methods of linear programming without considering such an important factor as mileage significantly affecting the operation cost. They are adequate only in a certain point or a very narrow period of time. Therefore, optimization or formation of car parks these methods will not give the desired results.

REFERENCES

1. **Voronkov O. A., Rogovskii I. L. 2016.** Analysis of the role of road transport in the transport-technological support of agriculture.A collection of abstracts of II-nd International scientific-practical conference "Modern technologies of agricultural production" (9-10 November 2016). Kiev. 215-216.

2. **Voronkov O. A., Rogovskii I. L. 2017.** Adaptation of vehicle use in technology of harvesting grain crops. Abstracts of the International scientific-practical conference "Modern technologies of grain production 2017" within the framework of VI International exhibition of innovative solutions in grain farming "Grain technologies 2017" (February 16, 2017). Kiev. 2017. 28-29.

3. **Voronkov O. A., Rogovskii I. L. 2017.** Classification features of vehicles in transport-technological processes in agricultural production. Abstracts of the II all-Ukrainian scientific-theoretical conference "the Problems with traffic flows and the ways of their solution" national University "Lviv Polytechnic (16-18 March 2017). Lions. 17-19.

4. **Voronkov O. A., Rogovskii I. L. 2017.** Analysis of current state of problem of optimization of transport and technological support AIC. The book of abstracts XI International scientific-practical conference "Obukhov" read (March 21, 2017). Kiev. 92-93.

5. **Voronkov O. A., Rogovskii I. L. 2017.** In-line transport technology of transportation of grain bread. Problems of development of transport and logistics. Collection of scientific works on materials of VII-th International scientific-practical conference, Severodonetsk, Odesa, April 26-28 2017 – Severodonetsk, Ukraine: publishing house VNU named after Volodymyr Dahl. 15-17.

6. **Voronkov O. A., Rogovskii I. L. 2017.** Methodology of experimental research of the traction characteristics of vehicles. The book of abstracts of the XVII international conference of scientific and pedagogical workers, scientific employees and graduate students "Problems and prospects of development of technical and bio-energy systems of environmental management" (20-24 March 2017). Kiev. 122-123.

7. **Voronkov O. A., Rogovskii I. L. 2017.** Analytical prerequisites to transport and technological systems of transportation of production of crop production. Theses of International Scientific Conference "Globalization of scientific and educational space.

innovations of transport. problems, experience, prospects" (3-12 May 2017) / Dresden (Germany) Paris (France). 47-50.

8. **Voronkov O. A., Rogovskii I. L. 2017.** Ways to reduce energy consumption in transportation and technological support for weight of transported grain crops. A collection of abstracts of the XIII International scientific conference "the Rational use of energy in technology. TechEnergy 2017" (17-19 may 2017). Kiev. 72-74.

9. **Voronkov O. A., Rogovskii I. L. 2017.** Analytical model for energy estimation of transport technological process of transportation of grain and crop products. Journal of mechanical engineering and transport. – Vinnitsa: VNTU. – Vol. 1. – 21-28.

10. **Voronkov O. A., Rogovskii I. L. 2017.** Approach to solving the problem of management of transport system for transporting of the grain harvest. The book of abstracts of V-th international scientific conference "Innovative maintenance of organic production in agriculture" in the framework of the XXI International agricultural exhibition "AGRO 2017" (05-06 June 2017). – Kiev. 44-46.

11. **Voronkov O. A., Rogovskii I. L. 2017.** Automation operators for the monitoring of vehicles for the carriage of grain bread Automatic – 2017: international conference on automatic control, Kiev, Ukraine, 13-15 September 2017: proceedings of the conference. Kiev. 181-182.

12. **Voronkov O. A., Rogovskii I. L. 2017.** Alignment of adjacent transport and technological operations of transportation of grain and crop products. Bulletin of East Ukrainian national University named after Volodymyr Dahl. – No. 3. – 36-43.

13. **Voronkov O. A., Rogovskii I. L. 2017.** General principles of creation of control systems of transport streams transport grain bread. Scientific Herald of National University of Life and Environmental Science of Ukraine. Series: Technique and energy of APK. Kiev. Vol. 258. 390-399.

14. **Voronkov O. A., Rogovskii I. L. 2017.** Options of structural solutions of the system of management of transport flows transport grain bread. Scientific Herald of National University of Life and Environmental Science of Ukraine. Series: Technique and energy of APK. Kiev. Vol. 262. 361-367.

15. **Shevchuk R. S., Krupych R. 2015.** Manual vibro-impact fruit shaker/ MOTROL Commission of motorization and energetics in agriculture. – Lublin-Rzeszow, Vol.17, №4., 153-159.

16. **Sydorchuk O., Triguba A., Makarchuk O. and oth. 2012.** Optimization of the life cycle of integrated programs for harvesting grain crops. MOTROL Commission of motorization and energetics in agriculture. – Lublin, Vol.14, №4. 131-140.

17. **Sydorchuk O., Ivasjuk I., Syatkovskyy A. 2012.** Influence subject to conditions terms of tillage, planting summer-autumn period. MOTROL Commission of motorization and energetics in agriculture. – Lublin, – Vol.14, №4. 16-20.

18. **Sydorchuk A., Ivasiuk I., Ukraynecz V., and oth. 2013.** Harmonization of the components of the technological system of soil cultivation and sowing of winter crops. MOTROL Commission of motorization and energetics in agriculture. – Lublin-Rzeszow, Vol.15, №4. 180-186.

19. **Rogovskii Ivan. 2016.** Graph-modeling when the response and recovery of agricultural machinery. Motrol : Motorization and power industry in agriculture. Lublin. T. 18. №3. 155-164.

20. **Rogovskii I. L. 2016.** Analysis of model of recovery of agricultural machines and interpretation of results of numerical experiment. Scientific Herald of National University of Life and Environmental Science of Ukraine. Series: Technique and energy of APK. Kyiv. No 254. 424-431.

21. **Rogovskii I. L. 2017.** Probability of preventing loss of efficiency of agricultural machinery during exploitation. Scientific Herald of National University of Life and Environmental Science of Ukraine. Series: Technique and energy of APK. Kyiv. No 258. 399-407.

22. **Rogovskii I. L. 2017.** Conceptual framework of management system of failures of agricultural machinery. Scientific Herald of National University of Life and Environmental Science of Ukraine. Series: Technique and energy of APK. Kyiv. No 262. 403-411.

23. Rogovskii Ivan, Eugeniusz Krasowski. 2018. Entropy Conditional Subjective Preferences for Alternative Functions Defined in Conditions at Early Diagnosis of Internal Diseases of Cattle. TEKA. An International Quarterly Journal on Motorization, Vehicle Operation, Energy Efficiency and Mechanical Engineering. Lublin–Rzeszów. Vol. 18. No 1. 95-104.

24. Victor Rebenko, Rogovskii Ivan. 2018. Technological Basis for Process Control of Production of Poultry Production. TEKA. An International Quarterly Journal on Motorization, Vehicle Operation, Energy Efficiency and Mechanical Engineering. Lublin–Rzeszów. Vol. 18. No 1. 79-86.

ИНТЕГРАЛЬНЫЙ ПОДХОД К ОРГАНИЗАЦИИ ТРАНСПОРТНОЙ РАБОТЫ ТРАНСПОРТИРОВКИ ЗЕРНОВЫХ

Аннотация. Особенностью транспортной безопасности сельского хозяйства показывает существенную роль автотранспорта в развитие предприятий по производству сельскохозяйственной продукции. Более 90 процентов объема внутренних перевозок продукции, а также предоставления ее реализации осуществляется автомобильным транспортом. Широкий спектр перевозимых грузов при низких partiinost для каждого из них определить неопределенность в структуре парка сельскохозяйственных агрегатов и является причиной низкой занятости грузовиков в течение годового периода, в связи с сезонностью производства и создает проблемы в эффективном использовании подвижного состава.

При изменении условий производства в сельскохозяйственных предприятиях за годы перестройки централизованного со времени становления социалистического общества, транспортной системы, сельского хозяйства уже не в состоянии эффективно обеспечить перевозки в

соответствующие условия. Диспаритет цен создал сложную финансовую ситуацию на предприятиях аграрной сферы, что, в свою очередь, не позволяют адаптировать структуру своих транспортных средств, чтобы изменить их специализации и условий среды сельскохозяйственного производства.

В настоящее время транспортный потенциал агропромышленного комплекса страны, несмотря на ее значительное снижение в постперестроечный период по-прежнему высок и довольно большие. Однако, чтобы раскрыть их полностью пока не представляется возможным, а использование парка АПК оставляет желать лучшего.

Транспортных технологий в сельском хозяйстве основаны на классической теории перевозке грузов. На современном этапе развития сельского хозяйства требует новых методов оценки эффективности транспортных технологий.

Транспорт подкомплекса перестроилась. Созданы новые типы машин для сельского хозяйства, охватывающий весь необходимый спектр возможностей, вплоть до небольших грузовиков для ЛПХ. Сегодня, однако, почти 60% территории района эксплуатируется более 20 лет. Парки в качестве компонентов их автомобили не приспособлены к местным условиям перевозки грузов, в результате чего стоимость эксплуатации оставляют желать лучшего.

Большинство методов для создания парков на основе методов линейного программирования без учета такого важного фактора, как пробег существенно влияют на стоимость операции. Они адекватны только в определенной точке или в очень узкий период времени. Таким образом, оптимизация или создание парковок эти методы не дают желаемых результатов.

В технологических показателей сельского хозяйства сыпучих грузов от минимума до максимума меняется 30 раз. Следовательно, этот фактор в промышленности должны рассматриваться как переменные. Работы в сельскохозяйственном производстве чаще всего считается для годовой период, из-за которых этот фактор имеет значительное влияние на конечные результаты деятельности транспорта.

Ключевые слова: метод, оценка, адаптация, транспорт, технологии, транспорт, урожай зерновых, рабочее, состояние, автомобиль.

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Physical Modeling of Electrical Conductivity of Soil when Measured with Use of Information Technology Systems Local Operational Monitoring Agrobiological Status of Agricultural Land

Oleksandr Brovarets

Kyiv Cooperative Institute of Business and Law
E-mail: brovaretsnau@ukr.net

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Abstract. Existing methods of control as agrobiological soil environment and soil sampling by existing methods do not account for variability of parameters on agricultural land. To implement differentiated technologies making process material is preferably used a simplified way of breaking even in the open field equal squares (preferably 5 area15 ha) For further diagnosis and management of field using such differentiation. On the one hand this division due to convenience and simplicity of this method, on the other - the lack of reliable operational data field and thus tool to split off for other criteria based on source data. According to this method roughly equal to the square of the field can enter areas with radically different parameters, mean that do not reflect the real parameters of the site. Method evenly split into equal squares field surface does not include the specific fields and areas of heterogeneity as a result of the low reliability of the data obtained using this method,

In some cases, the parameters of the soil environment will be understated, and some inflated within a square. Differentiated management application rate of technological material within this square, it should be carried out based on the average value of this parameter. Therefore thus making the implementation of differentiated technological material will not be effective.

Under these conditions, there is a need to find the most effective method for monitoring the operational status agrobiological farmland.

The most effective way of monitoring the operational status agrobiological farmland is electrically measuring the characteristics of the soil environment. Conductive properties of the soil environment is complex agrobiological indicator of its status, taking into account the hardness of moisture content of nutrients in the soil saturation bases, cation exchange capacity and so on.

The high content of moisture, salts and nutrients in the soil contribute to the performance of electrical conductivity of the soil environment within a field that recorded information technology system agrobiological local operational monitoring of agricultural land. This information reveals the variability of soil protection zone and subsequently manage agrobiological as farmland zones with consideration of heterogeneity.

To test the efficiency of information technology systems agrobiological local operational monitoring of agricultural land and reliability of the data, the physical modeling of soil electrical conductivity in the operation of such systems.

A physical modeling of soil electrical conductivity when measured using information technology systems agrobiological local operational monitoring of agricultural land.

This opens new perspectives to organic farming with the use of "smart" agricultural machines.

Key words: information-technical system, operational monitoring, soil samples, variability in magnitude.

INTRODUCTION

Review of current literature and scientific researches [1-22] shows that in recent years the process of integrating natural (organic or biological), biodynamic, extensive, intensive (industrial) and no-till farming with the latest technology, including information technology systems operational monitoring of agricultural land. This last trend is the most important and promising conditions for Ukraine.

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

An important task of monitoring the operational status of agricultural land is called «management units» - units with similar parameters spatial heterogeneity, which must be used the same type of technology of cultivation of crops. These technologies are the basis of decision-making system «decision-making systems», which allows you to make effective operational actions on the basis of the available data on the state of agrobiological soil environment.

Heterogeneity of soil can be represented as a hierarchical system events. Of course, the heterogeneity rather simply deducted when measured quantitatively comparable objects and thus quantitative criteria. The heterogeneity factor considered responsible for biodiversity, because through it formed part of the environmental and provides diversity of soil organisms [2, 3, 14-25].

Modern agricultural production involves extensive use of automated systems for monitoring agricultural land.

Implementation of modern agricultural technologies allows us to plan the costs of seed, fertilizer, pesticides and other process materials, including fuel, to determine the overall strategy of agrobiological potential field more. But today the implementation of these technologies lack the effective collection and registration (monitoring) mistsevyznachenoyi information (agrobiological and Phytosanitary) on the status of agricultural land in precision farming technology [2, 8, 10- 25].

One of the main approaches to the application of precision farming technologies - to optimize productivity and to ensure the environmental quality of agricultural products, taking into account areas of management and variability of agricultural fields. In this aspect plays an important role determining soil electrical conductivity for the determination of the profits based on spatial variability and nutrient content of the soil. Knowledge of the structure of a soil variability allows to take effective management solution agrobiological potential agricultural land [1].

OBJECTIVE

In this sense, takes Relevance development and use of a fundamentally new class of agricultural machines - Information Technology Systems operational monitoring of agricultural land.

So important is the development and study of the functional structure of modern information technology systems, operational monitoring of agricultural land.

THE MAIN RESULTS OF THE RESEARCH

Soil structure is changing in significant limits on many agricultural fields. The physical properties of the soil, such as soil structure, have a direct effect on water consumption, cation exchange capacity, productivity and more. The nutrients contained in the soil, plants used and their content in the soil decreases. The common characteristic of the nutrient content of the soil is nitrogen, whose presence in the soil largely determine yield. Mapping soil electrical conductivity is widely used as an effective means of mapping soil structure and other soil properties [5].

Quick description variability of farmland - an important component for zonal management [6-16].

Modern methods and means of registering properties of soil. Obviously, for the proper management of the quality of the environment is absolutely necessary condition is the organization of effective monitoring. To assess the environmental objective important operational information about critical factors of human actions on the actual and future state of the biosphere. There is a problem of organizing special supervision, monitoring and evaluation of the natural environment (monitoring) as in the areas of human action, and globally. [3] An important nowadays takes Registration conductive characteristics of the soil.

Electrical conductivity (soil conductivity) - a property of a material to transmit (conduct) electric current, measured in siemens per meter (S / m) or myllysymensah per meter (mS / m). The electrical conductivity of the soil can be expressed as a detsysymensah (MPA / m). Milisimens per meter (mS / m) - a standard unit of measure the electrical conductivity of the soil. In the siemens measure the electrical conductivity of materials. The advantage of a standard unit of measurement is that it provides accurate quantitative data. Visual assessment soil makes it easy to identify color differences, but does not quantify the value and explain the essence of color differences. Maps showing soil conductivity value in mS / m, which allows you to learn the same way and handle areas with similar rates conductivity. As shown by numerous laboratory and field studies,

Electromagnetic share many characteristics of soil properties of the soil, affecting crop yields. These include soil moisture content, particle size distribution of the soil, ECO, salinity content of exchange cations of calcium (Ca) and magnesium (Mg) and others. The electromagnetic characteristics of the soil do not allow to directly measure the nutrient content, but show significant variation in characteristics such as soil structure and content of exchange cations. This variation is too important to ignore it, and should be taken into account during sampling (Fig. 1) [17].

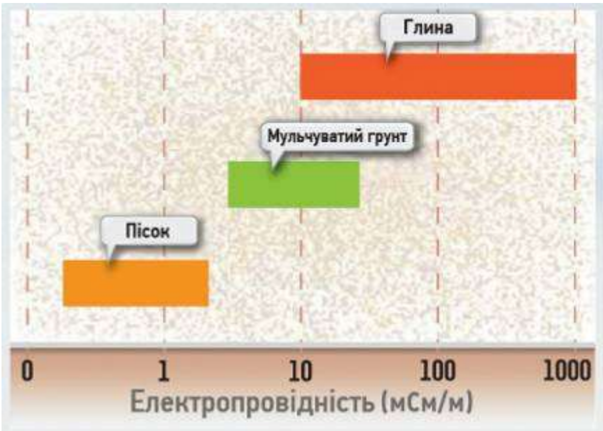

Fig. 1. Electrical conductivity of soil [17].

Maps of soil electrical conductivity make it possible to get cartograms:

- variable application rate of technological material (seeds and fertilizers) based on the expected yield of each individual site, calculated based on the value of electrical conductivity,
- variable seed application rate based on the depth of the upper (arable) layer of soil,
- variable rates of application of herbicides in the soil based on organic matter, soil structure and conductivity,
- variable application rate of lime based on soil environment agrobiological state according to the levels of electrical conductivity.

The most common device for monitoring the state of agrobiological soil environment, by measuring the conductive characteristics of the soil environment is soil mapping device EC Veris 3100. He pid`yednuyetsya to the SUV, which is equipped with on-board computer technology of parallel driving, GPS-receiver (Fig. 2) and trailer unit drives (drives with electrodes placed). While measuring unit moves from field embedded in the soil to a depth Disk 25 cmOne pair of insulated electrodes introduces electrical current into the ground, the other electrodes measure the current that varies depending on the soil resistance [4].

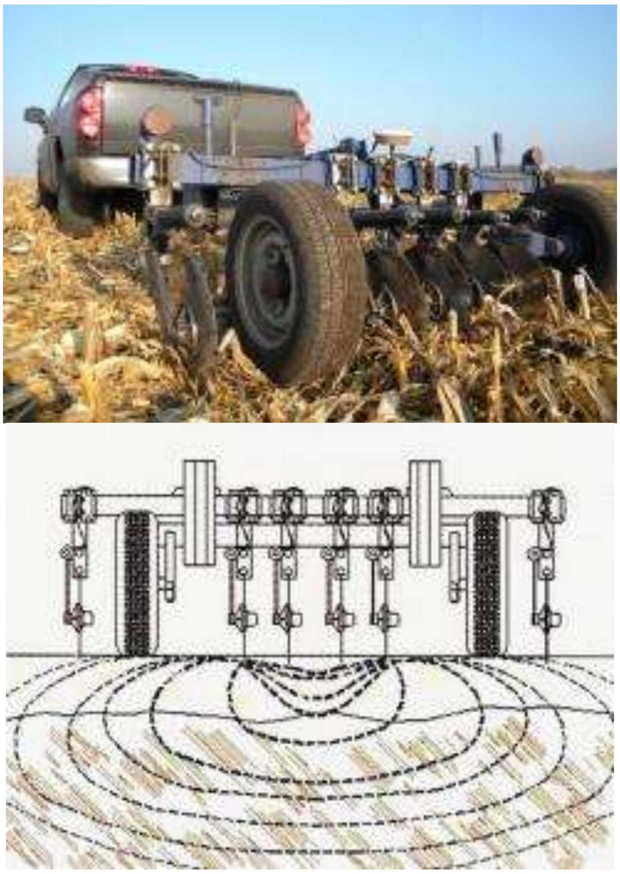

Fig. 2. Device EC Veris 3100.

Trailer unit Veris moving field, one pair of insulated electrodes introduces electric current in the ground, and the other pair measures the voltage drop, which will be different (eg, depth conducts current better than mud or sand). Measurements of electrical conductivity combined with GPS data and graphically displayed in a map. Veris 3100 uses two beams conductivity for mapping two depths of soil (0-30.5 cm and 0-91.5 cm) Simultaneously.

The device Veris 3100 creates two sets of maps - a map of the surface layer (30.5 cm) And a map covering the root zone (91.5 cm). Map outer layer often used to select sampling sites and deeper card - to determine the application rate of fertilizer (especially nitrogen) [5].

These devices are too costly to have design flaws and give a significant error in the measurement. This creates conditions for further research and improvement of existing systems.

The purpose of this study is the physical modeling of soil electrical conductivity when measured using information technology systems agrobiological local operational monitoring of agricultural land.

The aim is to obtain reliable data on the operational status agrobiological soil environment by reducing errors in determining the value of conductive properties of the soil. To ensure the aforementioned problems using information-technical system agrobiological local operational monitoring of agricultural land by measuring the electrical conductivity of the soil.

Information technology system agrobiological local operational monitoring of agricultural land use: before performing the technological operation, together with the technological operations (sowing, fertilization, etc.), during the growing season and after harvesting.

Explore symmetric distribution of electric wave type surface vpodovzh metal rod radius α. The electromagnetic field of the wave at $r > \alpha$ (Outside of the core) will be calculated through the electric Hertz vector with one element Π_Z^l Which is defined by the formula [2]:

$$\Pi_Z^l = \Pi^l(x, y)\cdot \exp(ihz),\ i^2 = -1 \qquad (1)$$

where h - wave number, $(x, y) \perp z$ - coordinates.

Magnitude h can be characterized as a vector projection $\vec{k}$ (Wave vector having absolute value $k = \omega/c$ where ω - circular frequency of the wave c - the speed of light) on the axle OZ.

Ingredient Π_Z^l satisfies the equation:

$$\frac{\partial^2 \Pi_Z^e}{\partial x^2} + \frac{\partial^2 \Pi_Z^e}{\partial y^2} + \frac{\partial^2 \Pi_Z^e}{\partial z^2} + k \cdot \Pi_Z^l = 0, \qquad (2)$$

and the function $\Pi^l(x, y)$ equation:

$$\frac{\partial^2 \Pi^l}{\partial x^2} + \frac{\partial^2 \Pi^l}{\partial y^2} + q^2 \cdot \Pi^l = 0, q = \sqrt{k^2 - h^2} \qquad (3)$$

where q - transverse wave number.

Knowing $\Pi^l(x, y)$ You can find all the components of the electromagnetic fields that occur near the rod (Cartesian coordinates):

$$\begin{cases} \mathrm{E}_x = i \cdot h \cdot \frac{\partial \Pi^l}{\partial x} \cdot e^{ihz}, \mathrm{E}_y = i \cdot h \cdot \frac{\partial \Pi^l}{\partial y} \cdot e^{ihz}, \mathrm{E}_z = q \cdot g^2 \cdot \Pi^l \cdot e^{ihz}; \\ \mathrm{H}_x = -i \cdot k \cdot \frac{\partial \Pi^l}{\partial y} \cdot e^{ihz}, \mathrm{H}_y = i \cdot k \cdot \frac{\partial \Pi^l}{\partial x} \cdot e^{ihz}, \mathrm{H}_Z = 0. \end{cases} \qquad (4)$$

In theory waveguides $q^2 > 0$ because $h^2 < k^2$. For perfect conductor (conductivity $\delta \to \infty$) $h^2 = k^2, q^2 = 0$. For the so-called slow waves [2] $h^2 < k^2$, so $h^2 - k^2 < 0$ And transverse wave number q is purely imaginary, ie $q^2 < 0$. In general, if the core is surrounded with a dielectric medium (relative) permeability ε and magnetic (relative) permeability $\mu = 1$, Then:

$$h = \sqrt{k^2 \cdot \varepsilon - g^2}. \qquad (5)$$

We say in the future h - longitudinal wave number. We introduce the notation:

$$p^2 = -q^2 = h^2 - k^2, \qquad (6)$$

if $q^2 < 0$.

Then equation (3) takes the form:

$$\frac{\partial^2 \Pi^e}{\partial x^2} + \frac{\partial^2 \Pi^l}{\partial y^2} + p^2 \cdot \Pi^l = 0. \qquad (7)$$

Find the solution (7) in cylindrical (z, r, φ) coordinate system. Using the approach [1, 2], we can find:

$$\Pi^l = R_m(r) \cdot \cos m\varphi \overset{або}{\Leftrightarrow} \Pi^l = R_m(r) \cdot \sin m\varphi, \qquad (8)$$

where the function $R_m(r)$ must satisfy the equation:

$$\frac{d^2 R_m}{dr^2} + \frac{1}{r} \cdot \frac{d^2 R_m}{dr} - \left(p^2 + \frac{m^2}{r^2}\right) \cdot R_m = 0. \qquad (9)$$

Function Π^l must satisfy the equation (9) index $m = 0$ Because we believe that:

$$\Pi^l = \mathrm{A} \cdot \mathrm{K_O}(pr), \qquad (10)$$

where $\mathrm{K_O}(pr)$ - Macdonald function of order zero argument (pr), $\mathrm{A} = const$.

We use to calculate fields $\vec{\mathrm{E}}$ and $\vec{\mathrm{H}}$ the following formula [2]:

$$\vec{\mathrm{E}} = graddiv\vec{\Pi}^l + k^2 \cdot \vec{\Pi}^l, \quad \vec{\mathrm{H}} = -i \cdot k \cdot rot\vec{\Pi}^l \qquad (11)$$

Then we will have a cylindrical coordinate system (for $r > \alpha$):

$$\begin{cases} \mathrm{E}_r = -i \cdot h \cdot p \cdot A \cdot K_1(p \cdot r) \cdot e^{i \cdot h \cdot z}, \mathrm{E}_z = \\ = -p^2 \cdot A \cdot K_0(p \cdot r) e^{i \cdot h \cdot z}, \mathrm{E}_\varphi = 0. \\ \mathrm{H}_\varphi = -i \cdot h \cdot p \cdot A \cdot K_1(p \cdot r) e^{i \cdot h \cdot z}, \\ \mathrm{H}_r = \mathrm{H}_Z = 0. \end{cases} \qquad (12)$$

If the rod is considered ideal conductor, then $h = k = \omega / c$. Typically, the core has a finite resistance, which leads to some slowing of waves that spread in this core. The wave becomes thus superficial, which usually is expressed rather weakly (as $h \approx k = \omega / c$) [2].

Besides resulting in a single and finite conductivity rod, which is easy to consider it if the surface of the Leontovich boundary condition:

$$\mathrm{E}_z = \vartheta \cdot \mathrm{H}_\varphi \text{ at } r = \alpha \qquad (13)$$

where ϑ - wave impedance of the metal, which is defined by the formula [2]:

$$\vartheta = k \cdot d \cdot (1 - i) / \sqrt{2}, \qquad (14)$$

$$k = \omega / c$$

where d - the depth of penetration of the field in the metal rod:

$$d = \frac{1}{2\pi} \cdot \sqrt{\frac{\lambda \cdot c}{\delta}} \qquad (15)$$

λ - the length of the electromagnetic wave,
c - speed of light in a vacuum,
δ - electrical conductivity core material.

Table 1 provides value d for metal rods at different wavelengths λ.

Table 1.

d, м	λ, м
0.4 m = 0.4 * 10^{-6}m	1 cm = 10^{-2}m
4 m = 4 * 10^{-6}m	1 m
40 microns = 40 * 10^{-6}m	100 m
0.4 m = 0.4 * 10^{-3}m	10 km = 10^4 m

Thus, you can get the characteristic equation (transcendental) to determine ρ:

$$\rho \cdot a \cdot \mathrm{K_O}(\rho a) / \mathrm{K_1}(\rho a) = i \cdot \vartheta \cdot k \cdot a \qquad (16)$$

where $\mathrm{K_1}(\rho a)$ - Macdonald first order function from argument (ρa). Knowing the (16) ρ, We find from (6) h:

$$h = \sqrt{p^2 + k^2} \qquad (17)$$

Thus, parameters ρ and h for a wave that runs vpodovzh rod by relations (16) and (17).

Using the formulas for $\mathrm{K_O}(\rho a)$ and $\mathrm{K_1}(\rho a)$ [2]:

$$\begin{cases} \mathrm{K}_m(\rho a) = \dfrac{(m-1)!}{2} \cdot \left(\dfrac{2}{pa}\right)^m, m = 1,2,3,...; \\ \mathrm{K_O}(\rho a) = \ln\left\{\dfrac{2}{\gamma \cdot pa}\right\}, \wp = 1{,}781... \end{cases} \qquad (18)$$

You can turn the equation (16) to form:

$$(\rho a)^2 \cdot \ln\left\{\frac{2}{\gamma \cdot pa}\right\} = i \cdot \vartheta \cdot ka. \qquad (19)$$

This equation was derived Sommerfeld back in 1899.

Using an iterative procedure [2], equation (19) can be solved numerically.

It should be noted that the slowdown wave propagating vpodovzh core, turns it into a surface wave and the wave energy is concentrated near the core, as follows from formula (12).

If denoted by r (50%) and r (75%) radius, coaxial this rod through cross sections which is under 50% and 75% of the capacity of the surface waves, then you can calculation reduce to Table 2 (for metal bars, which has radii a = 1 mm respectively and a = 5 mm).

Table 2.

The radii of the cylinders	$\lambda = 30$ sm		$\lambda = 3$ sm	
	a = 1 mm	a = 5 mm	a = 1 mm	a = 5 mm
r (50%), see	5	17	2	6.5
r (75%), see	38	100	9	14

These numbers (Tab. 2) show that the band decimeter and centimeter waves radial length field single core does not exceed a few (3-4) wavelengths (λ): at $\lambda = 30$ sm the length of the field (the range) → $\frac{100sm}{30sm} \approx 3{,}3\lambda$, at $\lambda = 3sm$ the length of the field (the range) → $\frac{14sm}{3sm} \approx 4{,}6\lambda$. So leverage decimeter waves (Fig. 3).

It should be noted that equation (19) can be rewritten as:

$$h^2 = k^2 + i\cdot\delta\cdot k/a\cdot\ln(2/\gamma\cdot pa) = k^2 + i\cdot\omega\cdot\tilde{C}\cdot Z_i, \quad (20)$$

where: $Z_i = \bar{\delta}/(2\cdot\pi\cdot a) = 2\delta/(c\cdot a)$,

$$\bar{C} = \frac{1}{2}\cdot\ln\left(\frac{2}{\gamma\cdot p\cdot a}\right). \quad (21)$$

Z_i - according to the formula:

$$\begin{cases} E_Z = Z_i\cdot I, I = 2\cdot\pi\cdot a\cdot I_Z, Z_i = \\ = R - i\cdot\omega\cdot L_i = \dfrac{\bar{\delta}}{2\cdot\pi\cdot a} = \\ = \dfrac{1-i}{2\cdot\pi\cdot a\cdot\delta\cdot d}, \\ R = \omega\cdot L_i = \dfrac{1}{2\pi\cdot a\cdot\delta\cdot d}, \end{cases} \quad (22)$$

is running an internal impedance rod (impedance per unit of its length).

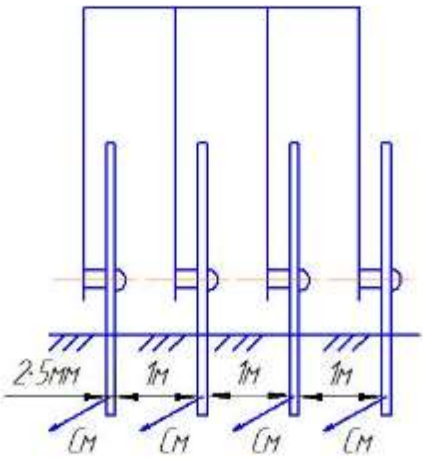

Fig. 3. Four-pole electrode system in contact with the ground.

In (22) I - complete the current through the core section, I_Z - density kvazipoverhnevoho current $\omega\cdot L_i$ - linear reactive impedance having an inductive character, L_i - Linear internal inductance rod R - linear resistance rod $\tilde{C}$ - can be called (in relation to the calculation of h) With some error ("stretch") per unit length uniform core capacity (as transmission line). Generally speaking, $\tilde{C}$ integrated value, but very rough approximation it can be considered a real number equal to 1/20.

The above formula can give electrodynamic calculations waves in two-wire line, taking into account the finite resistance rods placed next to each other (Fig. 4).

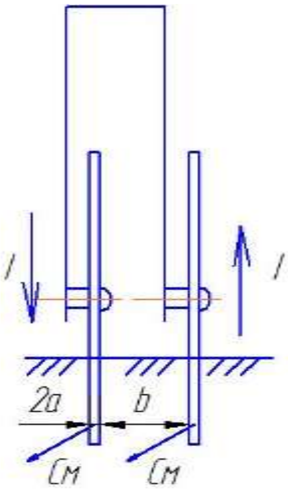

Fig. 4. The two-wire line.

According relations [2]

$$\oint H_\varphi ds = \frac{4\pi}{c}\cdot I \quad (23)$$

current that flows through a single core, which is surrounded by field (12)

$$I = I_o\cdot\exp(i\cdot h\cdot z) \quad (24)$$

where:

$$I_o = -\frac{c\cdot a}{2}\cdot i\cdot k\cdot p\cdot A\cdot K_1(pa) \quad (25)$$

which (this current) corresponds to a longitudinal electric field component:

$$E_Z = -\frac{2\cdot i\cdot p\cdot I_o}{c\cdot k\cdot a\cdot K_1(pa)}\cdot K_o(pr)\cdot e^{i\cdot h\cdot z} \quad (26)$$

If there is another / second rod at the same distance $в >> a$ the first, which is current $(-I)$, Then:

$$E_Z = -\frac{2\cdot i\cdot p\cdot I_o}{c\cdot k\cdot a\cdot K_1(pa)}\cdot[K_o(pr) - K_o(pr')]e^{ihz} \quad (27)$$

where r' - the distance from the observation point of the second axle rod.

In this formula h and p yet unknown. They can be identified by the condition $E_Z = Z_i\cdot I$ on the surface of the first core (second core condition gives the same), where Z_i - running internal impedance of the rod.

Under conditions $в >> a$ at $r = a$ will be considered $r' = в$ and to get p equal:

$$\begin{aligned} &-2\cdot i\cdot p\cdot[K_o(pr) - K_o(pв)] = \\ &= Z_i\cdot c\cdot k\cdot a\cdot K_1(pa) \end{aligned} \quad (28)$$

where c - the speed of light in vacuum.

If the condition $pв << 1$ (And hence also condition $pa << 1$), Then this equation (28) takes the form:

$$2p^2 \cdot \ln(в/a) = i \cdot \omega \cdot Z_i ,$$

$$h_2 = k^2 + i \cdot \omega \cdot 2 \cdot Z_i \cdot C ,\ C = \frac{1}{4} \cdot \ln(в/a),$$

which according to [2] C - Linear capacity two-wire line.

CONCLUSIONS

1. Thus, provided $pв << 1$ or, equivalently, provided $\sqrt{k^2 - h^2} \cdot в << 1$. We obtain the wave number h. Which coincides with that given telegraph equation. In this case the field in the neighborhood of two-wire line (at a distance of $в$ from both cores) is the quasi-static, through intensive interaction electrodynamic properties of two-wire lines radically different from those of a single rod.

2. In the reverse condition $pв >> 1$ condition (28) becomes the equation (16), which previously received for a single core. In this case, the interaction between the rods is little, because one field rod "not reaches" the second because of its superficial nature.

REFERENCES

1. **Sendreev J. N. 1976.** Management. Moscow. Nauka. 424.
2. **Krasovskyy N. N. 1968.** Motion Control Theory. Moscow. Nauka, 474.
3. **Roytenberh Y. A. 1978.** Automatic Management. Moscow. Nauka, 551.
4. **Egorov A. I. 1988.** Management systems. Kiev. High School. 276.
5. **Pontryagin L. S. 1961.** Mathematic theory processes. Moscow. Nauka, 391.
6. **Vladimir Donets, Svetlana Kochubey, Vitaly Yatsenko, Alexander Brovarets Taras Kazantsev, Vadim Brovchenko. 2014.** Spectral-field studies satellite validation remote vegetation. *TEKA*. Vol. 16, No 3. 195-201.
7. **Brovarets A. A. 2013.** Monitoring devices for field parameters at AIC. TEKA. № 11 (50). 131-141.
8. **Brovarets A. A. 2011.** Analysis of the disturbing irregularities ahrofoniv. *MOTROL*. №13B. 161-166.
9. **Robson M. A. 1996.** Practical guide to business process re-engineering. London. Gower Publishing Std, 96.
10. **Scherer F. M**. **1990.** Industrial market structure and economic performance. Boston, USA: Hongliton Mifflin Co. 90.
11. **Erlich A**. **1996.** Technical analysis of commodity and financial markets. Moscow: INFRA. 196.
12. **MacConnel L. 1993**. Ekonopis: Principles, problems and politics. Moscow. Manager, 103.
13. **Karibskiy A. V. 1989.** Modeling the development of the structure of large-scale production and transport systems. I, II. Automatics and telemechanics. №2. 116-131, №4. 139-154.
14. **Karibskiy A. V. 1996.** Business plan: financial and economic analysis and performance criteria. (methods of analysis and evaluation). Preprint. Moscow: Institute for Control Sciences, 19.
15. **Karibskiy A. V. 1991.** Managing the development of large-scale system. *Mathematics and Computers in Simulation*. 287-293.
16. **Shestakov N. V. 1991.** Use of computer modeling methods in the investment planning of petrochemical industries. *Abstracts of the International Scientific and Practical Conference "Management of large systems."* M.I.PU. 391.
17. **Karibskiy A. V. 1998.** Information technologies and features of financial and economic analysis of large investment projects in the oil industry. *World of Communication*. № 7-8. 72-77.
18. **Bakhrakh L. D., Bliskavitsky A. A. 1993.** The successes of physical sciences. V. 162, No. 2. 160.
19. **Landau L. D. 1982.** Electrodynamics of continuous media. Moscow. Nauka. 624.
20. **Brovarets O. O. 2011.** Analysis of the structure of perturbing roughnesses of agrofones. *MOTROL*. No. 13B. 161-166.
21. **Rogovskii Ivan. 2014.** Stochastic models ensure the efficiency of agricultural machines. *MOTROL*. Lublin. 2014. Vol. 16. No 3. 296-302.
22. **Rogovskii Ivan. 2016.** Graph-modeling when the response and recovery of agricultural machinery. *MOTROL*. Lublin. Vol. 18. No 3. 155-164.
23. **Rogovskii Ivan. 2017.** Analytical provision of regular preventive maintenance of agricultural machinery and system implementation. MOTROL. Lublin. Vol. 19. No 3. P. 185-191.
24. **Rogovskii Ivan. 2017.** Choice of model class and method of modeling the resilience of agricultural machinery. *TEKA*. Lublin–Rzeszów. 2017. Vol. 17. No 3. 101-114.

ФИЗИЧЕСКОЕ МОДЕЛИРОВАНИЕ ЭЛЕКТРОПРОВОДНОСТИ ПОЧВ ПРИ ИЗМЕРЕНИИ С ИСПОЛЬЗОВАНИЕМ ИНФОРМАЦИОННО-ТЕХНИЧЕСКОГО СИСТЕМЫ ЛОКАЛЬНОГО ОПЕРАТИВНОГО МОНИТОРИНГА АГРОБИОЛОГИЧЕСКИЕ СОСТОЯНИЯ СЕЛЬСКОХОЗЯЙСТВЕННЫХ УГОДИЙ

Аннотация. Существующие способы управления агробиологическим состоянию почвенной среды и отбором проб грунта по имеющимся методикам не учитывают вариабельности их параметров по площади сельскохозяйственных угодий. Для реализации технологии дифференцированного внесения технологического материала, преимущественно используется упрощенный способ равномерного разбиения поверхности поля на равные квадраты (преимущественно площадью 5-15 га) для дальнейшей диагностики и управления полем с использованием такой дифференциации. С одной стороны такое разделение обусловлен удобством и простотой данного метода, с другой - отсутствие достоверных оперативных данных о поле и, соответственно, инструмента для разделения поля по другим критериям на основе исходных данных. По этой методике к условно равного квадрату на поле

могут попадать участки с принципиально разными параметрами, среднее значение которых не отражать реальных параметров данного участка. Способ равномерного разбиения на равные квадраты поверхности поля не учитывает специфики поля и зон неоднородности, как следствие низкая достоверность данных полученных с использованием такого метода, а соответственно и возможность использования таких данных для качественного управления технологическим процессами с использованием технологии дифференцированного внесения технологического материала.

В некоторых случаях значения параметров почвенной среды будут занижены, а по некоторым завышены в пределах одного квадрата. Дифференцированное управление нормой внесения технологического материала, в рамках данного квадрата, должно будет осуществляться именно на основании среднего значения этого параметра. Поэтому такой способ реализации дифференцированного внесения технологического материала будет не эффективным.

В этих условиях возникает необходимость в поиске наиболее эффективного способа для оперативного мониторинга агробиологического состояния сельскохозяйственных угодий.

Наиболее эффективным способом оперативного мониторинга агробиологического состояния сельскохозяйственных угодий является измерение электропроводящих характеристик почвенной среды. Электропроводящие свойства почвенной среды является комплексным показателем его агробиологического состояния, учитывающий твердость влажность, содержание питательных веществ в почве, насыщенность основаниями, емкость катионного обмена и др.

Высокое содержание влаги, солей и питательных веществ в почве способствуют повышению показателей электропроводности почвенной среды в пределах одного поля, регистрируется информационно-технической системой локального оперативного мониторинга агробиологического состояния сельскохозяйственных угодий. Такая информация позволяет выделить зоны вариабельности почвенной среды и в дальнейшем осуществлять управление агробиологическим состоянием сельскохозяйственных угодий с учета зон неоднородности.

Для проверки эффективности функционирования информационно-технических систем локального оперативного мониторинга агробиологического состояния сельскохозяйственных угодий и достоверности полученных данных проведен физическое моделирование электропроводности почв при функционировании таких систем.

Проведено физическое моделирование электропроводности почв при измерении с использованием информационно-технической системы локального оперативного мониторинга агробиологического состояния сельскохозяйственных угодий.

Это открывает новые перспективы для ведения органического земледелия с использованием таких «умных» сельскохозяйственных машин.

Ключевые слова: информационно-техническая система, оперативный мониторинг, почва, пробы, вариабельность, величина.

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