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THEORETICAL ASPECTS OF FORMATION AND DEVELOPMENT OF CAVITATION PROCESSES IN TECHNOLOGICAL ENVIRONMENT

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Summary. The operation of a technological process under cavitation as a way of processing a dispersed environment. It is determined that the physical properties of the process medium have a decisive influence on the optimal modes of a technological process and conditions for the spread of vibrations carried through rheological properties. Features of signs of the environment of processing are called the loading mode to the emitter, the physical characteristics and conditions of impact on the emitter. It is assumed that electrical energy is converted into acoustic oscillations and radiation energy. The working environment must be such so that the radiator has to ensure the most efficient input of energy in coordination with the forces of resistance in this environment. This reaction is a response to the power operation system. Depending on the degree of absorption at the wave reflected from the boundaries of the volume occupied by the environment, and the environment itself, and the number of reflections and phase shifts the reaction to the emitter can be different. Is necessary to agree actual load of the process fluid to the radiator, which is performed on the basis of a solution of the contact problem of the interaction of these subsystems, which are subject to a single wave of the process through the use of a mathematical model that adequately reflects the cavitation treatment of the environment.

Analytical dependence made it possible to evaluate and formulate the principles of rational conditions and environment interactions of a cavitation system, improving performance parameters and energy.

Key words: pressure, absorption coefficient, energy, cavitation processing, rheological properties, technological environment.

INTRODUCTION

At the time of cavitation processing the technological environment, energy density of the sound field contact the zone of the "cavitation machine – environment" which is transformed into the high density energy of bubbles which are formed inside and around them, which eventually slam into each other.

ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

In general energy is expended on the formation of shock waves, heat, local electrification bubbles, sonoluminescence excitation, and the formation of free radicals [1]. Electrical energy is converted into acoustic oscillations and radiation energy. The working environment must be such so that the radiator has to ensure the most efficient input of energy in coordination with the forces of resistance in this environment. This reaction is a response to the power operation system.

The rheological properties are determined by changing technological environment that occurs during cavitation processing, which is tough, ductile and elastic [2] due to choice model [3–13], which takes into account these changes and methods of presentation in the mathematical description of the process of cavitation under which the bubbles are formed, their oscillation, followed by slamming development.

This process is accompanied by a complex transfer of heat and mass and [14] cavitation in the current field. It is clear that an accurate description of this process is too complex a task, but the undeniable fact is that the key parameter of the evolution of gas and air bubbles in the acoustic field is the energy components which are pressure, time and rate of occurrence of cavitation process. Such statements determined the main task of this study.

OBJECTIVES

The main objective is to establish the most influential parameters for the cavitation process from inception to slamming the volume of the bubbles to access the impact of the course of the process to determine these parameters.

THE MAIN RESULTS OF THE RESEARCH

The first objective study was to agree to terms on what grounds should conduct a classification machining environments. Signs of the environment of processing are called the loading mode to the emitter, the physical characteristics and conditions of impact on the emitter. So under these rules, the load on the radiator are divided into: unlimited acoustic environment with constant physical parameters, environment with constant dimensions with permanent physical parameters, unlimited acoustic environment with variable physical parameters, environment with variable dimensions or have variable physical parameters. In terms of physical characteristics: fluids, dispersed environment, solid medium. Under the impact of the emitter: neutral environment, chemically aggressive, temperature and aggressive.

An acoustically unlimited environment with constant physical parameters (whose values remain unchanged in the ultrasonic treatment) are characterized by the fact that the value of the input resistance of the medium, ie the load applied to the radiator remains constant and does not depend on the size of the object processing. In order for this technological object to satisfy this requirement, the size and magnitude of acoustic energy absorption per unit volume should be sufficient to neglect the reaction of the reflected waves on the radiator.

For the acoustically unrestricted fluid environment radiation resistance is the input resistance of the environment, is defined by its parameters, frequency, type and size of the radiator. For a limited acoustic environment with constant physical parameters and a constant size, the value of the input resistance depends on the size, as reflected waves in response emitter, depending on their amplitude and phase, determines the input resistance. Depending on the degree of absorption at the wave reflected from the boundaries of the volume occupied by the environment, and the environment itself, and the number of reflections and phase shifts the reaction to the emitter can be different. It may be that, because of the relatively small (compared with the surface of the walls) Square emitter and significant absorption of reflected waves, their reaction is so small that the input impedance can almost be defined as unrestricted acoustic environment. The efficacy of acoustic vibrations in unrestricted and restricted environments can be achieved by matching the input impedance value of the oscillation source (transmitter) and a waveguide system. For environments with variable parameters may change the absorption coefficient and the velocity of the waves, which is characteristic of a developed cavitation regimes.

Scientific research idea has accepted the position that the efficiency of formation of cavitation energy is determined by the structure and interaction of the basic elements of ultrasonic technological equipment, which are:

- Electric generator,
- Fluctuations in the electrical transformer speakers,
- The radiator,
- Technological device where the facility processing.

But the effectiveness of the introduction of acoustic vibrations in the vehicle manufacturing environment depends on a number of conditions to ensure:

- The maximum possible extraction of energy from the power fluctuations,
- Minimum energy dissipation in the elements of the design process apparatus,
- The greatest application of acoustic energy is introduced into the work environment to ensure the flow of the process,
- Maximum stability parameters of acoustic apparatus to predefined values of their technology and acoustic modes of the device.

So based on the above, the following hypotheses were formulated, the implementation of which will enable to achieve the desired result in the creation of a new or improvement of existing acoustic device.

1. Convert electrical energy into acoustic oscillations and radiation energy in the working environment must be such so that the radiator had to ensure the most efficient input of energy into the work environment in coordination with the forces of resistance in this environment, as a reaction to power system operation.

2. Is necessary to agree actual load of the process fluid to the radiator, which is performed on the basis of a solution of the contact problem of the interaction of these subsystems, which are subject to a single wave of the process through the use of a mathematical model that adequately reflects the cavitation treatment of the environment.

To determine the approach to the implementation hypotheses defined algorithm (Fig. 1), which will consider the physical aspects of the sequence of cavitation research process.

This approach will allow more intelligently and with less error to take a mathematical model for the studied environments, develop, or out of necessity, improve the methodology of research results are reliably determined by the levels of the difficulty of the cavitation process (Fig. 2), the distribution zones and areas developed cavitation considering changes physical properties of the dispersion environment, which is the density, impedance, absorption coefficient and others.

On the first level of the model is considered the physics of the formation and determination of dependencies radius individual cavitation bubbles R of time t, the intensity of ultrasonic vibrations I and rheological properties of the medium in particular, the density ρ, the coefficient of viscosity ν, the module of elasticity E which is linear materials, pseudo plastic and dilatant [3]:

$$R = f(t, I, \rho, \nu, E)\,. \qquad (1)$$

The dependence of the radius of the cavitation bubbles in accordance with (1) a precondition for the average level of detail model of cavitation field. Realization of this research can be used depending on the analytical studies [14–18] for some clarification numerical values of acoustic parameters and system environments. Because of this set allowable range of numerical values of intensity ultrasonic vibrations, which implemented slamming bubbles. At the secondary level (Fig. 2) are defined by a set of cavitation bubbles in the size of L, which is less than the length of the ultrasonic wave λ, but is much larger than the radius of the cavitation bubbles R:

$$\lambda >> L >> R\,. \qquad (2)$$

Adopted condition (2) makes it possible to establish dependent volume content of cavitation bubbles (3) and concentration (4) the intensity of ultrasonic vibrations I, time t and rheology liquid ρ.

$$V_b = \frac{4}{3}\pi R^3 n, \qquad (3)$$

$$n_b = g(t, I, \rho, \nu, E) \qquad (4)$$

where: n_b – the estimated concentration of cavitation bubbles, m^{-3}, V_b – volume content of bubbles, R – instantaneous radius of the bubble, which is defined on the lower level model city.

The third level is determined by the total volume and shape of the cavitation field, set the intensity of the ultrasonic action, under which conditions provided intensive mode of developed cavitation as completed stage of the process.

So mathematical model of manufacturing environment is a continual system [12] with three levels of implementation and taking into account the changes in its rheological properties.

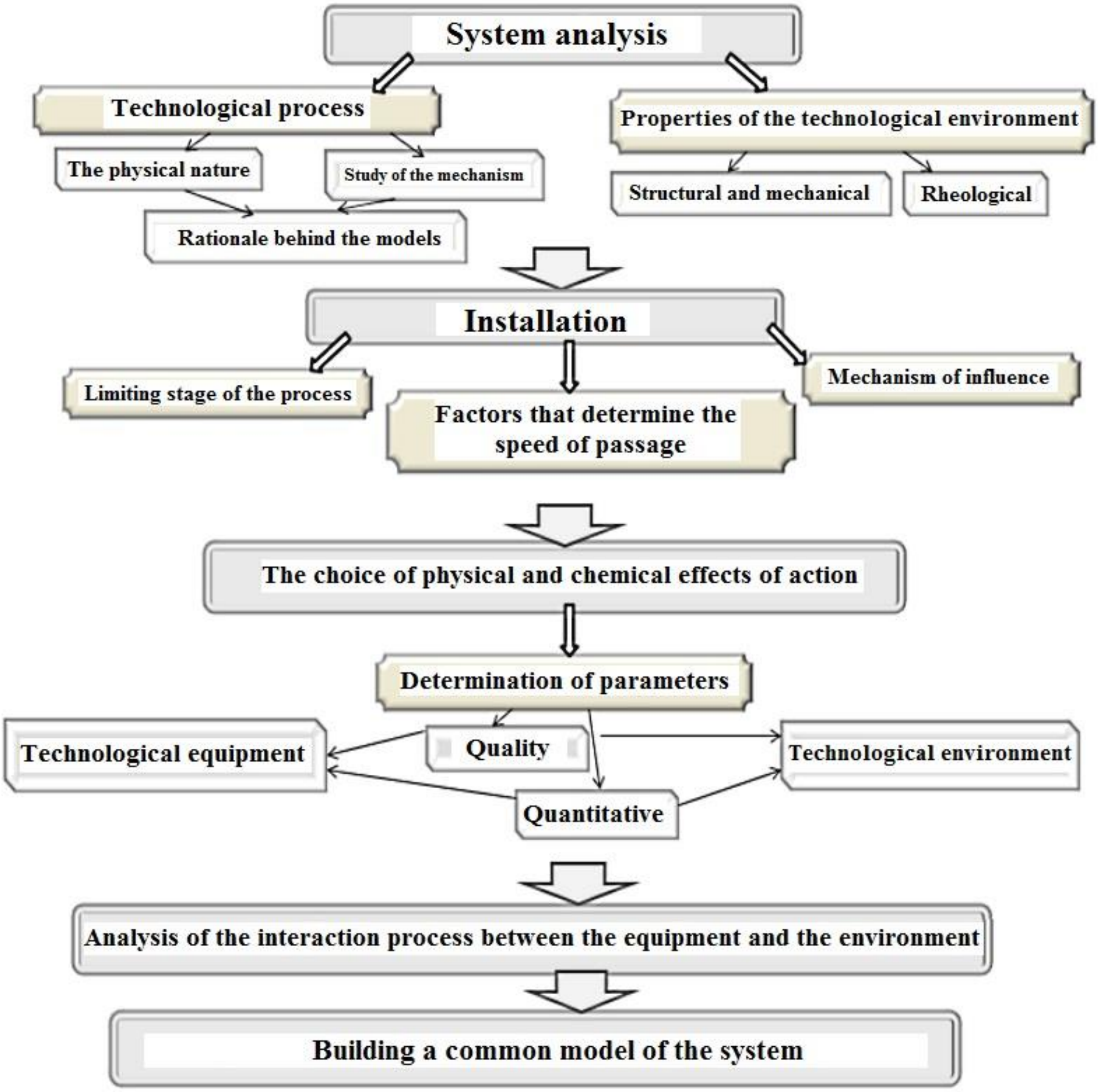

Fig. 1. The algorithm of conduct research

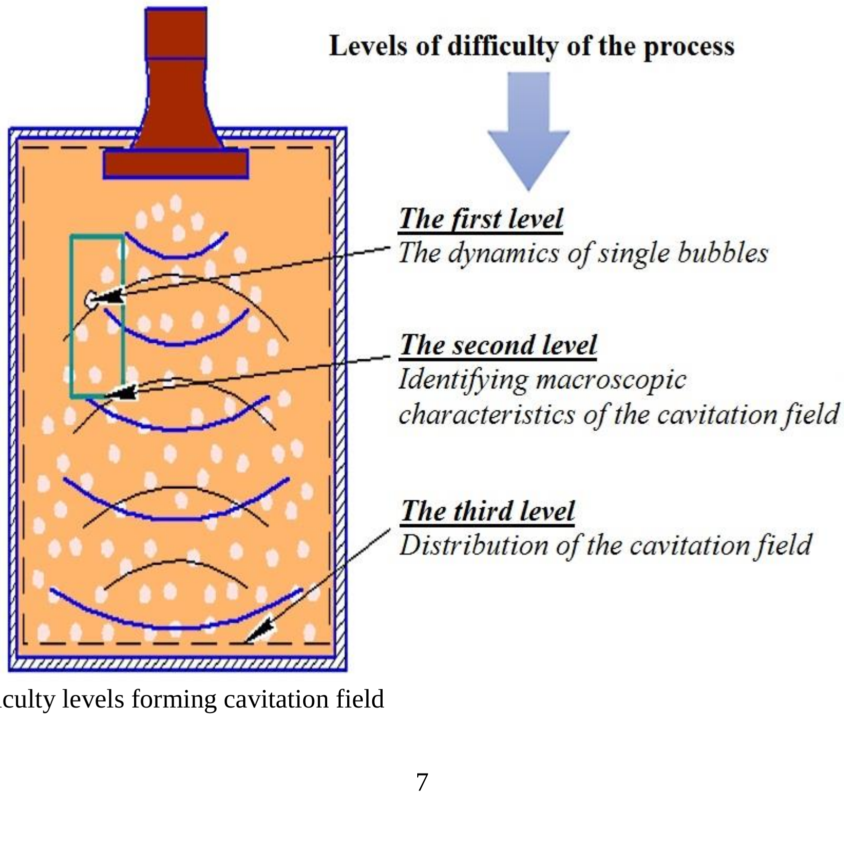

Fig. 2. Difficulty levels forming cavitation field

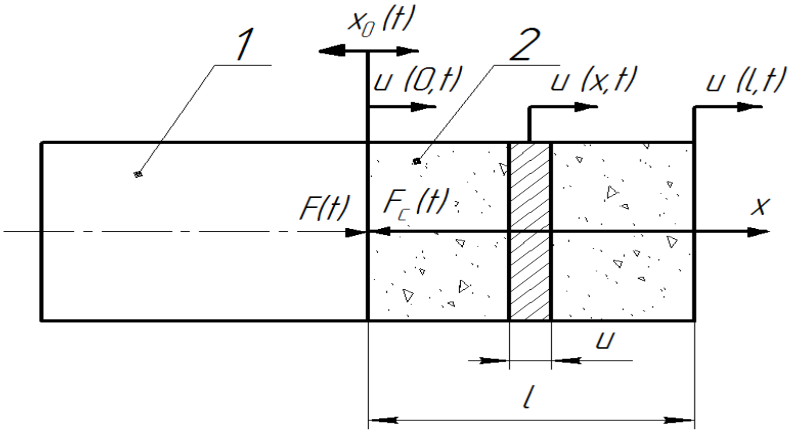

Fig. 3. Diagram of the system "cavitation machine - environment": 1 – cavitation device, 2 – environment, *u* – moving vehicle, *F (t)* – periodic forcing cavitator strength in the contact zone of the manufacturing environment, *u (x, t)* – longitudinal displacement current environment section treated with fluctuations, this movement depends on the location sectional /coordinates *x*/ and from time *t*, $F_c = 0$ – the reaction medium in section $l = 0$, $R \mid x = l$ – a reaction medium treated in section $x = l$.

The next task is to describe a model to determine the specific power of shock waves (P_n) per unit volume cavitation field, impedance environment ($\rho_c c_c$) and absorption coefficient (k_e).

Power (5) can be represented as

$$F_c = -E_e \cdot S \left.\frac{\partial u}{\partial x}\right|_{x=0}, \tag{6}$$

where: E_e – modulus environment, $\frac{\partial u}{\partial x}$ – deformation of the medium in the contact zone.

In shock movement is an important characteristic acceleration.

Therefore, on the other hand can contact force with some approximation to determine how

$$F_c = m_e' \ddot{x}\big|_{x=0}, \tag{7}$$

where: m_e' – mass medium, determining inertial properties at accelerating the contact zone of "cavitation machine – environment".

So determining the contact force needs of the deformation $\partial u/\partial x$ or acceleration $\ddot{x}$.

In any case, you must take the equation of the medium and on this basis to determine the contact force, and then the parameters included in the equation of the medium in the contact zone.

Wave equation environmental fluctuations take the form:

$$\frac{\partial^2 u}{\partial x^2} = \frac{\rho}{(E' + iE'')} \cdot \frac{\partial^2 u}{\partial t^2}, \tag{8}$$

where: *u (x, t)* – move current layer protection section in the direction of the force, which depends on coordinates *x* and time *t*, ρ – density of the medium, E', E'' – the complex modulus, *i* – the imaginary unit, indicating a shift in the angle $\pi/2$ between E' and i.

The physical meaning of complex components is their compliance with elastic (E') and not resilient (E'') properties, $\partial^2 u/\partial t^2$ – acceleration contact layer technology environment. If we take into account that:

$$\ddot{x}_{x=0} = \left.\frac{\partial^2 u}{\partial t^2}\right|_{x=0} \tag{9}$$

the equation (8) can be written as:

$$\frac{\partial^2 u}{\partial t^2} = \ddot{x}\big|_{x=0} = \left(\frac{E' + iE''}{\rho}\right)\left.\frac{\partial^2 u}{\partial x^2}\right|_{x=0}. \tag{10}$$

If we substitute the expression for acceleration (10) (7) and taking into account (6), we have that

$$m_e' = \frac{-E \cdot S \left.\frac{\partial u}{\partial x}\right|_{x=0}}{\left(\frac{E' + iE''}{\rho}\right)\left.\frac{\partial^2 u}{\partial x^2}\right|_{x=0}}. \tag{11}$$

Thus the problem of determining m_e' is to find strain $\frac{\partial u}{\partial x}$ and acceleration $\frac{\partial^2 u}{\partial x^2}$ values taken at A medium - density ρ and module *E*.

To solve this problem, we assume that the motion of "cavitation machine - environment" is:

$$u(x,t) = \left(A_1 \cdot e^{ikx} + A_2 \cdot e^{-kx}\right) \cdot e^{i\omega t}, \tag{12}$$

where: A_1 i A_2 – constant determined from the boundary conditions, *k* – complex wave number:

$$k = \omega/c \cdot (\eta + i\chi), \tag{13}$$

where: η i χ – factors that are by substituting (12) to (8):

$$\eta = \sqrt{\frac{\sqrt{1+\gamma^2} - 1}{2(1+\gamma^2)}}; \qquad \chi = \sqrt{\frac{\sqrt{1+\gamma^2} + 1}{2(1+\gamma^2)}}. \tag{14}$$

Dependence (14) obtained on condition that the complex modulus has the expression:

$$E^* = E' + iE = E \cdot (1 + i\gamma), \tag{15}$$

where: γ – loss factor which determines the ratio of energy dissipated volume in the environment ΔW of the period of oscillation to the potential energy W:

$$\gamma = \frac{1}{2\pi} \cdot \left(\frac{\Delta W}{W} \right). \qquad (16)$$

Dependence (13) can be somewhat simplified if we take into account that in practical terms the cavitation process numerical values of resistance to environmental matters $\gamma \le 0{,}4$, then after the adoption of the conditions obtain:

$$\eta = \frac{\gamma}{2}; \quad \chi = 1. \qquad (17)$$

This complex wave number (13):

$$k = \frac{\omega}{c} \cdot \left(\frac{\gamma}{2} + 1 \right). \qquad (18)$$

It is now possible to determine the required values deformation and its derivative. With (12) determine the deformation:

$$\left.\frac{\partial u}{\partial x}\right|_{x=0} = \frac{\omega}{c} \cdot \left(\frac{\gamma}{2} + i \right) \cdot \left[A_1 - A_2 \right],$$

considering that the wavelength is small, we get:

$$\left.\frac{\partial u}{\partial x}\right|_{x=0} = 0,$$

Then $A_1 \cdot e^{l(\eta + i\chi)} - A_2 \cdot e^{-l(\eta + i\chi)}$.

Where:

$$\frac{A_1}{A_2} = e^{-2l(\eta + i\chi)}, \qquad (19)$$

where: $\frac{\omega}{c} \cdot \left(\frac{\gamma}{2} \right) = \eta; \quad \frac{\omega}{c} = \chi$.

It is necessary to consider the second component pressure according to the relationship (15). That is, in general, the contact pressure is twofold – first (purely inertial) determined by the dependence (7) and dissipation:

$$\left| F_k \right| = \left| F_k^p \right| + \left| F_k^a \right| = -m_e q \ddot{x}\big|_{x=0} - m_e j \dot{x}\big|_{x=0}. \quad (20)$$

The coefficients q and j determine reactive and active components of resistance.

The energy lost in the process of cavitation flow is determined from the dependence:

$$E_e = \psi_e \frac{\left(\frac{\partial u}{\partial x} \right)^2 E}{2}. \qquad (21)$$

To determine the strain $\partial u / \partial x$ use the resulting dependence (19), which takes into account the real value ratios η and χ (15). As seen contact problem, the dependence (12) as the ultimate expression of deformation (19) can be simplified by writing the equations of motion (12) as:

$$u(0,t) = x_k c l \varphi \frac{x}{l} \left(\frac{\gamma}{2} + i \right) e^{i\omega t}, \qquad (22)$$

where: x_k – the amplitude of the contact zone, $\varphi = \frac{\omega l}{c}$.

Then deformation $\frac{\partial u}{\partial x}$:

$$\frac{\partial u}{\partial x} = \frac{\varphi\left(\frac{\gamma}{2} + i \right)}{l} \cdot \frac{sh\varphi \frac{x}{l}\left(\frac{\gamma}{2} + i \right)}{ch\varphi\left(\frac{\gamma}{2} + i \right)} x_k \qquad (23)$$

and expression $\left(\frac{\partial u}{\partial x} \right)^2$:

$$\left(\frac{\partial u}{\partial x} \right)^2 = \frac{\varphi^2}{l^2} \cdot \frac{ch\left(\varphi \frac{x}{l} \right) - \cos\left(2\varphi \frac{x}{l} \right)}{ch\gamma\varphi + \cos 2\varphi} x_k^2. \qquad (24)$$

Substituting (24) in (21) we obtain

$$E_e = \frac{\psi_e}{2} x_k^2 \omega^2 \rho k_E, \qquad (25)$$

where: k_E expresses the ratio of energy distribution

$$k_E = \frac{ch\left(\varphi\gamma \frac{x}{l} \right) - \cos\left(2\varphi \frac{x}{l} \right)}{\cos\gamma\varphi + \cos 2\varphi}. \qquad (26)$$

While the specific impact power:

$$\overline{P}_e = \frac{E_e \omega}{2\pi\rho} = \frac{\gamma}{2} x_k^2 \omega^3 k_E. \qquad (27)$$

In the end, a power value for cavitation processing environment:

$$P_e = \frac{m_e}{2} x_0^2 \omega^3 j, \qquad (28)$$

where:

$$j = \frac{sh(\varphi\gamma) - \frac{\gamma}{2}\sin 2\varphi}{\varphi(\cos 2\varphi + ch\varphi\gamma)}. \qquad (29)$$

Thus dependences (5) – (28) make it possible to assess the energy cost of "cavitator – environment". Installed the maximum total power generated shock waves will provide a measure of the efficiency of cavitation effects.

Under the influence of ultrasonic harmonic oscillations in medium pressure varies according to the law:

$$p(t) = A\omega\rho_c c_c \cos(\omega t - kr), \qquad (30)$$

where: ρ_c and c_c – density and sound velocity in a cavitating environment, ω – circular frequency sound wave, $k = \frac{\omega}{c}$ – wave number, A – amplitude of the radiator, then the amplitude of sound pressure P_m:

$$P_m = A\omega\rho_c c_c, \qquad (31)$$

where: $\rho_c c_c$ – impedance environment because it, as follows from formula (31), determines the speed of oscillation at a given acoustic pressure.

On Cavitation parameters significantly impact a number of other factors, including:

- speed of sound in the cavitation region,

- distance from the cavitation device that transmits energy environment,
- temperature and gas content liquid,
- the composition and concentration of dissolved impurities,
- the number of bubbles that are involved in the process of cavitation.

In practice, for convenience assess the cavitation bubbles substitute index numbers by a factor of cavitation index *K*, which is the average time the volume concentration of bubbles:

$$K = \frac{\sum_i V_i}{V_f + \sum_i V_i}. \tag{32}$$

where: V_f – the volume of fluid without bubbles, V_i – the average amount of cavitation bubbles, i = 1, N, N – number of bubbles.

The number of bubbles can be expressed through cavitation index:

$$N = \rho V_f, \tag{33}$$

where: $n = \frac{3K}{4\pi R_{cp}^3}$ – the concentration of bubbles, R_{ar} – average radius of the bubble.

Then the wave resistance cavitating advisable environment represented as a relationship:

$$\rho_c c_c = \rho_0 c_0 \left[\frac{1}{1 + \frac{K\beta_n}{\beta_0}} \right]^{1/2} \tag{34}$$

where: $\frac{\beta_n}{\beta_0}$ – the ratio of compressibility of vapor bubbles in the mixture to the compressibility of fluid water $\frac{\beta_n}{\beta_0} = 10^4$ [15, 16].

Bubbles, having high compressibility, take on the action of external forces in the sound waves, thus reducing the bulk modulus E_e and the speed of sound $c_c = \sqrt{\frac{E_e}{\rho_c}}$ [19]. Effect parameters on the occurrence of cavitation process considered in [11–19]. Thus, the dependent impedance environment of cavitation index (Fig. 4) shows that the index of cavitation only 0,2% impedance, and hence the amplitude of the current bubble in the sound pressure is reduced almost five times.

Another important parameter is the absorption coefficient in cavitating environments to determine the magnitude of which can use the equation [20], which describes the distribution of acoustic fields in the technological environment of cavitation bubbles filled with steam or gas:

$$\Delta p - \frac{1}{c_0^2} \cdot \frac{\partial^2 p}{\partial t^2} = -\rho_0 \frac{\partial^2 \overline{V}}{\partial t^2}, \tag{35}$$

where: t – time s, ρ_0 – equilibrium density of the medium, kg/m^3, p – instantaneous pressure environment, Pa c_0 – the speed of sound in the liquid phase, m/s, $\overline{V}$ – instant volume content of bubbles.

Unlike (8) in equation (35) takes into account the contribution of higher harmonics in which case the instant pressure and volume content of bubbles conveniently represented as a Fourier series [21]. Expansion in Fourier series in complex form in accordance with the classical theory [21] is:

$$\overline{p}(r,t) = \sum_{n=1}^{\infty} \overline{V}_n(r) e^{-in\omega t}, \tag{36}$$

$$\overline{V}(r,t) = \sum_{n=1}^{\infty} \overline{V}_n(r) e^{-in\omega t}, \tag{37}$$

where: ω – circular oscillation frequency acoustic device, which interacts with the environment, s^{-1} , r – radius vector of the point of the medium, m, n – number of harmonics.

After substituting (36) and (37) in the wave equation (35) it is transformed into the equation for each harmonic:

$$\Delta \overline{p}_n + \frac{n^2\omega^2}{c_0^2} \overline{p}_n = n^2\omega^2 \rho_0 \overline{V}_n, \tag{38}$$

Wave equation (35) for the 1st harmonic:

$$\Delta \overline{p}_1 + \frac{\omega^2}{c_0^2} \left(1 - \frac{\rho_0 c_0^2 \overline{V}_1}{\overline{p}_1}\right) \overline{p}_1 = 0. \tag{39}$$

In this form it is known Helmholtz equation [21]:

$$\Delta \overline{p}_1 + (k + ik_e)^2 \overline{p}_1 = 0, \tag{40}$$

where: k – the effective wave number cavitating environment, m^{-1}, k_e – effective absorption coefficient cavitating environment, m^{-1}.

Then from equations (39) and (40) we obtain the absorption coefficient cavitating environment:

$$k_e = -\frac{\omega}{c_0} \ln \frac{\rho_0 c_0 \overline{V}_1}{\overline{p}_1}, \tag{41}$$

It follows from (41) the absorption coefficient depends on complex amplitude of sound pressure in cavitating environments and complex amplitude volume content of cavitation bubbles. A convenient size for assessing energy performance ultrasonic cavitation is intensity oscillations (Fig. 5).

This is due to the fact that the intensity is related to the amplitude of sound pressure unambiguous relationship:

$$I = \frac{p^2}{2\rho_c c_c}. \tag{42}$$

Given (42) Absorption Rate (41) was presented in the form of:

$$k_e = -\frac{\omega}{c_0} lm \frac{\rho_0 c_0 \overline{V}_1}{(\sqrt{2\rho_c c_c I} e^{i\varphi})};$$

$$I = \frac{|\overline{p}_1|^2}{2\rho_c c_c};$$

$$\overline{p}_1 = |\overline{p}_1| e^{i\varphi}, \tag{43}$$

where: φ – phase shift ultrasonic pressure $\overline{p}_1$ councils.

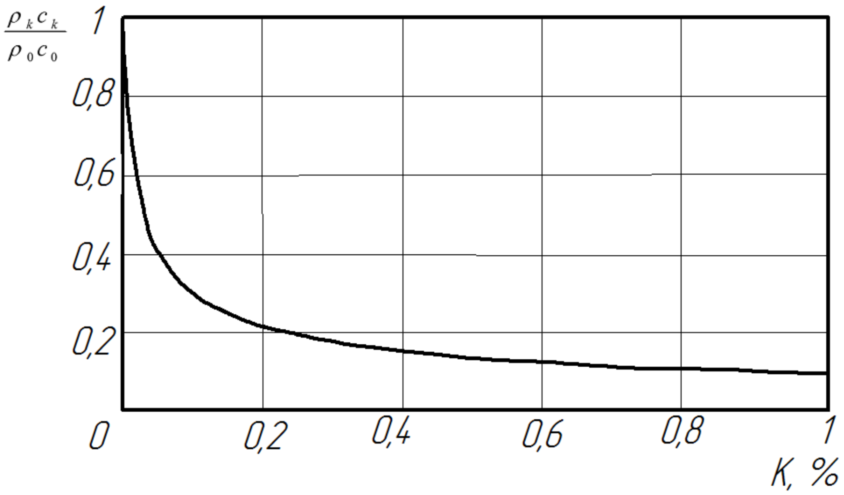

Fig. 4. Dependence of change of impedance protection from cavitation index.

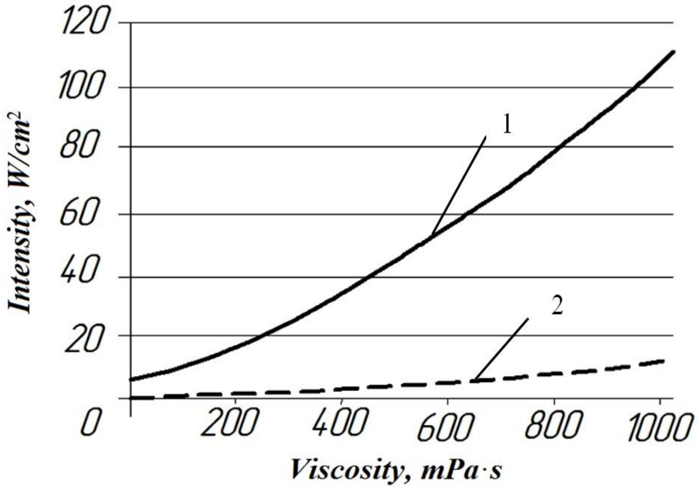

Fig. 5. Scope changes the intensity of cavitation processing of dispersed linear viscous process fluids: 1 – maximum intensity, 2 – low intensity.

Complex amplitude volume content of cavitation bubbles may be determined by direct Fourier transform:

$$\overline{V}_1 = \frac{\omega}{2\pi} \int_0^{\frac{2\pi}{\omega}} \frac{4}{3} \pi R^3(t) \overline{V}_\infty e^{-i\omega t} \partial t, \qquad (44)$$

where: *R(t)* – functional dependence of cavitation bubble radius (m) from the time detected by analyzing the third level of complexity (Fig. 1), $\overline{V}_\infty$ – fixed concentration of cavitation bubbles (m^{-3}) set based on the analysis of the second level of complexity of the process of cavitation. In its final form using dependencies (43) and (44) the formula for determining the absorption coefficient becomes:

$$k_e = -\frac{\omega}{c_0} lm \frac{\rho_0 c_0{}^2 \frac{\omega}{2\pi} \int_0^{\frac{2\pi}{\omega}} \frac{4}{3} \pi R^3(t) \overline{V}_\infty e^{-i\omega t} \partial t}{(\sqrt{2\rho_c c_c l}) e^{i\varphi}}, \qquad (45)$$

Analysis of the relationship (45) shows that the absorption coefficient at a certain intensity of the ultrasonic action in the formation, development and cavitation bubbles slamming area corresponds to the maximum effectiveness of cavitation process. Fig. 6 shows the dependence of absorption cavitating liquid on the intensity of exposure to different coefficients of viscosity.

The value of the absorption coefficient can serve as a measure of the efficiency of cavitation effects. The confirmation of this finding may be the relationship of the absorption coefficient of specific power shock waves through consideration of the local area treated medium volume $\Delta S \Delta x$. So, using the law of conservation of energy, we find that the power density shock wave can be determined according to the following expression:

$$P_{dens} = \frac{\Delta Sl}{\Delta x \Delta S} = \frac{\Delta S(I - Ie^{-k\Delta x})}{\Delta x \Delta S} = \frac{(I - Ie^{-k\Delta x})}{\Delta x} = K \frac{I(1 - e^{-k\Delta x})}{K \Delta x} \approx KI, \qquad (46)$$

where ΔI – change the intensity of this wave as a result of acquisitions, W/m^2.

Since (46) implies that the specific energy shock waves generated per unit time is the product of the absorption coefficient and the initial intensity ultrasound waves. Thus, the absorption coefficient is a measure of the effectiveness of ultrasonic cavitation, that determines the ratio of useful energy created in the form of shock waves and cavitation necessary for the implementation of process energy.

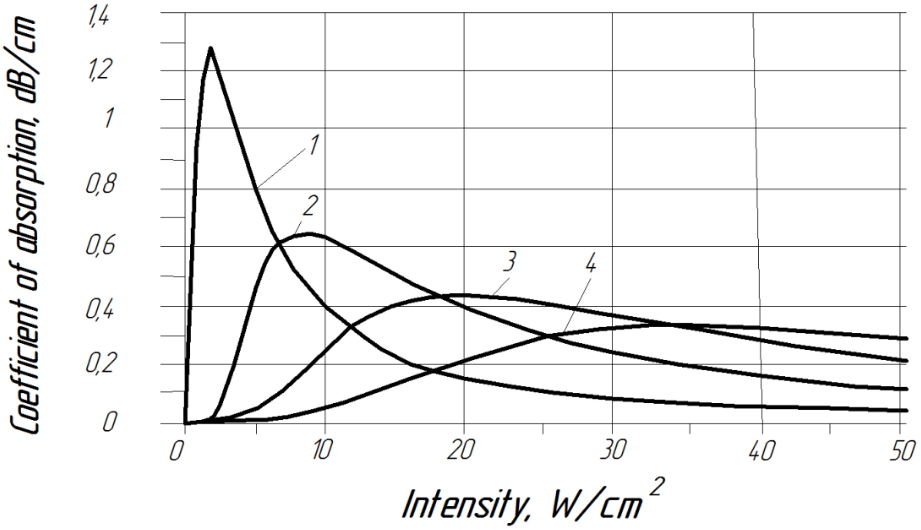

Fig. 6. The dependence of the absorption coefficient cavitating liquid in the intensity of the impact of different viscosity: 1 – 1 mPa·s, 2 – 200 mPa·s, 3 – 400 mPa·s, 4 – 600 mPa·s.

CONCLUSIONS

1. The exact description of cavitation processing technology dispersed environments is a difficult task, but the undeniable fact is that the key parameter of the evolution of bubbles in the acoustic field is the energy components which are pressure, absorption coefficient of energy, time and speed the flow of the process.

2. Revealed that featured machining environments that can be used to determine the rational model of the process are: load mode for the emitter, physical characteristics and conditions influence the radiator.

3. Scientific research idea was accepted position that the efficiency of formation of cavitation energy determined by the structure and interaction of the basic elements of ultrasound technology equipment technological environment. Necessary approvals real burden technological environment of the transmitter, based on solving the contact problem of interaction between these subsystems that conquered single wave processes through the use of mathematical models with distributed parameters, which adequately reflects the cavitation treatment of the environment.

4. Done description adopted mathematical model, which made it possible to get analytical dependence of power density shock waves per unit volume cavitation region, the wave resistance of the medium and the absorption coefficient. The absorption coefficient is a measure of the effectiveness of ultrasonic cavitation, that determines the ratio of useful energy created in the form of shock waves and cavitation necessary for the implementation of process energy.

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RESEARCH OF SETTINGS OF FORCED ACTION MIXER WITH CHANGING ANGLE BLADES

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Summary. Analysis and evaluation of structural and technological parameters of forced action mixer was carried out on the basis twin-shaft forced action mixer. Theoretical methods of moving material into the twin-shaft mixer chamber, using a stochastic approach were proposed in this article.

The process of moving material was researched by the theory of Markov chains. Based on the proposed method of improving system of quality assessment in terms the variation coefficient of mixture. And was predicted that the main parameter that affects the direction of movement particles of material and quality of mixing - is the rotation angle of the blade.

It was the main option of the research. To test the theoretical foundations of the movement of substances and improve the quality of the mixture, experimental stand was developed – Laboratory twin-shaft forced action mixer with changing angle blades.

The conducted experiments have confirmed the validity of theoretical research.

The Algorithm of design of new constructions of twins-shaft concrete mixers was proposed, based on conducted researches.

The working hypothesis that the movement of material between the mixing zones depends on the "transition probabilities", which is defined by angle blade was confirmed as a result of mathematical modeling of moving material and performed experimental studies.

On the basis of theoretical research the method of calculation of basic parameters of advanced laboratory twin-shaft concrete mixers was created.

The laboratory twin-shaft concrete mixers with rotary blades was created.

The investigations can improve the efficiency of the mixer by reducing cycle time and energy consumption.

Key words: mixer, twin-shaft concrete mixer, twins-shaft forced action concrete mixer, coefficient of variation, concrete, mixing stochastic model, Markov chains.

INTRODUCTION

Quite often the twin-shaft forced action mixers are used for the production of mixed concrete and for reinforced concrete structures.

ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

The scope of their optimal use is virtually unlimited, according to modern recommendations [1, 5, 6, 12, 15]. For example, mixture prepared in such mixer has the highest structural strength by water-cement ratio coefficient [10,16,19]. These mixtures are ideal for making hard and harder mixtures [19]. Their distinctive feature is the lowest duration of the mixing cycle – 45-90 sec, compared to other types of mixers. However, despite their many advantages, they have some disadvantages, namely the high cost of mixing, and consequently - high cost of driving mechanism, rapid wear armor mixer. Overall, the construction of this type of mixer is not well studied, so we should carry out research of processes and phenomena occurring in the middle of mixing chamber. An important trend in the development of this equipment is the desire to generalize the theoretical foundations of design and calculations of this type of construction equipment [1,5,12].

Therefore, improving the means of preparing concrete mixes and solutions that will have simpler design, lower energy loss and metal consumption is relevant and promising researching task for the development of engineering and construction industry in Ukraine.

The analysis and estimation of existing researches of mixers were carried out, that identified the main task of this work.

OBJECTIVES

The primary goal of research is increase efficiency of process preparation of mixture on twin-shaft forced action mixer by optimal blade angles of rotation and determination of mixing time, depending on the coefficient of variation, through mathematical modeling of moving particles mixture.

THE MAIN RESULTS OF THE RESEARCH

During the mixing process in its working volume occurs relative movement of particles of different components, which were "separated" or were implemented unevenly. As a result of mixing process, the particles location in the working volume of the mixer may be infinitely different. Under such conditions, the ratio of components in the mixture micro-volumes – the value is too random, because most of the known methods for assessing uniformity of mixture (quality) based on the methods of statistical analysis.

For simplicity, all mixture conditionally consists of two components: main component and secondary component that includes other components. This method helps to evaluate the homogeneity of mixture by using distribution parameter of a random variable – content of main component in the mixture samples. The component is easy to analyze or its distribution in the mix is very important for the technical requirements, is often choose as main component. This criterion of mixture quality is the coefficient of variation, %:

$$V_c = \frac{100}{\bar{c}} \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (c_i - \bar{c})^2} \ , \qquad (1)$$

where: $\bar{c}$ – arithmetic mean of concentration a main component in all n samples mixture %, c – concentration of a key component in the i-th sample mixture, % [14].

As for the mixing of building materials, this criterion is called the coefficient of heterogeneity, because of coefficient the heterogeneity of the mixture is increasing.

The analysis of experimental dependence $V_c = f(t)$ (t – mixing time), shows that the kinetic curve of mixing process has three characteristic areas (Fig. 1), where each of them reflects a certain period of time mixing.

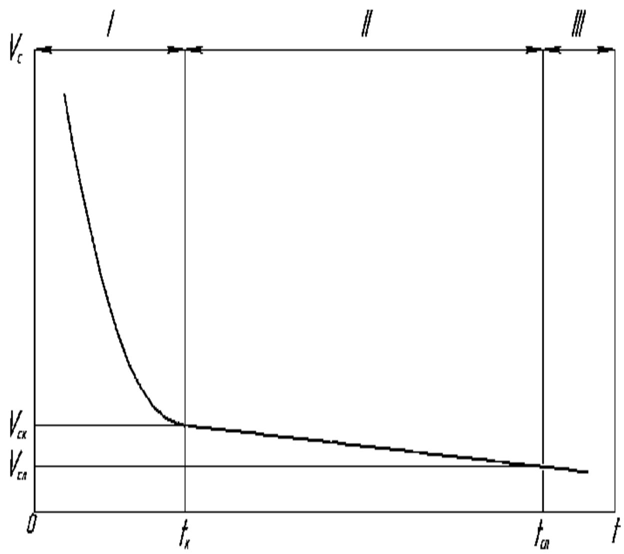


Fig. 1. Dependence of heterogeneity mixture from mixing time.

At 1-st period in mixer volume convection hyphenation of components is dominated. The process of segregation has low speed, compared with the process of moving. Therefore, in 1-st period V_c decreases sharply to some value V_{ck}. At the end of this period (t_{cp}) in the working volume of mixer virtually no aggregates (macro-volumes) consisting of particles of one component.

In 2-nd period, the mixing speed became equal to the speed of segregation, that is the value V_c varies slightly over time (compared with 1-st period). It self the mixing process is implemented mainly through the movement of individual particles relative to each other. Because of resemblance to the diffusion process of molecules it`s called diffusion.

In 3-d period the mixing speed equal to the speed of segregation, that is V_c does not change with time. The lowest value of coefficient of heterogeneity called marginal heterogeneity $V_{\text{сп.}}$ The time $t_{\text{сп}}$, at which the mixture becomes homogeneous (estimated value $V_{\text{сп}}$), is optimal mixing times because of further stirring V_c it doesn`t change.

In the 1st period the physical and mechanical properties of the mixture do not affect significantly the kinetics of mixing process, and in the 2nd and 3rd periods, their influence is noticeable. Therefore, different mixes in a mixer with different physical and mechanical properties will have different values of V_c. [10, 11, 14]

The physics of mixing process in a continuous mixer differs from cyclic mixer fact that the quality of mixing depends not only on the speed of mixing in the working volume of the mixer, but the nature of the power components.

Considering the mode of twin-shaft mixer to determine its nature effectiveness within a stochastic model in which the movement of matter is random and is described by probabilistic methods. [3]

To do this, all volume of the mixer is divided into the equal number of elementary volumes – mixing zones. At first step, define the volume one shaft of mixer – the cylinder without adjacent cylindrical segment that mixed by blades of nearby shaft (Fig. 2, shaded area).

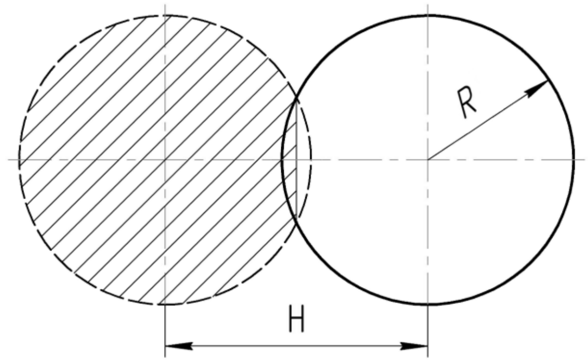


Fig. 2. The scheme of elementary volume: R – radius of the mixing zone, H – distance between the axis of the shafts.

Further, the cylinders are divided into mixing zones whose number equal to the number of blade arrangements mounted on the shaft (Fig. 3).

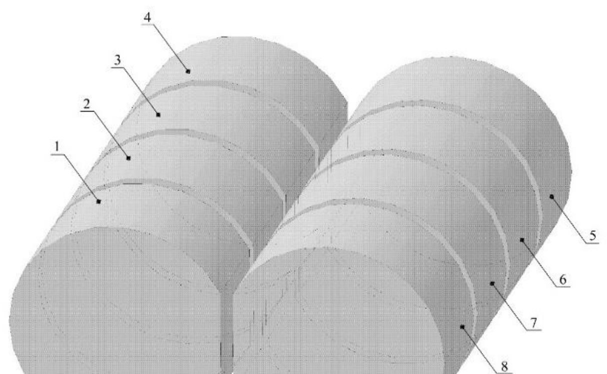


Fig. 3. The three-dimensional model of 8 mixing zones.

Based on the definition of mixing process in the theory of dynamical systems [20, 21], as the properties of the system "forget" about the initial condition (state) over time, we will determine this time. To describe the movement of heterogeneous systems we will use Markov chains theory [7, 13, 17, 18, 22, 23] so the transition probability $p_{ij}(t)$ depends on time and there is a time t, which corresponds to a transition in which n matrix of transitional probabilities are unchanged. This state of the system, "a state of oblivion" equal $t_{\text{сп}}$, time that determines the beginning of 3-d period of kinetic curve mixing process (see. Fig. 1), in which the mixing speed equal to the speed segregation V_c that doesn't change with time.

So, the analysis of workflow process forced action mixer is aimed at determination of the limiting factor of heterogeneity $V_{\text{сп.}}$ – the lowest value of coefficient in time $t_{\text{сп}}$, at which the mixture becomes homogeneous.

This indicator characterizes mixer, it effectiveness and mixing quality.

Based on the general theory of Markov chains, the initial state of system can be characterized by the vector $G(0)$, where each component $g_i(0)$ is the probability of finding of one of the components of the mixture in the i-th mixing zone:

$$G(0) = [\, g_1(0), g_2(0), \dots, g_k(0)], \qquad (3)$$

where: k – the number of mixing zones.

Then specified the value of transitions probability of particle from i-th mixing zone in a j-th, it is the probability matrix (connections). According to the theory of Markov after n transitions (rotating shaft) distribution of matter in the mixing zones can be written as matrix multiplication:

$$G(n) = G(0)p^n, \qquad (4)$$

where: n – the matrix of transition probability with dimension $k \times k$, $G(n) = [\, g_1(n),\ g_2(n)\ , \dots,\ g_k(n)]$ – the state vector system after n transitions.

To assess the heterogeneity V_n, %, distribution of material after transitions determined:

$$V_n = 100k \sqrt{\frac{1}{k-1}\sum_{i=1}^{k}\left[g_i(n) - \frac{1}{k}\right]^2}. \qquad (5)$$

The mixer, which reaches value V_3 in the less number of rotation shaft (less time mixing) is the best.

The scientifically-research idea took the position that the mixing efficiency is determined by the speed of the transition material from state of inhomogeneous embedded to the state of "forgetfulness".

The main performance indicators of twin-shaft forced action mixer include:

– the number of shaft rotations at which mixture becomes the homogeneity (the time of "forgetfulness" t_{cp}),
– the angle of blade rotation,
– the power drive on mixing,
– the productivity.

Thus, on the basis of the above, the following hypotheses were formulated, the implementation of which would achieve the desired result in the creation of new or would improve existing structures of twin-shaft forced action mixers.

1. The moving of material between the mixing zones in a particular direction depends on "transition probabilities", which physical meaning is defining as difference of entropy before and after the transition, which differently interprets the way of determination the power of mixing.

2. The moving of material is made within each transition (shaft rotating), that is a discrete model.

This approach will allow to get mathematical model for the researched environments, more intelligently and with fewer bugs or as necessary to improve the methodology of research results.

To determine the probability of transition material in one direction or another, consider the most common scheme of movement, which is shown in Fig. 4. It is believed that during one shaft rotation the material will be transiting with probability p to a nearby zone, with probability q to opposite zone and with probability r will remain in it:

$$p + q + r = 1. \qquad (6)$$

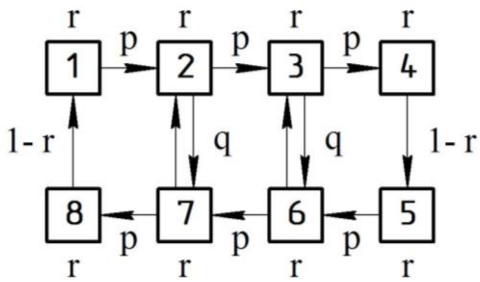


Fig. 4. The transition scheme of material for twin-shaft mixer.

The determination of probability of transition of material will be entirely experimental by the example of one of the mixing zones (Fig. 5).

With help of software MathCAD one transition of material in appropriate ways, depending on the blades angle is simulated.

The probability of transition is determined as numerous simulations of the transition by the randomly algorithm «white noise." The results are processed by statistical methods, resulting in transition probability becomes dimensional value that reflects the difference in entropy before and after the transition.

For adequacy of the experiment the rheological properties of the material (concrete mix) should be created, replacing it by some number of balls with some diameter and density of the material.

More accurate description of the mixing process can be provided by three-dimensional probabilistic model (Fig. 6). In this scheme the probability of leaving the material in the same mixing zone and description of the movement of particles of material in it is more widely understanding. As shown in Fig. 6, the movement of material into the mixing zone is made in the radial and circumferential directions, but on two-dimensional scheme it is described as remaining the matter in the same mixing zone, and consistent with probability r.

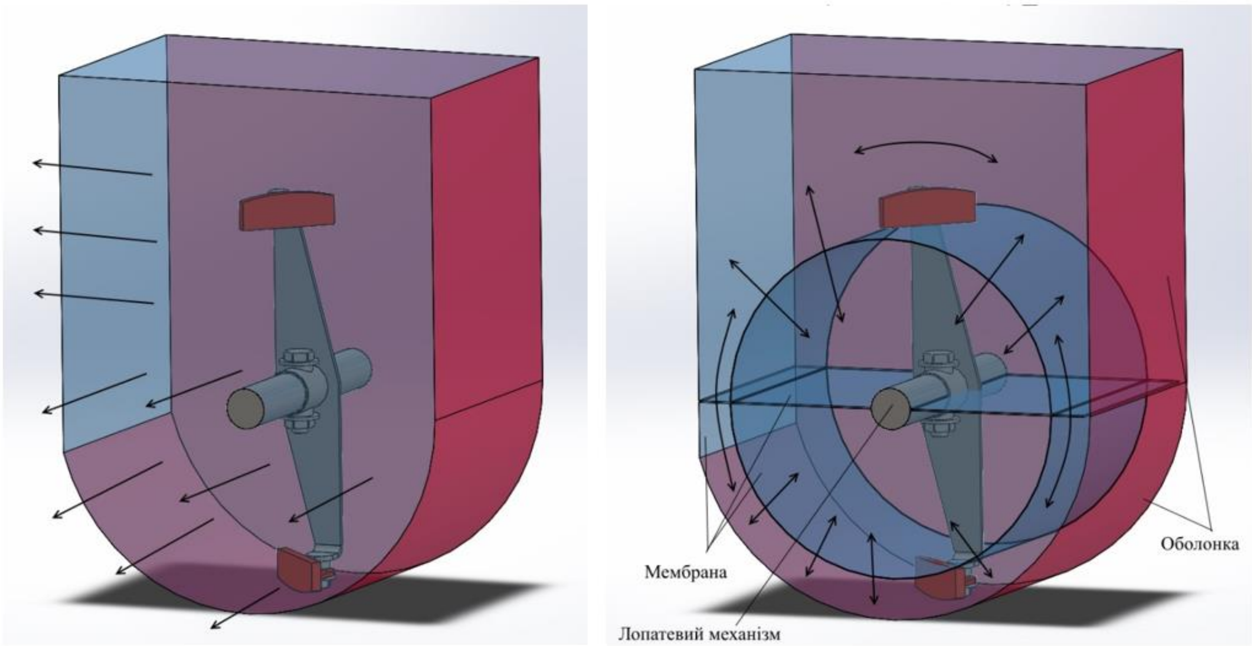


Fig. 5. The scheme to determinate the probability of movement material.

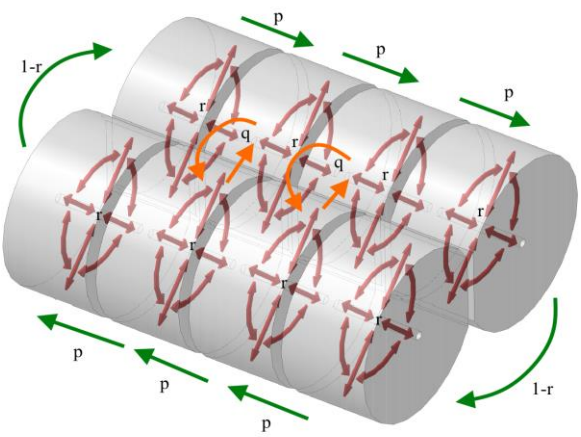


Fig. 6. The scheme of moving material in the mixer.

Considering the three-dimensional scheme of movement material and particles in the mixer, let`s introduce the probability of remaining of material in the same mixing zone as the total probability of moving material in the radial S and circumferential C direction.

Also, the movement of material along the axis of the mixing shaft determined as probability of axial movement A, and the probability of movement into opposite mixing zone E (Fig. 7.).

- *Radial direction* – s the movement of material within the ranks of the blade arrangements of the mixer in the direction from the axis to the largest radius (hull mixer) and in the opposite direction. Each of the mixing zones, is going to be divided in the radial direction on N_S equal rings,
- *Circumferential direction* – s the movement of material within the ranks of the blade arrangements of the mixer in a closed circulation circuit. Each of the mixing zones, is going to be divided in the circumferential direction on C_R sector level (α – angle sector, hail):

$$N_C = \frac{360°}{\alpha}. \tag{7}$$

For further calculation is necessary to know the values of the following parameters:

- Number of cells in each of the received parts (zones):

$$N_j = N_C \cdot N_S, \tag{8}$$

- Numbering mixing zones in each of the pieces obtained from the index growth:

$$J_C = (n_S - 1) \cdot N_C, \tag{9}$$

- Number of rings:

$$n_S = \overline{1, N_S}, \tag{10}$$

- The radius of the ring, provided the same amount of cells:

$$R_i = \sqrt{R_{i-1}^2 - \frac{R_0^2}{N_S}}, \quad i = \overline{1, N_S - 1}. \tag{11}$$

System status at time $\tau = k \cdot \Delta T$, were k – number of transition, ΔT – the duration of the transition, expressed as a column vector of size $(N_I \times N_j) \times 1$:

$$S^k = \left[S_1^k \;\; S_2^k \;\; \ldots \;\; S_{N_j}^k \;\; S_{N_{j+1}}^k \;\; \ldots \;\; S_{N_j \cdot (N_j - 1)}^k \;\; S_{N_j \cdot N_I}^k \right]^T,$$

The next state of the S^{k+1} depends on the current and can be presented in:

$$S^{k+1} = S^k \cdot P, \tag{12}$$

where: P – matrix of transition probabilities. In turn, the matrix of transition probabilities with regard the three direction of movement material particles is given by:

$$P = P_C \cdot P_S \cdot P_A, \tag{13}$$

where: P_C – matrix of transition probabilities when moving particles in the circumferential direction, P_S – matrix of transition probabilities when moving particles in the radial direction, P_A – matrix of transition probabilities when moving particles in the axial direction.

$$P_S = \begin{pmatrix} P_{S_{1.1}} & 0 & \cdots & 0 \\ 0 & P_{S_{2.2}} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & P_{S_{N_I - N_J}} \end{pmatrix}, \quad P_C = \begin{pmatrix} P_{C_{1.1}} & 0 & \cdots & 0 \\ 0 & P_{C_{2.2}} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & P_{C_{N_I - N_J}} \end{pmatrix}, \tag{14}$$

$$P_A = \begin{pmatrix} P_{A_{1.1}} & P_{A_{1.2}} & 0 & 0 & & 0 & 0 & 0 \\ P_{A_{2.1}} & P_{A_{2.2}} & P_{A_{2.3}} & 0 & \cdots & 0 & 0 & 0 \\ 0 & P_{A_{3.2}} & P_{A_{3.3}} & P_{A_{3.4}} & & 0 & 0 & 0 \\ & \vdots & & & \ddots & & \vdots & \\ 0 & 0 & 0 & 0 & & P_{S_{N_{I-1}-N_{J-2}}} & P_{S_{N_{I-1}-N_{J-1}}} & P_{S_{N_{I-1}-N_J}} \\ 0 & 0 & 0 & 0 & \cdots & 0 & P_{S_{N_I-N_{J-2}}} & P_{S_{N_I-N_J}} \end{pmatrix}$$

where: 0 – zero matrix of size $N_I \times N_I$ and $N_C \times N_C$ for matrices of transition probabilities when moving particles in the circumferential and radial and axial direction, respectively, $P_{C_{ij}}, P_{S_{ij}}, P_{A_{ij}}$ – block matrix of transition probabilities when moving particles in the circular (matrix size $N_j \times N_j, i = \overline{1,\ N_J}$), radial (size matrix $N_C \times N_C, i = \overline{1,\ N_J}$) and the axial direction, respectively, for each i-th particle mixing chamber (formula 15).

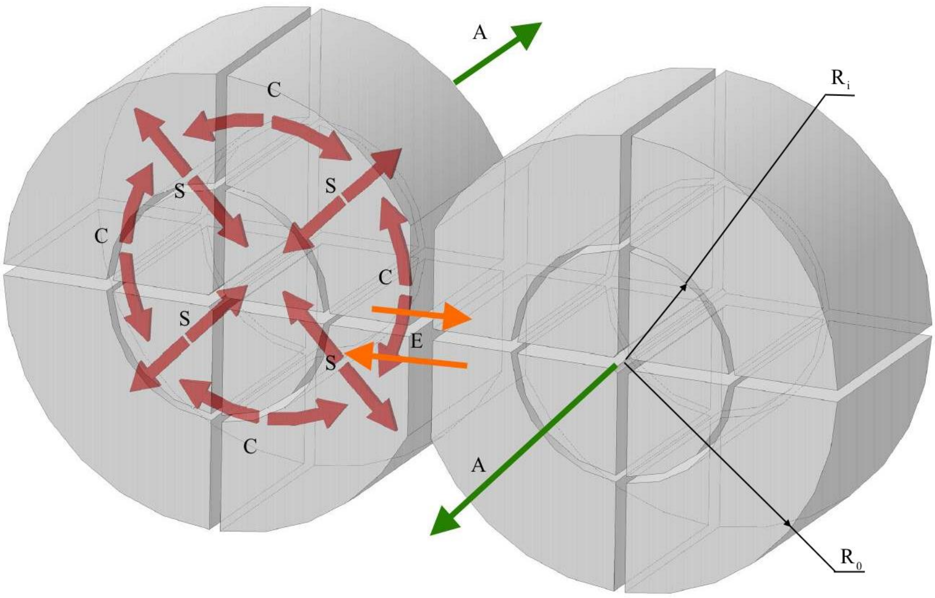


Fig. 7. The calculated scheme to describe all movement of material in the mixer.

$$P_{C_{ij}} = \begin{pmatrix} M_{C_{1.1}} & 0 & \cdots & 0 \\ 0 & M_{C_{2.2}} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & M_{C_{N_J\,N_J}} \end{pmatrix}$$

$$P_{S_{ij}} = \begin{pmatrix} M_{S_{1.1}} & M_{S_{1.2}} & \cdots & M_{S_{1,N_J}} \\ M_{S_{2.1}} & M_{S_{2.2}} & \cdots & M_{S_{2,N_J}} \\ \vdots & \vdots & \ddots & \vdots \\ M_{S_{N_J,1}} & M_{S_{N_J,2}} & \cdots & M_{S_{N_J\,N_J}} \end{pmatrix} \tag{15}$$

where: 0 – the zero matrix of size $N_J \times N_J$ and $N_C \times N_C$ or matrices of transition probabilities when moving particles in the circumferential and radial and axial direction, $M_{C_{i,j}}, M_{S_{i,j}}$ – block matrix of transition concentrations of the material from l cell to m cell at moving particles in the circumferential direction of the size $N_C \times N_C, i = \overline{1,\ N_J}$, radially direction of the size $N_C \times N_C, i = \overline{1,\ N_J}$, $j = \overline{1,\ N_J}$, respectively. For axially moving particles the block matrix of transition probabilities ($i = \overline{1,\ N_I}$, $j = \overline{1,\ N_I}$), will look like:

$$P_{A_{ij}} = \begin{pmatrix} p^a_{1+I_a,\ 1+I_a} & 0 & \cdots & 0 \\ 0 & p^a_{2+I_a,\ 2+I_a} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & p^a_{N_J+I_a,\ N_J+I_a} \end{pmatrix},$$

were $p^a_{l,m}$ – probability of transition concentration of the material while moving particles in the axial direction $l = \overline{1, N_I \cdot N_J}$, $m = \overline{1, N_I \cdot N_J}$, $I_a = (i-1) \cdot N_J$, and $J_a = (i-1) \cdot N_J$ indices of growth.

The block matrices of transitions of material concentration from l cell to m cell is the same for transition in the circumferential and radial directions (Formula 16):

$$M_{C_{i,j}} \begin{pmatrix} p^c_{1+I_c,1+I_c} & p^c_{1+I_c,2+I_c} & 0 & 0 & & 0 & p^c_{1+I_c,N_C+I_c} \\ p^c_{2+I_c,1+I_c} & p^c_{2+I_c,2+I_c} & p^c_{2+I_c,3+I_c} & 0 & \cdots & 0 & 0 \\ 0 & p^c_{3+I_c,2+I_c} & p^t_{3+I_c,3+I_c} & p^c_{3+I_c,4+I_c} & & 0 & 0 \\ & & \vdots & & \ddots & & \vdots \\ p^c_{N_C+I_c,1+I_c} & 0 & 0 & 0 & \cdots & p^c_{N_C+I_c,N_C+I_c} & p^c_{N_C+I_c,N_C+I_c} \end{pmatrix} \quad (16)$$

where: $p^c_{l,m}$ – the probability of transition concentration of material while moving particles in the circumferential direction $l = \overline{1, N_C}$, $m = \overline{1, N_C}$, $I_c = (i-1) \cdot N_C$ – indices of growth.

$$M_{S_{i,j}} = \begin{pmatrix} p^s_{1+I_s,1+I_s} & 0 & \cdots & 0 \\ 0 & p^s_{2+I_s,2+I_s} & & 0 \\ \vdots & & \ddots & \vdots \\ 0 & 0 & \cdots & p^s_{1+I_s,1+I_s} \end{pmatrix} \quad (17)$$

where: $p^s_{l,m}$ – the probability of transition concentration of material particles while moving radially $l = \overline{1, N_C}$, $m = \overline{1, N_C}$, $I_s = (i-1) \cdot N_C$ – indices of growth.

The system state can be represented as a column vector, for twin-shaft mixer:

$$S^k_D = \left[S^k_a \;\; S^k_b\right]^T \quad (18)$$

where: S^k_a and S^k_b – the state of system during rotation of the first and second shafts, respectively (Fig. 2.).

The state of system S^{k+1}_D can be represented in matrix form:

$$S^{k+1}_D = S^k_D \cdot P_D \cdot P_U \,, \quad (19)$$

where: P_D – mixing matrix that looks like:

$$P_D = \begin{pmatrix} P & 0 \\ 0 & P \end{pmatrix}, \quad (20)$$

where: 0 – zero matrix size $N_I \times N_J$.

P_E – exchanging matrix of material particles during rotation 1-st and 2-nd shafts. Matrix elements except the elements $p^e_{N_{j\cdot i_I - N_C + i}, N_{j\cdot J_I - N_C + j}}$, were $i = \overline{1, \frac{N_C}{2}}$, $i_I = \overline{1, N_I}$, $j = \overline{\frac{N_C}{2} + 1, N_C}$, $J_I = \overline{N_I + 1\,, 2 \cdot N_I}$, is zero.

The mathematical model allows us to calculate the number of transition (shaft rotation) after which the matrix of transition probabilities cease to vary over time, indicating that the system achieve steady state ("forgot" their original position), and therefore the maximum degree of homogeneity of the mixture.

To verify the obtained data the scheme of laboratory stand was developed and described.

It consists of a laboratory mixer, inductive sensor, frequency converter, analog-digital signal converter, a computer with specially developed software and photo camera.

The lab mixer equipped with a contactless inductive sensor and bracket on one of the shafts with which the number of rotations of the shaft can be read. The signal reaches the signal converter, and displayed on the monitor of computer. Also, through the signal converter the frequency converter is connected to the computer that controls electric laboratory setting. It maintains continuous operation at a given engine speed and stops it after a given number of rotations of lab twin-shaft mixer.

The value of the "forgetting time" that an equals the number of mixer shaft rotations at given blades angle, is entered into the computer, after it determining. And blades are set in the required position using a specially designed protractor. Then all previously dosaging components of the mixture in the mixer, are downloaded and the experiment begins.

On the basis of the experimental scheme was designed construction of the experimental setup [2, 4, 8, 9] - Laboratory twin-shaft concrete mixers (Fig. 8).

The lab mixer on the cart is situated in the correct place for experimentation and wheels fixed by stops (16).

Then, through the open side door (12), located in the cover (11), installing the position of blades (3) - rotation angle with a special protractor. Further downloaded all previously dosaging components of future mixture: scree, cement and sand. Then the side door (12) closed and connected to the control panel (17). By setting a mode of drive motor (9) with frequency converter (21).

Then, the initial process of mixing the dry components in which, depending on the selected initial provisions blades (3) material will be distributed over the mixing chamber (20 sec.).

Then, by CIP head system (13) uniformly sprayed water, and mixing ingredients of mixture are already in final form. This stage lasts 20-25 sec. and it is the most difficult mixing period, as there is a significant increase of dynamic and kinetic viscosity of the mixture and increase the resistance of the environment on the machine.

Another 20-25 sec. mixer working after stopping the water supply. Then drive motor (9) stopped and through the open side door (12) take the samples from different areas of the mixing chamber.

The residue is discharged through the unloading opening (6), driven by lever (8) which fixed with screws (7), is discharged from the mixing chamber.

After sampling and discharge residual mixture through unloading opening (6) the side door (12) and unloading opening (6) is closing, and mixing chamber is washed by water through the pipe system CIP (13) and then unloading hole open and poured all dirt.

Also laboratory mixer equipped with an emergency stop button, flashlight, two limit switches on the side door and appropriate warning label (Fig. 9), making it safe for use in the classroom.

The results of experimental researches are shown in Fig. 10. In a graph curves "oblivion" for different blades angles, which are obtained during the processing of data results by "slick average method".

As you can see from the graphs, for different blades angles α charts differ, since the probability of transition in certain direction is dependent on this parameter.

Among the researched values of blades angle the most efficient $\alpha = 34°$.

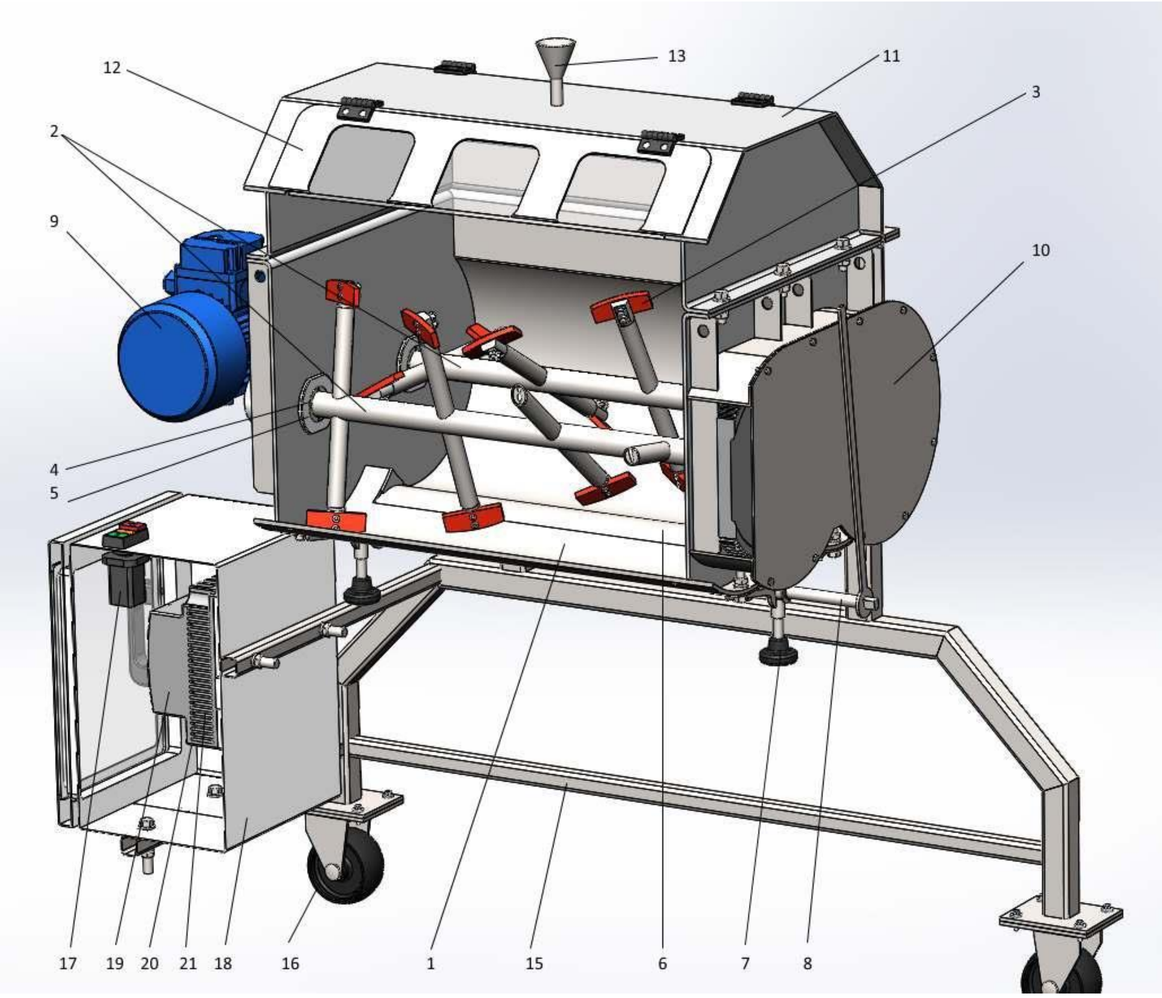


Fig. 8. The design of the experimental setup: 1 – the case, 2 – shafts, 3 – blades, 4 – bearing assembly, 5 – shaft seal, 6 – unloading opening, 7 – lock, 8 – the lever, 9 – drive motor, 10 – synchronizer, 11 – cover, 12 – side door, 13 – CIP pipe system, 14 – pin sensor, 15 – cart, 16 – wheel with stops, 17 – control panel, 18 – electrical cabinet, 19 – relay, 20 – fuse, 21 frequency converter.

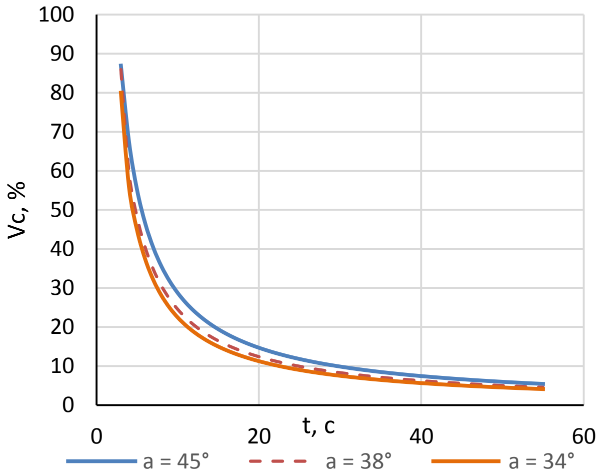
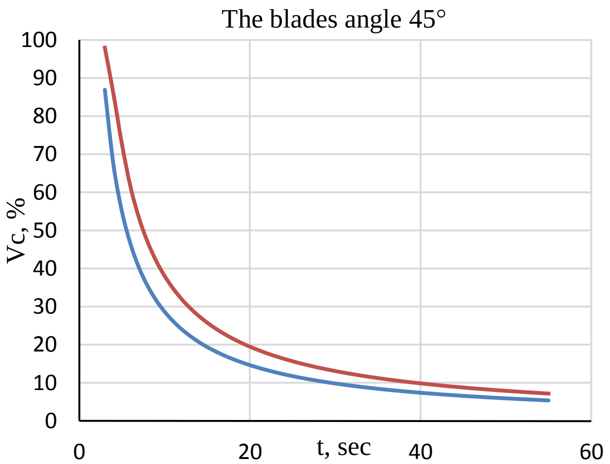


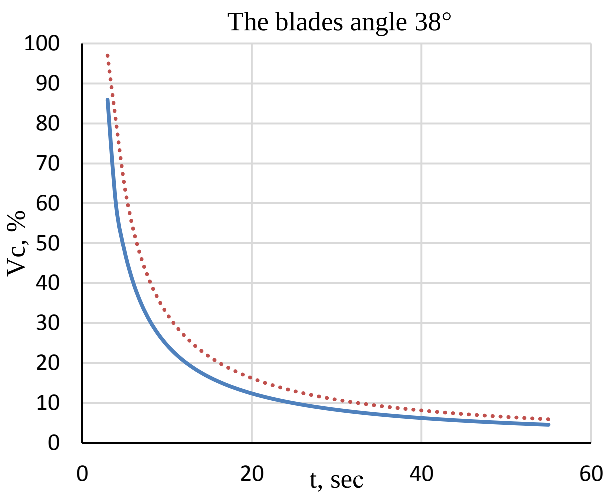
Fig. 9. The graphs of "Oblivion curves".

Comparing the experimental results and theoretical research (Fig. 10).

As follows from these graphs, the state of "forgetting" in an experimental and theoretical way doesn`t have big difference, and fit into the allowable error of 15%.

The evaluation and analysis of the test samples show that the quality of the prepared mixture meets the calculated time (number of rotations). The quality of the mixture was assessed visually and in terms of strength (Fig. 11).





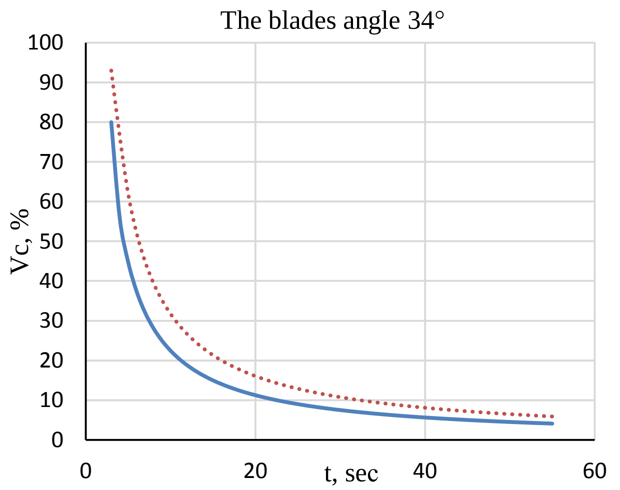


Fig. 10. The comparison of theoretical (solid line) and experimental (broken line) "Oblivion curves".

The data collected during the research probability of transition material processed by statistical methods, and based on their results define conversions (rotating shaft) and the mixing.

These parameters are essential for experimental studies of concrete mixture in a laboratory mixer, to confirm or refute the prevailing theoretical positions.

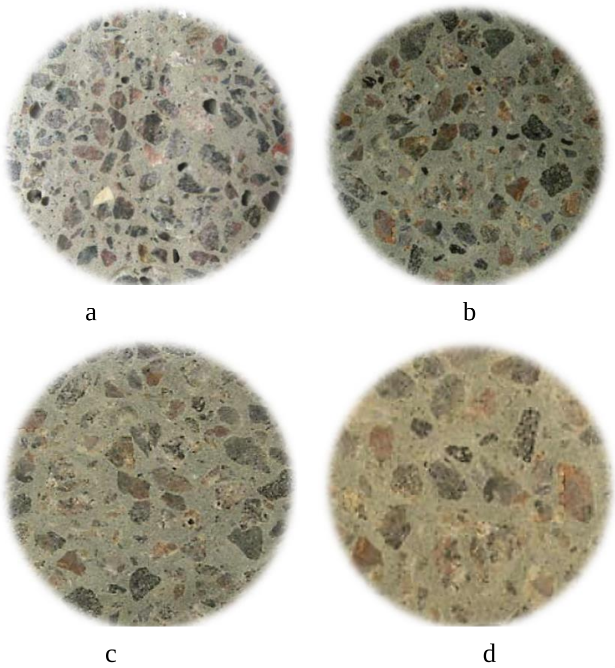


Fig. 11. The comparing of sections of prototypes: *a)* $t = 20c$, b) $t = 30c$, c) $t = 40c$, *d)* $t = 50c$.

CONCLUSIONS

1. The working hypothesis that the movement of material between the mixing zones depends on the "transition probabilities", which is defined by angle blade was confirmed as a result of mathematical modeling of moving material and performed experimental studies.

2. On the basis of theoretical research the method of calculation of basic parameters of advanced laboratory twin-shaft concrete mixers was created.

3. The laboratory twin-shaft concrete mixers with rotary blades was created.

4. The investigations can improve the efficiency of the mixer by reducing cycle time and energy consumption.

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REALIZATION OF OPTIMUM BREAKTHROUGH MODE OF REVERSAL OF ROLLER FORMING INSTALLATION

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Summary. For the purpose of increase in reliability and durability of roller forming installation the optimum mode of back and forth motion of the forming cart with a breakthrough reversal is calculated. Kinematic characteristics of the forming cart at the optimum breakthrough mode of a reversal are calculated. The design of roller forming installation with the drive from the high-moment step engine which is built in the rolling rollers of the forming cart is offered and provides reciprocating the movements of the forming cart with the optimum breakthrough mode of a reversal. Use in installation of the specified driving mechanism leads to improvement of quality of a surface to the processed concrete mix, reduction of dynamic loadings in elements of the driving mechanism, to disappearance of excess destructive loads of a frame design and, respectively, to increase in reliability and durability of installation in general.

As a result of the conducted researches for the purpose of increase in reliability and durability of roller forming installation the combined mode of back and forth motion of the forming cart with the optimum breakthrough mode of a reversal is calculated.

Kinematic characteristics of the forming cart are calculated at combined reciprocating the movements of the forming cart with the optimum breakthrough mode of a reversal.

The design of roller forming installation with the drive from the high-moment step engine which is built in the rolling rollers of the forming cart with a possibility of realization of the combined back and forth motion of the forming cart with the optimum breakthrough mode of a reversal is offered.

Results of work can be used further for specification and improvement of the existing engineering methods of calculation of driving mechanisms of cars of roller formation both at design/designing stages, and in the modes of real operation. Also results of work can be useful at design or improvement of mechanisms with back and forth motion of executive elements.

Key words: roller forming installation, mode of the movement, step engine, drive.

INTRODUCTION

In the existing installations of superficial consolidation of concrete goods the crank ram or hydraulic drive of back and forth motion of the forming cart with the condensing rollers is used [1-3]. During the constant starting and brake modes of the movement there are considerable dynamic loadings in elements of the driving mechanism and in elements of the forming cart which can lead to premature getting out of installation of the working condition.

ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

In the existing theoretical and pilot studies of cars of roller formation of concrete goods it is proved their design data and efficiency [1-3]. At the same time not enough attention is paid to a research to the operating dynamic loadings and the modes of the movement that considerably influences work of installation and quality of finished goods [4-19]. During the constant starting and brake modes of the movement there are considerable dynamic loadings in elements of the driving mechanism and in elements of the forming cart that can lead to premature getting out of installation of the working condition [4-19]. Therefore urgent there is a problem of improvement of the driving mechanism of roller forming installation for the purpose of providing such mode of the movement of the forming cart at which dynamic loadings in elements of installation would decrease and its durability increased.

OBJECTIVES

The purpose of work consists in improvement of a design of the driving mechanism of roller forming installation for increase in her reliability and durability.

THE MAIN RESULTS OF THE RESEARCH

For roller forming installation at consolidation of concrete mix it is desirable to have the constant speed of back and forth motion of the forming cart on all the site that positively would influence quality of finished product. However in practice such mode of the movement can't be carried out as in him there are no sites of start-up and braking without which there can't be a cyclic movement. Therefore it is offered to realize such mode of the movement of the forming cart at her movement from one extreme situation to another in which there would be sites of a reversal with the minimum dynamic loadings and movement sites with a constant speed.

For smooth process of a reversal of the forming cart it is offered to carry out him on the optimum breakthrough mode of the movement [20]. At the same time the speed and acceleration of the forming cart change smoothly, without creating considerable dynamic loadings in installation that in turn positively influences its durability.

Coefficients of unevenness of the movement and dynamism can be criteria of the mode of the movement of mechanisms and cars [20]. In this work as criterion of the mode of the movement the criteria action which is integral on time with sub integral function which expresses a measure of the movement or action of system is used. For the optimum breakthrough mode of a reversal we will have criterion of an optimality of the movement in a look:

$$I_W = \int_0^{t_r} W\,dt \to \min, \tag{1}$$

where: t – time, t_r – reversal duration, W – energy of breakthroughs:

$$W = \frac{1}{2}\cdot m\cdot \dddot{x}^2, \tag{2}$$

where: m – mass of the forming cart, $\dddot{x}$ – breakthrough (acceleration of the second order).

Poisson's equation is a condition of a minimum of criterion (1):

$$\frac{\partial W}{\partial x} - \frac{d}{dt}\frac{\partial W}{\partial \dot{x}} + \frac{d^2}{dt^2}\frac{\partial W}{\partial \ddot{x}} - \frac{d^3}{dt^3}\frac{\partial W}{\partial \dddot{x}} = 0, \tag{3}$$

where: x, $\dot{x}$, $\ddot{x}$ – movement coordinate, speed and acceleration of the cart respectively.

From expression (3) it is possible to write down:

$$\frac{\partial W}{\partial x} = \frac{\partial W}{\partial \dot{x}} = \frac{\partial W}{\partial \ddot{x}} = 0; \quad \frac{\partial W}{\partial \dddot{x}} = m\cdot\dddot{x}; \qquad \frac{d^3}{dt^3}\frac{\partial W}{\partial \dddot{x}} = m\cdot \overset{VI}{x} = 0. \tag{4}$$

From the last equation (4) we receive the differential equation and its decisions:

$$\begin{aligned}
&\overset{VI}{x} = 0; \quad \overset{V}{x} = C_1; \quad \overset{IV}{x} = C_1\cdot t + C_2;\\
&\dddot{x} = \frac{1}{2}\cdot C_1\cdot t^2 + C_2\cdot t + C_3;\\
&\ddot{x} = \frac{1}{6}\cdot C_1\cdot t^3 + \frac{1}{2}\cdot C_2\cdot t^2 + C_3\cdot t + C_4;\\
&\dot{x} = \frac{1}{24}\cdot C_1\cdot t^4 + \frac{1}{6}\cdot C_2\cdot t^3 + \frac{1}{2}\cdot C_3\cdot t^2 + {}\\
&\qquad + C_4\cdot t + C_5;\\
&x = \frac{1}{120}\cdot C_1\cdot t^5 + \frac{1}{24}\cdot C_2\cdot t^4 + \frac{1}{6}\cdot C_3\cdot t^3 + {}\\
&\qquad + \frac{1}{2}\cdot C_4\cdot t^2 + C_5\cdot t + C_6,
\end{aligned} \tag{5}$$

where: C_1, C_2, C_3, C_4, C_5, C_6 – integration constants which are defined from boundary conditions.

We will divide process of a reversal into two stages: braking and start-up.

When braking by entry conditions is: $t=0$: $x=-x_1$, $\dot{x}=\dot{x}_e$, $\ddot{x}=0$. Final conditions when braking: $t=t_b$: $x=0$, $\dot{x}=0$, $\ddot{x}=0$. Here x_1 – the coordinate of the beginning of process of braking, $\dot{x}_e$ – speed of the movement of the cart on established the mode prior to braking.

At start-up by entry conditions is: $t=0$: $x=0$, $\dot{x}=0$, $\ddot{x}=0$. Final conditions at start-up: $t=t_s$: $x=-x_1$, $\dot{x}=-\dot{x}_e$, $\ddot{x}=0$.

We will consider braking process. Having substituted boundary conditions of braking in the equations (5), we receive:

$$t=0:\quad C_6=-x_1;\quad \tilde{N}_5=\dot{x}_e;\quad \tilde{N}_4=0; \tag{6}$$

$$t=t_b:\begin{cases}
\frac{1}{120}\cdot C_1\cdot t_b^5 + \frac{1}{24}\cdot C_2\cdot t_b^4 + {}\\
\qquad + \frac{1}{6}\cdot C_3\cdot t_b^3 + \dot{x}_e\cdot t_b - x_1 = 0;\\
\frac{1}{24}\cdot C_1\cdot t_b^4 + \frac{1}{6}\cdot C_2\cdot t_b^3 + \frac{1}{2}\cdot C_3\cdot t_b^2 + {}\\
\qquad + \dot{x}_e = 0;\\
\frac{1}{6}\cdot C_1\cdot t_b^3 + \frac{1}{2}\cdot C_2\cdot t_b^2 + C_3\cdot t_b = 0.
\end{cases} \tag{7}$$

Having solved system of the equations (7), we receive integration constants C_1, C_2 and C_3:

$$\begin{aligned}
C_1 &= \frac{360\cdot\left(2\cdot\frac{x_1}{t_b}-\dot{x}_e\right)}{t_ô^4},\\
C_2 &= \frac{24\cdot\left(8\cdot\dot{x}_e-15\cdot\frac{x_1}{t_b}\right)}{t_b^3},\\
C_3 &= \frac{12\cdot\left(5\cdot\frac{x_1}{t_b}-3\cdot\dot{x}_e\right)}{t_b^2}.
\end{aligned} \tag{8}$$

After substitution of certain constants of integration (6) and (8) in system of the equations (5) we receive function of change of breakthrough of the forming cart in the course of braking from the established speed $\dot{x}_e$ to a full stop:

$$\begin{aligned}
\dddot{x} &= 180\cdot\left(2\cdot\frac{x_1}{t_b}-\dot{x}_e\right)\cdot\frac{t^2}{t_b^4} + {}\\
&+ 24\cdot\left(8\cdot\dot{x}_e-15\cdot\frac{x_1}{t_b}\right)\cdot\frac{t}{t_b^3} + {}\\
&+ 12\cdot\left(5\cdot\frac{x_1}{t_b}-3\cdot\dot{x}_e\right)\cdot\frac{1}{t_b^2}
\end{aligned} \tag{9}$$

or

$$\ddot{x} = \frac{12}{t_b^2} \cdot \left[\begin{array}{l} 15 \cdot \left(2 \cdot \frac{x_1}{t_b} - \dot{x}_e \right) \cdot \frac{t^2}{t_b^2} + \\ + 2 \cdot \left(8 \cdot \dot{x}_e - 15 \cdot \frac{x_1}{t_b} \right) \cdot \frac{t}{t_b} + \\ + \left(5 \cdot \frac{x_1}{t_b} - 3 \cdot \dot{x}_e \right) \end{array} \right]. \quad (10)$$

After that the criterion of an optimality of the movement in the course of braking taking into account expression (2) and (10) will have an appearance:

$$I_{Wb} = \frac{m}{2} \cdot \int_0^{t_b} \ddot{x}^2 \, dt =$$

$$= \frac{72 \cdot m}{t_b^4} \int_0^{t_b} \left[\begin{array}{l} 15 \cdot \left(2 \cdot \frac{x_1}{t_b} - \dot{x}_e \right) \cdot \frac{t^2}{t_b^2} + \\ + 2 \cdot \left(8 \cdot \dot{x}_e - 15 \cdot \frac{x_1}{t_b} \right) \cdot \frac{t}{t_b} + \\ + \left(5 \cdot \frac{x_1}{t_b} - 3 \cdot \dot{x}_e \right) \end{array} \right]^2 dt = \quad (11)$$

$$= \frac{72 \cdot m}{t_b^3} \cdot \left[5 \cdot \frac{x_1^2}{t_b^2} - 5 \cdot \frac{x_1}{t_b} \cdot \dot{x}_e + \frac{4}{3} \cdot \dot{x}_e^2 \right].$$

We will consider start-up process. Having substituted boundary conditions of start-up in the equations (5), we receive:

$$t = 0: \quad C_4 = 0; \quad \tilde{N}_5 = 0; \quad \tilde{N}_6 = 0; \quad (12)$$

$$t = t_s: \begin{cases} \frac{1}{120} \cdot C_1 \cdot t_s^5 + \frac{1}{24} \cdot C_2 \cdot t_s^4 + \\ \qquad + \frac{1}{6} \cdot C_3 \cdot t_s^3 = -x_1; \\ \frac{1}{24} \cdot C_1 \cdot t_s^4 + \frac{1}{6} \cdot C_2 \cdot t_s^3 + \\ \qquad + \frac{1}{2} \cdot C_3 \cdot t_s^2 = -\dot{x}_e; \\ \frac{1}{6} \cdot C_1 \cdot t_s^3 + \frac{1}{2} \cdot C_2 \cdot t_s^2 + C_3 \cdot t_s = 0. \end{cases} \quad (13)$$

Having solved system of the equations (13), we receive integration constants C_1, C_2 and C_3:

$$C_1 = \frac{360 \cdot \left(\dot{x}_e - 2 \cdot \frac{x_1}{t_s} \right)}{t_s^4},$$

$$C_2 = \frac{24 \cdot \left(15 \cdot \frac{x_1}{t_s} - 7 \cdot \dot{x}_e \right)}{t_s^3}, \quad (14)$$

$$C_3 = \frac{12 \cdot \left(2 \cdot \dot{x}_e - 5 \cdot \frac{x_1}{t_s} \right)}{t_s^2}.$$

After substitution of certain constants of integration (12) and (14) in system of the equations (5) we receive function of change of breakthrough of the forming cart in the course of start-up from a condition of rest to an exit to the set mode of the movement:

$$\begin{aligned} \ddot{x} &= 180 \cdot \left(\dot{x}_e - 2 \cdot \frac{x_1}{t_s} \right) \cdot \frac{t^2}{t_s^4} + \\ &+ 24 \cdot \left(15 \cdot \frac{x_1}{t_s} - 7 \cdot \dot{x}_e \right) \cdot \frac{t}{t_s^3} + \\ &+ 12 \cdot \left(2 \cdot \dot{x}_e - 5 \cdot \frac{x_1}{t_s} \right) \cdot \frac{1}{t_s^2} \end{aligned} \quad (15)$$

or

$$\ddot{x} = \frac{12}{t_s^2} \cdot \left[\begin{array}{l} 15 \cdot \left(\dot{x}_e - 2 \cdot \frac{x_1}{t_s} \right) \cdot \frac{t^2}{t_s^2} + \\ + 2 \cdot \left(15 \cdot \frac{x_1}{t_s} - 7 \cdot \dot{x}_e \right) \cdot \frac{t}{t_s} + \\ + \left(2 \cdot \dot{x}_e - 5 \cdot \frac{x_1}{t_s} \right) \end{array} \right]. \quad (16)$$

After that the criterion of an optimality of the movement in the course of start-up taking into account expression (2) and (16) will have an appearance:

$$I_{Ws} = \frac{m}{2} \cdot \int_0^{t_s} \ddot{x}^2 \, dt =$$

$$= \frac{72 \cdot m}{t_s^4} \cdot \int_0^{t_s} \left[\begin{array}{l} 15 \cdot \left(\dot{x}_e - 2 \cdot \frac{x_1}{t_s} \right) \cdot \frac{t^2}{t_s^2} + \\ + 2 \cdot \left(15 \cdot \frac{x_1}{t_s} - 7 \cdot \dot{x}_e \right) \cdot \frac{t}{t_s} + \\ + \left(2 \cdot \dot{x}_e - 5 \cdot \frac{x_1}{t_s} \right) \end{array} \right]^2 dt = \quad (17)$$

$$= \frac{72 \cdot m}{t_s^3} \cdot \left[5 \cdot \frac{x_1^2}{t_s^2} - 5 \cdot \frac{x_1}{t_s} \cdot \dot{x}_e + \frac{4}{3} \cdot \dot{x}_e^2 \right].$$

The general criterion of an optimality of the movement in the course of a reversal (11) and (17) will be defined with expressions by the following expression:

$$\begin{aligned} I_W &= I_{Wb} + I_{Ws} = \\ &= \frac{72 \cdot m}{t_b^3} \cdot \left[5 \cdot \frac{x_1^2}{t_b^2} - 5 \cdot \frac{x_1}{t_b} \cdot \dot{x}_e + \frac{4}{3} \cdot \dot{x}_e^2 \right] + \\ &+ \frac{72 \cdot m}{t_s^3} \cdot \left[5 \cdot \frac{x_1^2}{t_s^2} - 5 \cdot \frac{x_1}{t_s} \cdot \dot{x}_e + \frac{4}{3} \cdot \dot{x}_e^2 \right]. \end{aligned} \quad (18)$$

Having accepted equality of duration of braking of the cart and its start-up $t_b = t_s = t_1$, expression (18) can be given in the following look:

$$I_W = \frac{144 \cdot m}{t_1^3} \cdot \left[5 \cdot \frac{x_1^2}{t_1^2} - 5 \cdot \frac{x_1}{t_1} \cdot \dot{x}_e + \frac{4}{3} \cdot \dot{x}_e^2 \right]. \quad (19)$$

For ensuring performance of inequality (1) it is necessary to satisfy a condition:

$$\frac{\partial I_W}{\partial x_1} = \frac{144 \cdot m}{t_1^3} \cdot \left[10 \cdot \frac{x_1}{t_1^2} - 5 \cdot \frac{\dot{x}_e}{t_1} \right] = = \frac{720 \cdot m}{t_1^4} \cdot \left[2 \cdot \frac{x_1}{t_1} - \dot{x}_e \right] = 0. \tag{20}$$

From expression (20) it is possible to receive:

$$2 \cdot \frac{x_1}{t_1} - \dot{x}_e = 0 \quad \Rightarrow \quad x_1 = \frac{1}{2} \cdot \dot{x}_e \cdot t_1 . \tag{21}$$

Having substituted the second expression (21) in equalities (6) and (8) integration constants in the course of braking of the forming cart are received:

$$C_1 = 0, \quad C_2 = 12 \cdot \frac{\dot{x}_e}{t_1^3}, \quad C_3 = -6 \cdot \frac{\dot{x}_e}{t_1^2}, \quad \tilde{N}_4 = 0, \quad \tilde{N}_5 = \dot{x}_e, \quad C_6 = -\frac{1}{2} \cdot \dot{x}_e \cdot t_1 . \tag{22}$$

After that taking into account constants of integration (22) functions of change of movement, speed, acceleration and breakthrough of the forming cart in the course of braking are received:

$$x = \frac{1}{2} \cdot \dot{x}_e \cdot \left(\frac{t^4}{t_1^3} - 2 \cdot \frac{t^3}{t_1^2} + 2 \cdot t - t_1 \right);$$

$$\dot{x} = \dot{x}_e \cdot \left(2 \cdot \frac{t^3}{t_1^3} - 3 \cdot \frac{t^2}{t_1^2} + 1 \right); \tag{23}$$

$$\ddot{x} = 6 \cdot \dot{x}_e \cdot \left(\frac{t^2}{t_1^3} - \frac{t}{t_1^2} \right); \quad \dddot{x} = 6 \cdot \dot{x}_e \cdot \left(2 \cdot \frac{t}{t_1^3} - \frac{1}{t_1^2} \right).$$

Having substituted the second expression (21) in equalities (12) and (14) integration constants in the course of launch of the forming cart are received:

$$C_1 = 0, \quad C_2 = 12 \cdot \frac{\dot{x}_e}{t_1^3}, \quad C_3 = -6 \cdot \frac{\dot{x}_e}{t_1^2}, \quad \tilde{N}_4 = 0, \quad \tilde{N}_5 = 0, \quad C_6 = 0 . \tag{24}$$

After that taking into account constants of integration (24) functions of change of movement, speed, acceleration and breakthrough of the forming cart in the course of start-up are received:

$$x = \frac{1}{2} \cdot \dot{x}_e \left(\frac{t^4}{t_1^3} - 2\frac{t^3}{t_1^2} \right); \quad \dot{x} = \dot{x}_e \left(2\frac{t^3}{t_1^3} - 3\frac{t^2}{t_1^2} \right);$$

$$\ddot{x} = 6 \cdot \dot{x}_e \left(\frac{t^2}{t_1^3} - \frac{t}{t_1^2} \right); \quad \dddot{x} = 6 \cdot \dot{x}_e \left(2\frac{t}{t_1^3} - \frac{1}{t_1^2} \right). \tag{25}$$

On the set mode of the movement of the forming cart the coordinate of movement, speed, acceleration and breakthrough of her center of masses are described by the equations [20]:

$$x = x_{0e} + \frac{(x_{1e} - x_{0e}) \cdot t}{t_e};$$

$$\dot{x} = \frac{(x_{1e} - x_{0e})}{t_e} = const; \tag{26}$$

$$\ddot{x} = 0; \quad \dddot{x} = 0,$$

where: x_{0e} and x_{1e} – coordinates of initial and final provisions of the center of mass of the cart at the established movement, t_e – duration of the established movement.

In expressions (26) we accept the coordinate of initial position of the center of mass of the cart at the established movement x_{0e} equal x_1. Then, having accepted amplitude of movement of the cart from one extreme situation in another Δx, the final coordinate of position of the center of mass of the cart at the established movement can be determined $x_{1e} = \Delta x - x_1$.

Having substituted the received coordinates x_{0e} and x_{1e} in the second expression (26) dependence for determination of speed of the movement of the cart on the established movement is received $\dot{x}_e$:

$$\dot{x}_e = \frac{\Delta x - 2 \cdot x_1}{t_e} = \frac{\Delta x - \dot{x}_e \cdot t_1}{t_e} \Rightarrow \dot{x}_e = \frac{\Delta x}{t_e + t_1} . \tag{27}$$

Having accepted the general time of the movement of the forming cart from one extreme situation in another t_g, he can be divided into three parts: starting time – t_s, time of the established movement – t_e, braking time – t_b. For ensuring consolidation of concrete mix with the forming cart with a constant speed of the movement on the majority of her working course we will accept time of the established movement, for example, $t_e = 2/3 \cdot t_g$. Then, having set by a condition of equality of time of start-up and braking, they can be determined by corresponding expressions: $t_s = t_b = t_1 = 1/6 \cdot t_g$.

After this expression of speed of the movement of the cart on the established movement and coordinates x_1 will have an appearance:

$$\dot{x}_e = \frac{6 \cdot \Delta x}{5 \cdot t_g}, \qquad x_1 = \frac{\Delta x}{10}. \tag{28}$$

Considering the movement of the forming cart from one extreme situation in another and having substituted expressions (28) in equalities (23), (25) and (26), we receive functions of change of movement, speed, acceleration and breakthrough of the forming cart

– on the site of start-up:

$$x = \frac{216 \cdot \Delta x}{5} \cdot \left(\frac{t^3}{t_g^3} - 3 \cdot \frac{t^4}{t_g^4} \right);$$

$$\dot{x} = \frac{648 \cdot \Delta x}{5} \cdot \left(\frac{t^2}{t_g^3} - 4 \cdot \frac{t^3}{t_g^4} \right);$$

$$\ddot{x} = \frac{1296 \cdot \Delta x}{5} \cdot \left(6 \cdot \frac{t^2}{t_g^4} - \frac{t}{t_g^3} \right); \tag{29}$$

$$\dddot{x} = \frac{1296 \cdot \Delta x}{5} \cdot \left(\frac{1}{t_g^3} - 12 \cdot \frac{t}{t_g^4} \right);$$

– on the site of the established movement:

$$x = \frac{\Delta x}{10} + \frac{6 \cdot \Delta x \cdot t}{5 \cdot t_g}; \quad \dot{x} = \frac{6 \cdot \Delta x}{5 \cdot t_g} = const; \quad \ddot{x} = 0; \quad \dddot{x} = 0; \tag{30}$$

– on the site of braking:

$$x = \frac{3 \cdot \Delta x}{5} \cdot \left(216 \cdot \frac{t^4}{t_g^4} - 72 \cdot \frac{t^3}{t_g^3} + 2 \cdot \frac{t}{t_g} + \frac{3}{2} \right);$$

$$\dot{x} = \frac{6 \cdot \Delta x}{5} \cdot \left(432 \cdot \frac{t^3}{t_g^4} - 108 \cdot \frac{t^2}{t_g^3} + \frac{1}{t_g} \right); \tag{31}$$

$$\ddot{x} = \frac{1296 \cdot \Delta x}{5} \cdot \left(6 \cdot \frac{t^2}{t_g^4} - \frac{t}{t_g^3} \right);$$

$$\dddot{x} = \frac{1296 \cdot \Delta x}{5} \cdot \left(12 \cdot \frac{t}{t_g^4} - \frac{1}{t_g^3} \right). \tag{31}$$

Having accepted amplitude of movement of the forming cart $\Delta x = 0{,}4m$ and duration of the movement of the forming cart from one extreme situation to another $t_g = 3s$, on the equations (29)-(31) kinematic characteristics have been calculated and schedules of change of movement (Fig. 1, a), speeds (Fig. 1, b), accelerations (Fig. 1, c) and breakthrough are constructed (Fig. 1, d) at the movement of the forming cart from one extreme situation to another and in the opposite direction with the optimum breakthrough mode of a reversal.

The law of the movement of the cart described by the equations (29)-(31) can be carried out by the drive from the high-moment step engine which is built in the rolling rollers of the forming cart of installation. At the same time the law of change of angular speed of the driving step engine is described by the equations:

– on the site of start-up:

$$\dot{\varphi}_s = \frac{1}{R} \cdot \frac{648 \cdot \Delta x}{5} \cdot \left(\frac{t^2}{t_g^3} - 4 \cdot \frac{t^3}{t_g^4} \right), \tag{32}$$

– on the site of the established movement:

$$\dot{\varphi}_e = \frac{1}{R} \cdot \frac{6 \cdot \Delta x}{5 \cdot t_g}, \tag{33}$$

– on the site of braking:

$$\dot{\varphi}_b = \frac{1}{R} \cdot \frac{6 \cdot \Delta x}{5} \cdot \left(432 \cdot \frac{t^3}{t_g^4} - 108 \cdot \frac{t^2}{t_g^3} + \frac{1}{t_g} \right). \tag{34}$$

where: R – radius of the rolling rollers.

Having accepted time of start-up of the forming cart $t_s = {}^1\!/_6 \cdot t_g$, time of the established movement – $t_e = {}^2\!/_3 \cdot t_g$ and braking time – $t_b = {}^1\!/_6 \cdot t_g$ we receive the law of change of angular speed of the driving step engine at the movement of the forming cart from one extreme situation to another:

$$\dot{\varphi} = \frac{648 \cdot \Delta x}{5 \cdot R} \cdot \left(\frac{t^2}{t_g^3} - 4 \cdot \frac{t^3}{t_g^4} \right), \quad 0 \le t \le \frac{t_g}{6}, \tag{35}$$

$$\dot{\varphi} = \frac{6 \cdot \Delta x}{5 \cdot R \cdot t_g}, \quad \frac{t_g}{6} < t < \frac{5 \cdot t_g}{6}, \tag{36}$$

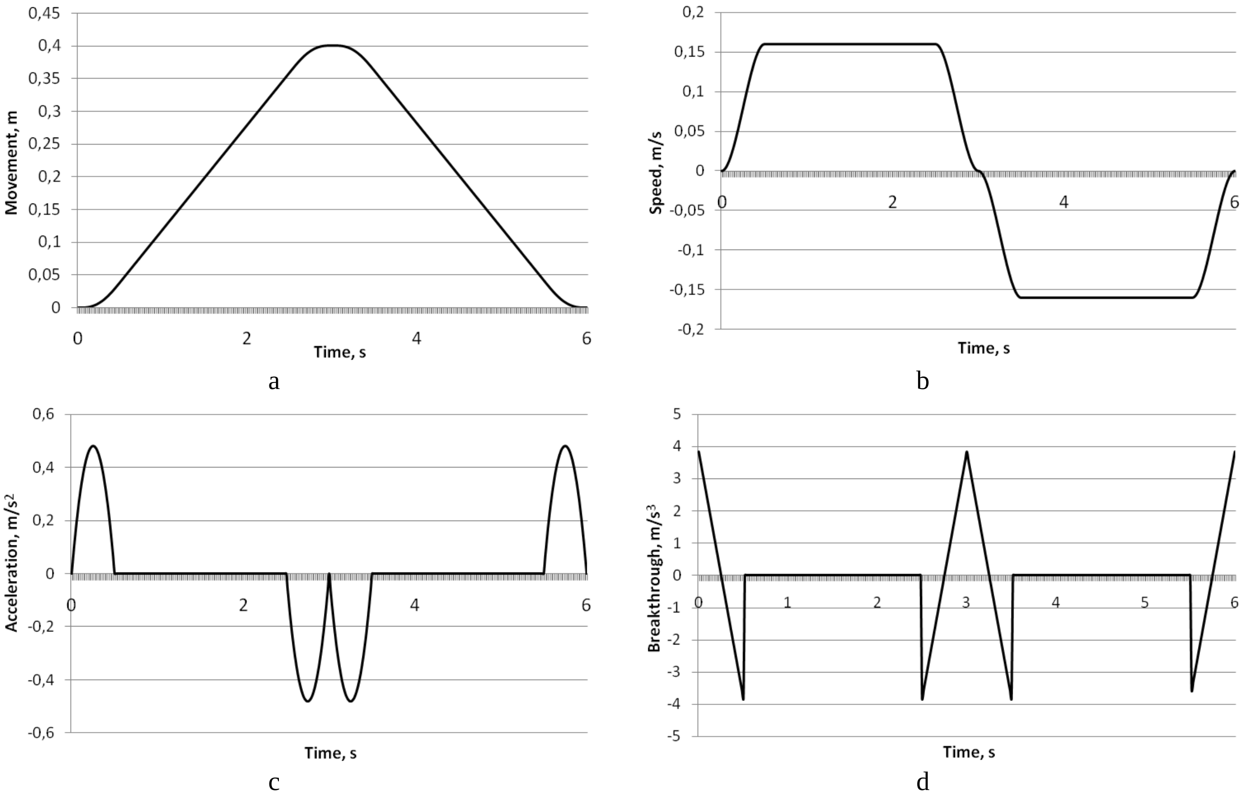

Fig. 1. Schedules of change of movement – a, speed – b, acceleration – c and breakthrough – d at the movement of the forming cart with the optimum breakthrough mode of a reversal.

$$\dot{\varphi}=\frac{6\Delta x}{5R}\left(\begin{array}{l} 432\dfrac{\left(t-\dfrac{5t_g}{6}\right)^3}{t_g^4}- \\ -108\dfrac{\left(t-\dfrac{5t_g}{6}\right)^2}{t_g^3}+\dfrac{1}{t_g}\end{array}\right),\quad \frac{5t_g}{6}<t\le t_g . \quad (37)$$

Similarly the law of change of angular speed of the driving step engine at the movement of the forming cart is defined in the opposite direction:

$$\dot{\varphi}=-\frac{648\cdot\Delta x}{5\cdot R}\cdot\left[\begin{array}{l}\dfrac{(t-t_g)^2}{t_g^3}- \\ -4\dfrac{(t-t_g)^3}{t_g^4}\end{array}\right],\quad t_g\le t\le\frac{7\cdot t_g}{6}, \quad (38)$$

$$\dot{\varphi}=-\frac{6\cdot\Delta x}{5\cdot R\cdot t_g},\qquad \frac{7\cdot t_g}{6}<t<\frac{11\cdot t_g}{6}, \quad (39)$$

$$\dot{\varphi}=-\frac{6\Delta x}{5R}\left[\begin{array}{l} 432\dfrac{\left(t-\dfrac{11t_g}{6}\right)^3}{t_g^4}- \\ -108\dfrac{\left(t-\dfrac{11t_g}{6}\right)^2}{t_g^3}+\dfrac{1}{t_g}\end{array}\right],\quad \frac{11t_g}{6}<t\le 2t_g . \quad (40)$$

For the purpose of reduction of dynamic loadings in elements of installation and for increase in her reliability the design of roller forming installation with the drive from the high-moment step engine for ensuring back and forth motion of the forming cart with the optimum breakthrough mode of a reversal (Fig. 2) is offered. Installation consists from the forming cart 1 which is mounted on the portal 2 and carries out back and forth motion in guides 3 over emptiness of a form 4. The forming cart contains the giving bunker 5 and the rolling rollers 6 on axis 7.

The cart is set in back and forth motion by means of the high-moment step engine which is built in rollers, and the axis of a roller plays a stator role, and a roller – a rotor [21].

When using in installation of the drive from the high-moment step engine which is built in the rolling rollers which law of change of angular speed is described by the equations given above quality of the processed concrete mix increases, dynamic loadings in drive elements decrease, excess destructive loads of a frame design decrease and, respectively, durability of installation in general increases.

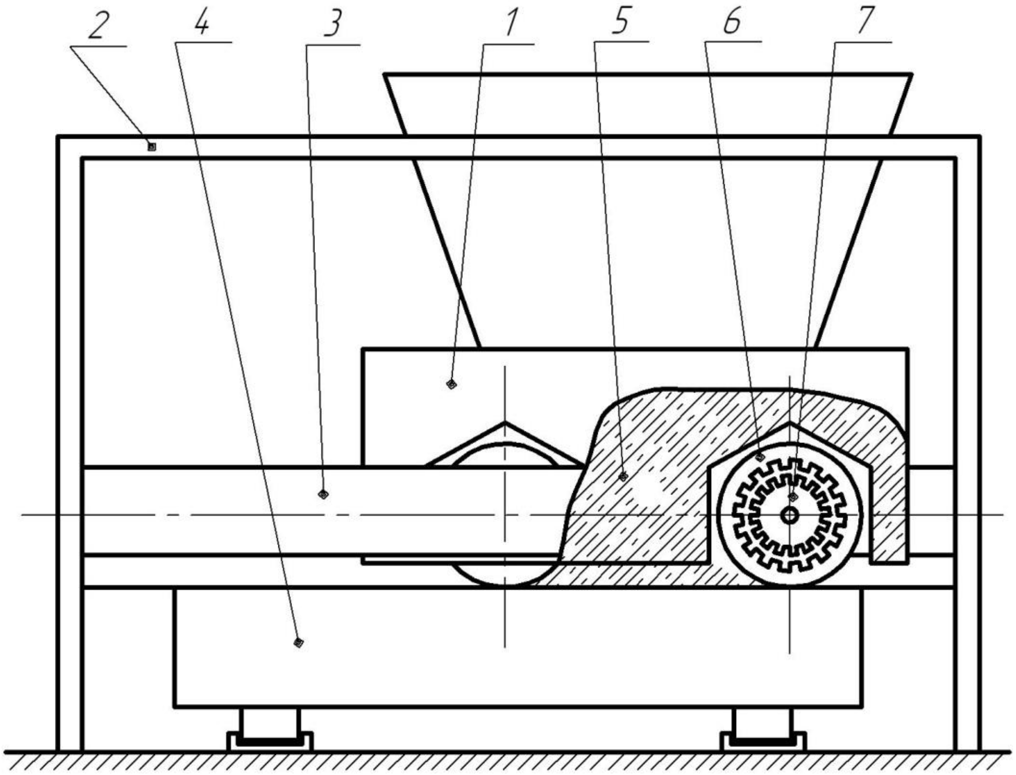

Fig. 2. Roller forming installation with the drive from the step engine.

CONCLUSIONS

1. As a result of the conducted researches for the purpose of increase in reliability and durability of roller forming installation the combined mode of back and forth motion of the forming cart with the optimum break-through mode of a reversal is calculated.

2. Kinematic characteristics of the forming cart are calculated at combined reciprocating the movements of the forming cart with the optimum breakthrough mode of a reversal.

3. The design of roller forming installation with the drive from the high-moment step engine which is built in the rolling rollers of the forming cart with a possibility of realization of the combined back and forth motion of the forming cart with the optimum breakthrough mode of a reversal is offered.

4. Results of work can be used further for specification and improvement of the existing engineering methods of calculation of driving mechanisms of cars of roller formation both at design/designing stages, and in the modes of real operation. Also results of work can be useful at design or improvement of mechanisms with back and forth motion of executive elements.

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MOTROL. Commission of Motorization and Energetics in Agriculture – 2017. Vol. 19. No 3. 33–37

THREE-PIPE CONCENTRIC HEAT EXCHANGER FOR STY

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Summary. On the basis of studies the influence of microclimate parameters on a physiological condition of animals it is established, that their productivity is greatly influenced by air exchange and air temperature in their premises. Constantly growing cost of power complicates the situation and aggravates the problem of introducing energy saving technologies, and also actualizes the economic problem of reducing specific power consumption on the production of livestock products. To achieve maximum animal productivity it is advisable, from the power point of view, to provide air exchange and air temperature in livestock premises by air heat exchanger, the use of which saves power, which is necessary for heating air in the premises.

Constructional and regime parameters of the three-pipe concentric heat exchanger for a 50 heads sty are calculated on the basis of the received theoretical and experimental dependences

As a result of calculations it is established that the power consumption for its operation during the heating period will be 5 times less for heating the same premise with abasic electric heater.

On the basis of the received theoretical and experimental dependences constructional and regime parameters of the three-pipe concentric heat exchanger for a 50 heads sty are calculated.

The use of a designed three-pipe concentric heat exchanger for a 50 heads sty during the heating period will allow to reduce the power consumption for heating the premises by 5 times, compared with a basic electric heater with a power of 10 kw.

Key words: air, microclimate, heat exchanger, constructional and regime parameters, sty, temperature.

INTRODUCTION

A significant part of the year, and for some technologies all year round, most farm animals are kept in premises. In this connection, it is necessary to create in livestock premises a microclimate corresponding to animal and poultry physiology, and in favorable affect their condition, health, productivity and product quality [1, 2, 3].

The microclimate of the livestock premises is the state of the environment, which is formed as a result of animals activity in the conditions of a certain technology.

The main indicators of the microclimate include: temperature T, relative air humidity W,%, chemical composition of air (carbon dioxide CO_2, NH_3 ammonia, hydrogen sulfide H2S), airborne dust (mechanical pollution) and micro-organisms (biological pollution), speed v, m/s, and the direction of air movement, lighting [3, 4].

The air regime is disturbed by the breathing of animals (heat, moisture, carbon dioxide, etc.), as well as by evaporation from dung. Among the pollution factors most influencing the animals growth are gases (carbon dioxide, ammonia, hydrogen sulphide), as well as such factors as moisture and heat.

Deviations of microclimate parameters from physiologically conditioned norms weaken animal resistance to diseases, cause the death to 40% of young animals, decrease by 10-20% of milk yield, and decrease of up to 30% in weight gain on fattening, shearings to 20%, require additional costs for feed and funds for treatment. The deterioration of the microclimate also reduces the term of operation of livestock farms and their technological equipment [5].

To achieve maximum animal productivity it is advisable, from the power point of view, to provide air exchange and air temperature in livestock premises by air heat exchanger, the use of which saves power, which is necessary for heating air in the premises.

The most perspective are recuperative heat exchangers for recycling of heat in the systems of ensuring of normative parameters of the air environment in livestock premises.

A recuperative heat exchanger is a surface type of heat exchanger for preservation of heat of the exhausted gas flows. In contrast to the regenerator, the exchange of heat takes place through a fixed heat exchange surface and the direction of motion of the heat carriers does not change [6].

Recuperative type of heat exchanger except for the heat exhanger often has two fans for exhaust and supply air flows. Often the construction includes various devices to automate its operation and improve the quality of supply air.

The advantages of recuperative direct-surface heat exchangers include a relatively large area of the heat exchange surface for small overall dimensions, high heat technical indicators. The simplicity of their design makes them reliable and durable. The efficiency of heat utilization in recuperative plate heat exchangers reaches 80-90% [7].

Today the construction of the three-pipe concentric heat exchengers for livestock premises is designed in Vinnytsia National Agrarian University. The technological scheme of which [8] includes: the pipes 1, 2 and 3 which are installed coaxially, a condensate removal pipe 4 that passes through the pipe 3 and located at the bottom of the pipe 2, an exhaust shaft 5 passing through the pipe 3, supply fan 6 and exhaust fan 7 (Fig. 1).

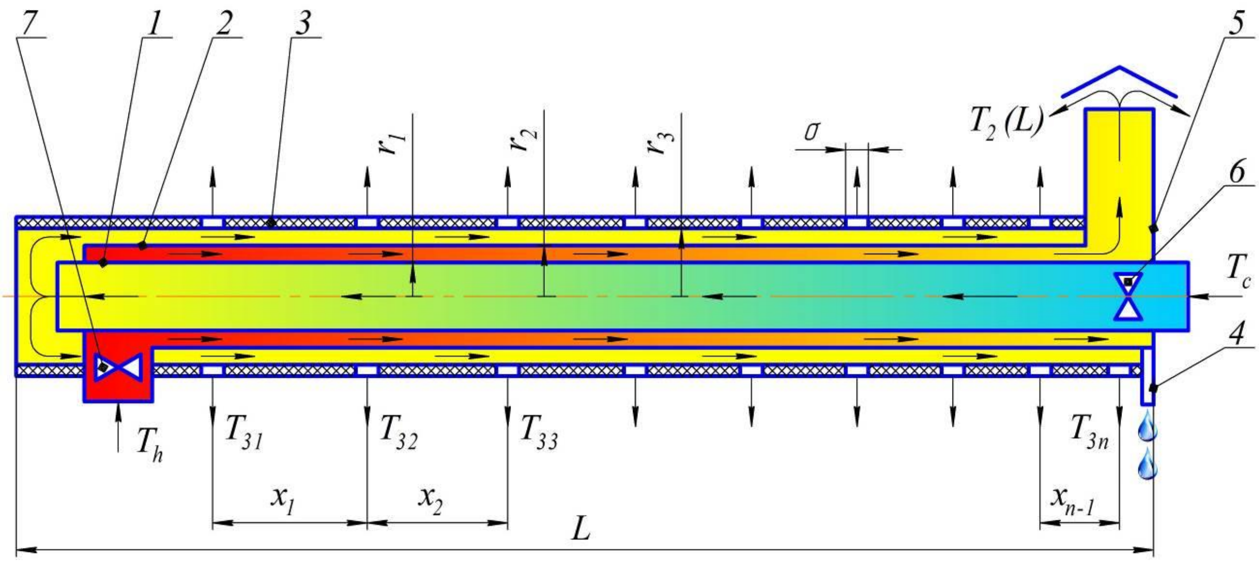

Fig. 1. Technological scheme of three-pipe heat exchanger with the basic parameters: 1, 2, 3 – pipes, 4 – condensate removal pipe, 5 – exhaust shaft, 6 – supply fan, 7 – exhaust fan.

The three-pipe heat exchanger carries out the technological process as follows. Supply (cold) air is supplied through the internal pipe 1 by the fan 6. By the fan 7 the exhaust (warm) air from the premises is injected into the space between the pipes 1 and 2, having an annular cross-section. The flows move in the opposite direction: the exhaust air exits into the external environment from the exhaust shaft 5, and the supply air turns around and continues to move in the opposite direction in the space between the pipes 2 and 3, which also has an annular cross-section. Thus, a process of heat exchange takes place between the supply and the exhaust air through the walls of pipes 1 and 2, so that the supply air is heated by a certain amount. When cooling exhaust air, a condensate is formed on the external surface of the pipe 1 and the internal surface of the pipe 2, for removing it the tube 4 serves.

In order to eliminate the process of cooling the air in the premises, the surface of the external pipe 3 is thermally insulated.

To test the efficiency of the developed three-pipe concentric heat exchanger for livestock premises it is necessary to conduct its production tests and to determine its technical and economic efficiency.

ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

As a result of theoretical and experimental studies [1, 9, 10, 11] the mathematical model of the heat transfer process in the three-pipe concentric heat exchanger was designed, taking into account the condensation phenomenon in it which allows to determine the distribution of temperatures of air flows the length of the heat exchanger and its thermal power.

A visual and statistical comparison of theoretical and experimental data has allowed to say about adequacy of the mathematical model, designed as a result of theoretical studies of the functioning of the heat exchanger for livestock premises and the possibility of using it for engineering calculations [12].

OBJECTIVES

To determine constructional and regime parameters of the three-pipe concentric heat exchanger for 50 heads sty and its technical and economic efficiency.

THE MAIN RESULTS OF THE RESEARCH

Production tests of the designed three-pipe heat exchanger will be carried out at the pig farm of the Uladovo-Lulinets experimental breeding station of the Institute of Bioenergetic Crops and Sugarbeet of the National Academy of Agrarian Sciences of Ukraine (Uladovo-Lulinets EBS IBC and SB NAANU) in the premises of fattining pigs. The brick sty (for 50 heads), which plan is represented in Figure 2, has a total size of 12.1 m × 6.2 m (75.02 m^2), including a easel room-51.5 m^2. Ceiling height - 3,0 m.

According to [13], the amount of carbon dioxide released by one adult pig on fattening is 49.3 l / h, then for 50 heads this value will be - 2465 l / h. For a sty, the allowable amount of carbon dioxide in 1 m^3 of air is 2.5 l/m^3, and the amount of carbon dioxide in 1 m3 of atmospheric air is 0.3 l/m^3. Then by formula

$$O_{CO_2} = \frac{E}{\varepsilon_1 - \varepsilon_2}, \qquad (1)$$

where: O_{CO2} – hour volume of ventilation, m^3/h,

E – amount of carbon dioxide released by all animals in an hour, l/h [14],

ε_1 – permissible amount of carbon dioxide in 1 m^3 of air in the farm, l/m^3,

ε_2 – amount of carbon dioxide in 1 m^3 atmospheric air, l/m^3.

As a result of calculations we have the hour volume of ventilation on accumulation of carbon dioxide which make O_{CO2} = 1120 m^3/h.

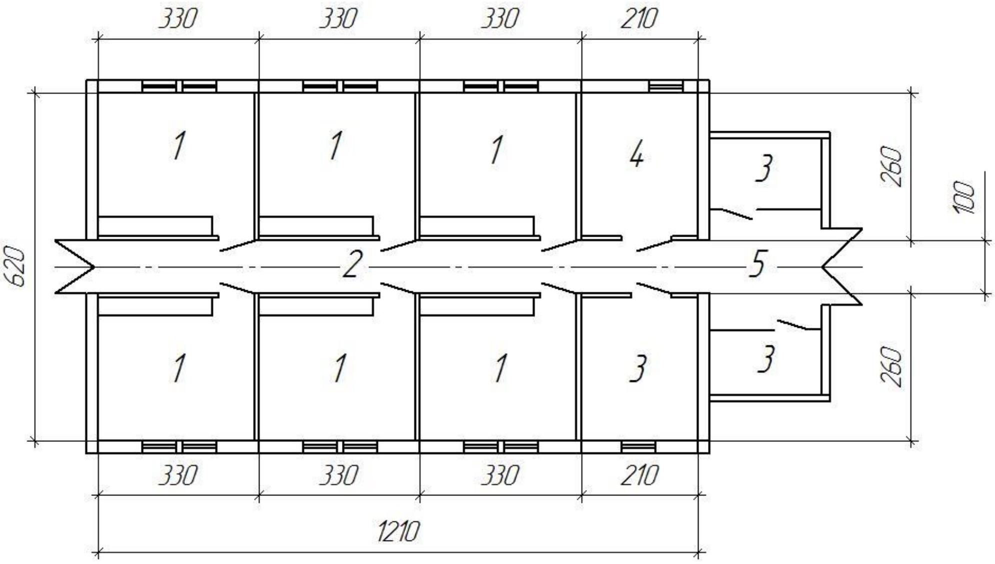

Fig. 2. Sty plan for 50 heads: 1 – easel room, 2 – pass, 3 – staff room, 4 – room for weights and tools, 5 – tambour.

According to [13] amount of water vapor which is emitted by one adult pig on fattening is 156,0 g/h, then for 50 heads this value will be – 7800 g/h. The absolute humidity of air in premises at which relative humidity remains within the standard is 10,15 g/m^3, and average absolute humidity of the external air entering in to the premises during a transition period is - 2,99 g/m^3 [13]. Then by formula

$$O_W = \frac{\Xi}{\omega_1 - \omega_2}, \tag{2}$$

where: O_W – amount of air that must be removed from the premises in one hour in order to maintain the relative humidity in it within norm (70-85 %), m^3/h. [13],

Ξ – amount of water vapor which is emitted by animals taking into account the moisture evaporating from a surface of a floor, feeding troughs, drinking bowls, walls and other fences in an hour, g/h.,

ω_1 – absolute air humidity in building, at which relative humidity remains within norm, g/m^3,

ω_2 – average absolute humidity of the external air entering to the premises during a transition period (November and March) in this climatic zone, g/m^3.

According to the calculations, the amount of air that must be removed from the premises in one hour is O_W = 1089 m^3/h.

For further calculation it is necessary to take the largest hour volume of ventilation O_W = 1120 m^3/h.

According to the obtained dependence [11]

$$L = 14{,}776 \cdot \frac{O_W}{3600} + 3{,}7335. \tag{3}$$

The heat exchanger length is L = 8.33 m, does not exceed the length of the sty. At the same time, the air volume flow is equal to

$$V = \frac{O}{3600} = 0{,}311 \text{ м}^3/\text{cc}.$$

We substitute the obtained data in

$r_3 = 0{,}3619 \cdot V + 0{,}1523,$ (4)

$r_2 = 0{,}686 \cdot r_3,$ (5)

$r_1 = 0{,}343 \cdot r_3.$ (6)

We receive radiuses of pipelines of the heat exchanger r_1 = 0,091 m, r_2 = 0,182m, r_3 = 0,265 m.

According to the developed algorithm, the air temperature T_3 (0) at the exit of the heat exchanger at ambient temperature of 0°C is 11.6 ° C, and its useful thermal power ΔN = 8206 W.

Taking into account the thermal power emitted by one pig at the fattening 73 W [13], so in the sty from 50 animals is emitted 3650 W.

Using the calculator "Heat Technical Calculator" [15], which is based on [16] heat losses through the fencing structures of sty are calculated to 3426W.

We calculate the power costs for heating the air in the sty from 0 ° C to 18 ° C at certain volume of air flow rates. According to the formula $d\dot{Q}_i(x) = \dot{m}_i C_p dT_i(x)$, the power cost is 13515W. Taking into account the heat losses through the fencing structures of premises, the total power consumption is 16941W.

As the sum of thermal power which is emitted from all animals and the useful thermal power of the heat exchanger is less than general power costs then to maintain the temperature in the sty at 18°C it is necessary to install an additional heater [17] with useful power of 16941W - 7300W - 8206W = 1435W.

To determine the geometry of the location of holes in the duct of a three-pipe concentric heat exchanger, we use the developed algorithm [10], according to which we obtain 9 holes located from each other at distances x_1 = 0,870 m, x_2 = 0,875 m, x_3 = 0,875 m, x_4 = 0,868 m, x_5 = 0,858 m, x_6 = 0,843 m, x_7 = 0,823 m, x_8 = 0,850 m, x_9 = 0,774 m, x_{10} = 0,694 m.

The received constructional parameters of the three-pipe concentric heat exchanger (Tab. 1) have been put in a prototype basis which will be installed in a sty for 50 heads of the Uladovo-Lulinets EBS IBC and SB NAANU (Fig. 3).

Table 1

Technical characteristics of three pipe concentric heat exchanger prototype for a 50 heads sty

Element Title	Element Options
Three-pipe module	Material – $ОЦ\dfrac{\text{А – О – 0,5×1000 ГОСТ 19904 – 74}}{\text{БСт3кп – ПК – МТ – УР – 1/2 ГОСТ 14918 – 80}}$, Total length – 8,33 m, External pipe diameter – 0,53 m, Middle pipe diameter – 0,36 m, Internal pipe diameter – 0,18 m, Pipe wall thickness – 0,0005 m
Angular modules	Material – $ОЦ\dfrac{\text{А – О – 0,5×1000 ГОСТ 19904 – 74}}{\text{БСт3кп – ПК – МТ – УР – 1/2 ГОСТ 14918 – 80}}$, Angle – 90°, Pipe diameter – 0,53 m, Pipe wall thickness – 0,0005 m.
Fan with controller	Model – ОВК 4Е 350, Production range – 0-2500 m^3/h, Overall dimensions (ØD×ØD$_1$×ØD$_2$×L) – 388×442×460×200, Rated power – 0,5 kw.
Electric heater	Model – ПЕТ-1,5, Temperature range – 0…+40 °C, Overall dimensions (L×W×H) – 648×246×174, Thermal power – 1,5 kw.

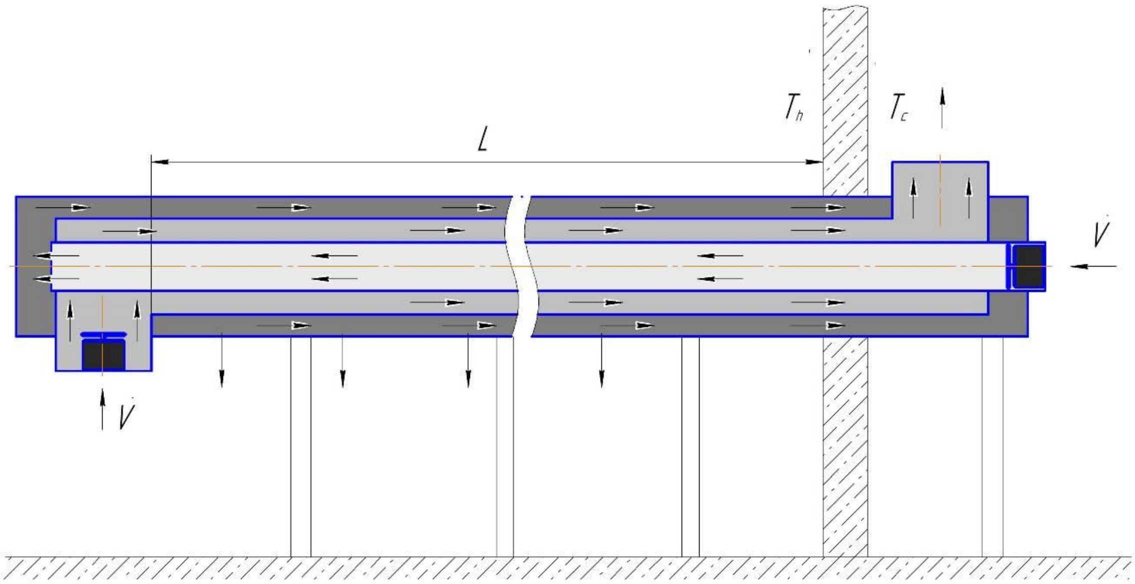

Fig. 3. Scheme of placing of concentric three-pipe heat exchanger for a 50 heads sty.

As a result of technical and economic calculations of the three-pipe concentric heat exchanger (see tab. 1) for a 50 heads sty of Uladovo-Lulinets EBS IBC and SB NAANU it was established that the power consumption for its operation during the heating period (October-April) will be 4200 kw/h. In the same period, the power consumption for heating the same premise with an electric heater (10 kw) was 21,200 kW/h, that is 5 times more consumed electricity by the heat exchanger.

CONCLUSIONS

1. On the basis of the received theoretical and experimental dependences constructional and regime parameters of the three-pipe concentric heat exchanger for a 50 heads sty are calculated.

2. The use of a designed three-pipe concentric heat exchanger for a 50 heads sty during the heating period will allow to reduce the power consumption for heating the premises by 5 times, compared with a basic electric heater with a power of 10 kw.

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CONTINUOUS BENDING OF MINIMAL SURFACES, FORMED BY MEANS OF PLANE CURVES OF COMPLEX CURVATURE

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Summary. Analytical description of one-parameter set of a associated minimal surfaces formed under their continuous bending, using complex variable was made. To find the equation of isotropic lines, parametric equations of logarithmic spiral and evolvent of circle defined by functions of natural parameter with complex curvature were used. Isotropic lines parametric equations are obtained from the condition of differential arc of spatial curve equality to zero. Analytical description of minimal surfaces and connected minimal surfaces were made in complex space with isotropic lines of grid transfer.

Expressions of the first and second quadratic forms of generated minimal surfaces coefficients were found. It is shown that the mean curvature of formed minimal surfaces equals zero at all points.

We investigated that minimum surface and connected minimal surface, which are formed on the base of isotropic line with the help of a logarithmic spiral with curvature of complex value share common properties with appropriate curvature surfaces built using logarithmic spiral curvature of actual value. Using various methods of analytical description of isotropic lines with evolvent of circle with curvature of complex value, minimal surfaces that with the replacement of variable have common properties with a curvature, but different metric characteristics were constructed.

Analytical description of one-parameter set of associated minimal surfaces allows to control their shape for solving various applications. Parametric equations of minimal surfaces were found in the form of elementary functions, allowing to explore their geometric properties and differential characteristics to optimize engineering methods of technical forms and architectural constructions design.

Key words: one-parameter set of a associated minimal surfaces, isotropic line, logarithmic spiral, evolvent of the circle, function of a complex variable, complex curvature, mean curvature of a surface.

INTRODUCTION

An important problem of modeling of continuous frame of engineering forms and architectural constructions is taking into consideration their geometric and differential characteristics.

That’s why the most essential are the design methods of curves and surfaces under specified conditions [1-3], research of trajectory of material points motion on the surface of the technical forms [4, 5], means of applying images to curved surfaces [6].

The average curvature at all points of a minimal surface equals zero, which is a prerequisite for solving the problem of finding the smallest surface area, which passes through a given plane or spatial curve. The geometrical shape of minimal surface provides even distribution of efforts in the shell of surface and extra rigidity. [7]

The first researches of minimal surfaces are known from J. Lagrange’s publications, he considered a practical problem [8]: "To find the smallest surface area that stretched to the specified contour" (1786). J. Lagrange concluded that the smallest surface area, given by the function must satisfy Euler-Lagrange equation [8]:

$$\left(1+q^2\right)\frac{\partial^2 z}{\partial x^2}-2pq\frac{\partial^2 z}{\partial x\,\partial y}+\left(1+p^2\right)\frac{\partial^2 z}{\partial y^2}=0, \quad (1)$$

where: $p=\dfrac{\partial z}{\partial x}, q=\dfrac{\partial z}{\partial y}$.

G. Monge in 1776 found that the equality of mean curvature to zero is a prerequisite of minimal surface area.

Euler-Lagrange’s differential equation (1) generally is not integrated so one of the modern research directions of minimal surfaces analytical description is to improve methods of numerical integration [9, 10].

In works [7, 11-13] for designing surfaces of technical forms and architectural constructions, grapho-analytical methods of surfaces construction close to minimal were developed. Geometric modeling of deformed sheet of parabolic reflector that takes a shape close to the minimum surface was made in the research [14].

A special area of research related to finding analytical description of minimal surfaces using the elementary functions is development of methods that use complex variable properties.

ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

To find analytical description of minimal surfaces by means of complex variable it is necessary to find parametric equations of zero length isotropic lines [15].

The authors of the research [16, 17] found parametric equations for isotropic lines according to Weierstrass and Schwarz formulas only in some cases. Modeling of isotropic lines with the help of fundamental splines was considered in work [18]. The method of analytical description of minimal surfaces using isotropic curves that lie on the surfaces of rotation assigned to isometric grid lines was realized in works [19-21]. In work [22] for analytical description of isotropic lines parametric equations of logarithmic spiral defined by functions of natural parameter with real curvature were used.

The opportunity to study analytical description of isotropic lines and corresponding minimal surfaces using planar curves with complex curvature value is required.

OBJECTIVE

To find analytical description of isotropic lines using parametric equations of logarithmic spiral and evolvent of circle, defined by functions of natural parameter with the complex curvature. Using isotropic lines to find analytical description of one-parameter set of associated minimal surfaces formed at their continuous bending.

THE MAIN RESULTS OF THE RESEARCH

Consider a plane curve, given by the complex curvature value:

$$k(s)=\frac{1}{i\cdot a\cdot s}, \tag{2}$$

where: $a-$ parameter curve, $i-$imaginary unit, $s-$ the arc length of the curve.

If $a=-i$, then expression (2) define curvature of logarithmic spiral.

Curvature of a plane curve $k(s)$ is determined from the formula [23]:

$$k(s)=\frac{d\varphi}{ds}, \tag{3}$$

where: $\varphi-$ angle between tangent curve and x-axis.

Calling the condition $\varphi(0)=0,$ we get plane curvature equation [23] from natural parameter s:

$$\begin{aligned} x(s)&=x(0)+\int_0^s\cos\left[\int_0^s k(s)ds\right]\cdot ds,\\ y(s)&=y(0)+\int_0^s\sin\left[\int_0^s k(s)ds\right]\cdot ds. \end{aligned} \tag{4}$$

Substituting the expression of complex curvature values (2) у (4), then under the conditions $x(0)=0$ і $y(0)=0,$ get:

$$\begin{aligned} x(s)&=\frac{a\cdot s}{a^2-1}\cdot\left[a\cdot\mathrm{ch}\left(\frac{\ln s}{a}\right)-\mathrm{sh}\left(\frac{\ln s}{a}\right)\right],\\ y(s)&=\frac{i\cdot a\cdot s}{a^2-1}\cdot\left[-\mathrm{ch}\left(\frac{\ln s}{a}\right)+a\,\mathrm{sh}\left(\frac{\ln s}{a}\right)\right]. \end{aligned} \tag{5}$$

From condition [15] $(x')^2+(y')^2+\ +(z')^2\ =0$ define the expression $z(s)=i\cdot s$ and write parametric equations of isotropic spatial lines:

$$\begin{aligned} x(s)&=\frac{a\cdot s}{a^2-1}\cdot\left[a\cdot\mathrm{ch}\left(\frac{\ln s}{a}\right)-\mathrm{sh}\left(\frac{\ln s}{a}\right)\right],\\ y(s)&=\frac{i\cdot a\cdot s}{a^2-1}\cdot\left[-\mathrm{ch}\left(\frac{\ln s}{a}\right)+a\,\mathrm{sh}\left(\frac{\ln s}{a}\right)\right],\\ z(s)&=i\cdot s. \end{aligned} \tag{6}$$

To find the equations of minimal and associated minimal surface, it is necessary to introduce replacement in isotropic curve parametric equations (6) [22]: $s=u+i\cdot v.$ Then we get parametric equations of minimal surface $X(u,v),\ Y(u,v), Z(u,v)$:

$$\begin{aligned} X(u,v)&=\mathrm{Re}\{x(u+i\cdot v)\},\\ Y(u,v)&=\mathrm{Re}\{y(u+i\cdot v)\},\\ Z(u,v)&=\mathrm{Re}\{i\cdot(u+i\cdot v)\}, \end{aligned} \tag{7}$$

and associated minimal surface $X^*(u,v),\ Y^*(u,v),$ $Z^*(u,v)$:

$$\begin{aligned} X^*(u,v)&=\mathrm{Im}\{x(u+i\cdot v)\},\\ Y^*(u,v)&=\mathrm{Im}\{y(u+i\cdot v)\},\\ Z^*(u,v)&=\mathrm{Im}\{i\cdot(u+i\cdot v)\}. \end{aligned} \tag{8}$$

Separating real and imaginary parts for each function (6), according to (7), (8), get the equation of minimal surface:

$$\begin{aligned} X(u,v)&=\frac{a}{a^2-1}\cdot[u\cdot\cos(\beta)\cdot(a\,\mathrm{ch}\,\gamma-\mathrm{sh}\,\gamma)-\\ &\quad -v\cdot\sin(\beta)\cdot(a\,\mathrm{sh}\,\gamma-\mathrm{ch}\,\gamma)],\\ Y(u,v)&=\frac{a}{a^2-1}\cdot[v\cdot\cos(\beta)\cdot(a\,\mathrm{sh}\,\gamma-\mathrm{ch}\,\gamma)+\\ &\quad +u\cdot\sin(\beta)\cdot(a\,\mathrm{ch}\,\gamma-\mathrm{sh}\,\gamma)],\\ Z(u,v)&=-v, \end{aligned} \tag{9}$$

where: $\beta=\beta(u;v)=\dfrac{1}{a}\mathrm{arctg}\left(\dfrac{v}{u}\right),$

$$\gamma=\gamma(u;v)=\frac{\ln(u^2+v^2)}{2a},$$

and associated minimal surface:

$$\begin{aligned} X^*(u,v)&=\frac{a}{a^2-1}\cdot[v\cdot\cos(\beta)\cdot(a\,\mathrm{ch}\,\gamma-\mathrm{sh}\,\gamma)+\\ &\quad +u\cdot\sin(\beta)\cdot(a\,\mathrm{sh}\,\gamma-\mathrm{ch}\,\gamma)],\\ Y^*(u,v)&=\frac{a}{a^2-1}\cdot[u\cdot\cos(\beta)\cdot(-a\,\mathrm{sh}\,\gamma+\mathrm{ch}\,\gamma)+\\ &\quad +v\cdot\sin(\beta)\cdot(a\,\mathrm{ch}\,\gamma-\mathrm{sh}\,\gamma)],\\ Z^*(u,v)&=u, \end{aligned} \tag{10}$$

where: $\beta(u;v)=\dfrac{1}{a}\mathrm{arctg}\left(\dfrac{v}{u}\right),\ \gamma(u;v)=\dfrac{\ln(u^2+v^2)}{2a}.$

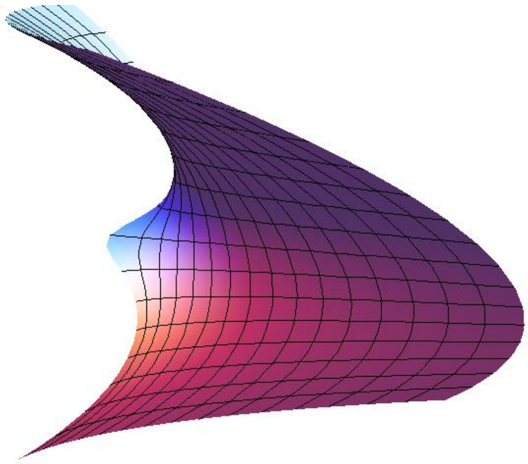

Fig. 1. Minimal surface built on equations (9).

In Fig. 1 minimal surface is shown, in Fig. 2 associated minimal surface is shown, which were built according to equations (9), (10) accordingly at $a = 0{,}9$, $u \in (0;\ 4]$, $v \in [-3;...3]$.

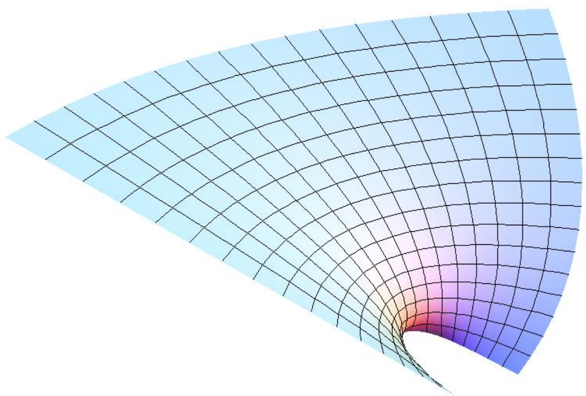

Fig. 2. Associated minimal surface built on equations (10).

We find coefficients of the first quadratic form of surface $X(u,v),\ Y(u,v), Z(u,v)$, which define metric properties of the surface according to the formulas [23]:

$$E = (X'_u)^2 + (Y'_u)^2 + (Z'_u)^2,$$
$$F = X'_u \cdot X'_v + Y'_u \cdot Y'_v + Z'_u \cdot Z'_v, \qquad (11)$$
$$G = (X'_v)^2 + (Y'_v)^2 + (Z'_v)^2.$$

The coefficients of the first quadratic form of minimal surface (9) and the associated surface (10) equal to:

$$E = G = \left[\frac{\ln(u^2+v^2)}{2a}\right]^2,\ F = 0. \qquad (12)$$

We find expressions of a second quadratic form of surface $X(u,v),\ Y(u,v), Z(u,v)$, that define the surface curvature properties of according to the formulas [23]:

$$L = \frac{1}{\sqrt{EG-F^2}} \cdot \begin{vmatrix} X''_{uu} & Y''_{uu} & Z''_{uu} \\ X'_u & Y'_u & Z'_u \\ X'_v & Y'_v & Z'_v \end{vmatrix},$$
$$M = \frac{1}{\sqrt{EG-F^2}} \cdot \begin{vmatrix} X''_{uv} & Y''_{uv} & Z''_{uv} \\ X'_u & Y'_u & Z'_u \\ X'_v & Y'_v & Z'_v \end{vmatrix}, \qquad (13)$$
$$N = \frac{1}{\sqrt{EG-F^2}} \cdot \begin{vmatrix} X''_{vv} & Y''_{vv} & Z''_{vv} \\ X'_u & Y'_u & Z'_u \\ X'_v & Y'_v & Z'_v \end{vmatrix},$$

The coefficients of the second quadratic form of minimal surface (9) equal to:

$$L = -N = -\frac{v}{a(u^2+v^2)},\ M = \frac{u}{a(u^2+v^2)}.$$

The coefficients of the second quadratic form of associated minimal surface (10) equal to:

$$L^* = -N^* = -\frac{u}{a(u^2+v^2)},\ M^* = -\frac{v}{a(u^2+v^2)}.$$

The coefficients of the first and second quadratic forms of the constructed minimal surfaces (9) and (10), turn the expression of mean curvature $H = \dfrac{E \cdot N - 2 \cdot F \cdot M + G \cdot L}{2(E \cdot G - F^2)}$ for each of the specified surfaces to zero.

Comparing expressions of coefficients of quadratic forms, it should be noted that for isotropic line (2) with complex curvature constructed minimal surfaces (9) and (10) that have common properties curvature but different metric properties of minimal surfaces formed by the study [22] with isotropic curve found based on parametric equations logarithmic spiral.

Minimal surfaces built on equations (9) and (10) have the same expression (12) of coefficients of the first quadratic form, that's why they allow continuous bending one above the other. Equations of one-parameter set of associated minimal surfaces formed with continuous bending are of the form [22]:

$$X_\varphi(u,v) = X(u,v)\cos\varphi + X^*(u,v)\sin\varphi,$$
$$Y_\varphi(u,v) = Y(u,v)\cos\varphi + Y^*(u,v)\sin\varphi, \qquad (14)$$
$$Z_\varphi(u,v) = Z(u,v)\cos\varphi + Z^*(u,v)\sin\varphi,$$

where: $X(u,v), Y(u,v), Z(u,v) -$ parametric equations of minimal surface (9), $X^*(u,v), Y^*(u,v), Z^*(u,v) -$ parametric equations of associated minimal surface (10), $\varphi -$ bending parameter of surfaces, $\varphi \in \left[0;\ \dfrac{\pi}{2}\right]$.

It is obviously that $\varphi = 0$ equations (14) define the minimal surface (9), at $\varphi = \dfrac{\pi}{2}$ equations (14) define the associated minimal surface (10), for other values $\varphi \in \left(0;\ \frac{\pi}{2}\right)$ equations (14) define associated minimal surfaces [19].

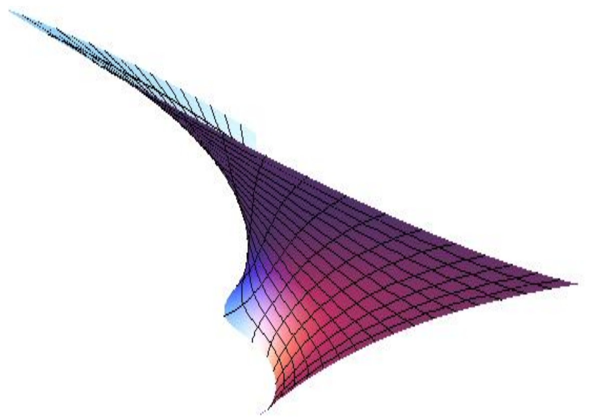

Fig. 3. Associated minimal surface built on equations (14) in accordance with $\varphi = \frac{\pi}{4}$.

In Fig. 3 we show a minimal associated surface constructed on equations (14) in accordance with $\varphi = \frac{\pi}{4}$, $a = 0{,}9$, $u \in (0;\ 4]$, $v \in [-3;...3]$.

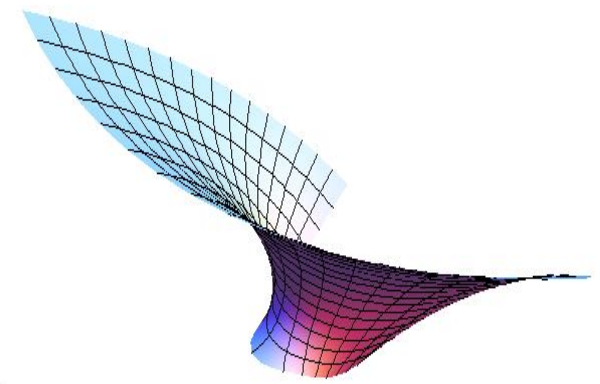

Fig. 4. Associated minimal surface built on equations (14) in accordance with $\varphi = \frac{3\pi}{8}$.

All associated minimal surfaces have equal corresponding expressios (12) of the first quadratic form coefficients.

Consider a plane curve, given by complex value of the curvature:

$$k(s) = \frac{1}{\sqrt{2a \cdot i \cdot s}}, \tag{15}$$

where: $a -$ the parameter curve, $i -$ imaginary unit, $s -$ arc length of a curve.

If $a = -i$, then expression (15) specifies the curvature of evolvent of a circle. Substitute the value of complex curvature (15) in (4), then under meeting the conditions $x(0) = 0$ and $y(0) = 0$, obtain:

$$\begin{aligned} x(s) &= i \cdot a\left[\cos\sqrt{-\frac{2is}{a}} + \sqrt{-\frac{2is}{a}}\sin\sqrt{-\frac{2is}{a}}\right], \\ y(s) &= -i \cdot a\left[\sqrt{-\frac{2is}{a}}\cos\sqrt{-\frac{2is}{a}} - \sin\sqrt{-\frac{2is}{a}}\right]. \end{aligned} \tag{16}$$

From condition $(x')^2 + (y')^2 + (z')^2 = 0$ [15] define the expression $z(s) = i \cdot s$ and write the parametric equations of a spatial isotropic line:

$$\begin{aligned} x(s) &= i \cdot a\left[\cos\sqrt{-\frac{2is}{a}} + \sqrt{-\frac{2is}{a}}\sin\sqrt{-\frac{2is}{a}}\right], \\ y(s) &= -i \cdot a\left[\sqrt{-\frac{2is}{a}}\cos\sqrt{-\frac{2is}{a}} - \sin\sqrt{-\frac{2is}{a}}\right], \\ z(s) &= i \cdot s \end{aligned} \tag{17}$$

To find the equations of minimal and associated minimal surface it is necessary to change parametric equations of isotropic curve (17) [22]: $s = u + i \cdot v$. Then, we will obtain a parametric equations of minimal surfaces $X_1(u,v)$, $Y_1(u,v)$, $Z_1(u,v)$:

$$\begin{aligned} X_1 &= -a \cdot m \cdot \mathrm{ch}(m \cdot \sin\alpha) \cdot \sin\alpha \cdot \sin(m \cdot \cos\alpha) + \\ &\quad + a\,\mathrm{sh}(m \sin\alpha) \times \\ &\quad \times [\sin(m \cdot \cos\alpha) - m \cdot \cos\alpha \cdot \cos(m\cos\alpha)], \\ Y_1 &= -a \cdot m \cdot \mathrm{ch}(m \cdot \sin\alpha) \cdot \sin\alpha \cdot \cos(m \cdot \cos\alpha) + \\ &\quad + a\,\mathrm{sh}(m \sin\alpha) \times \\ &\quad \times [\cos(m\cos\alpha) + m\cos\alpha\sin(m\cos\alpha)], \\ Z_1(u,v) &= -v, \end{aligned} \tag{18}$$

where: $m = m(u;v) = \sqrt{2}\left(\frac{u^2+v^2}{a^2}\right)^{\frac{1}{4}}$,

$$\alpha = \alpha(u;v) = -\frac{1}{2}\operatorname{arctg}\left(\frac{u}{v}\right)$$

and associated minimal surface $X_1^*(u,v)$, $Y_1^*(u,v)$, $Z_1^*(u,v)$:

$$\begin{aligned} X_1^* &= -a \cdot m \cdot \mathrm{sh}(m \cdot \sin\alpha)\sin\alpha \cdot \cos(m \cdot \cos\alpha) + \\ &\quad + a \cdot \mathrm{ch}(m \sin\alpha) \times \\ &\quad \times [\cos(m \cdot \cos\alpha) + m \cdot \cos\alpha \cdot \sin(m \cdot \cos\alpha)]; \\ Y_1^* &= a \cdot m \cdot \mathrm{sh}(m \cdot \sin\alpha) \cdot \sin\alpha \cdot \sin(m \cdot \cos\alpha) + \\ &\quad + a\,\mathrm{ch}(m \sin\alpha) \times \\ &\quad \times [-\sin(m \cdot \cos\alpha) + m \cdot \cos\alpha \cdot \cos(m\cos\alpha)]; \\ Z_1^* &= u. \end{aligned} \tag{19}$$

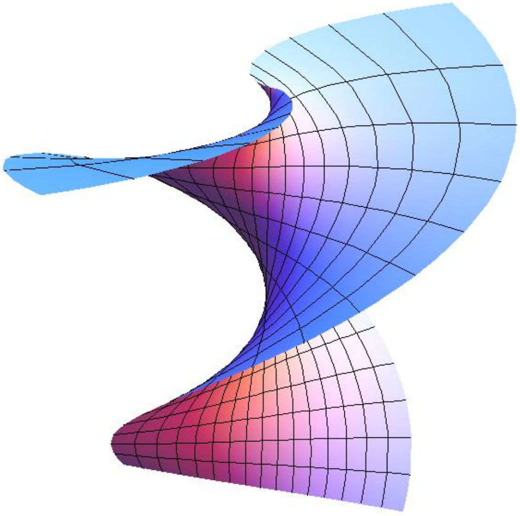

Fig. 5. Minimal surface built on equations (18).

In Fig. 5 a minimal surface is shown, Fig. 6 shows an associated minimal surface, that are built on equations (18), (19) in accordance with $a = 0{,}5$, $u \in [-3;...3]$, $v \in (0;\, 16]$.

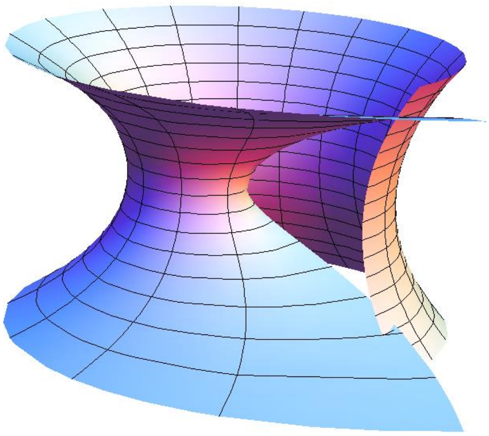

Fig. 6. Associated minimal surface built on equations (19).

The coefficients of the first quadratic form of minimal surface (18) and the associated surface (19) found by formula (11) equal to:

$$E = G = \mathrm{ch}^2\left[\sqrt{2}\left(\frac{u^2+v^2}{a^2}\right)^{\frac{1}{4}}\sin\left(\frac{1}{2}\mathrm{arctg}\frac{u}{v}\right)\right]; \quad (20)$$

$$F = 0.$$

The coefficients of the second quadratic form of minimal surface (18) found by formula (13) equal to:

$$L = -N = \frac{v}{2(u^2+v^2)}\cdot\sqrt{2+\frac{2u^2}{v^2}\left(\frac{u^2+v^2}{a^2}\right)^{\frac{1}{4}}}\times$$

$$\times\left[(v^2-u^2)\sin\left(\frac{3}{2}\mathrm{arctg}\frac{u}{v}\right) - 2uv\cos\left(\frac{3}{2}\mathrm{arctg}\frac{u}{v}\right)\right],$$

$$M = \frac{-v}{2(u^2+v^2)}\cdot\sqrt{2+\frac{2u^2}{v^2}\left(\frac{u^2+v^2}{a^2}\right)^{\frac{1}{4}}}\times$$

$$\times\left[(v^2-u^2)\cos\left(\frac{3}{2}\mathrm{arctg}\frac{u}{v}\right) + 2uv\sin\left(\frac{3}{2}\mathrm{arctg}\frac{u}{v}\right)\right].$$

The coefficients of the second quadratic form of associated minimal surface (19) equal to: $L^* = -N^* = -M$, $M^* = -L$,

where: M and L – the coefficients of the second quadratic form of minimal surface (18).

The coefficients of the first and second quadratic forms of the constructed minimal surfaces (18) and (19), turn the expression of mean curvature $H = \dfrac{E\cdot N - 2\cdot F\cdot M + G\cdot L}{2(E\cdot G - F^2)}$ for each of the specified surfaces to zero.

Minimal surfaces built on equations (18) and (19) have equal expressions (20) of the first quadratic form, that's why they allow continuous bending one upon the other. Equation of a one-parameter set of associated minimal surfaces formed under continuous bending are of the form [22]:

$$\begin{aligned} X_\varphi(u,v) &= X_1(u,v)\cos\varphi + X_1^*(u,v)\sin\varphi;\\ Y_\varphi(u,v) &= Y_1(u,v)\cos\varphi + Y_1^*(u,v)\sin\varphi;\\ Z_\varphi(u,v) &= Z_1(u,v)\cos\varphi + Z_1^*(u,v)\sin\varphi, \end{aligned} \quad (21)$$

where: $X_1(u,v); Y_1(u,v); Z_1(u,v)-$ parametric equations of minimal surface (18),

$X_1^*(u,v); Y_1^*(u,v); Z_1^*(u,v)-$ parametric equations of associated minimal surface (19),

$\varphi-$ bending parameter of surfaces, $\varphi \in \left[0;\, \dfrac{\pi}{2}\right]$.

At $\varphi = 0$ equations (21) define minimal surface (18), at $\varphi = \dfrac{\pi}{2}$ equations (21) define associated minimal surface (19),at other values $\varphi \in \left(0;\, \dfrac{\pi}{2}\right)$ equations (21) define associated minimal surfaces [19].

In Fig. 7, Fig. 8, Fig. 9, Fig. 10 images associated minimal surfaces built on equations (21) in accordance for $a = 0{,}9$, $u \in [-3;...3]$, $v \in (0;\, 10]$, at $\varphi = \dfrac{\pi}{8}$, $\varphi = \dfrac{\pi}{6}$, $\varphi = \dfrac{\pi}{4}$, $\varphi = \dfrac{3\pi}{8}$ respectively are built. These minimal surfaces are formed under continuous bending of a minimal surface (18) to attached minimal surface (19).

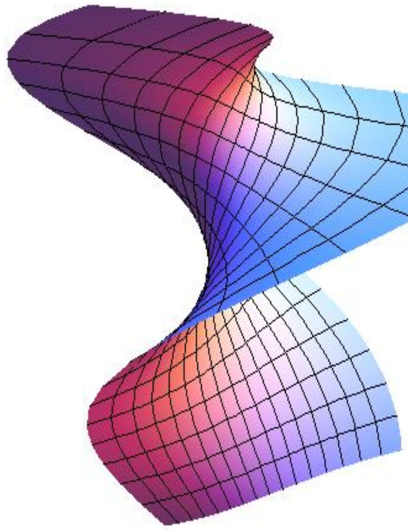

Fig. 7. Associated minimal surface built at $\varphi=\dfrac{\pi}{8}$.

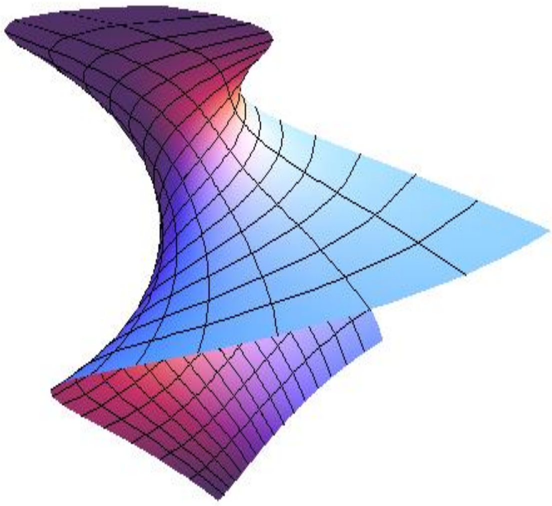

Fig. 8. Associated minimal surface built at $\varphi=\dfrac{\pi}{4}$.

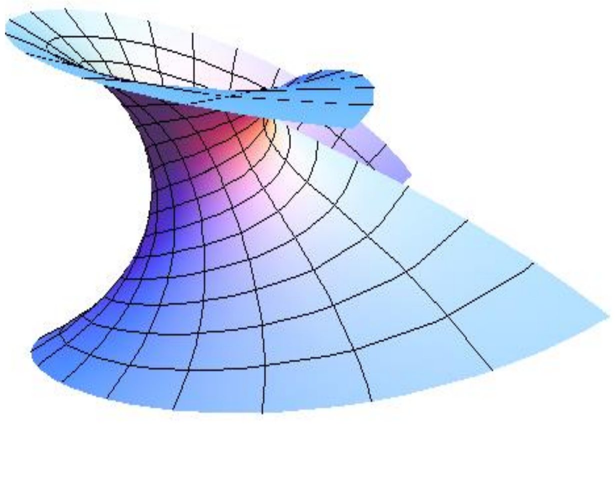

Fig. 9. Associated minimal surface built at $\varphi=\dfrac{\pi}{3}$.

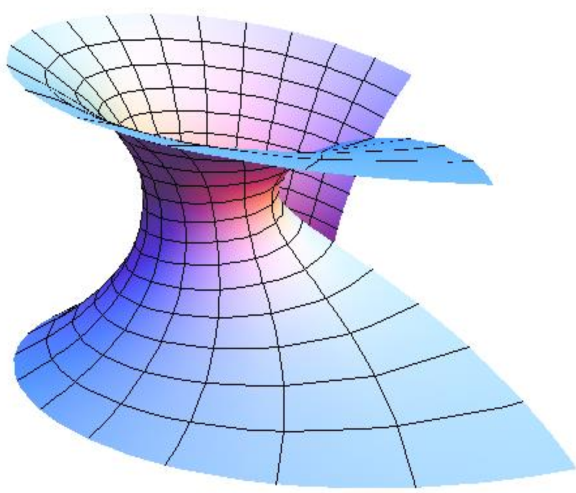

Fig. 10. Associated minimal surface built at $\varphi=\dfrac{3\pi}{8}$.

All built associated minimal surfaces have equal corresponding expressions (20) of the first quadratic form coefficients.

Consider a plane curve, given by complex value of the curvature:

$$k(s)=\frac{i}{\sqrt{2a\cdot i\cdot s}},\tag{22}$$

where: $a-$ the parameter curve,

$i-$ imaginary unit, $s-$ arc length of a curve.

Substitute the value of complex curvature (22) in (4), then under meeting the conditions $x(0)=0$ and $y(0)=0,$ obtain:

$$\begin{aligned}x(s)&=a\left[-\operatorname{ch}\sqrt{\frac{2s}{a}}+\sqrt{\frac{2s}{a}}\cdot\operatorname{sh}\sqrt{\frac{2s}{a}}\right];\\ y(s)&=i\cdot a\left[\sqrt{\frac{2s}{a}}\cdot\operatorname{ch}\sqrt{\frac{2s}{a}}-\operatorname{sh}\sqrt{\frac{2s}{a}}\right].\end{aligned}\tag{23}$$

From condition $(x')^2+(y')^2+(z')^2=0$ [15, p. 14] define the expression $z(s)=i\cdot s$ and write the parametric equations of a spatial isotropic line:

$$\begin{aligned}x(s)&=a\left[-\operatorname{ch}\sqrt{\frac{2s}{a}}+\sqrt{\frac{2s}{a}}\cdot\operatorname{sh}\sqrt{\frac{2s}{a}}\right];\\ y(s)&=i\cdot a\left[\sqrt{\frac{2s}{a}}\cdot\operatorname{ch}\sqrt{\frac{2s}{a}}-\operatorname{sh}\sqrt{\frac{2s}{a}}\right];\\ z(s)&=i\cdot s\end{aligned}\tag{24}$$

To find the equations of minimal and associated minimal surface it is necessary to change parametric equations of isotropic curve (24) [22]: $s=u+i\cdot v.$ Then, we will obtain a parametric equations of minimal surfaces $X_2(u,v), Y_2(u,v), Z_2(u,v)$:

$$\begin{aligned}
X_2 &= a\cdot m\cdot \mathrm{sh}(m\cdot\cos\alpha)\cdot\cos\alpha\cdot\cos(m\cdot\sin\alpha)-\\
&\quad -a\cdot\mathrm{ch}(m\cdot\cos\alpha)\times\\
&\quad \times[\cos(m\cdot\sin\alpha)+m\cdot\sin\alpha\cdot\sin(m\sin\alpha)],\\
Y_2 &= -a\cdot m\cdot\mathrm{sh}(m\cdot\cos\alpha)\cdot\cos\alpha\cdot\sin(m\cdot\sin\alpha)+\\
&\quad +a\cdot\mathrm{ch}(m\sin\alpha)\times\\
&\quad \times[\sin(m\cos\alpha)-m\sin\alpha\cos(m\sin\alpha)],\\
Z_2(u,v) &= -v,
\end{aligned} \tag{25}$$

where: $m = m(u;v) = \sqrt{2}\left(\dfrac{u^2+v^2}{a^2}\right)^{\frac{1}{4}}$,

$$\alpha = \alpha(u;v) = -\frac{1}{2}\mathrm{arctg}\left(\frac{v}{u}\right)$$

and associated minimal surface $X_2^*(u,v)$, $Y_2^*(u,v), Z_2^*(u,v)$:

$$\begin{aligned}
X_2^* &= a\cdot m\cdot\mathrm{ch}(m\cdot\cos\alpha)\cos\alpha\cdot\sin(m\cdot\sin\alpha)+\\
&\quad +a\cdot\mathrm{sh}(m\cdot\cos\alpha)\times\\
&\quad \times[-\sin(m\cdot\sin\alpha)+m\cdot\sin\alpha\cdot\cos(m\cdot\sin\alpha)],\\
Y_2^* &= a\cdot m\cdot\mathrm{ch}(m\cdot\cos\alpha)\cdot\cos\alpha\cdot\cos(m\cdot\sin\alpha)-\\
&\quad -a\cdot\mathrm{sh}(m\cdot\cos\alpha)\times\\
&\quad \times[\cos(m\cdot\sin\alpha)+m\cdot\sin\alpha\cdot\sin(m\cdot\sin\alpha)],\\
Z_2^* &= u.
\end{aligned} \tag{26}$$

The coefficients of the first quadratic form of minimal surface (25) and the associated surface (26) found by formula (11) equal to:

$$E = G = \mathrm{ch}^2\left[\sqrt{2}\left(\frac{u^2+v^2}{a^2}\right)^{\frac{1}{4}}\cos\left(\frac{1}{2}\mathrm{arctg}\frac{v}{u}\right)\right], \tag{27}$$

$$F = 0.$$

The coefficients (27) of the first quadratic form of minimal surface are different from coefficients (20). For a plane curve given by complex value curvature $k(s) = \dfrac{i}{\sqrt{2a\cdot i\cdot s}}$, it is possible to find coefficients of the first quadratic form of corresponding minimal surfaces. The coefficients of the second quadratic form of minimal surfaces (25), (26) coincide with the coefficients of the minimal surfaces (18), (19), using the change of variables u to v. The minimal surfaces (25), (26) have different metric properties with minimal surfaces (18), (19) respectively, but they have common properties of surface curvature.

CONCLUSIONS

1. The proposed method of finding isotropic curves parametric equations based on the logarithmic spiral and evolvent of circle with complex curvature allows to determine analytical description of one-parameter set of a associated minimal surfaces formed under their continuous bending.

2. It is investigated that minimal surface and associated minimal surface, which are formed on the basis of a isotropic line using logarithmic spiral with curvature of the complex value share common properties of curvature with appropriate surfaces built using logarithmic spiral curvature of the real value. Using various methods of analytical description of isotropic lines with the help of evolvent of circle with curvature of complex value, minimal surfaces that with the replacement of variables have common properties of a curvature, but different metric characteristics were constructed.

3. Parametric equations of minimal surfaces were found in the form of elementary functions, which allows to explore their geometric properties and differential characteristics to optimize engineering methods to design technical forms and architectural constructions.

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RESEARCH WORKING PROCESS SORTING OF MATERIALS AND DYNAMIC PARAMETERS OF VIBRATION SCREEN

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Summary. Reasonable preconditions and assumptions in the study of the working process of sorting construction material are selected model of the system "vibration damping roller - sorting material", which adequately reflects the actual sorting process. The influence factors of the process of material sorting are studied: granulometric composition and grain shape of the fraction, density and moisture content of the raw material, thickness of the material layer on the screen, the speed of the grains on the screen. As for the sieve, the following factors were: the sorting mode and its parameters - the amplitude and frequency of oscillations, the angle of inclination of the box, the shape and size of the holes of the sieve, the size of the surface of the sorting and the mode of operation of the sieve, which implements these parameters. It has been found that increasing the length increases the probability of passing particles through the screen, increasing the efficiency of the sorting. The working process of material sorting with successive movement of material particles in the field of harmonic and subsequently and shock-vibrational action is investigated. The evaluation of the sorting process and the parameters of this process are determined. It is proved that the use of common harmonic and shock modes of motion is effective. It is this hypothesis that is the basis of this study. The reliability of the direction is due to the fact that, when implementing the vibration damping mode of sorting, the force effect on the material particles is significantly increased. As a result, the possibility of self-cleaning of those openings in which material particles are stuck and the increase of efficiency and productivity of the sieve is realized. The design scheme is developed and the equations of the joint motion of the studied system are obtained. The solution of the equations is determined by dimensionless parameters, which serve as criteria for evaluation of the vibration shock mode of sorting. The determinated of changes in boundaries of dimensionless parameters that reflect the steady-state operation of a shock-vibration sieve, implementing an efficient sorting process in a mode that is close to resonant. A map of stability was provided and the vibration shock mode was provided at the main resonance. Experimental researches of efficiency of realization of joint vibration and shock mode of sorting on the newly created installation are carried out. Comparison of the parameters obtained by theoretical and experimental paths confirmed the reliability of the assumptions and assumptions adopted in the study. The algorithm of calculation of the "sieve - material" system is developed, the construction of a vibration damping crane is proposed, the novelty of which is confirmed by a patent for a utility model.

Key words: research, working, process, sorting, material, parameter, vibration screen.

INTRODUCTION

The sieves are widely used in construction, mining, chemical and other industries [1, 3-10]. A typical constructive scheme of the sieve is a mobile box, with a flat working surface installed in it as a screen or a bolter with openings [2, 3]. Generator of the motion of a box, as a rule, can be a mechanical [2] or an electromagnetic drive [6], generating external forces, which are the source of the sieve fluctuations. Most vibrating sieve operate in regression mode. Resonance modes are energetically most effective, however, practically not realized due to their low stability in linear resonance. This is due to narrow amplitude-frequency characteristic in the resonance zone, since even small changes in the load on the sieve result in it from the resonance mode and, as a result, to a sharp change in the working process parameters set by the technology. In addition to well-known studies on the direction of oscillation with the circular [1] or directed [2] movement of the working body of the sieve, the use of common harmonic and shock modes of motion deserves attention. It is this hypothesis that is the basis of this study of the mechanics of the process of sorting the construction materials on sieves Such choice of direction is conditioned by the fact that, when implementing the vibration shock mode of the sorting, the force effect on the material particles is significantly increased As a result, the possibility of self-cleaning of those openings in which material particles are stuck and, as a consequence, increases the efficiency and productivity of the sieve.

Thus, the problem is the development of a mathematical model of "sieve-material" which adequately reflects the real process of sorting and movement of the system as a whole, as well as the development of constructive solutions of the sieve with the implementation of the joint vibration and shock mode of sorting.

ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

In the mathematical description of the motion of the sieve, different approaches are used [1, 3, 12], which is the result of the huge number of constructive solutions of the sieves and their parameters [1-3, 7-10]. This is explained by the obvious fact of the emerging complexity of the process of taking into account the mass of the material in calculating the parameters of the sieve [3], the presence of such a phenomenon as the "debris" of screen sieve openings [2], determination of true productivity [16]. This approach forced researchers and designers to use empirical dependencies for a long time to determine the parameters of the sieve [2], derived from the processing the results of experimental studies. The reliability of such dependencies is valid only in the framework of the parameters and design characteristics of the working process used in the experiments to sorting, use of one or another material, with one or another granulometric composition. With the development of the theory of separation processes in the mining and processing industry [1], the development and creation of new designs of sieve in the construction industry [3, 16, 17, 18], there has been a tendency in the development of new calculation models. These models describe the process of sorting on the basis of deterministic and predictive representations and to a certain extent reflect the real picture of the motion of sieve mechanics.. One of the directions of the search for a model of adequate representation of the real sorting process is the methods of computer modeling of physical and technological processes based on the concept of discrete representation of a material - the method of particle dynamics (molecular dynamics) and the method of discrete elements [1, 2]. The method of discrete elements is considered as a justification of the method of finite elements. In the simulation of the sorting process, this method defines the initial positions and velocities of the particles, and then calculates the forces acting on each particle. The resulting force value is the source information for the next calculation. Such calculations are carried out throughout the whole process of the sorting process. An example of such a simulation is the graph (Fig. 1) obtained in [19].

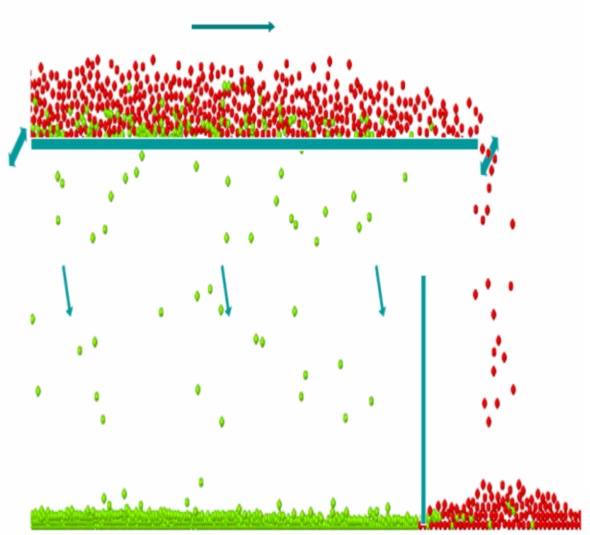


Fig. 1. The simulation painting of a steady sorting mode.

In work [19] a package of simulation of the dynamics of motion and mechanical interaction of a large number of particles of the friable medium is proposed, taking into account the interaction with the moving elements of the Bulk Flow Analyst TM classification equipment. However, a large variety of physical properties, granulometric composition, humidity and other characteristics of the material to be sorted is not taken into account in the quoted works [19] and does not solve the problem of creating a generally accepted mathematical model of "rumbling material". This conclusion is also confirmed by the fact that, besides the above-mentioned characteristics, the size of the screen cell affects the course of the process. Even the shape of a hole with a round or square gives a significant difference in obtaining the desired product with a given fraction composition. It is also possible to change the amplitude and frequency of oscillations, which leads to an increase or decrease in the number of contact grains with the surface of the screen. This can lead to a change in the conditions of self-cleaning the screen from grains that are stuck in the openings, resulting in a change in the efficiency and effectiveness of sifting. Also, the geometric sizes of the screen significantly affect such indicators as performance, efficiency of sorting, allocation of fine fractions from the source material. For example, in [20] (Fig. 2), it is noted that increasing the length of the screen increases the probability of passage of material particles through its openings, increasing, mainly, efficiency and only slightly increasing productivity.

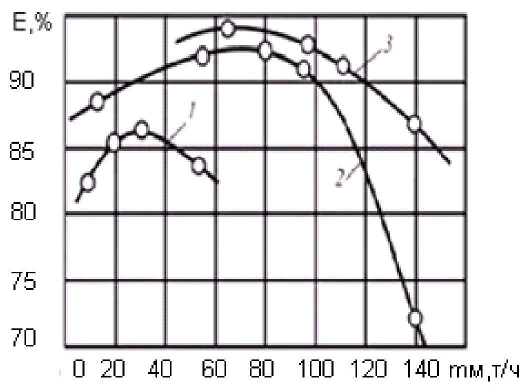


Fig. 2. The dependence of the efficiency of sifting E on the feed material on the sieve $m_{м}$ at a different length and constant width of the screen: 1, 2, 3 – the length of the screen, respectively, 800, 1600 and 2400 mm. the complexity of the sorting process on the sieve, attention is drawn to the work [21] (Fig. 3).

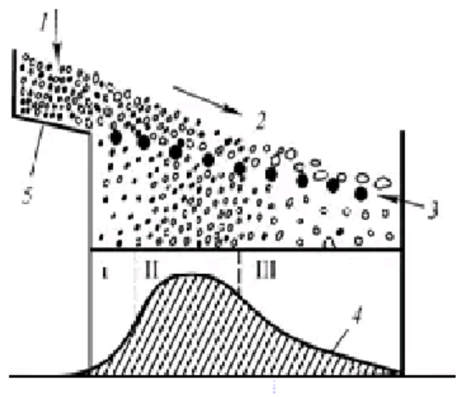


Fig. 3. Areas sorting: 1 – material, 2 – the direction of its movement, 3 – screen, 4 – ready product, 5 – the tray.

According to the author of the work, during the sort there are three characteristic areas of material passing, the formation of which depends on the velocity of particles passing: "In the first region (Fig. 3, I), the smallest the passage rate of the material due to the significant amount of material on the screen and insufficient segregation observed. In the second region (Fig. 3, II) there is a monolayer of particles and the speed of their passage is maximal. However, the close placement of particles does not allow them to bounce of the screen. . In the third region (Fig. 3, III), the sorting process is characterized by the absence of a monoshale, which leads to a small velocity of the flow of particles through a screen, since they have a disordered motion and the surface of the screen is not used completely "- the end of the quote. It is worth noting that such a division into zones is arbitrary, since the process of formation of so-called "areas" is largely determined not only by the parameters of the crash, but also by the parameters of the feeder and does not fully disclose the essence of the process.

OBJECTIVES

The order of study the working process of material sorting, we shall consider the progressive movement of the material particle in the field of harmonic and subsequently and shock-vibration for the purpose of evaluation of the process and for the analysis of the working process of the material sorting.

THE MAIN RESULTS OF THE RESEARCH

Without taking into account the influence of the neighboring grains and the inequalities of the screen, the motion of the grains with the diameter *d* (Fig. 4) in a screen with the size of the hole *D* under the action of the velocity *v* and gravitational forces can be expressed by the equations:

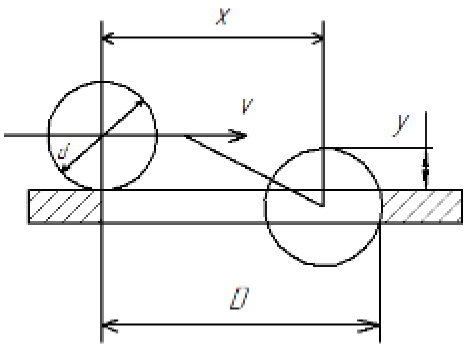


Fig. 4. Scheme of grains of the material on a screen.

$$y = \frac{gt^2}{2}; x = \upsilon t. \qquad (1)$$

Since $y = \frac{d}{2}, x = D - \frac{d}{2}$, then, solving the equation (2.1), we determine the relative velocity of the grains movement by screen:

$$\upsilon = (D - \frac{d}{2})\sqrt{\frac{g}{d}}. \qquad (2)$$

In order for the grain to move along the screen, it needs to provide an acceleration that develops the force of inertia that exceeds the forces of resistance. In vibrating sieve with directional oscillations, the working surface carries out harmonic oscillations with the amplitude X_0 and the frequency ω by law

$$x = X_0 \sin \omega t. \qquad (3)$$

The direction of oscillation forms the angle (Fig. 5):

$$\beta \angle \frac{\pi}{2}.$$

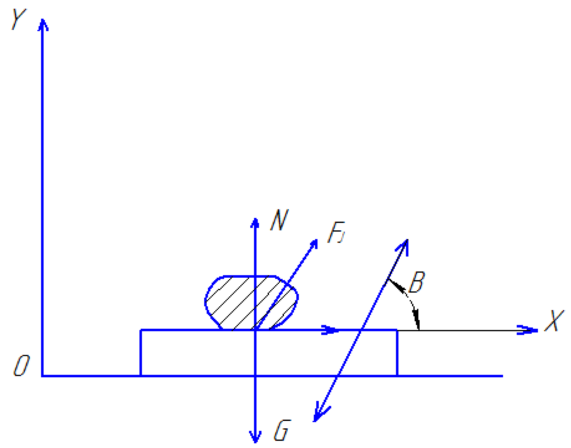


Fig. 5. Pattern of motion a material particle on horizontal surface.

To determine the motion of the vibrating mass *m* acting on the plane to mass forces (gravity G, friction $F_т$ and normal reaction N) should be added inertia F_i equal to the product of mass m to accelerate the plane $\ddot{x} = -X_0\omega^2 \sin \omega t$ and directed by Angle β to the horizontal.

Then the equation of the relative motion of the mass m of projections on the axes XOY, related to the vibrating surface will look like this:

$$m\ddot{x} = mX_0\omega^2 \cos\beta \sin\omega t + F_m;$$
$$m\ddot{y} = mX_0\omega^2 \sin\beta \sin\omega t - mg + N, \qquad (4)$$

where: $F_т$ – friction, associated with movement of particles in the plane $(y = 0)$ of the normal reaction *N* ratio:

$$F_m = -fN, \ddot{x} > 0; \quad F = +fN, \ddot{x} < 0, \quad (5)$$

where: *f* – coefficient of friction sliding..

In this case, the normal reaction can be determined from the second equation (2.4):

$$N = N(t) = mg - mX_0\omega^2 \sin\beta \sin\omega t.. \quad (6)$$

Moving the material forward in the plane (x> 0) is provided on condition:

$$mX_0\omega^2 \cos\beta \sin\omega t \geq F_m. \qquad (7)$$

Taking into account frictional forces $F_т$ and normal reaction we have:

$$mX_0\omega^2\cos\beta\sin\omega t \geq mgf - mX_0\omega^2\sin\beta\sin\omega t\sin\beta f, \quad (8)$$

where we determine the angular velocity necessary to move the material forward in a screen:

$$\omega = \sqrt{\frac{gf}{x_0\cos\beta\sin\omega t(1+f)}}. \quad (9)$$

It is likely that the minimum values of the angular velocity correspond to the position of the vibrational debalance, in which $\omega t = \frac{\pi}{2}$. Then the angular velocity:

$$\omega_0 = \sqrt{\frac{gf}{x_0\cos\beta(1+f)}}. \quad (10)$$

To clean the screen from stuck grains and to better separate the material, it is necessary to throw the material over the screen. The flight conditions of particles over a plane follow from equations (4) with

$F_m = N = 0$:

$$m\ddot{x} = mX_0\omega^2\cos\beta\sin\omega t;$$

$$m\ddot{y} = mX_0\omega^2\sin\beta\sin\omega t - mg. \quad (11)$$

Hence the conditions for pouring particles over the screen:

$$\frac{x_0\omega^2\sin\beta\sin\omega t}{g} \geq 1. \quad (12)$$

Minimum angular velocity required to allow particles to pass over the screen.

$$\omega = \sqrt{\frac{g}{x_0\sin\beta}}. \quad (13)$$

In inertial sieve with circular oscillations, the direction of inertia is determined by the angle of rotation $\psi = \omega t$ unbalances, and the total value of the inertia force per revolution of the unbalance is zero. Therefore, the surface of the sieve should be sloping so that the additional force $Q = G\sin\alpha$ (Fig. 6).

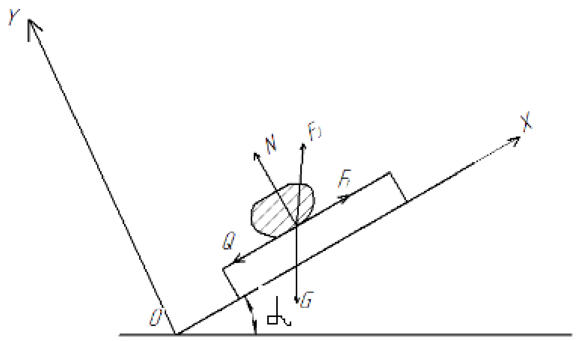


Fig. 6. Scheme of motion of particles on a sloping vibrating surface.

The equation of relative motion of particles in this case will look

$$m\ddot{x} = mX_0\omega^2\cos\beta\sin\omega t + Q \pm fmg;$$

$$m\ddot{y} = mX_0\omega^2\sin\beta\sin\omega t - G\cos\alpha + N. \quad (14)$$

For the right part of the first equation (14) the expression for slip friction is already substitute: the upper sign corresponds to sliding forward $(\dot{x} \succ 0)$, and the lower one – to slip backward $(\dot{x} \prec 0)$.

The material down the screen will move if the sum of the force *Q* and the inertia force p exceeds the resistance forces. In this case, the force *Q* promotes the movement of particles down the screen and prevents their movement in the opposite direction.

The minimum angular velocity required to move the material over the screen and which corresponds to $\varphi = \omega t = 0,$ are determined from the condition of equation (15):

$$\omega = \sqrt{\frac{g(f - \sin\alpha)}{x_0}}. \quad (15)$$

The maximum thrusting force will be provided with $\varphi = \omega t = \frac{\pi}{2}.$ Consequently, the minimum angular velocity required for particles to pass,

$$\varphi = \omega t = \frac{\pi}{2}. \quad (16)$$

Now consider the working process of the shock-vibration sieve, which can be represented by the resulted calculation scheme (Fig. 7a), in which the bottom frame of the sieve, based on the condition of its vibration isolation (the amplitude of its oscillations is 10 times smaller than the amplitude of the sieve), is still, and the box, carrying out oscillations, interacts with the particle material. Such an assumption will allow us to evaluate the parameters of the vibro-impact interaction process of the screen and the material particles, and proceed to the compilation and solution of the equation of motion of the general dynamic system "vibration damping – sorting material".

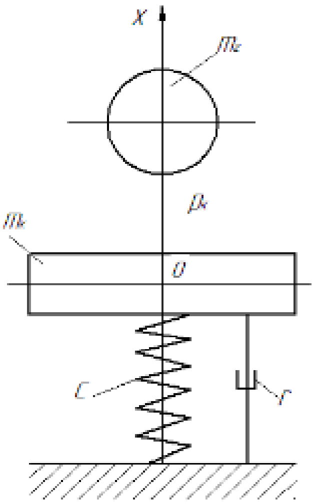
Under the action of the external action of the excitator, for each period of the fluctuations T (curve 1, Fig. 7, b), the mass of the box *M* and the mass of the particle *m* are collided, leaving the particle, having received the initial velocity, directed upwards, rises to a certain height *h* (see Fig. Fig. 7, a), and then by law in the form of a parabola (curve 2, Fig. 7, b) falls on a screen. Since it is assumed that work mode of the system under study is nonlinear (shock - vibration), then to estimate the movement of a material particle in conditions of interaction with the screen of the box, use the known ratio of velocities before and after impact [10] :

$$R = (\nu_2 - u_2)/(\nu_1 - u_1), \quad (17)$$

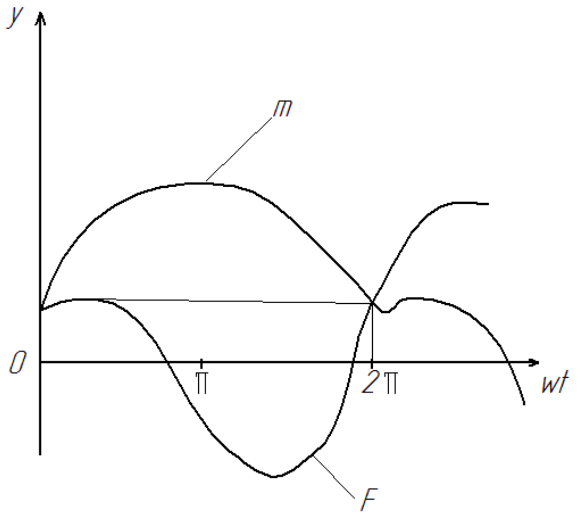
where *R* is the rate recovery rate, which represents the ratio of the relative velocity of the box and the sieve after impact, $\nu_2 - u_2$ to their relative speed before impact. In (1) ν_1, ν_2 – the speed of the box before and after the impact, u_1, u_2 – the velocity of the particle before and after the impact, respectively. As follows from Fig. 2, b, on the boundary between the collisions of the sieve box and the particle of the material is a fair condition:

by $t = 0; x_{\hat{e}} = x_{\div} = x_0 : x_{\hat{e}} = v_2 ; x_{\div} = u_2$, (18)

by $T = 2\pi / \omega; x_{\hat{e}} = x_{\div} = x_0 ; x_{\hat{e}} = v_1 x_{\div} = u_1$ (19)



a



b

Fig. 7. Scheme of the process of interaction of a material particle with a screen box *a* and their change of motion *b*.

On the interval between the singers, the particle moves according to the law:

$$x_{\div} = x_0 + u_2 t - gt^2 / 2 \qquad (20)$$

To determine the particle velocity before and after the collision with the screen box we use the above boundary conditions (19) and (20) Substituting them into the equation of motion of the particle (21) we obtain the particle velocity to the impact

$$u_1 = -\pi g / \omega. \qquad (21)$$

The velocity of the screen movement before and after collision with the particle is determined on the basis of the pulse theorem [10]:

$$\begin{aligned} v_1 &= [1 - R + 2K_e R / (1 + R)]u_2 \\ v_2 &= [1 - R - 2K_e R / (1 + R)]u_2 \end{aligned} \qquad (22)$$

where $K_e = m_i \,/\, m_{\hat{e}}$ – coefficient of payload which determines the ratio of mass of material, which is on the screen in the process of sorting it to the mass of the box.

The calculation scheme of the vibration damping sieve, taking into account all masses, is a system consisting of two masses (Fig. 8):

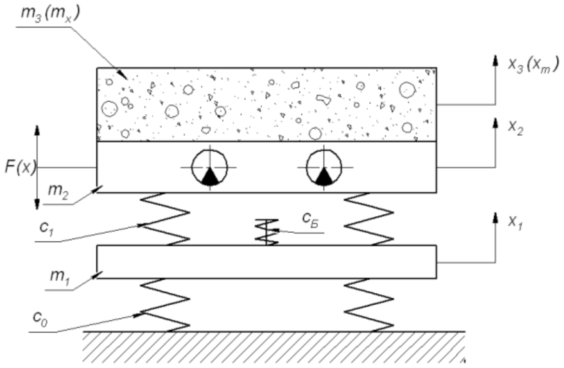


Fig. 8. Scheme of vibration damping system "sieve – material", C_0 – coefficient of elasticity of the lower mass, C_1 – the coefficient of elasticity between the lower and upper masses, $C_б$ – limiter of fluctuations of the upper mass (box).

Consider the equation of motion of such a system, we find the parameters that make it possible to provide a stable vibration shock mode. To simplify the scheme in the first stage, we assume that the movement of the box and the material is common. Then $x_2 = x_3$, the material mass m_3 is counted as attached to the mass m_2. The dissipative component will be taken into account at the final stage of the calculation.

Then the kinetic energy of the system:

$$T = \frac{1}{2}(m_1 \dot{x}_1^2 + m_2 \dot{x}_2^2). \qquad (23)$$

Potential energy consists of energy of weight Π_1 and energy of elastic forces Π_2 .

$$\Pi_1 = m_1 x_1 g + m_2 x_2 g. \qquad (24)$$

We make an expression for the potential energy of elastic forces. We denote f_{1cm} and f_{2cm} the compression of the springs in the position of equilibrium due to the action of weight:

$$f_{1cm} = \frac{1}{c_0}(m_1 + m_2)g;$$

$$f_{2cm} = \frac{1}{c_0} m_2 g. \qquad (25)$$

We find the compression f_1 and f_2 of the springs and with oscillations:

$$f_1 = f_{1cm} - x_1; \quad f_2 = f_{2cn} - (x_2 - x_1). \qquad (26)$$

Then

$$\Pi_2 = \frac{1}{2}(c_0 + f_1^2 + c_1 f_2^2), \qquad (27)$$

After simple transformations, we obtain the expression of potential energy:

$$\Pi = \Pi_1 + \Pi_2 = \frac{1}{2}(c_0 + c_1)x_1^2 - c_1 x_1 x_2 + \frac{1}{2}c_1 x_2^2. \quad (28)$$

Because $\frac{\partial T}{\partial \dot{x}_i} = m_i \dot{x}_i$, a $\frac{d}{dt}\cdot\frac{\partial T}{\partial \dot{x}_i} = m_i \ddot{x}_i$, then, taking into account expressions (23) – (28) we have the equation:

$$\begin{aligned} &m_1 \ddot{x}_1 + (c_0 + c_1)x_1 - c_1 x_2 = 0, \\ &m_2 \ddot{x}_2 + c_1 x_2 - c_1 x_1 = F_0 \cos\omega t \end{aligned} \quad (29)$$

Equations (29) reflect the movement of the system when the contact between the masses is violated. In the same way we obtain the equations for the joint motion of masses m_1 i m_2:

$$\begin{aligned} &m_1 \ddot{x}_1 + (c_0 + c_1 + c)x_1 - c_1 x_2 = 0, \\ &m \ddot{x}_2 + (c_1 + c_2)x_2 - (c_1 + c)x_1 = F_0 \cos\omega t \end{aligned} \quad (30)$$

The difference between equations (29) i (30) lies in the presence of (30) the boundary $C_б$, which is a key parameter that affects the stability of the system fluctuations in the material needed for sorting the material mode by the corresponding fractions.

The resulting system of equations (29), (30) can be somewhat simplified, given that ($c_0 << c$) and the obvious connection $x = x_1 + x_2$. Taking these conditions and subtracting from the second equation first, we obtain the form of the equation (29), (30), for x <0 (no contact):

$$\ddot{x} + c_1\left(\frac{1}{m_1} + \frac{1}{m_2}\right)x = \frac{F_0}{m_1}\cos\omega t \quad (31)$$

For x>0 (motion in contact):

$$\ddot{x} + (c_1 + c)\left(\frac{1}{m_1} + \frac{1}{m_2}\right)x = \frac{F_0}{m_1}\cos\omega t. \quad (32)$$

The number of variables in the resulting equations (31), (32) can be reduced by applying new dimensionless parameters (time τ and coordinate η):

$$\begin{aligned} &\tau = \omega t; \;\; \eta = \eta_1 - \eta_2; \;\; \alpha = m_1 / m_2; \\ &\eta_1 = \frac{m_2 x_1 \omega^2}{F_0}; \;\; \eta_2 = \frac{m_2 x_2 \omega^2}{F_0}. \end{aligned} \quad (33)$$

Taking into account that $(\ddot{x}_i)_t = \omega^2 (\ddot{x}_i)_\tau$ by substituting (33) into (31) and (32) and simple transformations, we obtain a new system of equations:

$$\begin{aligned} &\alpha\eta_1 - \eta_2 = -\sigma\cos\tau; \\ &\ddot{\eta}_2 + \xi_1\eta_2 = -f - \alpha\cos\tau; \\ &\ddot{\eta}_2 + \ddot{\xi}_2\eta_2 = -f - \sigma\cos\tau; \end{aligned} \quad (34)$$

In the new system of equations the following relations are taken:

$$\xi_1 = \sqrt{\frac{(m_1 + m_2)c_1}{m_1 m_2 \omega^2}},$$

$$\xi_2 = \sqrt{\frac{(m_1 + m_2)}{m_1 m_2}\frac{(c_1 + c_2)}{\omega^2}}, \quad (35)$$

$$f = \frac{m_2 g}{F_0}\left(\frac{m_1 + m_2}{m_2}\right), \quad (36)$$

A sign σ of the equations (34) takes into account the phase of coercive force.

Parameter ξ_1 determines the ratio of the eigen frequency of the fluctuations of the "sieve-material" system in that part of the period when there is no bundle of mass between them to the frequency of forced oscillations ω^2.

Parameter ξ_2 defines the ratio of the eigen frequency of the fluctuations of the "sieve-material" system in that part of the period when the blow occurred and the masses move together with the frequency of forced oscillations ω^2 The parameter *f* defines the ratio between the given weight and the external force of the oscillator vibrator. Consequently, at given values of the masses of the sieve m_1 and m_2, which are to be determined, there is the stiffness of the elastic elements c_1, $c_б$, and i is the static moment of the mass of the disturbances $m_0 r_0$, since the frequency of forced oscillations ω is usually given by the material sorting technology. In doing so, one must take into account the fact that in addition to finding parameters ξ_1, ξ_2 and f it is needed to know the time of contact mass τ. Obviously, it represents a certain part of the entire period of fluctuations.

Thus, the parameters $\xi_,\ f_,$ and τ determine the mode of operation, which is realized under the conditions (31) and (32).

When these conditions are realized, the movement of the masses will be carried out with a separation between them with variable blows between them through the buffer. In this case, the following modes are possible: one-strike, that is, during one period of mass movement, carry one free flight, respectively, one hit on the spring, superharmonious, when during a single period n of change of the forced frequency. There are several strokes, subharmonic when the number of strokes is less than the period of change of the forced frequency. In any case, the sequence of determining the parameters included in (35) and (36) consists of the following operations: the equations of motion of the system are in the segregated and unbroken modes, Then, to reduce the number of parameters, the equations are reduced to dimensionless form and the initial conditions for moving, velocities and time are determined, The given initial conditions are taken into account in the equations of motion and at the final stage the obtained equations of motion of the system in the contact and without contact are equated, which is caused by equal velocity values mass and spring at a time that corresponds to the transition from contact to contactless mass motion. The next step is to determine the change in the limits of parameters that reflect the steady-state operation of the shock-vibration sieve, implementing an efficient sorting process. Since shock-vibration machines operate in a mode that is close to resonance, it is likely that the prediction is that $\xi \geq 1$. Based on the expression for its own oscillation frequency, we can determine the contact time of the masses with the oscillation limiter:

$$t_{\kappa} = \frac{2\pi}{\omega_0} = 2\pi\sqrt{m/c} \qquad (37)$$

In (37) under the weight *m* is the reduced mass of the system $m_1 m_2 / (m_1 + m_2)$, and the coefficient of elasticity with the sum *c* of the coefficients $c_1 + c_{\hat{a}}$.

Its average values can be taken as, $\tau = \frac{1}{3}T$,

where *T* – is the period of fluctuations of the "sieve - material" system.

On the basis of the performed research, a map of stability of the vibration damping mode of the sieve was constructed, which makes it possible to determine the parameters ξ and f for the implementation of specific conditions and sorting mode (Fig. 9).

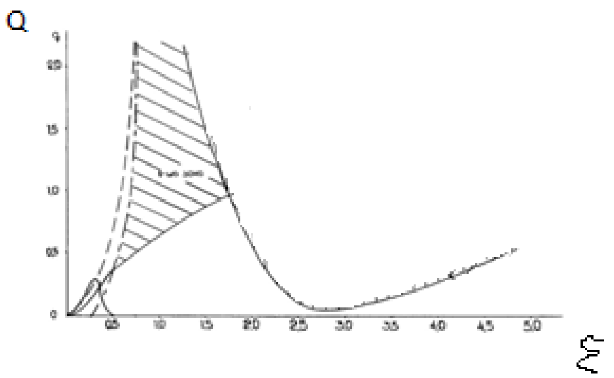


Fig. 9. Map of the stability of the vibration damping sieve for the implementation of the first stage of the stability of its work.

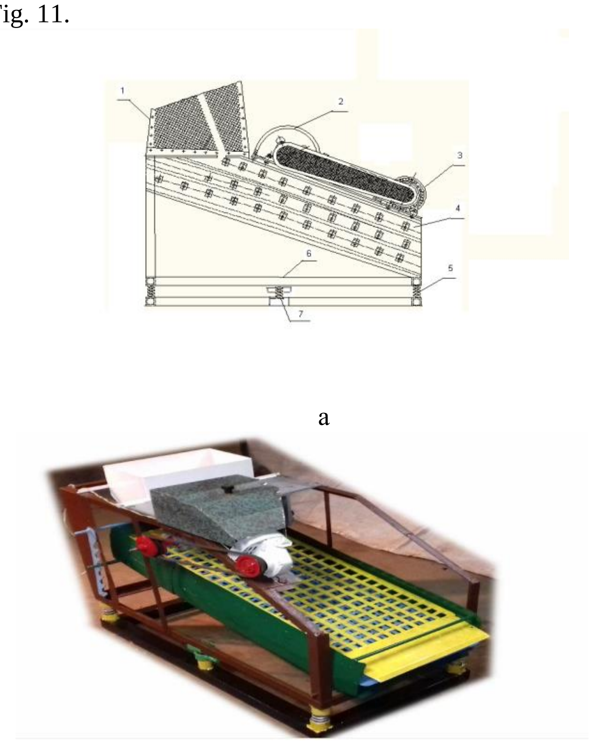
For the purpose of conducting experimental experiments, an installation (Fig. 10) was developed and made, which was a vibrating sieve with the ability to change the screen, adjust amplitude and frequency of oscillations in wide bands [17, 18].

Variable parameters in conducting experiments, in addition to the amplitude and frequency of oscillations, were the angle of inclination of the screen, the speed of the material on the sieve screen, the thickness of the material.

The screen were picked up depending on the fractional composition of the gravel with the appropriate size of the apertures. In accordance with the research methodology, a series of experiments was conducted, the parameters of the sorting process were recorded by special sensors. Their values were fixed on the computer display and entered in the table.

The next stage of research was based on graphs and compared the results of performed experiments with the estimated values of the results of theoretical studies.

The process of sorting with two screen for distribution into small and large fractions is shown in Fig. 11.



a

b

Fig. 10. Experimental vibration damping unit for sorting crushed stone: a – scheme, B – general appearance, 1 – bunker, 2 – box, 3 – drive, 4 – screen, 5 – bearings, 6 – frame, 7 – buffers.

Fig. 11. The process of sorting rubble on two vibrogram vibrating screen.

Comparison among themselves the results of the experiments with the calculated values of theoretical studies have shown satisfactory in the trials, the difference in the values of the unknown parameters. For example, the difference between the amplitude of oscillations sieve, obtained in the experiments and the calculations amounted to 14% and power – 17%. Fig. 12 shows an example of vibrogram vibrating amplitude changes that obtained in experiments and theoretical calculations performed.

The proposed algorithm for calculating the dynamic "sieve - material" system involves the following implementation procedure.

The first block involves making decisions on the values of output parameters: the required performance, fractional composition of the material and its density, necessary for this sorting process amplitude and frequency of oscillations. The second block includes the calculation: the fractional composition of the grinding products for the upper and lower screen of a two-sided sieve , the size of the holes for the corresponding screen, screen area and its size (length and width), sorting efficiency, Angle of inclination, Structural and technical characteristics of the sieve(the mass of the sieve and the material to be sorted, the elasticity of the supports and the buffer, the static moment of mass unbalance and the engine power), criteria of stability of the vibration damping mode of operation.

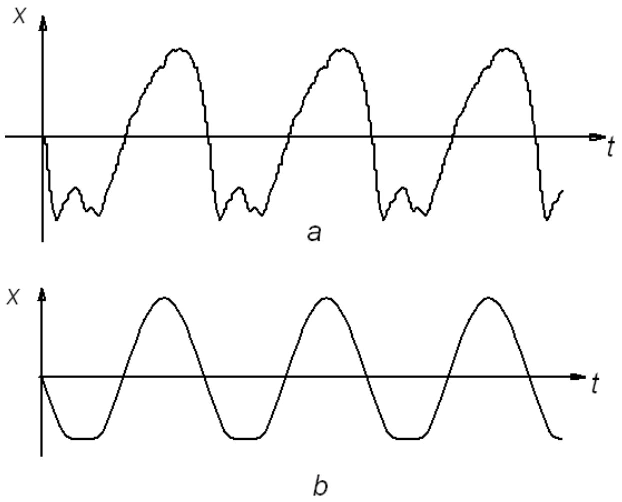


Fig. 12. Change in the amplitude of the oscillation of the screen, obtained in experiments *a* and performed in the calculations *b*.

The third block represents the verification of the obtained results: the numerical values of the amplitude and frequency of oscillation stability of the resonant vibration shock mode, On the basis of the algorithm the method of engineering calculation of the parameters of the "sieve - material" system is developed, the construction of the vibration damping crane is proposed, the novelty of which is confirmed by the patent for the utility model.

CONCLUSIONS

1. The performed review and analysis showed that improvement of the model of the system "vibration damping roller - sorting material" that adequately reflects the actual process of sorting is needed.
2. The working process of material sorting with the consistent movement of material particles in the field of harmonic and shock-vibrational action is investigated.
3. A calculation scheme is developed and the equations of the joint motion of the investigated system are obtained, the solutions of which are dimensionless parameters that serve as criteria for assessing the vibration-shock mode of sorting.
4. Determination of changes in boundaries of dimensionless parameters that reflect the steady-state operation of a shock-vibration sieve, implementing an efficient sorting process in a mode that is close to resonant. A map of stability was provided and the vibration shock mode was provided at the main resonance.
5. Experimental researches have been carried out to determine the influence of the amplitude and frequency of oscillations with different angles of the crater box inclination on the course of the crushing process. Comparison among the results of the performed experiments with the estimated values of the results of theoretical studies showed satisfactory, in the framework of the conducted research, the discrepancy in the values of the desired parameters.
6. The algorithm is proposed and the method of calculating the parameters of the "sieve-material" system is developed, the construction of the vibration damping crane is proposed, the novelty of which is confirmed by the patent for the utility model.

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RESEARCH OF BIOGAS METHANE FERMENTATION OF AFTER ALCOHOL BARD

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Summary. It is discovered that low yield of biogas is a significant problem when of biogas plants are operating on liquid manure, which reduces the profitability of such facilities. Therefore, to increase the yield of biogas co-substrates are used. Co-substrates are substrates with significant biogas yield – grass, silage corn and beet tops, grain and more. It is noted that the above listed substrates have good feeding value, so to increase the productivity of biogas plants it would be appropriate to use its wastes while ensuring their utilization. It is also noted that such substances could be wastes oil production - oil precipitate, oilcake and expeller, products of biodiesel production – raw glycerin, wine production wastewaters. It is noted that the use of additives in agricultural animal's manure allows 2-3 times productivity increase of biogas plant. Identified disadvantages of using this waste as co-substrate: fermentation cake and meal produced biogas with a significant concentration of sulfur-hydrogen due to high content of proteins, oil precipitate and crude glycerol resources are limited, wine production facilities are concentrated in areas of growing grapes at the same time wastewater transport over long distances is not profitable.

It is therefore advisable to determine other, more common wastes that would significantly increase biogas yield. It was recommended to use alcohol bard as a co-substrate – liquid waste of ethanol that could be used as animal feed, but it is often simply poured down the drain. An impact of alcoholic bard on biogas yield was experimentally studied. An experimental study included research of pure co-substrate fermentation and as additive to cattle manure It was discovered that the maximum yield of biogas produced using alcohol bard added to cattle manure in proportion 40-80% has increased 4,8-5,5 times compared to pure cattle manure fermentation. Digestion of pure bards compared with bard-manure mixture increased the maximum biogas output to 1,6-1,8 times. Since bard's intensive fermentation occurs within 1-2 days, after which the biogas yield is sharply reduced due to low content of organic dry matter, the bards fermentation should be performed during gradual mode of digester's load. It was determined that biogas obtained with the use of alcohol bards is high energy biogas with value of the methane content of 70-78%.

Key words: biogas digesters, co-substrate, alcohol bard, cattle manure, biogas plant, digesters, gas-holder.

INTRODUCTION

The main substrate for biogas production is animal wastes (manure of cattle, pigs, poultry, etc.), which, however, is characterized by relatively low productivity of biogas. The production of the full cycle biogas fermentation of cattle manure of 117 days is 237 liters/kg. That is, the average overnight gives about 2 liters of biogas from 1 kg of substrate. In practice, because of low biogas yield complete cycle of methane fermentation is not preserved. Biogas output during the first 10-20 days of fermentation is 5,7 liters/kg. With this productivity of 90-93% biogas in the autumn-winter-spring period and 64-83% in summer mode at mesophilic (fermentation temperature is 40°C) is spent on supporting thermal balance of concrete digesters [1].

Therefore, a significant problem for biogas plants that uses livestock biological processes waste as a substrate is small biogas productivity, leading to their low profitability [11]. To improve performance of biogas plants to add manure co-substrates [12] – substrates with significant biogas yield: grass, silage corn and beet tops, grain and more.

ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

Corn is the substrate, which is most commonly used in agricultural biogas plants due to high yields (350-650 kg/ha), of fermentation effective biomass. Corn biomass is silaged for storage purposes, which does not affect the efficiency of methane fermentation. After 3 month silage can be used in biogas plants. Out of biogas from green mass of corn and corn silage is 170-230 m^3 per ton of substrate with methane content of about 53%.

Recently started practicing joint cultivation of maize and sunflower. Because corn contains little amounts of fat (2-3% of dry matter), fat contents is trying to be increased by simultaneous cultivation of sunflower, thereby increasing the production of biogas. However, by itself sunflower is difficultly sillaged, so combination of sunflower and maize (that is easily silaged) is very successful.

In practice, along with the use of entire plants, some importance has the use of corn cobs. Depend on the methods and harvesting periods following biomass could be used: expeller of corn cobs rods, a mixture of rods and grain corn cobs and corn grain. expeller of corn cobs rods and a mixture of corncobs rods and seed is often silaged. Corn seeds can be either silaged when it is wet or process to expeller and then silaged, or dried. The energy density of these substrates is significantly higher compared with corn silage, but the energy output on the area is less because plant residues on the field.

To improve performance of biogas plants is also used silage from solid grains. Almost all crops and mixtures of them are suitable for its production, if they are ripened at once. Depending on local conditions for cultivation should be chosen mainly grain crops, which can provide the greatest yield of dry matter. For most regions is rye or triticale. The output of 170-220 m^3 of biogas per ton of substrate with methane content of about 55%.

Grass mixtures and grass silage are also used to enhance the production of biogas. However, grass mixtures with stirring tends to intertwine. Therefore, careful attention should be paid to grinding and selection of proper mixing equipment. Out of biogas production using mixtures and grass silage is 170-200 m^3/ton of substrate with a content of methane of about 55% [7].

However, keep in mind that the high concentration of proteins with a high content of grass mixture, green corn biomass or it's silage in the substrate may delay bacterial growth. [10]

Grain corps can also be used as a complement to the range for biogas co-substrates for biogas digesters. Due to significant biogas output (620 m^3/ton substrate with methane content of about 50%) and quick decomposition it becomes very suitable for fine control of biogas production process. This type of grain crops does not play a significant role. To ensure rapid transformation into a fibrous mass it is important that the dose of corn was crushed beforehand [7]. The use of grain as co-substrates have a positive effect on the production of biogas: the part of substance that easily decomposes, increases the activity of bacteria, leading to increased degree of decomposition of the main substrate in fermenter. In addition, if the substrate has a tendency to form a floating crust, it is important to include gain wastes to the mixture of substrates. Grain decomposes very quickly and leads to rapid overacidation. Due to the high protein content in grain the risk of delay in the development of bacteria is increased because the action of ammonia [10]. The experiments of adding flour to the cattle manure as a substrate showed that one should not admire co-substrate, because the methane content in biogas decreases, and fermentation may slow down or stop completely.

However, these substrates have feeding and nutritional value because of their massive use could lead to reduction in the production of feed and food.

Thus, the problem of determination of inexpensive farm animals manure additives (co-substrates) that could significantly increase the biogas yield and hence increase the profitability of biogas plants arises [123].

As it was found in literature following additives was researched in a role of co-substrate waste from the production of vegetable oil - oil precipitate [1], oilcake and expeller [10] (oilcake is 4-6% fat in the expeller – 1-2% [9]), from production biodiesel - raw glycerol [2] wine production wastewaters [3]. The use of these additives to farm animals manure allows 2-3 times biogas plant productivity increase.

When adding glycerol to the substrate biogas output intensity increases dramatically. The maximum biogas yield is observed on 2-5 day of fermentation and then descends as sharply. Often there is repeated growth of biogas yield, which maximum biogas output is mostly slightly lower. This type of methane fermentation is called diauxy and is explained as follows: after depletion of nutrients of particular type culture of methane generating bacteria enters the second lag-phase to prepare for the supply of other nutrients. Intense fermentation period without diauxy is 4-6 days with diauxy – 7-13 days. Excretion (1) show approximation of dependencies of maximum biogas yield, value of added glycerol into cattle manure and fermentation temperature when R^2=0,9999 [14, 15]:

$$
\begin{aligned}
Q = {} & 6\cdot 10^{-5}\cdot \mathrm{T}^2\cdot \Gamma^3 - 0{,}0047\cdot \mathrm{T}\cdot \Gamma^3 + 0{,}102\cdot \Gamma^3 - \\
& - 0{,}00086\cdot \mathrm{T}^2\cdot \Gamma^2 + \\
& 0{,}0633\cdot \mathrm{T}\cdot \Gamma^2 - 1{,}452\cdot \Gamma^2 + \\
& + 0{,}00168\cdot \mathrm{T}^2\cdot \Gamma - 0{,}0604\cdot \mathrm{T}\cdot \Gamma + \\
& + 2{,}826\cdot \Gamma + \\
& 0{,}000254\cdot T^2 + 0{,}0157\cdot T - 3{,}349
\end{aligned}
$$

where: Q – biogas output, l/(kg·day), G – glycerin content in the substrate relative to the content of cattle manure, %, T –- fermentation temperature, °C.

When using the batch load mode and use oil precipitate as an additive to the substrate, the output of biogas is identical to as if using glycerin as additive to the same substrates. It is also appeared to be 2,5 times higher when using no additives. Using progressive substrate load method biogas output can raise in 4,5-10 times, similar to the use of crude glycerin as an additive to the substrate. When using oil precipitate as co-substrate maximum biogas yield observed on 20 day of fermentation, while using crude glycerol fermentation is more intense and its attenuation observed for 4-5 days [1]. The heat of biogas combustion from a mixture of cow manure and oil precipitate was (determined by the method [13]) at the initial fermentation stages (the first five days) is 13-15 MJ/m^3, with the subsequent increase to 19-20 MJ/m^3, while the heat of biogas combustion derived from a mixture of cow manure and crude glycerol during the entire fermentation period is 17-18 MJ/m^3 [1].

Wine production wastewaters can be used to partially replace water when preparing substrates to produce biogas. Studies have shown that in all cases, the use of wine production wastewaters diauxy was observed, the same ne as if using two-component substrates. Two biogas output was observed. When fermentation substrate was produced with the addition of pure water, diauxy was not observed. When adding 3% wine production wastewaters to the water mixture the first maximum of biogas output was observed on the third day of fermentation. Biogas output was little – around 150 cm^3/hr. After a relatively long period of bacteria adjustment to the second component of the substrate during the second phase exponential phase appears on 24-30 day of fermentation. At this time, the maximum output of biogas slightly exceed 250 cm^3/hr. After 30 days of fermentation begins bacterial colonies are beginning to die because of nutrient depletion and accumulation of metabolic products of anaerobic microorganisms, resulting biogas yield is gradually reduced. Sometimes for long fermentation period, the fermentation time can reach up to two months. With increasing concentrations of wine production wastewaters the intensity of first exponential phase increases significantly while time is reduced. The maximum biogas yield appears when using 11% wine production wastewaters additives is 350 cm^3/hr., when using 22% output is about 600 cm^3/hr. Maximum output of biogas is observed on the second day of fermentation. The second exponential phase is not expressed clearly and when 11% additive fermentation appears on day 5, when using concentration 22% on day 11. Smaller content of wine production wastewater in the substrate does not significantly improved biogas output compared to using ordinary water [16, 17].

However, when using oilcake and expeller as a substrate, the produced biogas contains high concentration of hydrogen sulfide, which could be explain by high protein contents [7]. Oil precipitate and crude glycerol resources are limited, wine production wastewaters located in the areas of growing grapes, causing transportation over long distances unprofitable. Therefore, it is advisable to determine more common wastes for the role of co-substrates that would significantly increase biogas yield.

Alcohol bard may be used as an alternative to mentioned co-substrates as a large-scale liquid product of ethanol production industry. It is partially used as a liquid feed additive and partly drained to treatment plants that significantly harms the purification process. In this regard, the issue of recycling of the alcohol bards is very relevant, especially in summer, when animals fattening is carried out in pastures. Lack of liquid bard utilization can cause even production stop. That is why alcohol bard obtained as the result of ethanol production, is a promising feedstock not only as feed production, but also as as co-substrates for biogas production [19].

There are 44 distilleries registered in Ukraine [4], which totally produced 14,5 mln. dekaliters of ethanol in 2014 only [5]. The output of alcoholic bard is 135-150 m^3 of ethanol per 1000 dekaliters [6], that resource of is very significant. There are around 4 million. m3 of molasses and 3,6-3,8 mln. m^3 grain bard, and about 8 mln. m^3 of slightly contaminated wastewater I produced in Ukraine annually. These wastewater without treatment cannot be drained into water. On the mosts of the plants molasses bard is not being utilized and is drained without purification with sewage into settling tanks where the rot, polluting groundwater and air [18].

It is known that biogas yield of grain bards is 30-50 m^3/ton of substrate with methane content of about 56%, for potato bard the measures are following: 26-42 m^3/ton of substrate with methane content of about 52% [7].

However, the use of raw bards in most cases only possible to a limited extent due to low content of dry matter in it (about 6%) and the associated difficulties with transportation. The bard is evaporated [7] or dried before used.

Technology Bards preparation before use is as follows.

1. Mechanically divided bard into the wet precipitate of insoluble materials (pellet) and filtrate with substances diluted in it. Using separators and centrifuges would be the best for this purposes.

The result is 10 tons of pellet with humidity of 65% and 90 tons of hot filtrate containing dissolved solids, salts and acids of about 4% in it.

2. The pellet is dried in a simple and reliable way, preferably without the additional cost of steam, because not all boiler-house would tolerate additional load. There is appropriate equipment that allows to remove 6 t of moisture (6% of total weight). The process will be easier if the pellet is pre-mixed with dry grain shells that would absorb the part of th moisture due to its capillary-porous structure. It is easier to extract this moisture from the overall increased surface at low relative humidity.

3. The liquid filtrate is separated by membranes methods resulting 25% of the creamy brown concentrate (16 tons) and clean hot water (74 tons). Modern two-stage ceramic membranes facilities, makes it possible to reliably perform this separation even at high temperatures filtrate up to 100°C inclusive. There are techniques able to increase the percentage of division by obtaining multiple filter layer with addition of special additives to initial bard. Salt content in the water two times lower than in tap water, so it is beneficial in bringing back to the process of alcohol production.

4. Protein Concentrate also be dried on a different type of drying device with a higher strain in whole space of the dryer to moisture. Removing of the moisture by drying in the amount of about 12 tons (12% of the total initial weight) is quite difficult process too.

Thus, two dry products with different biological value and different cost are obtained as the output [20].

However, as the bard is easily decomposed, in anaerobic conditions environment overacidation occurs quickly. Therefore, when using pure bards only two-stage technologies should be used not to overload the methane bacteria. When using co-fermentation with other agricultural substrates for single-stage technology, they should be carefully selected, but due to the high water content in bard it is good material to use with dry matter content [8].

OBJECTIVES

The aim of the research is experimental determination of alcohol bards impact on the biogas yield and its energy after fermentation in pure form and using as co-substrates additives to cattle manure.

THE MAIN RESULTS OF THE RESEARCH

The effect of alcohol bards on biogas yield were conducted on laboratory biogas plant of National University of Life and Environmental sciences of Ukraine (Fig. 1).

Biogas plant consists of a cylinder with a conical bottom part digester volume of 29 m^3 and a wet gasholder with effective volume of 13 liters. Temperature in digesters is supported by heating water in a water jacket by electric-heater.

Fig. 1. Laboratory biogas plant National University of Life and Environmental Sciences of Ukraine.

Fig. 2. After alcohol Bard.

Fig. 3. Liquid manure of cattle.

Table 1

The composition of the substrate to the various studies of alcohol bards impact on biogas yield

Co-substrate component	content of bards, %					
	0	20	40	60	80	100
Cattle manure, liter	3,5	2,8	2,1	1,4	0,7	0
Bard, liter	0	0,7	1,4	2,1	2,8	3,5
Water, liter	4,3	4,3	4,3	4,3	4,3	4,3
Total, liter	7,8	7,8	7,8	7,8	7,8	7,8

In laboratory digester with total volume of 30 liters substrate consisting of a mixture of cattle manure, water and alcohol bards was fed through a pipe 6. The total volume of substrate fed into digesters, was 7,8 liters. Through the pipe 7 the same amount of processed bio-sludge was removed simultaneously with filling of the digester. The method of digesters loading is periodic (one-time substrate load until the end of the research).

Research conducted with different alcohol bard (Fig. 2) and cattle manure (Fig. 3) in supstrate that was added to digesters: no brad, 20%, 40%, 60%, 80% and 100% of bard (the water contents in the substrate remained constant and was 4,3 liters).

Table 1 shows the contents of the substrate for the various studies.

Also, the research of substrate fermentation consisting of pure bards (7,8 liters) without adding water was performed.

All studies were carried out in mesophilic mode at 40°C.

The lifting value of the cylinder-level gasholder was daily measured. Considering the cylinder diameter of 20 cm the biogas yield was determined. The output rate per of biogas production was determined by dividing this value by the time elapsed between measurements.

Part of the produced biogas burnt in the burner. The other part was placed in a sealed polyethylene bag and was transported in the SEC "Biomass" to determine its elemental composition for gas analyzers.

The results that are presented in Fig. 4 shows that fermentation takes place more rapidly with a high content alcohol bards in substrate than with low content of bards (or without it). This dynamic of biogas production matches the basic phases of development of microorganisms in batch load mode. Initially, a short phase of adjustment is observed after the new substrate was added (lag-phase). Then the logarithmic(exponential) phase starts. During this phase, there is rapid development of bacteria, that is accompanied by active allocation of their digesting product - biogas. Since the beginning of the media depletion and accumulation of waste products in the substrate, which reduces the pH of substrate logarithmic phase passes into a stationary phase.

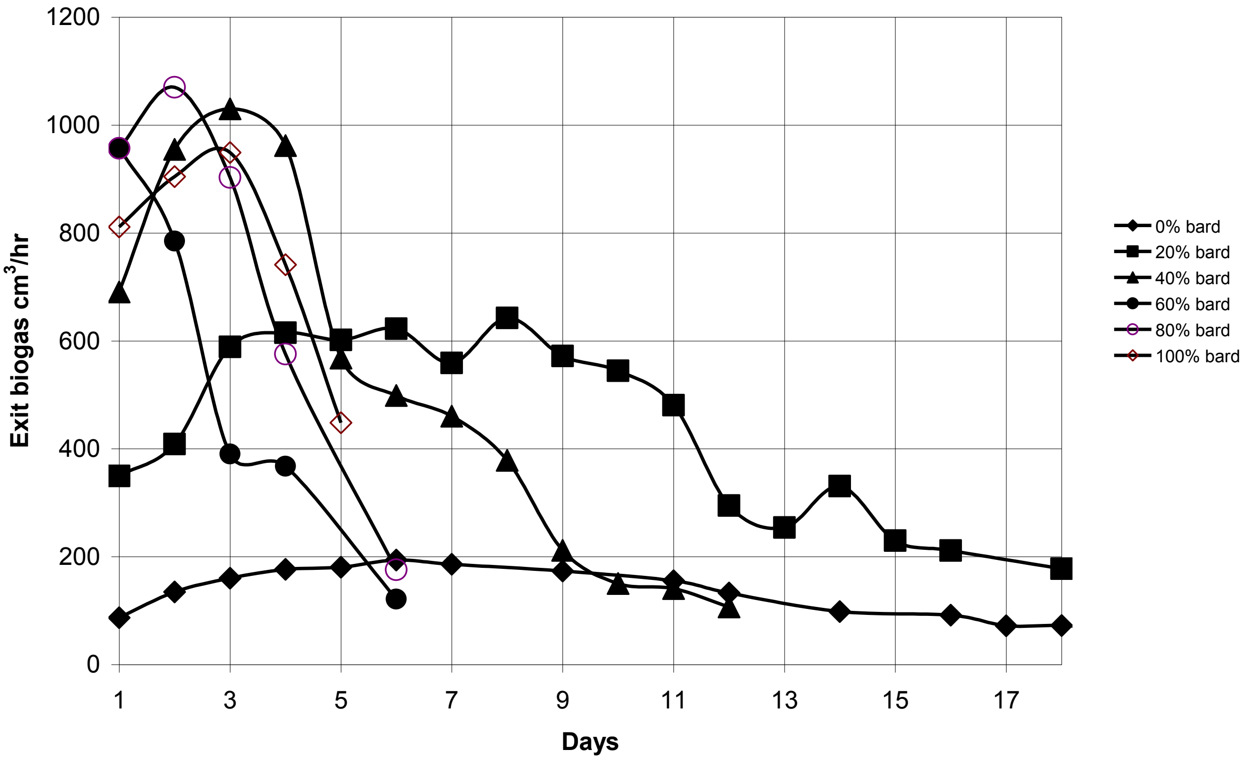

Fig. 4. Out of biogas substrate with different alcohol bard content.

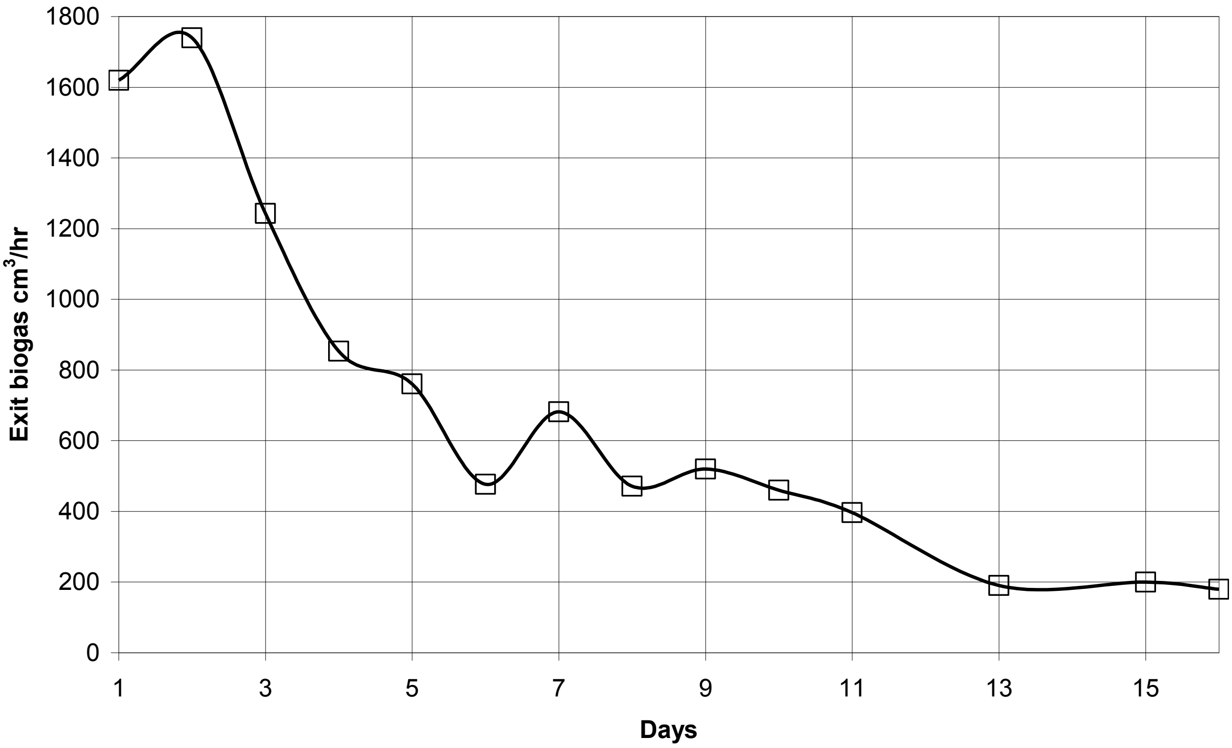

Fig. 5. Output of biogas during fermentation with pure alcohol bards.

Table 2

Increase of the maximum output of clean biogas fermentation alcohol bards compared with the substrate, consisting of cattle manure, and water bards

The content in the substrate bard,%	0	20	40	60	80	100
Increased output of biogas, times	9	2,8	1,8	1,8	1,6	1,9

Stationary phase is characterized by stabilizing of biogas production. Further depletion of the nutrient medium leads to a transition to extinction phase when the number of dead bacteria outnumbers created ones. Extinction phase characterized by gradual decrease of the intensity of biogas production.

In all experiments a short lag phase was observed (or not observed at all) that could be explained by constant temperature regime and uniform substrate consisting of cattle manure and bards in different proportions.

With high content of bards in the substrate (40-100%) logarithmic phase was short and intense, sharp increased release biogas. Stationary phase is very short and quickly turns into an intense phase of extinction. Fermentation is intense and quickly ends. This could be explained by low contents of easy digestible nutrients in the substrate with bard.

With high content of cattle manure in the substrate bacteria development is characterized by long-term periods of logarithmic, stationary phases and phase of extinction. The intensity of fermentation is lower and longer exposure time. This is due to the presence of hard digestible nutrients in the substrate.

When the content in the substrate bards from 40% to 100% biogas output peak occurs on 1-3 days of fermentation time and lasts no more than one day. At a high concentration of manure in the substrate (bards content is 20%) the duration of stationary fermentation phase is 8 days. During fermentation of cattle manure mixture with water without adding alcohol bard the duration of stationary phase is longer than 8 days. In this case, the length of the stationary phase is difficult to determine because it smoothly transfer to logarithmic phase and a phase of extinction.

The increase of the maximum biogas output during the stationary phase is common consequence of alcohol bard contents increase. However, stationary phase time itself decreases, indicating a more intensive fermentation, which quickly fades because of the low content of organic dry matter in the substrate.

Maximum biogas yield is significantly higher when clean alcohol bard is used in fermentation (Fig. 5). An increase of maximum biogas yield using clean alcohol bards compared to the substrates that are the composition shown in the table. 1, are presented in Table. 2.

The content of methane in the biogas is quite high and is 70-78%. The thermal value of biogas obtained is within 23,7-26,4 MJ/m^3 (33,9-37,8 MJ/kg).

CONCLUSIONS

1. The maximum biogas yield using alcohol bards when it is added to cattle manure 40-80% increases in 4,8-5,5 times compared to pure cattle manure fermentation.

2. Fermentation of clean bards increases the maximum yield of biogas in 1,6-1,8 times compared to adding it to the cattle manure. In the case of water dilution, bard biogas yield is slightly reduced.

3. Intensive bard fermentation occurs within 1-2 days, after which the biogas yield is sharply reduced because of low content of organic dry matter. Therefore, bard fermentation should be performed in digesters with gradual load mode.

4. Methane content in biogas, obtained by fermentation alcohol bards, is quite high and is 70-78%. It's thermal value is within 23,7-26,4 MJ / m^3 (42,3-63,6 MJ/kg).

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MOBILE ENERGY MEANS STRUCTURAL-LAYOUT SCHEME OF SELF-PROPELLED CHASSIS - STATUS AND WAYS OF DEVELOPMENT

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Annotation. The results of the analysis of the development of mobile power engineering devices for agricultural purposes, created according to the constructive layout scheme of the self-propelled chassis, are established on the basis of which it is established that the machines of this scheme can be used as part of aggregates for various purposes and for the construction of technological modules in different zones due to the fact that In the self-propelled chassis, in most cases, the engine, transmission, control post with the cab form a single unit located above the rear axle Ohm chassis, the front part represents a free frame for the installation of the body or hinge of machines and implements. In the chassis of one design, the engine may be located behind the cab, which makes it difficult to assemble machines and implements in the rear of the power facility, while in others the engine is located under the cab or in its front part, which eliminates the problems with the aggregation of machines and implements in the rear of the power facility and translates Its characteristics in a plane commensurable with in traction with the energy means of the classical and integral layouts.

The carrier multi-purpose self-propelled chassis is designed for integration with technological modules with a complex technological process and capable of withstanding heavy loads. According to their design, the multi-purpose self-propelled chassis significantly expanded the scope of use to the creation of harvesting units on their basis, without ensuring the directness of the process, and general-purpose units with front and rear gear and machines, including combined ones.

As a result of the conducted studies it was established that in order to ensure customer requirements, it is expedient to implement the construction and layout scheme of the self-propelled chassis in compliance with its main features inherent in the self-propelled chassis, free-sight tractor and multi-purpose chassis with certain differences that are concentrated in three variants of circuit solutions, the first Of which provides for the location of the control post above the rear axle and the rear position of the engine, not the reversible post control The second option provides for a reversible control post, the inter-base arrangement of the motor-power unit, the reverse transmission and the third variant provides for a reversible transversely-vertical control plane, reverse gear, inter-base arrangement of the engine-power unit.

Key words: mobile power tool, layout, self-propelled chassis, the design, development.

INTRODUCTION

Mobile energy means (MEM) is the basis for the creation of machine-tractor units (MTU). The volume of technological operations that can be performed with the use of this energy source and the efficiency of its use in the structure of the unit determine the composition of the machine and tractor fleet of the economy, and hence the cost of the final product. It is the ability to create aggregates for various purposes and layouts that depend significantly on the MEM construction and layout scheme. Recently, enterprises for the manufacture of specialized self-propelled machines put emphasis on the creation of such units based on self-propelled chassis. In such conditions, issues relevant to the study of the directions of the development of the MEM structural and layout schemes and the main objectives of the state target program for the implementation of technical policy in the agro-industrial complex are relevant [1-9].

ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

The operation of the MEM of the construction and layout of the self-propelled chassis is accompanied by both advantages and problems that determine the demand for such energy resources in agricultural production in general and in technological processes in particular. One of the main problems of the self-propelled chassis layout, at this stage, is the imperfection of the overall design in terms of maximum implementation of potential traction indicators and unsatisfactory conditions of aggregation with machines and implements using standard equipment for aggregation. The latter also explains that research and development work is still ongoing today designed to eliminate the shortcomings of the above-mentioned constructive-layout scheme. This requires a change in the overall design of machines and tools to create an MTU based on self-propelled chassis. In this connection, scientists and the machine-building industry concentrate their efforts in two directions, namely: the development of machines and tools for the integration with self-propelled chassis; Improving the conditions of aggregation. The works that were carried out in these areas often provided for the improvement of the overall layout of the energy facility, but, in most cases, were reduced to the improvement of technological modules and the development of devices to improve the conditions for aggregation. Specific technical solutions and results of individual studies from these directions are presented in [10-17].

OBJECTIVES

Determine the actual state of use and the direction of development of the constructive-layout scheme of MEM type "self-propelled chassis".

THE MAIN RESULTS OF THE RESEARCH

The design and layout scheme of MEM is subordinated to the functional purpose of the energy facility and is characterized by a set of separate design characteristics, namely: size and type of propulsors; arrangement of units and systems; availability of free space for hanging machines, tools and installation of technological tanks; base; the magnitude of road and agrotechnical gaps; coordinates of the center of mass [18].

Tractor self-propelled chassis (often use the phrase "self-propelled chassis", or "chassis") - transport motorized means, which is serially produced and executed, mainly, on the basis of units and aggregates of tractors.

Self-propelled chassis (Fig. 1 *a*) in layout occupy a special place among universal tractors. Such a chassis is characterized by the fact that the engine, transmission, control post with the cab form a single unit located above the rear axle of the chassis, the front part represents a free frame for mounting the body or hinge of machines and implements. In the self-propelled chassis of T-16MG type (Fig. 1*b*, *c*) manufactured by the Kharkov plant of self-propelled chassis (Ukraine) and the Vladimir tractor plant (Fig. 1*d*), the rear position of the engine behind the cab is implemented, which makes it difficult to equip machines and implements in the rear part of MEM, as is typical for energy facilities of classical and integral layouts. This disadvantage in the construction of self-propelled chassis manufactured by Fendt (Germany) is eliminated by locating the engine in front of the cab in the inter-basin space (Fig. 1*d*).

Fig. 1. Tractor propelled chassis of domestic and foreign production: *a* - is a schematic diagram; *b* - self-propelled chassis of T-16MG type (Ukraine); *c* - *i*n the self-master chassis of the type SSh-28 (Ukraine); *d* - self-propelled chassis of type VTP-30 SSh (Russia); *e* - self-propelled chassis of type Fendt F 231GT (Germany); *f* - self-propelled chassis of type Fendt F 255GT (Germany).

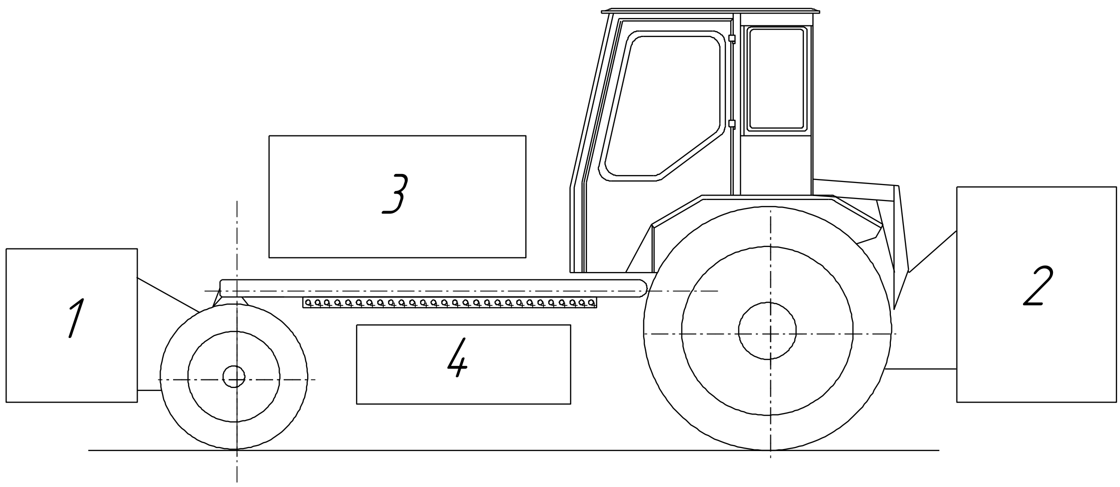


Fig. 2. Possible areas of aggregation of self-propelled chassis: 1 - front attachment of the technological module; 2 - rear hinge of the technological module; 3 - attachment (installation) of the technological module to the frame of the self-propelled chassis; 4 - inter-base station of technological module.

а)

б)

Fig. 3. Tractor with a free review of *a* - is a schematic diagram; *b* - a tractor of the type Fendt 380GT, an increase in the mass of the guns, which are intended for hanging from the front.

Analysis of the design and experience of using self-propelled chassis shows that they can be used as part of aggregates for various purposes and construction. In Fig. 2 shows the possible zones of aggregation of technological modules with a self-propelled chassis, which made it possible to create on their basis units for various purposes and layouts, which is explained by the presence of additional zones for aggregation in comparison with energy facilities of both classical and integral assemblies.

Special attention should be paid to tractors with free view (Fig. 3) proposed by Fendt in the early 90-s as an intermediate arrangement between the self-propelled chassis and the integral tractor, aimed at increasing the role of the front drive axle in the implementation of tractive effort (typical for domestic tractors of class 3 [19]) and the scope of tractors with free view practically covers the sphere of application of machines of classical and integral layouts and has the advantages that it is possible to place machinery and tools, technological tanks, etc. under the frame of working bodies, without deteriorating the requirements of ergonomics. Thus, the zones for aggregating such an energy facility with technological modules are similar to those shown in Fig. 2, but at the same time there are more opportunities for creating combined units. The carrier multi-purpose self-propelled chassis (Fig. 4*a*) is intended for assembly with harvesting machines (forage harvesters and sugar beet harvesters, etc.) and general-purpose tools (front and rear-mounted plows, cultivators), which increases its annual load. The frame of the chassis can be solid (Fig. 4*b*, *c*) or composed (Fig. 4*d*) of two half-frames connected by articulation. To improve the handling of the chassis, the front half-frame can be made slightly shorter than the rear. The cab has the ability to move along the longitudinal axis, which improves visibility and facilitates the hitching of tools and machines, both tillage and harvesting.

According to its design, multi-purpose self-propelled chassis significantly expanded the scope of use towards the creation on their basis of harvesting aggregates and general-purpose units with front- and rear-mounted implements and machines, including combined ones. It should also be noted that recently, new manufacturers of self-propelled multi-purpose chassis carriers have appeared on the market of agricultural machinery. So now the self-propelled specialized harvesters of Holmer are known. Several years ago, this company introduced a multi-purpose carrying self-propelled chassis (sometimes called a system vehicle) created using units and aggregates of the power module of self-propelled specialized vehicles. Machines of similar design are known and under the brand Vredo (the manufacturer from the Netherlands Vredo Dodewaard B.V.) - Fig. 5.

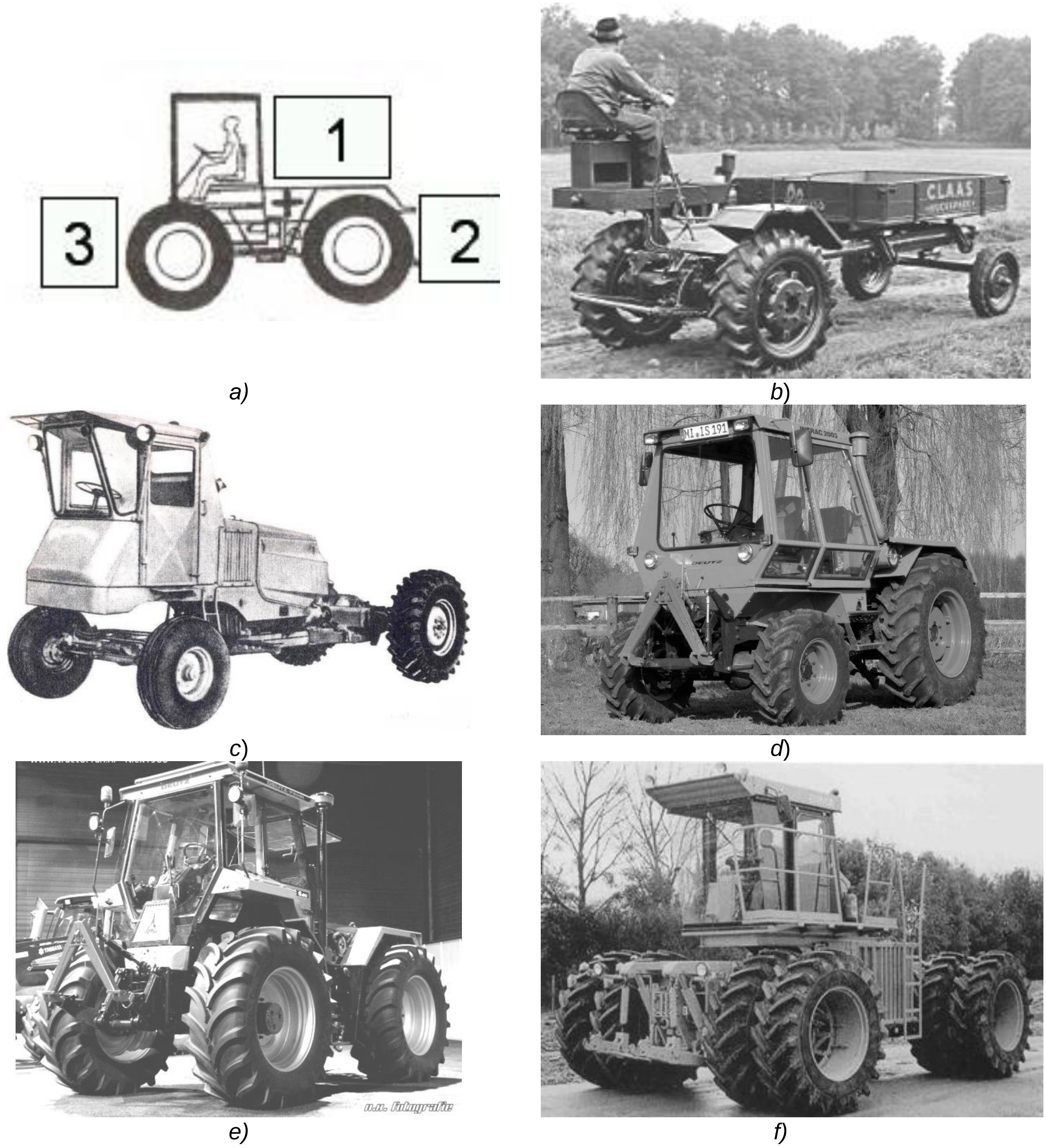


Fig. 4. Supporting multi-purpose self-propelled chassis: *a* - is a schematic diagram; *b* - self-chassis Claas Huckepack; *c* - the self-chassis of the SS-75 chassis (a similar configuration of the SSh-65, SSh-100, SSh-150); *d* - the energy facility Deutz Intrac 2003; *e* - power means Deutz-Fahr Intrac 6.60; *f* - energy facility Bima 300; 1, 2, 3 - zones of location of technological modules.

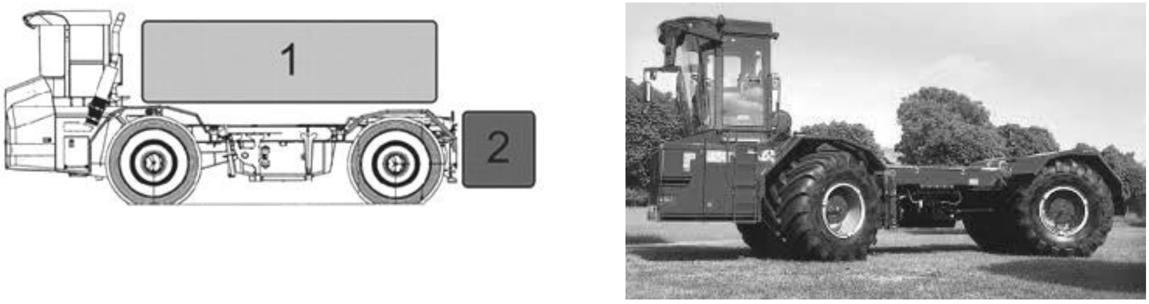
All the machines mentioned above are MEM of the constructive-layout scheme "self-propelled chassis", although they can perform a completely different list of technological operations (subject to guaranteed provision of technological modules) with different quality indicators.

Such capabilities of MEM are taken into account when investigating their levels of universality. According to the results of work [20] found that the self-propelled chassis of the T-16MG type is characterized by the level of universality $K_{yk} = 0.38$.

The maximum value of the named indicator for the constructive-layout scheme "self-propelled chassis", taking into account the modern development of technologies of tractor construction and agricultural production, could potentially be 0.95, and subject to an increase in the maximum speed of movement and 1.00, that is to reach the highest value.

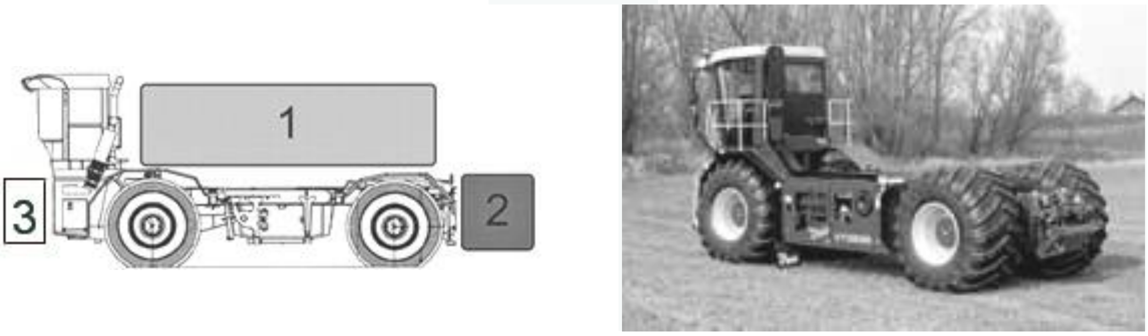
At the same time, in modern technological processes, the energy resources created in accordance with the constructive-layout scheme "self-propelled chassis" accepted for implementation in Ukraine are practically not used [21].

Holmer Terra Variant WA



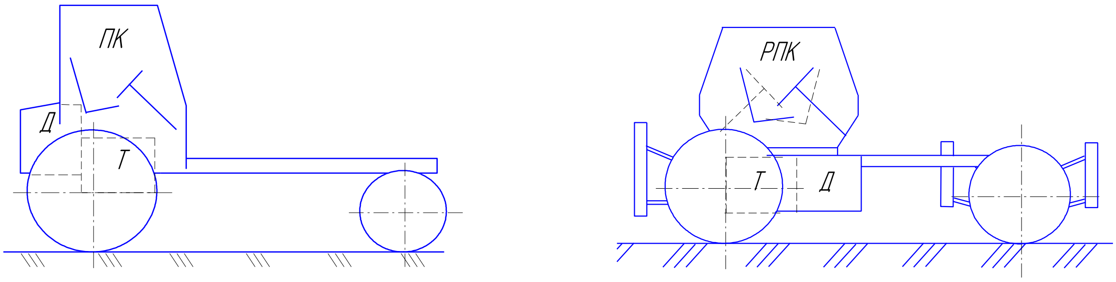
a) *b)*

Vredo VT 3936

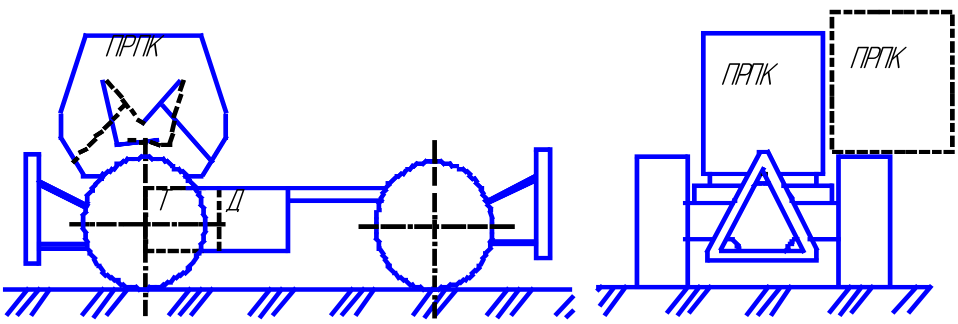


a) *b)*

Fig. 5. Multi-bearing, self-propelled chassis: *a* - is a schematic diagram; *b* - general view; 1, 2, 3 - zones of location of technological modules.



a) *b*)



c)

Fig. 6. Structurally-layout scheme of self-propelled chassis and forecast of its development: *a* - is a diagram of the T-16MG power supply; *b*-diagram of the Fendt 380GHA power supply; *c* - perspective scheme of self-propelled chassis; *Д* - engine; *Т* - transmission; *ПК* - control post; *РПК* - reversible control post; *ПРПК* - reversible reverse control post

However, despite the rather intensive introduction of self-propelled chassis in agricultural production in the leading countries of the world, it is worthwhile predicting such changes in Ukraine as a state where a significant share of the national gross product is produced in the agrarian sector of the economy.

It should also be taken into account the fact that, according to [20], the universal coefficient of Cook will reach only when all the indicators that affect its values will reach the maximum possible, for a given level of technology development, values. The structure-layout scheme of the energy means influences the value of the indicator "availability of cargo area" [20] and determines the possibility of uniting the technological module with a straight-through process (grain harvester, etc.) on the frame of the power facility.

Of the above-described self-propelled chassis designs, only Claas Huckepack and SSh-75 energy facilities have such characteristics, where a lateral location of the control station is provided (as in the Claas Huckepack design), or the possibility of moving the latter, together with the power unit, to one side (to one of Sides of the energy facility) with the help of appropriate equipment (as in the construction of the school-75). Under these conditions, in order to obtain the maximum value of the design universality coefficient, it is expedient to single out the main directions of development of the constructive-layout scheme of self-propelled chassis - Fig. 6.

Starting from Fig. 6 it can be argued that energy facilities that have a self-propelled chassis layout, in accordance with the requirements of the consumer, can change their consumer characteristics in a wide range of characteristics to achieve the maximum level of versatility of the construction K_{yk} = 1.00 due to the implementation of three variants of schemes, namely: 1 - the location of the control station above the rear axle and the rear engine location, not the reversing control station, not the reverse transmission, and all other features must correspond to those set out in p (Analog T-16MG); 2 - reversible control station, reversible transmission, inter-base arrangement of the motor-power unit, and all other characteristics should correspond to those set forth in [18] concerning the arrangement of the tractor with a free (Fig. 4, analogue of the Fendt 380GT); 3 - reversible transversely adjustable in the transverse-vertical plane control post, reverse transmission, inter-base arrangement of the motor-power unit, and all other characteristics should correspond to those for these are described in Ref. [18] concerning a carrying multi-purpose self-propelled chassis.

CONCLUSIONS

1. As a result of the conducted researches it is established that in order to ensure the requirements of the consumer, it is expedient to implement the construction and layout scheme of the self-propelled chassis in compliance with its main features inherent in the self-propelled chassis, free-sight tractor and multi-purpose chassis that are concentrated in three variants of circuit solutions, namely: 1 - location of the control post above the rear axle and rear engine location, no reversing control post, no reversible transmission; 2 - reversible control post, inter-base arrangement of motor-power unit, reversible transmission; 3 - reversible transitional in the transversely-vertical plane control post, reversible transmission, inter-base arrangement of the motor-power unit.

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RESEARCH OF INFLUENCE OF SPECIES OF RAW MATERIAL ON BIOGAS OUTPUT

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Summary. It is known that the output of biogas during the methane fermentation of raw materials in the bioreactor is the determining factor affecting the profitability of the entire process. An important influence on the output of biogas is the type of fermentable substrate. Raw materials that are exposed to methane fermentation are divided into the following categories: waste, agricultural raw materials, waste processing industry, organic waste. In addition, raw materials can be divided into basic and auxiliary. The main raw material for the production of biogas is manure cattle and small cattle, pigs, poultry manure. Often the fermentation material to improve the biogas yield is mixed, adding an auxiliary to the main raw material. Besides, we are talking about co-fermentation. In this work, a study was made of the effect of fermentable raw materials (cattle manure, dry bird droppings and their mixture) on the biogas yield during batch fermentation. It was determined that the small maximum yield of biogas from a unit of organic dry matter with fermentation of cattle manure, the fermentation of dry bird droppings gives the lowest maximum of biogas yield from a unit of organic dry matter, and the mixture of livestock manure and bird droppings is an intermediate result. The increase in the temperature regime of the methane tank during fermentation of the substrate causes an increase in the output of biogas irrespective of the type of raw material.

In the case of periodic fermentation of cattle manure, dried bird droppings and their mixtures, leads to maximum biogas yield from a unit of organic dry substance, is observed with fermentation of cattle manure, fermentation of dry bird droppings gives the lowest maximum yield of biogas from a unit of organic dry matter, and the fermentation of a mixture of manure cattle and bird droppings - intermediate result.

The increase in the temperature regime of the methane tank during fermentation of the substrate causes an increase in the yield of biogas, irrespective of the type of raw material.

Keywords. Biogas, methane tank, biogas plant, periodic charging, methane fermentation, manure cattle, bird droppings.

INTRODUCTION

The output of biogas during the methane fermentation of raw materials in the bioreactor is the determining factor affecting the profitability of the whole process. The more biogas is produced, the more efficient the process of its production. The efficiency of biogas generation in a methane tank is affected by many factors. Like, the presence of the necessary microflora, without which it is impossible to methane fermentation, the creation of an anaerobic conditions in the reactor, the content of organic substances in the sub-stratum, temperature regime of methane tank, optimum humidity of environment, the presence of inhibitors of the fermentation process or stimulating substances, the level of the loading of methane-tar, the exposition of fermentation, the creation of an acid-alkaline balance of the sub-stratum, Preventing light from entering the reactor, etc. [1]. One of the main factors influencing the output of biogas is the type of substrate that is fermented. Therefore, the investigation of the output of biogas during methane fermentation of different substrates is quite relevant.

ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

Anaerobic digestion of wastes with biogas production is traditionally carried out when fermenting animal waste, such as slurry or manure. These selections can be mixed with other horticultural wastes or wastes from the processing of raw materials in the food industry. Depending on the composition of the processed raw materials, we can expect a different level and energy value of biogas. The average amount of biogas, which is estimated at 20-25 м^3, although 30-35 м^3 is technically and economically profitable amount. This amount of gas can be obtained by combining animal and household waste with other raw materials, which are characterized by a high content of dry organic matter.

Raw materials that are exposed to methane fermentation can be divided into the following categories: waste, agricultural raw materials, processing industry waste, organic waste. The fermentation material can be divided into a basic (the fermentation of which can proceed independently, without the addition of other substances) and an auxiliary [2].

Often, the fermentation material is mixed to improve the biogas yield. The number of substrates (types of waste) that are used to produce biogas within a single biogas plant can vary from one to ten or more [3]. In this case, we are talking about co-fermentation.

The composition of biomass and its properties significantly influence the process of methane fermentation. When evaluating the substrate, it should be taken into account that only with a dry substance (DS), and in this case, only with its organic part (ODS), it is possible to obtain methane. Therefore, the content of organic dry mass in relation to the total mass is the first criterion for selecting the constituents of the mixture of substrates. The inorganic component of the substrate, which consists of sand, earth, stones, metal shavings, etc., that fall into the collected uranium and manure, or into organic waste, undesirable for the process of biogas production, since biogas can not be extracted from them and, In addition, they lead to technical problems, for example, the appearance of sediment in the methane tank.

Organic matter consists of protein (protein), fats, and carbohydrates. The basis of fats are triglycerides, which decompose into fatty acids and glycerol. Too much fat leads to the accumulation of organic acids, so the pH level decreases and the formation of acetic acid and methane is slowed down. Proteins are fold-molecular-weighted compounds, consisting of amino acids. They, like carbohydrates and fats, consist of carbon C, hydrogen H, oxygen O, also contain nitrogen, sulfur, and phosphorus. Proteins decay into peptides, theninto amino acids, and finally into organic acids. For the decomposition of protein and fat, the composition of the diet is not important compared with the decomposition of carbohydrates. Carbohydrates include: monosaccharides (glucose, fructose), oligosaccharides (sucrose (raw sugar), lactose (milk sugar), maltose (malt sugar)), polysaccharides (starch, glycogen, cellulose, inulin), heteropolysaccharides (Hemichael-lulose, pectin, lignin (which is not carbohydrate but is counted by analysts as a group of carbohydrates, it is lignified plant matter and resistant to decomposition by bacteria and acids, it is generally assumed that lignin is not digested).

Carbohydrates are broken down by bacteria into simple sugars and decomposed to fatty acids (acetic, oily, propionic). The amount of acids formed and the pro-cent of each acid depends on the composition of the carbon. From the process of digestion in ruminant artiodactyls, whose stomach is a biogas plant with a very short fermentation period, it is known that the rich starch and sugar substrates lead to an increase in the content of propionic and butyric acids, while cellulose and a fiber-rich substrate alters the composition of fatty acids in the direction of dominance of acetic acid. In addition, the composition of carbohydrates determines the pH level and the number of living microorganisms. If the food contains a lot of starch and sugar, the pH level decreases, the medium becomes acidified, becomes neutral or slightly acidic, and the number of bacteria increases rapidly. This leads to an even more rapid decomposition of carbohydrates and possible fermentation of the fermenter. The pH level decreases. The number of bacteria forming propionic acid increases, and those that produce acetic acid, on the contrary, decreases. Thus, the formation of acetic acid is slowed down as the output material for methane. Ruminant animals in such cases refuse to continue eating (cicatricial ace dosis).

When using substrates with a very high content of sugar or carbohydrates, such as wheat, corn or sugar beet, for example, it is worthwhile to closely monitor the supply of these materials. This is probably, one of the reasons why in practice the net use of grain or sugar beet as a substratum for methane fermentation has not been widely spread. Maintenance of such a process on conventional single-stage plants is simply too expensive [4].

It is believed that the output of biogas during fermentation of fats is 1250 l/kg of ODS, proteins – 790 l/kg ODS, carbohydrates – 700 l/kg ODS [5].

In modern biogas plants, substrates with a dry matter content of up to 12% and a maximal length of fibrous or stem-like particles not exceeding 30 mm can be processed. After loading the substrate in the methane tank, the biogas yield per unit time first sharply increases, and then gradually decreases after reaching the maximum. It should also be noted that the herb contains many protein substances, so in large quantities they can be used as a solvent. Preparation of raw materials requires the implementation of specific requirements. The condition for the use of organic material in the fermentation process is the appropriate grinding of the material, it can allow the production of bio-gas to increase to 20%. The use of a homogeneous biomaterial substantially increases the efficiency of the fermentation process [6].

The main raw material for the production of biogas is manure cattle and MPA, pigs, poultry manure.

Cattle manure is best suited for processing in biogas plants, since methane-forming bacteria are already contained in the cattle stomach. Uniformity of cattle manure allows us to recommend it for use in continuous fermentation plants [1]. The manure of cattle, depending on the method of maintenance, can be obtained as a solid or liquid. Solid manure is formed by the traditional method of keeping animals in barns with stalls with litter when using straw in an amount of 2 to 12 kg per head of cattle per day. Only in cowsheds with stalls with a small amount of litter straw can you get solid manure, which can be taken with pitchforks, as the urine of animals is excreted through special gutters. Such manure can be composted without problems with only a large amount of underlay. Dung with a small amount of underlay can be processed in biogas plants with good mixers. If there is a large amount of underlay, dilution should be taken: mixing with water or slurry in the substrate preparation tank with a cutting mixer. Straw must be ground up to 10 cm Before sprinkling the stall. For this kind of manure, the rates for chopping the straw are especially important (it is important that the straw is not only cut up, but also stratified by the fibers, since methane bacteria need the maximum surface area for their development). Solid lumpy manure, which is immediately exported to the fields or composted, is obtained with the maintenance of pedigree cows and calves.

Liquid manure is a mixture of feces and urine animals. From the point of view of the simplicity of education, it is this kind of stall-keeping that has become very popular over the last 30 years, primarily in the placement of dairy cows and fattening cattle [4].

Fresh manure mixed with water and extract from it undigested straw to prevent the formation of sediments and crusts. Urine cattle significantly increases the amount of biogas produced, so it is recommended to build farms with concrete floor and direct drain of excrement into a tank for mixing raw materials [7]. It should be noted that the manure of dairy cows is more liquid than that of young and goby, and the manure of young animals and dairy cows has a minimum of 10% less biogas yield due to the lower intensity of feeding compared to the manure of fattening calves. The manure of cattle contains, depending on the feeding, such feed particles as grass, hay and silage, or even underlay. These substances merge in the manure and, in case of incorrect mixing, form a floating crust, which can be so thick and tangled that it is difficult to separate them. Cattle manure has the worst indicators of gas yield. This is explained by the fact that cattle, like all ruminants, are easily digested due to the special flora of the stomach containing other and methane bacteria, as well as the long intestinal tract and strong grinding of substances, and consumes a considerable amount o raw fiber. This lack of manure cattle is aligned, however, by a high content of dry organic matter [4].

Porcine manure tends to form a sediment, first of all, if the undigested husks of corn or grain settle out of it. If mixing does not occur correctly, layers with a thickness of several decimetres can be formed over time, from which only the pickaxe can be removed. The precipitate formed decreases the useful volume of the reactor, so it must be periodically cleaned. Pig, like a person, is known for its poor digestion of food, which is caused by a single-chamber stomach and a short intestine. Therefore, the yield of gas is somewhat higher than that of manure from cattle because of the fact that pig manure contains many undegraded proteins. In addition, the output of biogas from manure from sows is about 10% higher than that of manure from pigs for fattening, since sows better digest food [4].

Sheeps and goats manure. For sheep and goats contained without paved coating, the situation is similar to that described one for pig manure. Since the goat truss is practically the only place for collecting sufficient manure, and only under the condition of thatched bedding, the raw material for the biogas plant is basically a mixture of manure and straw. Most systems that process such raw materials operate in a periodic loading mode, in which a mixture of manure, straw and water is loaded without prior preparation and remains in the reactor for a longer period than pure manure [7].

Bird droppings contain many feathers that tend to form a floating crust. In addition, due to the peculiarities of feeding, it contains a large amount of chalk and sand, therefore it is necessary to take into account the possibility of precipitation [4].

For the processing of bird droppings, it is recommended that the bird is kept in a cell or a perched over a limited area that is suitable for collection of manure. In the case of floor maintenance of birds, the proportion of sand, sawdust, straw in the litter will be too high. Therefore, it is necessary to take into account possible problems and clean the methane tank more often than when working with other types of raw materials [7].

Birds have a short digestive tract, so digestion of food is incomplete. The dung contains a large number of undigested proteins. Therefore, dung gives the greatest yield of gas. First of all, it is so rich in dry mass that, as a rule, it must be diluted with water [4]. When using pure poultry grain as a source of harmful effects of high concentrations of ammonia with a fertility inhibitor [7].

Investigation of the influence of raw material parameters on biogas production was carried out in the work [8]. It has been established that if the methane production rate falls significantly, despite the unchanged loading, it is necessary to start from the inhibitory effect on methanogenic bacteria. If the ratio of methane / carbon dioxide in biogas falls, and the composition of the substrate does not change, the reason may be increased acid formation in comparison with the formation of methane. In this case, the equilibrium of the mass fluxes of the decomposition process is violated. Weighing plants on reactor feed systems are more accurate and can be integrated into automatic process control systems. The growth of the bacteria depends on the concentration of the substratum an increase in the concentration of entails an increase in the concentration of growth, which means that within certain limits the process stabilizes independently. The optimum range of pH for methane formation in the range of 7,0 to 7,5.

When studying the yield of biogas during fermentation of cattle manure depending on the type of feeding carried out in [9, 10], it was found that an increase in the temperature of methane fermentation leads to a higher yield of biogas, but at the same time, the costs of heating the substrate are also increased. When using substrate mixing during the methane fermentation, the biogas yield is increased by at least 1.3 times. When feeding cattle with food containing a large amount of cellulose and hemicellulose, the yield of biogas is reduced by a factor of 1,7.

The study [11] is devoted to the study of the influence of underlay in manure on the output of biogas. It establishes that the decrease in the introduction of underlay for cattle from 7 to 5 kg/head per day leads to an increase in the output of biogas in half from 20 to 40 liters/head per day. For pigs, the output of biogas with decreasing underlay dose from 6 to 5 kg/head per day increases from 10 to 23 liters per head per day, and already with a decrease in the application of underlay from 3 to 2 kg/head per day the output of biogas was 43 and 50 l/head per day, respectively.

In the study [12], the kinetics of anaerobic fermentation of plant biomass was studied. It is established that the output of biogas and biomethane grows proportionally with the increase in the level of organic biomass growth in the reactor, and the fermentation time reaches 30% of the level of fermentation while decreasing exponentially. The results of studies [13] of the output of biogas when adding to a substrate based on manure of cattle crude glycerin are displayed in the paper. It is established that to increase the efficiency of biogas production as a co-substrate, it is possible to use waste from biodiesel production of crude glycerine, with utilization of which problems arise in biodiesel plants. When using as a co-abrasive waste production of biodiesel crude glycerol, it is recommended to add it to the main substrate, which is manure cattle, within 6,5-7% of the mass of manure in the substrate. At the same time, the maximum yield of biogas is increased by 5-7 times. The study [14] shows the results of studies of the output of biogas with additive to the substrate on the basis of fus manure of cattle – waste from the production of vegetable oil. It is determined that the use of fus as a co-substrate will increase the yield of biogas by 2,5 times with a periodic method of loading the substrate, and 4,5-10 times with a gradual one. The paper [15] presents the results of studies of gas evolution with a gradual supply of substrate to the methane tank, as a result of which it was established that gas evolution with a gradual loading of the substrate into the methane tank is more uniform in comparison with gassing during periodic loading. The paper [16] presents the results of an investigation of the output of biogas during fermentation of a mixture of manure for cattle and pigs with green mass of maize. It is established that the use of plant raw materials and manure in different ratios can be an effective factor in increasing the yield of biogas and increasing the usefulness of biogasenergetic plants. The greatest efficiency in the production of biogas is the raw material, consisting of 70% of the green mass of maize and 30% of the manure of pigs and cattle, respectively.

OBJECTIVES

Determine the influence of the type of main raw material on the output of biogas during methane fermentation.

THE MAIN RESULTS OF THE RESEARCH

The output of biogas during fermentation of cattle manure. The solid fraction of manure of cattle contains 16,4% of dry substance (DS) [17], 80% of which is an organic substance (ODS) [18].

In studies to determine the yield of biogas from cattle manure, 8,5 kg of substrate were replaced, of which 3,5 kg of substratum consisted of solid fraction of manure of cattle, and 5 kg of water.

Therefore, the content of dry substance in the manure of cattle, which was part of the substrate that was loaded into the methane tank, was:

$$\frac{3{,}5 \cdot 16{,}4}{100} = 0{,}547 \text{ kg.}$$

Accordingly, the content of organic matter was:

$$\frac{0{,}547 \cdot 80}{100} = 0{,}459 \text{ kg.}$$

The biogas yield was recalculated from the dimensionality of cm^3/hr, which does not allow comparing the obtained results with the data obtained from the literature sources to the dimensionality m^3/(hour·kg ODS). The results are shown in Fig. 1.

It is established that for 42 days of fermentation at a temperature of 55°C, 0,6535 m^3/(hour·kg OSD), is obtained, for 41 days of fermentation at a temperature of 50°C – 0,5043 m^3/(hour·kg ODS), for 36 days Fermentation at a temperature of 45°C – 0,4032 m^3/(hour·kg ODS), for 27 days of fermentation at a temperature of 40°C – 0,2723 m^3/(hour·kg ODS), for 74 days of fermentation at a temperature of 35°C – 0,3781 m^3/(hour·kg ODS).

The average yield value of the biogas yield at a fermentation temperature of 55°C is 0,0156 m^3/(day·kg OSD), at a temperature of 50°C – 0,0123 m^3/ (day·kg OSD), at a temperature of 45°C – 0,0112 m^3/(day·kg OSD), at a temperature of 40°C – 0,0101 m^3/(day·kg OSD), at a temperature of 35°C – 0,0051 m^3/(day·kg OSD).

The dependence of the average daily output of biogas during fermentation of cattle manure from the temperature regime of the methane tank (Figure 2) is approximated by the expression:

$$Q = 0{,}0005 \cdot T - 0{,}01 \text{ при } R^2=0{,}9221, \quad (1)$$

where: Q – average daily output of biogas, m^3/(hour·kg OSD), T – temperature mode of the methane tank, °C.

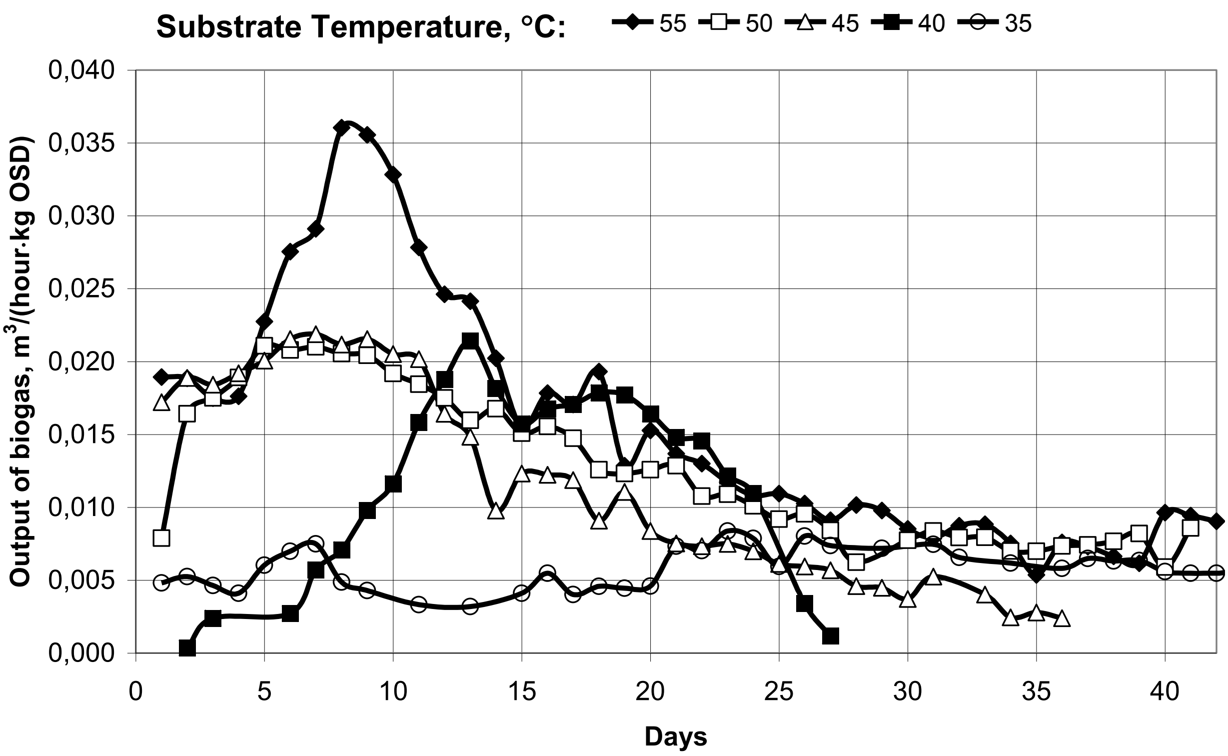

Fig. 1. Dependence of the output of biogas during the periodic regime of fermentation of manure of cattle from the temperature regime of the methane tank in time.

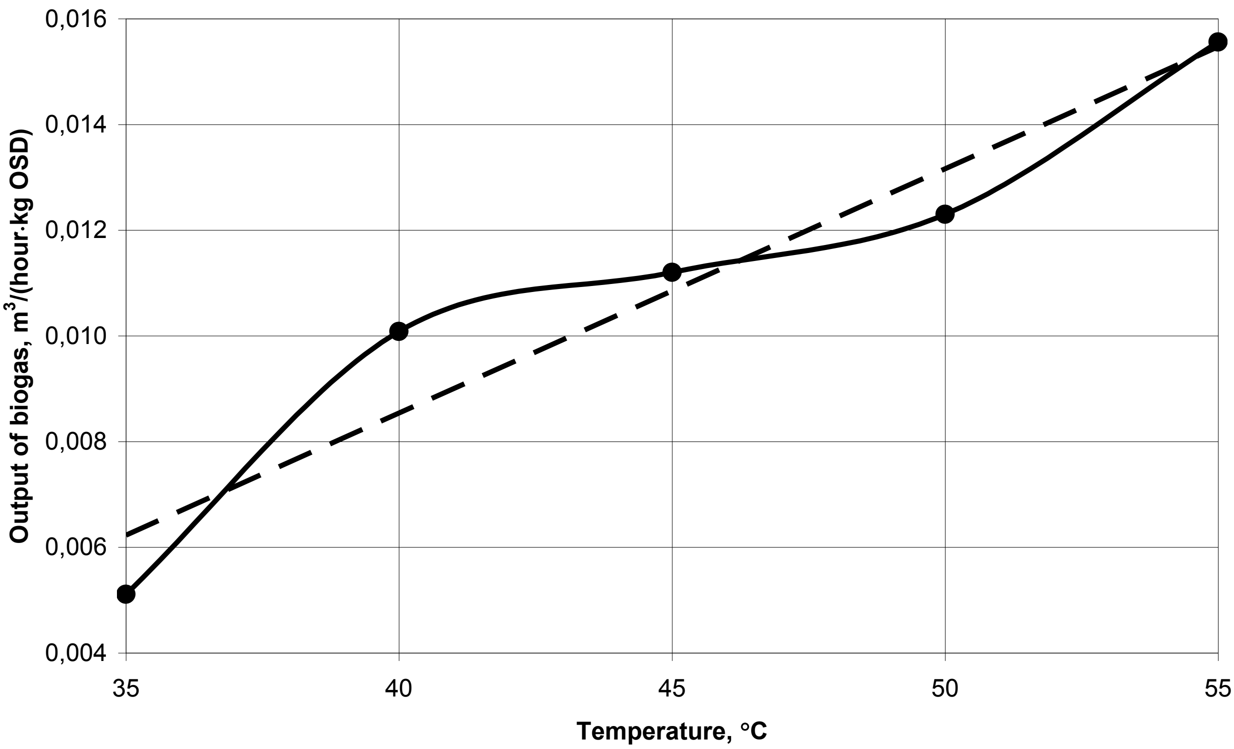

Fig. 2. Dependence of the average daily output of biogas during the periodic regime of fermentation of manure of cattle from the temperature regime of the methane: ——— experimental curve, — — — approximated line.

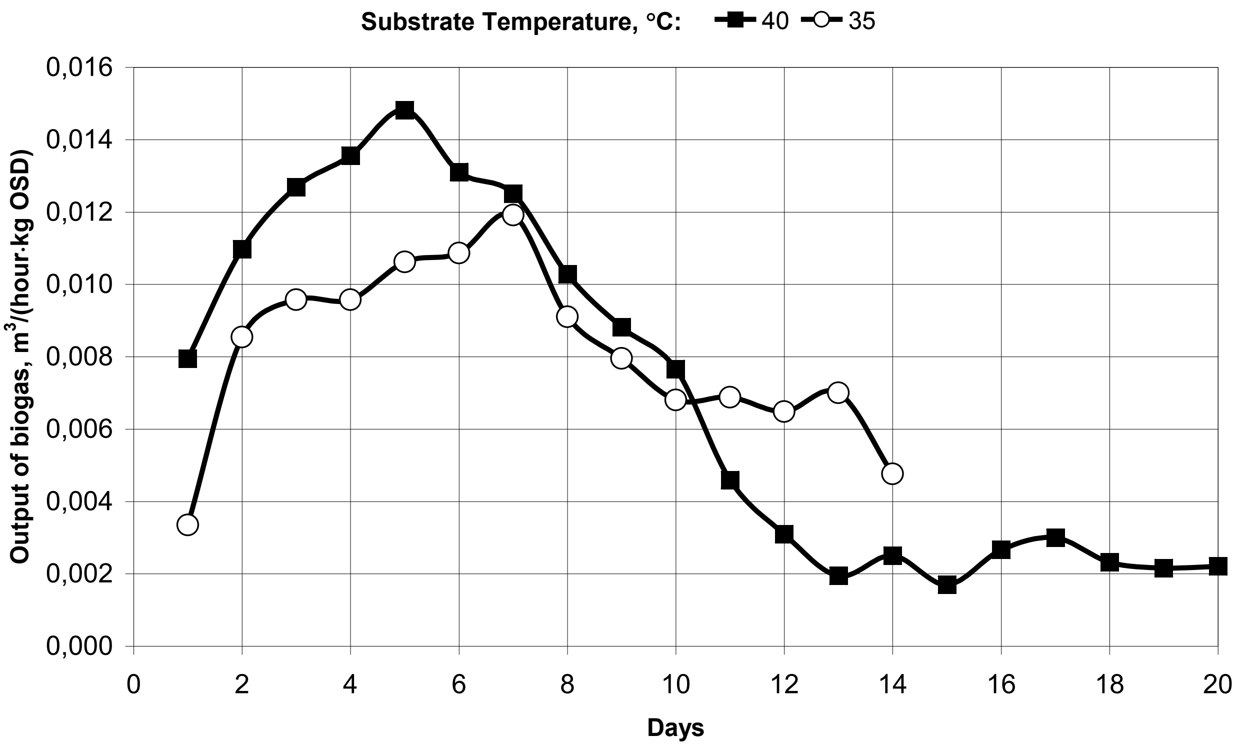

Fig. 3. Dependence of the output of biogas during the periodic regime of fermentation of dry bird droppings from the temperature regime of the methane tank in time.

At the same time, the output of biogas during the mesophilic regime of fermentation of manure of cattle, the periodic method of loading and the fermentation time of 20 days is 0,250- m^3/(hour·kg ODS) [7, 19], или 0,013-0,017 m^3/(hour·kg ODS). These values are close to the results obtained during our experimental studies.

The output of biogas during fermentation of dry bird droppings. Bird droppings contain about 65% water and about 20% organic substance [20], other 15% – inorganic substance. At the same time, dried bird droppings contain 25% moisture and 75% dry matter. After recounting, we establish that in the dried bird droppings contains 46,5% of dry organic substance.

In studies to determine the yield of biogas from dry bird droppings, 6,5 kg of substrate were replaced, 2,5 kg of the substrate consisted of dry bird droppings and 4 kg– water.

Therefore, the dry matter content of the dry bird droppings included in the substrate, which was loaded into the methane tank, was:

$$\frac{2{,}5\cdot 46{,}5}{100}=1{,}1625 \text{ kg.}$$

The results of a study of the yield of biogas during fermentation of dry bird droppings are shown in Fig. 3.

It was found that after 14 days of fermentation at a temperature of 40°C 0,1245 m^3/(hour·kg ODS) is obtained, at a temperature of 35°C – 0,1134 m^3/(hour·kg ODS).

The average daily value of the biogas yield at a fermentation temperature of 40°C is 0,0089 m^3/(day·kg ODS), at a temperature of 35°C – 0,0081 m^3/(day·kg ODS).

The output of biogas during fermentation of a mixture of cattle manure and dry bird droppings.

In studies to determine the yield of biogas from a mixture of manure cattle and dry bird droppock, 6,9 kg of substrate were replaced, of which 1,6 kg of the substrate was manure cattle, 0,8 kg – dry bird droppings, 4,5 kg water.

Since 16,4% of dry matter is contained in the solid fraction of manure of cattle [17], with which about 80% is an organic matter [18], the content of dry substance in manure, included in the substrate that was loaded into the methane tank, was:

$$\frac{1{,}6\cdot 16{,}4}{100}=0{,}262 \text{ kg.}$$

Accordingly, the content of organic substance was:

$$\frac{0{,}262\cdot 80}{100}=0{,}21 \text{ kg.}$$

We found that in dried chicken droppings contains 46,5% of dry organic substance. Then, the dry matter content in the dry chicken droppings that was part of the substrate, which was loaded into the methane tank, was:

$$\frac{0{,}8\cdot 46{,}5}{100}=0{,}372 \text{ kg.}$$

In this case, 0,21+0,372=0,582 kg of dry organic substrate is loaded into the methane tank. The results are shown in Fig. 4.

It was found that after 20 days of fermentation of a mixture of manure cattle and dry bird droppings at a temperature of 55°C – 0,2871 m^3/(hour·kg ODS) is obtained, at a temperature of 50°C – 0,2543 m^3/(hour·kg ODS), 45°C – 0,2351 m^3/(hour·kg ODS), 40°C – 0,2334 m^3/(hour·kg ODS), 35°C – 0,2165 m^3/(hour·kg ODS).

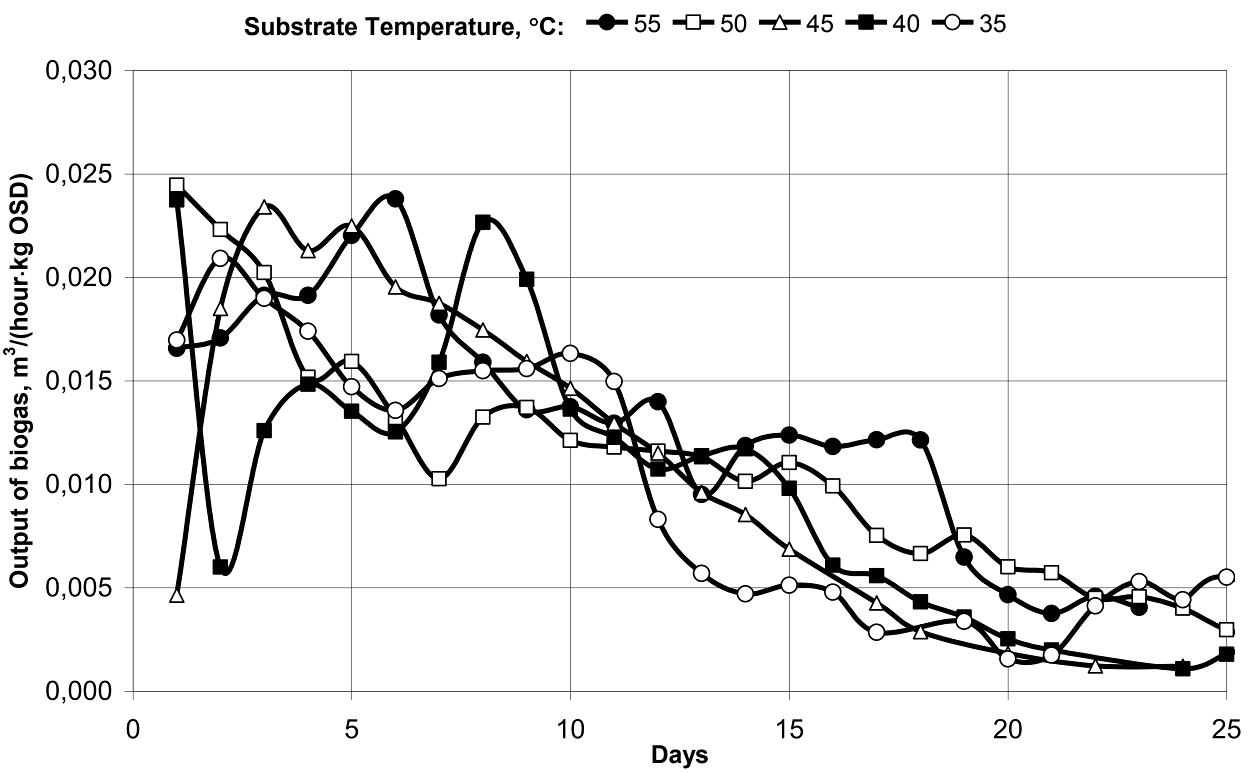

Fig. 4. Dependence of the output of biogas during the periodic regime of fermentation of the manure mixture of cattle with dry bird droppings from the temperature regime of the methane tank in time.

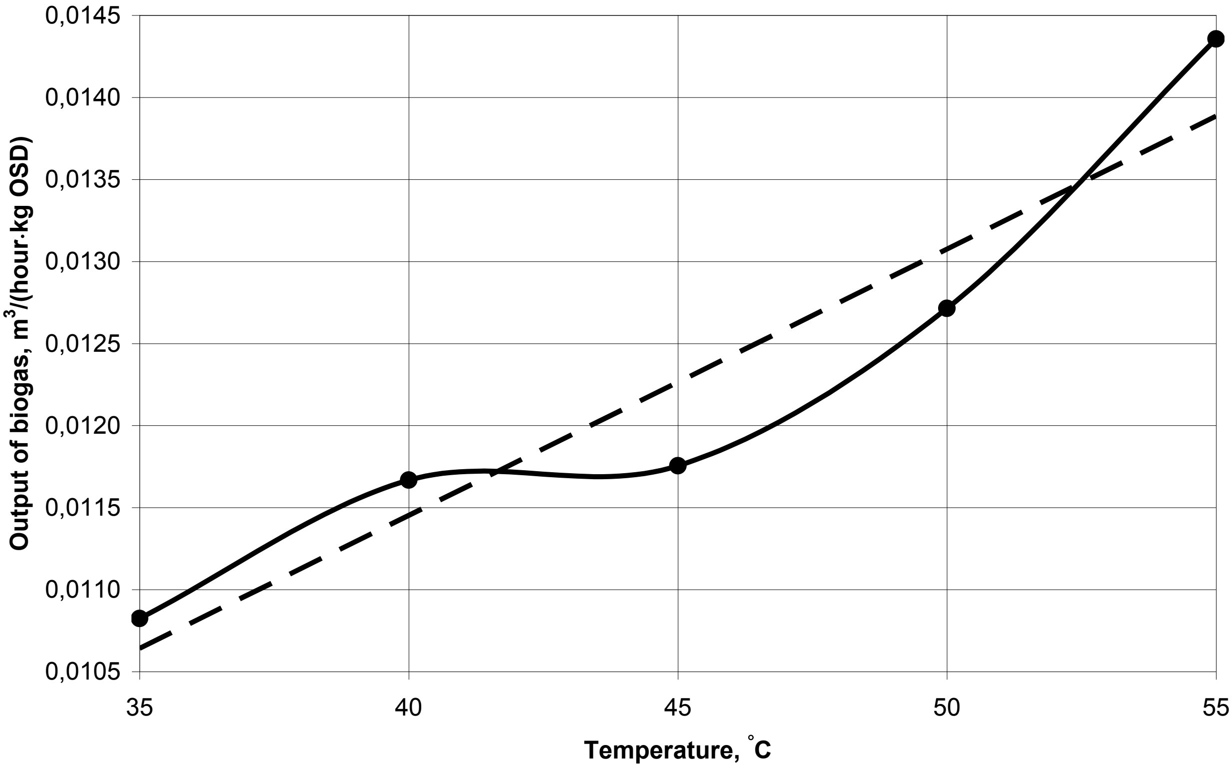

Fig. 5. Dependence of the average daily output of biogas during the periodic regime of fermentation of the manure mixture of cattle and dry bird droppings from the temperature regime of the methane: ——— the experimental curve, — — — approximate line.

The average daily value of the yield of bio-gas at a fermentation temperature of 55°C is 0,0145 m^3/(day·kg ODS), at a temperature of 50°C – 0,0127 m^3/(day·kg ODS), at a temperature of 45°C – 0, 0118 m^3/(day·kg ODS), at a temperature of 40°C – 0,0117 m^3/(day·kg ODS), at a temperature of 35°C – 0,0108 m^3/(day·kg ODS).

The dependence of the average daily output of biogas during fermentation of cattle manure from the temperature regime of the methane tank (Fig. 5) is approximated by the expression:

$$Q = 0{,}0002 \cdot T - 0{,}005 \text{ at } R^2=0{,}9052, \quad (2)$$

where: Q – average daily output of biogas, m^3/(day·kg ODS), T – temperature mode of the methane tank, °C.

CONCLUSIONS

1. In the case of periodic fermentation of cattle manure, dried bird droppings and their mixtures, leads to maximum biogas yield from a unit of organic dry substance, is observed with fermentation of cattle manure, fermentation of dry bird droppings gives the lowest maximum yield of biogas from a unit of organic dry matter, and the fermentation of a mixture of manure cattle and bird droppings - intermediate result.

2. The increase in the temperature regime of the methane tank during fermentation of the substrate causes an increase in the yield of biogas, irrespective of the type of raw material.

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OPTIMIZATION START-UP MODE OF BUCKET ELEVATOR BY CRITERION OF ROOT-MEAN-SQUARE VALUE OF RATE OF CHANGE EFFORT IN TRACTION BODY DURING TO CLASH ON TENSION DRUM

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Summary. The motion mode of dynamic model of the bucket elevator was constructed as a mechanical system with five degrees of freedom. Based on the dynamic model was established mathematical model for optimization motion mode of the bucket elevator. A method for optimizing motion mode, which is illustrated by the example of use as a criterion of optimization the root-mean-square (rms) efforts in the traction body during the clash on the tension drum. With the help of mathematical models derived the laws of motion nonworking and the working of branches, drive and tension drums and the drive mechanism. Optimal modes of motion of the bucket elevator with different number of boundary conditions designed. Using the software package Mathematica derived dependences of the kinematics' and power characteristics of the units taking into account the optimal driving mode. The indicators mean and maximum values were calculated the kinematics' and power characteristics of the drive mechanism and traction body for optimal motion mode and real mode of movement of the elevator.

The results of the optimal and real mode of movement of the bucket elevators analyzed for criteria of the mean effort in the traction body.

A dynamic model of the mode of motion of a bucket elevator in the form of a holonomic mechanical system with five degrees of freedom is constructed. On the basis of the constructed dynamic model, a mathematical model was created to optimize the mode of motion of the bucket elevator based on the criterion of the root-mean-square value the effort of the rate of change at the traction body during to clash on the tension drum. With the help of the developed mathematical model, dependences of the kinematic and power characteristics of the links for a real elevator with 32 loaded buckets and links of the constructed dynamic model are obtained considering the optimal mode of movement. Analyzing the results of Table 1, it can be seen that with the optimal mode of movement of the bucket elevator the maximum and rms values are significantly lower in comparison with the real movement of the conveyor on the dynamic characteristic of the drive motor.

It should also be noted that in the research obtained the optimal mode of motion with a constant force of resistance to scooping grain. It would be advisable to consider the influence of the variable resistance of scooping grain.

Key words: bucket elevators, optimization, drive mode, the criterion, mean efforts, traction body, tensioning drum, drum drive.

INTRODUCTION

Improving the efficiency of grain silos is one of the main areas of technology to improve the processing and transportation of grain.

While working grain elevator in areas transients (start, braking or locking switch from one speed to another) in the elements of the drive mechanism, traction body and supporting structures oscillations occur [1], which leads to an increase in these dynamic loads. This promotes the accumulation of fatigue stresses in the construction of the elevator and the consequent premature destruction of it complicates the technological process of grain overload materials (shattering and injury of grain) and negatively affects the safe operation of the elevator as a whole.

The solution is possible through optimization of movement grain elevator in areas of transient processes that will minimize vibrations of structural elements, the drive mechanism and the traction body.

ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

For optimization the modes of motion of the lifting machines used the methods of dynamic programming [2], the maximum principle [3] and the calculus of variations [4, 5]. Among these methods most widely used methods of calculus of variations [5, 6] which provides a smooth change as the kinematics' characteristics of machine parts and driving forces. But during optimization of motion of the transport vehicles importance is the selection of the criterion for their assessment [7]. In [8] the optimization of start-up mode of the bucket elevator for kinematics' criteria was conducted that do not always reflect the dynamic processes that occur during work conveyors. The traction body (ribbon) is the main element of grain elevator, that's why the modes of motion for optimization appropriate to use criteria that reflect the dynamic load in the traction body.

OBJECTIVE

Reducing the stress in the elements of bucket elevators by optimizing its mode of motion.

THE MAIN RESULTS OF THE RESEARCH

To optimize the mode of motion of the bucket elevator [9, 10], a dynamic model with five degrees of freedom is used, in which the kinematics' chain is conditionally opened at the point where the tape runs off the drive drum (Fig. 1).

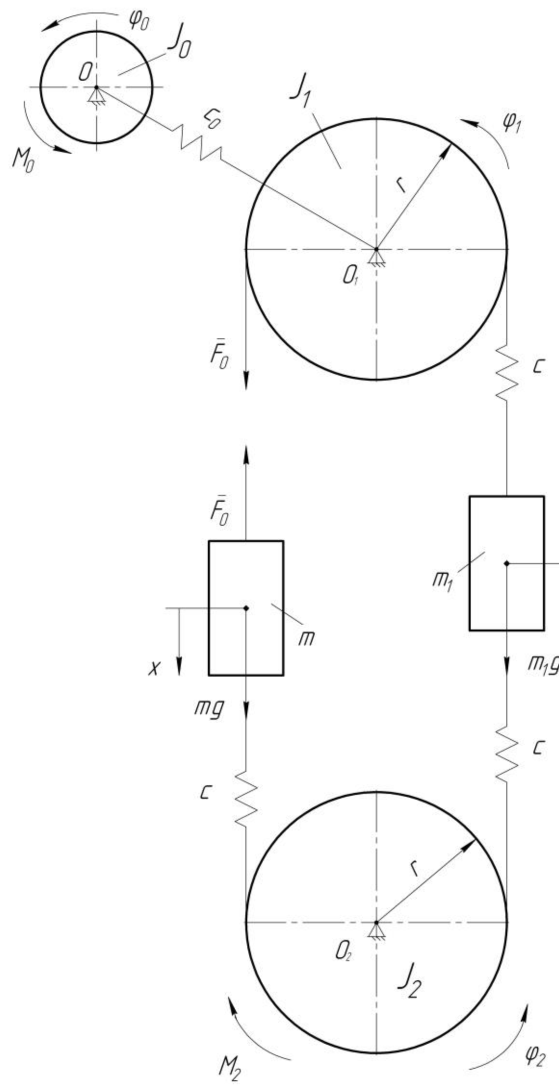


Fig. 1. Dynamic model of the bucket elevator.

For the generalized coordinates in this model was adopted the angular coordinates of the rotor of the electric motor, reduced to the axis of the drive drum φ0, the angular coordinates of the drive drum φ1 and of the tension drum φ2 and the linear coordinates of the centers of mass of the working x1 and non-working x branches of the elevator.

In the dynamic model (Figure 1) made the following notation: J_0 , J_1 , J_2 – moments of inertia relative to their axes of rotation of the drive mechanism, which was erected to the axis of rotation of the drive drum, drive and tension drum to accordance, m_1, m_2, – the total masses of the working and non-working branches of the elevator to accordance, c_0 – stiffness of elastic elements of the drive mechanism that reduced to the axis of rotation of the drive drum, c – stiffness of half the length of ribbon on the working (non-working) branch of the conveyor, M_0 – the driving moment on shaft of the motor that reduced to the axis of rotation of the drive drum, M_2 – the moment of resistance from loading buckets that reduced to the axis of rotation of the tension drum, r – the radius of the drive drum and tension drum, which were adopted equal, g – acceleration of free fall, $F_o = F_н + mg$ – force in the traction body when running off the drive drum, $F_н$ – force of pre-tension of the tape.

On the basis of d'Alembert's principle, a mathematical model of the bucket elevator is constructed, which is represented by the following system of differential equations:

$$\begin{cases} J_0\ddot{\varphi}_0 = M_0 - c_0(\varphi_0 - \varphi_1), \\ J_1\ddot{\varphi}_1 = c_0(\varphi_0 - \varphi_1) - cr(\varphi_1 r - x_1) + F_0 r, \\ m_1\ddot{x}_1 = c(\varphi_1 r - x_1) - c(x_1 - \varphi_2 r) - m_1 g, \\ J_2\ddot{\varphi}_2 = cr(x_1 - \varphi_2 r) - cr(\varphi_2 r - x) - M_2, \\ m\ddot{x} = c(\varphi_2 r - x) + mg - F_0. \end{cases} \quad (1)$$

Let's consider the process of optimization start-up mode of the bucket elevator [11 - 13] by the criterion root-mean-square value of the rate of change the effort in the traction body during to clash on the tension.

The force in the traction body during a run on the tension drum can be determined from the last equation of the system (1)

$$R_{02} = c(\varphi_2 r - x) = m\ddot{x} + F_0 - mg. \quad (2)$$

We differentiate expression (2) in time, as a result of which we obtain the dependence of the rate of change the effort in the traction body during to clash on the tension drum

$$\dot{R}_{02} = m\dddot{x}. \quad (3)$$

Then, the root-mean-square value of the rate of change the effort in the traction body during to clash on the tensioning drum is determined in the form of a functional

$$\dot{R}_{02ск} = \left[\frac{1}{t_1}\int_0^{t_1} \dot{R}_н^2 dt\right]^{\frac{1}{2}} = \left[\frac{m^2}{t_1}\int_0^{t_1} \dddot{x}^2 dt\right]^{\frac{1}{2}}. \quad (4)$$

The integrand of the functional (4) has the form:

$$f = \dddot{x}^2. \quad (5)$$

The minimum condition for criterion (4) is the Euler-Poisson equation:

$$\frac{\partial f}{\partial x}-\frac{d}{dt}\frac{\partial f}{\partial \dot{x}}+\frac{d^2}{dt^2}\frac{\partial f}{\partial \ddot{x}}-\frac{d^3}{dt^3}\frac{\partial f}{\partial \dddot{x}}=0. \qquad (6)$$

We substitute expression (5) into equation (6), as a result of which we obtain:

$$\overset{VI}{x}=0. \qquad (7)$$

Integrating equation (7), we find:

$$\begin{aligned}
&\overset{V}{x}=C_1;\ \overset{IV}{x}=C_1t+C_2,\\
&\dddot{x}=\frac{1}{2}C_1t^2+C_2t+C_3,\\
&\ddot{x}=\frac{1}{6}C_1t^3+\frac{1}{2}C_2t^2+C_3t+C_4,\\
&\dot{x}=\frac{1}{24}C_1t^4+\frac{1}{6}C_2t^3+\frac{1}{2}C_3t^2+C_4t+C_5,\\
&x=\frac{1}{120}C_1t^5+\frac{1}{24}C_2t^4+\frac{1}{6}C_3t^3+\frac{1}{2}C_4t^2+C_5t+C_6,
\end{aligned} \qquad (8)$$

where: C_1, C_2, C_3, C_4, C_5, C_6 – constants of integration, which are determined from the boundary conditions of motion and for the elevator start-up process have the form:

$$\begin{aligned}
&t=0: x=0, \dot{x}=0, \ddot{x}=0,\\
&t=t_1: \dot{x}=\upsilon_y, \ddot{x}=0, \dddot{x}=0.
\end{aligned} \qquad (9)$$

Here υ_y – the steady speed of movement of the traction body of the non-working branch of the elevator.

For boundary conditions of motion (9), the constants of integration are determined by the dependences:

$$\begin{aligned}
&C_1=72\frac{\upsilon_y}{t_1^4},\\
&C_2=-48\frac{\upsilon_y}{t_1^3},\\
&C_3=12\frac{\upsilon_y}{t_1^2},\\
&C_4=C_5=C_0=0.
\end{aligned} \qquad (10)$$

After substituting permanent integration (10) into the system (8) we obtain the law of motion non-working branch of elevator, which provides its minimum rms value of the rate of change the effort during to clash on the tension drum:

$$\begin{aligned}
&x=\frac{\upsilon_y}{t_1^2}\left(\frac{3}{5}\frac{t^5}{t_1^2}-2\frac{t^4}{t_1}+2t^3\right),\\
&\dot{x}=\frac{\upsilon_y}{t_1^2}\left(3\frac{t^4}{t_1^2}-8\frac{t^3}{t_1}+6t^2\right),\\
&\ddot{x}=12\frac{\upsilon_y}{t_1^2}\left(\frac{t^3}{t_1^2}-2\frac{t^2}{t_1}+t\right),\\
&\dddot{x}=12\frac{\upsilon_y}{t_1^2}\left(3\frac{t^2}{t_1^2}-4\frac{t}{t_1}+1\right),\\
&\overset{IV}{x}=24\frac{\upsilon_y}{t_1^3}\left(3\frac{t}{t_1}-2\right),\\
&\overset{V}{x}=72\frac{\upsilon_y}{t_1^4};\ \overset{VI}{x}=0.
\end{aligned} \qquad (11)$$

Now we determine the mode of motion of the non-working branch of the traction body of the elevator by the same criterion of the root-mean-square value of the rate of change the effort during to clash on the tension drum, but with the minimum possible number of boundary conditions during the start-up:

$$\begin{aligned}
&t=0: x=0, \dot{x}=0,\\
&t=t_1: \dot{x}=\upsilon_{y.}
\end{aligned} \qquad (12)$$

The general solution of equation (7) contains six arbitrary constants C_i *(i=1, 2,…, 6)* and for their definition is not enough given boundary conditions (12). To determine the conditions that are not sufficient, we find the variation of the functional:

$$\dot{I}(x)=\int_0^{t_1}\dddot{x}^2dt, \qquad (13)$$

which has the form:

$$\delta\dot{I}(x)=\int_0^{t_1}\dddot{x}(t)\delta\dddot{x}(t)dt. \qquad (14)$$

Integrating (14) by parts three times, we will have:

$$\begin{aligned}
\delta\dot{I}(x)&=\dddot{x}(t)\delta\ddot{x}(t)\Big|_0^{t_1}-\int_0^{t_1}\overset{IV}{x}(t)\delta\ddot{x}(t)dt=\\
&=\left[\dddot{x}(t)\delta\ddot{x}(t)-\overset{IV}{x}(t)\delta\dot{x}(t)\right]\Big|_0^{t_1}+\int_0^{t_1}\overset{V}{x}(t)\delta\dot{x}(t)dt=\\
&=\left[\dddot{x}(t)\delta\ddot{x}(t)-\overset{IV}{x}(t)\delta\dot{x}(t)+\overset{V}{x}(t)\delta x(t)\right]\Big|_0^{t_1}-\int_0^{t_1}\overset{VI}{x}(t)\delta x(t)dt.
\end{aligned} \qquad (15)$$

Expression (15) is equal to zero on the extremal x (t) of the functional (13). With an arbitrary $\delta x(t)$ it follows that $\overset{VI}{x}=0$. This is the Euler-Poisson equation for the functional (13). If the integral on the right-hand side of (15) is zero, then the boundary expression:

$$\left[\dddot{x}(t)\delta\ddot{x}(t)-\overset{IV}{x}(t)\delta\dot{x}(t)+\overset{V}{x}(t)\delta x(t)\right]\Big|_0^{t_1} \qquad (16)$$

also should be zero.

Since, according to the boundary conditions (12), the velocities at the edges are fixed, and also the position of the traction body is fixed at the initial instant of time, then $\delta x(0)=\delta\dot{x}(0)=\delta\dot{x}(t_1)=0$. Whence we have:

$$\begin{aligned}
&\overset{V}{x}(t_1)\delta x(t_1)=0,\\
&\dddot{x}(0)\delta\ddot{x}(0)=0,\\
&\dddot{x}(t_1)\delta\ddot{x}(t_1)=0.
\end{aligned} \qquad (17)$$

By virtue of arbitrariness $\delta x(t_1)$, $\delta\ddot{x}(0)$, $\delta\ddot{x}(t_1)$ in equation (17) we find that:

$$\dddot{x}(0)=0,\quad \dddot{x}(t_1)=0,\quad \overset{V}{x}(t_1)=0. \tag{18}$$

Then, based on (8), we find that

$C_1=0,\ C_3=0$

$$\frac{1}{2}C_1t^2+C_2t+C_3=0. \tag{19}$$

From the last equation it follows that $C_2=0$.

From the other three boundary conditions (12) we obtain: at $t=0$: $C_5=C_6=0$, at $t=t_1$: $v_y=C_4t_1$. Whence:

$$C_4=\upsilon_y/t_1. \tag{20}$$

As a result, we will have such a law of motion of the traction body in the non-working branch of the elevator, which provides the minimum root-mean-square value of the rate of change the effort during to clash on the tension drum with a minimum number of boundary conditions during the start-up:

$$x=\frac{1}{2}\upsilon_y\,t^2/t_1,\quad \dot{x}=\upsilon_y\,t/t_1,\quad \ddot{x}=\upsilon_y/t_1,\quad \dddot{x}=0. \tag{21}$$

Now, from the system (1) we determine the kinematic and power characteristics of the bucket elevator, which correspond to the optimal modes of motion of the non-working branch.

From the last equation of the system (1), we find the kinematic characteristics of the tension drum:

$$\begin{aligned}\varphi_2&=\left(x+\frac{m}{c}(\ddot{x}-g)+\frac{F_o}{c}\right)\Big/r,\\ \dot{\varphi}_2&=\left(\dot{x}+\frac{m}{c}\dddot{x}\right)\Big/r,\\ \ddot{\varphi}_2&=\left(\ddot{x}+\frac{m}{c}\overset{IV}{x}\right)\Big/r,\\ \dddot{\varphi}_2&=\left(\dddot{x}+\frac{m}{c}\overset{V}{x}\right)\Big/r,\\ \overset{IV}{\varphi}_2&=\left(\overset{IV}{x}+\frac{m}{c}\overset{VI}{x}\right)\Big/r.\end{aligned} \tag{22}$$

From the penultimate equation of the system (1) we determine the kinematic characteristics of the working branch of the elevator:

$$\begin{aligned}x_1&=\varphi_2r+\left(\frac{J_2}{r}\ddot{\varphi}_2+m(\ddot{x}-g)+F_o+\frac{M_2}{r}\right)\Big/c,\\ \dot{x}_1&=\dot{\varphi}_2r+\left(\frac{J_2}{r}\dddot{\varphi}_2+m\dddot{x}\right)\Big/c,\\ \ddot{x}_1&=\ddot{\varphi}_2r+\left(\frac{J_2}{r}\overset{IV}{\varphi}_2+m\overset{IV}{x}\right)\Big/c,\\ \dddot{x}_1&=\dddot{\varphi}_2r+\left(\frac{J_2}{r}\overset{V}{\varphi}_2+m\overset{V}{x}\right)\Big/c,\\ \overset{IV}{x}_1&=\overset{IV}{\varphi}_2r+\left(\frac{J_2}{r}\overset{VI}{\varphi}_2+m\overset{VI}{x}\right)\Big/c,\end{aligned} \tag{23}$$

and the tension of the traction body during to clash on the tension drum

$$R_{12}=c(\varphi_2r-x)+\frac{J_2}{r}\ddot{\varphi}_2+\frac{M_2}{r}. \tag{24}$$

From the third equation of system (1) we find the kinematic characteristics of the drive drum:

$$\begin{aligned}\varphi_1&=\left[2x_1-\varphi_2r+\frac{m_1}{c}(\ddot{x}_1+g)\right]\Big/r,\\ \dot{\varphi}_1&=\left[2\dot{x}_1-\dot{\varphi}_2r+\frac{m_1}{c}\dddot{x}_1\right]\Big/r,\\ \ddot{\varphi}_1&=\left[2\ddot{x}_1-\ddot{\varphi}_2r+\frac{m_1}{c}\overset{IV}{x}_1\right]\Big/r,\\ \dddot{\varphi}_1&=\left[2\dddot{x}_1-\dddot{\varphi}_2r+\frac{m_1}{c}\overset{V}{x}_1\right]\Big/r,\\ \overset{IV}{\varphi}_1&=\left[2\overset{IV}{x}_1-\overset{IV}{\varphi}_2r+\frac{m_1}{c}\overset{VI}{x}_1\right]\Big/r,\end{aligned} \tag{25}$$

and the tension of the traction body during to clash on the drive drum

$$R_{11}=c(x_1-\varphi_2r)+m_1(\ddot{x}+g). \tag{26}$$

From the second equation of the system (1), we determine the kinematic characteristics of the drive motor, which are reduced to the rotation axis of the drive drum:

$$\begin{aligned}\varphi_0&=\varphi_1\left(1+\frac{cr^2}{c_0}\right)+\left(J_1\ddot{\varphi}_1-crx_1-F_or\right)/c_0,\\ \dot{\varphi}_0&=\dot{\varphi}_1\left(1+\frac{cr^2}{c_0}\right)+\left(J_1\dddot{\varphi}_1-cr\dot{x}_1\right)/c_0,\\ \ddot{\varphi}_0&=\ddot{\varphi}_1\left(1+\frac{cr^2}{c_0}\right)+\left(J_1\overset{IV}{\varphi}_1-cr\ddot{x}_1\right)\Big/c_0,\end{aligned} \tag{27}$$

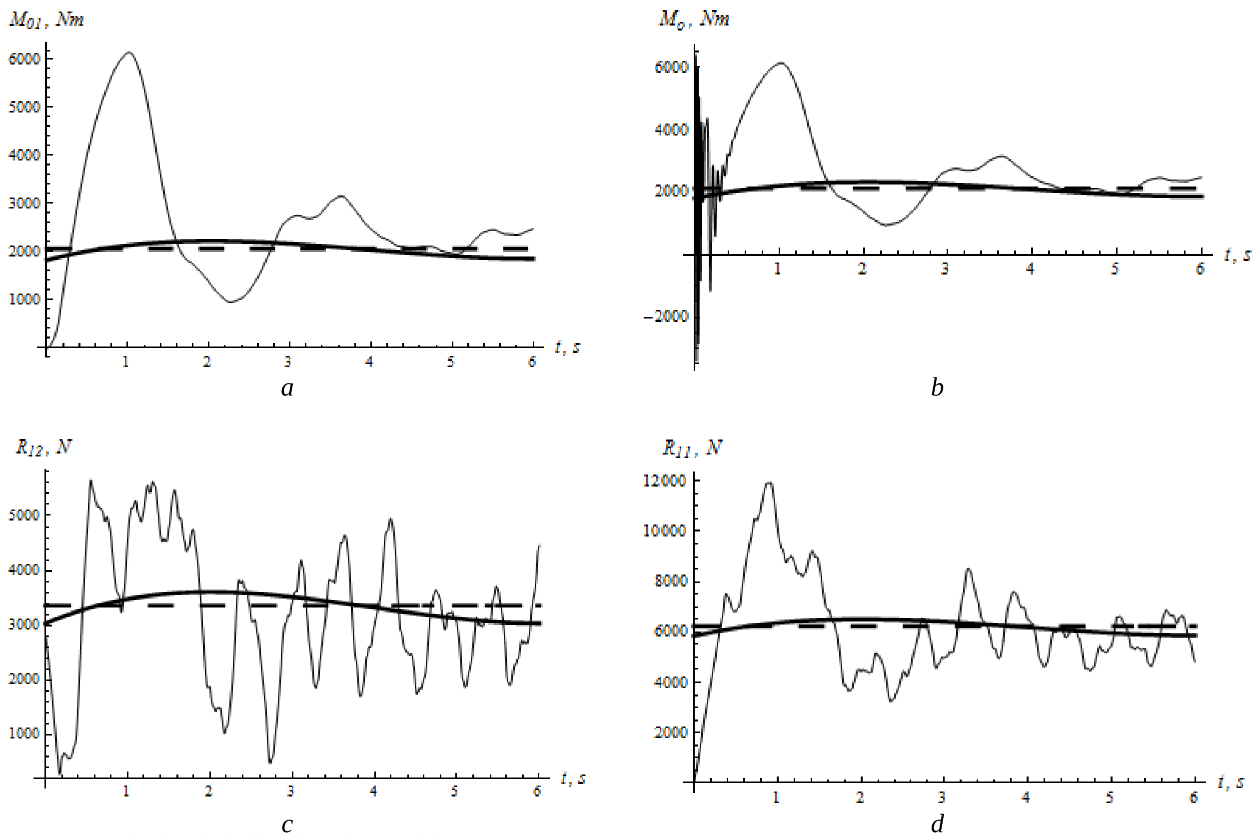
and the elastic moment in the drive mechanism, to the axis of rotation of the drive drum

$$M_{01}=cr(\varphi_1r-x_1)+J_1\ddot{\varphi}_1-F_or. \tag{28}$$

From the first equation of system (1) we find the driving moment on the shaft of the drive motor, reduced to the axis of rotation of the drive drum

$$M_o=c_0(\varphi_0-\varphi_1)+J_0\ddot{\varphi}_0. \tag{29}$$

For a real bucket elevator with 32 loaded and 32 empty buckets, the parameters [14, 15] were calculated: *J_o=65 kg·m², J_1=78,4 kg·m², J_2=78,4 kg·m², ω_y=5,7 rad/s, R=0,315 m, c_0=2000 N·m/rad, c=330000 N/m, n_1=32, n_2=32, $m_в$=9 kg, $m_к$=9 kg* . Using the software package *Mathematica 9.0*, the power (Fig. 2) and kinematic (Fig. 3) characteristics for the optimal and real modes of motion are defined, which are presented in the form of graphs.

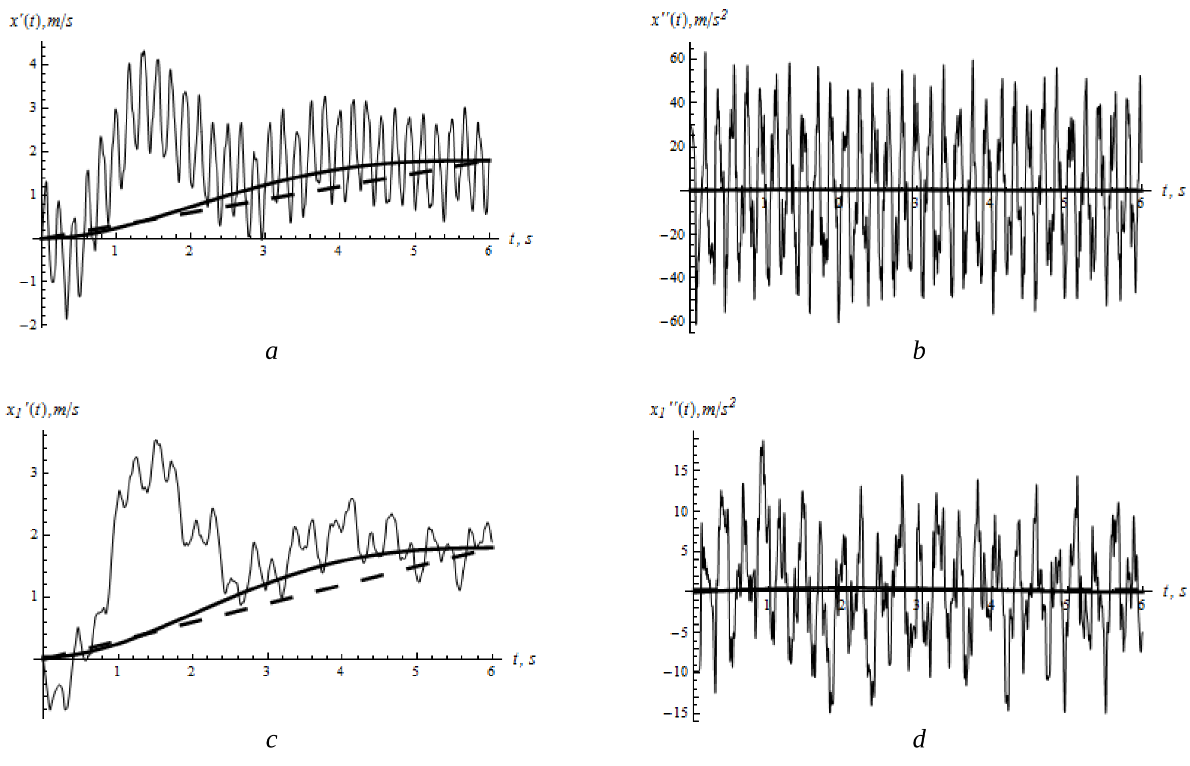


optimal mode 1 with all boundary conditions;

optimal mode 2 subject to the minimum possible number of boundary conditions;

the mode at the dynamic natural characteristic of the drive motor of elevator, represented 32 mass model for working and non-working branches

Fig. 2. Power characteristics of the dynamics of bucket elevator: *a* – change the elastic moment in the drive mechanism, *b* – change the driving torque on the shaft of the drive motor, *c* – efforts at the traction body for coincidence of the tension drum, *d* – efforts at the traction body during to clash on the drive drum.



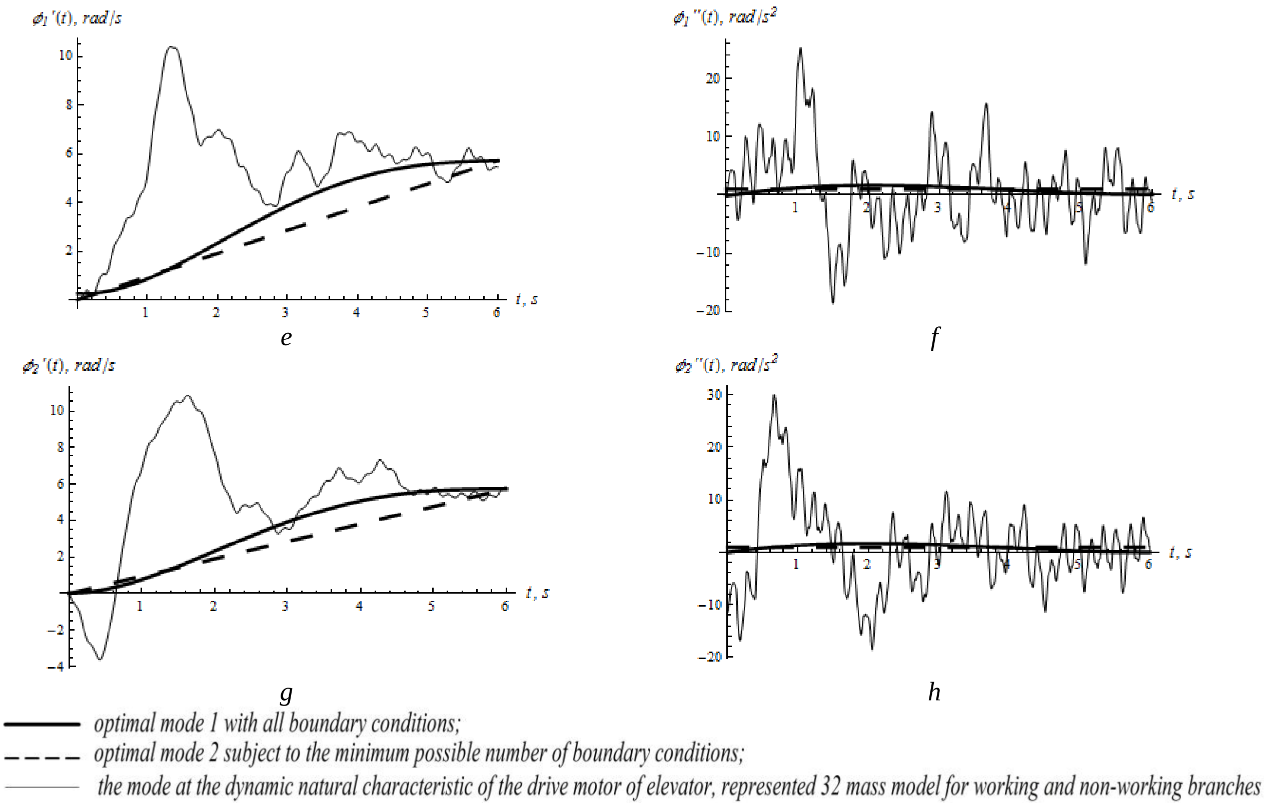


Fig. 3. Kinematic characteristics of the dynamics of bucket elevator: *a, b* – change the speed and acceleration of the center of mass non-working branch in accordance, *c, d* – change the speed and acceleration of the center of mass working branch in accordance, *e, f* – change the angular velocity and acceleration of the drive drum in accordance, *g, h* – change the angular velocity and acceleration of the tension drum in accordance.

From the obtained graphical dependencies it is evident that when a real elevator with 32 loaded buckets is started, in its moving parts there are significant oscillatory processes. The magnitude of these oscillations depends on the accuracy of modeling the working and non-working branches of the conveyor. However, with such a large number of buckets, mathematical models will be quite complex in optimizing transient processes and the accuracy in their calculations is not high enough. Therefore, to simplify the optimization of the driving mode by the criterion of the rms value of the rate of change the effort in the traction body, single-mass dynamic models on the working and non-working branches were used.

In the program Mathematica 9.0 [16], are calculated the mean-square and maximum values of the following indicators for the optimum mode and a real elevator with 32 masses on the working and non-working branches:

- linear velocities of the reduced masses in the middle part of the working $\dot{x}_1$ and non-working $\dot{x}$ branches,
- angular velocities of the drive $\dot{\varphi}_1$ and tension $\dot{\varphi}_2$ drums,
- the driving moment on the shaft of the drive mechanism M_o,
- the elastic moment in the drive mechanism M_{01},
- efforts at the traction body for coincidence of the tension drum R_{12},
- efforts at the traction body during to clash on the drive drum R_{11}.

As a result of the calculations the data given in Table 1:

Table 1

Indicator	Root Mean Square			Maximum value		
	Optim. 1	Optim. 2	32 masses	Optim. 1	Optim. 2	32 masses
$\dot{x}$, *m/s*	*1.254*	*1.039*	*2.019*	*1.800*	*1.800*	*4.330*
$\dot{x}_1$, *m/s*	*1.249*	*1.039*	*1.907*	*1.800*	*1.800*	*3.537*
$\dot{\varphi}_1$, *rad/s*	*3.941*	*3.299*	*5.819*	*5.715*	*5.714*	*10.387*
$\dot{\varphi}_2$, *rad/s*	*3.978*	*3.299*	*6.130*	*5.714*	*5.714*	*10.852*
M_{01}, *Nm*	*2063*	*2063*	*2932*	*2224*	*2063*	*6146*
M_o, *Nm*	*2121*	*2125*	*2991*	*2323*	*2125*	*6481*
R_{12}, *N*	*3362*	*3357*	*3434*	*3606*	*3357*	*5660*
R_{11}, *N*	*6228*	*6227*	*6490*	*6509*	*6227*	*11953*

Analyzing the results of the table it can be seen that the maximum values of all calculated indicators of a real elevator with 32 buckets on the working and non-working branches almost exceed these values with optimal driving regimes by 35% -65%. The maximum value of the bucket elevator with 32 masses is 6.5 kN, which is 2.8 times higher than the maximum value of the elevator's driving moment at an optimum mode of movement. It can also be seen that the maximum values for the optimum mode are practically no more than the rms values for a real elevator, except the effort value at the traction body. The difference between the optimal and real regime of the bucket grain elevator movement is about 30-35% by the rms values, while the force indicators at the traction body during to clash on the drive drum and for coincidence of the tension drum in real mode only by 2-4% are large then optimal.

CONCLUSIONS

1. A dynamic model of the mode of motion of a bucket elevator in the form of a holonomic mechanical system with five degrees of freedom is constructed. On the basis of the constructed dynamic model, a mathematical model was created to optimize the mode of motion of the bucket elevator based on the criterion of the root-mean-square value the effort of the rate of change at the traction body during to clash on the tension drum. With the help of the developed mathematical model, dependences of the kinematic and power characteristics of the links for a real elevator with 32 loaded buckets and links of the constructed dynamic model are obtained considering the optimal mode of movement. Analyzing the results of Table 1, it can be seen that with the optimal mode of movement of the bucket elevator the maximum and rms values are significantly lower in comparison with the real movement of the conveyor on the dynamic characteristic of the drive motor.

2. It should also be noted that in the research obtained the optimal mode of motion with a constant force of resistance to scooping grain. It would be advisable to consider the influence of the variable resistance of scooping grain, as was done in [17-20].

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INTENSIFICATION OF HYDRODYNAMIC CAVITATION PROCESSES FOR OBTAINING ASTRINGENTS WHEN PREPARING CONCRETE MIXTURE

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Summary. The research of the influence model of hydrodynamic cavitation on the processing of technological environments on the example of disperse media was done. It is determined that the choice of the model is based on the evaluation of the shock waves propagation mechanisms near the collapsing cavitation bubble and the shock action of cumulative microstreams in the asymmetric collapse of cavitation microbubbles. The basic preconditions and assumptions are formulated in the substantiation of the model and its mathematical description. A complex analysis of the influence of hydrodynamic cavitation on the process of mixing liquid media, as well as on chemical processes, has been applied, which made it possible to scientifically substantiate the choice of technological parameters of the process. Dependences for the calculation of the basic design dimensions of cavitation modules were obtained, which ensured the high productivity of equipment, required quality of finished products and reduced its cost. The result of the cavitation processing of technological environments is the research for the purpose of cement activation to obtain materials for different purposes and to evaluate the influence of cavitation on these processes in materials. The program and experimental research methods have been developed. The research was made with the help of an experimental device by activating water during the preparation of a concrete mixture. The results of special method research have been processed and a procedure for their evaluation has been performed. Now the preconditions and assumptions concerning the intensification of the processes of applied methods based on the results of measurements for increasing the strength of concrete samples are confirmed. An analytical dependence to determine the effective flow of the water activation process in the preparation of a concrete mixture that has become a predominant to improve the parameters and modes of the hydrodynamic device has been formulated. An algorithm of intensification of processes of cavitation processing was developed.

Key words: intensification, hydrodynamic cavitation, process, astringent, criteria, kinematic, characteristic, mixture.

INTRODUCTION

Determination of hydrodynamic cavitation models and methods to describe the process of cavitation [1, 2, 3] are caused by changes of rheological properties of the technological environment, such as viscosity, elasticity and plasticity.

The essence of the description of the processes and existing models of cavitation effects can be reduced to such mechanisms as: the dissemination of the shockwaves near collapsing cavitation bubble and cumulative microstream shock action with asymmetrical collapse of the cavitation microbubbles.

Intensification of the liquid media mixing process could be done with the help of such hydrodynamic cavitation effects as: the occurrence of pressure pulsations, the occurrence of dilution and compression waves during the pulsations of steam-gas bubbles, the destructive effect of cumulative stream, throbbing temperature, the formation of turbulent zones, chemical transformations.

However, the basic parameters that determine the effectiveness of the impact of hydrodynamic cavitation in processable environment are insufficiently studied in most known works today.

Comprehensive analysis of hydrodynamic cavitation influence on the liquid media mixing processes, as well as on chemical processes will enable us to make a scientifically substantiated choice of technological process parameters, and based on obtained dependences to calculate basic constructive sizes of cavitation module, providing high performance equipment and required quality of the finished product with a lower cost.

Based on the above we can say, that research aimed at a thorough study of the issues, related with progressive method of cavitation effect on the environment are relevant and important for national economy.

Due to this statement we have defined the main objective of this research.

ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

Nowadays, one of the perspective approaches to intensification technological processing of liquid media and improving the efficiency of mixing equipment are methods based on impulsive energy influences with different physical and chemical effects, that are using internal and external sources of energy.

Under the the intensification of these processes in a widemeaning usually means obtaining direct or indirect economic effect by increasing productivity, efficiency, energy and material cost reduction, improving product quality as well as economic and social indicators.

To intensify the processes of mixing building material we need to create mixing equipment with the ability to use cavitation effects for mixing technology environment. The revelent method today is to create cavitation device that would allow you to receive the most advanced cavitation with minimum energy costs.

Analysing the various literary sources we need to develop a technological methods of calculation and assessment of the cavitation impact in liquid systems and in solid phase inclusions as well (from technological point of view, erosional destruction of the walls, due to the destructive effects of cavitation and working tools of vehicles or whole solid boundaries of stream are undesirable and should be excluded).

If the liquid is heterogeneous (combines two or more immiscible liquids in order to obtain emulsion, for example oil and water), we need to consider processes of drops destruction due to large tangential stresses on the borders of cavitation micro vortex. In the process of dispergating elastic or solid fibrous particles in liquid, micro vortex formation is no longer a defining part, but hydrodynamic penetration of a cumulative micro-stream into the material is. And if the penetration depth is more then typical particle size, it means they will be destroyed. In the reverse ratio for destroying particles cavitation processing time should be increased.

Let's consider how the impact of cavitation microbubles will affect the organization of the different technological processes [4]. In this case, particular importance will have the dispersion of particles, small enough to be compared with the size of molecules or with intermolecular distance of a carrier phase.

Schematic diagram of power interaction of shock waves from the collapse of cavitation microbubbles and dispersed phase are shown in Fig. 1.

OBJECTIVE

The main purpose of the research is to establish the main parameters on the basis of which the model is formed and determine the effectiveness of the influence of hydrodynamic cavitation on the processing medium.

THE MAIN RESULTS OF THE RESEARCH

Note that mixing of solids in suspensions and emulsions in each case has its own peculiar characteristics. The determining factors of hydrodynamic cavitation processing is the number and size of cavitation bubbles, formed during the decay of caverns [5, 6].

They depends on the basic hydrodynamic parameters of the process flow, such as: stages of cavitation and its speed, that are caused by constructive peculiarities of device.

Structural features of cavitation machines determines the form of cavitation (the size and movement type of cavitation bubbles), her intensity [7, 8] and her erosion activity [9].

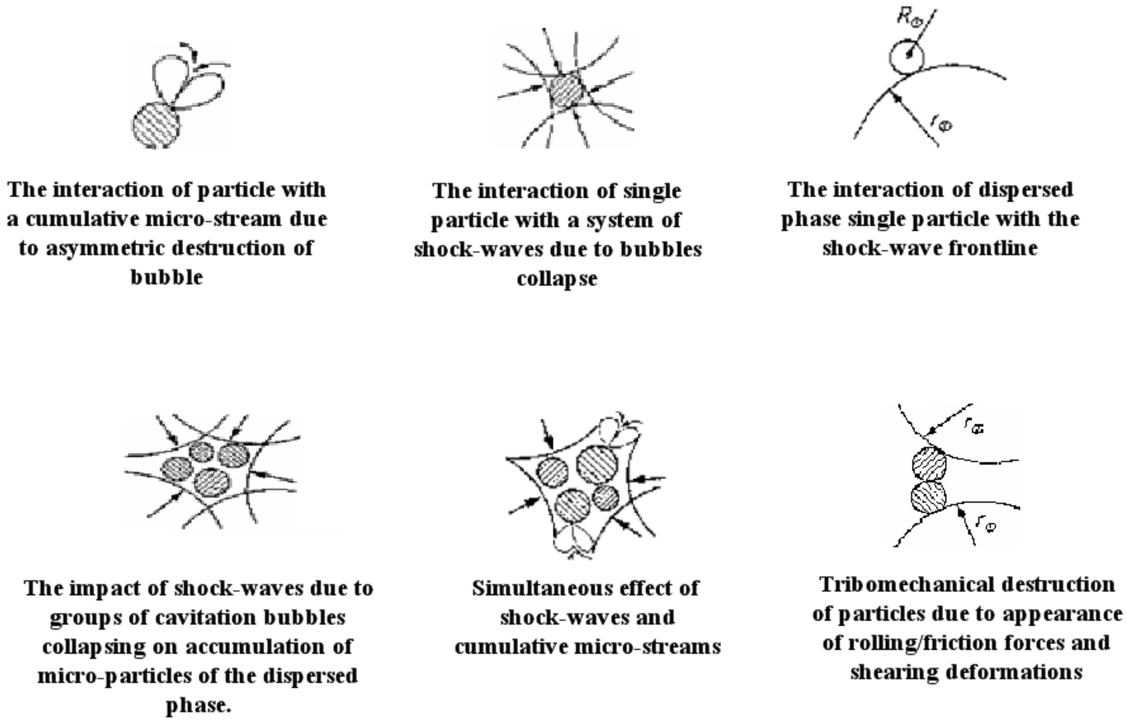

Fig. 1. Schematic diagram of the influence of cavitation shock waves on dispersed phase in fluid stream.

The cavitation number is related with her stage. The equation for determining the critical cavitation number for dynamic cavitation devices defined with the following dependence [10]:

$$\sigma_i = \frac{P_a + \gamma_{ж} h - P_{н.п} + \frac{2}{3} 2 \sigma_П / R_з}{0{,}5 \rho v^2} \quad (1)$$

where Pa – atmospheric pressure, $P_{н.п}$ – the saturated vapor pressure, $\gamma_{ж}$ – specific weight of the liquid, *h*– height of the liquid layer under a mixer, v – the rate of blades flow, $R_з$ – the radius of of the embryo. $\sigma_П$ – the surface tension

The main parameters that determine the intensity of energy impact of cavitation treatment on the technological environment is the stage of cavitation and its processing multiplicity. Satisfacted frequency of processing are individual for each environment and determined experimentally. Also, processing efficiency of fluid is increased with increasing temperature. Under the regulation and maintenance of some value that determines the efficiency of speed in your device, you can reach certain conditions of collapse of cavitation bubbles and localize a cavitation field in the volume of the working chamber of the gravitational flow mixer. As a result, we have high quality of environment processing. By adjusting each of these parameters, we can customize hydrodynamic cavitation device at a different level of energy impact on environment.

Thus, analyzing the above, to achieve the desired result of practical research we need to provide multiple passing the treated environment through cavitation zone.

Evaluation and analysis of scientific and technical information and conducted experimental research, also the hydrodynamic conditions and, first of all – speed of the process flow, is one of the most important criteria that determines the effectiveness of the shock-wave impact of hydrodynamic cavitation on a processed environment.

The equation that is used to assess the cumulative rate of micro-streams $\nu_к$ (during the asymmetric collapse of caverns) [11]:

$$v_k = \left(\frac{2}{3} \frac{P_0}{\rho_0} \left(\frac{R_0^3}{r^3} - 1 \right) \right)^{1/2} \frac{1 + \cos^2 \varphi(r)}{\sin^2 \varphi(r)}, \quad (2)$$

where: P_0 – permanent pressure, R_0 – an initial radius of bubble, r – variable radius of bubble.

Analyzing the known structures of hydrodynamic cavitation mixer we can noticed that regulation occurs only due to changes in pressure at the outlet of the device. We find a perspective solution to create some types of hydrodynamic cavitation device, ensuring the possibility of setting up an independent degree of cavitator with specific hydrodynamic characteristics.

If you can calculate the speed of cumulative micro-streams, so it could be possible to estimate the value of shock pressure P_k by equation of N.E. Zhukovskyy:

$$P_k = \rho_0 \cdot a \cdot v_k \,. \quad (3)$$

Physico-chemical properties of the liquid medium such as viscosity significantly influence the effectiveness of processing. Increased viscosity inhibits the process of bubble collapsing and reduces the speed rate of cumulative micro-streams [12, 13] worsening terms of liquid processing and its quality, but in turn reduces deterioration of the working bodies of the hydrodynamic device.

The density of processed environment affects in the same way [14, 15].

The higher density of the fluid means the larger cavitation bubbles we have. Surface tension accelerate the process of bubble collapse [15]: the smaller cavern is means the greater impact it contributes to surface tension and prevents its transformation into cavern of finite size [14].

According to the formula of Rayleigh [16] length of cavitation vapor bubble collapse is determined by the formula:

$$\tau_c = 0{,}915 R_{max} \sqrt{\rho / p_\infty} \quad (4)$$

where: p – hydrostatic pressure in the liquid.

If →0 it means that useful power *W* will be transformed into impulse.

The destruction time of cavitation bubble is determined by the equation [11]:

$$\tau = \frac{3\rho}{2P_0} \int_R^{R_m} \frac{R^{3/2} dR}{\sqrt{(R_m^3 - R^3)}} \quad (5)$$

where: R_m – maximum radius of bubble.

Analyzing the equation (4) it is clear that the length of the cavitation processing are considerably affected by the density of the processed fluid and hydrodynamic pressure of the fluid flow being processed right now. Experimental research of the dynamics of cavitation bubble collapse confirmed the assumption collapse rate reduction and increasing the shock wave intensity with an increased hydrostatic pressure due to a certain value [17].

Next, lets consider the example of water changing its physical and chemical properties under hydrodynamic cavitation. Changes in physical and chemical properties of water under the influence of an external force action is experimentally established fact today. There is a huge number of methods of water processing based only on the physical effects, i.e., without using any chemical additives (chemicals).

New developments in this area includes a research of hydrodynamic cavitation ways of water processing. Physico-chemical aspects of cavitation phenomena have been already explored before using cavitation generator [18]. Due to research, we can see the emergence of complex of physical and chemical processes under the action of hydrodynamic cavitation in water and water solutions (Fig. 2), which are classified as follows [19]:

- Redox reactions in the water between the solute and water degradation products that arise in the cavitation bubbles and pass into solution after collapse.
- The reactions between dissolved gases inside of cavitation bubbles.
- Chain reactions in solution initiated by decomposition products in the cavitation bubbles of impurity substances.
- The destruction of macromolecules and polymerization.

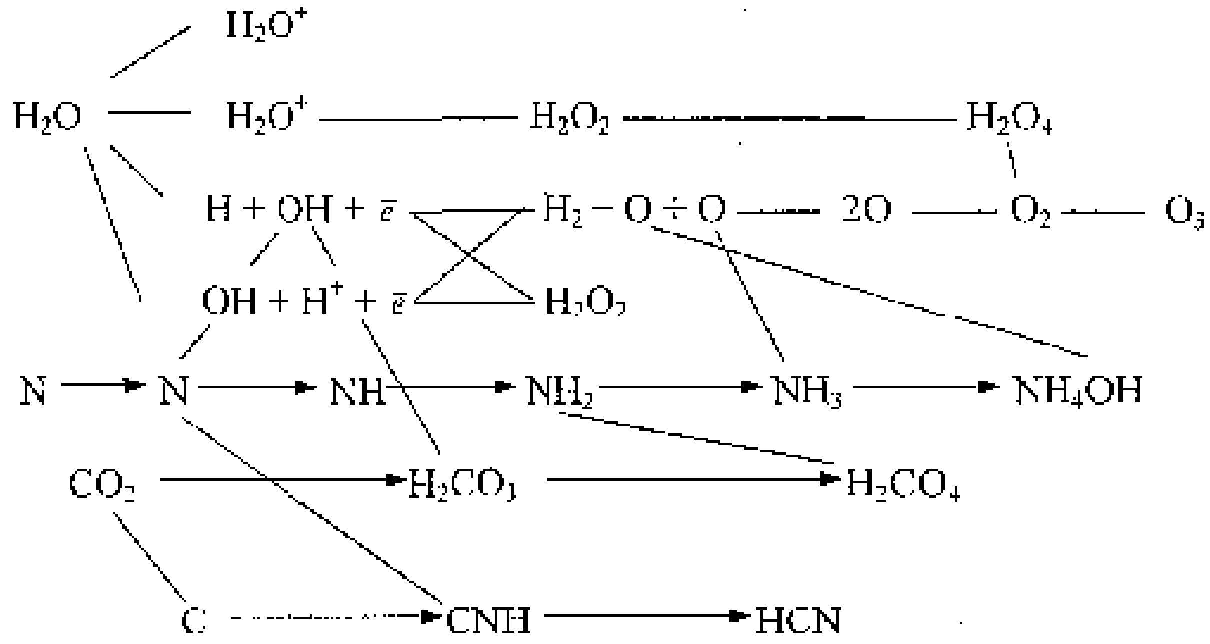

Fig. 2. Scheme of chemical shifts in the water under the action of hydrodynamic cavitation.

Pulsation of cavitation effects transforms every bubble into the hydrodynamic cavitation reactor, where conditions for the occurrences of mechano-chemical reactions have been created. At the same time we can see some water structure changings with the formation of free hydrogen relations, which causes the increased activity of the reagent ability.

Conducted laboratory researches [20, 21, 22, 23, 24] and industrial tests have shown that uniform distribution of the various components of micro impurities in a relatively large volume of liquid media is achieved by using hydrodynamic cavitation devices. Also we can see the formation of finely dispersed and stable emulsions and growing intensity of components extraction.

The water-cement suspension which is subjected to the cavitation processing and added to the concrete mix increases compressive and tensile strength of concrete products. Using of cavitation to produce stable and highly dispersed emulsions and suspensions imposed in concrete, can increase the strength of concrete by 15-20% [25].

CONCLUSIONS

1. It is revealed that the change of rheological properties in the process of hydrodynamic cavitation realization, which is viscosity, elasticity and plasticity, should determine the physical and mathematical model of the technological environment. These characteristics for the effective flow of the cavitation process were taken into account in determining the parameters of the proposed equipment.

2. An analysis of literary sources has made it possible to determine the main directions of research of the mechanism and the kinetic regularities of the intensifying effect of hydrodynamic cavitation when processing liquid media. Determination of power and hydrodynamic characteristics of devices of dynamic and static types, mechanism of chemical reactions in water and other types of liquid media.

3. The presented theoretical equations and their solutions allowed to obtain analytical dependences for the effective process of hydrodynamic cavitation and to evaluate the laws of the motion of the processing substances and their mixing.

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ASSESSMENT OF FEASIBILITY OF MACHINE-TRACTOR UNITS BASED ON POWER UNIT CLASSIC LAYOUT FROM PERSPECTIVES ITS DEVELOPMENT

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Summary. The results of research on the assessment of the impact on the creation of machine and tractor aggregates of the main directions of the development of the classical construction and layout scheme of energy resources are outlined in accordance with two variants of circuit solutions, in the first case, the rear location of the control post, not the reversing control post, nor the reverse transmission, but in the second – rear location of the control post, reversing control station improved visibility, reverse gear.

The studies were carried out using the criteria of aggregate aggregation, maintainability of the unit and the functional saturation of the energy medium for the most preferable versions of machine-tractor units created on the basis of the above-mentioned two types of circuit solutions of the classical constructive-layout scheme of energy resources used in the technological process of growing cereals with basic operations that involve the introduction Mineral fertilizers, basic soil cultivation, pre-sowing treatment Ku soil, sowing, spraying crops and harvesting.

As a result of the conducted studies it was established that for the technological process of growing grain crops the use of energy resources of the classical (traditional) constructive-layout scheme makes it possible to obtain the criteria for the collection and maintainability of the unit at the level of 0.70, and the criterion for the functional saturation of the energy facility at the level of 0.83, While the mobile energy means of the improved classical constructive-layout scheme with improved visibility and canopy Under the condition of effective functioning of combined units on its base and the availability of machines and tools for creating the necessary aggregates, it will be possible to obtain the named indicators at a level of 0.80 and 1.00, respectively.

Key words: mobile power tool, tractor units, acquisition, assessment, classic design-layout scheme, criterion.

INTRODUCTION

The efficiency of the use of mobile energy means (MEM) is one of the foundations for the formation of the cost price of agricultural production, which is determined both by the quantitative and qualitative composition of the machine and tractor parks of farms. In this regard, both in the products of domestic tractor construction, and in the production of foreign tractor-building enterprises, it is observed the practice of creating energy facilities of new modifications with the declaration of high consumer qualities, including the conditions of aggregation. Such approaches find expression even in the creation of machines with improved, and sometimes new, in this class of energy facilities, constructive-layout schemes.

And it is the constructive-layout scheme of the MEM that determines the possibility of creating aggregates for various purposes and arrangements [1–8]. In particular, recently enterprises for the manufacture of specialized self-propelled machines put emphasis on the creation of similar units based on self-propelled chassis. Such approaches to the creation of machine-tractor units (MTU) did not always have a positive effect on the cost of the final output of agriculture. In such circumstances, there is an urgent need to assess the potential of the machine in the implementation of both existing and new technologies at the design stage and which, in the final analysis, will allow to concentrate funds on optimal technical solutions.

ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

Mobile power means – a multifunctional machine, in the process of using which the human activity is carried out in two directions, namely: ensuring the operation of the actual power source, ensuring the performance of a technological operation, or technological process.

In accordance with this, the technical and technological operation of MEM differs in [9–11]. The authors of [9–11] proposed to assess the degree of technological efficiency of the energy source by three generalized indicators: productivity, agrotechnical qualities of the technological operation and the cost of work. In addition, these papers show the dependencies for determining the technological universality and efficiency of the use of the energy facility. However, the functional dependences cited by the authors of [9-11] do not allow us to concretize the evaluation of the design of the machine in order to optimize it, and can serve only as a framework for generalized requirements.

In [12], the prospects of constructing agricultural machinery are recommended to be estimated by the coefficient of universalization of Ku according to the composite quantitative index

$$K_{\text{у}} = K_{\text{р}} + K_{\text{к}} + K_{\text{а}}, \quad (1)$$

where: $K_{\text{р}}$, $K_{\text{к}}$, $K_{\text{а}}$ – coefficients, respectively, different usage of machines, combination and aggregation.

The disadvantages of this technique is the fuzzy differentiation of constructive possibilities and their actual implementation in the indicator of disagreement, and so on.

The authors of [13] proposed a method for determining the design universality coefficient according to the dependence:

$$K_{УК} = \sum_i^j Z_{ji} / \sum_i^m Z_{i\,max}, \qquad (2)$$

where: $K_{УК}$ – design universality coefficient, i, j – respectively, the i-th representative indicator and j-a machine, as well as the total number of indicators i in the j-th machine, Z_{ji} – a quantitative estimate of the i-th representative exponent in the j-th machine, $Z_{i\,max}$ – the maximum score of the i-th index in points, m – is the total number of indicators for a given type of machine.

The method for determining the design universality coefficient from the reduced dependence (2) provides for the determination of the ratio between the sums of real indicators and their maximum scores in scores. The main disadvantage of this technique, in our opinion, is the use of ball judgments that introduce certain subjectivism into the final result, and when using such estimates, the estimated values of $K_{УК}$ can reach values that are not correctly compared. In addition, such a technique complicates the evaluation of the design of MEM during its further use in the MTU of different equipment and design, that is, subject to consideration of several technological processes.

It has been proposed in [14, 15] to estimate the overall design of the energy facility according to three criteria, namely:

- MTU collection criteria:

$$K_{С} = \frac{m(P)_{С}+1}{m(P_n)}, \qquad (3)$$

where: $K_{С}$ – is the collection criterion, $m(P)_{С}$ – the quantitative composition of the set of possible subsets of MTU, which can be obtained when constructing the aggregate, $m(P_n)$ – the quantitative composition of the MTU degree set, calculated, leaving only its composition

$$m(P_n) = 2^n, \qquad (4)$$

where: n – is the number of modules of which the MTU consists,

- MTU maintainability criterion:

$$K_{Р} = \frac{m(P)_{Р}+1}{m(P_n)}, \qquad (5)$$

where: $K_{Р}$ – is the maintainability criterion, $m(P)_{Р}$ – the quantitative composition of the set of possible subsets that can be obtained for any MTU disassembly sequence at a certain level,

- criterion of functional saturation of energy:

$$K_{Ф} = \frac{M_{Ф}}{M}, \qquad (6)$$

where: $M_{Ф}$ – the actual number of technological operations provided by the energy source, M – is the total number of operations in the technological process on which the energy facility is used.

The experience of using the above methods has made it possible to stop the choice of the method described in [14, 15] and suggests the definition of criteria for the collection, maintainability of the unit and the functional saturation of the energy facility. The efficiency of the chosen technique is estimated in [16] using the example of comparison of the simplest energy facilities of the classical and integral constructive-layout schemes.

OBJECTIVES

The purpose of the work is to assess the prospects for the development of an MTU based on the MEM of the classical construction and layout scheme, taking into account the prospects for its development.

THE MAIN RESULTS OF THE RESEARCH

The classic design and layout of the MES proved its viability due to a number of advantages, namely:

- relative simplicity of construction,
- maximum use of the tractor's weight when using the rear drive axle,
- satisfactory visibility of trailed or rear guns, machines,
- satisfactory maneuverability due to the ability to rotate the front driven wheels of a smaller size at greater angles,
- high agrotechnical clearance, etc. [17].

It is known that MEM of the classical constructive-layout scheme at the request of the consumer can change their consumer characteristics in a wide range of characteristics to achieve the level of versatility of the construction K_{yk} = 0.80 with a maximum value of 1.0 due to implementation of two variants of circuit solutions, namely [18]:

1 - *the main characteristics of the circuit*: the rear location of the control post, no reversing control post, no reversing transmission – Fig. 1*a*.

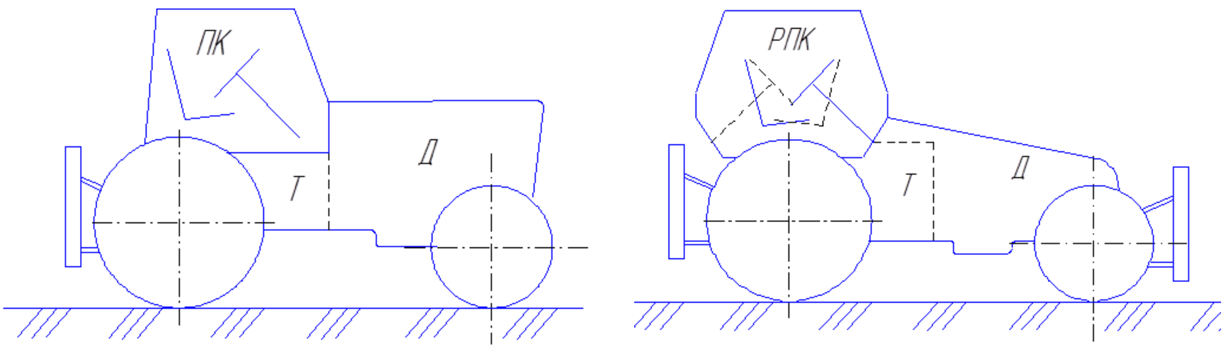


Fig. 1. Classical design-layout scheme energeticheskogo mobile tools and stages of its development priorities: *a* – rear location of the control station, no reversing control post, no reverse transmission, *b* – reversible control post, *Д* – engine, *Т* – transmission, *ПК* – control post, *РПК* – reverse control post.

Additional characteristics of such a scheme are: front engine location, serial line arrangement of transmission units, Controlled front wheels with a diameter much less than the diameter of the rear, The transmission is made in one unit and is rigidly connected to the engine. With this arrangement, up to 70...75% of the tractor's mass, in static, falls on the rear drive wheels, which ensure the traction of the tractor, and the front drive wheels (if their drive is provided by the design) perform an auxiliary role when working on wet loose ground,

2 - *the main characteristics of the circuit*: the rear location of the control station, the reversing control post of improved visibility, the reverse transmission (Fig. 1b).

Additional characteristics of such a scheme are: an increased proportion of the mass of the tractor falling on the front driving bridge from 25...30% to 35...40%, Increased the size of the tires of the front drive wheels, Front portal bridge replaced by a more powerful beam type bridge, The angle of rotation of the front steerable wheels to increase maneuverability is increased to 50...55°, and (or is provided for installation) a complete front mounted device. Such a constructive layout scheme is a further improvement of the improved classical layout.

According to the results of [18] it was established that the energy facilities of the classical constructive-layout scheme, in accordance with the requirements

The investigations were carried out for possible variants of machine-tractor units created on the basis of the two types of circuit solutions of the classical constructive-layout scheme described in Fig. 1. To conduct research, the technological process of growing grain crops was adopted, and in it the main operations were identified, which were: the introduction of mineral fertilizers, basic tillage, presowing soil cultivation, sowing, spraying crops and harvesting. For each variant, the values of the collection and maintainability criteria were determined in the context of the named technological operations and averaged them in the context of the technological process. The value of the criterion for the functional saturation of the energy medium was determined (only for the selected operations). In addition, before the research was carried out, it was agreed that the elements of the set-power of a certain set of modules that characterizes the composition of the MTU can be all that really exist, at least in stationary conditions, the combination of the modules included in this unit, except for those obtained by additional (Not typical for this type of unit and energy) of the assembly and assembly operations.

In Tabl. 1 shows a list of the above technological operations and for each of them the layout layouts of the MTA are drawn up on the basis of the energy means of the classical construction and layout scheme. Schemes of aggregates are selected those that are most often used. For each operation, the values of the collection and maintainability criteria determined using dependencies (3) and (5) are given, and at the end of the table (the last line) is the criterion of the functional saturation of the energy facility determined according to the dependence (6), but only in the context of technological operations , Accepted for consideration.

So the aggregate for mineral fertilizers consists of the energy module - a (MEM of the classical configuration, corresponds to the scheme - figure 1a) and two more modules: technological - in, which is intended for the accumulation (body) and spreading (spreading spreader) fertilizers, as well as an auxiliary - with (chassis spreader).

The modules b and c are located in the same machine and are inseparable, that is, if the spreader of mineral fertilizers is considered to be a set of modules M, then it can be represented as follows:

$$M = \{b, c\}$$

In this case, the MTU, as a set of modules, can be represented as follows:

$$MTA = \{a, \{b, c\}\}$$

Such a record means that on the basis of the membership relation $a \in \{b, c\}$, $\{b, c\} \in MTA$, $b, c \in \{b, c\}$, but b, c does not belong to MTA [8].

In this case, the quantitative composition of the set of real subsets of the MTU that can be obtained by assembling (disassembling) the latter, provided that $P = \{a\}, \{b, c\}, \{a, \{b, c\}\}$, is $m(P)_{\text{C}} = m(P)_{\text{P}} = 3$. The quantitative composition of the set-power of this aggregate is $m(P_n) = 2^3 = 8$.

The quantitative values of the criteria for collection and maintainability are determined by means of dependences (3) and (5) and are equal to each other and equal to 0.5. This indicates that the analyzed unit for the application of mineral fertilizers, created in accordance with the above scheme, has low collectability and maintainability because of the presence in its composition of an auxiliary module c of the running part of the spreader of mineral fertilizers. This auxiliary module does not directly participate in ensuring the execution of the technological operation, and can not be used in another operation, but it distracts attention when servicing the unit and may require the creation of separate repair areas.

The unit for basic tillage (see Tabl. 1) consists of two modules: power - a (tractor) and technological - b (plow). In this case, the aggregate for basic tillage, as a plurality of modules, can be written as follows:

$$MTA = \{a, b\}.$$

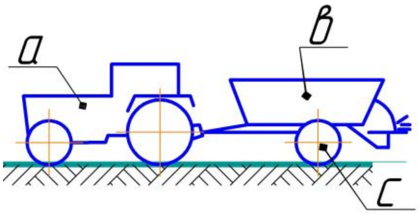
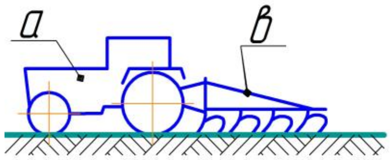
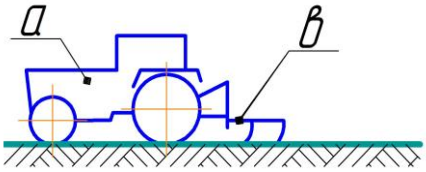
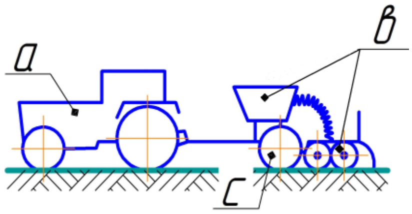
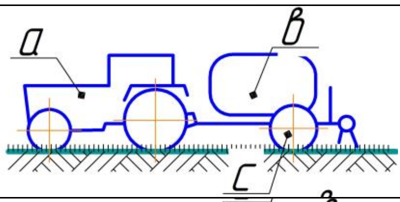
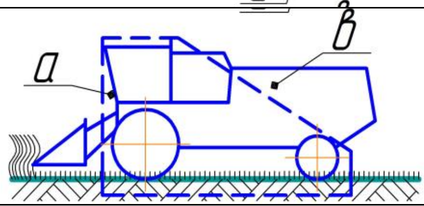
Then the real number of subsets in the assembly (disassembly) of MTU, with $= \{a\}, \{b\}, \{a, b\}$ is equal to, $m(P)_{\text{C}} = m(P)_{\text{P}} = 3$. The quantitative composition of the multiple power of this aggregate is $m(P_n) = 2^2 = 4$.

In this case, the values of the collection and maintainability criteria are equal to each other and equal to 1.00, which indicates the maximum collection and maintainability of the unit for basic tillage.

Using the above methodology, the values of the criteria for collection and maintainability were determined and for the last four operations (see Tabl. 1). The averaged value for operations where the energy of the classical constructive-layout scheme is involved according to the schematic solution presented in Fig. 1a is 0.7, which is below the maximum possible value of 1.00.

Table 1

Evaluation of the implementation process of crops cultivation process units on the basis of the power unit of the classical design-layout scheme constructed in accordance with the schematic shown in Fig. 1*a*

Process operation name	Layout of the MTU *	Values of criteria and characteristic values for their determination
Introduction of mineral fertilizers		$m(P)_{\mathrm{C}} = m(P)_{\mathrm{P}} = 3$ $m(P_n) = 8$ $K_{\mathrm{C}} = K_{\mathrm{P}} = 0{,}5$
Basic tillage		$m(P)_{\mathrm{C}} = m(P)_{\mathrm{P}} = 3$ $m(P_n) = 4$ $K_{\mathrm{C}} = K_{\mathrm{P}} = 1$
Presowing tillage		$m(P)_{\mathrm{C}} = m(P)_{\mathrm{P}} = 3$ $m(P_n) = 4$ $K_{\mathrm{C}} = K_{\mathrm{P}} = 1$
Sowing		$m(P)_{\mathrm{C}} = m(P)_{\mathrm{P}} = 3$ $m(P_n) = 8$ $K_{\mathrm{C}} = K_{\mathrm{P}} = 0{,}5$
Spraying crops		$m(P)_{\mathrm{C}} = m(P)_{\mathrm{P}} = 3$ $m(P_n) = 8$ $K_{\mathrm{C}} = K_{\mathrm{P}} = 0{,}5$
Harvest		$m(P)_{\mathrm{C}} = m(P)_{\mathrm{P}} = 1$ $m(P_n) = 4$ $K_{\mathrm{C}} = K_{\mathrm{P}} = 0{,}5$
The average values of the collection criteria K_{C} and maintainability K_{P}		0,70
Criterion of functional saturation of energy K_{Φ}		0,83
*) ***a*** – power module (tractor), ***в*** – technology module, ***c*** - auxiliary module		

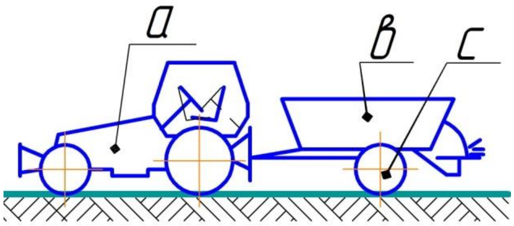
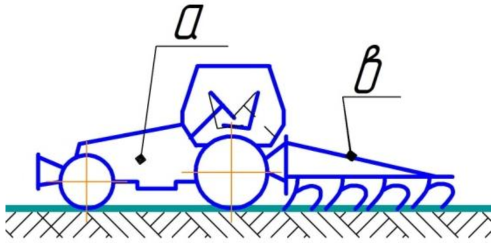
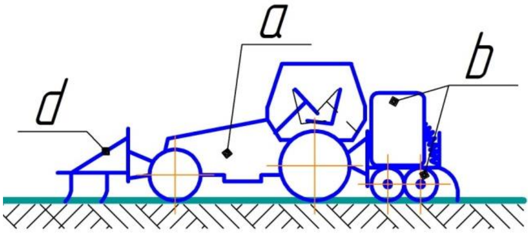
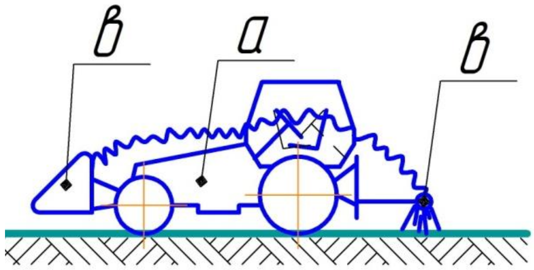
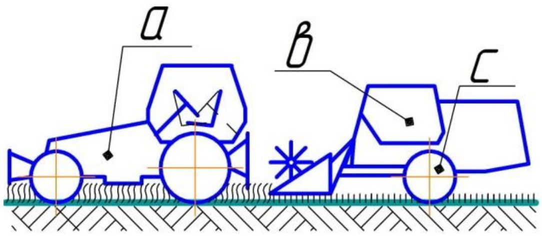
The technological process, which is realized on the basis of the tractor of the classic constructive-layout scheme, requires the use of a self-propelled combine harvester, which negatively affects the criterion of the functional saturation of the energy source. According to (6), it will be K_{Φ} = 0.83, which is below the maximum possible value of 1.00.

The above results were obtained basing on the technological maps operating in Ukraine, taking into account the machine and tractor fleet available in the farms and provided for by the current system of machines.

In order to assess the prospects of technical solutions that are possible and occur in the design and layout of MEM of the classical configuration and are provided by the circuit solution presented in Fig. 1*b*, similar studies were conducted. At the same time, the analysis was carried out and taking into account the possibility of creating MTU, which include technological modules of non-traditional designs. The results of these studies are presented in Tabl. 2.

Table 2

Evaluation of the implementation process of crops cultivation process units on the basis of the power unit improved classical design-layout scheme constructed in accordance with the schematic shown in Fig. 1*b*

Process operation name	Layout of the MTU *	Values of criteria and characteristic values for their determination
Introduction of mineral fertilizers		$m(P)_{С} = m(P)_{Р} = 3$ $m(P_n) = 8$ $K_{С} = K_{Р} = 0{,}5$
Basic tillage		$m(P)_{С} = m(P)_{Р} = 3$ $m(P_n) = 4$ $K_{С} = K_{Р} = 1$
Presowing tillage and sowing		$m(P)_{С} = m(P)_{Р} = 7$ $m(P_n) = 8$ $K_{С} = K_{Р} = 1$
Spraying crops		$m(P)_{С} = m(P)_{Р} = 3$ $m(P_n) = 4$ $K_{С} = K_{Р} = 1$
Harvest		$m(P)_{С} = m(P)_{Р} = 3$ $m(P_n) = 8$ $K_{С} = K_{Р} = 0{,}5$
The average values of the collection criteria $K_{С}$ and maintainability $K_{Р}$		0,80
Criterion of functional saturation of energy $K_{Ф}$		1,00
*) ***a*** – power module (tractor), ***в, ∂*** – technological modules, ***c*** - auxiliary module		

During the research of the technological process, implemented on the basis of MEM improved classical layout with improved visibility and capacity for inspection, the combined soil-cultivating-seeding unit (inclusion of this unit is provided in [19-23]), composed of one energy *a* and two technological modules *b* and *∂* modules. In this case, auxiliary modules were not used.

The unit for presowing tillage and sowing (see Tabl. 2) is made up of three modules: power - *a* (tractor) and two technological modules: *c* – seeder, *∂* - cultivator. In this case, the unit for presowing tillage and sowing, as a set of modules, can be written as follows:

$$MTA = \{a, b, д\}.$$

Then the real number of subsets when compiling (disassembling) MTA, with $P = \{a\}, \{b\}, \{д\}, \{a, b\}, \{a, д\}, \{b, д\}, \{a, b, д\}$ is equal to $m(P)_{С} = m(P)_{Р} = 7$. The quantitative composition of the set-powers of this aggregate is $m(P_n) = 2^3 = 8$.

In this case, the values of the collection and maintainability criteria are equal to each other and equal to

1.00, which indicates the maximum collection and maintainability of the combined unit for presowing tillage and sowing.

In addition, in the spraying of crops, an aggregate was used with a separate technological unit, which, as one of the units, included a tank for the working solution and a pumping station, and as a second, sprayers with pipeline fittings. To operate this dismembered technological module, you do not need to use any auxiliary equipment or organize additional workplaces for repair and maintenance. The same pipelines are used to connect the blocks of the technological module, but of a longer length. In this case, the plant for spraying the crops will also have the maximum values of the criteria for collection and maintainability, which are equal to each other and equal to 1.00 (see Tabl. 2).

Thus, the energy resources of the improved classical design and layout scheme have the best potential in providing an effective implementation of the process under consideration in comparison with the energy facilities of the classical (traditional) layout, as the values of the collection and maintainability criteria are at the level of 0.80 versus 0.70 for the classical constructive Layout scheme. However, to achieve a positive result, it is necessary to ensure the efficiency of the operation of the combined units on their basis and the availability of machines and tools for creating the necessary units, which has become one of the main problems of introducing tractors of the type LTP-155 and KhTP-16131 into agricultural production.

The results of the conducted studies, even with a significantly reduced list of technological operations, indicate that the constructive layout layout of the energy medium makes a significant impact on the indicators characterizing the efficiency of acquisition of aggregates on its basis, and the criteria used to estimate it make it possible to obtain a qualitative overall picture of the prospects for implementation in Agricultural production of energy resources of various construction and layout schemes.

Thus, in particular, the use of an improved classical construction and layout scheme in the technological process of growing grain crops of MEM allows achieving significantly higher values of the estimated criteria for the aggregate collection, maintainability of the unit and the functional saturation of the energy facility that correspond to values of 0.80 and 1.00 against 0, 70 and 0.83 for the classical (traditional) layout, respectively, at the maximum possible, provided for the method used for the research, The ratios of these indicators are equal to 1.00.

CONCLUSIONS

1. As a result of the conducted researches it is established that the constructive layout layout of the energy medium has a significant effect on the indicators characterizing the efficiency of manning of the units on its basis.

2. For the technological process of growing grain crops it is established that the use of energy resources of the classical (traditional) constructive-layout scheme allows obtaining the values of the criteria for the collection and maintainability of the unit at the level of 0.70, while the criterion for the functional saturation of the energy facility is at the level of 0.83, while MES improved classical construction and layout scheme with improved visibility and capacity, provided that the combined unit On their basis and the availability of machines and implements to create the necessary aggregates will allow to obtain the named indicators at the level of 0.80 and 1.00, respectively.

3. In order to improve the design of energy facilities, it is necessary to direct research and development work in the direction of creating the necessary means and conditions for aggregating the energy module with technological modules, which may constitute directions for further scientific research on this issue.

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RESEARCH OF PHYSICAL AND MECHANICAL PROPERTIES OF OILSEED CROPS

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Summary. The values of the physical and mechanical properties of oilseed crops (flax Svetlozir, sunflower Nadioznyy, mustard Tavrichanka, camelina Prestige, rape Legion, soybeans Deni) are received, such as: the indicators characterizing flowability of seeds (angle of repose φ) frictional properties of seeds (static friction coefficient f) porosity ε and the density ρ, size and mass characteristics of seeds (length L, width W, thickness T, the effective diameter D_e, the mass of 1000 seeds M_{1000}). On the basis of the obtained experimental data the analysis of the affect of moisture content of seeds W_b on the studied characteristics was made. Based on these studies, it can be argued that when designing and calculating of the machines for cleaning and separation of oilseed crops as the initial dimensional indicators of seeds, their averages values can be taken. Also, the data of the study on the determination of physical and mechanical properties of oilseed crops will allow obtaining input data for modeling the process of their cleaning and separating, choice of optimal machine parameters to ensure these processes.

The results of studies of the size and mass characteristics of oilseed crops show that the sizes of the basic weight of seeds slightly deviate from the average size, but impact of moisture content on the studied parameters is traced.

On the basis of the conducted studies, it can be argued that when designing and calculating the machine for cleaning and separating the seed materials of oilseed crops, their average values can be taken as the initial dimensional indicators of the seeds. Also, data from the study on determination of physical and mechanical properties of oilseed crops will allow obtaining basic data for modeling of their cleaning and separating process, and the selection of optimal machine parameters to support these processes.

Aerodynamics of seeds (flax Svetlozir, sunflower Nadioznyy, mustard Tavrichanka, camelina Prestige, rape Legion, soybeans Deni) in air flow was studied for various fractions of the material that was beforehand divided in sizes.

As a result of the research, the dependences of the speeds of whirling on the geometric parameters of the seeds were obtained, from which it was determined that with the increase in the geometric sizes of seeds, their whirling speed increases linearly for each oilseed crops.

Key words: seeds, oilseeds, physical and mechanical properties, sunflower, rape, mustard, saffron, soybeans.

INTRODUCTION

The technology of postharvest processing of oilseed crops is a complex functional system that exerts many-sided impact on quality of the received seeds and depends on its physical and mechanical properties [1].

The unsatisfactory quality of seeds leads to a significant decrease in the yield of agricultural products, to a large overexploitation of the seed material. Physical and mechanical, physical and chemical and biological properties of oilseed crops and its oil raw materials determine the choice of machines and the technology of its processing [1].

Numerous studies of the processes of oilseed crops formation have shown that their different quality caused by different conditions of the temperature, water and nutrient regimes is appeared not only in morphological, but also in physical characteristics. The fullness of seeds of seeds of modern varieties and hybrids, the epidermal membrane ratio, hypodermis, layer of sclerenchyma fibers and other structural components directly affect on the strength characteristics of the seeds, their ability to withstand during threshing and cleaning at grain cleaning complexes. At the same time, their physical and mechanical properties are significantly changed, on which the grain harvester's settings depend, technological parameters of machines for postharvest processing, cleaning and drying of seeds. The amplitude adjustment and frequency of oscillation of sieve box, the choice of the sizes and types of sieves, the speed of the air flow in the aspiration system, the permissible speed of movement of seed mass in the norias, and other indicators depend from the physical and mechanical properties. The ability of oilseed crops to resist compression and bending must be taken into consideration not only when transporting and storing seeds at elevators, but also when processing them at fat-and-oil and confectionary enterprises.

Power consumption of tumble (drying) machines, oil presses and other processing equipment depend on ultimate strength [2].

The physical and mathematical description of technological mixing processes, mechanical aeration of organic waste, and later formation of a heap, is quite complex, as it includes a mathematical apparatus of discrete environments with inhomogeneous, physical and mechanical anisotropic and rheological properties. Therefore, the problem of creating scientific bases for the technological process of mixing and mechanical aeration of organic waste should be solved in a complex.

ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

The patterns of the morphological parameters affect of the seed material of oilseed crops on their physical and mechanical properties (Fig. 1) make it possible to create the corresponding database and to systematize the seeds of a number of varieties of oilseed crops. Based on the identification of characteristic of morphological indicators for each type of oilseed crops, for which the cleaning and separation process is carried out, it is possible to develop the latest technologies and equipment for implementing the above-stated processes.

The physical and mechanical properties of seeds are important indicators that should be considered in their postharvest processing, practically all seeds are exposed to mechanical action: destruction, mixing, transportation, storage, etc [3, 4]. Designing and calculating of equipment for technological operations is impossible without knowledge of the properties that are processed [5, 6]. The value of the mass of 1000 seeds, density, friction coefficient, angle of repose etc. should be known for the formation of models and empirical mathematical dependences to determine optimal and rational parameters of working bodies that are used in technological processes of cleaning and separating of seed materials [7, 8].

The works of many researchers are devoted to determination of properties of oilseed crops [9, 10, 11, 12, 13]. Data, that are known in the literature, about physical-mechanical and technological properties give a general characteristic , which is possible to use when developing of typical models of processes for cleaning and separating seeds. In order to intensify the processes of cleaning and separating of oilseed crops (flax, sunflower, mustard, saffron, rape, soybean), it is proposed to study their physical and mechanical properties.

OBJECTIVES

Study of physical and mechanical properties of oilseed crops, depending on their moisture content.

THE MAIN RESULTS OF THE RESEARCH

To solve these problems, a program of experimental studies was developed that provided for the determination of the following physical and mechanical properties of oilseed crops, namely:

- the indicators characterizing flowability of seeds (angle of repose φ),
- frictional properties of seeds (static friction coefficient f),
- porosity (duty cycle) ε and the density ρ,
- size and mass characteristics of seeds (length L, width W, thickness T, the effective diameter D_e, the mass of 1000 seeds M_{1000}).

The object of the study was seeds of selection of the Institute of Oilseeds of the National Academy of Sciences: (Flax Svetlozir, sunflower Nadioznyy, mustard Tavrichanka, camelina Prestige, rape Legion, soybeans Deni).

In the course of the experimental studies, the moisture content of seeds W_b changed. In order to give certain moisture content to oilseed crops, it was added a calculated amount of water, thoroughly mixed, and then the received mix was pressurized in separate plastic bags. Subsequently, the samples were held at 50° C in a heat insulating cabinet for one week. Before each test, the required number of samples was taken from the heat insulating cabinet and allowed to warm them to room temperature. All physical and mechanical properties were determined at moisture content, equal to 7,0 ± 0,2%, 10,0 ± 0,2%, 13,0 ± 0,2% and 16,0 ± 0,2%.

Frequency of each measurement was made by 5 times.

Dimensional characteristics of randomly selected of 100 seeds were determined by the length, width and thickness of each seed. The measurements were carried out using a micrometer with an accuracy of 0,01 mm. The effective diameter, expressed as the size, was calculated using the following equation [14, 15, 16, 17]:

$$D_e = (L \cdot W \cdot T)^{\frac{1}{3}}. \tag{1}$$

The mass of 1000 seeds was determined by randomly selecting of 100 samples and weighing in electronic scales with a sensitivity of 0,001 g.

The real density (ρ_T) was determined by the method of displacement of toluene [14]. Volumetric density (ρ_b) of the seeds was determined by filling of the cylinder of known volume (100 mm × 100 mm × 100 mm) and weighing on an electronic balance.

<table>
<tr><th>Morphological Parameters</th><th>Physical and Mechanical Properties</th></tr>
<tr><td>Form:
rounded, ovate, oval, kidney-shaped, cordate, triangular, rectangular, spindle-shaped, club-shaped and other.</td><td>Center of mass</td></tr>
<tr><td rowspan="2">Size:
length, width, thickness</td><td>Coefficient of friction, movement and rest</td></tr>
<tr><td>Coefficient of internal friction</td></tr>
<tr><td>Mass</td><td>Coefficient of air resistance</td></tr>
<tr><td rowspan="2">Surface:
Pubescence, gloss, opacity, wax, raid</td><td>Specific weight</td></tr>
<tr><td>Elasticity</td></tr>
<tr><td rowspan="3">Coloring:
Main color, color inclusions</td><td>Coefficient of windage</td></tr>
<tr><td>Whirling speed</td></tr>
<tr><td>Color</td></tr>
</table>

Fig. 1. Morphological and Physical and Mechanical Properties of seeds of selection-genetic material of oilseed crops.

The porosity was calculated by the formula [14, 15, 16]:

$$\varepsilon = 100\frac{(\rho_t - \rho_b)}{\rho_t}. \quad (2)$$

The angle of repose was defined as the arctangent of the ratio of the double height to the diameter of the handful seeds that were placed on the round plate [11, 22]. Seeds were poured from a height of 200 mm into a round plate with a diameter of 200 mm.

The static coefficient of friction was determined for steel. For this measurement, one of the friction surfaces was attached to the screw. Seeds were placed on the friction surface, one end of which was raised with the screw. A tangent of angle at which the seed began to slide on the surface and it was determined as the static friction coefficient [23].

Geometric parameters and physical and mechanical properties determine the aerodynamics of seeds in the air flow. When the air moves through the layers of oil seeds (in the process of technological processing – cleaning, heat drying, active ventilation, etc.) seed behavior is determined by the speed of air movement. At low speeds, the seeds keep the properties of the layer, and air passes through the pores of the layer. Increasing the speed of air movement leads to the fact that the seeds begin to move relative to each other. The concentration of seeds in the layer decreases sharply, and the volume of the layer increases. There is a fluidization, then pseudo-boiling, when the resistance of the air flow becomes close in value to the weight of the bodies. The speed of the gas or air flow, at which the particles of the loose medium are in hover, is the whirling speed for this material. The speeds of oilseed crops were measured on the testing machine.

The scheme of the experimental machine is shown in Fig. 2. On bedplate 1 it is rigidly mounted the vertical frame 2 and the air blower 3 with a variable speed of rotation of the impeller (with the help of the LATR the engine speed is changed). The corrugated hose 4 connects the air blower and the vertical pipe 5, the grid 6 is mounted on the bottom part. The air speed is measured by the cup anemometer 7, height of rising of particles – a scale of 8. On the grid of the vertical pipe there was a layer of seeds 3-5 mm thick. After turning on of the electric engine of the air blower, the rotor speed is gradually increased. Winding speed was determined by the height of the rising of the particles. When about 50% of the particles of the layer are raised in the tube space, indications of an anemometer are read out. It was studied various fractions of the material that were beforehand divided in size.

Analyzing the obtained data and constructed on the basis of their experimental curves (Fig. 3) it is possible to draw a number of conclusions and to determine affect of moisture content of oilseed crops on the studied indicators.

Aerodynamics of seeds in airflow was studied for various fractions of the material that was beforehand divided in sizes.

Figure 4 shows the trend lines that are as accurate as possible (the determination coefficient is R2 = 0,94-0,97) describe the experimental dependences of the speed rotation on the geometric parameters of the seeds.

– flax Svetlozir

$$V_a = 2{,}4085\ D_e + 2{,}9388 \quad (R^2 = 0{,}9916), \quad (1)$$

– camelina Prestige

$$V_a = 3{,}0598\ D_e + 3{,}0549 \quad (R^2 = 0{,}9969), \quad (2)$$

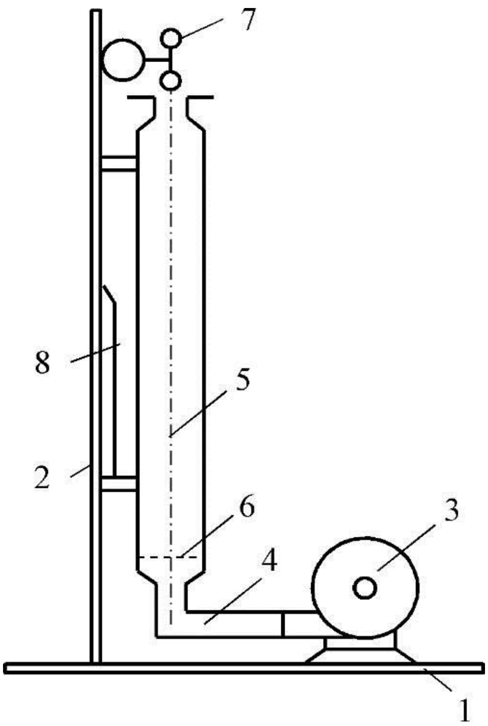

Fig. 2. Scheme of the unit for determining the rates of seed wandering: 1 − bedplate, 2 – frame, 3 − air blower, 4 − corrugated hose, 5 − pipe, 6 − grid, 7 − cup anemometer, 8 – scale.

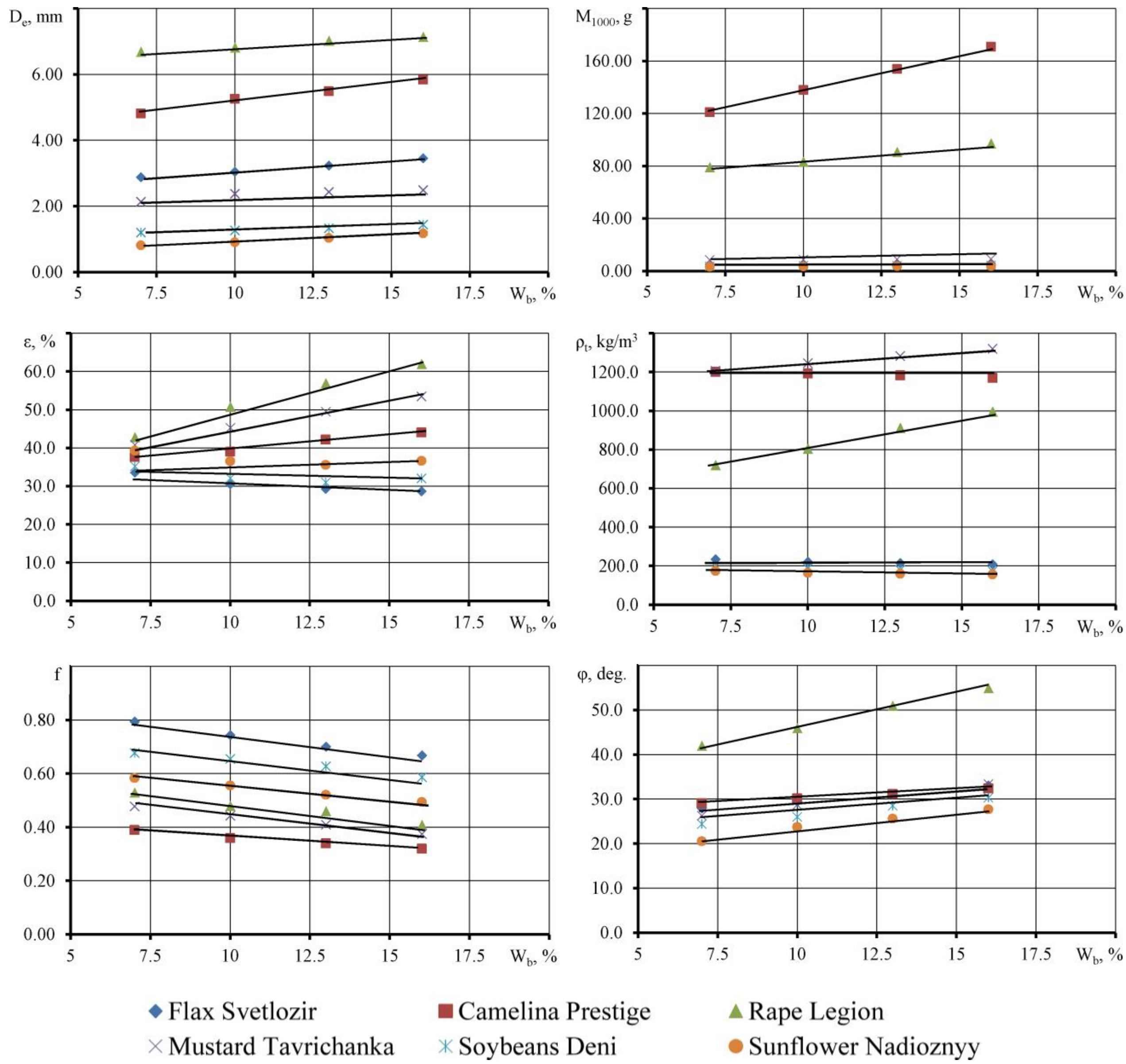

Fig. 3. Dependence of affect of moisture content of seeds W_b on the effective diameter D_e, the mass of 1000 seeds M_{1000}, the porosity ε, the actual density ρ_t, angle of repose φ, the coefficient of friction f.

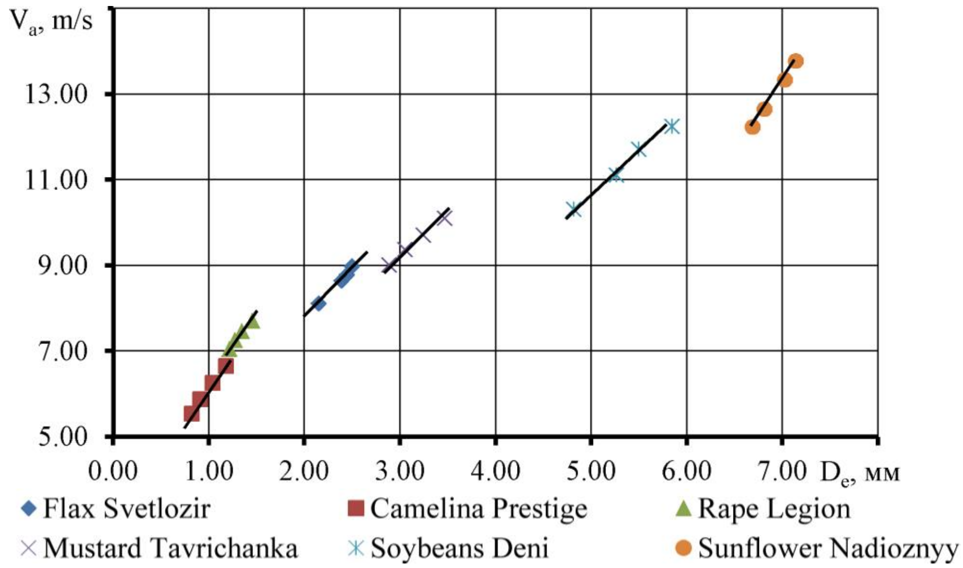

Fig. 4. Dependence of the speed of whirling on the geometric parameters of oilseeds crops.

– rape Legion

$$V_a = 2{,}7271\ D_e + 3{,}7796 \quad (R^2 = 0{,}9874), \qquad (3)$$

– mustard Tavrichanka

$$V_a = 1{,}8798\ D_e + 3{,}6221 \quad (R^2 = 0{,}9975), \qquad (4)$$

– soybeans Deni

$$V_a = 1{,}9247\ D_e + 1{,}0544 \quad (R^2 = 0{,}9934), \qquad (5)$$

– sunflower Nadioznyy

$$V_a = 3{,}405\ D_e – 10{,}548 \quad (R^2 = 0{,}9991), \qquad (6)$$

where: D_e – effective diameter, mm, V_a –whirling speed, m/s.

Analysis of the graphics shows that with increasing of geometrical sizes of seeds, the rate of their growth increases linearly for each oilseed crops.It is important to note that a promising feedstock for biodiesel production is oilseeds, especially rapeseed that has a high content of fatty, essential oils [24]. Rapeseed is a universal crop that occupies about 10% of the total area of oilseed in the world. Rapeseed is practically equal to sunflower in terms of oil content, and significantly exceeds oil content of soy and other oilseeds. The average yield of rapeseed is 25-30 centners per hectare, and sunflower yields are 15-25 centners per hectare. The yield of oil is almost 1300 liters per hectare, and from sunflower - up to 1000 liters per hectare, from mustard seeds - up to 600 liters per hectare, soybeans - up to 500 liters per hectare. Thus, rape seeds contain 38-50% of oil, 16-29% of protein, which is optimally balanced for feeding animals, 6-7% of fiber, 24-26% of nitrogen-free, extractive substances. Rapeseed is a valuable forage crop. When it is processed, more than 40 kg of oil and more than 50 kg of oil cake are obtained from each 100 kg of seeds, the coefficient of digestibility of organic substances during feeding of animals reaches 71%, and for example the digestibility of sunflower cake is only 56%. Phosphates are taken after purification of the rapeseed oil, which are used in the production of phosphate concentrates.

CONCLUSIONS

1. The values of the physical and mechanical properties of oilseeds (Flax Svetlozir, sunflower Nadioznyy, mustard Tavrichanka, saffron Prestige, rape Legion, soybeans Deni) are received, such as: the indicators characterizing flowability of seeds (angle of repose f) frictional properties of seeds (static friction coefficient f) porosity ε and the density ρ, size and mass characteristics of seeds (length L, width W, thickness T, the effective diameter D_e, the mass of 1000 seeds M_{1000}). a It was analyzed the affect of moisture content of the seeds W_b on studied parameters on the basis of the experimental date.

2. It has been determined that the moisture content of seeds of oil crops (W_b = 7-16%) has a significant affect on their physical and mechanical properties. The coefficient of friction (f = 0,32-0,79) of seeds depends on the roughness of the friction surface and decreases with increasing of moisture. This is due to the fact that with increasing of moisture, the forces of molecular attraction of the seed coat to the surface of the material decrease.

3. Increasing of the moisture content of oilseeds crops is the subjective determining factor of its density. With increasing moisture content (W_b = 7-16%), the density of seeds increases (ρ = 158-1321 kg/m^3).

4. The angle of repose of the oilseed crops grows as a result of an increase in the moisture content of the material. This is because with increasing moisture content (W_b = 7-16%), the flowability of any agricultural material decreases, and this eventually leads to an increase in the angle of repose (φ = 20,6-55,0%).

5. The results of studies of the size and mass characteristics of oilseed crops show that the sizes of the basic weight of seeds slightly deviate from the average size, but impact of moisture content on the studied parameters is traced. On the basis of the conducted studies, it can be argued that when designing and calculating the machine for cleaning and separating the seed materials of oilseed crops, their average values can be taken as the initial dimensional indicators of the seeds. Also, data from the study on determination of physical and mechanical properties of oilseed crops will allow obtaining basic data for modeling of their cleaning and separating process, and the selection of optimal machine parameters to support these processes.

6. Aerodynamics of seeds (flax Svetlozir, sunflower Nadioznyy, mustard Tavrichanka, camelina Prestige, rape Legion, soybeans Deni) in air flow was studied for various fractions of the material that was beforehand divided in sizes. As a result of the research, the dependences of the speeds of whirling on the geometric parameters of the seeds were obtained, from which it was determined that with the increase in the geometric sizes of seeds, their whirling speed increases linearly for each oilseed crops.

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REVIEW OF THREADED PRODUCTS STANDARDIZATION OF AGRICULTURAL MACHINERY

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Summary. Threaded joints are the most numerous elements of agricultural machinery. Threaded products used in agricultural machines are manufactured according to various standards-international, national, industrial, machine-building enterprises.

The choice of threaded products for the analysis of the regulatory framework of Ukraine's standards is justified by their greatest applicability, as well as the necessity to create conditions for the production of modern agricultural machinery designs, as well as for upgrading previously created ones.

The characteristic of the fund of standards for fasteners is given. The analysis of normative documents made it possible to determine the percentage ratio of normative documents developed and approved in different periods.

In agricultural machines, hexagonal bolts and nutts are the main fasteners, so special attention was paid to regulatory documents for these product groups. A group of general standards has been singled out that establish general requirements for standardized bolts, screws, pins and nuts. The analysis of common national standards was developed on the basis of ISO standards and replacing of analogous outdated interstate standards that operated in Ukraine was carried out. The level of harmonization of national standards with international ISO standards, including standards for traditional threaded products and modern progressive designs, has been analyzed.

The carried out researches testify, that there are no progressive fasteners in a design of agricultural machinery.

To increase the competitiveness and quality of agricultural machines, which is influenced by the technical level of threaded connections, further work is needed on the modernization and standardization of fasteners.

Key words: threaded products, standards, hexagon bolts, nuts, agricultural machinery.

INTRODUCTION

Threaded joints are widely used in engineering, and is one of the most common ways of collapsible joining of machine parts. They are reliable and convenient for assembly and disassembly, they have small dimensions, are easy to manufacture, they allow precise installation of the parts to be connected and almost any degree of tightening.

In the designs of modern machines, their share is 30-40% of the total number of joints, and in individual machines and mechanisms - up to 80%.

In the designs of modern machines, their share is 30-40% of the total number of joints, and in individual machines and mechanisms - up to 80%.

Threaded joints are the most numerous elements of agricultural machinery. Thus, the share of threaded connections used on modern combine harvesters is about 1% by weight and 1.1-1.8% - at the cost of the combine. Spring washers as elements of detachable joints are an integral part of modern agricultural machinery, their number reaches 3000 pieces (2).

Threaded joints are one of the most numerous elements of seeders. System analysis of the design of the SZ-3,6A seeder indicates that this seed machine includes a large range of components. At the same time, many components at different levels of complexity have threaded connections, which allows to assert their importance and determine their number. The main elements of threaded connections are bolts, screws, washers and nuts. Based on the statistical analysis, it is established that the total number of fasteners of the seeder, including bolts, nuts, washers, screws, is 1265 pieces.

ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

Threaded products used in agricultural machines, including seeders, are manufactured according to various standards-international, national, industrial, machine-building enterprises. The presence of a large number of normative documents is explained by the fact that fasteners used in various machines differ in technical requirements, parameters and dimensions, strength and accuracy, materials, coatings. As a result, the designer has the choice of the most suitable standard fastener for specific conditions.

OBJECTIVES

The choice of threaded products for the analysis of the regulatory framework of Ukraine's standards is justified by their greatest applicability, as well as the need to create conditions for the production of modern agricultural machinery designs, as well as for upgrading previously created ones.

The aim is to analyze the state of standardization of threaded products used in agricultural machines and to analyze the level of harmonization of national standards with international ISO standards, including standards for traditional threaded products and modern progressive designs. To analyze the effect of threaded products on the technical level of agricultural machinery.

THE MAIN RESULTS OF THE RESEARCH

The Ukrainian classifier of normative documents currently includes about 344 documents for fasteners (Table 1).

Analysis of regulatory documents indicates that among them:

• 26% of interstate standards (GOST), approved in the 1970-1980s. It indicates that the standards are based on requirements reflecting the level of development of technology and technology in the 1960s and 1970s;

• 47% of the comparatively newer standards of the 1990s (GOST DSTU, DSTU) - these standards, previously harmonized with international and European standards, now require updating due to the fact that during this period new versions of international standards were adopted;

• 27% of new standards developed in recent years based on updated international ISO standards.

The Standards Foundation for Fasteners is a system of regulatory documents that establishes the requirements to a product or group of homogeneous products that must satisfy these requirements in order to ensure the conformity of the products to meet the intended purpose. A significant part of the fund is made up by the general standards that apply to all fasteners or groups of homogeneous products, to subgroups of products of special design or purpose. These standards, as a rule, are reference standards for specific fasteners and are used in a complex. These normative documents generally include the following sections: classification, basic parameters and (or) dimensions; general technical requirements; acceptance rules; marking, packaging, transportation, storage.

In agricultural machines, the main fasteners are hexagonal bolts and nuts, so special attention was paid to regulatory documents for these product groups.

Among of set of documents it is possible to allocate the group of standards of the general character which establish the general requirements to the standardized bolts, screws, hairpins and nuts.

GOST 27017-86 and DSTU 2412-94 establish the terminology and nomenclature of fasteners used in general engineering. In these documents, German, English, French and Russian analogues of standardized terms (definition in Russian) are taken as reference, from international and state standards. In fact, DSTU 2412-94 is a translation into Ukrainian as a GOST 27017-86.

GOST 1759.0-87 and DSTU ISO 8991: 2005 contain the requirements for the designation of fasteners. The consumer is offered two different notation systems, which simultaneously operate in the territory of Ukraine.

The national standard DSTU ISO 225-2001 is identical to ISO 225: 1983 and contains commonly accepted symbols and their definitions in three official languages (English, French, Russian). In addition, the document provides definitions of terms in German, Italian and Spanish.

The national standard DSTU ISO 8992: 2006 establishes general requirements for standardized bolts, screw pins and screws; complements the requirements of standards for dimensions and tolerances, as well as requirements for the mechanical and functional properties of products.

To the standards defining the main parameters and sizes, mechanical properties, materials, coating, marking, methods of testing and control of fasteners, the current standards are GOST 1759.0-87, GOST 1759.4-87. In addition to these standards, DSTU ISO 898-1: 2003 as active, which is the identical translation of ISO 898-1: 1999.

The new standard describes a system of materials designations, mechanical and physical properties, minimal destructive and trial loads, a lot of attention is paid to test methods, hardness measurement, surface defects control, and product marking.

The application area of the standard is limited by the range of nominal thread diameters with large and small steps from M1.6 to M39 for bolts, screws and pins made of carbon and alloy steel.

Table 1

Analysis of regulations on threaded products

Types of fasteners	Standards				Total, pcs.
	GOST	DSTU	DSTU GOST	DSTU ISO	
Fixing hardware in general	9	1	7	18	35
Of them bolts, screws, studs	26	-	73	52	150
Nuts	6		30	23	59
Washers	13	1	11	1	26
Rivets	15		6		21
Pins, nails	17	1	7		25
Rings, bushings, sleeves, cuffs	1		7		8
Clamps, clamps	1		11		12
Other Fasteners	1		6		7
Total, pcs. (%)	89 (26%)	2 (1%)	158 (46%)	94 (27%)	343 (100%)

Table 2

Regulations on bolts

Threaded products	Standards		
	GOST	DSTU GOST	DSTU ISO
Hexagon head bolts	GOST 10602-94	DSTU GOST 7798:2008 DSTU GOST 7805:2008 DSTU GOST 15589:2008 DSTU GOST 24671:2008	DSTU ISO 4014-2001 DSTU ISO 4015:2007 DSTU ISO 4016:2007 DSTU ISO 4162:2007 DSTU ISO 15071:2009 DSTU ISO 15072:2009
Hexagon head screws		DSTU GOST 7795:2008 DSTU GOST 7796:2008 DSTU GOST 7808:2008 DSTU GOST 7811:2008 DSTU GOST 7817:2008 DSTU GOST 15590:2008 DSTU GOST 15591:2008 DSTU GOST 18125:2008	

In fact, GOST 1759.0-87, GOST 1759.4-87, DSTU ISO 898-1: 2003 to some extent repeat each other. GOST 1759.0-87 contains requirements for the main parameters and sizes; technical requirements including appearance, mechanical properties and materials, coating, marking; acceptance; control methods; transportation and storage. GOST 1759.4-87 includes the following information: designation system, material, mechanical properties, control of mechanical properties, minimum destructive overloads and test loads, test methods. It should be noted that GOST 1759.0-87, GOST 1759.4-87 do not work in Russia.

Old international standards GOST 1759.1-82, GOST 1759.2-82, GOST 12414-94 are among the general standards for threaded fasteners.

A set of interstate standards has been introduced, which came into force as national and regulating the dimensions of individual elements of bolts, screws and nuts: DSTU GOST 24670-2008, DSTU GOST 24671: 2008.

Based on ISO standards, the basic general national standards have been developed that replaced analogous outdated interstate standards acting in Ukraine and establish the general technical requirements for threaded fasteners, test methods, acceptance rules, quality assurance systems for fasteners, etc. (22, 23, 24, 25, 26, 27, 28, 29, 36, 37, 40).

Standards for specific fasteners contain detailed product design drawings and all measurement for a specific size range, the most widely used frame sizes, and references to common standards that should be applied together.

Table. 2 shows the standards for hex bolts that are currently in force.

The bolts with hexagonal head of accuracy classes A, B, C are interstate standards that regulate their design and dimensions (13, 14, 15), are identical to the old GOSTs approved in 1970. In addition, the new standards (30, 31, 32, 35) have been approved for these bolts, where technical conditions are indicated.

Interstate standards of DSTU GOST are applied to bolts with a hexagonal reduced head, however these bolts are not used and are not manufactured abroad.

Table 3 shows the standards for hex nuts and nuts, hexagonal self-locking, slotted and crowned, with bevelled collar, low, high. It contains many new standards DSTU ISO. However, this table reflects the standards of GOST, developed in the 1980s.

Among of set of standard documents on nuts it is possible to allocate the group of the standards establishing general technical requirements, methods of control and tests (about 25%). The old interstate standards GOST 1759.3-83, GOST 1759.5-87, which were approved in the 80s of the last century, are still in force on nuts and harmonized national standards have been developed (25, 27, 37, 38, 40). The standards (7, 9, 25, 27) describe the mechanical properties, the designation system, test loads, test methods for nuts.

National and international standards (18, 19, 20, 33, 34) act simultaneously on hex nuts of accuracy class A, B, C.

Interstate standards have been developed on hexagon nuts with reduced turnkey size which are not used anywhere else in the world.

Nuts hexahedral slotted and crown are GOST standards, but there are no documents for this type of nuts in the ISO standards fund.

As the analysis has shown, the normative documents are developed mainly on traditional fasteners. Belong to this group widely used threaded products - bolts with a normal and a reduced hexagon head, hexagonal nuts normal, low and high, nuts slotted and crowned, different types of washers - flat normal and enlarged, spring, locking serrated (1). These fasteners are used and will long be used wherever they are indispensable. In developed countries, hexagonal fasteners are gradually becoming a thing of the past.

In the designs of sowing machines, a large number of locknuts, flat and spring washers prevail.

Table 3

Regulations on nuts

Threaded products	Standards		
	GOST	DSTU GOST	DSTU ISO
Hexagon nuts	GOST 10605-94	DSTU GOST 2524:2008 DSTU GOST 2526:2008 DSTU GOST 5915:2008 DSTU GOST 5927:2008 DSTU GOST 10608:2008 DSTU GOST 10610:2008 DSTU GOST 15521:2008 DSTU GOST 15526:2008	DSTU ISO 4032-2002 DSTU ISO 4033-2002 DSTU ISO 4034:2003 DSTU ISO 4775:2007 DSTU ISO 8673:2007 DSTU ISO 8674:2007
Nuts hexahedral slotted and crown-shaped		DSTU GOST 2528:2008 DSTU GOST 5918:2008 DSTU GOST 5919:2008 DSTU GOST 5932:2008 DSTU GOST 5933:2008 DSTU GOST 5935:2008 DSTU GOST 10606:2008 DSTU GOST 10609:2008	
Nuts, hexagonal, self-locking			DSTU ISO 2320:2006 ДСТУ ISO 7040:2010 DSTU ISO 7041:2009 DSTU ISO 7042:2009 DSTU ISO 7043:2009 DSTU ISO 7044:2009 DSTU ISO 7719:2009
Hexagon nuts with beveled collar			DSTU ISO 4161:2007 DSTU ISO 10663:2007
Hexagon nuts, low	GOST 10607-94	DSTU GOST 5916:2008 DSTU GOST 5929:2008 DSTU GOST 15522:2008	DSTU ISO 4035:2006 DSTU ISO 8675:2007
Hex nuts, high		DSTU GOST 5931:2008 DSTU GOST 15523:2008 DSTU GOST 15524:2008 DSTU GOST 15525:2008	

The predominance of traditional threaded products in grain sowers type SZ-3,6A leads to a large weight of not only sets of fasteners, but also to assembled units, high labor intensity of assembly work, inadequate quality and reliability of threaded connections during operation. Spring washers are widely used on other agricultural machines. The carried out analysis (2) shows that failures of spring washers are the cause of refusals of grain harvesting equipment and the result in significant expenditures of working time and resources.

Fig. 1. Traditional fasteners on grain seeders SZ-3,6.

As a result of the analysis, it can be stated that the design services of factories do not put into the design documentation for agricultural machinery the progressive designs of fasteners, because they are not in the current standards, and the metalware plants accordingly do not manufacture them and do not master new technologies.

In domestic agricultural machines fasteners of low consumer quality are used with a very low level of unification. Threaded parts for the same purpose, but designed at different factories, in different departments of the same plant, have significant differences in shape, size, including the thread pitch, turnkey size, head height, thread runs, fillet head bolts, rod diameters, the dimensions of the end facets, tolerances, strength classes, materials, notations. These shortcomings were obtained in many respects, because of the lack of system in the applicable regulatory framework for fasteners.

Firstly, the plants use OSTs, GOSTs and original own drawings simultaneously.

Secondly, the above standards are not being improved and now play a conservative role, contradicting the requirements of modern foreign standards.

Thirdly, there are simply no many types of fasteners for Ukrainian standards, but there are no plans for their development either.

At present, new fastener designs have been developed and introduced in the world practice that reduce the overall dimensions and weight of joints, increase the strength and reliability of joints, prevent self-unscrewing and loosen the tightening in conditions of increased vibration, simplify and facilitate the assembly and maintenance of machines (3). Progressive is called fastening products with additional functional properties that allow to solve many tasks due to the appearance of new properties, for example, self-locking nuts, bolts with star-shaped internal or external drive, which allow to transfer large torque torques, screws, bolts and nuts with a flange that do not require the use of washers.

The carried out analysis of the studies made it possible to distinguish two groups of properties, fasteners and joints. First, the optimality of the assembly for assembly in the conveyor, the cost of acquiring the fastener and for assembly work (for example, comparison of modern domestic and foreign mechanical grain seeders shows that the number of fasteners is 10-30% more). Secondly, manufacturability in the conditions of operation of agricultural machinery, the labor intensity of fastening operations during maintenance, the need for tightening the joints (the share of traditional fastening operations for maintenance is 30-50% of the total labor-intensive maintenance).

It should be noted that national standards based on ISO have been developed for such types of progressive fasteners as self-locking nuts. Normative documents of DSTU ISO 2320: 2006, DSTU ISO 7040: 2010, DSTU ISO 7041: 2009, DSTU ISO 7042: 2009, DSTU ISO 7043: 2009, DSTU ISO 7044: 2009, DSTU ISO 7719: 2009 establish the mechanical and operational properties of hexagonal steel self-locking nuts, technical conditions for self-locking all-metal nuts of different strength classes, self-locking nuts with non-metallic liners of different strength classes, self-locking nuts with bevelled edges. Wide use of self-locking nuts allows to reduce the number of parts in the joints, increase their reliability and maintenance between machines. The basis for locking with self-locking nuts is to create a guaranteed tightness and increase friction in the threaded pair due to deformation of the threaded part of the nut or use without threaded elastic liners.

In the designs of the sowing machines presented at the Second Agroindustrial Exhibition "AgroExpo 2017", flange bolts and nuts are used. Calculations and tests show that the use of flange fasteners increases the reliability of the threaded connection, because under the head of the applied forces of tightening and workloads, plastic deformations do not occur in the connected part. An increase in the area of the supporting surface provides the best stopping properties. However, there are currently no standards for flange fasteners.

Threaded joints largely determine the operability of units and assemblies, as well as the reliability and efficiency of machines and equipment in the process of their operation, their reliability, affect the design and safety of their maintenance.

Operational experience shows that deterioration in performance indicators or loss of efficiency of individual mechanisms, aggregates or parts in many cases is caused by the failure of threaded connections.

Fig. 2. Flanged bolted connections on sowing technology produced by "Elvorty".

It is proved that 15-25% of failures of combine harvesters of the first year of operation are due to failures of threaded joints (2).

The conducted researches (41) show that in the tractors, cars, combine harvesters and agricultural machines one of the weakest elements is threaded joints. When defective, it turned out 11-18% of parts with worn or damaged threads.

Threaded connections affect the technical level and quality of the machine. In particular, in determining the concept of quality and technical level of threaded joints mean compliance with the requirements of regulatory documentation, the definition of consumer properties that allow you to maintain the tightening force of connections during operation and ensure the safety of the operator. The results of investigations of the SZ-3,6 seeders showed, that the threaded connections did not correspond to the normal requirements for the bolt ends to protrude beyond the nuts (42). When assessing the technical level of machines, the role of design is strengthened, design indicators expand the concept of the quality of technology, serve as a basis for developing proposals for its improvement, and for improving the quality of machines that are produced serially. Reducing the performance of the rod of threaded connections will make it impossible to grab clothes, injure, scratch on the skin and ensure the safe operation of the machine operator when servicing the seeder. Such a constructive solution will add to it the compositional integrity, completeness.

The study of foreign experience in the use of progressive fasteners in tractors and agricultural machines allows us to formulate the main directions of the development of fastening systems and their elements:

• Reduced use of spring and flat washers;
• transition to flange bolts and nuts;
• use of self-locking nuts;
• using bolts with a captive washer.

Due to the fact that the technology of manufacturing agricultural machinery has changed significantly, their new designs have appeared, it is necessary to work on the development and approval of standards for progressive designs of threaded products based on international ISO standards.

CONCLUSIONS

1. In Ukraine, the basis for a full harmonization of standards for fasteners has been created: most standards for threaded products have been developed and harmonized with international ISO standards.

2. The analysis showed that the regulatory framework in the field of fasteners consists of the following documents:

• 26% of interstate standards (GOST), approved in the 1970-1980s;

• 47% of the standards (GOST DSTU, DSTU), approved in the 1990s;

• 27% of new standards developed in recent years based on updated international ISO standards.

3. Further harmonization of obsolete standards is required.

4. To increase the competitiveness and quality of agricultural machines, which is influenced by the technical level of threaded connections, further work is needed on the modernization and standardization of fasteners.

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TECHNOLOGICAL COMPLEX TECHNICAL PROVIDING REMOVAL FRUITS WALNUTS

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Summary. The development of walnuts in Ukraine is due to its a proper profitability is due to the presence and use of technological systems technical support of production processes, including the removal of fruit. The absence of scientifically grounded recommendations for rational technical providing technical process of removing the walnut fruit is one of the important problems of production. Analysis of recent publications and research on technical substantiation of technological systems of agricultural production allowed to establish that the available scientific and methodological provisions can not be applied in resolving this issue in horticulture.

Performed meaningful analysis of the basic terms and concepts in the field manufacturing of technological systems has allowed the hierarchical structure justify their technical and technological components applied to gardening and reveal the contents of many engineers and technical tasks related to each of these terms. It is proved that in solving problems rational technical providing horticulture should be considered appropriate technologies at four levels – general technological, of mechanized, machine and organizational-technological (technological processes).

To justify the options technological complexes technical providing removal walnut fruit developed and used by a method of structural and operational analysis available on the market machinery technologies and technical means. The method includes five stages of analysis and is based on the hierarchical structure of technical and technological terms gardening.

Performed structural and operational analysis available on the market (external and internal) machinery technology and technical means for removing fruit walnuts has allowed to classify and justify the seven major technology options and fifteen variants of technological complexes of machines to perform the appropriate process.

Key words: collection, walnuts, technology, analysis, structure, technics, facilities.

INTRODUCTION

The walnut production in recent years, intensively developing in Ukraine. This is due to its proper profitability. However, as practice shows, the technological processes of harvesting are characterized by organizational and technological imperfection, which consists in the timing of their implementation and reducing the quality of harvested nuts. The lack of evidence-based recommendations on determination of rational parameters of their technical support depending on the size and area of the garden is the main cause of deficiencies noted. This reduces the production efficiency. Thus, there is the applied scientific problem of ensuring the timeliness and efficiency of technological processes of harvesting walnuts, in particular, removing their fetuses regardless of dimensional characteristics of trees and area of garden.

ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

Mechanized technologies and technical means for the removal of walnuts was developed by many scientists [1-9]. However, missing information on the substantiation of rational parameters of technical support of technological processes of cleaning.

The analysis of scientific works on this issue in the field of agriculture shows that they developed a new model that takes into account the probabilistic nature of the relevant technological processes [10-17].

Scientific-methodical bases of creation of such models are important for gardening.

However, their use in the horticultural industry is impossible because of the peculiarities of technological processes, in particular, changing dimensional characteristics of the objects of labor, technical actions on them, agrometeorological conditions of the harvest season, etc.

Analysis of recent research in the field of agricultural engineering can be stated that a scientific-methodological basis of the decision of its main tasks is based on the system analysis of technological processes of interaction of working bodies with the objects of labor and work in the fields of the individual machines, machine units and production lines [17-22]. They are also important for the development and use of the structural-operational analysis of machine technologies in horticulture, without which it is impossible to objectively justify the technical parameters of technological systems of harvesting walnuts.

OBJECTIVE

To perform a structural-operational analysis available on the market of machinery technologies of removal of fruits of walnut, and to substantiate alternatives of technological complexes for their technical support.

THE MAIN RESULTS OF THE RESEARCH

To create rational technological systems (TS) horticulture one of the most important tasks is to substantiation of rational parameters of their technical support. The term vehicle implies a set of functionally interrelated technological equipment, production items and performers to perform in regulated manufacturing environments required technological processes (TP) or operations [21]. The term TP refers to the portion of the production process, relating only to concerted action for change (or) the establishment of the state of the object of labor. And the term production process understand the totality of all the actions of the people (artists) and tools required in the enterprise for the manufacture of products [22].

Thus, TP is a deliberate action by using technical means (technical support) of the object (objects) of labour for the purpose of modifying or establishing his (their) quality status and spatial movements required for these actions. Direction of action is determined by production technology of a product (products). The term technological complex of technical means is necessary and sufficient for the nomenclature of many of them, ensuring full compliance with the required number of operations TP.

Changes in the qualitative condition, and the location in space of fruits of walnut, their dimensional characteristics and characteristics of the trees to occur as a result of certain biological, chemical, physical-technical and combined effects that are the basis of technologies of gardening. In term-based effect is always at least one law (the regularity), which characterizes the qualitative change in the state (spatial displacement) grown on trees the fruit of a walnut. In particular, the physical-technical effects are determined by physical laws, regularities and their consequences. These effects (phenomena) are used for mechanical action of the working bodies of the fruits of walnut (objects of labor) [23].

These effects (E) determine the methods (A) qualitative transformation (spatial movement) of the subject (subjects) of the work from the initial to the desired state, which is the basis for determining the range, consistency and temporal modes of technological operations (A) (Fig. 1). The term the way you understand a particular action, technique or system of techniques that allows us to do, to realize something, to achieve something [24].

Development (creation) of technologies of gardening is usually preceded by the design (development) of technical means, in particular, their working bodies. In this case, allocate mechanized operations (MeO) - for each transaction (About) justify the type (form) of the working body to ensure its implementation. The action is based (interaction) of the working body of the object (objects) of labour is a particular physical-technical effect [6], which allows to select (designate) the type (form) of the working body and the maintenance of appropriate mechanized operations (MeO). A lot of them relative to the specified labor subject determines the content meganisyou - constant technology (Metl).

Working bodies that perform MeO, always synthesized (assembled) hardware (cars, guns). Designing and creating these tools, the synthesis of the working bodies may be different. Technical means can only include homogeneous or heterogeneous working bodies, respectively, to perform one or more mechanized operations. Therefore, the same Metl can run alternative technical means.

To distinguish between possible variants of realization of the specified Metl alternative technical means, we introduce the term machine operation (Mao) and engine technology (Matl) is a system of knowledge not only about the content of elementary operations and types of their working bodies qualitative transformation (spatial movement) of the subject (subjects) of labor, but also on the number of these operations being carried out by different technical means, as well as about the many different types of funds, ensuring the implementation of appropriate Metl. Knowledge about the performance of individual machines (technical equipment) of a certain number of MeO, and the number of different types of machines reflect the essence of the corresponding Matl.

Information about Mall is an integral part of modeling and design of TP removing walnuts. The difference between these technologies is the basis for establishing numerical values of the energy and funds in the relevant TP, which are investigated on the basis of modeling of organizational and technological operations (OTO). Unlike Mao, they relate not only to their content and their fixation with cars, but also implementing – fixing the number of performers for technical means, determining the planned scope of their mechanized operations, etc.

The indicated structure of the basic technological concepts (terms) horticulture is defined by the many technical challenges in creating new technologies, technical means, TP and TS [21,25]. It is also the basis of the developed method of structural-operational analysis Matl this production. This method allows you to systematically reveal the structure available on the market Matl, and technical means. The sequence (algorithm) such disclosure is based on the structure of the main technological concepts of gardening, and also takes into account the influence of each of them on the target (the system), the result of which are variants of Mutl and set (item) for technical assistance (technological complexes of machines) for removing the fruit of a walnut.

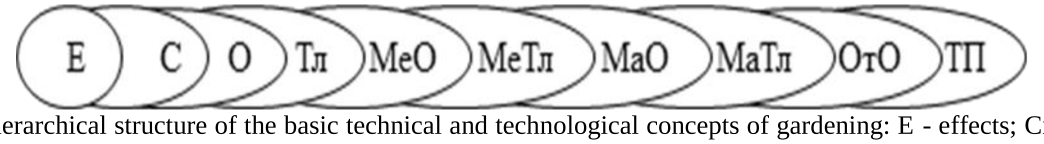

Fig 1. Hierarchical structure of the basic technical and technological concepts of gardening: E - effects; Cn - methods; O - technological operations; Тл - technologies; MeO - mechanized operations; MeTl - mechanized technologies; MAO - machine operations; MaТл - machine technologies; Otto - organizational and technological operations; TP - technological processes.

This method includes:

1) identification and structural and technological analysis of the available mechanized technologies,

2) the definition of atomic (indivisible) operations and identification for each alternative of the working bodies,

3) identification of commercially available technical means that have these working bodies,

4) determining the number of main and auxiliary mechanical operations carried out by different technical means (machines),

5) study of alternatives МаТл and nomenclature (technological complexes) of different types of technical means to ensure their implementation.

To perform the structural-operational analysis МаТл of removal of fruits of walnut in the first place, consider the object (objects) of labour. In our case, fruits are the main subject (subjects) of labor.

However, considering the (justifying) the technological operations of removing them from the trees, coming to the conclusion that they can be done in different ways, which are determined by the initial qualitative state of the individual fruit. Given the fact that during the harvesting of the fruit can to be in with a cracked hull, and the other part is in a condition with no cracked pericarp, ways of their removal from the tree can be different.

The fruits with cracked husk can be removed on the basis of minor impact (application of force impulse) in the fetus. To remove a fruit of the walnut with strong (netremote) pericarp, if the destruction of the stalk [3], which is achieved due to the shaking (vibration) of the fetus, or separation on the basis of the application of longitudinal or transverse to the stem strength. In addition, the peduncle can be cut with scissors.

Analyzing in detail each of the five ways of removing fruit from the tree, notice that in the first case we can act locally only on the fetus, which is in a state with a cracked hull. In other cases (condition netremote pericarp) of the fruit can be removed only by destroying the peduncle or vibrating (shaking) effect on the branch of a tree, or the action (the application of a force) on the fetus, or direct cutting.

Given this, it can be argued that the removal of the fetus (fetuses) method vibration (shaking) is not a direct effect on the fetus and indirectly through the vibrations of the branches of the tree.

So not only dealing with the main subject of labor (the fruit), and additional (branch) on which it is located. Impact on the branch with the aim of loosening (vibration) refers to the indirect action on the main object of labour (fetus). At the same time, it belongs to the direct effect on additional labor subject (tree trunk, branch).

Conceptually analyze the existing technology of removing the fruit of a walnut. For this, select the components that are in a certain relationship (Fig. 2). The first component of the call of the fruit shake, the second is to collect the fruit, and the third – their selection from the surface between rows. However, note that Matl shaking the fruit can be carried out using or without using their catcher. The use of the trap eliminates the need to run Mao on the selection of the fruit, after shaking. However, taking into account the fact that in the process of ripening there is a part that can spontaneously (mostly under influence of wind) to fall (to fall) on the surface of aisles, to dispense with the execution of Mao selection of fruits

impossible. Therefore, the relevant Mao must be run before Mao by shaking the fruits in an established catcher.

Content Mall of removal of fruits of walnut in the implementation of Mao in their shake without using the catcher as follows:

1) selection of samiopoula fruit,

2) shake the remaining fruit,

3) selection of fallen fruits.

That is, Mao on the selection of the fruit when using МаТл their withdrawal without the use of the catcher is performed twice – first for the selection snoopafly fruit, and then forced to scragnoth.

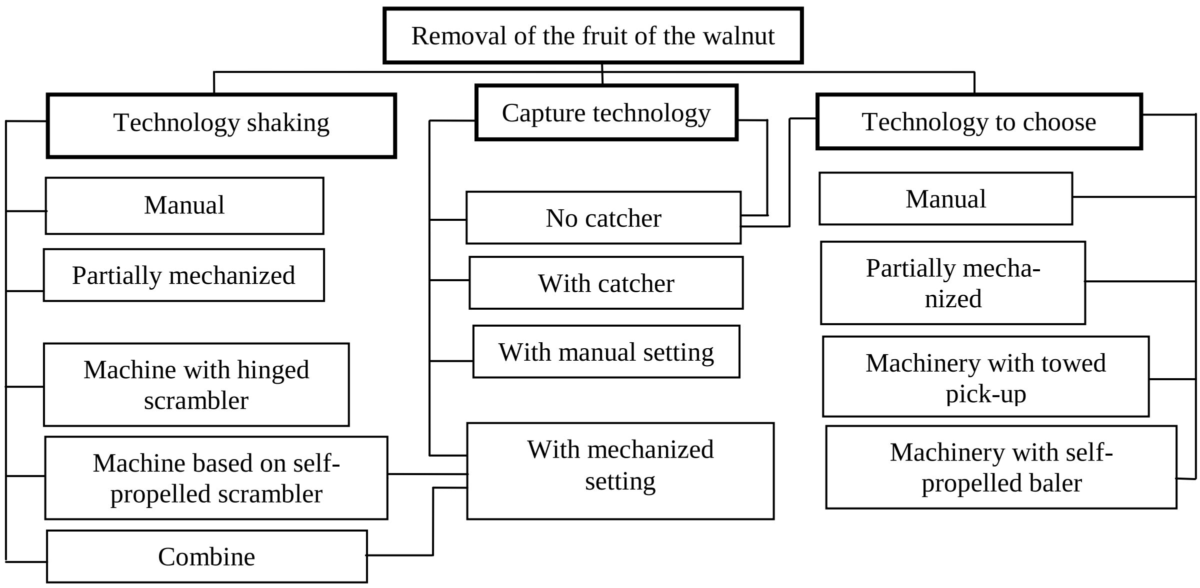

Fig. 2. The classification scheme of the components of the removal of walnut fruit.

Thus, based on the above, МаТл of removal of fruits of walnut in the first place, should be classified by content and sequence of performance of Mao in two types – with and without the catcher. The following classification criterion is the level of mechanized operations in the relevant МаТл.

This symptom МаТл shaking the fruit divide into:

1) manual,
2) partially mechanized,
3) machine with hinged scrambler,
4) machine based on the self-propelled scrambler,
5) combine.

Relatively Matl selection of fruits of walnut from the surface between the rows, the sign of the level of mechanized operations, they also are divided:

1) manual,
2) partially mechanized,
3) machine based on the mounted and trailed forage,
4) machine based on the self-propelled round bale.

In addition Matl shaking of fruits of walnut using the catcher should also be divided according to the level of mechanization of operations related to its installation – manual and mechanized. Based on the results of the structural-operational analysis and classification Matl of removal of fruits of walnut, explain the alternative variants of technological complexes of technical means for their implementation. First, highlight a set of technical tools for manual technique to remove the fruit walnut fruit without using a trap (Tabl. 1). Then, on the basis of information on the Internet will make a technological complex of technical means for options: partially mechanized technology, without using the catcher. For each technology such complexes can be formed by one. Considering the options in machine technology with the scrambler, with and without the use of the trap, we see that for each of them you can make four variants of the technological complexes of the respective machines.

Table 1.

Variants of technology of their technological complexes technical means for the removal of walnut fruit

Abbreviation of technology	Name the components of technology	The list of technical means of technological complexes	Manufacturer	Source
RBU	Shake	Scrambler manual telescopic	Germany	[26]
	Selection	Roll-tool	Ukraine	[27]
		Pick-up needle-drum	Ukraine	[28]
RSU	Shake	Scrambler manual telescopic	Germany	[26]
	Selection	Roll-tool	Ukraine	[27]
		Pick-up needle-drum	Ukraine	[28]
	Capture	Catcher mobile	USA	[36]
CMBU	Shake	Scrambler manual vibrating	Italy	[29]
	Selection	Pick-up needle-drum with power tillers	Ukraine	[28]
CMS	Shake	Scrambler manual vibrating	Italy	[29]
	Selection	Pick-up needle-drum with power tillers	Ukraine	[30]
	Capture	Catcher mobile	USA	[36]
MVBU	Shake	Scrambler mounted	Ukraine	[31]
		Scrambler is self-propelled	USA	[32]
	Selection	Baler is towed	Germany	[33]
		Baler self-propelled	Italy	[34]
MVS	Shake	Scrambler mounted	Ukraine	[31]
		Scrambler is self-propelled	Italy	[32]
	Selection	Baler is towed	Germany	[33]
		Baler self-propelled	Italy	[34]
	Capture	Catcher is mounted on the scrambler	Ukraine, Italy	[31, 32]
К	Shake and Capture	Combine walnut	USA	[35]

Decoding the abbreviations of the variants of technology of removal of fruits of walnut next: RBU, RSU, respectively, without manual and with catcher, CMBU, CMS – partially mechanized, respectively without and with the catchers, MVBU, MVS, respectively a machine with a scrambler without a catcher, and harvester.

Thus, a classification of technologies removal of fruits of walnut, allowed to split into seven options, as well as to establish for each of them the options of technological systems technical support, source of information to substantiate its parameters (configuration) concerning the vehicle, the harvesting of these nuts.

CONCLUSIONS

1. Solution of basic engineering tasks of gardening require the development of new methodological foundations of machine and operating analysis of the relevant technologies, in particular, the withdrawal of fruits of walnut.

2. Developed method of structural-operational analysis of existing machine technologies this process involves the sequencing system solutions hierarchical multiple tasks in accordance with the structure of basic technological concepts.

3. Classification by content and sequence of performance of technological operations the basic technologies available for removing the walnuts helped to identify the twenty-eight types.

4. Machine-operational and structural-technological analysis available in the market of technical means for removing the fruit of a walnut allowed to reveal the distribution of elementary technological operations between the existing technical means, and to substantiate that the seven core technologies there are fifteen variants of technological systems for their technical support.

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FORMING RELIABILITY OF MEANS FOR PREPARATION AND DISPOSAL OF FORAGE

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Summary. The article analyzes the technology and design of tools for the preparation and distribution of forage on cattle farms. In recent decades, the most promising machines have been a machine with a working member in the form of one or more vertical conical augers. The positive aspects of these machines are the quality of the technological process, the simplicity of construction and operational reliability. Such machines are used on farms where in the rations of feeding the long stalked forages with different moisture prevail or are harvested in a compressed form.

The longevity of the working organs decreases when they are established in a position that corresponds to the maximum degree of grinding of the constituents of the feed, Operation of the machine at high screw speeds, Presence of foreign inclusions. When using the means for preparing and distributing feeds, it is necessary to monitor the criteria for the ultimate condition of the knives, including the thickness of the cutting edge. The restoration process must be carried out with the help of equipment and rigging providing the appropriate angle of sharpening and the shape of the knives. Firms manufacturers to increase the longevity of work tools and quickly wear parts offer additional coatings from special alloys.

The reliability of the machines has a special impact on the professional level of the machine operator, formed during its preparation are professionally important qualities.

It is recommended to minimize the risks of failures during operation, during maintenance, repair, storage, disposal, which are caused by imperfection of the component "human operator".

Key words: Means for preparation and distribution of forage, knives, reliability, failure, restoration, system, human-operator.

INTRODUCTION

To implement the tasks with the livestock production occupies a special place feeding, and in the first place, complete feed mixtures. For small and medium livestock farms, where the construction of the feed is impossible or it would neither be economic nor from a technological point of view, as the supply of prepared feed mixtures is difficult, you can use universal mobile means for preparation and feeding (SPRK).

In the 90 of the last century with the advent of new technology of feeding different groups of cattle via mobile SPRK growth of the market for these units in the leading countries of Europe and the USA, and the beginning of 2000 has been widespread in the CIS countries.

The first time there has been a trend towards the use of horizontal feed mixers equipped with one, two or three horizontal augers for grinding-mixing.

In recent years, on cattle farms in vast majority of used SPRK with a working body in the form of one or more vertical conical augers which have a number of positive indicators, including the quality of the technological process, simplicity of design and enhanced operational reliability.

Engineering firm with production SPRK take into account the existing sizes of livestock farms.

ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

In the last decade in Ukraine and CIS countries in scientific and practical research identified the following areas of work with the efficiency of modern SPRK: theory and analysis of the process of grinding, mixing and dosing of feed [1, 5, 8, 16, 17, 25], the study of cutting processes [1, 2, 24], the effective use and organization of the use of technological operations of transportation and distribution of feed mixtures [7, 15, 21], improving the reliability and health [3, 4, 13, 14, 20], analysis of the impact of design elements SPRK to ensure the quality of the feed mixture and their implementation to the consumer [22, 25].

As noted in several articles [6, 21, 22], in the market of Ukraine appeared a wide selection of SPRK foreign production, which is represented by such leading companies as "Kuhn", "Seko", "DeLaval", "Trioliet", SILOKING "the Roto-mix" and many others. As for the CIS, the production of such machines established in Belarus and is presented on the Ukrainian market shredders – mixers - distributors of the series of ISWC-12 "Host" and RSK-12 "White Mix", which are manufactured by the firms "Zapagromash" under license from foreign firms. In Russia the production of feeders KIS-8, AKM-9, individual items of scientific support for which is provided in [9, 17].

Production SPRK introduced on machine-building factories of Ukraine, LLC "Bratslav agricultural machinery plant", LLC "haleschyna Mashzavod", JSC "Omniformat".

The level of reliability of domestic SPRK, in large measure due to the use of basic components and assemblies from leading manufacturers from Italy, Germany, Russia, Ukraine. But, as the analysis shows, the prospects of creating a national SPRK at the level of best foreign samples over small-scale production and require constant improvement.

OBJECTIVES

The purpose of this article is to improve existing methods of evaluation and ways of ensuring reliability SPRK on the basis of studying the characteristic of parts, analysis of ways to improve their durability, methods of recovery, impact on their reliability of the human factor.

THE MAIN RESULTS OF THE RESEARCH

For the preparation of complete feed mixtures in cattle in our country and abroad there is an ongoing scientific search for the most technologically advanced and reliable SPRK. But their effectiveness largely depends on the existing methods of assessment and reliability of SPRK. When solving practical problems scholars prefer analysing and improving the design of these machines.

Conducted research and analysis of literature sources revealed that the uniformity of distribution of the feed mixture depends not only on the design of the unloading conveyor or additional technical devices, and to a large extent from the experience of the operator who manages SPRK [9]. In fact, the uniformity of the distribution varies in different parts of the discharge, and for individual models SPRK depends on increase of rations per head of cattle. The performance of the discharge decreases as the discharge unit, and this requires an additional increase in speed of the unit or changing the speed of the conveyor or open the damper. Therefore, it would be advisable for the manufacturer in the instruction with the operation of SPRK to include recommendations for configuring the unit for optimum uniformity of mixing and distribution. Of particular importance is the professional level of the operator SPRK formed in the preparation of its professionally important qualities.

In the article [2] describes the main structural and technological scheme of mobile SPRK on farms cattle, advantages and disadvantages. The author of the article justification of the choice of constructive - technological scheme of machines for dairy farms cattle which was based on a vertically - screw working body. Based on the research conducted, the author offers farm cattle cars with two or more vertical screw working bodies based on the quality of the implementation process, their high reliability and availability of a smaller number of parts that wear out. Such SPRK should be used on farms, where feeding is dominated by long stalked feed with different moisture content, which also harvested in an extruded form. As confirmed in [2], long stems wound on the feed screw if the diameter of the lower base reaches up to 2 m.

It should be noted, and it is confirmed in some scientific works [2, 9] that SPRK with vertical augers have a higher ratio of technological reliability, because they can give large inclusions in feed mixtures due to the large gaps between the tines. Along with this, the design of machines with vertical augers are cheaper than horizontal per 1 m3 of feed mixture per 1 m2 of hopper capacity, but have large dimensions and high loading height, which often limits their application in areas of livestock farms with a low gate for entry.

Some manufacturers SPRK with vertical augers to reduce the overall size and loading height propose to use smaller wheels, and for better distribution of mass – to install dual wheels or tandem axles. However, the tandem axles are characterized by deterioration in performance and increase resistance to rolling.

Also, from the analysis of the literature and practice of using SPRK individual brands found that after the process of preparation and distribution of feed in the bins of most machines, including STRAUTMANN, on the surface of the auger Assembly remains a certain amount of the feed mixture. With passport data on SPRK known that the permissible balance weight of the feed mixture in the hopper should be 30 ... 50 kg, which makes it difficult not only to conduct their maintenance and repair, but also requires the removal of residues by hand. Even the increase in frequency of rotation of the vertical auger SPRK envisaged for individual machines, does not allow to achieve complete self-purification of surface coils due to centrifugal forces. The disadvantage of such devices is that screws used with a perpendicular placement of the coils to the axis at small frequency of rotation is not self-cleaning from residual feed mixture at the end of discharge [9].

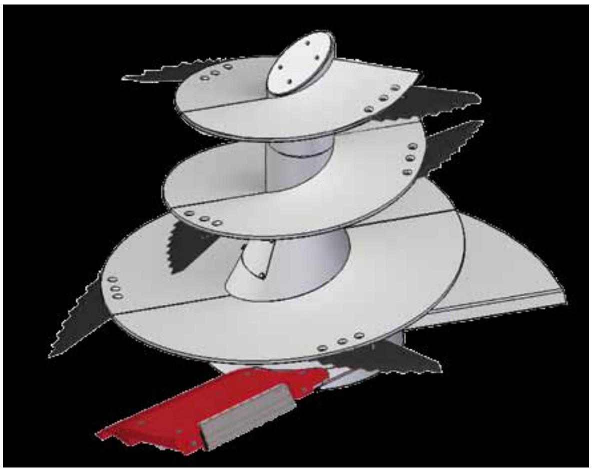


Fig. 1. Turbo screw SILOKING.

Deserves attention the development of SILOKING, which is used in SPRK - turbocnc with turbochrom and highly powerful magnet [10]. Big turbocnc with extra coil is designed in such a way that the design allows intensive mixing of the components of the diet for a short time, and thus slowly rotate and save the forage. With the help of his hollow scraper turbocnc raises from the bottom of small components and draws them into the mixture. This gives you the ability to load components into the hopper SPRK in any sequence.

It is known that worn knives SPRK, which have a thicker cutting edge to increase energy expenditure and affect the mixing process. Based on this, an interesting and very useful for the analysis are recommendations with the use of a mobile feed distributor VMP-10. For VMP-10 manufacturer provided the possibility of adjustment of cutting blades, respectively, and the degree of decomposition [16]. The degree of grinding of feed depends not only on the speed of rotation of the worm, auger with knives, but the knife in one of three positions. That is, the design of the knives and plates for fastening there are three possible work location: In - standard position, A - position reduced grinding degree, C - the position of the maximum increase of the degree of grinding. Depending on the method of operation of the feeder [16], their knives, after making a certain number of feed mixtures require sharpening, adjustment or replacement.

Analysis of operating conditions and characteristic failures of SPRK shows that the durability of the working bodies, including the knives is greatly reduced in the following cases: setting the knives in a position that corresponds to the maximum degree of size reduction of the components of the feed, the machine at high speeds of rotation of the screw, presence of foreign objects, sand and stones in the feed. A review of the instructions with the operation and maintenance of SPRK shows that the recovery of the knives can be carried out directly in the hopper with the use of portable equipment or in repair shops [16]. Auger knives can be sharpened using a grinder, but a high-quality restoration of the knives recommended in the workshops, equipment for sharpening or grinding. If the cutting edge of the blade is not chipped, the recovery is grinding using a whetstone, a small grain to a flat surface. The recovery process is best carried out with the grinding stone special shape providing the appropriate sharpening angle. During sharpening individual firms point to the need for intensive cooling of the blade. It should be noted that only the user [16] it is recommended to provide thickness to the cutting edge and sharpening angle of the knives of the shredding machine-mix 9°, as shown in Fig. 2.

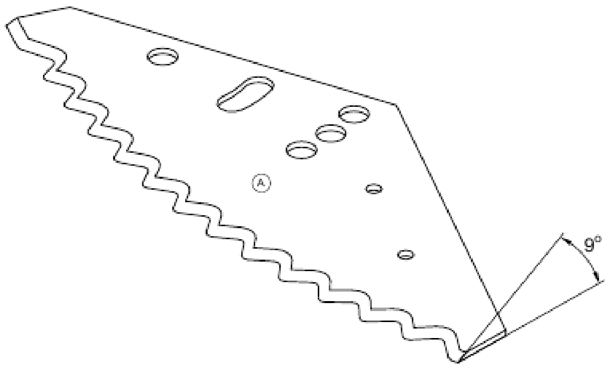
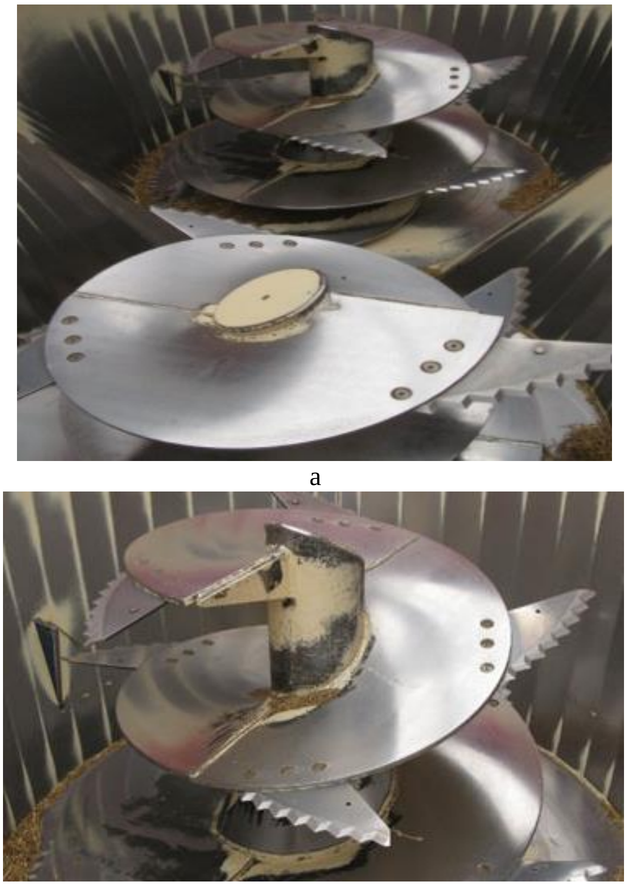


Fig. 2. Knife of grinding-mixing mechanism VMP-10 T015.

The blades of the mixing screw SILOKING TrailedLine [10] (with the exception of the top two knives) is regulated by establishing three possible positions according to the design of the knives and the auger. If all components of the feed when you load an already well-shredded, the knives should be in a concealed position, which corresponds to the minimum of the degree of grinding. In this case, the power required for grinding-mixing is reduced to 15%. Changing the installation angle of the knife by three screws, which fix its position on the screw. For best results when mixing in bunkers [12] can be fixed counter-plate, manual or hydraulic drive. Changing the position counter of the plates in the hopper is dependent on components of the feed. Their presence and the possibility of regulating improves the grinding process of components of feed and prevents "roll over" blend. It is in the instructions for the operation indicates that reliable operation of SPRK is provided using the mechanisms of grinding - mixing scrapers made from steel St 70 and multilayer blades that can be installed in three possible positions.

The use of the machines by SILOKING XS-knife with adjustable angle of attack gives the ability to quickly cut the rough components such as hay, straw and the like. Knives should be sharpened, because when they limit the wear and tear, increasing the time of grinding-mixing feed to the required fraction, and this leads to an increase in General wear and tear of the machine.



a

b

Fig. 3. Knives of machines of a lineup Siloking.

Ongoing support knife operable guarantees optimum chopping length of the components of the feed, reduces mixing time and increases their service life. To increase the service life interchangeable knife Guidance with operation [23] it is recommended to conduct the reinstallation, as the lower are subject to greater wear than the top.

Feed blending machine V-Mix ECO, V-Mix PLUS [11] in the oval tank has a vertical mixing auger is equipped with knives, which, depending on the structure of the components, which are mixed, can be used in aggressive (Fig. 4, (position 1)) or a variable declining balance (Fig. 4, (position 2)) position. The aggressive position of the knife provides for short mixing time with high engine power of the tractor, and a declining balance – a longer time of grinding and intermixing the mixture and the use of the tractor power take-off shaft power is 15% less than nominal. For machines V-Mix ECO provide special vehicle plates that are used for lengthening of the knife (Fig. 4, (position 3)) the grinding of dry and long-fibre fodder components. Machines of this model series for smaller chopping and quick mixing of the components can be equipped with control. Position contours you can manually change the setting in three possible positions or automatically from the remote control using a hydraulic system. In the Instructions for the operation focuses on the continuous monitoring of the working bodies, sharpening knives it is recommended to use a grinder with a sanding disk, but the absence of criteria for their limit state.

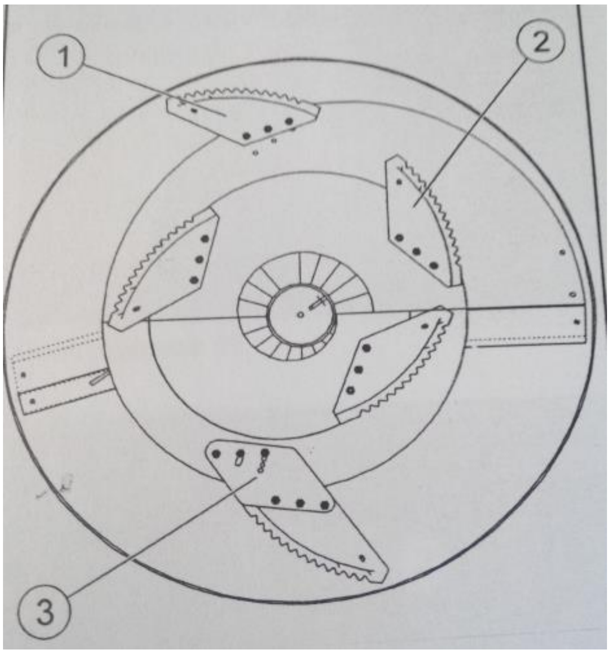


Fig. 4. Mixing screw with knives feed mixer V-Mix ECO.

Analytical studies which have been undertaken in [5] it is established that forming the blades of the knives located on the periphery of the coils of the conical screw must be in the form of a logarithmic spiral with a constant slip angle $\tau = 77^o$. The author offers individual teeth knives which are mounted on the vertical auger SPRK to sharpen at an angle of 35-40^o consistently versatile way. In addition, the results of researches it is established [5] that to achieve self-cleaning of the screw, which rotates with a frequency of 29-32 min^{-1} forming the coils should be set at an angle of 7-13^o to the horizon. In addition, the author notes that the uniformity of the feed mixture up to 15% can be achieved by equipping the vertical auger additional ejector blade, which is installed on the opposite side of the lower loop. The screw pitch shall be 500 mm and the opening height of the discharge loop of at least 180 mm.

Experience in the use of SPRK shows that the inner surface of the hopper and the screw flights are subject to intense wear during their operation. Firm SILOKING to increase the service life of these nodes offers an additional coating of a special alloy SILONOX. SILONOX is a special high quality steel, used for machines of the model range the SILOKING combines such advantages as durability, resistance to deformation and fracture, resistance to corrosion and chemical damage. Proposed by the manufacturer of the special surfacing with SILONOX on the edge of the turns of the spiral screw increases the lifespan approximately 2 times. In Fig. 5 shows the auger is coated with SILONOX.

a

b

Fig. 5. Enhanced screw surfaces with special alloy SILONOX.

An effective way to increase the reliability of the SPRK is the covering of the hopper plates made of SILONOX, which allow to improve the wear resistance of not less than 2 times. For different models, the cover can be manufactured to a height of 1200 mm from the bottom of the hopper. Developed the technology for welding of sheets with protective coating not only on the plant, but during restoration work in the workshops. The coating can be ordered from the factory by the serial number of the machine. In Fig. 6 shows a wear-resistant sheets, which are welded to the bottom and walls of the silo.

However, under these constructive possibilities of the presented subsystems of the mechanisms of grinding-mixing (MPZ) SPRK, a decision on the position of the blades and the counter plates, the necessity of their regulation on the basis of components of feed, the operator must make the operating of these machines.

As shows the analysis of operating manuals and maintenance SPRK [10-12, 16, 23], in them practically there is no information about the criteria of limit state of the working bodies and recommendations for the restoration of their health. The decision on necessity of repair or replacement, and therefore the high quality repair work provides technician or locksmith service.

a

b

Fig. 6. Wear-resistant sheets that are welded to the walls (a) and bottom of the hopper (b)

That is the basis of the conducted analysis of literary sources and research SPRK as complex technical systems "Man - Machine" (its "world Cup"), it can be noted that in the illustrated instructions on the operation and maintenance, little attention is paid to the skills of the operator, who will use the machine for the purpose, to carry out its maintenance and repair.

In addition, the efficiency of the machines is influenced by the subsystem control mechanism (MU), which has complex relationships in STS "CHM" SPRK. Subsystem of MU SPRK and its constituent elements are implemented, the vast majority of how resistant to failure configurations that are characterized by high complexity and require a high level of professionally important qualities. But some elements of the subsystem of MU SPRK have limitations to recovery with loss of serviceability or efficiency, since the majority belong to those that are not restored in case of loss of health, and should be replaced.

For selection and justification of methods of evaluation and ways of ensuring the health of the SPRK should conduct reliability analysis and assessment of the risk of failure for the subsystems (mechanisms) as the STS "world Cup" given the design of machines, modes of operation and operating conditions. This requires constant monitoring of changes in the design of modern SPRK and their working bodies, development of models for each implementation and indicates the need to analyze them in staff training.

Modern means for the preparation and distribution of forages in a wide range of foreign and domestic firms provide high quality performance of technological process of grinding, mixing, dispensing and distribution of feed mixtures, effective in operation, are characterized by a relevant level of reliability. As a result of the evaluation of the presented areas with reliability SPRK it should be noted that there is a dominant trend in the technical development of these tools as STS "world Cup", that is component of the "machine".

However, there is no clear direction in the development component of the "human operator" which affects the reliability of STS "world Cup" and is also the determining factor for efficient use of SPRK.

CONCLUSIONS

Reliability analysis and risk assessment failures as SPRK STS "world Cup" shows, to ensure the reliability of machines, you need to:

1) more attention to focus on the investigation of the reliability of the subsystem control mechanism,

2) to study the periods when the SPRK is not used as intended, and are stored,

3) to minimize the risks of failures in the operation, maintenance, repair, storage, utilization, which are due to the imperfection of the component "human operator".

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EXPERIMENTAL RESEARCH OF DYNAMICS OF LIFTING AND LOWERING LOAD ON VEHICLE

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Abstract. The analysis the experimental data, obtained for the modes of lifting and lowering of the load, has been carried out in the article. The basis for the cargo landing is the platform of the vehicle. It has been modeled as an elastic-viscous bond.

The statistical criteria for estimation of experimental data and their correspondence with theoretical calculations have been offered. The analysis of dynamic and kinematic data and their comparison with the results of simulation of the lifting and lowering modes showed a sufficient coincidence. Thus, the mathematical models accepted in the calculations are adequate.

The dependencies were found: the maximum force in the rope and the maximum acceleration of the crane bridge. They depend on the weight of the load and the duration of the speed change during the transition from the landing speed to the nominal *T*. The statistical estimation of coefficients of regression functions and their statistical significance have been determined. The regression functions allowed to establish the rational value of the duration *T*, in which the dynamic loads in the rope and crane bridge significantly decrease, and the cycle duration increases slightly.

In the implementation of optimal control of the movement of the lifting mechanism, a slight deviation of the angular speed of the rope drum from the desired characteristic has been observed. For example, for the mode of elimination of the rope slack, the mean square deviation of theoretical and experimental data equal to 0.05-0.09 rad/s at a nominal speed of 3.45 rad/s. The indicated deviations are the result of insufficiently high dynamic parameters of the drive and frequency inverter, inaccurate determination of certain factors (for example, friction forces in kinematic couplings, block and tackle, and also parameters of the electric drive) and neglect in calculations of backlashes and gaps. However, minor deviation of the angular speed of the drum does not cause a significant increase in optimization criteria.

On the basis of the regression analysis, the expressions that describe the dependence of the maximum values of the force in the rope and the crane bridge on the weight of the load and the duration *T* of the transition between the nominal and landing speeds of the lifting (lowering) of the load have been found. Analysis of the expressions found that the values of undesirable dynamic loads depend heavily on *T*. For example, for $T = 4.8$ seconds, the maximum force in the rope during lifting of the load is reduced by 15.4% (by 13.8% for lowering), the maximum acceleration of the crane bridge is reduced by 4.66 times (3.76 times for lowering) compared with the movement of the lifting mechanism, which occurs when the drive motor operates on a natural mechanical characteristic.

A further increase the duration *T* of the transition between the nominal and landing speeds of lifting (lowering) the load does not lead to a significant reduction of the undesirable dynamic loads in the system.

The decrease of crane bridge and load acceleration is explained by drive mechanism smoothness movement in the implementation of optimal control.

Key words: crane, vehicle, dynamics, loads, experiment.

INTRODUCTION

Bridge and gantry cranes are widespread in metallurgy, engineering, light industry, agriculture and forestry, and construction. In the case of operation of a crane and a vehicle (during lifting and lowering of a load) in both machines significant dynamic loads appear.

They additionally load the vehicle and lifting crane, which is undesirable because its reliability is reduced.

For dynamic calculations of cranes it is necessary to obtain an adequate mathematical model of load lifting and lowering processes. In this case, it is necessary to take into account the dynamic properties of the basis (the load lowers on it). It complicates the task.

The synthesis of an adequate mathematical model should be based on the verification of data, which are obtained with lifting and lowering the load simulation and the experimental researches.

ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

In studies [1-9] the motion dynamics of the crane lifting mechanism have been carried out.

Some scientific works [2, 4, 6, 7, 9] present the results of experimental studies, as well as their comparison with theoretical calculations.

In [6], the main factors that influence the divergence of the theoretical results and experimental data have been indicated.

One of them is the dynamical properties of the basis.

Thus, as a result of the analysis of experimental studies on the dynamics of lifting and lowering the load, it has been established that it is necessary to take into account the dynamic effect of the load on the basis (on which lowering of the load takes place) and vice versa.

In this case, possible significant deviations of theoretical calculations and experimental data should be explained [10].

OBJECTIVES

The purpose of this work is to analyze the experimental data, which obtained for the mode of lifting and lowering the load on the vehicle.

In order to achieve the purpose, the following tasks must be achieved:

1) substantiate the choice of statistical indicators for the evaluation of the quality of the mathematical model,

2) to analyze the adequacy of the mathematical model of the load lifting mode,

3) to evaluate the dynamic loads of the crane and vehicle components during optimal process of the lowering of the load.

THE MAIN RESULTS OF THE RESEARCH

Experimental researches were carried out for a crane-beams carrying capacity of 3.2 ton at carrying out loading-unloading operations on a vehicle GAZ-53. In order to interpret the experimental data obtained for the selected crane calculations and the basis on which the cargo is lowered, it is necessary to use the similarity theory [11], which is based on the similarity of the physical processes that take place in the object of experimental research and the bridge crane chosen for calculations.

Using the similarity theorem, conditions for similarity for the lifting mechanism of the load and the vehicle have been calculated. Parameters of the machine are expressed through the appropriate parameters of its physical model (object of experimental research) and similarity coefficients. Calculated values of similarity coefficients are used to interpret experimental data for the dynamics of a crane.

During the experimental research, the following parameters were measured: the strength of the rope, the linear speed of running of the rope from the drum, the acceleration of the load, the acceleration of the vehicle and the acceleration of the bridge. All accelerations have been measured on a vertical axis (the direction of the gravity action). For the recording of data on a personal computer, the device ADA-1406 [12] has been used. It contains an eight-channel analog-to-digital converter (ADC).

The practical implementation of the optimal laws [13] of the lifting mechanism electric drive has been carried out with the frequency inverter FR-D740-080 (vector type of the Mitsubishi Electric company) [14]. The connection between the frequency inverter and the PC is performed with a serial COM port [15].

From the PC to the frequency inverter in a certain sequence were sending control signals that lead to a change in the frequency and amplitude of the drive voltage. It cases the change of the drive angular speed. The performing of the calculation and sending of control signals is carried out with the program „Optimal lift / lower the load" [16] (Fig. 1).

In order to establish a connection between the PC and the frequency inverter, the user selects the port. Then, by pressing the „ON" button, the port opens. From the open port data the data will be transferring to the frequency inverter. By default, the frequency inverter has an external control. In order to set up control over the network (computer control), the user chooses the „NET" in the „CONTROL" panel and presses the „SET" button. In the future it is necessary to calculate an array of discrete values of frequency, which will be sent to the frequency inverter during the controlling of the drive speed. In order to do this, the operator first sets the parameters in the „PARAMETERS" panel: acceleration and deceleration time („Acceleration / deceleration time, s" field), duration of the nominal speed during pulling the rope („Duration of the nominal speed of the pulling rope, s" field), duration of nominal speed of movement of load (field „Duration of nominal load's speed, s"), the value of the intermediate speed of the drive (field „Intermediate speed of drive, %"), duration of intermediate speed (field „Duration of intermediate speed, s").

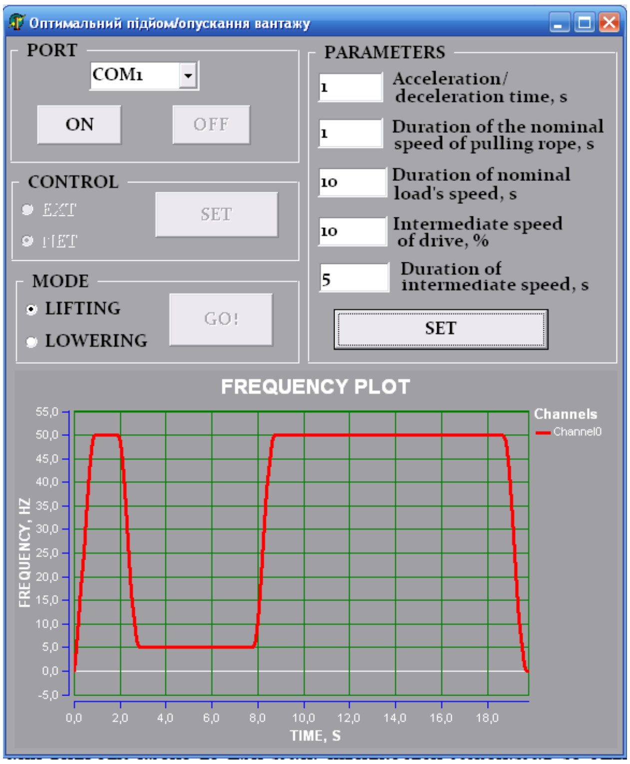

Fig. 1. Window of the program „Optimal lift / lower the load".

When the „SET" button is pressed, the program calculates an array of discrete values of the driver's the frequency depending on the mode of movement of load (lowering or lifting). The mode of movement of the drive is selected in the „MODE" panel: the mark „LIFTING" or „LOWERING" is set. The results of calculating the array can be seen using the plot. The plot illustrates the time variation of the engine power supply frequency („FREQUENCY PLOT" panel). By changing the process parameters in the fields of the „PARAMETERS" panel and pressing the „SET" button, one can see the effect of these parameters on the character of the change in drive supply frequency.

In order to start the control of the electric motor the user presses the button „GO!". In this case, the frequency converter receives a command that sets the set frequency of the drive supply frequency. The value of this frequency is the first element of the calculated array. After that, the command for launching the frequency inverter is received. In this case, the frequency of the supply voltage begins to increase from zero to a constant value. In the future there is a delay of 0.1 seconds after which from the PC to the frequency inverter sends the next control signal, which contains the value of the second element of the calculated array. The frequency of the drive voltage changes and the drive, in accordance with the frequency change, changes the speed of rotation. The process is repeated until the last frequency value is sent. The last command causes the stopping of the frequency inverter, which in turn leads to the drive stopping the lifting mechanism.

In order to close the program, one need to convert the frequency inverter to the external control mode (select „EXT" in the CONTROL panel and press the „SET" button) and disconnect from the communication port (press „OFF" in the „PORT" panel).

All experimental researches have been divided into two series. The first series of experiments has been carried out at the work of the lifting mechanism electric drive on the natural mechanical characteristic.

The main goal of the second series of experimental researches is to establish the basic laws of changing the kinematic and dynamic parameters of the research object during optimal control.

Independent experimental factors are the mass of the load (it varies on tree levels), and the duration of the lifting speed change of the cargo lowering (it varies on five levels).

Each experiment has been executed with a fivefold repetition.

Experimental data stored on a PC are multi-dimensional arrays. The processing experimental data is conventionally composed of two stages. At the first stage, a preliminary data fragment is executed.

The purpose of this stage is to create an array of experimental data that will be suitable for statistical analysis. In the second stage, statistical processing of data has been carried out directly using the statistical criteria.

At the first stage, the experimental data was read from a file, where measurements from all channels of the ADA-1406 device have been recorded. Data processing was performed for each channel separately. We have made a copy of the necessary data from one channel from a single experiment file.

Than we have established the correspondence between the values of voltage (signal) recorded in it and the moments of the time.

Subsequently, using the tare data for a specific sensor (for accelerometers and extensometer), or algorithm for counting the number of pulses (for encoders), the correspondence between the value of the measured physical value and the time when it took place has been established. Thus, for each measured parameter received a two-dimensional array of numbers.

The element of the received array shows the value of the measured value and the time corresponding to it. The length of two-dimensional arrays is equal to the length of an array from a single experimental file.

For data obtained with a linear encoder, they were further processed.

One of the main parameters that affects the lifting and lowering of the load is the speed of the rope drum.

Therefore, it is necessary from the discrete function of the position of the cable drum to form to a discrete function of the speed of its rotation.

The well-known formula for finding the approximate value of the derivative of the function [17] was used here:

$$v_{j+0,5} \approx \frac{x_{j+1.exper} - x_{j.exper}}{\Delta t}, \qquad (1)$$

where: $v_{j+0,5}$ – discrete value of the rope drum speed (linear speed of rope at the moment of time $(j+0,5)\Delta t$), j – number of array element, which are being calculated, $x_{j.\,exper}$ and $x_{j+1.exper}$ – experimental positions of rope drum at the moments of time $j\Delta t$ and $(j+1)\Delta t$ respectively, Δt – duration of time between measurements (the time step).

In the study we have used the compliance criteria. They are statistical indicators: maximum deviation, mean square deviation and coefficient of variation [18].

The maximum deviation of theoretical and experimental data was determined by the expression:

$$\max\left|a_{j.exper} - a_{j.theor}\right|,\ j = \overline{(1,\ n)}, \qquad (2)$$

where: $a_{j.exper}$ and $a_{j.theor}$ – are the experimental and theoretical values of the parameter at the moment of time $j\Delta t$, respectively.

The calculation of the mean square deviation of theoretical and experimental data was performed according to the formula:

$$\delta = \sqrt{D} = \sqrt{n^{-1}\sum_{j=0}^{n}(a_{j.exper} - a_{j.theor})^2}, \qquad (3)$$

where: δ – mean square deviation of the measured parameter,

D – dispersion of theoretical and experimental data deviation,

n – is the length of the data array (the number of measurements in the experiment).

In order to estimate the relative deviation of theoretical and experimental data, the coefficient of variation was used.

It shows the percentage of the average deviation of theoretical and experimental data:

$$v = \frac{100\%}{n} \cdot \sum_{j=0}^{n} \frac{\sqrt{(a_{j.exper} - a_{j.theor})^2}}{a_{j.theor}}. \qquad (4)$$

For indicators measured in all experiments, three indicators were calculated.

In order to analyze the kinematic and dynamic parameters measured in the first series of experimental studies, we construct graphs of functions (Fig. 2). The graphics correspond to the nominal load capacity of the crane.

Gray line on Fig. 1 shows plots of functions obtained using numerical integration of the mathematical model of the studied system.

In order to evaluate the operation of the lifting mechanism in Table 1, statistical indicators are given.

In Table 1, each cell contains three values that correspond to the weight of the load of 300, 550 and 720 kg (the lesser weight – on the bottom of the cell, the greater weight – on the top).

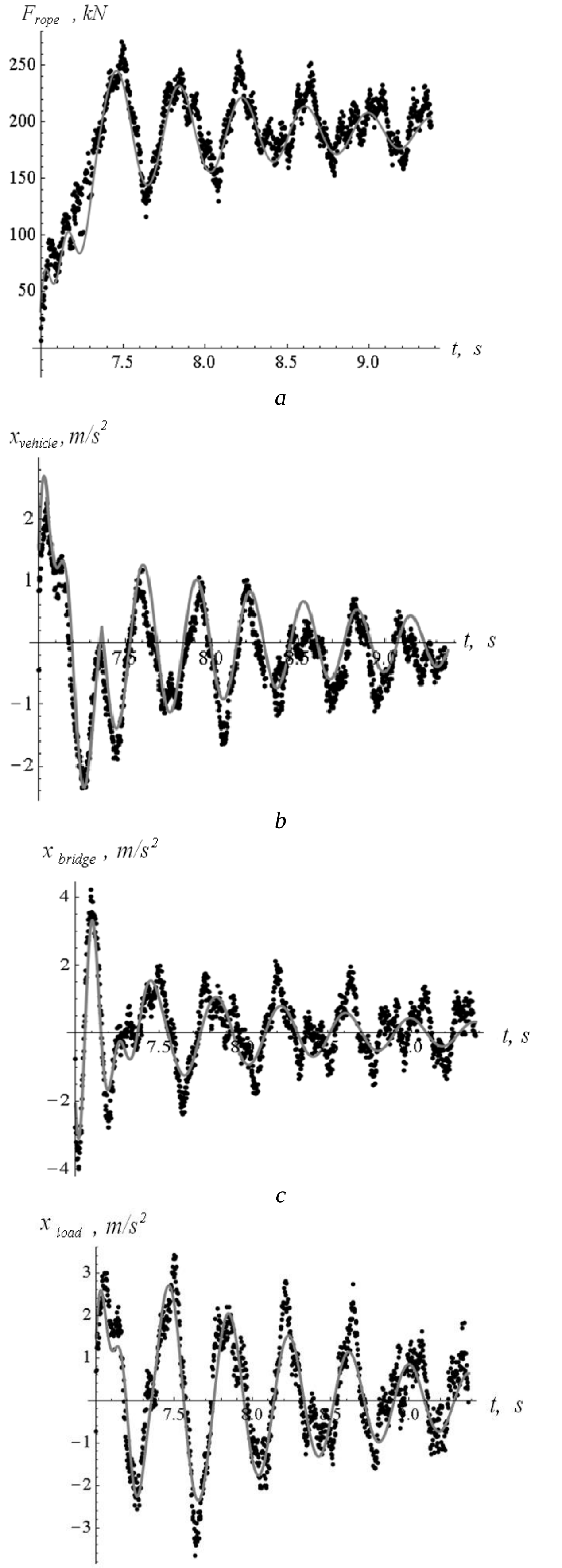

Fig. 2. Plots of kinematic and dynamic parameters during the load lifting: *a* – force in the rope, *b* – acceleration of the vehicle, *c* – acceleration of the crane bridge, *d* – acceleration of the load.

Table 1.

Statistical indicators for the first series of experimental studies

Measured value	Statistical indicators		
	Maximum deviation of theo-retical and experimental data	Average square deviation of theoretical and experimental data	Coefficient of variation, %
Force in the rope	35,5 kN 41,1 kN 37,7 kN	22,2 kN 15,6 kN 13,6 kN	16,2 11,0 10,1
Acceleration of the vehicle	0,82 m/s^2 0,72 m/s^2 0,80 m/s^2	0,51 m/s^2 0,50 m/s^2 0,41 m/s^2	21,0 19,0 14,6
Acceleration of the crane bridge	1,43 m/s^2 1,22 m/s^2 1,21 m/s^2	0,63 m/s^2 0,65 m/s^2 0,57 m/s^2	10,5 10,9 9,6
Acceleration of cargo	1,49 m/s^2 1,67 m/s^2 1,22 m/s^2	0,31 m/s^2 0,33 m/s^2 0,22 m/s^2	5,9 6,0 4,6
Angular speed of rope drum	1,10 rad/s 1,21 rad/s 1,10 rad/s	0,23 rad/s 0,14 rad/s 0,11 rad/s	19,7 13,0 9,2

For the natural crane these values, respectively, are 8280, 15180 and 19872 kg.

The analysis of the indicators, which are in Table 1 makes it possible to establish that the data coincidence is best for experimental data which reflect higher weight of the load.

Analysis of the data, which are presented in Table 1, indicates that the theoretical calculations of the model adequately describe the processes, that occurring in the system „lifting mechanism of load – load – vehicle".

Sufficient coincidence of theoretical and experimental data also indicates the accuracy of the determination of parameters. Indeed, in the case when the parameters of the mathematical model are not correctly selected, the results obtained on it do not reflect those processes that take place in the actual mechanism of the load lifting and in the suspension of the vehicle.

One of the most important indicators of the dynamics of loading and unloading operations is the force in the rope. The mode of lifting the load significantly influences the level of dynamic loads of ropes, which, in turn, determine the term of their mechanical life.

For steel ropes used in cranes, mechanical life is 0.5-0.2 years (for regime groups 4M-6M). An increase in the mechanical life of ropes can be achieved by reducing the dynamic loads.

The biggest load in the rope equal to 271 kN (Fig. 2). It took place at the stage when the weight of the load has completely shifted from the suspension of the vehicle to the rope. Fluctuations of the load in a horizontal direction cause the dynamic load of the rope. The oscillations have a converging character, which is characterized by a decrement of oscillations. For the given experimental data, the decrement of vertical oscillations of the load is equal to 0,082.

According to the plots of load acceleration, crane bridge and vehicle (Fig. 2) it is possible indirectly to determine the level of their dynamic loads. In addition, the analysis of the results of the experimental data shows that in the acceleration plots there are higher harmonic components that do not have large amplitudes and therefore have a small effect on the dynamic performance of the studied system.

For the mode of load lowering during the optimal control of speed changing from the nominal to the landing speed need to establish the character of the rope force changing, acceleration of the crane bridge and load with the variation of independent factors.

For experimental data obtained during carrying out experiments on load lowering with the implementation of optimal control, regression functions have been found. They approximate the maximum values of rope force maximum and maximum values of crane bridge acceleration. The regression model for maximum force in the rope is presented in the following form:

$$F_{rope}^{\max} = A_0 + A_1 T + A_2 m_{load} + A_3 T m_{load} + A_4 \times \times T^2 m_{load} + A_5 T^2 m_{load}^2 + A_6 T m_{load}^3, \tag{5}$$

for maximum acceleration of the crane bridge

$$\ddot{x}_{brige}^{\max} = B_0 + B_1 T + B_2 m_{load} + B_3 T_{load}^2 + B_4 \times \times T^2 m_{load} + B_5 T^2 m_{load}^2 + B_5 T m_{load}^3, \tag{6}$$

where: $A_0 ... A_6$ − parameters of the regression model for maximum effort in the rope,

$B_0 ... B_6$ − parameters of the regression model for maximum acceleration of the crane bridge,

m_{load} – mass of the load,

T – mode duration of the speed of load lowering decreasing.

In expressions (5) and (6) only statistically significant coefficients are recorded. The calculated parameters of regression models are given in Table 2. For regression functions (5) and (6) the determination coefficients have been calculated, which are equal: 0.9916 − for expression (5), 0.9990 − for the expression (6). Thus, the parameters of the models (5) and (6) have been estimated very accurately. The given results of statistical calculations are valid for a confidence level of 0.99.

The analysis of regression expressions (5) and (6) shows that an increase in the length of the transition between the lifting speeds of the load (from landing to nominal and vice versa) leads to a decrease in the maximum accelerations of the bridge crane and load both during lowering and during lifting. Of course, this increases the cycle time for lifting/lowering the load.

Table 2.

Statistical indicators of regression functions (5) and (6)

Coefficients of the regression model	Values of statistical indicators		
	coefficient value	standard error	Student criterion
The maximum of rope force $F_{rope}^{\max}$			
A_0	$1,12\cdot10^{3}$	$1,39\cdot10^{2}$	$8,05\cdot10^{1}$
A_1	$-2,80\cdot10^{3}$	$5,30\cdot10^{2}$	$-5,28\cdot10^{0}$
A_2	$1,25\cdot10^{1}$	$1,04\cdot10^{-1}$	$1,19\cdot10^{2}$
A_3	$-0,48\cdot10^{0}$	$7,80\cdot10^{-2}$	$-6,09\cdot10^{0}$
A_4	$9,98\cdot10^{2}$	$1,20\cdot10^{-2}$	$7,95\cdot10^{0}$
A_5	$-5,42\cdot10^{-6}$	$6,68\cdot10^{-7}$	$-8,11\cdot10^{0}$
A_6	$1,34\cdot10^{-9}$	$1,41\cdot10^{-10}$	$9,54\cdot10^{0}$
The maximum of bridge acceleration $\ddot{x}_{brige}^{\max}$			
B_0	$9,58\cdot10^{-1}$	$3,47\cdot10^{-3}$	$2,76\cdot10^{2}$
B_1	$-5,33\cdot10^{-2}$	$1,32\cdot10^{-2}$	$-4,02\cdot10^{0}$
B_2	$2,15\cdot10^{-5}$	$2,62\cdot10^{-6}$	$8,22\cdot10^{0}$
B_3	$-1,22\cdot10^{-5}$	$1,96\cdot10^{-6}$	$-6,21\cdot10^{0}$
B_4	$1,35\cdot10^{-6}$	$3,13\cdot10^{-7}$	$4,29\cdot10^{0}$
B_5	$-4,98\cdot10^{-11}$	$1,67\cdot10^{-11}$	$-2,98\cdot10^{0}$
B_6	$2,04\cdot10^{-14}$	$3,53\cdot10^{-15}$	$5,78\cdot10^{0}$

Based on the analysis of experimental data, it has been found that with an increase in T to a value of 4.8 seconds, undesirable dynamic parameters are significantly reduced, and thus the duration of the cycle lifting/lowering the load increases slightly. For example, the maximum force in the rope is reduced by 13.8%, the maximum acceleration of the crane bridge is reduced by 3.76 times compared to the across-the-line starting of the crane drive.

The experimental studies have been carried out for the mode of creation and eliminating of a strain weakness. During these studies, an optimal eliminating of the rope slack occurred. For the lowering of the load, after the weight of the load has completely moved to the suspension of the vehicle, the weakness of the rope must be creating (so that it can be removed from the hook). Note that for all experiments, the weak rope was equal to 0.32 m.

The only characteristic that gives an assessment of the quality of the optimal mode of motion of the system for this mode of motion is the angular velocity of the rope drum. In Fig. 3 plots are shown. They correspond to the elimination and creation of the slope of the rope (for lifting and lowering modes, respectively). The gray line shows the desired characteristic of the angular velocity of the rope drum, while the black dots show data that obtained experimentally.

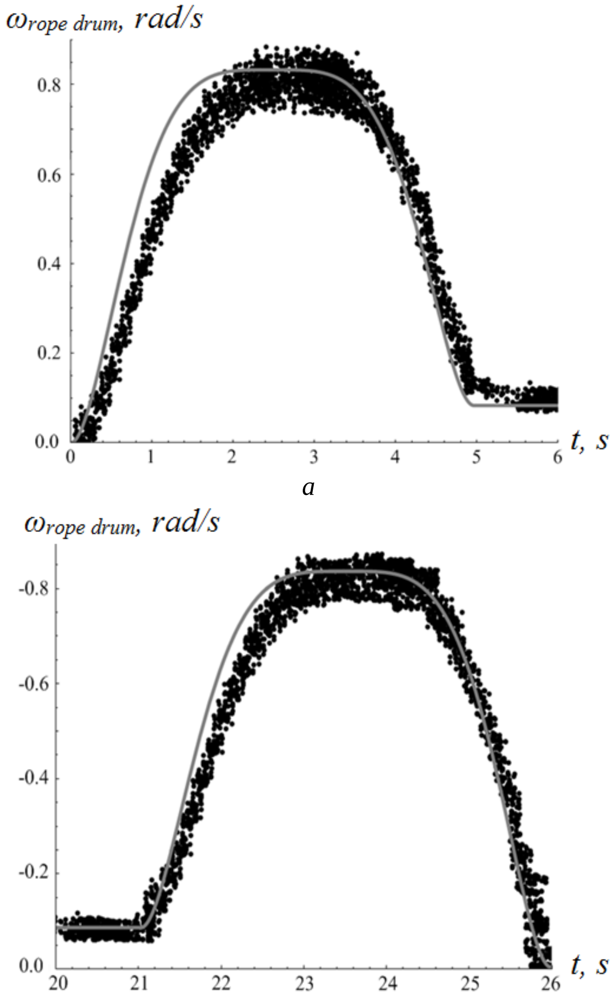

Fig. 3. Plots of the angular speed of the rope drum for the modes: *a* – the elimination of the rope slack, *b* – the creation of rope slack

From the plots shown in Fig. 3, it follows that the experimental data have a slight deviation from the desired characteristic of the change in the angular speed of the rope drum. A quantitative estimate of the deviation can be obtained by analyzing the statistics for these experimental data.

All calculated statistical data for the second series of experimental studies (in the angular speed of the rope drum) is listed in Table 3.

The largest deviation of theoretical and experimental data of the rope drum angular speed has been observed in the modes of the drive speed change (acceleration and braking) (Fig. 3).

Moreover, experimental data show that the real angular speed is always „lagging" from the desired (given) characteristic.

It indicates that the desired speed of the drive, which is set by changing the frequency and voltage of the drive, changed inaccurately.

The errors in rope drum angular speed depend on the dynamic characteristics of the frequency inverter and the drive (they form a controlling action in the system).

Table 3.

Statistical indicators for the angular speed of the rope drum (modes of eliminating and creation of the slack of the rope)

Statistical indicators	Mode	
	elimination of rope slack	creation of rope slack
Maximum deviation of theoretical and experimental data, rad/s	0,12-0,21	0,08-0,19
Average square deviation of theoretical and experimental data, rad/s	0,05-0,08	0,05-0,09
Coefficient of variation, %	12,2-26,7	11,1-30,2

Note that a small change in the angular speed of the drive leads to an even smaller change in the value of the integral optimization criterion [19]. Therefore, for the modes of creation and elimination of rope slack, the implementation of a given change in the drive angular speed „absolutely precisely" is not required, since this does not lead to a significant reduction in the value of the optimization criterion.

CONCLUTIONS

1. The analysis of experimental data at uncontrolled mode of the lifting mechanism (across-the-line starting of drive) and analysis of statistical data showing the deviation of experimental data from theoretical calculations is insignificant. For example, the coefficient of variation for the value of the force in the rope is within the range of 10.1-16.2%, to accelerate the vehicle within 14.6-21.0%, to accelerate the crane bridge 9.6-10.9%, for angular speed of the rope drum 9.2-19.7%. This indicates the adequacy of the models accepted in theoretical calculations.
2. In the implementation of optimal control of the movement of the lifting mechanism, a slight deviation of the angular speed of the rope drum from the desired characteristic has been observed. For example, for the mode of elimination of the rope slack, the mean square deviation of theoretical and experimental data equal to 0.05-0.09 rad/s at a nominal speed of 3.45 rad/s. The indicated deviations are the result of insufficiently high dynamic parameters of the drive and frequency inverter, inaccurate determination of certain factors (for example, friction forces in kinematic couplings, block and tackle, and also parameters of the electric drive) and neglect in calculations of backlashes and gaps. However, minor deviation of the angular speed of the drum does not cause a significant increase in optimization criteria.
3. On the basis of the regression analysis, the expressions that describe the dependence of the maximum values of the force in the rope and the crane bridge on the weight of the load and the duration T of the transition between the nominal and landing speeds of the lifting (lowering) of the load have been found. Analysis of the expressions found that the values of undesirable dynamic loads depend heavily on T. For example, for T = 4.8 sec-

onds, the maximum force in the rope during lifting of the load is reduced by 15.4% (by 13.8% for lowering), the maximum acceleration of the crane bridge is reduced by 4.66 times (3.76 times for lowering) compared with the movement of the lifting mechanism, which occurs when the drive motor operates on a natural mechanical characteristic. A further increase the duration *T* of the transition between the nominal and landing speeds of lifting (lowering) the load does not lead to a significant reduction of the undesirable dynamic loads in the system. The decrease of crane bridge and load acceleration is explained by drive mechanism smoothness movement in the implementation of optimal control.

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ANALYSIS OF ORGANIZATION SYSTEMS OF AGRICULTURAL MACHINERY IN MODERN CONDITIONS

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Summary. When designing agricultural machines primary mind always diverted performance issue and technical and economic indicators (maintainability, life cycle costs, etc.).

However, the desire to achieve higher characteristics of samples of agricultural machinery has led to the necessity of equipping them with sophisticated avionics system. As a result, the design of agricultural machinery is much more complicated, and the process of maintenance and repair necessitated additional work and increased cost of maintenance and repair. This was particularly noticeable for agricultural machines of new generation.

Analyzing the fleet of agricultural machines in Ukraine and the procedure for its exploitation we can state the fact that it is less reliable, and increasing labor costs for maintenance, increased downtime agricultural machines without their functional use, which reduced the indicators of their readiness to perform the assigned tasks. Was recognized the fact that the reliability and maintainability of agricultural machinery should be attributed to the main characteristics, which depends on their readiness for safe use.

A successful solution to the problem of maximizing the efficient use of all technical and running features of agricultural machines with their high willingness to use depends on how the organizational structure of services of technical inspection and forms of operation correspond to the level of its performance properties and degree of perfection of the means of its operation, that is, from the accepted system of maintenance and repair. All other factors are of subordinate importance, and also depend on the condition and quality operating equipment maintenance and repair.

It is known that in the structure of expenses, which reduce profitability and increase the operating costs of machinery, costs related to maintenance and repair 20-30%, ranking second only to fuel costs. And the critical funding situation, an invalid low condition of agricultural machinery put forward a number of priority issues of development and improvement of the system of technical maintenance and repair.

Efficiency of functioning of system of technical maintenance and repair significantly depends on the effectiveness of the subsystem of the agricultural machines. This puts a number of actual research tasks the task of assessing the impact of subsystem-recovery of complex technical systems on the effectiveness of the process of technical operation.

Key words: analyze, organization, system, agricultural machinery, condition.

INTRODUCTION

In scientific literature the recovery process of complex technical systems have received little attention. This explains the relative small number of works devoted to the restoration of agricultural machinery. Existing methods of techno-economic evaluation of the effectiveness of the process of technical operation of agricultural machinery rehabilitation works of technical objects and their components are not separated. They are considered part of the overall process of technical maintenance as one of the conditions of evolution of technical systems over time provided that the aggregate repairs and unlimited kit parts and materials. This makes it impossible to assess the impact of the subsystem recovery process maintenance and repair.

Therefore, there is an actual scientific-technical problem consisting in the development of method of optimization of the recovery process of agricultural machinery, the use of which provides a given level of technical reliability of agricultural machinery and minimum system costs of maintenance and repair.

ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

To determine the recovery subsystem let us consider the process of technical operation of agricultural machinery, as a set of operations to control the technical condition of its functional elements and of the work performed under the results of control. In operation let us assume that the ship consists of the following main systems:

– body of the main part of agricultural machinery, consisting of the impermeable sheathing [1-3],

– power setup consisting of the main engines, which actuate engine, diesel generators, switchgear, auxiliary mechanisms and systems [4-7],

– propeller, three types devices intended for control of agricultural machinery and ensure its operation [8-11],

– systems to ensure operation of power plant and is designed to create normal conditions of use [12-14],

– radio navigation equipment [15-18],

– means of automation [19-22].

Naturally, the technical condition of the functional elements defines the technical condition of agricultural machinery [7]. In modern conditions a significant part of the objects of on-Board equipment of agricultural machinery is operated to failure or state. The object that failed or the results of the technical inspection is recognized as faulty, once replaced with serviceable exchange Fund and sent to repair on the recovery [14].

Consider the process of technical operation of agricultural machinery, as a set of stages (levels) of maintenance and repair of objects of SK [21].

OBJECTIVE

The aim of this work is to increase the efficiency of the process of technical maintenance and repair of agricultural machinery to provide required level of technical reliability of agricultural machinery in modern conditions.

THE MAIN RESULTS OF THE RESEARCH

During the transition (first level) continuous monitoring of the state of SC consists of the identification of failures of functional systems (FS) agricultural machines and their most important elements (units, units), depending on the vessel type, using the built-in controls (GCS) or automated on-Board controls (BASC). The fault is at the level of structurally-replaceable units of a particular FS (unit, unit) during operational service.

At the second level (port of registry) during the operational types of preparations and regular maintenance, search failures is carried out using the GCS (BASC), control and test equipment (KPA) and ground-based automated control systems of the vessel (ACK1) the scope of the FS, which was denied. The Assembly refused and removed from the vessel and replaced with a serviceable exchange Fund port of registry.

The third level during the periodic maintenance of repair shops (RTS) operators the search of failures is carried out using the GCS (BASC), KPA and ACK1 within FS that was denied. Search the cracks within the aggregates, recognized as faulty and removed from the vessel according to the testing results of each of the levels is done using a special KPA (SKPA) and automated systems of control and diagnostics of dismantled equipment (ACK2). For this is a subunit, or the fee that refused are on the backup warehouse staff ZIP. Recycled aggregate is checked for serviceability and restores exchange Fund RTS of the operator. The unit cannot be restored under these conditions, is sent to shipyards (SRH).

The fourth level – factory level of service. This can be either the FSA or the enterprises of other ministries and departments. At this level of service turns out to be defective and is replaced by part of the node or Board Assembly is faulty. Recycled aggregate is checked for serviceability and sent to warehouses on supply.

General scheme of functioning of maintenance and repair of agricultural machinery is presented in Fig. 1.

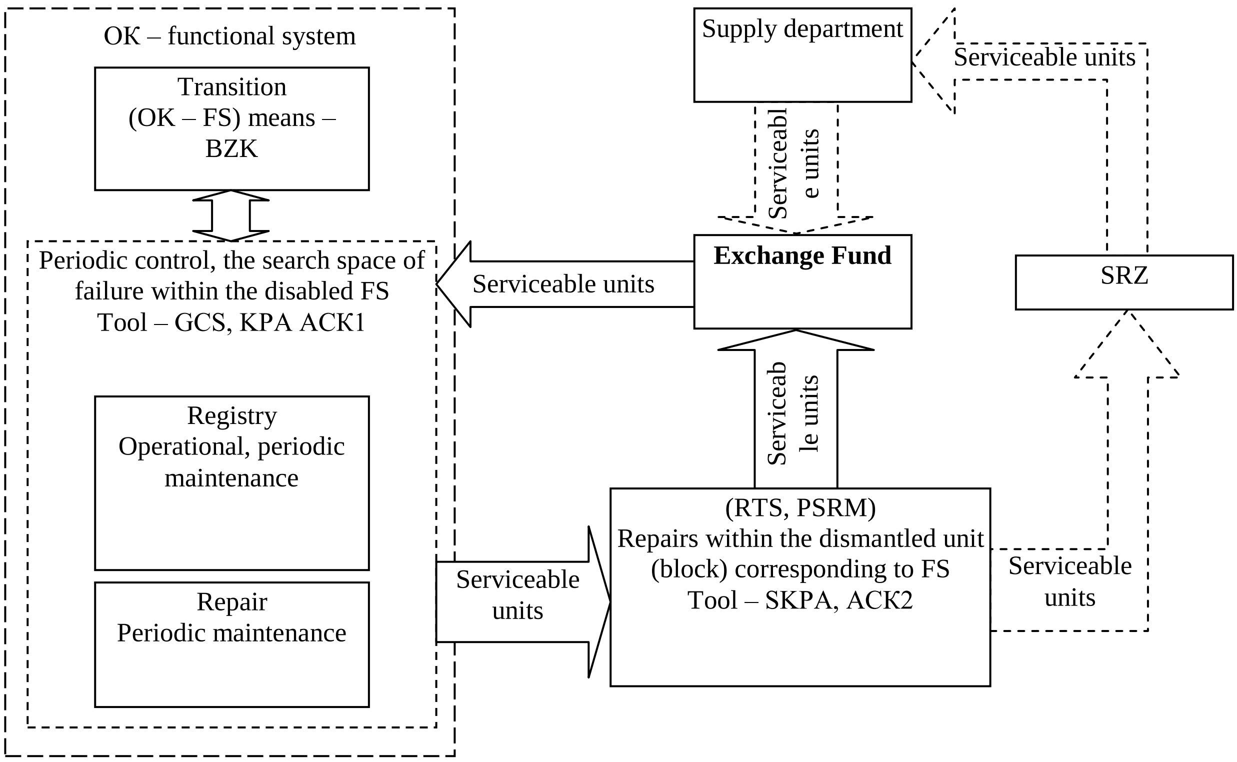

Fig. 1. Structural-functional scheme of technical maintenance and repair of agricultural machinery.

Such a process view of maintenance and repair makes it possible to identify options for the organization of the recovery process on-board equipment of agricultural machinery (building subsystem recovery as part of maintenance and repair), as the possible combinations of phases of the control and recovery of the technical condition of objects of agricultural machinery.

In accordance with the representation of the process of technical operation of agricultural machinery, like combination of stages of maintenance and repair of objects of SK highlight possible directions the process of recovery of airborne equipment of agricultural machinery.

In the General case, there exists a finite number of options for the organization of the recovery process, which is determined by:

– main requirements for the system technical maintenance and repair,

– parameters of the system adopted technical maintenance and repair,

– technical characteristics and composition of funds in-service inspection and repair, used to define the technical state and search of a place of failure, and set by the regulations of technical operation for each type of agricultural machinery,

– existing repair network,

– accepted system of training engineers,

– adopted by the supply chain management of spare parts and materials to customer.

On this basis, the main directions of improving the system recovery that will ensure the smooth functioning of the repair network facilities for agricultural machines and will resolve the contradiction between the need of ensuring the required level of serviceability of agricultural machinery and the existing system of tor are:

1. Reasonable structure of the repair network in Ukraine.

2. Improvement of resource-saving methods and modes of tor agricultural machinery of the courts.

3. Improvement in the repair of agricultural machinery due to the expansion of the range of units that are being restored to operating conditions.

Direction 1 provides a solution to a complex dynamic problem of locating repair companies, subject to park and locations of agricultural machinery and organs of supply, opportunities strategy tor management of the technical state of agricultural machines, and the like.

Due to the fact that such a complex technical system as an agricultural machine combines a large set of structurally separate detachable units with different characteristics of reliability and maintainability (reliability, seriousness, accountability, technical maintainability), areas 2, 3 require research on:

– effectiveness of strategies tor for each type of the separate detachable units,

– extension to the special conditions of the volume of repair transactions (completeness of recovery),

– effectiveness of the means of the operational control and repair information as part of the process of control of technical state of agricultural machines and their impact on the efficiency of the recovery process of agricultural machines.

The analysis of possible directions of perfection of system restore allows you to define the basic variants of its organization. The main options for system recovery on-board equipment agricultural machinery dismantled in consequence of the refusal and qualitative assessment of the advantages and disadvantages of each of these options is given in Table 1.

Table 1.

Main variants of organization of system for recovery of complexes of agricultural machinery

<table>
<tr><th>Embodiments of the recovery system for agricultural machines</th><th>Advantages</th><th>Disadvantages</th></tr>
<tr><td rowspan="3">1. Recovery of SK by replacing the COA without their further recovery.</td><td>Do not need technological equipment to restore the PPC.</td><td rowspan="3">Significant economic costs.</td></tr>
<tr><td>The minimum recovery time, the maximum level of preparedness of the UK.</td></tr>
<tr><td>The lower level requirements of knowledge and skills.</td></tr>
<tr><td rowspan="2">2. The restoration of COA to repair factories and enterprises.</td><td>Do not need technological equipment to restore the PPC to centre.</td><td>Significant recovery time units.</td></tr>
<tr><td>Reduction of requirements to level of qualification of experts of RTS.</td><td>Simple IC in failed state.</td></tr>
<tr><td rowspan="2">3. The restoration of the COA forces and means of RTS.</td><td rowspan="2">Reduced downtime of agricultural machinery in an inoperable condition.</td><td>Needs a large number of costly bench and process equipment.</td></tr>
<tr><td>Increase in number of specialists of high qualification in operator.</td></tr>
<tr><td rowspan="4">4. Repair KUO in the RC (regional databases of repair) using standard means of ground control or autocontrols dismantled equipment (ACK2) (repair works as the exception).</td><td>The decrease in economic costs.</td><td>Development and production of systems such as ACK2.</td></tr>
<tr><td>Reducing recovery time units.</td><td rowspan="3">Need for sustainable building maintenance and repair taking into account requirements for effective functioning of SC and capabilities of system repair.</td></tr>
<tr><td>Downtime IC in a failed state.</td></tr>
<tr><td>Reduction of requirements to professional level of specialists of engineering service (in case of introduction into operation ACK2).</td></tr>
</table>

Are given in Table 1 recovery options for the objects of agricultural machinery and their combinations determine the final number of variants of the organization of the recovery system.

As can be seen from Table 1, the most appropriate process is the recovery of the dismantled because of agricultural machinery in a fourth embodiment.

The advantage of which, compared with others, will depend on the share of on-Board equipment that is restored in the conditions of the operator. But it is necessary to solve a number of difficult theoretical and practical tasks such as:

1. During the development of new agricultural machines or upgrading those that are used by the operator:

– introduction to design of IC elements are high reliability, manufactured using new technologies and new materials, reducing the number of components, assemblies and parts in the system design,

– ensure high testability of the system with search capability of failure point with a precision of structurally-replaceable units

– accessibility to the main elements and units,

– the development of improved means of the on-Board control, display and localization of failures,

– reduction in the use of special control and test equipment, wide application of standard controls.

2. In the framework of the system of technical operation:

– reduction of the list and scope of work and repair, introduction to the practice of the method of operation as,

– reduction in the range, number and size of facilities,

– development or procurement of automated systems for monitoring and diagnosing the technical condition of the products SK.

As can be seen from the analysis information system is based on recovery of funds and operational control, which is used to solve the tasks of health checks of onboard equipment of agricultural machinery at the crossings, when performing operational tasks and preventive maintenance, the search space of failure during the repair of SK.

Currently for the control IC used in such tools:

– on-board automated controls (BASC),

– built-in controls (GCS) of the individual systems,

– automated control system of agricultural machines (АСК1),

– automated systems of monitoring of dismantled equipment (АСК2),

– onboard monitoring (PBSC),

– testing equipment (KPA).

In addition, in recent time received the intensive development of artificial intelligence system and as one of their areas of expert systems, which are widely implemented in real time.

The system of operational control means shown in Fig. 2. Onboard automated system of control is designed to control technical condition of onboard equipment at the crossings and at the port in preparation for the trip and also to detect the event of violation of operational constraints and error mechanics on transitions, display and documentation of inspection results.

BASK, depending on the implementation, in turn, are divided into internal and external.

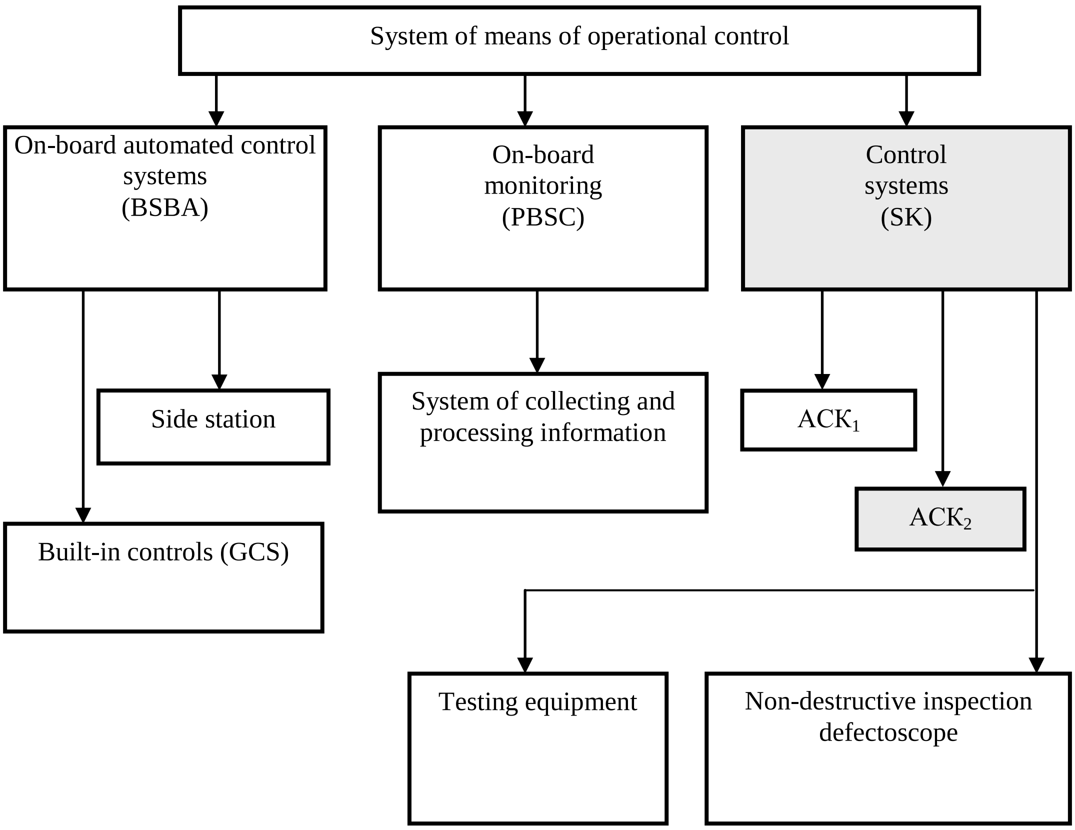

Fig. 2. System of means of operational control of technical maintenance and repair of agricultural machinery.

GCS enhance the reliability of the fs and to provide the necessary level of security, automatic control of agricultural machinery at all stages of the transition. gcs work during the whole time of functioning and performed in the general construction of a control object. indication of failure, that issued the gcs is used by mechanics at the transitions for a decision about the possibility or impossibility of execution of the task.

Back constructively in a separate device. main tasks basc – implementation of operational control because of agricultural machinery in the transition, localization and liquidation of failure, the output of the vehicle because of the crew or a memory device which are equipped with external back.

PBSC are used to control and check the transitions of the parameters that characterize the technical condition of the main systems of agricultural machines, automatic interpretation and analysis of recorded information.

On the basis of the fixed information to solve problems: evaluation of TC systems that are monitored and forecasting of TS of the uk and recommendations for maintenance, analysis of the causes of events and monitoring of driving technique.

Automated control system used to control the technical state of the ic when performing maintenance and repair, preparation for navigation, troubleshooting, targeted and periodic inspections. depending on the level of interaction with the test object, they are divided into two groups: the ACP is not dismantled equipment (АСК1) and ask dismantled equipment (АСК2).

АСК1 designed to determine the vehicle agricultural vehicles, their power plants because of localization of the ground fault in the coa. information about the vehicle controlled objects is issued at the expense of display and other media. used automated control system of dismantled equipment (АСК1) for various forms of service because of agricultural machinery and are used in both stationary and mobile execution.

Disadvantages АСК1 is insufficient depth inspections and detailed inspections of each unit node unit.

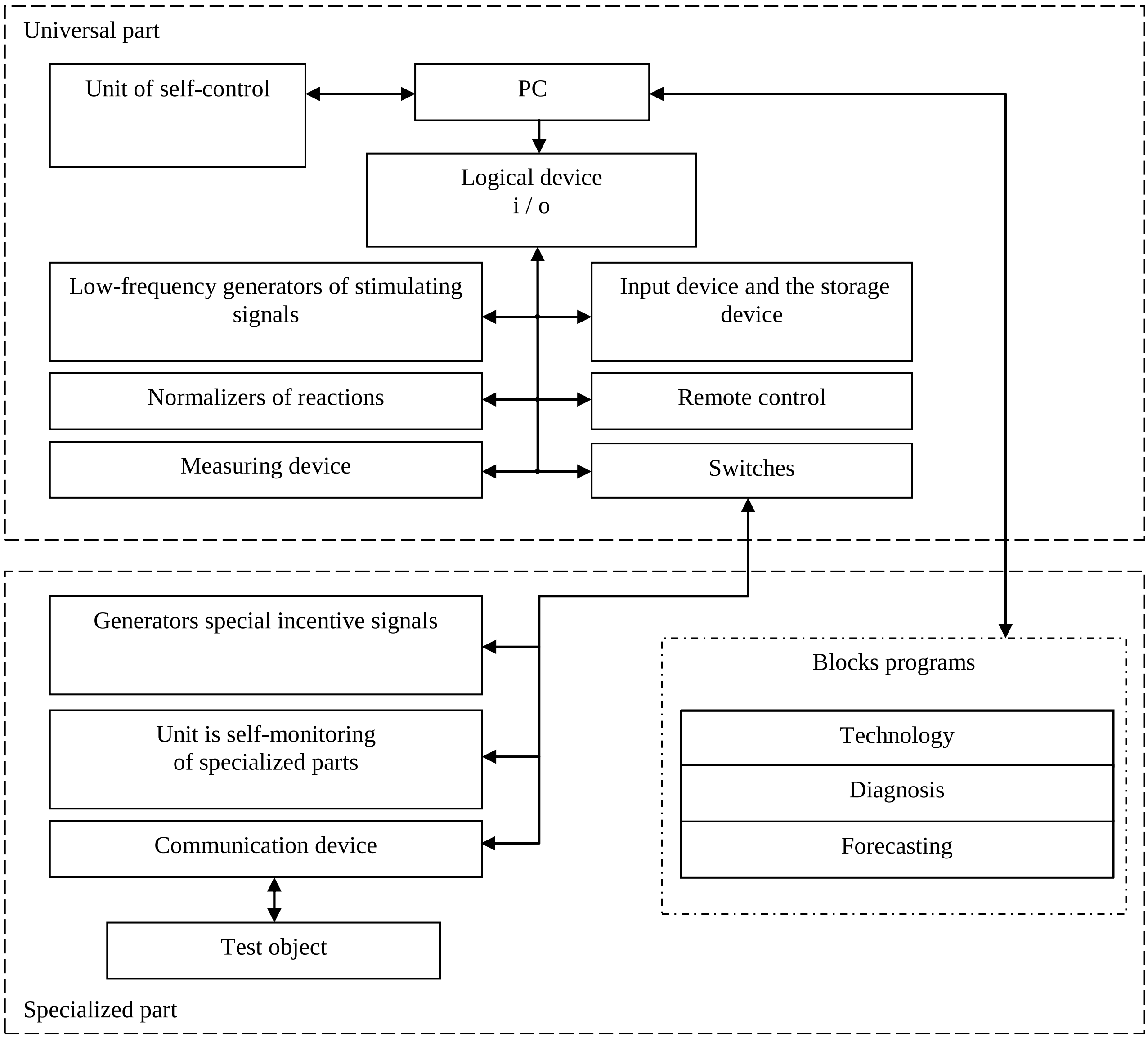

Fig. 3. Simplified diagram of unified АСК2.

Modern controls type ACK2 belong to the class of multi-purpose information-measuring complexes, solving the problems of health monitoring, diagnosis, forecasting in the evaluation of the technical state of complex dynamic systems. designed for: block check, adjustment and adjustment for holding of rejection blocks when sending them for repair and testing after return from repair, the exact localization of the fault, as well as conducting preventive and routine maintenance. Wide possibilities of such systems are provided with application in their structure of computers (PC).

The advantage of ask the dismantled components: high control accuracy, high automation level, the localization of faults to a replaceable module, a relatively high throughput and objectivity of testing results, a full verification of the blocks using a list of monitored parameters, the ability to document testing results for the prediction tasks to reduce requirements for qualification of personnel.

Currently in development of means of control of complex dynamic systems there are such trends.

The desire to reduce cost on the one hand, and expansion of functional capabilities and effectiveness, on the other, leads to the emergence of the unified automated control systems. with high performance, these funds can control several types of control objects, which gives the opportunity to reduce controls.

Unified ACK2 consist of a universal part that includes those devices that are common when testing all types of control objects, and a specialized part, which includes the device, specific for each type of test object. in Fig. 3 shows a simplified scheme of the unified ACK2.

Separate the functions carried out by the specialized part may be transmitted to the universal part. for example, the computer is able to programmatically generate various types of special incentive signals. in this case there is no need to develop specific stimuli generator that is included in a dedicated part of the control system.

High flexibility of control systems, which can be achieved due to more complete use of possibilities of computers and application of the modular principle of construction. ACK2 are built from separate software and hardware functional units, combining which it is possible to get a new device. hardware modules are built on the basis of a unified device that gives you the opportunity to increase individual monitoring devices by connecting them with unified bonds that are subject to the exchange of information between the processor and other devices.

In addition, the emergence in recent years of a compact, yet super powerful computers allow to create a new control system of the type ACK2, which was characterized in comparison with existing:

– much less weight and size,

– reduction of time to prepare for use,

– detection capability 100% failure rate and in 95% of cases to identify the cause of failure of a block or node

– high methodological and instrumental accuracy control.

In the system of General technical requirements engineering specified some parameters of system operation monitoring and, above all, the indicators of the testability of the IC.

So completeness of control in the preparation $\eta_o^* = 0{,}95$ of the vessel for going to be the probability of failure taking into account the real characteristics of the controls (testing reliability) – $P \geq 0{,}85$ percentage error of marriage from all results is not suitable when control of the vessel is less than 20%, the ratio of the depth of search failure (the depth of diagnose) by means of monitoring and diagnosing, >0,9 the COA.

The results of a detailed analysis of the means of control in our country and abroad conducted by the author and the comparative characteristic of modern means of control courts and their foreign counterparts, showed a number of problematic trends that arise during their development and operation:

1. The GCS should be considered as one of the main elements of the onboard systems. Currently, developers can't provide in preparation for the transition given full control (95%):

$$\eta_o = m_{nk} / m_n \,,$$

where: m_{nk} is the mathematical expectation of the number of controlled failures,

m_n – the expected total number of failures (damages) within the specified operating time.

Therefore, the level of fault, as a rule, is 50...80%, which leads to the problem of latent failures, which reduce the real level of safety of agricultural machinery.

2. Requirements for mobility and autonomy the use of agricultural machines, reduction of maintenance costs and level of qualification maintenance of the composition cause the necessity of increasing the depth of search failures to the level of the printed circuit Board element in their 100% localization:

$$\Gamma_{пв} = \lambda_{кв} / \lambda \,,$$

where: $\lambda_{кв}$ – failure rate, which is controlled by the data means with a depth of structurally-replaceable units,

λ – the General failure rate of the test object.

On the other hand, increasing the fullness and depth of the on-board control leads to an increase in the weight of the equipment and the rising proportion of false rejections of up to 50% and above.

CONCLUSIONS

1. The versatility, integration, resiliency, structural and information redundancy of modern on-Board equipment allow to carry out the task if a fault is detected at the crossings, which increases the requirements for continuous monitoring and timely indication of failure. On the other hand, display transitions may cause the unwarranted termination of the execution of tasks in case of minor or false failures.

2. Negative experience of use in parts ACK1 MK, and, on the other hand, high characteristics of the American system AFTA raises a number of questions concerning the choice of directions of improvement of ground controls (to change the strategy of using, modifying software to improve the indicators for test or modify the design).

3. For this group of contradictions requires the solution of complex theoretical and practical task in the design stages of SK, the directions 1, 2, 3, and validating requirements for airborne and ground control of a vessel, surface of ask of dismantled equipment, direction 4.

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ANALYSIS AND JUSTIFICATION OF EFFECTIVENESS OF PROCESS OPERATIONAL AND TECHNOLOGICAL RELIABILITY OF COMBINE HARVESTERS

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Summary. The analysis suggests that to solve the contradiction between the need of ensuring the required level of serviceability of combine harvesters and capabilities of existing system and repair management of the technical state of combine harvesters at the present stage, there is a need to improve the subsystem recovery combine harvesters subject to the requirements of readiness to perform tasks on purpose and financial capacity for its maintenance.

Analysis of scientific literature showed that today the unsolved problem of search and introduction of effective methods and repair combine harvesters are: development of mathematical models of the process and repair, which would allow comparative assessment of technical and economic efficiency of different modes, and repair objects combine harvesters, alternative strategies for their repair, with the aim of improving the quality of control of technical condition of the vessel in conditions of limited funding.

Consideration of the process of technical maintenance of combine harvesters as a set of stages and repair objects combine harvesters allows to identify possible directions of improving the system restore. The analysis allowed to determine four basic options for its organization and to make a qualitative assessment of the benefits and disadvantages of each of these options.

Reduced operating costs in the operation of combine harvesters, along with other measures of organizational and technical nature require greater automation of control of technical condition. Automation of technical state control of combine harvesters developed in the following areas: embedded systems control, on-board automated control systems, specialized control systems and universal control systems dismantled equipment. A large share of false failures in equipment, violation of industrial relations in the repair network on-board equipment, the shortage of maintenance fund require implementation and operation.

Most fully able to examine the efficiency of the process of operation of complex technical systems using analytical models.

Existing approaches to the assessment of the recovery system can be classified also according to the used indicators of effectiveness: the number of constructive variables of units that are replaced (restored) for a predetermined period of operation of the control object, repair cost of the constituent elements of the functional system for a specific period at different depths of the control and completeness of the recovery, the downtime of the test object within a certain period, for comprehensive reliability, such as coefficient of readiness, coefficient of technical use.

Key words: analyze, justification, effectiveness, process, operation, technology, reliability, combine.

INTRODUCTION

As is known, the choice of indicators to assess the effectiveness of the process, which is investigated, is an important part of the analysis, the quality of which depend the results of the analysis and the objectivity of rational choice (optimal for the modern period) solutions. In this regard, in the modern period in literature, which is devoted to techno-economic analysis of the efficiency of operation of complex technical systems (CTS), has developed three main approaches [1-12]:

- evaluation of the effectiveness of one composite index (scalar),
- based on a number of indicators (vector),
- evaluation metrics used in common, the most important indicators.

ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

Under the effectiveness of any technical system understand the degree of completeness of implementation of the tasks set before her, and the magnitude of costs associated with its implementation under certain conditions and time interval [13-20]. Efficiency is characterized by the intensity of its manifestation, which is called the index of effectiveness [21].Thus, the efficiency index W is a measure of the degree of conformity of real result Y the result is what you want (goal) SW. In turn, based on the goal of the recovery subsystem on-Board equipment of the vessel [22], the goal of the process and R, and hence the process of technical operation (PTO) SK associated with the costs of various resources: material C, Tr employment, financial F, time T, and the resource. Therefore, when evaluating the effectiveness of the recovery process objects combine harvesters it is necessary to consider, in addition to the target score g, and the costs of different resources (C, Tr, F, T) occurring when executing operations. It follows that the efficiency indicators of operational modes of the objects combine harvesters must have a technical and economic nature [23].

OBJECTIVE

In paper carried out the analytical and generalization analysis and evaluation of performance indicators of process operational and technological reliability of combine harvesters.

THE MAIN RESULTS OF THE RESEARCH

Thus, the results Y the recovery process, combine harvesters, what is studied, is an R-dimensional vector of characteristics result the operating rules including the appropriate groups component $R = r_1 + r_2 + r_3 + \ldots$:

$$Y^{\langle R\rangle} = (g^{\langle r1\rangle}, C^{\langle r2\rangle}, T_r^{\langle r3\rangle}, F^{\langle r5\rangle}, \ldots) \qquad (1)$$

That is, the result required, should also be represented by a target vector to lodging,

$$Y_{в}^{\langle R\rangle} = (g_{в}^{\langle r1\rangle}, C_{в}^{\langle r2\rangle}, Tr_{в}^{\langle r3\rangle}, F_{в}^{\langle r5\rangle}, \ldots), \qquad (2)$$

what sets the boundaries of permissible values of the corresponding indicators $Y^{(R)}$ of real result of the operation process that is studied.

To describe the correspondence between Y and $Y_в$ use some numerical function ρ on the set of the results of the recovery process that is considered, and that is a function matching:

$$\rho = \rho\ (Y(u), Y_в), \quad u \in U,$$

where: U the many options for organizing the recovery process, which represent the system of rules of control of technical condition of the objects combine harvesters for maintenance or repair, which directly determine the scope (volume) the type and frequency of recovery operations.

The magnitude of the correspondence between elements of the same name the component Y and $Y_в$:

$$\begin{Bmatrix} \rho_1^g(g_1, g_{1в.}) \\ \rho_2^g(g_2, g_{2в.}) \\ \ldots\ldots\ldots\ldots \\ \rho_{r_1}^g(g_{r_1}, g_{r_1 в.}) \end{Bmatrix},$$

$$\begin{Bmatrix} \rho_1^C(C_1, C_{1в}) \\ \rho_2^C(C_2, C_{2в}) \\ \ldots\ldots\ldots\ldots \\ \rho_{r_2}^C(C_{r_2}, C_{r_2 в}) \end{Bmatrix},$$

$$\begin{Bmatrix} \rho_1^{Tr}(Tr_1, Tr_{1в}) \\ \rho_2^{Tr}(Tr_2, Tr_{2в}) \\ \ldots\ldots\ldots\ldots \\ \rho_{r_3}^{Tr}(Tr_{r_3}, Tr_{r_3 в}) \end{Bmatrix},$$

define the set of partial performance indicators $W_g^{\langle r_1\rangle}$, $W_C^{\langle r_2\rangle}$, $W_ц^{\langle r_4\rangle}$, $W_F^{\langle r_5\rangle}$, $W_T^{\langle r_6\rangle}$, … , each of which may represent a scalar or more generally a vector that is created by group of indicators of the effectiveness of this.

Partial indices W_r, $r = \overline{1, R}$ efficiency, reliability (reliability), economic, social and other types of performance form a vector efficiency $\vec{W}$ index of restoration of objects of combine harvesters in the process and repair management

$$\vec{W}(u) = (W_1(u), W_2(u), \ldots, W_r(u), \ldots, W_R(u)), \quad r = \overline{1, R},$$

where R is the total number of partial indicators of the effectiveness of the recovery process.

Indicators in the evaluation of the effectiveness of the process of technical operation of the vessel, and hence the operation of the recovery system combine harvesters, as a rule, divided into the indicators of technical efficiency and economic efficiency.

Indicators of technical efficiency. In accordance with the purpose of functioning of the repair system, effectiveness of the recovery system on-Board equipment of combine harvesters we understand its ability to maintain a given level of readiness of combine harvesters to carry out tasks as directed.

Thus, the problem reduces to the selection of indicators to quantify the quality of recovery of the system and its impact on the efficiency of the process of technical operation of combine harvesters.

A property of the system of technical maintenance and repair of grain harvesters to complete the task relatively continuous maintain a given degree of readiness of combine harvesters to carry out tasks is determined by its effectiveness which includes the technical perfection of design and operational reliability of grain harvesters.

Numerous studies evaluating the effectiveness of the process of technical maintenance of combine harvesters, show that the willingness of harvesters to use is largely determined by its reliability. Moreover, the reliability depending on the purpose of the study refers to the combination of such elements as: reliability, maintainability, durability and persistence.

Since the main function of system restore is the translation of the object of repair to a healthy state, it is logical to assume that system restore affects the efficiency of the object through the characteristics of its reliability.

On the other hand, the main requirement when selecting a performance indicator is a compliance indicator the purpose of the study the aim of this study is to improve the system of technical maintenance and repair of combine harvesters, so that as the main figure should choose one of the indicators of reliability.

All the components of reliability are assessed using quantitative parameters.

In the practice of evaluation of reliability of combine harvesters used the figures given in the Table. 1.

As can be seen from table 1, the individual indicators of reliability characterize one of the properties of a technical object (e.g., reliability) while integrated indicators characterize several properties.

The main indicators of reliability of non-renewable combine harvesters in accordance with DSTU 2862 is the probability of failure, failure rate, mean time between combine harvesters to failure. The probability $P(t)$ of failure-free operation of combine harvesters is the probability that within a given experience of failure will not occur, that is, the object began to work at time $t = 0$, to perform reliably over time t:

$$P(t) = P(\xi > t) = 1 - F_{\xi}(t),$$

where: ξ – random operating time of combine harvesters to failure, $F_{\xi}(t)$ – distribution function developments combine harvesters to failure.

Table 1.

Main indicators of reliability of combine harvesters

Property	Index	Marking
Single		
Reliability	Probability of failure	$P(t)$
	Failure rate	$\lambda(t)$
	Parameter flow of failures	$\omega(t)$
	Average time to failure	T_1
	Average time to failure	T_0
Durability	Average resource	T_n
	Service resource (average service resource)	T_e
	Gamma-percent service resource	$T_{\gamma e\%}$
Maintainability	Probability of recovery	P_e
	Recovery rate	$\mu(t)$
	Average duration of recovery	$T_в$
Persistence	Average time persistence	$T_з$
	Gamma-percent resource persistence	$T_{\gamma з\%}$
Integrated		
Reliability and maintainability	Availability	$K_г$
	Coefficient of operational readiness	$K_{ог}$
	Coefficient of technical use	$K_{тв}$

It is obvious that the distribution function of the achievements of combine harvesters to failure $F_\xi(t)$ the probability of failure of the object over time t.

In differential form the law of distribution of time to failure is called the density of distribution of time to failure $f_\xi(t)$:

$$f_\xi(t) = -\frac{\partial P(t)}{\partial t}.$$

Value characterizes $f_\xi(t)\partial t$ the probability of failure over a range $(t + \partial t)$ of developments combine harvesters, taken at random from the set of identical harvesters.

It is unknown whether this functional object to the beginning of the interval at the time t, was denied informed. It's not always convenient in practice $f_\xi(t)$, as an independent indicator finds limited application.

Often used similar definition of failure rate:

$$\lambda(t) = \frac{f_\xi(t)}{P(t)}.$$

Failure rate, generally regarded as the relative rate of reduction in the value of the reliability function $P(t)$ with increasing t.

Performance elements of the combine harvesters (functional systems, modules, assemblies, parts) characterized by their serviceability, that is, the condition that meets the requirements of normative-technical documentation. Any deviation from the technical requirements is considered as a fault and is defined by the term rejection.

Combine harvesters and their functional systems relate to the recovery of objects, the performance which in case of detection of failure to restore these conditions by repair or replacement of nodes or elements, that had failed. The process of their functioning is described by continuous random variables characterizing the length of time of correct operation, *T*, the duration of the recovery period $T_{відн}$, or time between failures and updates

$$T_\Sigma = T + T_{відн}.$$

In addition, we introduce a discrete random variable characterizing the number of failures $n(t_{i-1}, t)$ or recoveries $n_в(t_{i-1}, t)$ over a period of time $[t_{i-1}, t]$.

As features the average number of failures expected in a small period of time for recovery of objects using a parameter of stream of refusals $\omega(t)$, that for ordinary stationary flow failure is determined by the formula

$$\omega(t) = 1/T_0,$$

i.e. $\omega(t)$ – expected number of failures of combine harvesters with the recovery per unit time for steady-state operation.

Usually in the theory of reliability, as a rule, do not distinguish between intensity and parameter flow of failures, due to the fact that the stream of refusals is physically there always ordinary. Therefore, the parameter of stream of refusals is asymptotically equal to the probability of failures in the interval Δt.

One of the quantitative indicators of reliability of combine harvesters being restored is the average time between failures:

$$T_0 = \frac{T}{M[n(t)]},$$

where: $M[n(t)]$ – the expected number of failures over a given period of operating time T.

The individual indicators of reliability have a peculiar technological character: they are necessary for use in calculations of integrated (operational) indicators of reliability of combine harvesters. These indicators are intended for subsystems (elements) of complex technical systems (CTS). For example, if CTS is convenient to characterize the availability (operational metric), each of the constituent elements must be characterized by a single performance – distribution practices and the recovery time (or their main parameters such as mathematical expectation) as they allow to calculate the reliability index of the system as a whole, taking into account features of the processes of operation and maintenance.

It should be noted that the statistical material these parameters are calculated by the operating time of combine harvesters excluding downtime for operations and R.

To account for periods of repair and maintenance are calculated complex indicators of reliability. These include the coefficient of readiness, coefficient of operational readiness and the coefficient of technical use.

Availability factor Kg(t) is defined as the likelihood that harvesters will be in working state at any time, except the planned periods during which the use of combine harvesters for the purpose not provided.

For any distribution of achievements between failure and recovery time can prove that the stationary availability factor is equal to:

$$K_г = \frac{M(T_0)}{M(T_0) + M(T_в)}, \quad (3)$$

where: $M(T_0)$ – average time of finding combine harvesters in good condition,

$M(T_в)$ – average recovery time combine harvesters.

The dependence of $K_г(t)$ on time is often called the nonstationary availability factor (function ready). To obtain the expression for non-stationary coefficient of readiness in the analytical form is quite complicated in the General case

$$K_г(t) = P(t) + \int_0^t P(t-\tau)\cdot \omega_в(\tau)dt,$$

where: $\omega_в(\tau)$ – parameter of stream restorations.

In DSTU introduce also the notion of the coefficient of operational readiness $K_г(t, t+\tau)$ as the probability that the object will be in working order for any period of time, except for planned periods during which the use of combine harvesters for the purpose provided, and from this point on, will work flawlessly within a given time interval τ.

$$K_г(t, t+\tau) = P(t+\tau) + \int_0^t P(t+\tau-x)\cdot \omega_в(x)dt \cdot$$

Along with the availability factor in the study of influence of methods and regimes of maintenance on the efficiency of the process of technical operation used $K_{тв}$ the coefficient of technical use is equal to the ratio of mathematical expectation (MO) time interval of stay of combine harvesters in a healthy state for a certain period of operation $M(T_0)$ to the sum of the MO residence time of combine harvesters in working condition and the total downtime in all types of maintenance and repairs is $M(T_{пр})$:

$$K_{тв} = \frac{M(T_0)}{M(T_0) + M(T_{пр})},$$

where: $M(T_{пр})$ – the sum of mathematical expectations of downtime of combine harvesters on a periodic, regular, seasonal work, when carrying out improvements, repairs, Troubleshooting and so on.

The analysis of the advantages and disadvantages of the above indicators of technical efficiency shows that as the indicator that characterizes the efficiency of organizational structures, from the point of view of providing the required level of readiness of combine harvesters to the application, it is advisable to choose a stationary coefficient of readiness $K_г$, characterizing the readiness of combine harvesters to be used in an arbitrary sufficiently remote period of time and defined as the value of the coefficient of readiness defined by the working conditions of combine harvesters, when the average parameter flow of failures and the average duration of the recovery remain constant. Stationary availability factor is a complex indicator of reliability that characterizes simultaneously two different object properties – reliability and maintainability.

It is clear that when using this indicator, the impact of the system recovery determines the average recovery time depends on many factors (comprehensiveness and technological cooldown system, logistics, etc.).

The next task is the selection of the indicators, giving a quantitative estimate on the price achieved or that the value of the stationary coefficient of readiness for the chosen variant of the organization of the recovery system u, $u \in U$.

Under the economic indicators of complex engineering systems understand the indicators of the expenditures for the development, manufacture and operation of products and economic efficiency of its operation.

Abroad, in the practice of the design and operation of combine harvesters found a use method of assessing the effectiveness of the concepts developed according to the indicator life-cycle costs.

Under the life cycle cost of a system refers to a specific type of integral discounted the cost of its development, production and operation.

Under the life cycle (LC) system is the calendar time period covering the stage of research, development and testing stage of production the required number of systems and the operational stage.

The leading foreign construction firms have developed a number of methods for evaluating the lifecycle cost of the ship and engines on the basis of mathematical models, allowing to calculate the values on the electronic computing machines (computers).

So, according to foreign sources known to the analytical model of the lifecycle cost of combine harvesters and engines of combine harvesters, which were used to optimize the tactical and technical parameters of the prospective combine harvesters, as well as operational and technical characteristics of hell to them.

As a rule, the indicator of life cycle cost is used as objective function for optimization of the processes of development, production and operation of combine harvesters on the stage. It is an integrated indicator, giving the opportunity to more fully consider the costs and effects at all stages of the life cycle. Cost analysis of life cycle objects combine harvesters allows to obtain at the early stages of creating the information necessary for the evaluation of the decisions taken at various stages of the life cycle.

Because the harvesters not a manufacturing sector and does not give a positive economic effect resulting from its operation, to evaluate the economic efficiency of functioning of system operation of grain harvesters it is advisable to use only those indicators that reflect the magnitude of different cost elements (material, energy E and labour Tr, F financial, etc.) presented in any form (absolute, relative, specific, reduced), to achieve a certain result.

In the proposed to evaluate the economic efficiency of the process of technical operation of combine harvesters in the parameters of the cost and complexity of IT and R.

Labour intensity $T_{r\,num}^{TO}$ (the ratio of the complexity that is mathematical expectation of the total labor costs for maintenance of combine harvesters for a certain period of operation to mathematical expectation of the developments of combine harvesters during this period:

$$T_{r\;num}^{\;TO}(T)=\frac{M\left[\sum_{i=1}^{N}T_{r\,To\,i}\right]}{M\left[\sum_{i=1}^{I}t_{0i}\right]},$$

where $T_{r_{TOi}}$ the effort required to conduct the i-th,

N – number of works for the period of operation, which is considered

t_{0i} – life object as a part of combine harvesters in the i-th cycle of operation.

Taking into account the above notation, we get:

$$T_{r\;num}^{\;TO}(T)=\frac{M\left[\sum_{j=1}^{J}T_{r\,O.Обс.\,j}+\sum_{k=1}^{K}T_{r\,П.Обс.k}+\sum_{p=1}^{P}T_{r\,Діагн.\,p}+\sum_{f=1}^{F}T_{r\,Зб.\,f}\right]}{M\left[\sum_{i=1}^{I}t_{0i}\right]},$$

where $T_{r\,O.Обс.\,j}$ – period of operation of combine harvesters is considered:

$T_{r\,П.Обс.k}$ – labor for k operational services,

$T_{r\,Діагн.\,p}$ – work on the periodic maintenance, effort required to perform the robot, the diagnostics of combine harvesters,

$T_{r\,Зб.\,f}$ – work on the execution of works on the first save.

The specific complexity of the repairs $T_{r\;num.}^{\;Рем.}$ (the ratio of the complexity of the repairs) is the mathematical expectation of the total labor costs for carrying out all types of repairs of objects of combine harvesters for a certain period of operation to the mathematical expectation of the operating time of the object during the same period:

$$T_{r\;num.}^{\;РЕМ.}(T)=\frac{M\left[\sum_{h=1}^{H}T_{r\,Відн.h}+\sum_{v=1}^{V}T_{r\,Пл.Рем.v}\right]}{M\left[\sum_{i=1}^{I}t_{0i}\right]}$$

where: $T_{r\,Відн.h}$ – the effort at elimination on the h-th failure or refusal,

$T_{r\,Пл.Рем.v}$ – work v-th planned maintenance.

It is obvious that the figures $T_{r\,num}^{TO}$ and $T_{r\,num}^{Рем}$ expressed by the formula value that will correspond to the unit cost of maintenance $C_{num}^{TO}(T)$ and the unit cost of repair of combine harvesters $C_{num}^{Рем}(T)$, respectively.

Integrated assessment process the technical operation of combine harvesters from the point of view of economic efficiency, regardless of the adopted strategy and $C_{num.}^{ПТЕ}$ combine harvesters, use the index of unit costs of process of technical exploitation as the ratio of expected costs of the process of technical maintenance of combine harvesters during the period of operation expressed in value or complexity, the mathematical expectation of the operating time of the object during the same period, and that taking into account the accepted notation takes the form

$$C_{\;num}^{\;ПТЕ}(T)=M\left[\sum_{j=1}^{J}C_{O.Обс.j}+\sum_{k=1}^{K}C_{П.Обс.k}+\sum_{h=1}^{H}C_{Відн.h}+\sum_{v=1}^{V}C_{Пл.Рем.v}+\sum_{z=1}^{Z}C_{Дор.z}+\sum_{p=1}^{P}C_{Діагн.p}+\sum_{w=1}^{W}C_{Трп.w}+\sum_{f=1}^{F}C_{Зб.f}+\sum_{q=1}^{Q}C_{Оч.q}\right]\Bigg/M\left[\sum_{i=1}^{I}t_{0.i}\right].$$

where $C_{O.Обс.j}$ – cost of j operational services,

$C_{П.Обс.k}$ – the cost of k-th periodic maintenance,

$C_{Відн.h}$ – the cost of restoration of h-th failure or refusal,

$C_{Пл.Рем.v}$ – the cost of carrying out the n-th planned maintenance

$C_{Діагн.p}$ – the cost of performing work at the p-th object diagnostics of combine harvesters,

$C_{Дор.z}$ – the cost of performing j-th job,

$C_{Трп.w}$ – the cost w-transportation (delivery) of combine harvesters,

$C_{Зб.f}$ – the cost of the f-saving (idle period in good condition) objects combine harvesters ,

$C_{Оч.q}$ – costs associated with the expectation of combine harvesters of various types and repiar.

As can be seen from the expression rate in contrast $C_{num.}^{ПТЕ}$, C_{num}^{TO} and $C_{num.}^{Рем}$, allows to take into account one indicator of the redistribution of the costs of the process of technical operation (PTO) combine harvesters between operational, periodic types and scheduled, unscheduled repairs with the economic assessment of different strategies and repiar.

But considering the purpose of the study, when determining the cost of recovery of combine harvesters during operation due to the fact that the process of recovery combine harvesters does not affect the regimes and the adoption of the strategy and repiar, cost accounting at operational, periodic, seasonal works, planned repairs and improvements does not make sense. Additionally, if you select one option or the other organizations of the recovery process, more important is the definition of a direct cost recovery system for reaching a specified level of serviceability combine harvesters.

Recovery system for combine harvesters as an integral part of the system of technical maintenance and repair has a significant impact on quantitative and qualitative characteristics of the exchange Fund combine harvesters. Therefore, when determining the cost of recovery of grain harvesters it is necessary to consider the cost of the system to ensure (supply) for the creation, storage, transportation and replenishment of the exchange fund combine harvesters.

Thus the costs for repairing the combine harvester during operation is proposed to determine how the total cost of the recovery system and supply system according to the expression

$$M\left[C_{в\sum}(T)\right] = M\left[C_в(T)\right] + M\left[C_{зб}(T)\right],$$

where: $M\left[C_{в\sum}(T)\right]$ – the average total recovery cost of combine harvesters during the period under review,

$M\left[C_в(T)\right]$ – average cost for the restoration of combine harvesters during the period under review,

$M\left[C_{зб}(T)\right]$ – the average cost of the assurance system in the reporting period.

The cost recovery of complex technical systems, consisting of a large number of blocks, modules, circuit boards or other structurally-replaceable units (the COA), without considering the cost of Troubleshooting the failure of the block in the operating organization, it is advisable to assess by using the expression:

$$M\left[C_в(T)\right] = \sum_{i=1}^{k} C_{б_i} \cdot \left(1 - Q_{в\,i}\right) \cdot M\left[n_i(T)\right],$$

where: $M\left[C_в(T)\right]$ – the mathematical expectation of costs for recovery of combine harvesters during the period under review,

$C_{б_i}$ – the purchase price of the object of combine harvesters (unit, unit, unit) of the i-th type,

$Q_{в\,i}$ – complete reconstruction of the i-th unit in the operating organization,

$M\left[n_i(T)\right]$ – the average number of substitutions of the i-th block (COA) system for the period of operation of

k – the number of types, the user will be restored.

Costs of providing system using the define method, as described by the expression:

$$M\left[C_{зб}(T)\right] = \frac{1}{t_з}\left\{T \cdot C_{зч} \cdot k + M\left[\left(C_{трn}\right)\right] + C_з \cdot \left\{k \cdot T \cdot e^{-N \cdot \lambda \cdot T} + \right.\right.,$$

$$\left.\left. + \sum_{i=1}^{k} \frac{N \cdot \lambda \cdot T}{i!} \cdot e^{-N \cdot \lambda \cdot T} \cdot \left\{(k - i) \cdot T + \sum_{j=1}^{i} M\left[\tau_j\right]\right\}\right\}\right\}$$

where: $M\left[C_{зб}(T)\right]$ – the average cost of the assurance system during the period under review,

$C_{зч}$ – the purchase price, COA,

$M\left[\left(C_{трn}\right)\right]$ – the average cost of the system to ensure transportation of spare parts for the period that is investigated,

$C_з$ – notional value save one CC for one hour,

N – the number of objects of a particular type of operation,

λ – the failure rate of an object combine harvesters,

T – the period of time that is considered,

$t_з$ – interval AF procurement,

$M\left[\tau_j\right]$ – the expected time to the occurrence of the first failure in a finite time interval T,

k – the scope of supply (procurement) during the study time, which is defined as

$$k = \left(M\left[n_i(T)\right] - l\right),$$

where: l – point of order.

Based on the analysis of existing indicators of the effectiveness of complex technical systems and the objectives of the study proposes to assess the influence of the recovery system of combine harvesters on efficiency of their maintenance and repair using the following indicators:

$K_г$ – stationary coefficient of readiness of combine harvesters,

$M\left[C_{в\sum}(T)\right]$ – the average total cost of recovery of combine harvesters during the period under review,

$M\left[n_в(t)\right]$ – the average number of substitutions (recoveries) combine harvesters for a certain period of operation.

Thus, the selected basic indicators of efficiency of functioning of systems of combine harvesters, which fully reflect its impact on the efficiency of the process and R combine harvesters that operated.

Existing approaches to the assessment of technical and economic efficiency of combine harvesters differ in the degree of the given set of objects, which are investigated, and the period of their functioning.

As practice shows techno-economic assessment of complex technical objects define four approaches in which last seen:

1) as a single object,
2) the totality of the Park of the same objects,
3) in a certain operating organization,
4) in the aggregate of organizations operating the same type of objects.

The first and third approaches generally relate to the formulation in statics, i.e. relative to some fixed point in time, the second and fourth approaches involve dynamic methods of solving the problem by evaluating the technical and economic efficiency of technical objects.

The choice of a particular approach is determined by the purpose of the task, which is solved.

In addition, analysis of these approaches shows that the choice of a particular one depends essentially on the completeness and volume of the original information of the monitored process of technical operation of technical objects at the time of the study.

Detailed and complete source of information about the process under study, allows to receive more accurate and complete characterization of the operation of the facility and make the most informed decisions for management of the technical condition of the exploited.

However, in practice, have only a limited amount of input data, usually determined by the stage of the life cycle of the object on which the research is being conducted.

For example, during the development phase of a technical object provides the least amount of information regarding actual operational performance of the new object, while at the stage of mass exploitation on the basis of the results of the statistical evaluation of the functioning of the park of the same objects there is the most complete and reliable information.

In this regard, it is advisable to use different approaches towards techno-economic assessment of the process of technical maintenance of combine harvesters.

From the analysis of literature, devoted to technical-economic estimation of objects of the combine harvesters, the methods currently used to predict the performance of their efficacy at various stages of the life cycle, are divided into three groups.

1. Methods based on the collection of statistical information and evaluation of actual values of indicators of technical and economic efficiency of existing models of technical objects, as well as methods of extrapolation and interpolation based on the use of the principle of analogy to objects that are created. At the core of these methods is the study of the relationship of the key operational and technical characteristics of analogues (prototypes) with indicators of technical and economic efficiency, extrapolation and interpolation of these ties on the parameters of the objects that are investigated.

2. Structural-logical methods and decision trees (methods of examination), are to determine the trends in the indicators of technical and economic efficiency on the basis of expert assessments. This uses the questionnaire survey, the weighted estimates, metric methods, the method of paired evaluations, etc.

3. Methods of mathematical modeling allow to investigate the dynamics of performance indicators in key operational and technical characteristics of combine harvesters, modes and repair, maintenance strategy.

Each of these methods has its advantages and disadvantages, which determine their degree of applicability to predict the performance indicators for different stages of the life cycle combine harvesters.

So to predict the technical and economic indicators at the stages of development and production is most commonly used in domestic and in foreign practice, methods of analogies and expert estimations, while for forecasting the costs of maintenance and repair uses different methods of modeling.

The main disadvantage of the methods of the first group is the necessity of practical implementation of methods and modes, and repair to obtain the statistical data that is associated with the risk of significant material losses.

Structural-logical methods are quite simple to apply, but require a large number of experts to develop appropriate schemes of decision-making that is not always possible.

In addition, these methods have the following disadvantages: subjective views of experts, the inability to assess the adequacy of the decisions taken, the solution of the problem only on a qualitative level, without a quantitative assessment of performance indicators.

Basic research tool of efficiency of processes of technical maintenance in conditions of rapid development of computer technology are the methods of the third group.

Distinguish between analytical, simulation and combined mathematical models.

Simulation models of operating processes based on simulation, usually with the help of computers, accumulation products developments, operations and repair, write-off, the formation of reserves and the like.

Simulation models are largely adequate to the processes that are investigated, but require a much larger volume of information than analytical, the time of preparation of source data and calculation.

Methods of simulation allow relatively easy to quantify the efficiency of the process of maintenance of technical system construction of complex models, and successfully complement analytical methods of solution in the case of the bulkiness of the latter.

But simulation has the following significant drawbacks: the impossibility of obtaining optimal solutions in a compact mathematical form, low visibility, large amounts of computation.

Most fully able to examine the efficiency of the process of operation of complex technical systems (CTS) using analytical models.

Analytical models (in discrete or continuous form) of processes of functioning of CTS that uses the theory of recovery, the theory of random processes, sequential analysis, theory of inventory management, mathematical programming can solve a wide range of tasks that are limited by the difficulties of computational character.

The development of computational techniques has allowed to generate and implement on a computer more complex analytical models of operational processes of CTS, represent a system of integro-differential equations which are reduced to the recurrent differential procedures and are solved by numerical methods.

In the analytical models of the process of functioning of object of the research is presented in the form of certain functional relations or logical conditions.

The most complete study can be carried out while obtaining the explicit dependencies linking activities performance indicators with the parameters that characterize a process of technical operations, and the initial conditions of the study.

The analysis suggests that the most rational approach to evaluation and forecasting of technical and economic efficiency of the process of technical maintenance of combine harvesters in the assessment of the effect of the introduction of hardware-software means of control and diagnostics of its technical condition, the effects of different operational parameters and modes, and repair, alternative recovery strategies marine systems is mathematical modeling of the process that is investigated.

CONCLUSIONS

1. To assess the effectiveness of the process of technical maintenance of combine harvesters have developed and applied a wide range of indicators. Therefore, to implement a comprehensive assessment of the impact of the recovery process dismantled due to the failure of equipment combine harvesters on technical and economic efficiency of the process of technical operation of grain harvesters it is necessary to use a vector performance indicator that includes a number of private utilization, reliability

and economic efficiency with the isolation of the group overall, the most important indicators.

2. Comparative analysis of different methods and approaches showed that the task of estimation and forecasting of technical and economic efficiency of the process of technical operation of modern combine harvesters, taking into account various operational factors, the strategy they then repair must be solved with the use of the concept of mathematical modeling.

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DEPENDENCE OF INDEXES OF EFFICIENCY OF PROCESS OF TECHNICAL EXPLOITATION OF MACHINES FOR FORESTRY WORK FROM CHOSEN VARIANT OF ORGANIZATION OF RECOVERY SYSTEM

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Summary. Proposed indicators to measure the effectiveness of the process of maintenance and repair of machines for forestry work, which is in contrast to the known take into account the indicators of reliability of onboard and ground means of verification, frequency of monitoring, reliability of machines for forestry work and the amount of exchange Fund. The results of the author studies the dependence of values of performance indicators of process of technical exploitation to the organization of the recovery system proves that: the restoration of parts of machines for forestry work under operating conditions gives, respectively, 20% and 35% savings compared to the traditional orientation to the rehabilitation of machines for the forestry works mainly in the system repair plants. For self-propelled machines for forestry work, the gain in (17-3) % (depending on the completeness of the recovery equipment operator) is obtained only if the process of recovery equipment according to the variant in which the fullness of the restoration of the equipment in the conditions of the operator will not be less than 40 %, provided the process of restoration of the equipment certain types of machinery for forestry work on the variant in which the machine takes place mainly in exploitably organizations (as an exception, repair works), total savings over the six years of operation is from 40 to 7 million 816 thousand UAH 11 mln 568 644 thousand UAH, depending on the completeness of the recovery equipment in exploitably organizations.

Study of the effect of the application of automated systems of control of dismantled equipment on the efficiency of the process and R showed that: depending on the variant of the organization of recovery systems of machines for forestry work application of the automated control systems of dismantled equipment allows to obtain in comparison with existing variant of the organization of the recovery process savings within: 10-70 % and 10-40% of machines for forestry work, the use of the automated system of monitoring of dismantled equipment for six years gives a total saving for all types of machinery for forestry operations in 14 million 82 thousand UAH 288 by eliminating false failures reducing the cost of providing the required number of spare blocks and assemblies, ensure the highest possible completeness of recovery, the use of automated control systems reduces the coefficient of readiness of the ship, on average, by 3.2% due to the increase of detected failures, but leads to a reduction of the reinstatement value of the equipment due to the exclusion error (excess return) of personnel on repair that makes it possible to reduce the requirements for professional level engineering staff.

The validity and reliability of results is confirmed by well-posed scientific objectives of the research, using proven mathematical consistency of scientific results and of the calculations performed by the developed technique during the evaluation of efficiency of alternative variants of the organization of the process of recovery of machines for forestry work with data from real operation

The results of the study can be used by operators of machines for forestry works and maintenance to assess solutions for managing the technical condition of machines for forestry work to reduce the costs of restoring the equipment of the forest complex during the life cycle and maintaining the readiness of machines for forestry work application at the specified level.

Promising directions for further research can be: the creation of a methodology for determining the required number of regional bodies repair and their placement depending on the composition and the number of operators of machines for forestry work, determining the impact of the recovery of machines for forestry work in terms of operators on the level of reliability and safety of operation.

Key words: index, process, technical exploitation, machine, forestry work, variant, organization, system.

INTRODUCTION

As you know, the technical condition of machines for forestry work in the course of its operation depends on the quality of the engineering operations of the repair facilities and workshops. Engineering of machines for forestry work is carried out by the exploiter, which organizes and guides the work of all engineering staff of the enterprise. The main task of the operator is to maximize the efficient use of all technical and tactical capabilities of machines for forestry work for the solution of tasks with a high availability of machines to use. The successful solution of this problem depends on how the organizational structure of the service and operation of machines for forestry work correspond to the level of performance properties that have of the operator, and the degree of perfection of the means of its operation. All other factors are of subordinate importance, and also depend on the condition and operational quality and means of its maintenance and repair.

However, in modern conditions the issues related to the provision of health machines for forestry work and, in particular, the question of the elimination of failures that occur during its operation, are among the most complex. The complexity of the task of rebuilding machines for forestry operations is governed by the random nature of the failures on the one hand and the considerable economic cost of providing this element of preparedness on the other.

It is known that one of the ways to improve the readiness of machines for forestry work and the effectiveness of their application is the improvement of the maintenance and repair.

The main requirements to the system of technical maintenance and repair of machines for forestry work outlined modern theory and practice of the use of machinery are: the efficiency of machines to the destination, the readiness of machines for forestry work prior to the application, economy of operation, and the like.

In conditions of limited financing of the forest complex efficiency and cost-effectiveness of the system of technical maintenance and repair of machines for forestry work during the operation is crucial task.

ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

The traditional focus on the restoration of faulty units (blocks, components) mainly in the system of the factory repair was ineffective and does not take into account a number of features of functioning of maintenance and repair in modern conditions [1], such as: loss a strong base of factory repair of machines for forestry work [2], reducing ties with industry, a sharp reduction of financing, a limited set of spare parts in warehouses at a considerable distance from the bodies repair and supply [3], a sharp decline in training of engineering staff, lowering the quality and increase the recovery time of machines for forestry work [4].

This leads to an increase in the cost of operating machinery for forestry work, significant downtime of machines for forestry work in an unhealthy state, the readiness of machines for forestry contractors to perform tasks on the purpose and effectiveness of the operation as a whole [5-11].

For example, according to [12-18] in the faulty condition are about 254 units blocks and engines that need repair on repair enterprises. To restore the model of machines for forestry work need to send about 250 units and units to repair facility. Not the best way things are in other companies [19].

Thus, obvious is the contradiction between the need of ensuring the required level of serviceability of machines for forestry work and capabilities of the existing system and repair that in conditions of limited funding puts the priority issues of improving efficiency and effectiveness of the system of technical maintenance and repair of machines for forestry work in Ukraine.

The effectiveness of the system of technical maintenance and repair (and repair) and the level of security forestry transport largely depend on the measures for control of technical condition of machines for forestry work and work performed in accordance with the results of the examinations, that is, from the efficiency of the subsystem reconstruction of machines for forestry work [20].

In this study, under the subsystem reconstruction of machines for forestry operations (further recovery system) we understand a set of machines for forestry work, their means of control, diagnostics and repair and performers interacting with objects operating in accordance with the adopted strategy and repair.

System restore machinery for forestry contractors, as part of a repair system has a significant impact on quantitative and qualitative characteristics of the Fund's equipment, which in turn affects the condition of the fleet of machines for forestry work [21].

According to the operating machinery for forestry works of Ukraine of equipment failures account for 80% of the total flow of failures and cause up to 40% of the total idle time of machines in a healthy state [22].

On the other hand, foreign experience of operation of machines for forestry work by appointment testifies to the technical capabilities, operational importance and economic efficiency of the recovery equipment of machines for forestry work in operator [19].

OBJECTIVE

To perform analytical calculations of the dependency of indicators of efficiency of process of technical exploitation of machines for forestry work from the chosen variant of the organization of the recovery system

THE MAIN RESULTS OF THE RESEARCH

For the feasibility study of the process of recovery of machines for forestry work was carried out a complex computational studies based on the synthesized method.

The simulation algorithm of the process of technical maintenance and repair that is formalized with the help of regenerative recovery process, was realized in algorithmic language high-level programming in Object Pascal integrated programming environment Delphi 7.0.

Computational studies based on indicators of efficiency of process of technical exploitation to the organization of the recovery system were conducted on the example of technical operation model of the Park of machines for forestry work, as defined under class "A", class "M" and class "R".

To determine the effect of repair of machines for forestry work, dismantled as a result of failure on the efficiency of the process of maintenance and repair. In accordance with the method of the feasibility study of the process of recovery of machines for forestry work in conditions of exploitation were identified following initial data:

- the lifetime that is 6 years (2012-2017),
- average time exploits for the appointment of class "A" for a certain period – 19140 h,
- average time exploits to designate a class "M" for a certain period – 30642 h,
- average time exploits to designate a class "R" for a certain period – 26796 h,
- the frequency of each of the stages of control:
- the monitoring frequency of transitions X1 = 1 h (when execution transitions health monitoring is performed almost continuously, however the results – Troubleshooting, used only after the completion of the transition),

- the frequency of the control when performing the operational types of preparations x2 = 56 h,

- the frequency of the control during the execution of routine maintenance X3 = 720 hours.

The calculations of the values of the performance indicators for the defined options for the organization of the recovery system for different values of: the completeness of the reconstruction ($Q_{вi} = Q_{вi\max}$, $0{,}8 \cdot Q_{вi\max}$, $0{,}6 \cdot Q_{вi\max}$), the coefficient of the exchange fund operator ($k_{оф} = \overline{0{,}1}$) and different values of the proportion of erroneous rejections (k_1=0,5, k_2=0,3, k_3=0).

The study was conducted for the cases of regular use of technological equipment and special means of control of dismantled equipment.

Analysis of the results for A (Fig. 1 - Fig. 4), M (Fig. 4 - Fig. 6), and R (Fig. 7 - Fig. 9), allowed to determine the necessary levels of costs and volumes the exchange Fund for the restoration of onboard equipment for different variants of organization of the system of recovery for a given level of stationary coefficient of readiness, to choose the optimal, in terms of this study, a variant of the organization of the recovery process.

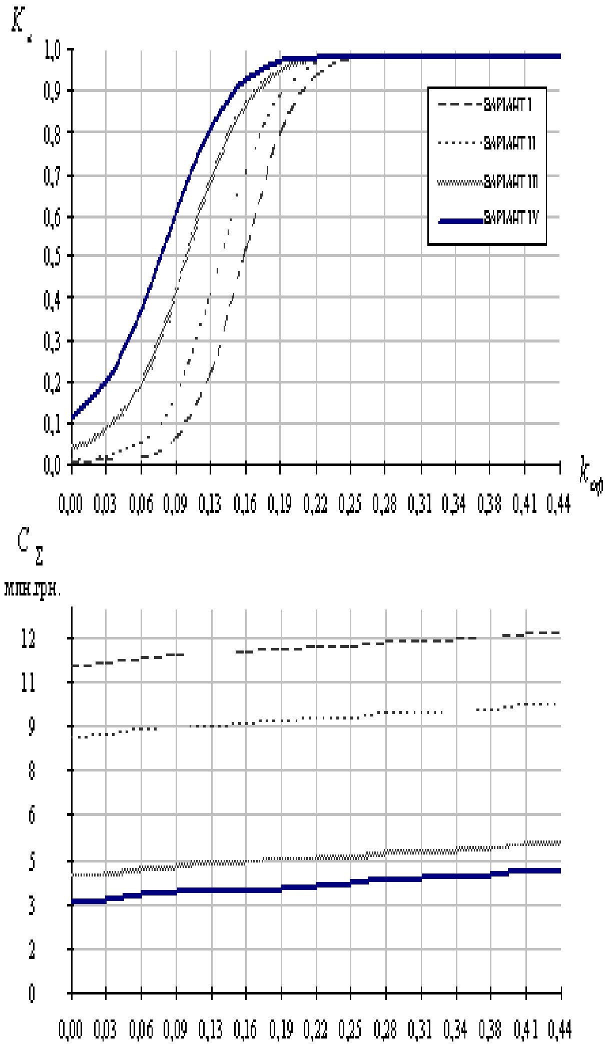

Fig. 1. Relationship between indicators of efficiency of the process and repair A from the coefficient of the exchange fund on-board equipment options for system recovery ($Q_{вi} = Q_{вi\max}$, k =0,3).

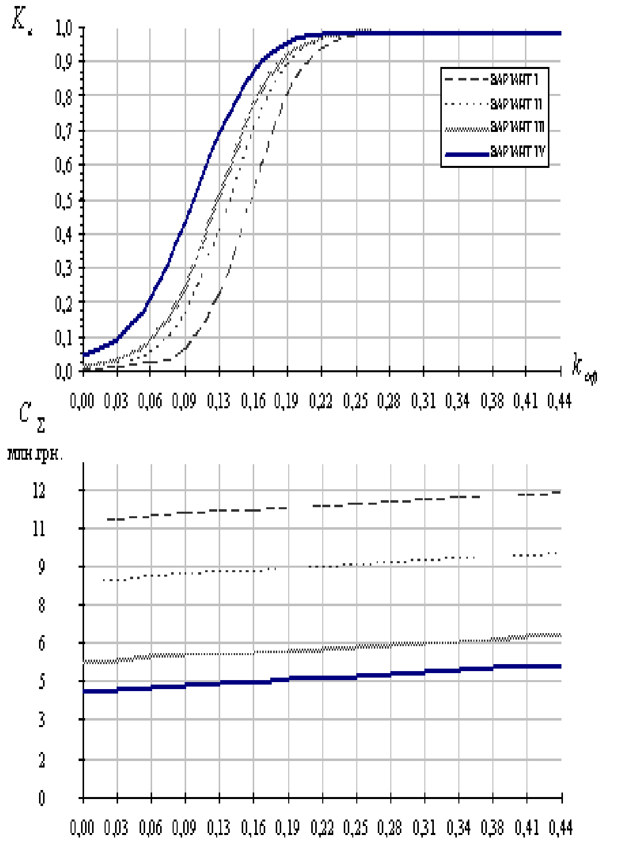

Fig. 2. Relationship between indicators of efficiency of the process and repair A from the coefficient of the exchange fund on-board equipment options for system recovery ($Q_{вi} = 0{,}8 \cdot Q_{вi\max}$, k =0,3).

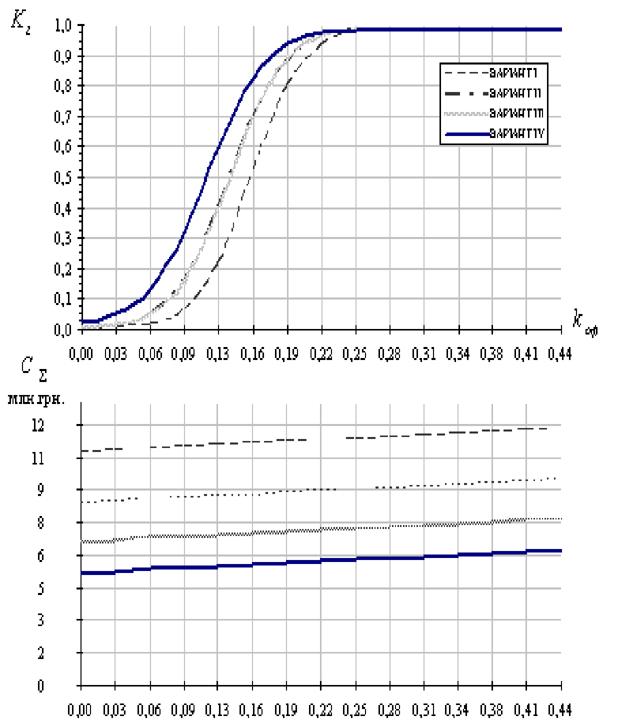

Fig. 3. Relationship between indicators of efficiency of the process and repair A from the coefficient of the exchange fund on-board equipment options for system recovery ($Q_{вi} = 0{,}6 \cdot Q_{вi\max}$, k =0,3).

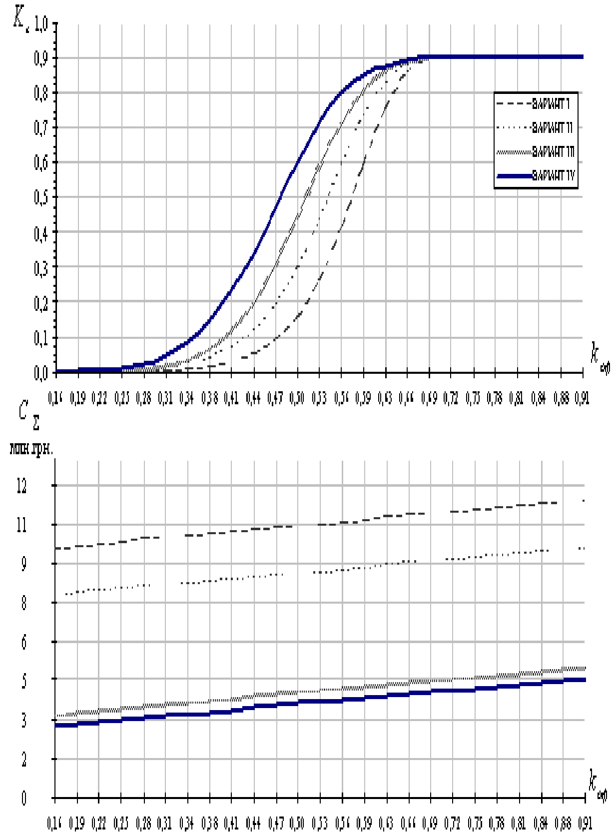

Fig. 4. Relationship between indicators of efficiency of the process and repair M from the coefficient of the exchange fund on-board equipment options for system recovery ($Q_{вi} = Q_{вi\max}$, k =0,3).

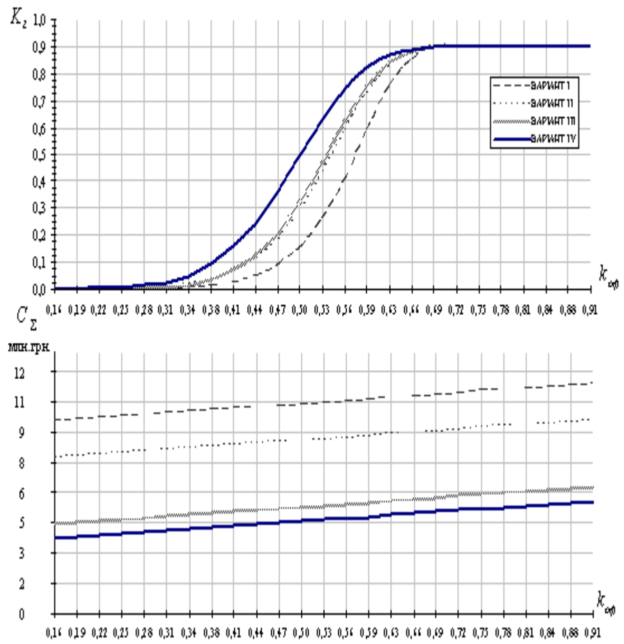

Fig. 5. Relationship between indicators of efficiency of the process and repair M from the coefficient of the exchange fund on-board equipment options for system recovery ($Q_{вi} = 0{,}8 \cdot Q_{вi\max}$, k =0,3).

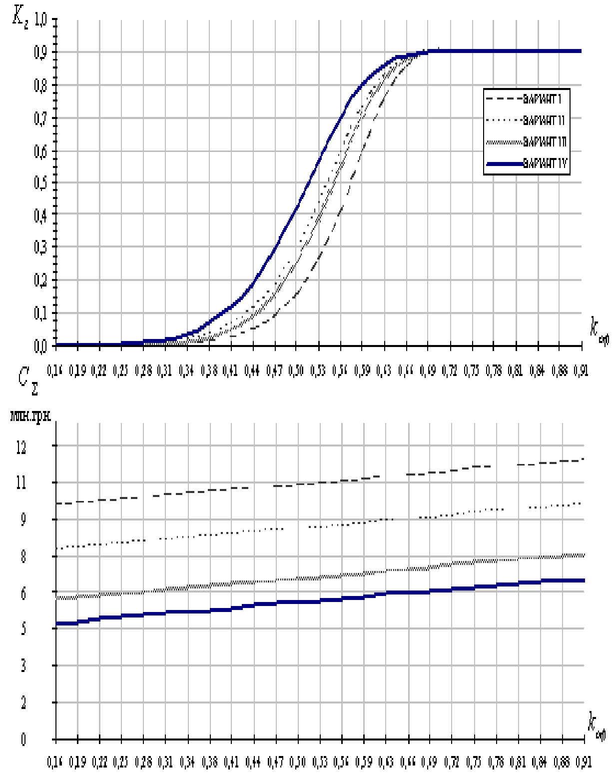

Fig. 6. Relationship between indicators of efficiency of the process and repair R from the coefficient of the exchange fund on-board equipment options for system recovery ($Q_{вi} = 0{,}6 \cdot Q_{вi\max}$, k =0,3).

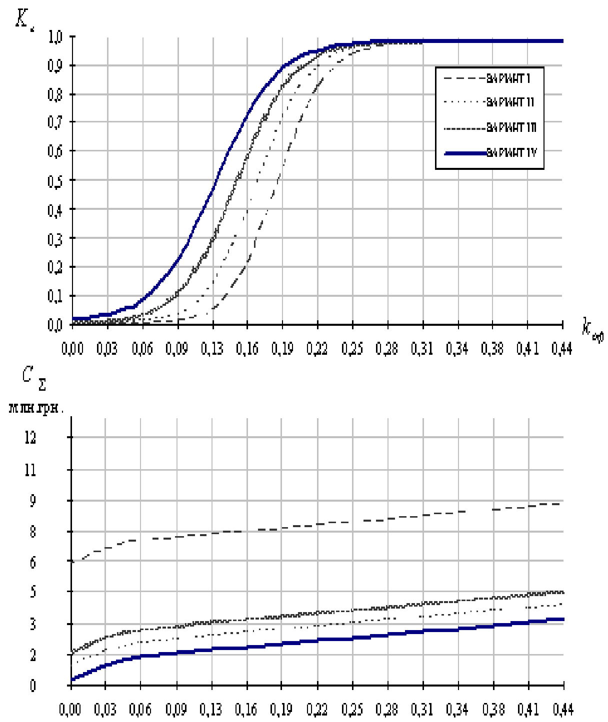

Fig. 7. Relationship between indicators of efficiency of the process and repair R from the coefficient of the exchange fund on-board equipment options for system recovery ($Q_{вi} = Q_{вi\max}$, k =0,3).

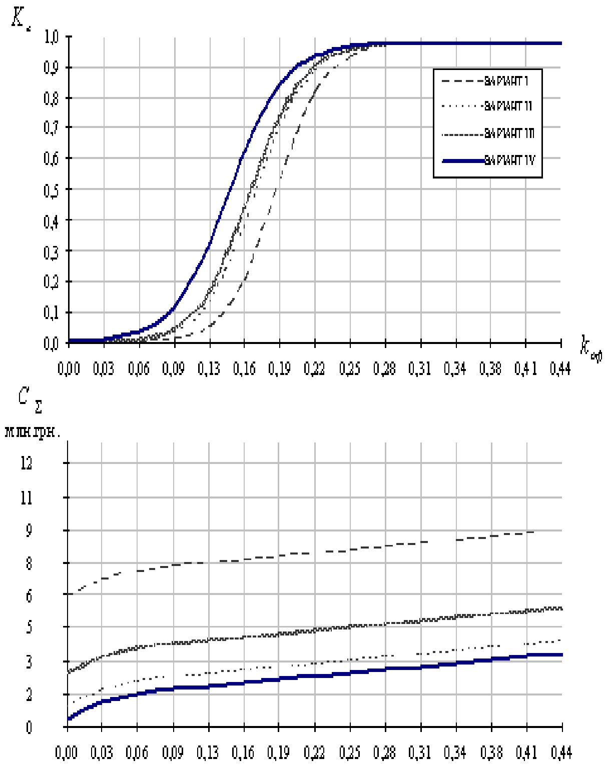

Fig. 8. Relationship between indicators of efficiency of the process and repair R from the coefficient of the exchange fund on-board equipment options for system recovery ($Q_{вi} = 0{,}8 \cdot Q_{вi\max}$, k =0,3).

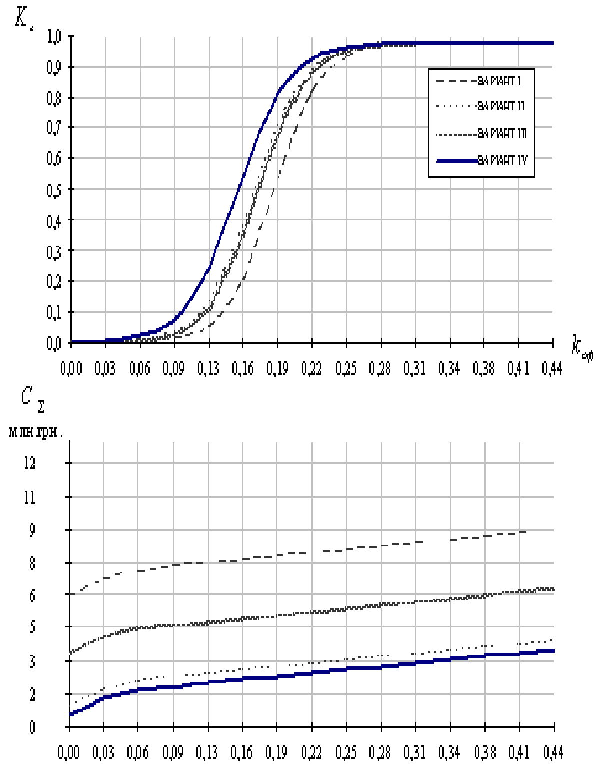

Fig. 9. Relationship between indicators of efficiency of the process and repair M from the coefficient of the exchange fund on-board equipment options for system recovery ($Q_{вi} = 0{,}6 \cdot Q_{вi\max}$, k =0,3).

Table 1

Total cost of the system reconstruction of machines for forestry work on achieving a specified level of availability ratio of 0.8 at different options for the organization of the recovery process

Type	Option	The relative completeness of recovery	Coefficient of exchange fund	Total cost recovery (UAH)	Relative cost recovery	ΔC_{Σ} (UAH)
A	I	-	0,19	11 192 270	1,24	-2 177 927
	II	-	0,17	9 014 343	1,00	0
	III	1	0,15	4 332 759	0,48	4 681 585
		0,8	0,16	5 637 669	0,63	3 376 675
		0,6	0,17	7 039 797	0,78	1 974 546
	IV	1	0,12	3 423 240	0,38	5 591 103
		0,8	0,14	4 448 445	0,49	4 565 898
		0,6	0,15	5 532 492	0,61	3 481 851
M	I	-	0,64	10 766 714	1,21	-1 888 189
	II	-	0,62	8 878 525	1,00	0
	III	1	0,60	4 203 225	0,47	4 675 300
		0,8	0,61	5 560 572	0,63	3 317 953
		0,6	0,62	6 879 050	0,77	1 999 475
	IV	1	0,56	3 718 410	0,42	5 160 115
		0,8	0,58	4 763 854	0,54	4 114 671
		0,6	0,59	5 789 118	0,65	3 089 407
R	I	-	0,22	7 843 673	2,87	-5 110 663
	II	-	0,2	2 733 010	1,00	0
	III	1	0,18	3 290 840	1,20	-557 830
		0,8	0,2	4 264 351	1,56	-1 531 341
		0,6	0,2	5 174 138	1,89	-2 441 128
	IV	1	0,17	1 915 584	0,70	817 426
		0,8	0,18	2 107 421	0,77	625 589
		0,6	0,19	2 263 452	0,83	469 558

Note: When calculating the total costs of repair per unit costs taken for the restoration of dismantled equipment repair works (Option 2).

The obtained results (Table 1) prove that:

1. Given limited exchange fund the most rational is the fourth variant of the organization of the recovery system.

2. For a given level of fixed availability the restoration of the on-board equipment A, M, under operating conditions, i.e. the organization of the recovery process with the third and fourth options ($Q_{вi} = 0{,}6 \cdot Q_{вi\,\max}$) provides, compared to existing (Version II), respectively, 20% and 35% savings. For R, the benefit is obtained only when the process of recovery equipment for the fourth option, and is 17 - 30%, depending on the completeness of recovery equipment of the operator. This is because A is, primarily, machines for forest engineering works, equipment which consists of an old element base, as a result, in the modern period, completeness of recovery of equipment at repair factories and the operator are almost identical. Assuming the difference $Q_{вi} = 0{,}25 \cdot Q_{вi\,\max}$ in cost of recovery equipment for the fourth and second options are equal to zero.

1. Recovery equipment in a fourth embodiment, with an equal number of items in the exchange Fund for each of the options allows you to increase the availability factor Kg on average 40% in comparison with the existing option (option 2) and this advantage is greater, the greater the fullness of the restoration of the COA and the lower the amount of exchange Fund.

2. In case of a restore process of the equipment certain types of machinery for forestry work on the fourth option, the total saving for the six years of operation is from 7 to 40 million 816 thousand UAH to 11 568 million 644 thousand UAH depending on the completeness of recovery of airborne equipment in operating organizations.

Study of the effect of automated systems of control of dismantled equipment on the efficiency of the process of maintenance and repair for selected variants of the organization of the recovery process. To study the effect of automated systems of control of dismantled equipment on the efficiency of the process and repair, were carried out complex numerical studies based on the synthesized method, with certain source data.

In the calculations were taken the following assumptions about the technical characteristics of the automated systems of monitoring and diagnostics of machines for forestry work:

- the probability of failure when performing routine maintenance and checking of the blocks with a suspected failure P = 0,99999,
- the probability of monitoring false information refusal q = 0,
- full control η = 0.95,
- time Troubleshooting – 2 hours,
- the application allows to achieve the maximum possible in the conditions of the completeness of object recovery machines for forestry work.

Based on performance indicators of process and repair from chosen version of process of recovery machines for forest engineering works for case of application of system graphically shown in Fig. 10 – Fig. 4.12.

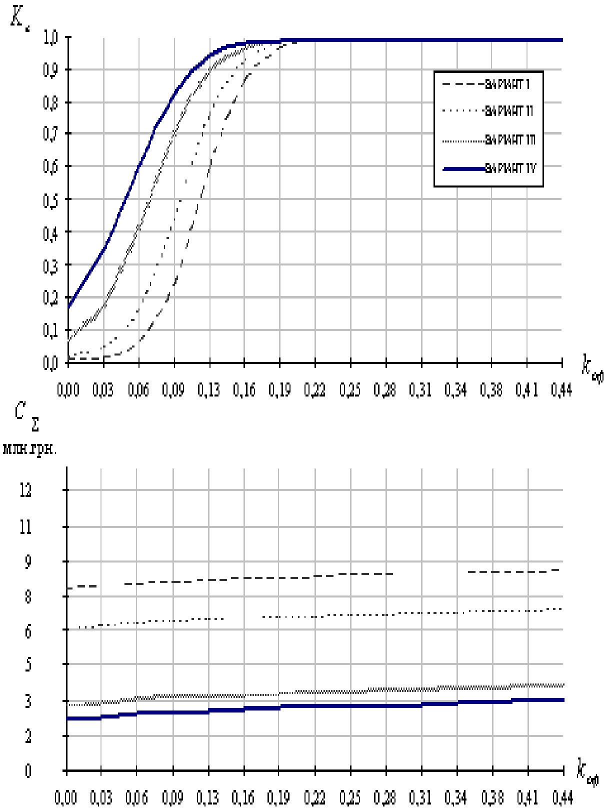

Fig. 10. Dependence of performance indicators of process and repair A from coefficient of exchange fund because of group options for system recovery in case of application of system ($Q_{вi} = Q_{вi\,\max}$, k =0,3).

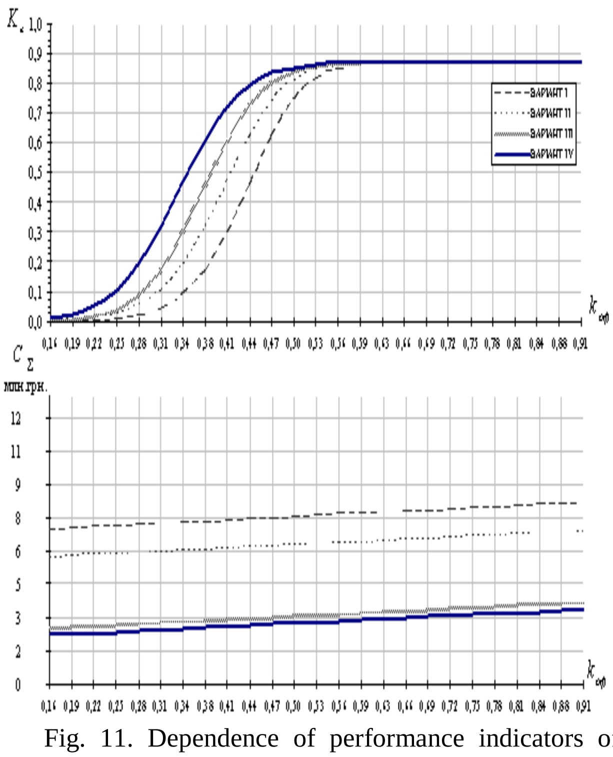

Fig. 11. Dependence of performance indicators of process and repair M from coefficient of exchange fund because of group options for system recovery in case of application of system ($Q_{вi} = Q_{вi\,\max}$, k =0,3).

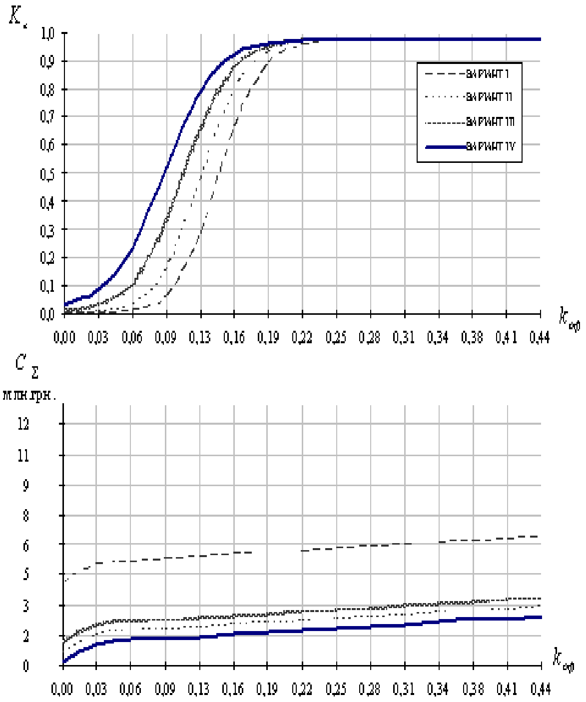

Fig. 12. Dependence of performance indicators of process and repair R from coefficient of exchange fund because of group options for system recovery in case of application of system ($Q_{ві} = Q_{ві\,\max}$, k =0,3).

Comparing the obtained results with the results of research of influence of the process of recovery equipment according to different variants on the efficiency of the process and repair prove that:

1. The application of the system provides in comparison with existing variant of the organization of the recovery process, depending on the variant of the organization of the recovery system of machinery for forestry work (Table 2), savings in the range:

- 10-70% for M and A,
- 10-40% for R.

2. Organization of the system of recovery of the equipment on any of the specific options, subject to the application of the system to achieve the specified level of serviceability of machines for forestry work while reducing the required number of spare blocks and units by nearly 40%.

3. In comparison with the existing ways of organizing the system restore (Table 1, option II), the organization of the recovery system in a fourth embodiment of using the system (Table 2, option IV) gives the total savings for all types of DOG, 14 288 million 82 thousand UAH that is 68% by eliminating false failures, reducing the cost of providing the required number of spare blocks and assemblies, ensure the highest possible completeness of recovery.

Table 2

Total cost of recovery system of machines for forestry work on achieving specified level of availability ratio of 0.8 at different options for organization of restoration process, subject to application system

Type	Option	The relative completeness of recovery	Coefficient of exchange fund	Total cost recovery (UAH)	Relative cost recovery	ΔC_{Σ} (UAH)
A	I	-	0,15	8 127 304	0,90	887 040
	II	-	0,13	6 403 488	0,71	2 610 855
	III	1	0,11	3 121 081	0,35	5 893 263
		0,8	0,12	4 040 726	0,45	4 973 617
		0,6	0,13	5 019 436	0,56	3 994 907
	IV	1	0,09	2 467 676	0,27	6 546 668
		0,8	0,11	3 200 592	0,36	5 813 752
		0,6	0,12	3 968 505	0,44	5 045 839
M	I	-	0,5	7 521 437	0,85	1 357 088
	II	-	0,50	6 205 924	0,70	2 672 601
	III	1	0,5	2 962 301	0,33	5 916 224
		0,8	0,5	3 889 718	0,44	4 988 807
		0,6	0,50	4 800 214	0,54	4 078 311
	IV	1	0,4	2 627 108	0,30	6 251 417
		0,8	0,5	3 355 782	0,38	5 522 743
		0,6	0,5	4 072 605	0,46	4 805 920
R	I	-	0,2	5 593 113	2,05	-2 860 103
	II	-	0,16	2 006 913	0,73	726 097
	III	1	0,2	2 419 687	0,89	313 323
		0,8	0,2	3 081 551	1,13	-348 541
		0,6	0,16	3 717 434	1,36	-984 424
	IV	1	0,1	1 448 806	0,53	1 284 204
		0,8	0,1	1 590 571	0,58	1 142 439
		0,6	0,2	1 701 431	0,62	1 031 579

Note: When calculating the total cost to update the per unit costs taken for the restoration of dismantled equipment repair works with the use of regular means of operational control (Option II, Table 1).

To assess the impact of system performance on the performance indicators of the process and R, were calculated indicators of efficiency in the existing organization of the recovery system for the cases of application of standard controls and systems with the assumption of the absence of erroneous refusals in the total flow of failures (Fig. 13).

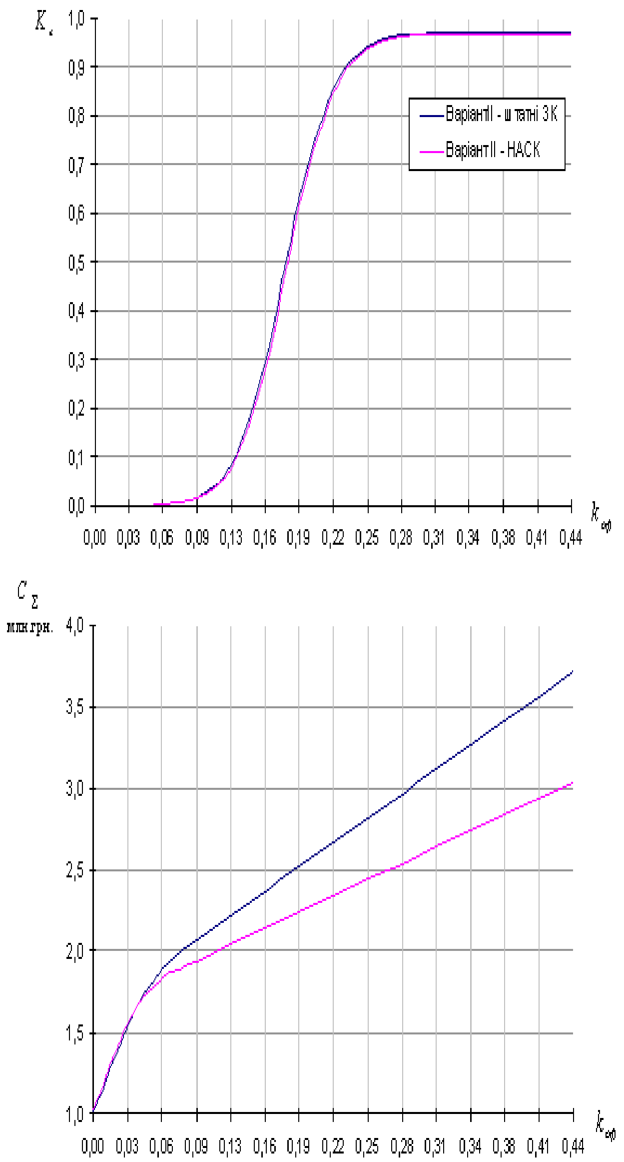

Fig. 13. The dependence of the performance indicators of the process and repair R from the coefficient of the exchange fund equipment and the means used in the operational control ($Q_{ві} = Q_{ві\max}$, k =0)

Studies have shown that the use of automated control systems reduces the availability of machines for forestry work by 3.2% due to the increase of detected failures (regular means – 443 failure, using the system – 456 failure), but leads to a reduction of the reinstatement value of the equipment due to the exclusion error (excess return) of the personnel of repair of the body.

Studies show that the main direction of development and improvement of system repair is to empower operators to restore the faulty units, units, functional units of the systems of machines for forestry work. The reorganization of the repair can be carried out in the following ways:

1. The establishment of a regional database repair (RBR), as the new organizational structure.

2. The establishment of regional groups of repair on the basis of the RTS operators within the existing organizational structure.

Reorganization for the first path provides significant costs of building and equipping such a structure that in modern conditions is almost impossible. In addition, the structure should be able to maintain (restore) the different types of machines for forestry work that requires:

- a high level of professional training of personnel RBR,

- significant amount of funds for monitoring and diagnosing various items of equipment of machines for forestry work, which leads to reduced mobility and flexibility of the system recovery

- the perfect structure support.

More appropriate at the present stage is the second way of reorganization of the recovery system. The establishment of regional groups repair should be based on the principle of recovery of the equipment by its type, that of the operator, whose level of professional training of specialists of the groups, regulation and repair of RTS, allows you to achieve maximum completeness of recovery of dismantled equipment of a particular type. This path requires concentration of a large range of controls and repairs, reduces the requirements to the professional level of the personnel (specialization), simplifies the operation of the system to ensure ZCHM (targeted delivery), but it is logical to assume an increase in transport costs and an increase in need of repair Fund.

But the reorganization of the system of repair according to the variant in which the restoration of equipment occurs primarily in the conditions of the operator shall require completion of a number of conditions such as:

- the development of new operational and repair documentation, which significantly expanded the scope of repairs on the item and fullness recovery units, units of functional systems of machines for forestry work,

- ensuring maintenance on the operator of technological equipment (bench kits, maintenance panels or system in case of equipping each of the upgraded units multiplexed information bus) technical capabilities that, when assessing the technical condition of objects of control in a constructive and optional units allow you to achieve the highest possible completeness of recovery conditions,

- creating a single database of accounting of rapid number-specific changes of technical condition and movement of equipment in operation.

- the establishment of an operational system to ensure spare parts and materials based on actual needs in accordance with the new repair.

The analysis of the existing and future means of control of technical condition of machines for forestry work and evaluation of application systems allow to formulate the following requirements for the automated systems of monitoring of dismantled equipment.

Procedure of health monitoring and failure with the removed blocks should be performed by the system in accordance with algorithms that are issued by developers of equipment for all tasks. The system should be elected (to be developed) based on the following feasibility criteria:

- full control within the unit (block) η should be not less than 0.9,
- depth of diagnostic control should ensure that the search space of module failure (circuit board),
- the inspection and search of a place of refusal should be reduced by at least 5-10 times compared to existing control systems,
- the number and cost of spare parts to exchange and repair the funds of the operator by reducing recovery time defective the COA must be reduced by at least 1.5-2 times compared to existing control systems,
- total costs for testing, repair, and regulation of defective systems, units and blocks of equipment should be reduced by at least 30-40% compared to existing control systems,
- the reduction in the number of highly qualified specialists by automating the process of finding a place of failure and documenting the results of monitoring and diagnosing.

However, the introduction of such a system in the process of technical operation of machines for forestry work is advantageously carried out simultaneously with their upgrading provided that during the modernization of machines for forestry work will be provided with the right level of harmonization of the same type of equipment and systems of machines for forestry work, the control connectors of stimulating signals, methods of control of the same equipment.

CONCLUSIONS

1. The use of synthetic in the section justification of the method of organization of the recovery of machines for forestry work under operating conditions allows to choose the most effective variant of restoration of the complex technical objects. To determine the costs of the recovery system in the absolute values of cost for a certain period of operation. In addition, the use of the method allows a high degree of reliability to carry out the calculations of the quantity of changes (restores) the object of the equipment in the process and P for different recovery strategies.

2. The synthesized method can be used as a tool to analyses the performance of the repair system and evaluating the effectiveness of solutions for managing the technical condition of the objects of machines for forestry work on the stages of their development, modernization and operation.

3. Using the synthesized method are investigated the questions of dependence of the performance characteristics of the process and repair (stationary availability factor and average total costs of repair of machines for forestry work over a period) from operating conditions, among which are considered: embodiments of the restore process, characteristics of reliability and maintainability model of machines for forestry work held by operators, funds operational control.

4. Analysis of the results shows the following: the most effective repair option from the point of view of costs and level of readiness of machines for forestry work application is option IV, which provides for the restoration of dismantled equipment mainly in the operator considering the real completeness of recovery.

5. The use of automated control systems type of system to restore the dismantled equipment and inspection machines for forestry work with a suspected failure reduces costs by 17-20%, which gives the opportunity to recoup the cost of purchase of automated controls over 5-6 years depending on the intensity of use of machines for forestry work.

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METHODS OF ASSESSMENT OF ADAPTATIONS TRANSPORT TECHNOLOGY FOR TRANSPORTATION OF GRAIN HARVEST TO OPERATING CONDITIONS VEHICLES

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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

Since 2013, implemented the priority national project of the State program of development of agriculture and regulation of markets of agricultural products, raw materials and food for 2013-2020, covering the entire range of directions of development of agriculture, the food supply of the country and sustainable development of rural areas.

According to the Program of manufacture of agricultural products by 2020 (in comparable prices) should increase in relation to 2012 of 24.8 percent, food products – by 32.5 percent. The increase of production in agricultural organizations, peasant (farmer) farms, including individual entrepreneurs, potatoes up to 6 million tons, vegetables – up to 5.2 million tonnes of greenhouse vegetables up to 1.4 million tons.

The growth of agricultural production requires new approaches to solving transport problems of the agroindustrial complex, contributing to a radical improvement of transport service industries.

The leading place in the transport subcomplex is road transport. Relevance is determined not only by the overwhelming volume of traffic and turnover, but also direct participation in the implementation of production processes of agricultural enterprises.

ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

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 [1-3]. 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 [4-8]. Wide range of transported goods at low partinost 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 [9-14].

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 [15]. 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 [16-19].

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 agroindustrial complex leave much to be desired [20].

Full disclosure of potential opportunities of the transport subcomplex today is the actual national economic problem. The primary task consists in sharp increase of efficiency of use of cargo fleet for agricultural production. A radical solution to the problem of efficient use of trucks agroindustrial complex is organically related to the improvement of the structure of the vehicle fleet of agricultural enterprises. Formation of car parks should take into account the specific characteristics of agricultural production, technology of transport processes, and unique design of the cars, defining their technological adaptation to make full use of their operational parameters under these conditions. Formed on this basis, vehicle parks shall conform to the requirements of the conditions of production of agricultural enterprises as a whole at some individual elements (the cars) [21].

Addressing these issues will improve the efficiency of the vehicle fleet agroindustrial complex by fully realize the potential of each vehicle, as well as the entire park will increase the possibility of winning the peak traffic volumes with fewer vehicles, reducing the need in borrowed cars. This will entail a reduction in the share of transport expenses in the cost of production of agricultural products and will result in significant savings [22].

Due to the fact that the theoretical and methodological issues related to the study of this problem, is not fully developed, the need for such research, and creation on their basis of methods of formation of Park of agricultural enterprises determined the choice of study subjects.

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

In connection with the intensive saturation of the vehicle fleet of agroindustrial complex of the trucks there was a problem of their effective use.

One of the most effective ways to enhance the efficiency of road transport of agroindustrial complex is to increase the fitness of the car and parks in which they work, the conditions in the processing complexes.

Efficiency of rolling stock largely depends on the parameters and design features of the vehicles for each specific type of transportation, ie a specific set or combination of factors operating.

Only under full compliance with the design parameters of vehicles-specific conditions to ensure minimal cost of transportation, and the lowest labor costs on their performance, economical consumption of fuel and other materials, the highest safety of transported goods, safety and harmlessness for the environment.

This explains the need to examine the level of compliance of vehicles conditions of use.

With the development of the economy before the science there was a need to identify the needs of national economy in different types of cars, the most efficient for all modes of transportation. This was the first study to ensure that the car Park of the country throughout the structure appropriate for the desired.

Developed type was a systematic group of the basic types of vehicles needed for the national economy and dedicated to automotive industry. The development and implementation of a type allowed to solve two problems. On the one hand, the systematization and the reduction of the base models increases the adjusted type to the production, since very limited number of varieties of cars were created conditions for increasing their production. On the other hand, the type of operation allowed us to have a uniformity and commonality in the formed car Park, and this, in turn, creates favorable conditions for the supply of spare parts and materials, maintenance and repair, transportation.

The type of car contributed to improving the fitness of the vehicle fleet of the country to the economy, for which it was designed.

With the development of the Soviet economy requirements for the type of change. So periodically, he was considered and updated in accordance with technological progress in the automotive industry.

Studies conducted to determine conformity of the vehicle Park the volume of traffic of the economy, showed that its structure lacks the heavy-duty vehicles, the most cost effective mode of transport of mass and krupnoplodnyh goods. However, the increase in the carrying capacity of vehicles was limited to road conditions – the strength of roads, bridges and other road structures.

In ICAT conducted a comprehensive study of the state of the road network and prospects of its development, the distribution of freight traffic on the road network, trends of scientific-technical progress in the automotive industry.

On the basis of this study was determined the expediency of increasing the carrying capacity of rolling stock for mass transport of goods, by increasing the number of reference axes. Practically it was solved by application of three-axle vehicles and the use of trailers and semitrailers.

Promising type, approved for the period, was augmented by the new families of three-axle heavy vehicles: group B, intended for use on all roads and A – roads with capital types of coatings.

To improve the adaptation of vehicles to work in the trains there is a need to have in the fleet cars-trucks characterized by high engine power corresponding to the total mass of the road train. This helps to reduce the engine power a single car that gave the reduced demand for the metal used in vehicle production and fuel savings during operation.

In order to improve compliance with the planned production of cars for the needs of transportation has introduced a system of State acceptance test each new basic model. Subsequently, these tests were replaced by the interdepartmental.

At the present stage of development of country's transportation problem is the full utilization of the rolling stock in different conditions has great urgency.

Notes that in the study of conformity of the vehicle operating conditions, a new research direction that explores his fitness. While referring to research conducted in Tyumen Polytechnic Institute, adaptability (adaptability) vehicles in the North. He developed the scientific basis of this property, affecting mainly the scope of technical operation.

In the field of car Park formation of agricultural enterprises, this issue has almost not been considered, because science, first and foremost, sought to provide recommendations to the transport, where the conditions of transport of goods, with a small approximation can be attributed to the permanent.

In this regard, it is appropriate to cite the statement in this regard: "it Should be emphasized that if conditions or permanent due to small fluctuations can be considered constant, then the consideration of the properties of adaptability has no relevance. This can, in particular, to explain the later development of scientific foundations of fitness and insufficient development of problems of influence of various operating conditions on the efficiency of car use".

The problem of full use of the rolling stock sharper expressed in agriculture. Having a great transport potential, agriculture uses it much worse.

Therefore, efforts should be aimed at the study of the properties of adaptation of vehicles, primarily as applied to agriculture.

In this respect, some acceptable theoretical propositions from the works of authors that can be used to develop quantitative indicators and mathematical models to estimate the properties of adaptation of vehicles on one or more factors operating conditions.

As one of the indicators for measuring adaptability in work the coefficient of adaptation, which shows how many times the value of the efficiency index $У$ in these conditions differs from its nominal value $У_н$:

$$K_a = У/У_н. \qquad (1)$$

The best adaptation is achieved when $K_a = 1$. This means that the vehicle according to its technical and operational parameters fully complies with the conditions. Therefore, the efficiency of its operation is equal to the nominal inherent in the design of the car, i.e. full fitness. When the values of $K_a < 1$ car worse suited to the environment in which it operates, therefore its potential is not fully used.

Other quantitative indicators of fitness, mainly used in mathematical models are the sensitivity S and the parameter adaptation. Overall, they both characterize the intensity changes of the indicator, but have completely different limits changes.

At full fitness for a specific factor setting suitability equal to one, which in process of deterioration is reduced to zero. Complete suitability indicates a zero response of output to change of input factor. Changes in the parameters of adaptability and sensitivity are within:

$$1 \geq a > 0, \qquad 0 \leq S < \infty.$$

The connection between them are the equations:

$$a = e^{-S}, \quad S = -lna.$$

Figure 1.1 shows the geometric meaning of the parameters of fitness. On the charts they represent the slope and curvature of the lines characterizing the change of rate at change of factor x.

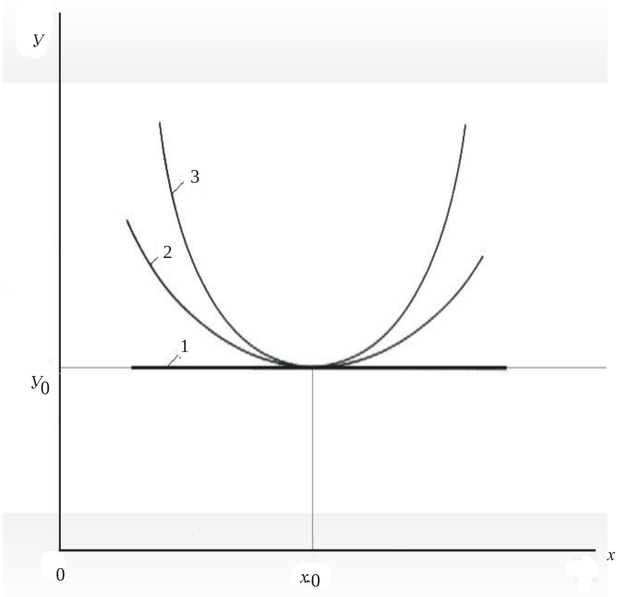

Fig. 1. Geometric interpretation of the parameters of fitness.

For example, if the output parameter to consider the fuel consumption of a vehicle depending on the air temperature, the curvature of the lines 2 and 3 will show different adaptation $a_2 < a_3$, $S_2 < S_3$, which indicates a better adaptation of the second car. There are cases where the output rate independent of changes in x (line 1). Thus $a_1 = 1$ and $S_1 = 0$, which means complete suitability for the factor x.

$$a_1 = 1, S_1 = 0, a_2 > a_3, S_2 < S_3.$$

Questions of fitness of a car to the transported goods is considered in offers to evaluate this property using the adoption rate, expressed as a percentage:

$$K_j = (1 - n_i / N)100,$$

where: n_i – the number of i's cargo that fit this body type,

N – the total number of goods transported in road transport.

In addition, the adaptability of the body is characterized by the increased work load as the volume of a body and its area.

The ratio of cargo capacity by volume of the body is determined by the formula:

$$\gamma qv = \rho_V / q\ V_K\ \eta v,$$

where: ρ_V – the average density of load, t/m^3,

q – capacity of vehicle, t,

V_K – volume of the body (internal), m^3,

η_V – the coefficient of utilization of volume of the body,
and the load rating at the area of the body:

$$\gamma qs = \rho_S / q\, S_K\, \eta_S,$$

where: ρ_S – the surface density of cargo, in t/m^2,

S_K – the area of the body, m^2,

η_S – the coefficient of space utilization of the body.

The author also developed a system for evaluating the boundary conditions using parameters of the body when you change the bulk density of the cargo (Fig. 2). In this proposed threshold coefficients adaptation: capacity – A_q, the amount of body – A_V.

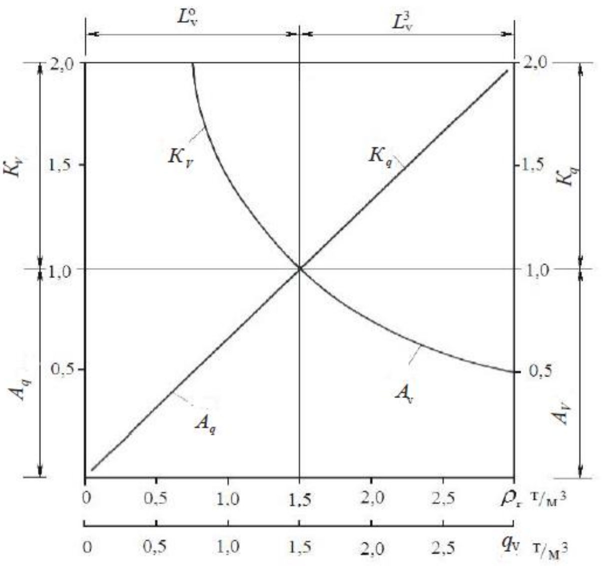

Fig. 2. Threshold coefficients adaptation of the car body when the specific capacity q_v = 1,5 t/m^3.

A function of the threshold coefficient of fitness of the vehicles with the full use of the geometric volume of a body is described as:

$$A_q = \begin{cases} 0 \ in\ \rho_{vx} < \rho_{vmin} \\ \rho_{vx}/\rho_v \ in\ \rho_{vmin} < \rho_{vx}, \\ 1 \ in\ \rho_{vx} = \rho_v \end{cases} \qquad (1)$$

where: q_v – the specific volumetric capacity, t/m^3.

A function of the threshold ratio by volume in the form:

$$A_q = \begin{cases} \rho_v/\rho_x \ in\ \rho_{vx} \neq \rho_v \\ 1 \ in\ \rho_{vx} = \rho_v \end{cases}, \qquad (2)$$

The functions (1) and (2) show that for goods with a density of 1,5 t/m^3 (see Fig. 2) comes complete suitability as payloads, and volume of the body. When the deviation of density from this value more or less than the full "adaptation" is broken and in order to restore it, you must either increase the capacity or volume of a body.

This assessment of fitness of a car is very important in the transport of agricultural goods as the terms and conditions characterized by a significant range of goods, different in their properties, including volume and mass, forced to take such measures, allowing to choose the most efficient rolling stock.

However, many of the questions on the evaluation of the properties of the fitness of vehicles with regard to specific features of agricultural production response in the works there.

Considering the above in the previous sections of this Chapter, a more detailed development of this issue by the factor bulk density of the cargo, and the factor of the annual employment of the cars in production. In addition, we need the integral criterion of adaptation of a car by several factors operating conditions. The final stage of these developments needs to be a practical outlet with the formulation of specific recommendations for improving the efficiency of use of car and vehicle parks to the conditions of production of agricultural enterprises.

Based on the study of the properties of the fitness of vehicles is important to the development of technical and operational requirements for vehicles for agricultural purposes.

In the end of this Chapter, the following should be noted.

Analysis of the current state in the field of transport support of the agricultural complex have shown that agriculture has the country's largest car Park, despite a significant reduction in the years of perestroika. Today he improved and quality. The last time he was filled with the cars of new models with better properties. Not only improved the organizational forms and methods of formation of the vehicle fleet. However, the level of transport service industry is not improving. Moreover, the intensity of car use from year to year, although slowly, declining. Deteriorate such indicators as output per payroll autotone, the utilization of the Park, the cost of 1 tkm. The share of transport expenses in the cost of agricultural products remains high.

There are several reasons, hitherto not taken into account in the formation and operation of the vehicle fleet in the specific conditions of agricultural production.

Rolling car Park of agro-industrial complex in the majority does not comply with the conditions of carriage of agricultural goods. Of the commercially available type of trucks most under these conditions have the trucks, mostly 3rd and 4th group, which is the reason for the rapid growth of their share in the General Park APK. However, the problem of intensification of transport of the country they do not solve. Radically change the situation in the transport service APK could cars with interchangeable bodies in view of their better adaptation to rapidly changing conditions of production of collective and state farms. This is confirmed by the positive results of the tests in the farms of these types of vehicles, but in mass production, they are not yet available.

Increasing supply in the industry of heavy vehicles increase the potential of vehicle fleet farms, however, without ensuring of appropriate conditions to use them effectively is difficult. First, the use of such vehicles should be combined with high-performance material handling-handling equipment and agricultural machinery, which in most cases in the agricultural enterprises could not be applied. This leads to a sharp decrease in the intensity of use of heavy vehicles with the deterioration of all related indicators. This situation is typical of many farms in the country.

However, there is experience of effective use of agricultural trucks of the type, but today there are no criteria to determine in which cases the use of such vehicles in the farms is justified.

The widespread use of trailers for transportation of agricultural loads could significantly increase the intensity of car use, however, is constrained by their small supply in the industry, and the paucity of character trailers intended for the transport of agricultural goods.

These causes have a significant impact on the fitness of the vehicle fleet to perform the traffic APK. The presence of such features known in the science and scientists being developed, but currently this property is not taken into account either when designing a vehicle or during operation.

There is no scientific methods of increasing and assessing suitability of rolling stock to the traffic conditions. Car parks agricultural enterprises formed without taking into account this property, which is inherent not only individual cars, but the Park in General. As a result, the existing motor transport division of agriculture have a low tolerance to local conditions, which determine the low rates of use of the car Park industry.

Effective use of the transport machines in agricultural production depends on their specific qualities required for industry conditions. The quality of transport cars as technical designs intended for the movement of goods is a combination of certain properties, describing their compliance with the requirements of use: capacity, capacity, throughput, reliability, cost, efficiency etc.

The properties of the machines is their objective peculiarity, which are laid in their design and show itself when it starts to operate. The essence of these properties is a combination of parameters representing a specific characteristic of the individual brand machines.

A variety of conditions led to the specialization of vehicles, providing the greatest efficiency for their use in specific conditions. In this case, the design of transport machine sets the set of properties which it must possess in order best to fulfil its industrial purpose.

The specific properties of the transport cars provide the opportunity to exploit it when shipping, when a combination of factors conditions do not allow to effectively use the other.

The car has numerous properties as well as structurally, is a uniquely complex machine. These properties can be combined according to certain criteria. Most of them are performance properties. They are work vehicles depends on the conditions in which they occur.

The factors of the terms of use define the specific properties of the vehicles – adaptation. It is important to emphasize that the property of adaptation is revealed only under operating conditions.

As noted, because of the particular specificity of production and transportation conditions in agriculture should be considered as technological.

Operational properties of the vehicles, which characterize the adaptation of vehicles to the conditions of agricultural production and processing properties.

As you know, factors operating conditions can be stable or changing during the time period.

Constant operating conditions for which designed vehicle adaptation properties are not detected and output its values are in nominal values. This indicates full adaptation of vehicles. However, if the deviation of any factor from the standard output indicators are reduced.

The extent of these changes vary for vehicles of different makes and models, which is a manifestation of a different kind and level of adaptability. This is evidenced by the operating experience and carried out by many authors.

The property of adaptation (adaptation) of the conditions of agricultural production today becomes the main priority in order to improve the efficiency of the transport machinery (Fig. 3). Possessing a certain quality of the car has a set of properties S1, S2,... Sn, which are a collection of parameters {p1}, {p2},...{pn}. These properties, interacting with constant X1, X2,... Xn and a time-varying X1(t) X2(t),... Xn(t) factors of operating conditions, reveal the suitability of the vehicle to these conditions. And the adaptability is expressed as a function of properties of the vehicle and factors in terms of both permanent and changing.

$$Q = \mathrm{f}[\mathrm{S, X, X(t)}]. \quad (3)$$

In turn, the efficiency of use in agriculture is largely dependent on the production conditions of the industry, i.e. is a function of the adjustment:

$$E = F(Q).$$

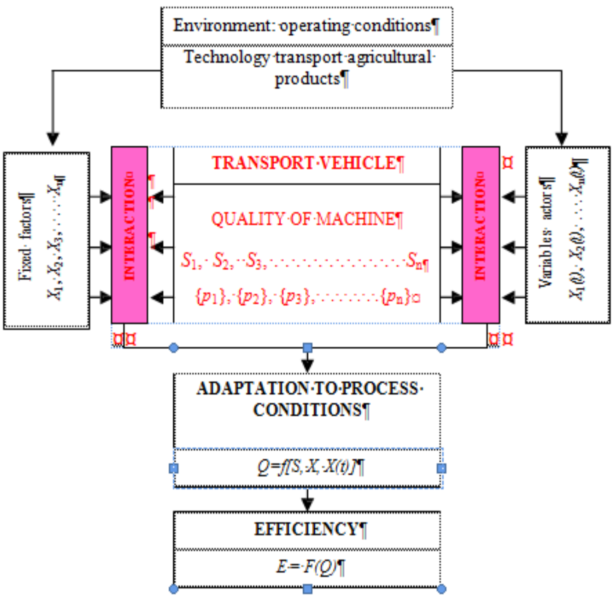

Fig. 3. Formation of efficiency of use of transport vehicles with regard to their adaptation to technological conditions of carriage.

The property of adaptability is inherent not only to transport the car as a whole and its units and even individual parts. Therefore, this operational property should be considered systematically.

This means that all the specific studies aimed at improving the parameters and properties of vehicles, you need to consider eventually as to increase their adaptability to the transportation of goods under certain conditions with the lowest cost.

The concept of the system approach involves comprehensive and broad coverage in all research of significant factors of operating conditions in close connection with elements of the system.

The concept of the system and its elements is relative. Thus, the system can act as an element of some larger system. For example, a car is a system of units and at the same time element of the respective car park.

A systematic approach does not allow the adoption of local solutions, i.e. on the basis of insufficient number of factors. Such solutions are usually inefficient and in practice do not give proper results. The interaction of the system components among themselves leads to the appearance of synergistic (systemic) effects. Notes that effect the system as a whole may not coincide with the sum of its separate elements, this is the effect of integrity of complex systems. For example, the suitability of a car Park to the operating conditions depend on the fitness of each individual car, but not equal to their sum.

The variable character of the conditions of operation of vehicles in agriculture and a wider range of change factors compared to other industries require more accurate disclosure of the meanings of the terms adaptability and adaptivity.

According to the author, the term fitness is more suitable for solving this features in relation to specific, constant or changing in a small limited range of operating conditions. The authors in their work have used the term adaptability of the vehicle.

The solution to the problem of fitness of transport vehicles agricultural enterprises, as well as the actual cars, which are their elements, it becomes one of the main directions of increase of efficiency of use of the parks.

The essence of this problem consists in ensuring the efficiency of transportation of agricultural goods by improving the level of adaptation of transport vehicles and parks in which they work, the conditions of carriage. To solve the adaptability as the most important property of the vehicle must be fully studied and in the transportation aspect. It is necessary to control the suitability of car parks at their formation based on the changing factors of operating conditions of agricultural enterprises.

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.

4. In agriculture technological indicator of the bulk cargo from minimum to maximum changes 30 times. Therefore, this factor in the industry should be considered as variables. Operation in agricultural production is most often considered for the annual period, due to which this factor has a significant impact on the final performance of the transport.

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SYNTHESIS TECHNICAL SUPPORT FOR EARLY DIAGNOSIS OF INTERNAL DISEASES OF CATTLE

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Summary. In this work, based on the analysis of existing methodological approaches the analysis of the patent-conjuncture, analytical and experimental basis of foreign and domestic experience in systems technical support for early diagnosis of internal diseases of cattle. The authors have determined the analytical preconditions of formation of system of technical providing early diagnosis of internal diseases of cattle. In a experimental background for the formation of systems of technical support for early diagnosis of internal diseases of cattle. Also defined mehanotron properties of the main methods of organization of communication in the engineering systems of early diagnostics of the internal diseases of cattle.

This project uses a synergistic approach, according to which any interaction of natural systems leads to exchange between matter, energy and information. While one of the systems (early diagnostics of the internal diseases of cattle) is the emitter, the other (technical mechatronic system) – battery. The sudden discharge of the first synergy of the two systems, the other system can accumulate surplus synergy with the simultaneous sudden strengthening of the dynamics of internal processes that leads to the structuring of the system and dissipation. In this self-organization leads to changes in the transmission mechanism of synergy to mechatronic system for the more intense condition.

Object of research – the structure and mechanical properties of technical support for early diagnosis of internal diseases of cattle.

Subject of research – analytical regularities of changes of structure and properties of mechatronic technical support for early diagnosis of internal diseases of cattle.

The aim of the research is to improve the adequacy of the analytical description of the structure of an adaptive system, which will include itself system technical support, system management, the environment and the system of early diagnostics of the internal diseases of cattle.

Research methods – theoretical and experimental methods of analogies and clarifications, synergetic theory at the acceptable value and regularities of parameter changes, time studies, statistical analysis, experiment planning.

It should be noted that dictionaries and encyclopedias are still identify and diagnosis the term "diagnosis" is often a medical kind of recognition, meanwhile, this kind of knowledge is distributed in different areas of scientific and practical activities of man.

Diagnosis, like scientific component as a field of scientific practice is socially determined, changing in the course of historical development of society. Its modern development in the XXI century is in the direction of empowering faster and more accurate closer to the goal, recognition of the causes of deviations from norms of a technical object. In turn, the development of diagnostics is characterized by the irregularity of the variability of its individual parties, as well as influence each other different characteristics or parameters of the controlled objects from the standpoint of information content, and often even from the standpoint of redundancy information flow. This applies to all levels and sections-theoretic adaptive systems synthesis technical support for early diagnosis of internal diseases of cattle.

Key words: synthesis, technic, support, early diagnosis, internal diseases of cattle.

INTRODUCTION

The term "diagnosis" is of Greek origin (diagnostikos), consisting of the words dia (between, apart, after, through) and gnosis (knowledge). Thus, the word diagnostikos can be interpreted as the ability to recognize.

In the ancient world diagnostics refers to people who, after fighting on the battlefield counted the number of dead and wounded. In the Renaissance, the diagnosis is already a medical term, meaning the detection of the disease. In the nineteenth and twentieth centuries, this concept has become widely used in philosophy and then in psychology, medicine, engineering and other industries. In a General sense, diagnosis is a special kind of knowledge between scientific knowledge entity and knowledge of any single phenomenon. The result of such cognition – diagnosis, i.e. the conclusion about belonging of the entity expressed in the individual event, to a specific set of science classes.

In turn, examination of the teachings about the methods and principles of recognition of diseases and symptoms that characterize certain diseases. In the broadest sense of the word recognition process is used in all branches of science and technology, is one of the elements of knowledge of matter, i.e. allows to determine the nature of phenomena, substances, materials and specific items. From a philosophical and logical points of view, the term "diagnosis" is legitimate can be used in any fields of science. So the technical diagnostics is the science of recognizing (attributing to one of possible classes) the condition of a technical system. When the diagnosis object is set by matching of knowledge accumulated by science about the group classes of the corresponding objects.

Let's introduce another term – "individuality". Individuality is the uniqueness of the object, its identity, equality with itself. In nature, there can be no two are identical objects. The individuality of the object is expressed in the presence of a unique combination of features not found in other similar object. These features for the subject of diagnostics are the size, shape, temperature, color, weight, material structure, surface topography and other characteristics. For example, for cattle it is the structural features of the head, limbs, and physiological characteristics of an organism. For technical objects – change of physico-mechanical properties, diagnostic criteria, technical parameters in different conditions of operation.

Once the individual objects of the material world, identical to themselves, they, therefore, peculiar to the individual characteristics and properties. In turn, these features of objects are changeable and affect other objects. Means to display also an individual that have the property of variability.

On the other hand, all material objects undergo continuous change (FDC sick, aging, equipment wear, etc.). Some of these changes occur rapidly, others slowly, some changes may be significant and others not so significant. Although the objects change constantly, but for some time remain the most stable part of their characteristics that allow identification. Here, the identification means the identification between the regularities of the diagnostic parameters and the different state of the object. When you identify a specific object often pay attention to threshold values of any physical quantities, with the important role played by diagnostic signs of a state change of the object in the process of its recognition. A property of material objects to maintain all their signs, despite their changes expressed through the relative stability.

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Diagnosis, like scientific component as a field of scientific practice is socially determined, changing in the course of historical development of society. Its modern development in the XXI century is in the direction of empowering faster and more accurate closer to the goal, recognition of the causes of deviations from norms of a technical object. In turn, the development of diagnostics is characterized by the irregularity of the variability of its individual parties, as well as influence each other different characteristics or parameters of the controlled objects from the standpoint of information content, and often even from the standpoint of redundancy information flow. This applies to all levels and sections-theoretic adaptive systems synthesis technical support for early diagnosis of internal diseases of cattle.

ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

Synthesis technical support for early diagnosis of internal diseases of cattle solves a wide range of tasks, but the main is the recognition of the conditions of technical systems in conditions of limited information. the solution diagnostic task (the classification of an object to a working or faulty condition) is always associated with the risk of false alarms or missed defects [1-5].

It should be noted that threatening in its development the destruction of AO fault can be divided into three groups [6-10]:

1) faulty very quickly (within fractions of a second or several seconds) to the accident, or almost the same, faulty, too late detected using the available diagnostic tools,

2) faults that can develop in a car accident within a few minutes, and malfunction, the nature and pace of development which cannot be reliably predicted on the basis of the achieved level of knowledge. the occurrence of such faults should lead to immediate results signal the crew (or staff test stand) to attract attention, assess the situation and take the necessary measures

3) malfunction, or are developing relatively slowly revealed cash diagnostic tools at such an early stage that their transition into the accident in continuation of this flight can be considered virtually eliminated. early detection of such faults and forms the basis of forecasting of stock.

The time interval from the appearance of the first symptom of a fault to the threat of development is not so much a physical characteristic of a specific fault, as the measure of the level of our knowledge about the causes, signs and processes of development [11-15].

One of the practical problems of diagnostics research in the field of dynamics of development of faults AO is to minimize the number of faults the first and second groups and gradually "translate" them into a third, expanding, thus, early diagnosis and long-term forecasting of stock. High confidence diagnosis not only improves the security of the state of the object (BP), but also contributes to a significant reduction in operating costs related to the violation of the regularity of the surveys [16-17].

Experience solving synthesis shows that correct diagnosis is necessary in the first stage to know in advance all possible States on the basis of a priori statistical data and of the probability of situations, and an array of diagnostic features that respond to these conditions. As already noted, the process of qualitative change of properties of AO occurs continuously, and this means that the number of possible States is infinite and even a lot of. One of the tasks of synthesis is to partition the set of States into finite and small number of classes. In each class combined States, possessing similar attributes selected as features for classification. The statistical base parameters obtained by the above methods of diagnosis must be impartial and real [18].

Not all options that can be used in the diagnosis, equivalent to the content of information about the functioning systems of synthesis. Some of them bring information about many properties of the working modules, while Others are extremely limited. Of course, preference should be given to diagnostic parameters that are flucture nature, not those that are constant or change very slowly. For example, the sound of the heart and its vibration number information have a great advantage over such a stable, inert signals, as the body temperature of cattle, etc., although these parameters as well as noise and vibration are dependent on the state of cattle. Therefore, in the second stage it is interesting to consider the problem of linkages of diagnostic parameters, their changes and the possible impact on each other, and to assess the significance of the signs of the various functional parameters of the synthesis [19].

It is known that the theory of diagnosis is quite well described by the General theory of communication, which is one of the sections of the control theory. In the service of the diagnosis it is possible to put mathematical and logical apparatus, system mastered concepts and terminology [20].

OBJECTIVE

The aim of the research is to improve the adequacy of the analytical description of the structure of an adaptive system, which will include itself system technical support, system management, the environment and the system of early diagnostics of the internal diseases of cattle.

THE MAIN RESULTS OF THE RESEARCH

You only need to find a physical interpretation of abstract formulas and ways of practical implementation of the envisaged approaches. thus, in the third stage, you must confirm, using known principles of information theory, the importance of diagnostic features, and to form a diagnosis, and further, to forecast predown States. This part of the work associated with the greatest difficulties, because the functional synthesis system is multivariate, but not all parameters are equally important (informative) in certain specific conditions.

Refer to the classical interpretation of structuring the diagnosis with some addition of this scheme (Fig. 1).

Presents an integrated structure is characterized by two interrelated areas: pattern recognition theory and the theory of information. The theory of pattern recognition supplemented by new elements of classification and includes the following sections related to the construction of recognition algorithms, decision rules, identification of objects of control and diagnostic models and their classification. The theory is informative in this context means obtaining diagnostic information using known methods and means of diagnostics, automated monitoring and development of search algorithms of diseases, minimization of the process of diagnosis.

Another range of tasks in the field of synthesis is associated with the continuous introduction of diagnostic systems in practice. Condition for their implementation is the availability of special methods and programs for diagnostics and algorithms of decision-making on the further establishment of the treatment. The necessary conditions are the availability of modern instrumentation, traceable-certified equipment and personnel with the appropriate level of qualification.

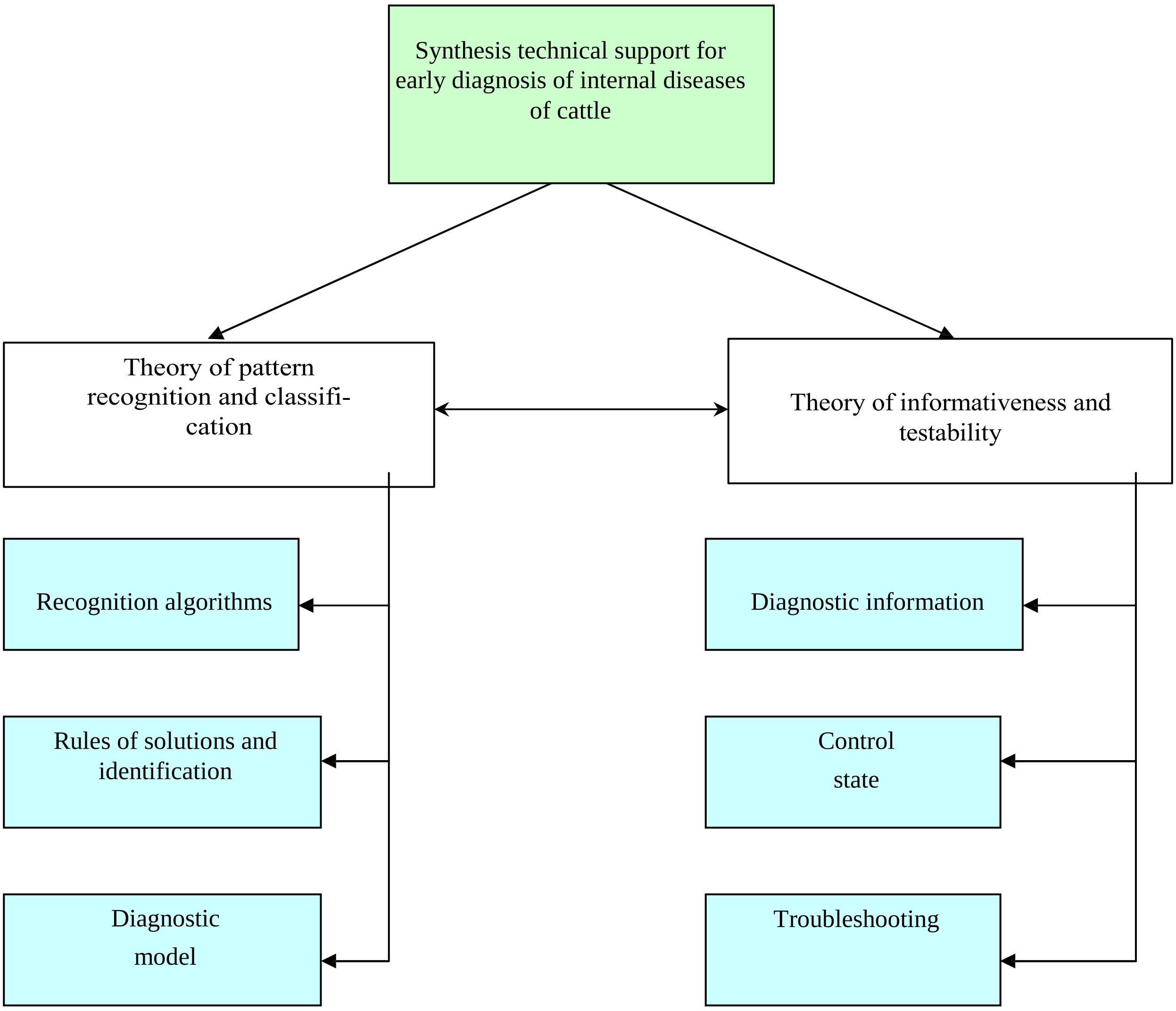

Fig. 1. Structure synthesis technical support for early diagnosis of internal diseases of cattle.

The following sections describes the theoretical and informational aspects of methods of diagnosis, methods of diagnosis are discussed in the information positions, specific examples in the field of information diagnostics.

The collection, processing and automated analysis of clinical parameters of the animal is an important component of many diagnostic methods of modern veterinary medicine. Diagnosis and prognosis of disease, the choice of methods of treatment of a sick animal are largely based on objective analysis of bioelectrical signals recorded in the monitoring process. In some cases, the possibility of signal processing by a doctor, however, the automatic calculation of informative parameters with the use of computer has advantages and lower costs. Automatic data processing has a number of advantages, namely: 1) data processing is carried out according to the same scheme, 2) the results are presented in a standardized form, 3) it is possible to use only standard terminology. A computer system for gathering and mathematical processing of electrophysiological signals are complex hardware - software complexes, which consist of many software components that perform the functions of registration for biomedical information, its processing and system analysis, diagnostic and service operations.

Rapid development and introduction of information systems into clinical practice has led to the need for their standardization. Standardization in medical Informatics in General, biomedical devices and systems, in particular, has a number of difficulties, primarily due to the difficulty in formalization of objectives and the construction of unified models of such systems. However, despite the fact that the development of biomedical systems is characterized by contradictory and inconsistent standards for health information exchange successfully developed and implemented at the level of large and medium information systems. The task of developing information standards is to build on the basis of modeling a variety of biomedical data of a single item, universal methods of representing and coding data, and a messaging system that allows you to integrate subsystems from different manufacturers within a single information environment.

The creation of a huge number of similar functions, but completely incompatible with other systems, became a serious obstacle to the development of the industry as a whole. The most difficult task facing the developers of any software biomedical system is to provide a high level of interoperability between biomedical applications developed by different manufacturers and running on different platforms. This concept has a broad meaning: to have access to the various systems common information resources, the ability of systems to communicate effectively between themselves for the solution of applied problems in real-time.

Among the clinical indicators that determine during the mass studies of cattle is thermometry and determine the heart rate. The thermometry is typically carried out using mercury or electronic thermometers rectally. The heart rate is determined using ponendo or phonendoscope.

The disadvantages of these methods is the high complexity of the process, a large role of subjective factors in the diagnosis, the need for reliable fixation of the animal.

Systematic monitoring is called monitoring. It monitoring helps identify trends in the development of the state, presented in the form of statistical trends. For them perform a retrospective analysis using a computer and telemetry technologies is an actual problem

Therefore, the determination of clinical parameters in farm animals using a computer and telemetry technologies is an important issue.

Diagnostics industry knowledge that includes a set of methods and tools determine the state of any object (of the health of a living being, a technical condition – technical devices) at a particular point in time. The main task of diagnostics is early detection of pathologies.

Animals do not speak the language. Not always external signs to determine their condition. So the diagnosis of animals is more difficult diagnoses (except Pediatrics) and is close to technical diagnostics. Modern diagnostics of animals is based on the information obtained by chemical analysis of domestic technological liquids or excreta, measuring changes in physical parameters and the use of visual methods.

The basis for the development of a system for remote diagnostics of clinical indicators in animals lies with the outer measurements of mechanical parameters.

It is possible to measure parameters that have frequency characteristics:

1. Work of the heart.
2. The respiratory rate.
3. The process of chewing.
4. The work of scar.
5. The temperature of the skin.
6. The condition of the joints.
7. The conductivity of individual sections of the skin.

Physical processes 1-5 in cattle have a frequency range that does not exceed units of Hz (low frequency processes). Range condition of the joints (6) is a few tens of Hertz, and the electrical conductivity of individual sections of the skin of hundreds and thousands of Hz.

According to current data, any pathology is evident in its development of versatile. When a sufficiently strong development of the pathology unmask her visual, auditory, temperature, and other organoleptic characteristics established empirically. Thus, the equipment support must include sensors of various physical parameters.

The earliest diagnosis of the disease largely depends on the methods and technical capabilities of the tools to detect abnormalities. The methodology should be based on the latest scientific achievements. Applied instrumentation should cover the maximum number of telltale factors and have a high sensitivity to them.

Systematic monitoring are called monitoring. It monitoring helps identify trends in the development of States, predstavlennyh in the form of statistical trends. For them perform a retrospective analysis (recovery mechanism) and predict as a certain future).

The depth and accuracy of analysis, diagnosis and prognosis depends on many objective and subjective factors to calculate which is not always possible in advance. In any case, the diagnosis may not be more likely and more complete the initial information on the status of a research object.

Remote monitoring is not possible without the presence of any non-contact method of transmitting measurement data. Out of competition - radio waves. It is the presence of special telemetry radio link provides the remoteness of diagnosis. Setting standards and monitoring characteristics of the transmission lines is carried out by different national or international agencies (depending on the nature of the lines: satellite telemetry - international agreements, industrial telemetry, the institutions of state control, and the like).

The main stages of which are being developed telemetry system is:

- source of the data, which is usually a sensor that converts the measured parameters into electrical signals
- method of transmitting data
- receiving device and restoring the data transmitted.

A typical telemetry system is according to the scheme: a set of sensors, modulator - oscillator frequency - transmitter antenna receiver antenna - the receiver - demodulator - end signal Converter - computer.

Radio is the main component that provides the remoteness, however, except primalco transmission nodes in the work on the scheme involved several complex and expensive components. In addition, to ensure coordinated activities of contractors on the transmission and reception necessarily need to have an additional channel service of telephone communication between them.

Consider the fundamental issues and basic techniques of radio communications systems for remote diagnostics.

A. Individual radio Amateur band.

State standards for home telemetry allocated to several radio ranges - 165 Hz to 400 Hz, for several VHF bands.

To build a system of remote diagnostics according to this method should:

• perform a radio transmitter in accordance with special technical requirements for power, wanted and unwanted emissions,

• document the development,

• register the transmitter in the relevant state institutions.

To communicate over distance up to 300 m no permit is required to operate this transmitter.

Individual radio special VHF range. To build a telemetry system diagnosis by this method is necessary and sufficient to manufacture a radio transmitter in accordance with the technical requirements and to obtain confirmation of the technical services of distribution of radio frequencies.

This scheme can arrange a remote connection in humane medicine between doctor and patient, almost all the developers tools diagnostic control (TREDEX, Oxycon Mobile, ZEPHYR BioHamess, RADIOCHATTER, TELECARD the like).

There are certain restrictions for the development of such schemes for the diagnosis of animal - standardized power limitations of the transmitter and, consequently, increased requirements to the filtering of spurious emissions and receiver sensitivity.

V. Computer consoles BLUETOOTH.

Easy to operate telemetry device. To log into the computer console is equipped with a special interface. However, it is necessary to transmit a signal, which has already agreed to host part digital form. As sensitive elements of any sensors by definition have analog voltage or current output, it will require on the side of the transmitter analog-to-digital Converter. This greatly complicates the measuring unit. In addition, communication is provided only in a direct vision between transmitter and computer at a distance up to 10 meters.

G. A Radiotelephone.

This kind of communication is fundamentally possible to use for remote diagnostics in areas which provide a wired telephone connection. The principle consists in using a kind of radio extendable to eliminate the usual cable that is attached to the tube.

The composition of the handset of the radio telephone includes a microphone and a receiver-transmitter for communication with individual stand (base). Stand on the side of the receiver and transmitter are interconnected by wires of a telephone cable network and can reside anywhere. The handset can be located within a radius of 100 m from the base of the individual. The advantages of such schemes for remote communication is that the communication channel is ready to use. It is only necessary to mount in the sending unit of the input device and the transmitter, and the receiving unit receiver with shogouki device for inputting received signals to the computer. In addition, it is necessary to develop and manufacture a few specific electronic components.

D. Other communications systems

The Internet is wired and wireless communication lines and covers a significant portion of the planet. Communication via the Internet protocols RS-232, RS-485, TCP/IP, ETHERNET, and so on. Special means of entrance and exit modems are becoming more functional, less overall yet inaccessible at the price. This type of communication is the future.

Satellite systems that work on a ground-based transmitter - artificial Earth satellite - ground receiver have the Best performance on all settings. However, the use of satellites at low altitudes does not provide the continuity and long duration sessions. Solves the problem of increasing the number of such satellites. Using this type of communication solved the problems of determining the ground coordinates of the transmitter (GPRS), used for monitoring migratory animals.

Thus, traditional means of communication are not universal and need individual designs and costs for implementation. Sapognikova - Internet communication channels in its potential application for remote condition monitoring of an unlimited number of animals in unlimited time the most attractive. They are currently undergoing a stage of rapid development and require significant capital investment. This is the future.

E. Cellular communications.

Has the advantages of home phone and does not need a landline in places of work. For example, patented technology Telemetrix T3000 provides the possibility of transmission in cellular communication systems: meter reading, data from the systems monitoring the health of patients at home, monitoring systems, fire safety, and so on.

Work of system of cellular communication in the VHF frequency ranges UHF 400, 900, 800 and 1800 MHz with a bandwidth of 3 MHz. The drawbacks of such systems is a high-quality communication limit range. Affects the radius of the power and the distance between repeaters, and between the mobile phone and the repeater and is 1-40 km, and the Number and power of the repeaters is growing. In the future cellular communication might become the basis of real world communication. Today mobile phone are cheaper and easier to buy than to establish domestic (home), besides you can pick up a fare without restriction of time of communication, which is important when working with animals whose behaviour is not always predictable.

Thus, the problem of creating a wireless monitoring system requires the following tasks:

• selection of sensors

• development of a method of mounting the sensors,

• development ushagelova input device (modulator),

• development ushagelova device for the receiving part

• (demodulator),

• develop filters to control by the Registrar,

• choice of Registrar

• choice of the configuration of the computer

• software development.

The choice of sensor equipment.

During the observation, the first group of the above-mentioned physiological parameters of animals (1-4, 6,7) refers to exclusively pavlinovna, and the temperature is almost constant parameters. Therefore, the main requirements of sensor equipment can be summarized as follows:

• performance in the frequency range up to 6 Hz,

• high sensitivity,

• small size,

• low stromsparen,

• possibility of fastening on an animal.

Competent designing of the diagnostic system includes careful selection of appropriate subsystems.

It is necessary to pay special attention to methods of anchoring means on the animal and the means of protecting devices from damage.

To simplify the practical implementation advise you to use serial sensors, which are included in the stand kit "Dolphin".

Accelerometers series ANS have been used successfully in the first phase of research using a wired connection between the accelerometers and the Registrar.

The sensor in the rumen (experimental design) advanced based on the results of the first phase of the research. This sensor contains a three-band and measuring acoustic noise, vibrations and relative displacements.

Thermocouple standard sensor reusable.

As in any system, one of the main problems in the systems of remote diagnostics is the measurement accuracy. It is therefore necessary to consider the frequency bandwidth of the system. The main causes of accuracy degradation are noise and interference channels. Atmospheric noises are introduced into an electromagnetic wave (a signal that is transmitted) by means of amplitude modulation method (AM), i.e. the noise signal causes changes in the amplitude of the useful signal. This means that AM radio is most sensitive to atmospheric interference. To improve the noise characteristics of the AM-line communication possible by increasing transmission power. The signal of the FM method (FM, frequency modulation) carries information related to frequency changes and not amplitude, so the amplitude change can be eliminated at the receiver using the "limiter". The limiter is designed to align the amplitude of the FM-signup, keeps constant the amplitude of the FM signal and reduces all AM components.

Increased noise immunity of the FM-channels of communication often acts as the deciding factor. In this frequency division multiplexing is widely used to "seal", that is, the connection of one phone line for multiple subscribers with the preservation of frequency standards in each channel (400-4000 Hz). However, for the organization of the system of remote diagnostics of animals such an approach is fundamentally impossible. From the above it is known that unlike the human voice, which has a wide range of several kilohertz, most of the physiological parameters of animals is prenisolone plot of the energy spectrum. To communicate this range of frequencies does not matter. For the diagnosis of animals, on the contrary, it is necessary to transmit a narrower range of frequencies and at a much lower frequency portion of the spectrum. Therefore, the bandwidth of telephone channel filters must be divided into several strips which are discharged through separate channels. To minimize mutual influence of channels, filters, emit signals of individual channels of transmission and reception must have a sufficiently large attenuation in the frequency bands that are occupied by other channels. The advantage of the system with frequency division is that there are various modes of operation. Separate channels can run independently from each other or team up for more broadband information channel.

You must calculate the possibilities when using the FM radio channels of cellular communication for remote diagnostics of animals.

According to DSTU telephone network has a bandwidth G - 400 - 4000 Hz. When using the specific the world Cup compacted telephone channel that is dividing the bandwidth into a number of frequency bands RK width of 400 Hz, will receive at least 8 information channels. Taking theoretical guidance regarding the exclusion of the mutual influence of the channels the frequency deviation O = - 7.5% and a modulation index of 1 = 5 to get the real bandwidth F1 - F2 of each of the 8 channels:

F1 - F2 = Fx a x D/T = 400 x 0,075 / 5 = 6 Hz

The rise time T, knitted with a bandwidth of F as

T= 0,35 / (F1 – F2),

where T is in MS,

F1 - F2 in kHz.

If the real signal has a bandwidth of 6 Hz, then the minimum rise time will be:

T = 0,35/0,006 = 58 MS.

Current rise time can be used for signals.

Usually, the conditions of communication need of modulation index of 5. Some data can be used over a wide frequency band. If the modulation index remains unchanged, it is necessary to use a large frequency deviation of ±15%. It is possible to apply such a frequency deviation not at all, but on certain channels selectively.

Thus, it becomes possible to transmit per-channel physiological parameters 1-5 using a modified channel of cellular communication. To obtain information on item 6 by combining all channels into one and using a high index modulation up to ±15%. To transfer 7 parameter modifications of the channels is not necessary. High-frequency sensor may be included instead of the mobile phone's microphone and receiver-side signal input from the earphone Jack need to apply directly to the Registrar. In this case, one phone can transmit only one signal.

Unit recording information (peripheral module) a set of sensors, modulator, mobile phone, power source-battery and locking elements. Modulator, mobile phone and battery are combined into one unit.

Transfer point selected in areas of maximum manifestation of the studied processes.

For the study of the respiratory system on the left side in the 4 intercostal space at 7-8 cm above the line Lopatko of the shoulder joint.

For the study of the heart on the right side in 4 intercostal space at 4-6 cm below the line Lopatko-shoulder joint.

To study processes of mastication – left (right) horn (at the base).

To study the work of the scar – in left hungry fossa.

To study the state of the joints – carpal joint of the left front limb.

To determine skin temperature and electrical skin resistance sensor mounted in the fourth intercostal space on the line Lopatko-shoulder - joint to the right or left side.

Modulator, mobile phone and battery, which are combined into one unit, fixed in the region of the withers. For fixing use "sticky tape" with rubber inserts. In places of listening of the heart, the respiratory system and the condition of the joints, it is desirable to remove the wool and processed with a special gel.

There are various methods of the FM-detection and selection. The basis of most methods is the use of the slope of the frequency characteristic of the resonant circuit. The amplitude of the feedback varies with frequency. The output signal corresponds to the frequency deviation of the input signal (although not entirely linear, in a simple resonant circuit) and thus reflect the primary modulating signal. The selected sensor signals is input to a multichannel recorder and then into the computer.

Real music, which is transmitted to the service channel is fed through the headphone Jack on the free channel of the Registrar and in parallel in the filter unit. Filters are set to frequency corresponding to the second harmonic for the most remote on the spectral scale long sound "And...and...and... and...with...With..." that says works Manager. Depending on the filter that work occurs on or off the recorder.

Multichannel recorder.

With the aim of accelerating the development of the system remote diagnostics recommend you to use Registrar "Dolphin" designed and manufactured JSC "Cyclone", Lugansk, which has the following characteristics.

CONCLUSIONS

1. Thus, the use of modern diagnostic methods will improve the accuracy of measurements, speed up the diagnosis of the disease both in terms of livestock units, and in hospital clinics veterinary medicine, will reduce the time and resources to carry out veterinary activities.

2. Modern equipment of domestic production may expand the diagnostic capabilities of the specialist of veterinary medicine that will effectively carry out medical examination in terms of the economy, to recognize the disease early and promptly treat animals.

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DECISION FOR TECHNICAL MAINTENANCE OF COMBINE HARVESTERS IN SYSTEM OF RCM

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Summary. The most progressive form of industrial repair of combine harvesters is centralized repair on a technical condition in which the identification of combinations of defects of each unit occurs with the pre-repair diagnosis.

In this approach, an integral element of the process of diagnosing is a person (the operator-diagnostician). Applying the method of scientific idealization, the object complex, whose specific diagnosis in determining the technical state of the product can be defined as the human-machine system having in each case inherent advantages and disadvantages. It is no secret that the weakest link in the system, whether high-tech computerized station or a primitive engine, is the man.

A deeper study of technological processes of diagnostics products leads to the conclusion that a significant number of recognition errors of the defects and the appropriate allocation of repaired units on technological routes of repair can be avoided by excluding the influence of the operator-diagnostician on the formation of the final result of diagnosis.

Significantly reduce losses resulting from failed pre-repair diagnosis coming in for repair of units of cars using promising cognitive artificial system based on mathematical apparatus of artificial neural networks. Therefore, the formation of scientific and methodological foundations of development, training, and practical application of this mathematical apparatus in subsystems pre-repair diagnosis repair Fund of units of the car is an important and urgent task.

The presence of recognition errors in determining the technical condition directed repair of vehicle parts, but also in the distribution of defective units in a specific technological routes leads to production losses on performing unnecessary repairs and costs to remove the missed defects, which does not allow to fully realize the benefits CRTS of units of the car, and in some cases leads to complete rejection of it in favor of a major overhaul.

The currently existing forms and methods of organization CRTS not allow full use of the advantages of this type of repair, because reliable distribution of CRE units required the accumulation of large amounts of statistical data.

Key words: synthesis, technic, support, early diagnosis, internal diseases of cattle.

INTRODUCTION

The analysis of experience of application of mathematical apparatus of artificial neural networks in tasks of technical diagnostics of complex technical devices has led to the following conclusions.

The use of this device eliminates the need for the systematic accumulation of statistical information of multiparameter nature as a basis for the design of a rational structure of the technical system CRTS used in the existing scientific and methodological developments.

These technologies have a high degree of flexibility that allows to predict the occurrence of defects even before the receipt of goods for repair.

Eliminates the need for constant monitoring of the technical condition of products, since the required values of the relevant parameters can be obtained at the stage of pre-repair diagnosis with high accuracy of recognition of combinations of defects.

It is possible to achieve a significant reduction of human factor influence in the formulation of the final diagnosis on the technical condition of entering the repair of units of cars.

Constructing models of Ann in problems of technical diagnostics and distribution of CRE units repair Fund in their CRTS, you can use the information obtained during the pre-repair diagnosis.

Thus, the analysis of the state allowed to formulate the objective of the present research – the organization subsystem the pre-repair diagnostics of units of the car based on the generated automated workplace of the operator-diagnostician that reduce internal losses by the repair company for the functioning of the centralized repair on a technical condition.

The above allows to present a working hypothesis of the study the following assumption: there are ways of defining and classifying the feature space, evaluating the technical condition of the repaired products and their distribution in the feature space characterizing the recovery processes of their technical condition, do not use the probabilistic characteristics to assess their effectiveness.

ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

Abroad for more than 20 years ago, we began to see systems that were integral automated system to increase efficiency in control processes of maintenance and repair at the enterprises of technical service of cereal combine harvesters [1-4].

In the repair industry in 1989 was marked by the decline of the performed services of maintenance and repair of combine harvesters, so many businesses were forced to rapidly expand the range of services offered to customers [5-9]. At that time there were about 17 thousand free repair companies who, unlike brand, carried out the repairs combine harvesters of all makes [10-14].

For example, on the order of Bosch, Germany, developed a system to handle data and information on available repair shops [15]. This system was introduced nearly 300 companies - partners of the firm Bosch.

When developing the system came from the fact that it needs to be a communication tool, as repair businesses need a significant amount of information [16-18]. The software package of this system provided access to the database and allowed to make worksheets, invoices, bills, etc. in addition, the user is provided with updated catalogue on the supply Bosch with prices [19]. Optionally, the system could make data of other manufacturers, if the company intends to cooperate with them [20].

At the end of 80s, in Bulgaria the Sofia scientific-research technological Institute developed the automated control system (ACS), which was intended for the collection and processing of information from the work stations of measurements of controlled parameters of a part, assembly, or unit. The block diagram of the working of the post shown in Fig. 1.

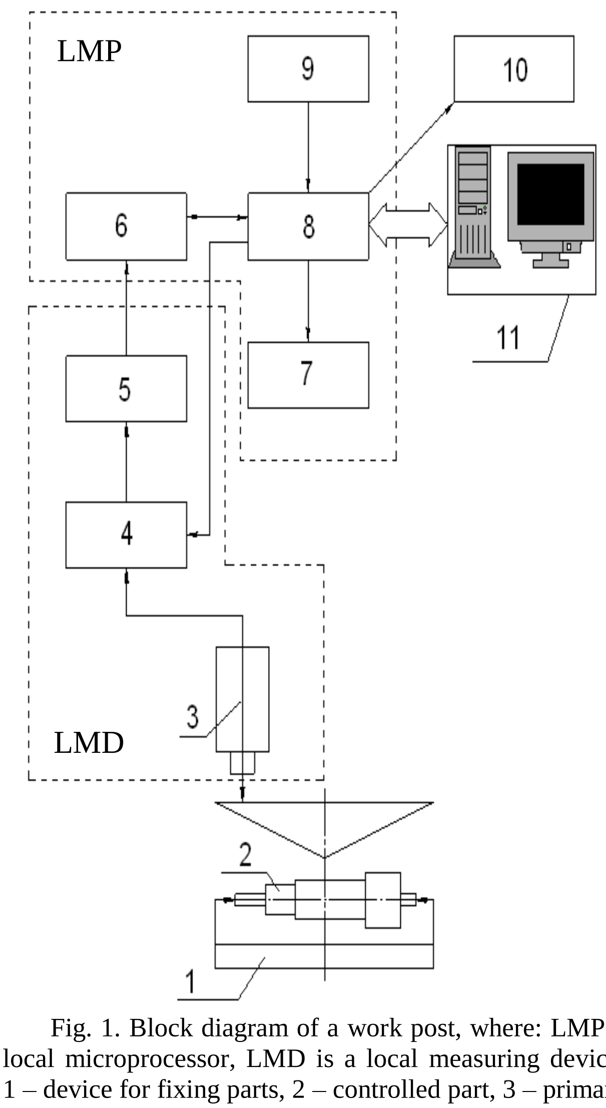

Fig. 1. Block diagram of a work post, where: LMP – local microprocessor, LMD is a local measuring device, 1 – device for fixing parts, 2 – controlled part, 3 – primary converters, 4 – multiplexer, 5 – Converter amplifier, 6 – analog-to-digital Converter (ADC), 7 – display unit, 8 – microprocessor 9 control unit, 10 – printer, 11 –computer.

To one computer you can connect up to 8 work stations. Every working station was able to measure up to 16 monitored parameters, and the distance between posts can be up to 300 meters, which satisfied the requirements of the collection and processing of information, because, for example, in the auto repair enterprise is often carried out control of a technical condition of details in the areas of fault detection and picking in the areas of repair and restoration of parts and in the acceptance of new parts.

OBJECTIVE

The aim of the study organization of the subsystem pre-diagnosis units of combine harvesters on the basis of the generated by the automated workplace of the operator-diagnostician that reduce internal losses by the repair company for the functioning of the centralized repair on a technical condition.

THE MAIN RESULTS OF THE RESEARCH

The use of SAC was especially effective with acquisition of parts and assigning routes to restore worn parts, since the decision about the technical condition of a part, Assembly or Assembly was carried out by computer, which allowed to reduce the influence of subjective factors in the allocation of maintenance Fund for trails.

Functionality of most computerized control systems and repair at auto repair facilities were expanded by adding the possibility of inventory management and maintenance personnel.

Later, any system, EAM system (from the English. Enterprise Asset Management), which are mainly used to maintain production equipment and machinery in good technical condition. These systems can consistently manage the following processes:

- maintenance and repair,
- manage inventory,
- logistics,
- management of finance, quality and human resources under a unified strategy.

When implementing data systems in the enterprise focus on reducing costs on maintenance and repair equipment without compromising reliability, or to improve certain production parameters without increasing costs.

From EAM systems for service sector appeared in the integrated management and maintenance – the MRO system (from the English. Maintenance, Repairand Overhaul), whose main purpose is automation of the planning activities of staff involved in the administration and repairs of harvesters and providing them with the necessary resources. In addition, these systems involve functionality for informing and solving a number of problems:

- manage timing of service and writing off of rolling stock,
- optimization of the structure and size of the fleet,
- storing information about each unit of rolling stock fleet, the failures in operational process, and made the repairs.
- support the territorial units of the enterprise involved in the repair of combine harvesters in a single strategy, etc.

In Ukraine and abroad in several industries industries apply "the system of information support of product life cycle". Which is based on the standardized representation of product data and assumes brand warranty and post-warranty service. Such technologies typically include control system reliability: the system collects information about failures, scheduled and emergency repairs, as well as about the technical condition detected with special test and diagnostic tools. Similar systems are being introduced in the high technology industries of our country, and in the sphere of agrarian complex use of individual elements of the system.

Currently in the theory of process control, service and repair of combine harvesters is popular techniques service-oriented reliability of machinery and equipment – known in the world as RCM, shown in Fig. 2, (Reliability – centered Maintenance), which was created in the 60–ies of the last century for the civil aviation industry. According to this method, the maintenance of all items of machinery and equipment in immaculate condition not an end in itself, what matters is the efficiency of the production system as a whole and not the performance of each unit.

The goal of RCM is to ensure reliable operation of critical facilities (in accordance with their criticality), failure of which will entail significant consequences. In the assessment of impacts takes into account the various risks – disruption of the production plan, compliance with product quality, environmental disaster, etc.

The main stages of the RCM analysis:

• A definition of the limits of the system and/or subsystem,

• B – define all functions of the system and/or subsystem,

• C – identification of functionally significant items (FSI),

• D – define the reasons of failures of functional elements, forecasting of failures and probability of their occurrence,

• E – use problem solving to classify the results of the failure of functionally important elements,

• F – select operations for initial program or fixation

• G – in case some operations when then repair can not be established, the set of operations is reviewed,

• H – create dynamic programs and R as a result of planned and systematic maintenance by monitoring (systematic monitoring), the collection and analysis of operational data.

The first step when using the RCM methodology is to define the limits or boundaries of the subsystem. This means that the system is divided into subsystems of more than simple complexity.

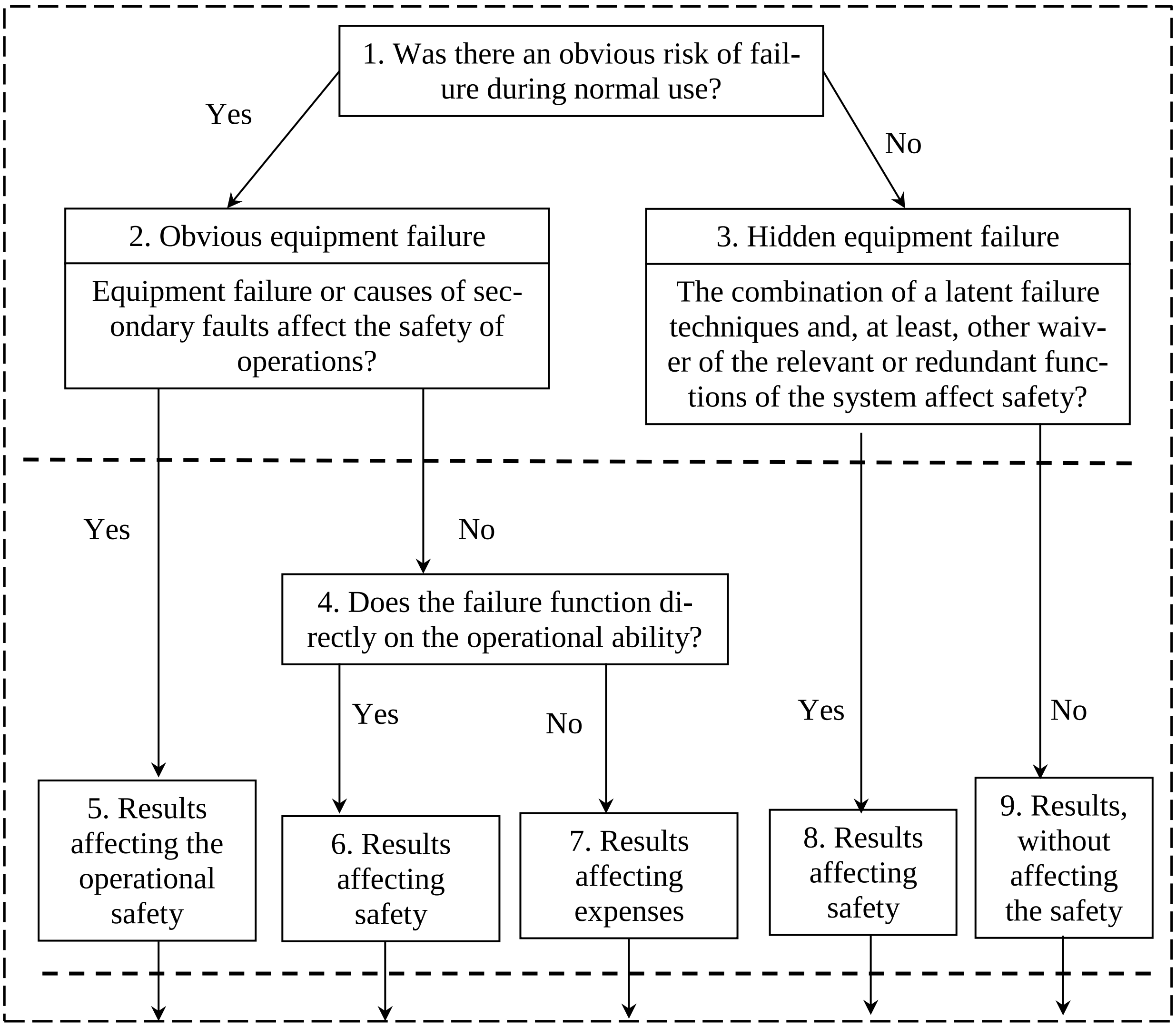

Fig. 2. The decision tree for service and repair in the system of the RCM.

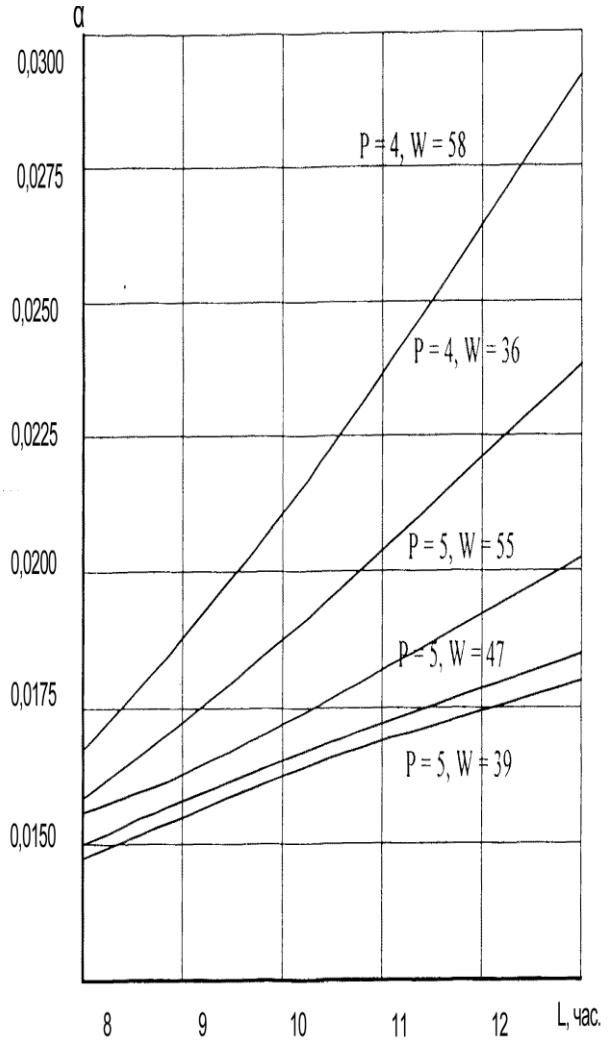

Fig. 2. The dependence of the probabilities of errors of the 1st kind, the first shift from time to time taking into account the category and age of the operator-diagnostician.

Subsystem more simple level of complexity. The second step is the identification of functionally significant elements. The next step involves identifying the causes of failures of functionally important elements and the prediction of the probability of their occurrence.

Qualitative methods (based on the collective professional opinion and practical application) and quantitative methods (e.g., method of analysis of the nature and consequences of failures (FMEA–Failure Modeand Effect Analysis) or the method of risk analysis) can be used to identify the causes and results of failure elements.

The average time to failure is based on a competent analysis in a "cause-failure-effect".

Logical tree of decision-making shown in Fig. 1.6, is used to classify the results of failures.

Analysis of the nature and consequences of failures (FMEA) and logic tree decision making (FTA–Fault Tree Analysis) faults, can be a successful approaches in solving the tasks related to the prioritization of Troubleshooting in the first place.

If the probability of failure was predictable even during normal system operation, this denial is explicit, otherwise it is classified as hidden.

Central repair on a technical condition based on the principles of routing technology, the basic principles of which are set out in the works and information technology, a key factor in the question of its effectiveness.

However, in addition to the technological and information support, on the effectiveness of CRTS also significantly affected by the human factor, which is the source of errors 1-th (a"false defect") race and the 2nd ("pass defect") kind of at the stage of pre-repair diagnosis.

In Fig. 2 and Fig. 3 presents the dependence of the recognition errors of the 1st kind from the time of day (depending on shift) taking into account the category and age of the operator-diagnostician, where α is a recognition error of the 1st kind (a"false defect) in the definition of the operator-diagnostician of repair works, P – working category of the operator-diagnostician, W – the age of the operator-diagnostician, years, L – shift working time pre-repair diagnosis, hour.

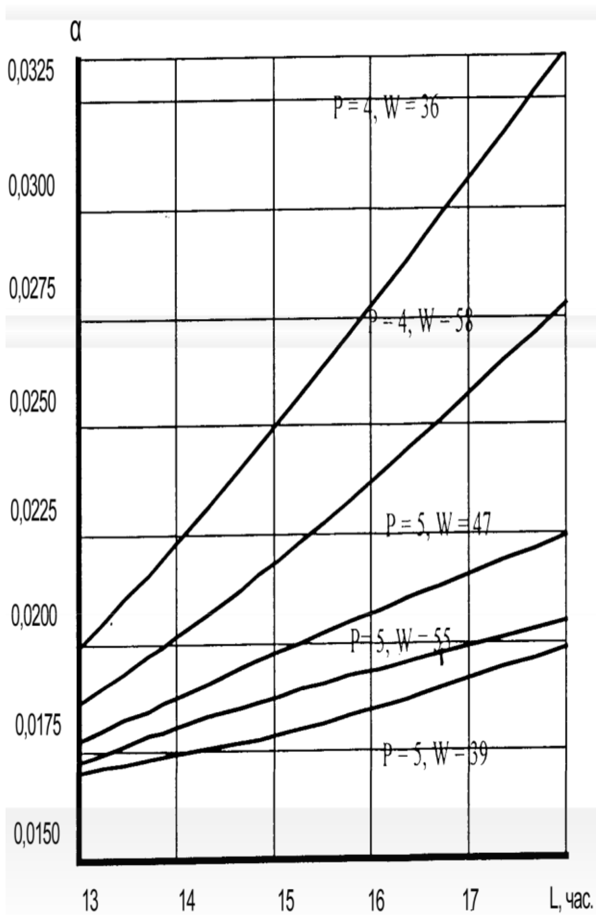

Fig. 3. The dependence of the probabilities of errors of the 1st kind the second shift from time to time, taking into account the category and age of the operator-diagnostician

In Fig. 4 are presented the dependence of the recognition errors of the 2nd kind from various factors, where β is the recognition error of the 2nd kind (a "pass defect") in the definition of the operator - diagnostician of repair works, P – working category of the operator-diagnostician, W – the age of the operator-diagnostician, years, L – shift working time pre-diagnosis, hour, N – the time unit (mileage), thousand km.

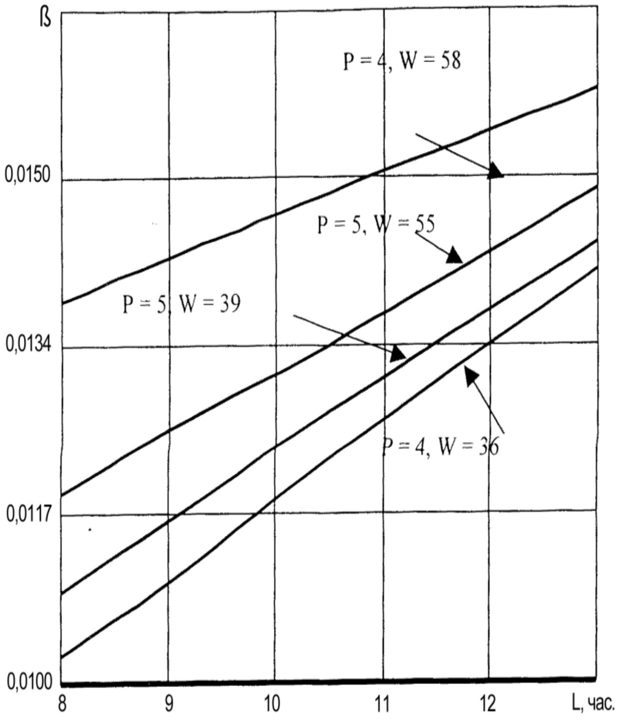

Fig. 4. The dependence of the probability of error of the 2nd kind from the time of the day taking into account the category and age of the operator-diagnostician.

CONCLUSIONS

1. Central repair on an actual technical condition allows to reduce the loss of resource under-utilization of parts, components and assemblies of vehicles, thereby increasing the efficiency of the use of motor vehicles.

2. Among the factors influencing the formulation of correct diagnosis by the operator-diagnostician at CRTS of units of the car, identified as the objective (work shift, time of day) and a subjective (working category, age, etc.).

3. The presence of recognition errors in determining the technical condition directed repair of vehicle parts, but also in the distribution of defective units in a specific technological routes leads to production losses on performing unnecessary repairs and costs to remove the missed defects, which does not allow to fully realize the benefits CRTS of units of the car, and in some cases leads to complete rejection of it in favor of a major overhaul.

4. The currently existing forms and methods of organization CRTS not allow full use of the advantages of this type of repair, because reliable distribution of CRE units required the accumulation of large amounts of statistical data.

5. A significant reduction of human factor influence on the result of diagnosis about the presence (or absence) of defects and the distribution of units on the technological routes of repair facilitated by the use of artificial cognitive systems in tasks CRTS.

6. The goal of RCM is to ensure reliable operation of critical facilities (in accordance with their criticality), failure of which will entail significant consequences. In the assessment of impacts takes into account the various risks – disruption of the production plan, compliance with product quality, environmental disaster, etc.

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ANALYTICAL PROVISION OF REGULAR PREVENTIVE MAINTENANCE OF AGRICULTURAL MACHINERY AND SYSTEM IMPLEMENTATION

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Summary. The study relates to the field of computer technology, in particular to methods and devices of control and may find application in the practice of exploitation for the optimal control of preventive maintenance of agricultural machines on the current status of its reliability, and can be used in various fields of technology, particularly in the maintenance system for decision-making on preventive maintenance of machines. The technical result is to determine the optimal time interval between adjacent maintenance of agricultural machinery on the current status of its reliability, taking into account time and money costs. The device comprises a sensor failure of agricultural machinery, count bounce, the unit of measurement of time between failures, the Central processor of the automated workplace of the operator input block information, the block display, the block selection of the distribution law of the random time between failures, the block selecting confidence probability, a unit of determination of the confidence interval failures, the evaluation unit crucial functions of the block decision, the setpoint value of the fines.

For actual implementation of the idea of remote monitoring of technical service, need to create a system of mobile equipment maintenance of agricultural machinery.

For modern agricultural production there is no obligatory samples and the normative assessments that are suitable for all occasions. But the creation of developed infrastructure of maintenance for the village compulsory. Quantitative and qualitative parameters of the technical service should be diverse, ranging from small private firms to inter engineering technological centers, technological and rolling stations, mobile mechanized squads for various purposes. Reducing the cost and improving the quality of services is possible only in conditions of competition service enterprises in the presence of extensive engineering market.

So, there is a hypothesis that to date is seen for the effective organization of operational efficiency of equipment in field conditions on farms (owners of equipment) on the basis of specialization and division of labor, changes in the existing material-technical base of farms or facilities maintenance, provision of agricultural producers with technical services in the “purchasing – operation - maintenance”, and the choice of contractor maintenance occurs on the basis of its technical and financial capabilities and distance to the owner of the equipment. This principle will reduce the downtime for technical reasons and thus to improve the efficiency of the entire technological complex of machinery in the field harvesting crops.

Key words: analytic, maintenance, machinery, system, implementation.

INTRODUCTION

System maintenance is an objective need for ensuring availability of machines in agriculture, but in the course of reforming the agrarian sector has undergone significant changes:

- ten times reduced volume of maintenance works,
- the number of service stations perials on the issue of “non-core” products, and some even ceased operations,
- the level of use of production capacities is from 10 to 36% depending on specialization
- the number of employees has decreased almost three times,
- availability of equipment has decreased due to the almost complete suspension of its serial production,
- existing equipment is obsolete and physically actuated,
- production and supply of agricultural farms of normative-technical documentation almost stopped,
- level delivery logistics decreased tenfold due to the sharp decline in purchases of farms machinery, equipment, spare parts, materials (fertilizers), metal, energy,
- manufacturers not engaged in the maintenance of their machines – are actually not responsible for substandard technique,
- the burden of service work has moved directly into sector, where halted construction of maintenance, industrial base is outdated or non-existent, there is a shortage of engineering personnel,
- the collapse of engineering structures of government, particularly the district level.

These features encourage the use of new forms of organization of maintenance. However, at present the issue of maintenance is not warranted little attention. And the questions that are developed in this region, usually very narrow and do not cover the entire scope of work, which includes maintenance. There is no clear theoretical justification of the system of maintenance in modern production environments of agro-industrial complex.

ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

A method of determining optimum maintenance period of the product, implemented when using the known device determine the optimum maintenance period of the product [1-3]. In the known method the optimal service period of the object is determined taking into account the factor of aging and the time allotted for maintenance [4-7]. Criterion optimization maintenance is the minimum coefficient of downtime for a given acceptable percentage of time maintenance of the product [8-10]. When implementing the known method solves the problem of increasing the accuracy of determining the optimal service period of the object [11-14]. This problem is solved due to the introduction of the second block multiplication, the second unit and the fourth delay element and also by changing the number of interconnects and inter-element relations [15-18].

The disadvantage of this method of determining optimum maintenance period of the facility is the limited sphere of use, namely, only for the object with the factor of aging failures of which are distributed according to the Rayleigh law, as well as routine maintenance work without taking into account the current state of reliability of the object [19].

The closest analogue in part of the method is a method of determining optimum maintenance period of the object, implemented using known devices to determine the optimal maintenance program of the system. The method is to implement the mathematical model, allowing to determine the temporal programme of maintenance to ensure optimal service intervals for each of the subsystems and the system as a whole [20].

The device realizing the known method is the closest analogue in of the device contains memory block, two block multiplication, three adder, two unit, subtracter, block nonlinearity, time sensor, comparator unit, integrator, three delay element, a scheme or waiting multivibrator, a memory element, a key, and the shift register [21].

However, the known method and device for determining optimum maintenance period of the product does not take into account the nature of the changes made to the current failure rate relative to operating conditions and types of operating devices [22].

The problem solved by the proposed method is to provide a method and system of determining the optimum time of the regular preventive maintenance of the facility as its reliability, in which time and cost expenses for carrying out preventive and repair work will not be above the cost of carrying out repair work without maintenance [23].

OBJECTIVE

The method of determining the time of the regular preventive maintenance of object and system for its implementation

THE MAIN RESULTS OF THE RESEARCH

The technical result is to determine the optimal time interval between adjacent maintenance on the current status of its reliability by taking into account time and money costs of preventive and repair work.

This is achieved in that in the method of determining the start time of the regular preventive maintenance of object and count the number ni of failures in the time interval from 0 to the i-th control preventive maintenance and measure the time tj between neighboring failures, conduct statistical analysis of failures of the object on the basis of which to build a histogram of failures of the object and select the value of the integer argument K, which using the formula of distribution of Erlang set the appropriate law of distribution of time between failures of the object, and estimate the failure rate λi of the object in each i-th point in time at a given confidence level β and compute the coefficients rH, rB, define respectively the lower and upper bounds of the confidence interval of the failure rate, to determine the time between adjacent maintenance of the object using a function in the form

$$Y(n_i)=\frac{\left[(K-1)!\sum_{l=0}^{K-1}\frac{\left(\lambda\sum_{j=1}^{n_i}t_j\right)^l}{l!}\right]\left[C_2/C_1-\ln\sum_{l=0}^{K}\frac{\left(\lambda\sum_{j=1}^{n_i}t_j\right)^l}{l!}\right]}{\sum_{j=1}^{n_i}t_j\left(\lambda\sum_{j=1}^{n_i}t_j\right)^K},$$

where: C1 – penalty for failure object, C2 – fine for preventative maintenance (PFR) of an object compute the critical function for the current value of cracks and for cracks, corresponding to the lower and upper limits of the confidence interval of the failure rate at a given time interval $Y_1=Y(r_H n_i,)$, $Y_2=Y\{n_i)$ and $Y_3=Y(r_B,n,)$, the decision to conduct a regular preventive maintenance take in that case, if $Y_1>Y_2>Y_3$ and $Y_3<1$, and if the number of failures $n<100$, the value of the integer parameter K corresponding to the law of distribution of time between failures of an object, select the shape of the histogram, if $n\geq 100$ – on the criterion of consent N. X2 or Kolmogorov χ^2.

System for determining the time of preventive maintenance contains the sensor failure object, the output of which is connected to the input of the counter of the number of failures, the output connected to the first input of the Central processor of the automated workplace of the operator of the control service, the unit of measurement of time between failures, is included between the sensor output and the second input of the Central processor, the third input of which is connected to the output unit of the information input and the first output to the input of the block display, the block selection of the distribution law of the random time between failures, the first input connected to a second output of the Central processor, and the second input with the output of the unit of measurement of time between failures, series-connected unit of a choice of confidence probability, a unit of determination of the confidence interval failures, the evaluation unit crucial functions and block decision-making, as well as the setpoint value of the fines, the output is connected to the fourth input of the Central processor, a fifth input connected to the output of the block selection of the distribution law of the random time between failures, the third output - with the input of the block selecting confidence probability, and the fourth output of the Central processor is connected with the second input unit determine the confidence interval of failures and the corresponding input unit of the calculation of decisive function, the other inputs of which are connected respectively to the outputs of the unit of measurement of time interval between failures, count bounce, the second and fifth outputs of the Central processor unit, a sixth output connected to a hardware and software device service operator preventive maintenance, and the sixth input-output block decision-making.

The total function of fines may be submitted to:

$$C = \lim_{t\to\infty} \frac{C_1 M\left[N_1(t)\right] + C_2 M\left[N_2(t)\right]}{t}$$

where: C1 – penalty for failure object, M[N1(t)] – mathematical expectation of the number of product failures in the interval [0,t], C2 – penalty for preventative maintenance (PFR) of an object, M[N2(t)] – expected number of preventive maintenance on the interval [0,t].

It is known that if the condition of a constant function failure rate after carrying out abnormally-recovery work fair the following relationship:

$$\lim_{t\to\infty} \frac{M\left[N_1(t)\right]}{t} = \frac{M\left[N(T_\Pi)\right]}{T_\Pi}$$

and

$$\lim_{t\to\infty} \frac{M\left[N_2(t)\right]}{t} = \frac{1}{T_\Pi}$$

where: M[N(TA)] – this function restores the device in the time interval [0,TP] between the two neighboring FIU.

It follows that:

$$C(T_\Pi) = \frac{C_1 M\left[N(T_\Pi)\right] + C_2}{T_\Pi}$$

and the function of the restorations:

$$M\left[N(T_\Pi)\right] = \int_0^{T_\Pi} \lambda(x)\,dx$$

where: λ(x) – failure rate of the object.

By minimizing the function S(TP) parameter TP you can find the best expression for the time interval between FIU:

$$T_{opt} = \frac{C_2 \big/ C_1 + \int_0^{T_{opt}} \lambda(x)\,dx}{\lambda(T_{opt})} = \frac{C_2/C_1 - \ln P(T_{opt})}{\lambda(T_{opt})}$$

where: P(Topt) – probability of failure of the object in the time interval Topt.

The formula is obtained taking into account the fact that:

$$P(T_{opt}) = \exp\left(-\int_0^{T_{opt}} \lambda(x)\,dx\right)$$

Then

$$\int_0^{T_{opt}} \lambda(x)\,dx = -\ln P(T_{opt})$$

Dividing the left and right side of the expression:

$$T_{opt}\ \frac{C_2/C_1 - \ln P(T_{opt})}{\lambda(T_{opt})}$$

at Topt, and given that Topt=nT T where nT is the expected number of failures of an object in the time interval [0,Topt], get:

$$\frac{C_2/C_1 - \ln P(n_T T)}{n_T T \lambda(n_T T)} = 1$$

The meaning of this expression is as follows. If the time interval between adjacent FIU chosen optimally, then the cost (time and money) to carry out maintenance and repair work between them will be equal to the average of the costs of conducting the repair work without the RPF. In the second case, the number of failures and restorations will naturally be more. If the time until the next PFR will be substantially more than the established optimum, it will lead to higher failure rate of the facility, increased costs for repair work compared to the optimal level. The left side of expression (1) is less than 1. In the case of a substantial decrease in the time interval until the next FIU will be additional costs for maintenance work, which will not cover the cost advantages from reducing the number of failures and recoveries as a result of additional. In this case, the left side of expression (1) will be greater than 1.

Thus, the formula (1) is the base for the development of rules for making decisions at the output of the object to another FIU based on the failure statistics of the object, the cost of the repair and maintenance work.

With this aim we introduce the function:

$$Y(n_i) = \frac{C_2/C_1 - \ln P(n_i T)}{n_i T \lambda(n_i T)} \triangleright 1$$

If $n_i = n_T$, than $Y(n_i)=1$.

As:

$$n_T T \equiv \sum_{j=1}^{n_i} t_j$$

where tj – random time between two consecutive failures,

$$Y(n_i) = \frac{C_2 \big/ C_1 - \ln P\left(\sum_{j=1}^{n_i} t_j\right)}{\sum_{j=1}^{n_i} t_j \cdot \lambda\left(\sum_{j=1}^{n_i} t_j\right)} \triangleright 1$$

Estimation of the failure rate of the object in the i-th moment control system maintenance for a given confidence probability β is made using the reference tables of the distribution χ^2 or Poisson distribution:

$$\hat{\lambda} = K \cdot n_i \Big/ \sum_{j=1}^{n_i} t_j$$

$$\hat{\lambda}_{min} = r_H \hat{\lambda},\ \hat{\lambda}_{max} = r_B \hat{\lambda}.$$

Coefficients rH, rB define the lower and upper bounds of the confidence interval of the parameter $\hat{\lambda}$.

From these expressions it follows that:

$$\sum_{j=1}^{n_i} t_j = \frac{K \cdot n_i}{\hat{\lambda}}$$

If the failure rate of an object is the number of failures per unit time, ni is the number of failures in the time interval from 0 to the i-th technical object. Therefore, there are strict upper and lower bounds on the number of failures in the time interval ni min=rHni, ni max=rBni.

This fact means that the crucial values of the function Y(ni) should be outside of the range of values of Y(GVP) and Y(GNP).

To describe a random time between failures of an object in terms of the tasks used appropriate use of such a universal distribution, so by changing its parameter it would be possible to transform it into one of the known, which is most appropriate for the description of available statistical data the time between failures of the device in question. Such a universal distribution of random time between failures can be erlang distribution of K-th order:

$$P(t)=\sum_{l=0}^{K}\frac{(\lambda t)^{l}e^{-\lambda t}}{l!}$$

and

$$\lambda(t)=\frac{\lambda^{K}t^{K-1}}{(K-1)!\sum_{l=0}^{K-1}\frac{(\lambda t)^{l}}{l!}}$$

By changing the integer parameter K transformerait the random distribution of time between failures in one of the famous. For example, if K=1 this distribution transformirovalsya in exponential, if K=2 in the Rayleigh distribution, when K>10 transformirovalsya in the normal distribution. The choice of a particular distribution, and therefore, the setting of parameter K, determined results of processing of statistical data, as well as engineering considerations on the nature of the wear of the object.

If the time between failures of the object is distributed according to the law of the erlang K-th order and according to the statistics of failures in the time interval from 0 to the current time control TM is installed, что $r_B n_i > n_T$, то решающая функция определяется неравенством $Y(r_B n_i)<1$.

If it is established that $r_B n_i \le n_T$, the decisive feature is equal to or exceeds the value $Y(r_B n_i)\ge 1$.

Indeed, since the functions λ{t) and P(t) is monotone and λ{t) is an increasing function, the rate of increase of the function tλ{t) is greater than the rate of increase of the function lnP(t).

Therefore, with the increase of time interval t decreases the value of the expression (3). Therefore, if $r_B n_i > n_i$, that $Y(r_B n_i)<Y(ni)$.

In accordance with the formula (2), Y(nT)=1. Therefore, if $r_B n_i > n_T$, the decisive function of $Y(r_B n_i)<1$. In $r_B n_i \le n_T$ fair condition $Y(r_B n_t)\ge 1$.

Thus, the decision rule that determines the need for another FIU as the frequency of failures of the object is set by the inequality:

$$Y(r_B n_i)<1.$$

In this case, when performing this calculation is the number of fixed failures exceed their expectation is beyond the expectations, increasing the failure rate of the object, which requires expeditious conduct regular preventive maintenance. The ability of the method is confirmed by specific example describing the system for determining the time of preventive maintenance as element of track facilities of the railway. Fig. 1 shows a block diagram of a system for determining the time of the next preventive maintenance item facilities.

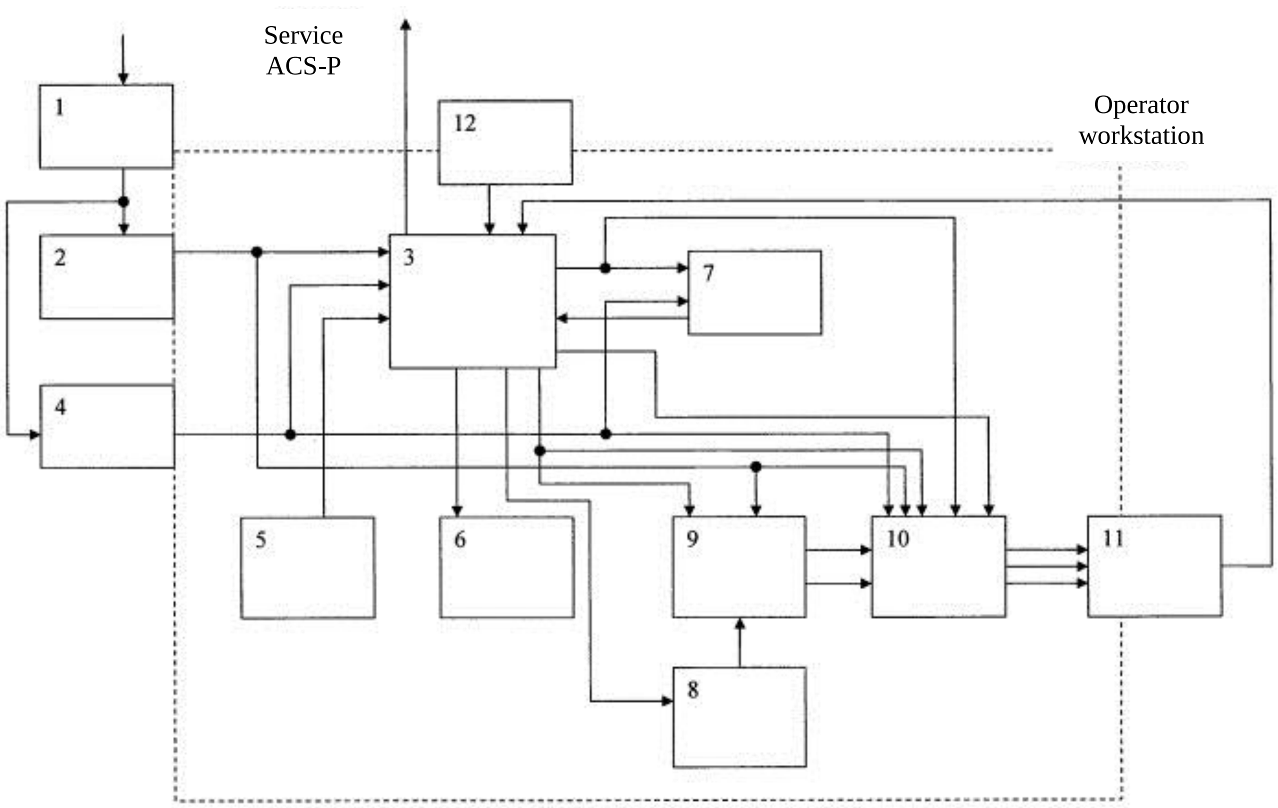

Fig. 1. Block diagram of system implementation for regular preventive maintenance of agricultural machinery.

The system includes a sensor 1 failure of the object, the output of which is connected to the input of counter 2. the number of failures, the output connected to the first input of the CPU 3 workstation 13 operator control service, block of 4 measuring the time between failures, is included between the output of the sensor 1 and the second input of the CPU 3, the third input of which is connected to the output unit 5 of the information input and the first output - to the input unit 6 display unit 7 choice of the distribution laws of random time between failures, the first input connected to a second output of the CPU 3, and second input-output unit 4 measuring the time between failure, connected in series block 8 choice confidence, the block 9 determine the confidence interval of failure, the control unit 10 calculate a critical function and the block 11 of the decision, as well as setpoint 12 value of fines, the output is connected to the fourth input of the CPU 3, the fifth input connected to the output of block 7 of the choice of the distribution laws of random time between failures, the third output with the input unit 8 choice confidence and the fourth output of the CPU 3 is connected with the second input unit 9, determine the confidence interval of failures and the corresponding input unit 10 calculation of decisive function, the other inputs of which are connected respectively to the outputs of block 4 measurement of time interval between failures, counter 2 the number of failures, the second and fifth outputs of the Central processor unit, a sixth output connected to a hardware-software device operator services of the automated management system of track facilities of ACS-P, and the sixth input to the output of block 11 of the decision.

The system works in the following way.

Sensor 1 failure signals from the automated ACS-P detects a failure of an element of the track of the economy within a given period of time, the counter 2 counts the number of failures ni, and sends the received data to a first input of the CPU 3 workstation 13 operator control service. At the same time the block 4 measuring the time between failures measures the time tj between failure and sends the measured data to the second input of the CPU 3.

The CPU 3 on the basis of the received data is the primary statistical processing of data, the results of which calculates the failure rate of each i-th time control element track management, builds a histogram of failures of the element according to time and sends it to the visual display unit 6. The intervals of sampling selects a service operator control and introduces them to the CPU 3 via the unit 5 input. To create a histogram using standard software tools e.g. MATLAB.

The operator analyzes the screen unit 6, the histogram, and the form pre-selects the type of distribution of a random time between failure-mi, which would not contradict the engineering considerations on the nature of the wear element of the study, and introduces to the CPU 3 via the unit 5 integer parameter K corresponding to the selected law of distribution.

In addition, the CPU 3 calculates the failure rate of the element in the i-th point in time $\hat{\lambda}$, an estimate of the number ni of failures in the time interval from 0 to the i-th control preventive maintenance of the facility. If $n_i>100$, the choice of the distribution law of the random time between failures of an element is carried out according to the criterion of consent A. N. Kolmogorov χ^2. This operation is performed in block 7 of the choice-of-law distribution. In this case, the CPU 3 generates a corresponding signal and displays the information about exceeding the allowable number of failures on unit screen 6 display. The operator is using the unit 6 selects the criterion of the consent and through the Central processing unit 3 transmits the value to the input unit 7, the other inputs of which receives information characterizing the failure in the i-th moment of time and values of time tj between failures.

In block 7 select the integer parameter K corresponding to the known law of distribution closest to the distribution of a random time between failure item on the results of statistical data processing.

At the same time the universal distribution of time between failures use the Erlang distribution of K-th order:

$$F(t) = 1 - \sum_{l=0}^{K} \frac{(\lambda t)^l e^{-\lambda t}}{l!}$$

where: l – index of summation, K – parameter corresponding to the failure distribution law for the object that is represented by the formula of erlang.

As you know, by changing the value of integer parameter K can be transformed to the random distribution of time between failures in one of the famous. For example, if K=1 this distribution is transformed into exponential, if K=2 in the Rayleigh distribution, when K=2 – in the Rayleigh distribution, when K>10 transformirovalsya in the normal distribution.

Thus, in block 7 choose the value of the parameter K which the estimated erlang distribution of K-th order most closely match selected by statistical processing of value functions and random distribution of time between failures of the item, as well as engineering considerations on the nature of the wear element.

From the output unit 7 information characterizing the selected parameter value To be transmitted to the corresponding input of the CPU 3.

The CPU 3 depending on the number ni bounce passes to the input of block 8 of the definition of confidence intervals of the failure value of the parameter To the output unit 5 or unit 7. Inputs of the unit 9 also receives information about the condence probability β and the number of failures ni, respectively, from the outputs of the block 9 and counter 2.

Unit 8 selection of trust information specifies the following values of β: 0,85, 0,9, 0.95 is. The selection of the appropriate value of the condence probability β carries the operator through the Central processing unit 3 through unit 5.

In unit 9 according to the known tables taking into account a given confidence probability β and the law of distribution of random time between failures (parameter K) determines the boundary values of the confidence interval bounce rH, rB, which is directed to respective inputs of the block 11 calculation of decisive function.

In addition, the input of the Central processor 3 is also fed information from the outputs of setpoint 12 value of fines - information on the amount C1 of the penalty for failure of an element of track facilities and C2 fine for the preventative maintenance item track facilities. Moreover, the value of the penalties C1 and C2 values are normalized. If the value of the constant C1, C2 depend on the object of preventive maintenance.

The CPU 3 calculates the ratio of C1 to C2, and sends the value of C1/C2 to one input unit 10 calculation of decisive function to the other inputs of which receives information about the failure rate and the distribution of a random time between failure K with the corresponding outputs of the Central processor 3, information about the number of failures ni - output of the counter 2 the number of failures, as well as information tj from the output unit 4.

According to the formula decisive function counting function $Y(r_H\ n_i,)$=Y1, $Y(n_i)$=Y2 and $Y(r_в,n_i,)$=Y3.

In block 11 of the decision check a condition $Y_1>Y_2>Y_3$. If the condition is true and at the same time $Y_3<1$, I take the decision to carry out regular maintenance. In this case, the corresponding information from the output unit 11 is sent to the corresponding input of the CPU 3, which forms a team to conduct the maintenance activities of the studied element tracks and sends it to the hardware and software of the device the operator of the service path and track facilities. Otherwise, the information team to carry out repair and maintenance work does not work researched element continues.

CONCLUSIONS

1. The method of determining the time of the regular preventive maintenance of object, lies in the fact that the time interval from 0 to the i-th control preventive maintenance of the facility count the number of failures ni and tj measure the time between adjacent failures, conduct statistical analysis of failures of the object on the basis of which to build a histogram of failures of the object and using the formula of erlang distribution of K-th order select the integer parameter K that corresponds to the law of distribution of time between failures of an object and also estimate the failure rate λi of the object in each i-th point in time at a given confidence level β and compute the coefficients GN, GW, defining respectively the lower and upper bounds of the confidence interval of the failure rate, to determine the time between adjacent maintenance of the object using a function.

2. System for determining the time of the regular preventive maintenance of the object containing the sensor bounce of the object, the output of which is connected to the input of the counter of the number of failures, the output connected to the first input of the Central processor of the automated workplace of the operator of the control service, the unit of measurement of time between failures, is included between the sensor output and the second input of the Central processor, the third input of which is connected to the output unit of the information input and the first output to the input of the block display, the block selection of the distribution law of the random time between failures, the first input connected to a second output of the Central processor, and the second input with the output of the unit of measurement of time between failures, a series-connected unit of a choice of confidence probability, a unit of determination of the confidence interval failures, the evaluation unit decides-ing functions, and the unit of decision making, as well as the setpoint value of the fines, the output is connected to the fourth input of the Central processor, a fifth input connected to the output of the block selection of the distribution law of the random time between failures, the third output - with the input of the block selecting confidence probability, and the fourth output of the Central processor is connected with the second input unit determine the confidence interval of failures and the corresponding input of the evaluation unit crucial functions the other inputs of which are connected respectively to the output of the unit of measurement of time interval between failures, count bounce, the second and fifth outputs of the Central processor unit, a sixth output connected to a hardware-software device operator preventive maintenance, and the sixth input - output block decision-making.

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We are pleased to announce that the magazine “MOTROL – Motorization and Energetics in Agriculture” (ISSN 1730-8658) has undergone a positive evaluation of the IC Journals Master List 2013, the result of which is granting the ICV Index (Index Copernicus Value) 6.56 pts. The resulting score was calculated on the basis of a survey submitted by the Editorial Team as well as assessments made by the professionals from Index Copernicus. We invite you to familiarize yourself with the methodology of IC Journals Master List evaluation:

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– Every page of the paper including the title page, text, references, tables and figures should be numbered,

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Note that the following should be observed:

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7. Kasaja O., Azarevich G. and Bannel A.N. 2017. Econometric Analysis of Banking Financial Results in Poland. Journal of Academy of Business and Economics (JABE), Vol. IV. Nr 1, 202–210.

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