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Қ. И. Сәтпаев атындағы Қазақ ұлттық техникалық зерттеу университеті

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ИЗВЕСТИЯ

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DEVELOPMENT OF MATHEMATICAL MODELS DESCRIBING THE PROCESSES OCCURRING IN THE RAILWAY TRACK CONSTRUCTION AS A WHOLE, OR IN THE WORK OF ITS INDIVIDUAL ELEMENTS

Abstract. The article presents the development of mathematical models describing the processes occurring in the construction of a railway track as a whole, or in the work of its individual elements, an example of calculating the stress-strain state of the soil of two-layer embankments filled from the soils of the South Kazakhstan.

Key words: ground, embankment, railway, roadbed, finite element model.

Introduction. When designing an earthen cloth in the traditional calculations of normal, tangential and principal stresses, it is conventionally assumed that the grounds under the influence of a temporary train load operate in an elastic stage. In this case, the calculations do not take into account the heterogeneity of the constituent embankments. In mathematical models of embankments, they are assumed to be isotropic.

Such design schemes and assumptions do not correspond to the actual load of the roadbed from the rolling stock. The top of the roadbed actually perceives the load from the ballast prism, which perceives the pressure of the sleeper sole. Behind the ends of sleepers, the top of the road bed is not loaded with a vertical train load [1-6].

As a consequence of this stresses distribution in the embankment body, in the initial period of railway embankments stabilization, longitudinal cracks running deep into the embankment, which are usually grounded by a uniform ground, can often be seen on their bumps.

In traditional calculations of the roadbed, the top track structure (rail type, sleepers, ballast prism sizes) and the earthen cloth shape (width of the main platform, steepness of the slopes, the presence of berms, etc.) are not taken into account, the characteristics of which significantly affect the distribution of the train load top of the roadbed and in the roadbed body.

In traditional calculations, the embankment sediments and the sediments of its base are considered as one-dimensional, although in fact deformations vary both along the path and the height of the embankment, that is, they are voluminous. Traditional calculations of the roadbed cannot calculate many modern ways of roadbed treating. The drawback of the traditional calculating method of the roadbed is the lack of a unified approach to assessing the mechanical properties of the roadbed. Thus, in calculating the embankments sediments and their bases, the ground is considered elastically deformable. When calculating the local and full stability of the embankment, it is considered that the ground is absolutely rigid. Also, different situations are possible, depending on the embankments arrangement from different types of grounds, which are not regulated by normative documents.

These drawbacks of the traditional calculations of the roadbed were due to the lack of computational computing systems and computing facilities (which are available today), as well as insufficient knowledge of the physical and mechanical (strength) properties of local grounds. It is obvious that with inaccurate initial data on the ground characteristics, precise numerical methods of calculations are inexpedient.

Thus, the article considers:

- improvement of the installation for ground testing on shear in order to determine reliable initial data, taking into account the influence of vibrodynamic and pulsating loads on the strength and deformation parameters of clay grounds of various types;
- development of mathematical models describing the processes occurring in the construction of the railway track as a whole, or in the work of its individual elements;
- an example of calculating the stress-strain state of groung of two-layer embankments spilled from the soils of the Southern region of Kazakhstan

A great contribution to the study of the stress-strain state under the train load, using detailed virtual prototypes of railway embankments, was made by the professor [5-13].

Theory of the question. Finite element models of railway embankments. When considering a rigid body as an undeformable (absolutely solid), it is described by its mass $m = \iiint \rho dv$, the moment of inertia with respect to an arbitrary axis $\vec{r}_0$ $I_{\vec{r}_0} = \iiint \rho[\vec{r}, \vec{r}_0]^2 dv$, the position of the center of inertia $\vec{r}_{(i.c.)} = \iiint \rho \vec{r} dv$, and the orientation $\vec{\varphi}$. All inertia moments of the body can be expressed through three moments of inertia relative to the main mutually perpendicular axes (passing through the center of inertia). The moment of inertia about an axis that does not pass through the center of inertia, located at a distance R from it, can be recalculated: $I = I_{(i.c.)} + R^2 \iiint \rho dv$. For a body of constant cross section, the moment of inertia of the section relative to the axis perpendicular to it can be introduced: $I_{\vec{r}_0(sec)} = \iint \rho[\vec{r}, \vec{r}_0]^2 ds$.

Deformations of a rigid body can be described by a displacement vector $\vec{u} = \vec{r}_{deformed} - \vec{r}$ of each point $\vec{r}$ of a solid body, but this description is convenient only for describing the change in the position of the entire body, but not its deformations. It is used to describe the motion of an undeformed body, since for this it is necessary to consider only the position of the center of mass and the orientation of the body ($\vec{r}_{(i.c)}$ and $\vec{\varphi}$).

To describe the deformations of a rigid body and the resulting stresses, such a method requires the introduction of additional quantities characterizing the relative displacements of the points of the solid body. Such a value is the strain tensor $\hat{\varepsilon}$, which is introduced by means of the expression: $(d_{\vec{r}_{deformed}})^2 - (d\vec{r})^2 = 2d\vec{r}\,\hat{\varepsilon}d\vec{r}$. The strain tensor $\varepsilon_{jk} = \frac{1}{2}\left(\frac{\partial u_j}{\partial x_k} + \frac{\partial u_k}{\partial x_j} + \frac{\partial u_j}{\partial x_k}\frac{\partial u_k}{\partial x_j}\right)$ – is a symmetric tensor that, when going over to the theory of linear deformations, is rewritten in the form: $\varepsilon_{jk} = \frac{1}{2}\left(\frac{\partial u_j}{\partial x_k} + \frac{\partial u_k}{\partial x_j}\right)$. It can be divided into two parts, characterizing the volumetric and shear deformation: $\varepsilon_{jk} = \frac{1}{3}\varepsilon ll\delta_{jk} + \left(\varepsilon_{jk} - \frac{1}{3}\varepsilon ll\delta_{jk}\right)$. The components of the strain tensor have no dimension.

The stress tensor, which characterizes the "strength" characteristics of the deformation of a rigid body, is determined by an expression $f_j = \sigma_{jk} n_k$, that makes sense if we consider within the body the

allocated volume, to which force $\vec{F}_{(in)} = \oint\int \hat{\sigma} d\vec{s} = \iiint div\hat{\sigma} dv$ and moment $\vec{M}_{(in)} = \oint\int [\vec{r}, \hat{\sigma} d\vec{s}] =$ $= \iiint [\vec{r}, div\hat{\sigma}] dv$ "acts", the same expressions are valid for the whole body. The components of the stress tensor have the dimensionality of pressure [14, 15].

When considering the linear theory of elasticity, the tensors of stresses and deformations are connected by means of a fourth-order tensor: $\sigma_{jk} = \lambda_{jklm} \varepsilon_{lm}$, all properties of which will not be described here. The tensor λ_{jklm} characterizes the elastic properties of matter and, in the most general case, has 21 independent components of 14. The elastic properties of isotropic substances are described by two independent components (6 for orthotropic substances). Naturally, the tensor λ_{jklm} itself can be a function of the coordinates if the substance is inhomogeneous. The components of the tensor λ_{jklm} have the dimension of pressure.

In many technical calculations, the elastic properties of substances are characterized by the Young's modulus E and the Poisson's ratio μ, they completely describe the elastic properties of an isotropic substance with linear elasticity, they are used for finite element calculations of technical structures. For problems with nonlinear elasticity characteristics, the quantities E and μ can be introduced as functions that depend on the local values of the strain tensor ε_{jk}. The Young's modulus of elasticity E has the dimension of pressure, and the Poisson's ratio μ is a dimensionless quantity. The deformed state of a rigid body is described by an equation connecting the stress tensor $\hat{\sigma}$ with the "external" forces $\vec{f}$ acting on the body and the acceleration of its individual points: $div\hat{\sigma} + \vec{f} = \rho\vec{a}$.

The application of methods for describing the motion of an absolutely elastic body to solids with finite values of elastic modules has an approximate nature.

For a complete description of the rigid body state, it is necessary to twice integrate the equation $div\hat{\sigma}(\vec{r}) + \vec{f}(\vec{r}) = \rho(\vec{r})\vec{a}(\vec{r})$ in which each of quantities is a coordinate function of the point $\vec{r} - 3$ of scalar quantities. If it is impossible to use any simplifying assumptions in the problem, then the order of the system is formally equal to infinity. Naturally, such problems in some cases allow an analytical description, but in practice this happens very rarely, and analytical methods are used only as approximate descriptions and approximations.

Classical calculation methods allow solving problems only with significant idealization, replacing the actual construction with its design scheme. The introduction of computer systems into engineering practice allows, using numerical methods, to perform calculations of almost any complex structure, breaking it into finite elements.

Standard engineering structures can be considered as combinations of structural elements connected by a discrete number of nodes. If the "force-displacement" relation is known for individual elements, then using the well-known techniques for calculating structures, one can obtain properties and study the behavior of the combined structure.

Many complex theoretical problems of the railway track could not be solved in the past due to the lack of appropriate computer technology and software. Today, this technique can be effectively used to solve urgent problems of track economy. New materials, new machines and technological processes and a new strategy for servicing the railway track affect its design and its characteristics.

It is advisable to begin the search for a constructive solution with the creation of a mathematical model and its analysis. The creation of the mathematical model is preceded by a comprehensive analysis of the behavior of the railway track during operation, the collection of load test characteristics, physical modeling of operational situations. The long-term work of the railways scientists of a number of countries has led to the establishment of important properties and elements characteristics of the force-displacement path that are necessary for preliminary assessment of the possible changes range in the initial data. Considerations of a qualitative nature are taken into account additionally and kind of "background" for mathematical modeling.

The models give an approximate mathematical description of the processes occurring in the railway track construction as a whole, or in the work of its individual elements.

Models contain the target optimized function and some set of constraints. Varying variables, objective functions and constraints constitute a mathematical optimization problem.

In physical modeling, it is usually possible to take into account only the main factors, and the influence of the unaccounted "background" should be checked when testing new path designs. The test system usually includes experimental research, operation on the experimental track sections of a number of railways, and then, after completion and sufficient testing, new technical solutions are fixed by standards for temporary and permanent use on the railways network. But the beginning of this complex path should not be the manufacture of an experimental design from drawings (the use of the trial and error method), but the study of new path design models or a new element in order to find and justify the parameters of reliable structural elements. Only when this is done, it is possible to manufacture prototypes for their further testing.

Recently, new mathematical models have been developed that describe a virtual prototype of the path design. They contain all of its elements, taking into account their technical condition. These models can describe a worn path or path with separate deviations from specifications [16-19].

In models as elements there are:

-rails;

- all elements of intermediate rail fastenings, namely: linings and gaskets, metal sub-rail pads with flanges, terminals of intermediate rail fasteners, mortgages and anchor bolts, nuts and washers;

- reinforced concrete sleepers with reinforcement, washers;

- crushed ballast prism;

-sand cushions, various options for reinforcing the ballast prism and earthen cloth with nets, carpets of non-woven materials, plates of expanded polystyrene.

Elements of the path in models have strictly corresponding to the actual geometric dimensions and physical properties.

EXPERIMENTAL PART. The use of the finite element method (FEM) for path constructions calculating. When calculating designs by this method, instead of the traditional design scheme, a precise geometric description of the structure is made, for which the following model objects are created: "points" (PT), "curves" and "lines" (CR), "contours" (CT), "surfaces" (SF) and "regions" (CP), "volumetric bodies" (VL, PH, PA). The types of finite elements that characterize their constants and physico-mechanical properties are declared. A finite element mesh can be created manually or with a parametric or automatic "splitting" of geometric objects, boundary conditions and loads can be declared for individual grid elements and for groups of elements associated with geometric objects. The design is calculated (in static, dynamics, oscillations, evaluation of the development of cracks, optimization of parameters, etc.). The results of calculations can be presented in the form of data lists, graphs, color diagrams and figures, "deformed species" or animation of the calculated processes (Figure 4).

The solution of linear static problems reduces to the solution of the matrix equation:

$$[R]\{U\} = \{F\},$$

where [R] is the square stiffness matrix; {U} is the vector of unknown node displacements; {F} is the vector of external influences.

The decision

$$\{U\} = [R]^{-1}\{F\},$$

reduces to the inversion of the rigidity matrix [R].

The load of a railway track by a moving rolling stock is a random process, depending on its design and parameters, axial loads, speed of movement, deformations of the path under load, irregularities on rails and wheels, dynamic qualities of rolling stock, variability of stiffness and dissipation characteristics, stresses, etc.

To ensure a complete similarity of the model in-kind, compliance with: geometric, mechanical, kinematic and dynamic similarity of the model in kind is required.

The difficulties of physical modeling usually consist in the impossibility of meeting the contradictory requirements of the determining similarity criteria while reducing the linear dimensions of the model. The search for self-similarity zones and domains of applicability of the equations makes it possible to partially solve these problems. When using "virtual prototypes" of models on a computer, there are no problems with linear dimensions and properties of materials.

The finite element model of the railway track is shown in figures 1 and 2.

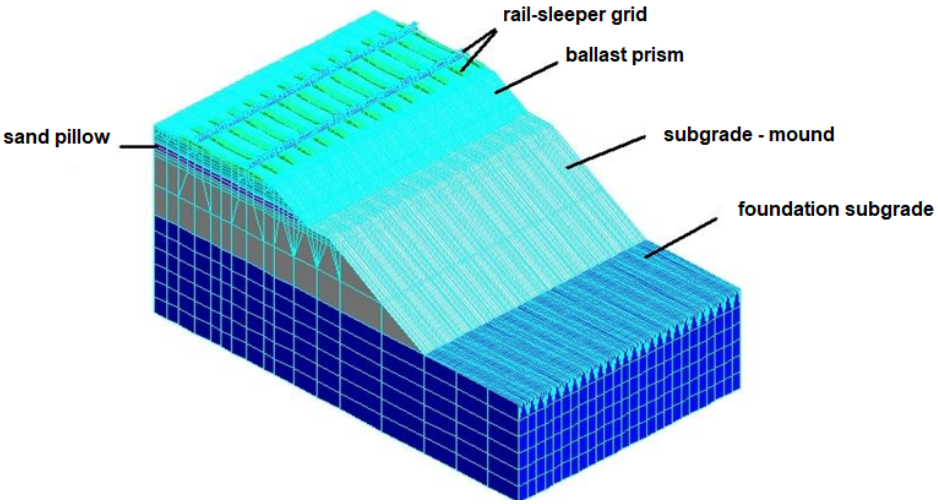

Figure 1 – Axisymmetric finite element model of the railway track section (double-track line)

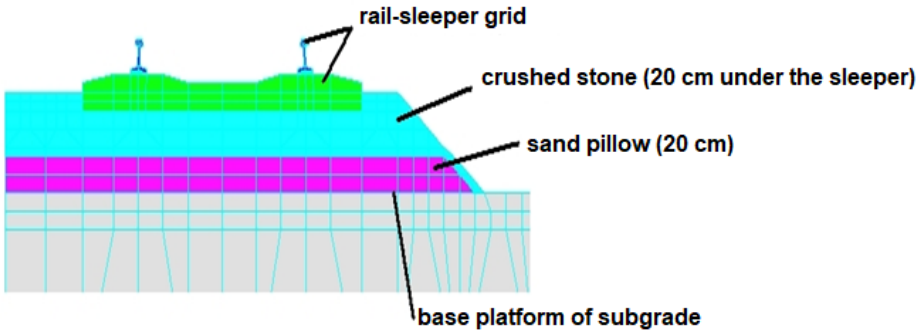

Figure 2 – Fragment of the axisymmetric finite element model of the railway track
(contact zone of the upper track structure and the roadbed top)

The above technique can be used for calculating the roadbed on a weak base and in the presence of karst cavities in the bottom of the embankment. The applicability of numerical calculations methods to the assessment of the stress-strain state of ground embankment is substantiated by numerous works of academician NAS of Kazakhstan Sh. M. Aitaliyev and his students [4].

Calculation of the stress-strain grounds state of two-layer embankments spilled from the grounds of the Southern region of Kazakhstan. Most of the time, the stresses in the ground embankment are determined by the intrinsic weight of the ground. On the axis of the embankment, they are equal to the hydrostatic pressure:

$$\sigma = \gamma \cdot h, t/m^2,$$

where γ – specific gravity of ground, t/m^3; h – distance from the top of the roadbed, m.

The train load causes the greatest additional stresses on the main area of the roadbed under the sleeper. With the removal down from the main site, these additional stresses decrease because of the spread to an ever larger area. Where σ- the stress component of the train load becomes less than σ> 0,1⊙hγ of hydrostatic pressure, the lower boundary of the working zone of the subgrade is located.

Consider the application of the numerical calculation method for the stress-strain state of a railway embankment using the example of a two-layer embankment on a solid foundation on a straight track. The characteristics of the two types of ground used for mound filling are given in table.

Calculation characteristics of a two-layer embankment ground

Characteristics of the ground layer	Modulus of deformation E, MPa	Poisson's ratio	Specific gravity, t/m^3
1st layer	16,0	0,25	1,7
2nd layer	5,0	0,30	1,75

The developed finite-element model of a two-layer embankment (cross-section) is shown in figures 3 and 4.

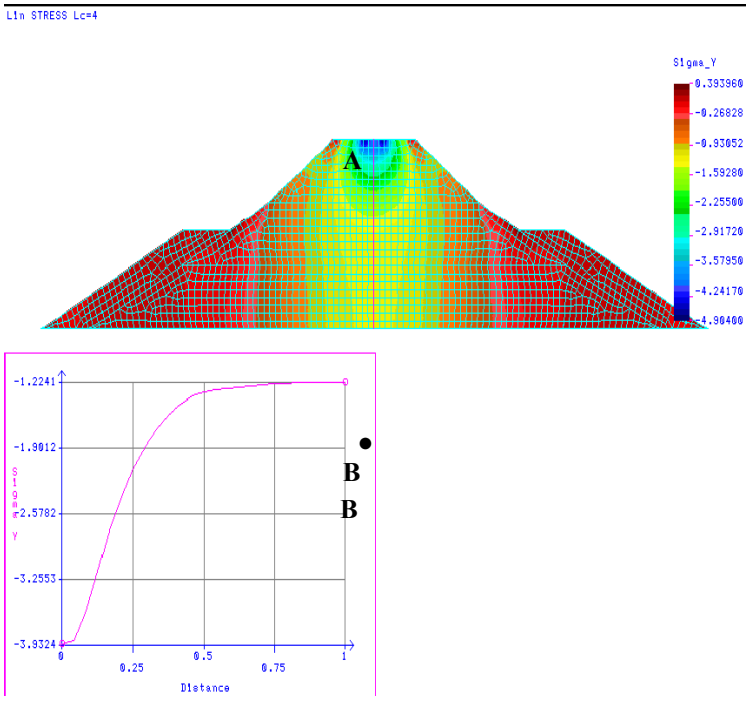

Figure 3 – Distribution of vertical stresses in the grounds embankmentfrom the train load at the device of berms. Line A-B – vertical along the axis of the embankment

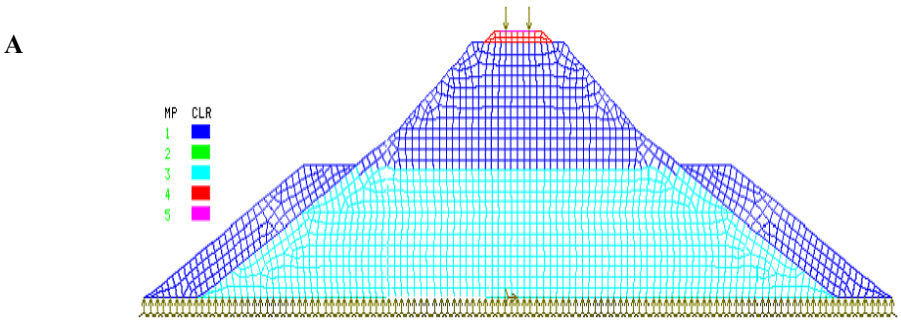

Figure 4 – Embankment variant with the device of two berms

Calculations are performed using the FEM method for distributing vertical stresses and complete displacements of the embankment grounds under a train load of 10 tf per running meter of railway track.

As the calculations have shown, the lower - less durable layer of the ground has the characteristic deformation of the spreading of the embankment (this can be seen on the vector plot of ground movement under load (figure 5). Despite the small absolute values of spreading slopes from a single loading, the rheological nature of the lower ground layer will lead to the need for straightening of the path lifting on rubble, which is associated with the costs and restrictions of the speed of the movement of trains.Structural measures are necessary to prevent such deformations of the ground embankment, for otherwise It is a long time in the operation of the path will have to lead the way on, lifting of the ballast and to limit the speed of the large local subsidence way.

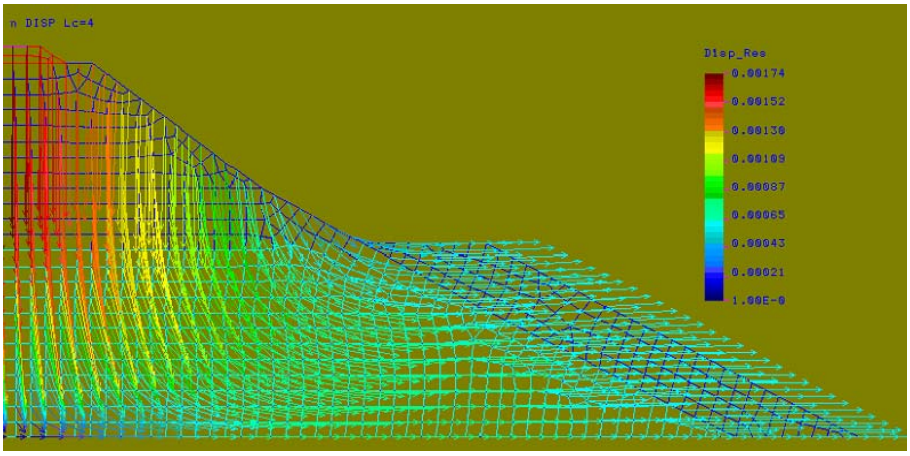

Figure 5 – Vector plot of mound deformations with the berms device

Considering two variants of embankment reinforcement: a 6 m high berm device and a "wall in the ground" device on the width of the main site of the roadbed in weaker ground (figure 6). We will perform calculations of these variants and compare the new data with the initial calculation.

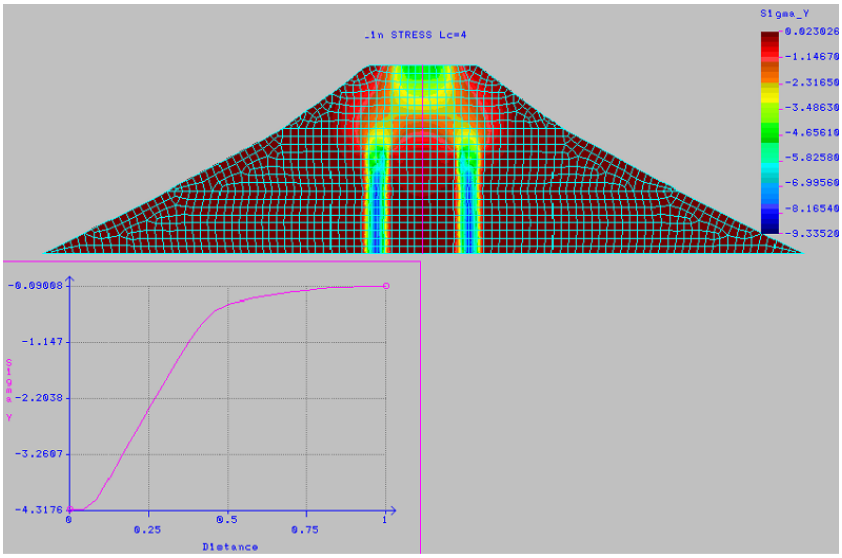

Figure 6 – Distribution of vertical stresses in the ground embankment from the train load when the wall is installed in the ground. Line A-B - vertical along the axis of the embankment

After installation of a double-sided berm 4m wide on rubble top, delivered by train, the transverse movements of the weak lower layer of the embankment decreased slightly. Vertical sediments from the train load exceed the deformations of the variant with the "wall in the ground" device. According to the calculation (figure 6) in the version of the device "walls in the ground", the sprawl of the ground in the projection of the main site of the embankment ceased (figure 7).

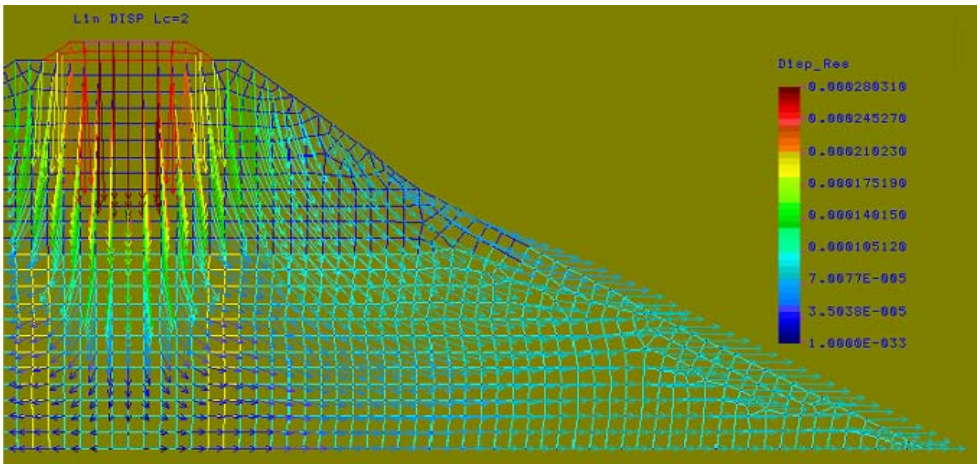

Figure 7 – Vector graph of mound deformations with the construction of a wall in the ground

The total elastic sediment of the embankment became smaller than in the version of the bilaterial berm apparatus. The mound stabilizes only when the width of the berm is 8 m.

Conclusion.

1. Appearance on the newly constructed railway sections of the "diseased roadbed" except for the violation of the technology of work is caused by the excessive use of standard designs, inaccuracy of the initial design data of the roadbed and the imperfection of traditional calculation methods, in which the ground embankments is considered as one-dimensionally deformable isotropic material under train load.

2. In cases where heterogeneous grounds are used for erecting a roadbed, it is recommended to check their stress-strain state under the train load by numerical methods.

3. It is recommended to use the finite-element virtual path model developed by us for calculating the stress-strain state of a layered embankment, including the upper structure and the earthen cloth.

4. To evaluate the possible plastic deformation of a less durable ground layer in the embankment ("creep in the mound"), it is recommended to calculate a vector plot of the ground displacement of the embankment under the train load. If the tangential stresses from the load exceed the permissible ground stresses, the lines of ground particles movement will noticeably deviate from the vertical and this is an indication of the need to reinforce the layered embankment.

5. Comparison of options for possible design solutions for the stabilization of layered embankments should be carried out according to their technical and economic indicators, while the characteristics of the stressed-deformed ground state in the embankments variants are equal.

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ЖАЛПЫ ТЕМІР ЖОЛ КОНСТРУКЦИЯСЫНДА НЕМЕСЕ ОНЫҢ ЖЕКЕЛЕГЕН ЭЛЕМЕНТТЕРІНІҢ ЖҰМЫСЫНДА БОЛЫП ЖАТҚАН ПРОЦЕСТЕРДІ СИПАТТАЙТЫН МАТЕМАТИКАЛЫҚ ҮЛГІЛЕРДІ ӘЗІРЛЕУ

Аннотация. Мақалада жалпы темір жол конструкциясында немесе оның жекелеген элементтерінің жұмысында болып жатқан процестерді сипаттайтын математикалық модельдерді әзірлеуге арналған. Қазақстанның оңтүстік аймағының топырақтарынан төгілген екі қабатты үйінділер топырағының кернеулі-деформацияланған жай-күйін есептеу мысалы келтірілген.

Түйін сөздер: топырақ, үйінді, темір жол, жер төсемі, ығыстыру.

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РАЗРАБОТКА МАТЕМАТИЧЕСКИХ МОДЕЛЕЙ, ОПИСЫВАЮЩИХ ПРОЦЕССЫ, ПРОИСХОДЯЩИЕ В КОНСТРУКЦИИ ЖЕЛЕЗНОДОРОЖНОГО ПУТИ В ЦЕЛОМ, ИЛИ В РАБОТЕ ЕГО ОТДЕЛЬНЫХ ЭЛЕМЕНТОВ

Аннотация. Статья посвящена разработке математических моделей, описывающих процессы, происходящие в конструкции железнодорожного пути в целом, или в работе его отдельных элементов. Приведен пример расчета напряженно-деформированного состояния грунта двухслойных насыпей, отсыпанных из грунтов Южного региона Казахстана.

Ключевые слова: грунт, насыпь, железнодорожный путь, земляное полотно, сдвиг.

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A NEW APPROACH TO THE EVALUATION OF BIOCLIMATIC POTENTIAL OF LANDSCAPES ON THE EXAMPLE OF NORTHERN KAZAKHSTAN

Abstract. Based on the laws of natural processes, an integrated model has been developed for assessing the bioclimatic potential of landscapes, which mainly includes an assessment of the productivity of vegetation and soil cover, allowing to determine the patterns of formation and functioning of landscape systems, depending on latitudinal zonality and altitude zonation for effective use of agricultural land and to identify their regional differences.

The development of the model and assessment of the bioclimatic potential of landscapes of the natural system is based on the methodology of system studies in the field of geography and ecology, as well as on methods of mathematical modeling of the production process in biology.

Based on the climatic index of the biological productivity of landscapes, D.I. Shashko (B_C) and the energy expended on soil formation, determined by the formula of V.R.Volobuev (Q_i) developed a mathematical model for assessing the bioclimatic potential of landscapes of the natural system, which were used to assess the bioclimatic potential of the landscapes of Northern Kazakhstan.

To assess the bioclimatic potential of the landscapes of the natural system of Northern Kazakhstan, the long-term data of meteorological monthly menus on the meteorological stations of the regions of Northern Kazakhstan, submitted by RSE "Kazgidromet" of the Republic of Kazakhstan, were used.

Analysis of the results of calculating the index of biological productivity of vegetation cover (B_C) and energy spent on the soil-forming process of landscape systems (Q_i) in Northern Kazakhstan indicates that they strictly obey the laws of geographical zoning. Consequently, the climatic index of the biological productivity of landscapes (C_l), which is determined by the ratio of such averaged indicator values as the soil cover productivity index (C_s) and the indicator of the climatic index of the biological productivity of the vegetation cover (C_{bv}) also strictly obey these laws of nature.

The proposed model of the climatic index of the biological productivity of landscapes (C_l) provides opportunities for a real assessment of the resource potential of the natural system when developing an adaptive landscape system of farming and a program of agricultural activities with an optimal load on the geoecosystem.

Based on the climatic index of the biological productivity of landscapes D. I. Shashko (B_c) and energy soil on soil formation, defined by the formula V. R. Volobuyev (Q_i) developed a mathematical model for estimation of bioclimatic potential of the landscapes of the natural system with the use of multi-year meteorological data monthly meteorological stations of the Northern regions of Kazakhstan, submitted to "Kazgidromet" RSE, defined by their quantitative values that can be more accurately determined by means of the climatic index of the biological productivity of landscapes (C_l).

Keywords: nature, landscape, climate, productivity, biology, ecology, potential, index.

Introduction. For the solution of problems of interaction between society and nature, as well as problems related to the understanding of the natural systems functioning, it is necessary to have a detailed description of the landscapes on the major factors, expressed in the form of some mathematical models to evaluate their natural resource potential.

Productivity of landscape systems is not reflected adequately in the existing methodological approaches and methods of assessment of the climate productivity, which requires the development of complex bio-ecological assessment methods of landscapes productivity on the basis of fundamental laws of nature, which should include private assessment of the productivity of its components, that is, soil productivity and vegetative cover.

A complex or integrated feature of climate, soil and other factors positively influencing the growth and development of plants and soils, representing the energy resources of natural systems should be understood under the bio-ecological assessment of productivity of landscapes. The environmental assessment productivity landscapes should be based on the use of geographical laws, manifested in the scale of territorial units of different hierarchical rank, which gives the possibility to explain the nature of the formation and functioning of landscape systems [1, 2].

Purpose of this study is to develop an integral model for the evaluation of bioclimatic productivity of landscapes, including mainly the assessment of plants and soil productivity, to determine the regularities of formation and functioning of natural systems depending on the latitudinal zonation and altitudinal zones for efficient use of agricultural lands and the identification of their regional differences.

Methods. As a theoretical basis for the development of the model, the concept of maximum productivity of Tooming X.G was used. (1977), the climatic productivity of A. Meyer's landscapes (1926), S.V. Torrentway (1931), N.N. Ivanova (1941), I.A. Prescott (1946), D.I. Shashko (1967) to determine the productivity of the climate, which reduces to the expression of the magnitude of the climatic coefficient of moistening, use the ratio of the sum of atmospheric precipitation to some function of the deficit of air humidity. R. Lang (1920), E. Marton (1926), S.V. Torentweit (1931), W. Keppen (1931), G.T. Selyaninov (1937), M.I. Budyko (1956), S.L. Merkin (1960) uses precipitation ratios and some air temperature functions as a relative characteristic of moisture supply. G.I. Vysotsky (1905), S.V. Torrentway (1931), N.N. Ivanov (1941), Blaine-Criddel (1950), A.N. Kostyakov (1951), V.Ya. Bakalo (1960) used certain evaporation functions as energy resources in determining the moisture content of geographic zones. The modern views of foreign scientists in the field of geography, biology and ecology, such as the estimation of plant productivity, formulated in the works of A.N. Polevoy (1983, 1988), as well as methods for assessing the microclimatic variability of climatic elements in hilly relief (EN Romanova, 1977; ZA Mishchenko, 1984). For a more detailed assessment of agroclimatic conditions, a ten-day period

Long-term data of meteorological monthly at the meteorological stations of the Northern regions of Kazakhstan, submitted by "Kazgidromet" RSE [3; 4] were used to assess the bioclimatic potential of the landscapes of the natural system of Northern Kazakhstan.

Model development and evaluation of bioclimatic potential of the natural system landscapes is based on the methodology of system researches in the field of geography and ecology, as well as on the methods of mathematical modeling of production process in biology. The methodology is based on: geo-systemic approach that considers natural environment as a single organized structure (landscape) consisting of a number of interconnected and interdependent components – surface layer of the atmosphere, climate, soil, vegetation, groundwater and surface water, and others. Fundamental here are the teachings of V.V. Dokuchayev – A.A. Grigoriev - M.I. Budyko – laws of evolution and geographical zonality of the landscape.

For a quantitative estimation of bioclimatic potential of the natural system landscapes, that is, formation of the production process of the plant and soil covers in the landscape system, the climatic index of biological productivity of landscapes of D. I. Shashko (B_c) [5] and energy spent on projects determined by the V. R. Volobuyev formula (Q_i) [6] are used.

Influence of heat and moisture landscapes on the biological productivity is expressed on a relative scale of bioclimatic potential of the natural system, that is the climatic index of biological productivity of vegetation landscapes of D. I. Shashko (1) [5]:

$$B_c = GF_{(wf)}[\ 100(\sum t > 10^0 C / \sum t > 10^0 C_0], \quad (1)$$

where B_c - climatic index of biological productivity of the vegetation cover of landscapes; $\sum t > 10^O C$ - the sum of average daily temperatures above +10°C, reflecting the amount of solar energy and heat provision of landscapes; $\sum t > 10^O C_o$ - the sum of average daily temperatures above 10°C, equal to the

initial zone of flow formation of river basins, equal to 1000 °C; $GF_{(wf)}$- growth rate for annual rate of atmospheric moisture, which is a ratio of productivity under these conditions moisture for maximum productivity in terms of optimal moisture, and is determined by the formula (2) [5]:

$$GF_{(wf)} = 1.15 \lg (20 \cdot M_d) - 0.21 + 0.63 \cdot M_d - M_d^2. \quad (2)$$

Where $M_d = O_c / \sum d$ - humidity index; O_c - atmospheric precipitation, mm; $\sum d$ - sum of the deficit of air humidity of biologically active period of the year, mb.

Thus, when the quantitative value of the humidity index will be equal within $Md = 0.50 \div 0.60$, value of the coefficient of growth $GF_{(wf)} = 1.0$ (figure 1) [5].

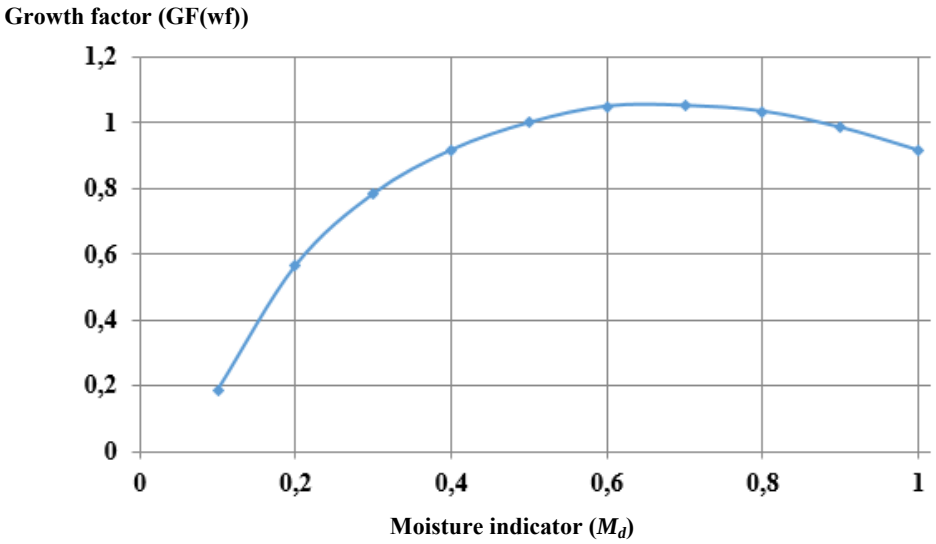

Figure 1 – The dependence of growth rate ($GF_{(wf)}$) of the humidity index (Md)

Bioclimatic potential, expressed in points, is an integral indicator is the main indicator for assessing agro-climatic importance of the climate and approximately displays biological productivity of zonal soil types, as the yield depends on soil fertility and characterizes the favorable climate [5], which gives the opportunity to determine the potential value of climatic index of biological productivity of vegetation at $GF_{(wf)} = 1.0$ (3):

$$Bpf = [\, 100 \cdot (\sum t > 10^0 C / \sum t > 10^0 C_0), \quad (3)$$

The climate index of the biological productivity of vegetation layer (Bp) to the potential value of climatic index of biological productivity of vegetation layer of natural systems at $GF_{(wf)} = 1.0$ (Bpf), that is, $C_{bv} = Bp / Bpf$ are indicators of climate index of vegetation biological productivity.

Energy consumed for soil formation, defined by the V. R. Volobuyev formula [6] to some extent characterizes the productivity of the soil landscapes (4):

$$Q_i = R \cdot \exp(-\alpha_o \cdot \overline{R}), \quad (4)$$

where Q_i - energy consumed for soil formation, kJ/cm^2; α_o - coefficient taking into account the condition of the soil surface.

In a natural system, the principle of energy balance of heat and moisture is observed in natural conditions, where the radiation index of dryness ($\overline{R}$) is equal to 1.0. Therefore, as a criterion of the radiative index of dryness ($\overline{R}$), you can take the limit in the range of 0.9-1.0.

Then, the potential energy expended on soil-forming process (Q_n) provides the potential productivity of the soil can be determined by expression (5):

$$Q_n = R \cdot \exp(-0.9 \cdot \alpha_O). \quad (5)$$

Consequently, the ratio of energy consumed for soil formation under natural conditions (Q_i) to the potential energy expended in soil-forming process (Q_n) represents the productivity of the soil landscapes, that is, $C_S = Q_i / Q_n$ [7].

Thus, the climate index of the biological productivity of landscapes (C_l) is determined by the ratio of such averaged indicator values as an indicator of the productivity of the soil surface (C_S) and the indicator of climatic index of biological productivity of vegetation (C_{bv}): $C_l = C_{bv} \cdot C_S$.

Thus, the developed model of climatic index of the biological productivity of landscapes allows, first, to give quantitative values of qualitative changes of habitats; secondly, modelling of transformation of natural systems under climate change; third, landscape-ecological zoning of the natural systems.

Results. The following parameters were used to assess the energy resources of the natural system of Northern Kazakhstan: the sum of air temperature ($\sum t$) above 10 °C, the amount of humidity deficit of air ($\sum d$, mb), evaporation (E_O, mm), photosynthetic active radiation (R, kJ/cm^2) and the amount of precipitation (O_C, mm) (table 1) [4].

As can be seen from table 1, the quantitative values and energy resources of Northern Kazakhstan decrease from Akmola region to the North-Kazakhstan region, but rainfall increases, according to the laws of geographic zonality. In this case, the sum of air temperature during biologically active periods of the year within Northern Kazakhstan range from 2051 to 3083°C.

Table 1 – Natural-energy resources of Northern Kazakhstan landscape systems

Weather stations	The absolute height (H), m	Indicators of natural and energy resources				
		$\sum t, ^oC$	$\sum d$, MB	E_O, mm	R, kJ/cm^2)	O_C, mm
Akmola region						
Yesil	219	2439	1633	951	139.1	372
Atbasar	303	2267	1504	884	133.4	386
Yeremen-Tau	397	2244	1509	875	132.6	444
Astana	347	2295	1556	895	134.3	411
Kokshetau	228	2241	1408	717	132.5	291
Shuchinsk	398	2051	1230	656	126.2	382
Kostanay region						
Kostanay	169	2359	1546	754	136.4	373
Tobol	207	2373	1537	759	136.9	403
Zhetigara	247	2311	1598	739	134.8	344
Arkalyk	343	2552	2370	817	142.8	373
Turgay	124	3083	2434	925	160.4	282
Pavlodar region						
Irtyshsk	93	2287	1418	732	134.0	359
Uspenka	112	2344	2180	750	135.9	330
Sherbakty	148	2377	1653	760	137.0	319
Pavlodar	144	2486	1510	795	140.6	352
Caldai	162	2369	2200	758	136.7	411
Ekibastuz	197	2511	1729	803	141.4	334
Chiderty	240	2338	2170	748	135.7	378
Bayan-aul	494	2410	1732	771	138.1	401
North-Kazakhstan region						
Ruzayevka	226	2242	1418	718	132.5	392
Bulayevo	132	2049	1202	655	126.1	320
Petropavlovsk	134	2081	1174	665	127.2	320
Yavlenka	114	2164	1283	692	129.9	310

Climatic assessment of landscape systems productivity in Southern Kazakhstan is defined on the basis of indicators characterized by a degree of endowments of the natural environment: humidity coefficient (*Wf*= O_C/ E_O) [8], index of dryness ($\overline{R} = R / LO_C$) [9], hydrothermal coefficient (*HTC*= *10*· O_C/ $\sum t$) [10], bio-climatic productivity (*BCP* = *Wf* ($\sum t$/*1000*) [10] and increased humidification ($M_d = O_C / \sum d$) [5] (table 2).

Table 2 – Climatic productivity of landscape systems in Northern Kazakhstan

Weather stations	The absolute height (*H*), m	Indicators of heat and humidity				
		Wf	*HTC*	*BCP*	M_d	$\overline{R}$
Akmola region						
Yesil	219	0.34	0.15	0.83	0.23	1.49
Atbasar	303	0.36	0.17	0.82	0.26	1.44
Yeremen-Tau	397	0.43	0.18	0.96	0.26	1.33
Astana	347	0.37	0.18	0.85	0.18	1.31
Kokshetau	228	0.43	0.16	0.96	0.26	1.45
Shuchinsk	398	0.51	0.17	1.05	0.31	1.32
Kostanay region						
Kostanay	169	0.39	0.16	0.92	0.24	1.36
Tobol	207	0.46	0.17	1.09	0.26	1.32
Zhetigara	247	0.40	0.15	0.92	0.22	1.56
Arkalyk	343	0.46	0.15	1.17	0.21	1.53
Turgay	124	0.16	0.09	0.49	0.12	2.27
Pavlodar region						
Irtyshsk	93	0.43	0.16	0.98	0.25	1.49
Uspenka	112	0.44	0.14	1.03	0.28	1.62
Sherbakty	148	0.32	0.13	0.76	0.19	1.72
Pavlodar	144	0.31	0.14	0.77	0.23	1.60
Caldai	162	0.54	0.17	1.28	0.22	1.33
Ekibastuz	197	0.32	0.13	0.80	0.19	1.69
Chiderty	240	0.51	0.16	1.19	0.24	1.44
Bayan-aul	494	0.38	0.17	0.92	0.23	1.38
North-Kazakhstan region						
Ruzayevka	226	0.43	0.17	0.96	0.26	1.35
Bulayevo	132	0.58	0.16	1.19	0.27	1.58
Petropavlovsk	134	0.56	0.15	1.17	0.21	1.59
Yavlenka	114	0.60	0.14	1.30	0.24	1.61

As can be seen from table 2, the parameters characterizing heat and moisture supply of Northern Kazakhstan landscape systems increase from the Southern to the Northern part of the region, taking into account the quantitative values of indicators of energy resources and rainfall. Thus, the humidity index (M_d) within Akmola region ranges from 0.18 to 0.26, Kostanay region – 0.12-0.26, Pavlodar region - 0.19-0.28 and North Kazakhstan region - 0.21-0.26.

On the basis of information and analytical materials presented in table 1 and 2, which characterize energy resources and heat and moisture supply landscape systems of Northern Kazakhstan, defines bioclimatic potential (*BCP*) and climatic index of biological productivity (B_C) of landscapes (table 3).

As can be seen from table 3, the climatic index of biological productivity (B_C) of landscape systems of Northern Kazakhstan in regions, that is, within Akmola region varies from 105.6 to 126.8, Kostanay

region – 101.7-128.1, Pavlodar region - 111.7-129.3 and North Kazakhstan region - 114.7-121.1 points, to a certain extent is provided by the similarity with the moisture ratio (*Wf*) [8], index of dryness ($\overline{R}$) [9], hydrothermal coefficient (*HTC*) [10], bio-climatic productivity *BCP* [10] and an indicator of hydration (M_d).

Table 3 – Bioclimatic potential (*BCP*) and climatic index of biological productivity (B_C) of Northern Kazakhstan landscape systems

Weather stations	The absolute height of terrain (*H*), m	Indicators of bioclimatic potential			
		M_d	$GF_{(wf)}$	$\frac{\sum t>10^o C}{\sum t>10^o C_o}$	B_C, points
Akmola region					
Yesil	219	0.23	0.52	2.439	126.8
Atbasar	303	0.26	0.54	2.267	122.4
Yeremen-Tau	397	0.26	0.54	2.244	121.2
Astana	347	0.18	0.46	2.295	105.6
Kokshetau	228	0.26	0.54	2.241	121.0
Shuchinsk	398	0.31	0.58	2.051	118.9
Kostanay region					
Kostanay	169	0.24	0.53	2.359	125.0
Tobol	207	0.26	0.54	2.373	128.1
Zhetigara	247	0.22	0.51	2.311	183.2
Arkalyk	343	0.21	0.50	2.552	127.6
Turgay	124	0.12	0.33	3.083	101.7
Pavlodar region					
Irtyshsk	93	0.25	0.55	2.287	125.8
Uspenka	112	0.28	0.57	2.344	133.6
Sherbakty	148	0.19	0.47	2.377	111.7
Pavlodar	144	0.23	0.52	2.486	129.3
Caldai	162	0.22	0.51	2.369	120.8
Ekibastuz	197	0.19	0.47	2.511	118.0
Chiderty	240	0.24	0.53	2.338	123.9
Bayan-aul	494	0.23	0.52	2.410	125.3
North-Kazakhstan region					
Ruzayevka	226	0.26	0.54	2.242	121.1
Bulayevo	132	0.27	0.56	2.049	114.7
Petropavlovsk	134	0.21	0.50	2.081	104.1
Yavlenka	114	0.24	0.53	2.164	114.7

The analysis of plant cover biological productivity index calculation results (B_C) and of the energy expended in the soil formation process landscape systems (Q_i) of Northern Kazakhstan suggests (table 4) that they strictly obey the laws of geographic zonality. Thus, the climate index of the biological productivity of landscapes (C_L) which is determined by the ratio of such averaged indicator values as an indicator of the productivity of the soil surface (C_S) and the indicator of climatic index of vegetation biological productivity (C_{bv}):

Table 4 – Climatic index of the biological productivity of landscapes (C_L), the index of soil surface productivity (C_S) and the indicator of climatic index of vegetation biological productivity (C_{bv}) of Northern Kazakhstan landscapes

Weather stations	Index of biological productivity						C_S
	of vegetation			of soil cover			
	B_C	B_{CP}	C_{bv}	Q_i	Q_n	C_S	
Akmola region							
Yesil	126.8	243.9	0.52	69.1	80.4	0.86	0.447
Atbasar	122.4	226.7	0.54	67.6	86.3	0.78	0.421
Yeremen-Tau	121.2	224.4	0.54	71.3	82.9	0.86	0.464
Astana	105.6	229.5	0.46	72.2	82.4	0.88	0.405
Kokshetau	121.0	224.1	0.54	67.1	82.8	0.81	0.437
Shuchinsk	118.9	205.1	0.58	67.9	78.9	0.86	0.498
Kostanay region							
Kostanay	125.0	235.9	0.53	68.4	85.2	0.80	0.424
Tobol	128.1	237.3	0.54	73.6	85.6	0.86	0.464
Zhetigara	183.2	231.1	0.79	64.9	84.3	0.77	0.608
Arkalyk	127.6	255.2	0.50	69.5	89.3	0.78	0.390
Turgay	101.7	308.3	0.33	55.0	100.3	0.55	0.181
Pavlodar region							
Irtyshsk	125.8	228.7	0.55	66.5	83.8	0.79	0.429
Uspenka	133.6	234.4	0.570	63.6	84.9	0.75	0.427
Sherbakty	111.7	237.7	0.47	61.6	85.6	0.72	0.338
Pavlodar	129.3	248.6	0.52	66.4	87.9	0.75	0.390
Caldai	120.8	236.9	0.51	73.5	85.4	0.86	0.438
Ekibastuz	118.0	251.1	0.47	64.1	88.4	0.72	0.338
Chiderty	123.9	233.8	0.53	68.7	84.8	0.81	0.429
Bayan-aul	125.3	241.0	0.52	70.8	86.3	0.82	0.426
North-Kazakhstan region							
Ruzayevka	121.1	224.2	0.54	70.6	82.2	0.85	0.459
Bulayevo	114.7	204.9	0.56	60.4	78.8	0.77	0.431
Petropavlovsk	104.1	208.1	0.50	60.7	79.5	0.76	0.380
Yavlenka	114.7	216.4	0.53	60.7	81.2	0.75	0.397

Thus, the proposed model for the evaluation of bioclimatic potential of landscapes in natural systems, compared to the humidity index (M_d) and climatic index of biological productivity (B_C) of the landscapes is characterized in that the first model allows to estimate any of the fundamental predictors of vegetation and soil cover, to determine the resource potential and productivity of landscapes, and secondly the soil and climatic potential of landscapes installed using the most important indicators such as increased soil productivity, which is determined on the basis of the energy expended in the soil formation process in natural conditions and the climate indicator index of biological productivity of vegetation, providing a comprehensive accounting of climate and environmental conditions of natural systems.

Discussion. Based on the climatic index of the biological productivity of landscapes D. I. Shashko (B_C) and energy expended on soil formation, defined by the V. R. Volobuyev formula (Q_i) developed a mathematical model of the bioclimatic potential of landscapes in natural systems taking into account the formation and functioning of the soil and vegetation of landscape systems..

The comparative assessment of the climatic index of the biological productivity of landscapes (C_L), which is determined by the ratio of such averaged indicator values as the indicator of soil cover productivity (C_S) and the indicator of the climatic index of the biological productivity of the vegetation

cover (C_{bv}) also strictly obey these natural laws with the existing methods for assessing the climatic productivity of the natural system, that is, the wetting factor ($Wf = O_C/E_O$) [8], the dryness index ($\overline{R} = R/LO_C$) [9], the hydrothermal coefficient ($HTC = 10 \cdot O_C/\sum t$) [10], the biology productivity (see table 2 and 4), that they have many similarities, they also obey the laws of geographical zoning, only differ in quantitative values, characterizing the qualitative state of the natural system.

The proposed model opens up possibilities for a realistic assessment of the resource potential of natural systems in the development of adaptive-landscape farming systems, and agricultural program activities with optimal load on geoecosystem.

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СОЛТҮСТІК ҚАЗАҚСТАН ЖАҒДАЙЫНДА ЛАНШАФТТАРДЫҢ БИОКЛИМАТТЫҚ ӘЛЕУЕТІН БАҒАЛАУДЫҢ ЖАҢА ЖОЛЫ

Аннотация. Табиғи жүргінің заңдылықтарының негізінде, құрамында өсімдік және топырақ жамылғысының өнімділігін бағалауға бейімделген, ландшафттардың биологиялық-климаттық әлеуетін бағалауға арналған интегралдық үлгісі құрылған. Ал ол ландшафттық жүйелердің ендік аймаққа және биіктіктік белдеулікке байланысты қалыптасу және қызмет ету заңдылықтарын анықтай отырып ауылшаруашылыққа арналған жерлерді тиімді пайдаланудың жолдарын және аймақтық өзгешілігін анықтай алады.

Табиғи жүйенің ландшафттарының биологиялық-климаттық әлеуетінің үлгісі және оны бағалау география және экология саласының жүйелік зерттеу әдістемесіне және биология ілімінің өнімдік жүргісі математикалық үлгілеудің әдісіне негізделген.

Солтүстік Қазақстанның ландшафттарының биологиялық-климаттық әлеуетін бағалау үшін, Д.И. Шашконың ландшафттық биологиялық өнімділігінің климаттық белгісін ($Б_к$) және В.Р. Волобуевтың топырақтың түзілуіне шығын болатын күн сәулесінің қуатын (Q_i) анықтауға арналған өрнегінің негізінде табиғи жүйенің ландшафттарының биологиялық-климаттық әлеуетінің үлгісі құрылған.

Солтүстік Қазақстанның табиғи жүйелерінің ландшафттарының биоклиматтық әлеуетін бағалау үшін Қазақстан Республикасының «Қазгидромет» РМК-ның Солтүстік Қазақстан облыстарының метеорологиялық бекеттерінің көпжылдық орташа айлық мәліметтік деректері пайдаланылды.

Солтүстік Қазақстанның ландшафттық жүйелерінің өсімдік жамылғысының биологиялық өнімділігінің белгісін ($Б_к$) және топырақтың түзілуіне жұмсалған энергия қуатын (Q_i) есептеудің нәтижелерін талдау негізінде, олардың географиялық аймақтандыру заңдылығына қатаң түрде сәйкес келетіндігі көрсетілді. Сондықтан, топырақ жамылғысының өнімділігінің өлшемдік көрсеткіші (K_n) және өсімдік жамылғысының биологиялық өнімділігінің климаттық белгісінің ($K_{бр}$) ортақтасқан көрсеткіштердің арақатынасымен анықталатын, ландшафттардың биологиялық өнімділігінің климаттық белгісі ($K_л$) табиғи заңдылықтарға қатаң түрде сәйкес келеді.

Ландшафттардың биологиялық өнімділігінің климаттық белгісін анықтауға ұсынылып отырған үлгі ($K_л$), егіншіліктің бейімделген-ландшафттық жүйесін құру кезінде табиғи жүйелердің қорлық әлеуетін шынайы бағалауға және геологиялық-экологиялық жүйеге түсетін жүктемені оңтайлау арқылы ауылшаруашылық қызмет бағдарламаларын әзірлеуге мүмкіндік береді.

Түйін сөздер: табиғат, ландшафт, климат, өнімділік, биология, экология, әлеует, индекс.

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НОВЫЙ ПОДХОД К ОЦЕНКЕ БИОКЛИМАТИЧЕСКОГО ПОТЕНЦИАЛА ЛАНДШАФТОВ НА ПРИМЕРЕ СЕВЕРНОГО КАЗАХСТАНА

Аннотация. На основе законов природных процессов разработана интегральная модель для оценки биоклиматического потенциала ландшафтов, включающая преимущественно оценку продуктивности растительного и почвенного покровов, позволяющих определить закономерности формирования и функционирования ландшафтных систем в зависимости от широтной зональности и высотной поясности для эффективного использования земель сельскохозяйственного назначения и выявления их региональных различий.

Разработка модели и оценка биоклиматического потенциала ландшафтов природной системы базируется на методологии системных исследований в области географии и экологии, а также на методах математического моделирования продукционного процесса в биологии.

На основе климатического индекса биологической продуктивности ландшафтов Д.И. Шашко ($Б_к$) и энергии, затрачиваемой на почвообразование, определяемой по формуле В.Р. Волобуева (Q_i), разработана математическая модель для оценки биоклиматического потенциала ландшафтов природной системы, которые использованы для оценки биоклиматического потенциала ландшафтов Северного Казахстана.

Для оценки биоклиматического потенциала ландшафтов природной системы Северного Казахстана, использованы многолетние данные метеорологических ежемесячников по метеорологическим станциям областей Северного Казахстана, представленные РГП «Казгидромет» Республики Казахстан.

Анализ результатов расчета индекса биологической продуктивности растительного покрова ($Б_к$) и энергии, затраченной на почвообразовательный процесс ландшафтных систем (Q_i) Северного Казахстана свидетельствует о том, что они строго подчиняются законам географической зональности. Следовательно, климатический индекс биологической продуктивности ландшафтов ($K_л$), который определяется соотношением таких осредненных индикаторных величин, как показатель продуктивности почвенного покрова ($K_п$) и показатель климатического индекса биологической продуктивности растительного покрова ($K_{бр}$) тоже строго подчиняются этим законам природы.

Предложенная модель климатического индекса биологической продуктивности ландшафтов ($K_л$) открывает возможности для реальной оценки ресурсного потенциала природной системы при разработке адаптивно-ландшафтной системы земледелия и программы сельскохозяйственной деятельности с оптимальной нагрузкой на геоэкосистему.

Ключевые слова: природа, ландшафт, климат, продуктивность, биология, экология, потенциал, индекс.

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SIMULATION OF THREE-PHASE TRANSFORMER OPERATIONAL CONDITIONS

Abstract. With the purpose of improvement of power transformer current protection, it is necessary to know their behavior in various operating modes. This article is concerned with the mathematic simulation of three-phase power transformer operating modes. Building of mathematical model was carried out according to the equivalent circuit for double-wound transformer, that takes into account, apart from resistance and reactive resistance, mutual induction resistance and loads. The proposed mathematical model, written as a system of differential equation system, is universal, since it describes all the possible operating modes that occur during the operation of power double-wound intact transformer. The adequacy of the proposed mathematical model is confirmed by the results of experiments performed. Comparison of simulation results and experiments showed that the simulation error does not exceed the allowable values for relay protection.

Key words: transformer, mathematical model, protective relay, current protection.

The behavior analysis of a three-phase transformer protective relay is carried out under natural operational conditions and in an emergency operation mode. At the same time, considerable attention is paid to transient phenomena [1, 2].

As a rule, most of the time while in operation, the transformer runs in a steady state, and transients occur in it when switching from one steady state to another one, for example, when the voltage of the electrical network or load changes, and when the transformer is hooked up or during a short circuit. In turn, emergency transients in transformers occur during sudden short circuits in the windings, load or network [3, 4].

The process of energy conversion in transients and steady-state modes in the three-phase transformers is described to the fullest extent possible by a mathematical model with phase coordinates, the differential equations of which are built for phase voltages according to Kirchhoff's law [3-5]. However, such a model is not able to simulate these processes in transformers when voltage or load is unbalanced, since in this case the phase voltages are unknown. In addition, the calculated values of currents and voltages are obtained in reduced, but not in a natural form. To solve these problems is proposed as follows.

The circuit for the generation of differential equations of the mathematical model with the phase coordinates of a three-phase transformer is shown in figure 1.

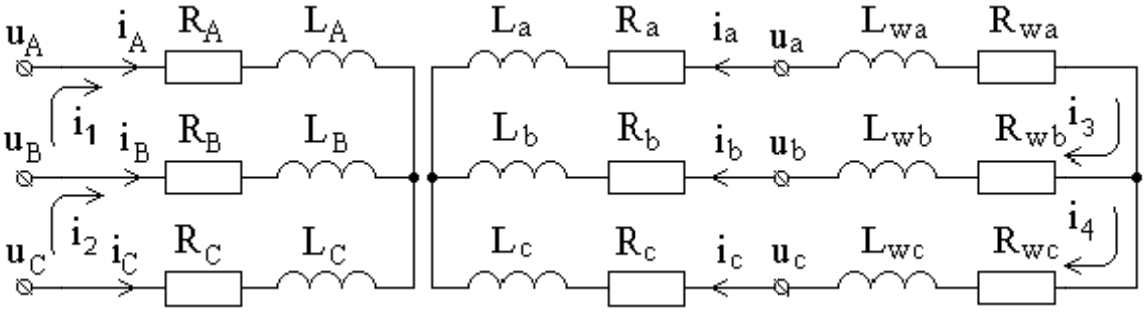

Figure 1 – Three-phase double-wound transformer circuit

In accordance with this circuit and [5], the operation of a three-phase transformer at a balanced voltage in the network and a balanced load is described by a system of differential equations

$$\left.\begin{aligned} u_A &= R_A i_A + d\psi_A/d \\ u_B &= R_B i_B + d\psi_B/dt \\ u_C &= R_C i_C + d\psi_C/d \\ 0 &= (R_a + R_{wa} + jL_{wa})i_a + d\psi_a/dt \\ 0 &= (R_b + R_{wb} + jL_{wb})i_b + d\psi_b/dt \\ 0 &= (R_c + R_{wc} + jL_{wc})i_c + d\psi_c/dt \end{aligned}\right\}, \qquad (1)$$

where u_i, i_i – instantaneous phase voltages and currents in the primary and secondary windings (i = A, B, C and a, b, c); R_i and ψ_i – resistance and flux linkages of primary and secondary windings; $Z_{wi} = R_{wi} + jL_{wi}$; R_{wi} and L_{wi} – resistance and load inductance of phase (i = a, b, c).

The flux linkages of primary and secondary windings are expressed in terms of phase current and relevant inductance as follows:

$$\begin{aligned} \psi_A &= i_A L_A + i_B L_{AB} + i_C L_{AC} + i_a L_{Aa} + i_b L_{Ab} + i_c L_{Ac}, \\ \psi_B &= i_A L_{BA} + i_B L_B + i_C L_{BC} + i_a L_{Ba} + i_b L_{Bb} + i_c L_{Bc}, \\ \psi_C &= i_A L_{CA} + i_B L_{CB} + i_C L_C + i_a L_{Ca} + i_b L_{Cb} + i_c L_{Cc}, \\ \psi_a &= i_A L_{aA} + i_B L_{aB} + i_C L_{aC} + i_a (L_a + L_{wa}) + i_b L_{ab} + i_c L_{ac}, \\ \psi_b &= i_A L_{bA} + i_B L_{bB} + i_C L_{bC} + i_a L_{ba} + i_b (L_b + L_{wb}) + i_c L_{bc}, \\ \psi_c &= i_A L_{cA} + i_B L_{cB} + i_C L_{cC} + i_a L_{ca} + i_b L_{cb} + i_c (L_{Cc} + L_{wc}). \end{aligned} \qquad (2)$$

It should be noted that in formulas (1) and (2) there used inductances associated only with the main magnetic flux in the transformer. In accordance with [6], the exact calculation of the inductance and inductive reactance of the windings in a three-phase transformer is rather complicated. However, if it is granted that the magnetic circuit of the transformer is not saturated, then they can be simplified as follows:

If the phase voltage U_l, the no-load current I_{nl} of the transformer and the resistance of the primary winding R_l are known, then the impedance and inductive reactance of the primary winding phase, as well as its inductance L_l, can be calculated [6] as follows:

$$Z_l = \dot{U}_l / \dot{I}_{nl}, \quad X_l = \sqrt{Z_l^2 - R_l^2}, \quad \text{a } L_l = X_l / 2 \cdot \pi \cdot f_c, \qquad (3)$$

where f_c - network frequency. It should be added that the phase voltage U_l, no-load current I_{nl} and resistance R_l of the primary winding are easy to determine experimentally.

Providing that the inductances of the transformer windings are proportional to the square of the number of turns, then the inductance of the secondary winding and the mutual induction of the primary and secondary windings are calculated as

$$L_2 = (w_2/w_1)^2 \cdot L_1 \quad \text{and} \quad L_{12} = \left((w_1 \cdot w_2)/w_1\right)^2 \cdot L_1, \tag{4}$$

where w_1 and w_2 - number of turns in primary and secondary windings.

As a result, in mathematical expressions (1) and (2) the own inductances of the phases of the primary and secondary windings

$$L_A = L_B = L_C = L_1 \quad \text{and} \quad L_a = L_b = L_c = L_2. \tag{5}$$

In this setting mutual inductance between the phases of the windings

$$\begin{gathered} L_{AB} = L_{BC} = L_{CA} = L_1/2 \text{ and } L_{ab} = L_{bc} = L_{ca} = L_2/2, \\ L_{Aa} = L_{Bb} = L_{Cc} = L_{Ac} = L_{Ba} = L_{Cb} = L_{Ab} = L_{Bc} = L_{Ca} = L_{12}. \end{gathered} \tag{6}$$

The resistance of the phases of the primary and secondary windings

$$R_A = R_B = R_C = R_1 \quad \text{and} \quad R_a = R_b = R_c = R_2, \tag{7}$$

where R_1 and R_2 - resistance of the phases of the primary and secondary windings of the transformer. They can be calculated by the known cross section and the length of the windings wire. In practice, the values of these resistances are easiest to obtain by measuring.

Since it is impossible to use the system of equations (1) when there is an unbalanced voltage in the network or an unbalanced load, in this case the differential equations of the mathematical model should be composed by the mesh-current method. A similar result can also be achieved by the rearrangement of the system of equations (1) in terms of subtracting the corresponding lines [5, 6] with the subsequent replacement of the phase currents by the loop currents. As a result of the corresponding lines

$$\left.\begin{aligned} u_{AB} &= i_A R_A - i_B R_B + d\psi_{AB}/dt \\ u_{BC} &= i_B R_B - i_C R_C + d\psi_{BC}/dt \\ 0 &= i_a (R_a + R_{wa}) - i_b (R_b + R_{wb}) + d\psi_{ab}/dt \\ 0 &= i_b (R_b + R_{wb}) - i_c (R_c + R_{wc}) + d\psi_{bc}/dt \end{aligned}\right\}, \tag{8}$$

where flux linkages

$$\begin{aligned} \psi_{AB} &= i_A (L_A - L_{AB}) + i_B (L_{AB} - L_B) + i_C (L_{AC} - L_{BC}) + \\ &+ i_a (L_{Aa} - L_{Ba}) + i_b (L_{Ab} - L_{Bb}) + i_c (L_{Ac} - L_{Bc}), \end{aligned} \tag{9}$$

$$\begin{aligned} \psi_{BC} &= i_A (L_{AB} - L_{AC}) + i_B (L_B - L_{BC}) + i_C (L_{BC} - L_C) + \\ &+ i_a (L_{Ba} - L_{Ca}) + i_b (L_{Bb} - L_{Cb}) + i_c (L_{Bc} - L_{Cc}), \end{aligned} \tag{10}$$

$$\begin{aligned} \psi_{ab} &= i_A (L_{aA} - L_{bA}) + i_B (L_{ab} - L_{bB}) + i_C (L_{ac} - L_{bc}) + \\ &+ i_a (L_a + L_{wa} - L_{ba}) + i_b (L_{ab} - L_b - L_{wb}) + i_c (L_{ac} - L_{bc}), \end{aligned} \tag{11}$$

$$\begin{aligned} \psi_{bc} &= i_A (L_{Ba} - L_{Ca}) + i_B (L_{bB} - L_{cB}) + i_C (L_{bc} - L_{cC}) + \\ &+ i_a (L_{ba} - L_{ca}) + i_b (L_b + L_{wb} - L_{cb}) + i_c (L_{bc} - L_c - L_{wc}). \end{aligned} \tag{12}$$

The replacement of the phase currents by the loop currents is carried out by applying the equations

$$i_A = i_1,\ i_B = i_2 - i_1,\ i_C = -i_2,\ i_a = i_3,\ i_b = i_4 - i_3,\ i_c = -i_4, \tag{13}$$

which are composed according to the circuit in figure 1.

As a result, after substituting formulas (13) into the system of equations (8) and rearranging it, it is possible to obtain a new system in terms of

$$\left.\begin{aligned} u_{AB} &= i_1(R_A + R_B) - i_2 R_B + d\psi_1/dt \\ u_{BC} &= (i_2 - i_1)R_B + i_2 R_C + d\psi_2/dt \\ 0 &= i_3(R_a + R_b + R_{wa} + R_{wb}) - i_4\left(R_b + R_{wb}\right) + d\psi_3/dt \\ 0 &= (i_4 - i_3)\left(R_b + R_{wb}\right) + i_4\left(R_c + R_{wc}\right) + d\psi_4/dt \end{aligned}\right\}. \tag{14}$$

In this system of flux linkage of the circuits

$$\begin{aligned} \psi_1 &= i_1 L_{11} + i_2 L_{12} + i_3 L_{13} + i_4 L_{14}, \\ \psi_2 &= i_1 L_{21} + i_2 L_{22} + i_3 L_{23} + i_4 L_{24}, \\ \psi_3 &= i_1 L_{31} + i_2 L_{32} + i_3 L_{33} + i_4 L_{34}, \\ \psi_4 &= i_1 L_{41} + i_2 L_{42} + i_3 L_{43} + i_4 L_{44}. \end{aligned} \tag{15}$$

In this case internal inductances of the circuit

$$\begin{aligned} L_{11} &= L_A - 2 \cdot L_{AB} + L_B, \\ L_{22} &= L_B - 2 \cdot L_{BC} + L_C, \\ L_{33} &= L_a + L_{wa} - 2 \cdot L_{ab} + L_b + L_{wb}, \\ L_{44} &= L_b + L_{wb} - 2 \cdot L_{bc} + L_c + L_{wc}, \end{aligned} \tag{16}$$

and mutual inductances of these circuits, consequently

$$\begin{aligned} &L_{12} = L_{21} = L_{AB} - L_{AC} - L_B + L_{BC},\ L_{23} = L_{32} = L_{Ba} - L_{Bb} - L_{Ca} + L_{Cb}, \\ &L_{13} = L_{31} = L_{Aa} - L_{Ab} - L_{Ba} + L_{Bb},\ L_{24} = L_{42} = L_{Bb} - L_{Bc} - L_{Cb} + L_{Cc}, \\ &L_{14} = L_{41} = L_{Ab} - L_{Ac} - L_{Bb} + L_{Bc},\ L_{34} = L_{43} = L_{ab} - L_{ac} - L_b + L_{bc}. \end{aligned} \tag{17}$$

Such mathematical model makes it possible to simulate the processes in a transformer at both unbalanced supply voltage and unbalanced load. In this case, the currents in all windings of the transformer are obtained in their natural form, which, in turn, greatly facilitates the analysis of processes in any transients.

The switching from one steady state to another one involving system of equations (14) is simulated as follows. At the initial instant of the transformer transient mode, the currents $i_1 \div i_4$ in the primary and secondary windings are taken to be equal to these currents as they are at the time when the previous mode ends. For example, when the transformer is hooked up into the network, the currents $i_1 \div i_4$ in the primary and secondary windings are taken to be equal to zero. The time of the process under study is divided into time intervals with duration Δt and it is considered that the currents $i_1 \div i_4$ within each time interval are constant. When passing from time interval q to time interval q+1, these values are calculated using the formulas below.

In a transient mode, the current in circuit i [7] is calculated as the sum of the current i_{pi} of the periodic (forced) and aperiodic (free) components, i.e.

$$\dot{i}_i = \dot{i}_{pi} + \dot{i}_{ai}. \tag{18}$$

The periodic component of current i in the time interval q is sought as a particular solution of the system of non-homogeneous equations obtained from (14). In this system, voltages are considered to be sinusoidal, and differentiation operator d/dt is replaced by jω [7]. As a result, system (14) is transformed to

$$\left.\begin{aligned}
\dot{U}_{AB} &= \left[\left(R_A + R_B\right) + jX_{11}\right]\dot{I}_1 + \left(-R_B + jX_{12}\right)\dot{I}_2 + jX_{13}\dot{I}_3 + jX_{14}\dot{I}_4 \\
\dot{U}_{BC} &= \left(-R_B + jX_{21}\right)\dot{I}_1 + \left[\left(R_B + R_C\right) + jX_{22}\right]\dot{I}_2 + jX_{23}\dot{I}_3 + jX_{24}\dot{I}_4 \\
0 &= jX_{31}\dot{I}_1 + jX_{32}\dot{I}_2 + \left[\left(R_a + R_b + R_{wa} + R_{wb}\right) + jX_{33}\right]\dot{I}_3 + \left[\left(-R_b + R_{wb}\right) + jX_{34}\right]\dot{I}_4 \\
0 &= jX_{41}\dot{I}_1 + jX_{42}\dot{I}_2 + \left[\left(-R_b + R_{wb}\right) + jX_{43}\right]\dot{I}_3 + \left[\left(R_c + R_b + R_{wc} + R_{wb}\right) + jX_{44}\right]\dot{I}_4
\end{aligned}\right\}, \tag{18}$$

where inductances are calculated as $X_{vw} = \omega L_{vw}$, and v and w take on a value from one to four.

The aperiodic component of the current i_{ai} is sought as a full solution of a system of homogeneous differential equations. This system is also derived from (14), taking $u_{AB} = 0$ and $u_{BC} = 0$. In the numerical solution of this system dt and di in it are replaced by Δt and Δi. Then the components of the resistance voltage drop are transposed to the left-hand side of the equations. As a result, the change in currents Δi in the circuit elements over the time interval is calculated by solving the system of equations

$$\left.\begin{aligned}
\left[R_B i_2 - \left(R_A + R_B\right) i_1\right]\Delta t &= L_{11}\Delta i_1 + L_{12}\Delta i_2 + L_{13}\Delta i_3 + L_{14}\Delta i_{14} \\
\left[R_B i_1 - \left(R_B + R_C\right) i_2\right]\Delta t &= L_{21}\Delta i_1 + L_{22}\Delta i_2 + L_{23}\Delta i_3 + L_{24}\Delta i_{14} \\
\left[R_b i_4 - \left(R_a + R_b\right) i_3\right]\Delta t &= L_{31}\Delta i_1 + L_{32}\Delta i_2 + L_{33}\Delta i_3 + L_{34}\Delta i_{14} \\
\left[R_b i_3 - \left(R_b + R_c\right) i_4\right]\Delta t &= L_{41}\Delta i_1 + L_{42}\Delta i_2 + L_{43}\Delta i_3 + L_{44}\Delta i_{14}
\end{aligned}\right\} \tag{19}$$

Since at the initial instant of the transformer transient mode, the currents in the circuits are taken to be equal to these currents as they are at the time when the previous mode ends, the aperiodic component of the current in them at the time of load-break switch contact closure is taken to be equal to the periodic component but with the opposite sign. And its value in circuit i within the interval q+1 is calculated as

$$\dot{i}_{ai,q+1} = \dot{i}_{ai,q} + \Delta_{ai,q}. \tag{20}$$

Thus, the obtained mathematical model allows simulating almost all steady-state and transient processes in an intact three-phase transformer.

This mathematical model verification was carried out using an experimental transformer of TSZI-6 type (three-phase dry-type self-cooled transformer), in which the transformed secondary winding had 12 turns of copper wire with a cross section 2,5 mm^2. Parameters of this transformer are shown in table. Rheostats with a resistance of 6.7 Ohm were used as the load.

Parameters of an experimental transformer of TSZI-6 type

Parameters of transformer of TSZI-6 type	Notation	Value
Phase voltage, V	U_1	230
No-load current, A	I_{nl}	0,31
Number of turns in primary/secondary windings	w_1/w_2	447/12
Resistance of primary/secondary windings, Ohm	R_1/R_2	1,26/0,06
Load resistance, Ohm	R_w	0,165-6,7
Load inductive reactance, Ohm	X_w	0

The results of simulation and experiment in the form of currents in the windings of the experimental transformer at a balanced voltage in the network and a balanced load depending on its value are shown in figure 2, where the first are represented by lines and the other one - by dots. To simulate the processes on a PC, the application package MATLAB 6.1 was used.

Correlation of the results of calculations and experiments shows that the modeling error in the whole range of allowable loads does not exceed 10-12%.

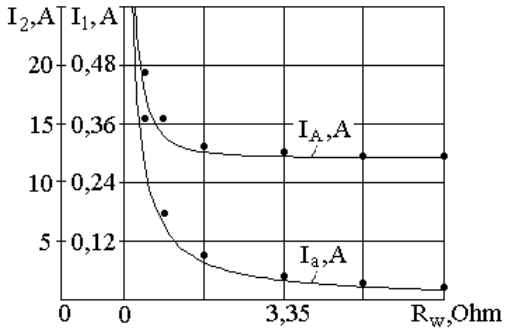

Figure 2 – The results of simulation and experiment of currents
in the windings in the transformer of TSZI-6 type at a balanced supply voltage and load

Figures 3, a and 3, b show the results of the simulation of currents in the windings in the transformer of TSZI-6 type at an unbalanced supply voltage and an unbalanced load. The relationships in figure 3, a are obtained at $U_{AB} = 0{,}8U_l$, $U_{BC} = U_l$ and $U_{CA} = U_l$, where U_l is the line voltage of the network. In turn, the relationships in figure 3, b were obtained at an unbalanced load specified as $R_{wa} = 0{,}7R_w$, $R_{wb} = 0{,}7R_w$ and $R_{wc} = 0{,}7R_w$.

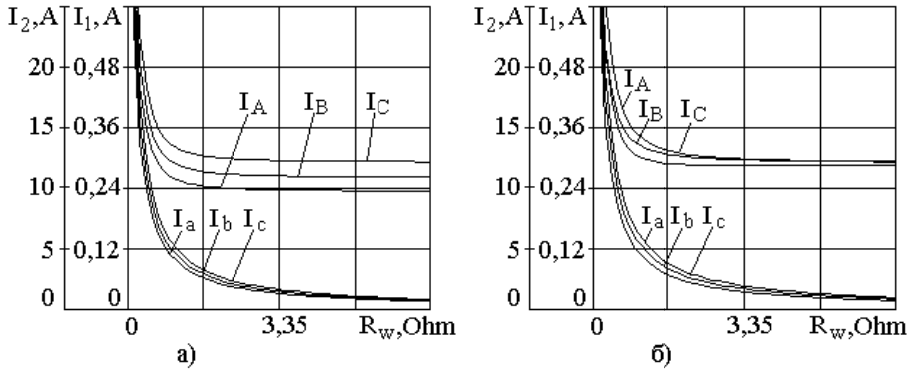

Figure 3 – The results of the simulation of currents in the windings
in the transformer of TSZI-6 type when there is unbalance of supply voltage and load

The capabilities of the mathematical model, when simulating transients, were carried out using, as an example, a three-phase short circuit at the secondary winding end at $R_w = R_d = 0{,}165$ Ohm, where R_d is the arc resistance. The simulation results in the form of currents in primary and secondary windings are shown in figure 4. Correlation of the results of calculations and the experiment shows that the modeling error does not exceed 10%.

Figure 4 – The results of the simulation of currents in the phase A windings
in the transformer of TSZI-6 type in event of a three-phase short circuit at the secondary winding end

Thus, the proposed mathematical model of a three-phase transformer makes it possible to simulate the currents magnitudes in its windings in both steady-state mode and transient mode with accuracy acceptable for protective relay.

The process of energy conversion in the three-phase transformers in event of unbalance of supply voltage and load in transients and steady-state modes is described to the fullest extent possible by a mathematical model, the differential equations of which are composed using the mesh-current method for line voltage.

The modeling error of currents in the transformer windings in the whole range of allowable loads when there is unbalance of supply voltage and load, as well as in transients applying this model does not exceed 10-12%.

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ҮШ ФАЗАЛЫ КҮШ ТРАНСФОРМАТОРЫНЫҢ ЖҰМЫС РЕЖІМДЕРІН МАТЕМАТИКАЛЫҚ ҮЛГІЛЕУІ

Аннотация. Күш трансформаторларының тоқ қорғанысын жетілдіру үшін олардың түрлі пайдаланушылық режімдердегі әрекеттерін білу қажет. Осы мақала үш фазалы күш трансформаторының жұмыс режімдерін математикалық үлгілеуге арналған. Математикалық үлгіні құру екі орамалы трансформаторды алмастыру сызбасы бойынша жүзеге асырылған, онда белсенді және реактивті кедергілерден басқа өзара индукция мен жүктеу кедергісі ескерілген. Дифференциалдық теңдеулер жүйесі түрінде жазылған ұсынылған математикалық үлгі әмбебап, өйткені ол зақымдалмаған екі орамды күш трансформаторын пайдаланған кезде туындайтын барлық мүмкін жұмыс режімдерін сипаттайды. Ұсынылған математикалық үлгінің баламалылығы жүргізілген тәжірибелердің нәтижелерімен расталған. Үлгілеу және тәжірибелердің нәтижелерін салыстыру үлгілеудің ауытқуы релелік қорғаныс үшін мүмкін мәндерден артпайтынын көрсетеді.

Түйін сөздер: трансформатор, математикалық үлгі, релелік қорғаныс, тоқ қорғанысы.

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МОДЕЛИРОВАНИЕ ЭКСПЛУАТАЦИОННЫХ РЕЖИМОВ РАБОТЫ ТРЕХФАЗНОГО ТРАНСФОРМАТОРА

Аннотация. Для совершенствования токовых защит силовых трансформаторов необходимо знать поведение их в различных эксплуатационных режимах. Данная статья посвящена математическому моделированию режимов работы трехфазного силового трансформатора. Построение математической модели осуществлено по схеме замещения двухобмоточного трансформатора, в которой учитывались, кроме активных и реактивных сопротивлений, сопротивления взаимоиндуции и нагрузки. Предлагаемая математическая модель, записанная в виде системы дифференциальных уравнений, универсальна, так как она описывает все возможные режимы работы, которые возникают при эксплуатации силового двухобмоточного неповрежденного трансформатора. Адекватность предложенной математической модели подтверждена результатами проведенных экспериментов. Сопоставление результатов моделирования и экспериментов показало, что погрешность моделирования не превышает допустимых значений для релейной защиты.

Ключевые слова: трансформатор, математическая модель, релейная защита, токовая защита.

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THE COMPARATIVE ANALYSIS OF COMPUTER MODEL OPERATION OF TOOTH GEARING WITH EVOLVENT GEARING AND NOVIKOV'S GEARING

Abstract. In the article settlement sizes of the maximum contact tension by techniques of various authors taking into account solutions of Hertz are specified, researches on comparison of load ability of elements of the gears with evolvent gearing applied in the drives of ball mills and gears with Novikov's gearing are considered. The numerical finite element models (FEM), calculated tooth gearing and boundary conditions and also calculation the stress-strain state of FEM by means of the programs MSC/Patran, MSC/Nastran are developed.

As a result of research the load ability of Novikov's gearing from conditions of contact endurance of active surfaces of teeths which is higher, than for gears with evolvent gearing, with the same overall dimensions, owing to the big specified radius of curvature of the contacting teeths is established.

Keywords: tooth gearing, Novikov's gearings, evolvent gearing, tooth module, finite element model, deformation, tension.

The efficiency and economic indicators of modern machines in various industries depend to a considerable extent on the performance of gear drives. Creation of tooth gearing with high performance criteria ensures the improvement of not only drives, but also machines in general, and this is relevant for modern mechanical engineering. One of the ways to improve gear drives is the development of tooth gears with increased load capacity and a long service life.

The creation by Michael Leontievich Novikov [1-3] in the middle of the 20th century of the original gearing system as an alternative to evolvent gearing was revolutionary character, accompanied by a surge of large-scale research and large investments, multifaceted industry projects and demonstrative examples of industrial implementation. One of the most significant advantages of Novikov's gearings was an extraordinarily large margin for contact resistance of the teeth and, as a result, high constructive flexibility [1].

There is a number of works on a comprehensive evaluation of Novikov's gearing, in the experience of theoretical research and practical results of using these gearings in the industry was generalized [4].

Comparative estimates of Novikov's gearings with evolvent gearing are most often based on understating evolvent gearing indicators and overvaluation of Novikov's gearing parameters. Kinematic principle of pointwise spatial engagement M.L. Novikov is based on axial intermating of the teeth (with the failure of the conditions for the end overlap with point conjugation of the end profiles of the interacting teeth and the approximation of the centers of their curvature to the instantaneous axis of rotation) and proceeds from the conclusions [3], which are presented in the following form:

- conclusion No. 1 - on the independence of the contact strength of the teeth at the linking pole from the shape of the tooth profiles and from the gearing system;

- conclusion No. 2 - about the absence of the possibility of a noticeable decrease in contact stresses in gears with an initial-linear touch of the teeth;

- conclusion No. 3 - about a particularly favorable (with a tenfold increase in the thickness of the oil layer) hydrodynamics of contact lubrication of Novikov's gearing;

- conclusion No. 4 - about the possibility of a significant reduction in contact stresses exclusively in the pointwise non-polar Novikov's gearing.

All the conclusions are completely justified within the framework of the accepted physical basis, in which even theoretically Novikov's point contact was initially modeled by the compression of parallel elastic cylinders-their radiuses are equal to the radiuses of the normal curvature of the screw contact lines of the interacting teeth.

The initial solution of the contact problem was proposed by Hertz for two possible variants of the initial contact: point and linear.

As is known in Hertz theory, the following calculated assumptions are accepted [5]:

1) The contacting bodies are smooth and uncoordinated (smoothness means no risks, scratches, defects in the contact zone, and inconsistency is a difference in the shape of the profiles of the contacting bodies).

2) The compressive force is normal to contact areas and its line of action passes through the centers of sections of curvilinear surfaces

3) Only normal pressures act within the contact area, while frictional forces are neglected

4) The dimensions of the contact pads are small in comparison with the surfaces of the contacting bodies and the radii of their curvature

5) Only elastic deformations occur in the contact zone, and the material of the bodies satisfies Hooke's law.

The result of solving the problems of Hertz depends in principle on the type of initial contact.

For a point contact, we have the following basic relationships:

$$p_m = \left[P\left(\frac{1}{R_1}+\frac{1}{R_2}\right)/\left(\frac{1}{E_1}+\frac{1}{E_2}\right)\right]^{\frac{1}{2}}, \quad (1)$$

where R_1, R_2 - the radiuses of the contacting cylinders, P - the normal force of compression arising under compression, E - the modulus of elasticity.

The greatest contact stress σ_H is determined by the formula

$$\sigma_H = \frac{3}{2}\cdot\frac{P}{\pi ab}, \quad (2)$$

where a, b - semiaxes of contact ellipses.

It should be noted that assumptions 1 and 2 suggest the inapplicability of classical Hertz formulas for point contact in Novikov's gearing, since at the tooth's beginning, the tooth profile of the gear wheel and the cogwheel has a geometrically consistent shape (figure 1) [6].

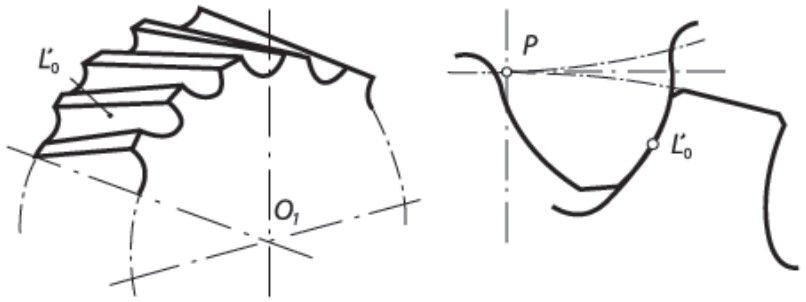


Figure 1 – Novikov's gearing with a convex concave butt-end profile of the tooth

The failure of the theory in the classical form is confirmed by the calculated values of σ_{max}, found by the methods of various authors developed with allowance for the Hertz solutions given in table 1 [1].

Table 1 – Settlement values of the maximum contact tension by techniques of various authors

Determined values	Information sources				
	Hertz [7]	Kovalev M.N. [5]	Makushin M.I. [6]	VNIINMACH [1]	IMACH [3]
$\sigma_{\max}$, МПа	9771	3843	9818	4473	3206
$\varphi_\sigma = \frac{\sigma_{\max}}{\sigma^*_{\max}}$	14,00	5,50	14,06	6,41	4,60
$\varphi_F = \varphi_\sigma^3$	2743	167	2783	263	97

From table 1 it follows that the calculated values of the stresses are approximately 14 times higher than the voltage σ_{max} = 698, taking place in Novikov's gearing. The indicated increase of σ_{max} corresponds to a decrease in the loading ability of the Novikov's gearing by contact stresses.

To compare the physical nature of the contact in evolvent gearing and Novikov's gearing, we refer to the experimental data of the author M.I. Sakhanko [7], dealing with the issues of contact endurance of steels, depending on the geometric parameters of the dimensions of the contacting bodies. The author introduces the concept of the material's resistance in the contact zone and provides a formula for determining the contact voltage with allowance for the coefficients ϑ_1, ϑ_2- coefficients that take into account the curvature of the contacting bodies at the point of their mutual contact

$$\sigma_{max} = \frac{4100}{\vartheta_1 \cdot \vartheta_2} \sqrt{P\left(\sum_\rho \frac{b}{a}\right)^2}, \quad (3)$$

where P - load, $\sum_\rho \frac{b}{a}$ - the sum of the curvature of the contacting bodies. Experiment was established for a circular contact $\frac{b}{a} = 1$ composition $\vartheta_1 \cdot \vartheta_2$=1, and for elliptic surfaces the pressure $\frac{b}{a} = 0{,}05$, for surfaces close to a linear contact, the product $\vartheta_1 \cdot \vartheta_2$=2 (figure 2).

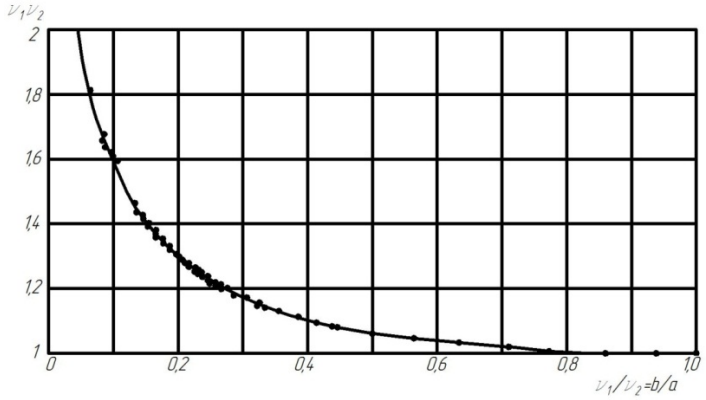


Figure 2 – The interrelation between the product of the coefficients ϑ_1, ϑ_2 and their ratio $\frac{\vartheta_1}{\vartheta_2} = \frac{b}{a}$

"Along the way," the author notes that when compressing hardened balls, the material in the zone of the circular pressure surface becomes stronger until the fracture at a coefficient $\frac{P}{D^2}$ = 50, while at compression of hardened rollers the material in the zone of linear contact already at the loading factor $\frac{P}{Dl}$ = 10-12 (l - length) of the roller is in a state of fluidity.

It is known that in the mutual deformation of contacting bodies, the material on the pressure surface is in a state of three-dimensional compression which characterizes three main stresses. If the contact is circular then volumetric compression on the pressure surface into linear compression, at this point the two principal stresses are zero and the contacting surface is the main, and from the theory of elasticity it is

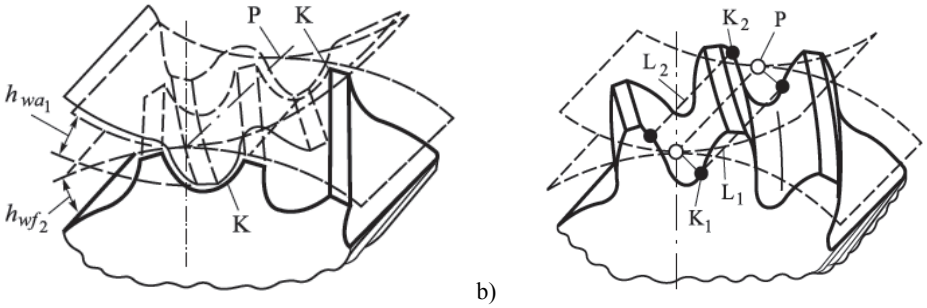
known that on the principal areas tangential stresses $\tau_{ij} = 0$. The most favorable slip of the parts of the crystal lattice or dislocation is determined by the value $\alpha = 45^0$ for which $\tau_{max} = 1/2\sigma$ [8]. This argument speaks in favor of Novikov's point gearings.

Advantages and disadvantages of Novikov's gearings:

- a helical cylindrical transmission with lines or close to the contact lines of the cogwheel, in which the convex surfaces of the initial teeth heads interact with the concave surfaces of the initial legs of the teeth and the coefficient of end overlap equal to or close to zero. Approaching a linear contact is provided by slightly less curvature of the profile of the concave surface of the tooth in comparison with the curvature of the convex surface of the profile of the conjugate tooth.

Smoothness of work is achieved due to axial overlap, the coefficient ε_a which is chosen to be greater than unity.

There are Novikov's gearings from one (*scheme a*) and two (*scheme b*) lines of gearings.



a) b)

Figure 3 – The scheme of contact in Novikov's gearings

In *scheme a* the notation: *K* - the contact point moved translationally during the transmission operation (*K* moves along the path parallel to the pole line, *P* - the contact line of the initial cylinders); h_{wa1} and h_{wf2} - respectively the height of the initial head of the tooth gear wheel and the height of the initial foot of the tooth cogwheel.

In *scheme b* the notation: *P* - the pole line; K_1 and K_2 - contact points, respectively, on the stem and head of the tooth; L_1 and L_2 - the gearing lines-the trajectories of the contact points K_1 and K_2, respectively.

The contact points on the same gearing lines are moved one after another at an interval denoted by q_{21}. The spacing between two contact points on different gearing lines q_{22} is the smallest distance between two end sections of the conjugate cogwheel drawn through contact points of the same surfaces of two adjacent cogwheel's teeths.

Apply Novikov's gearing with two lines of gearing. They have teeth with convex surfaces of the initial heads and concave surfaces of the initial legs. The teeth of the gear wheel and cogwheels can be cut with one tool, in contrast to Novikov's gearing with one gearing line.

The geometric calculation of the Novikov's gearings with two lines of gearing is performed depending on the parameters of the *initial contour* [7].

Calculation of geometric parameters is performed in accordance with GOST 15023-76 in figure 4 shows the profile of gearing [6].

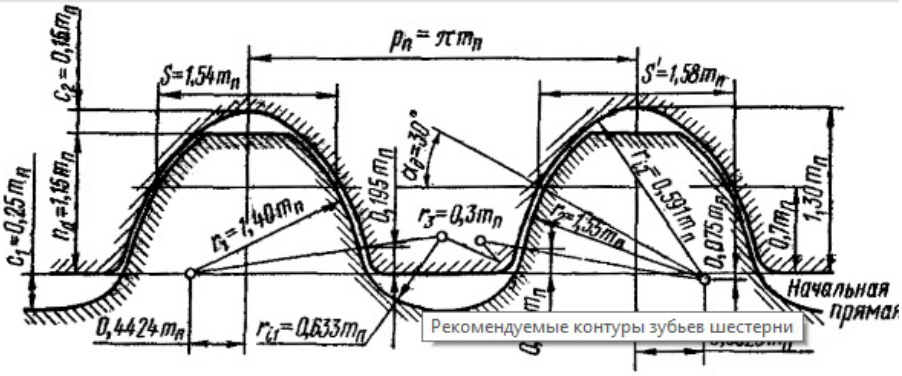


Figure 4 – Profile of Novikov's gearing

Dividing cogwheel diameters:

$$d_1 = \frac{mz_1}{cos\beta}; \quad d_2 = \frac{mz_2}{cos\beta}, \tag{4}$$

where z_1, z_2 - number of teeth of cogwheels, m - module, β - angle of inclination of the tooth line (β = 10 ... 22° in helical teeth and β = 20 ... 30° in chevron gearings). Axial step P_x= π m / sinβ. Width of a ring gear of a cogwheel b_2= (1 ... 1, 2) P_x or b_2= (2 ... 2.2) P_x or b_2= (3 ... 3,3) Px or b_2= (4 ... 4.4) P_x (with such values, the maximum transfer capacity is provided). Width of a ring gear of a wheel $b_1 = b_2$ + (0.4 ... 1.5) m.

Center distance

$$a = 0{,}5\, m(z_1 + z_2) / \cos\beta. \tag{5}$$

Diameters (circles) of vertices

$$d_{a1} = 2h_a;\ d_{a2} = d_2 + 2h_a. \tag{6}$$

Diameters (circles) of depressions

$$d_{r1} = d_1 - 2h_a - 2c;\ d_{r2} = d_2 - 2h_a - 2c. \tag{7}$$

Where h_a and c – the initial contour.

Novikov's gearing is used for hardness of tooth surfaces H ≤ HB 320 (3200 MPa); module m ≤ 16 mm; the circumferential velocity v ≤ 20 m/s. The load capacity of Novikov's gearing from the condition of contact endurance of the active surfaces of the teeth is 2 times higher than for gears with evolvent gearing with the same overall dimensions, due to the greater reduced radius of curvature of the contacting teeth. But since Novikov's gearing are used with low hardness of the surface due to technological difficulties of grinding the teeth, then by criteria of contact strength and endurance they can be inferior to gears with evolvent gearing. The strength of the teeth in bending is approximately 5 ... 15% lower than for gears with evolvent gearing.

Novikov's gearing has a higher efficiency due to the rolling of the teeth without the geometry of sliding, but is sensitive to changes in the interaxial distance. Manufacturing error and/or deformation of the shaft/supports lead to differences in the gearing edge and the main transmission properties with involute gearing. Axial movement of the point contact in the Novikov's gearing leads to a change in the reaction of the shaft support during one cycle of gearing and, accordingly, can cause additional vibration. For these reasons, Novikov's gearing requires a high precision of manufacture and high rigidity of shafts and supports [7].

To compare the load capacity of the gearing elements with evolvent gearing used in the drives of ball mills and gears with Novikov's gearing, a numerical finite element method is used.

Work on the calculation of the ring gear of the ball mill drive was carried out in the following volume and sequence:

1. Drawing up of the design scheme corresponding to the test loading. Purpose of loading regimes .

2. Using the MSC/Patran finite element program model (hereinafter referred to as "KEM") of the design to be calculated, boundary conditions corresponding to the pinning of the gear in the experimental rig, as well as the external load model.

4. Carrying out calculation of the stress-strain state (hereinafter – VAT) of the CEM with the help of the SAE program. The programs MSC/Patran, MSC/Nastran were used .

The creation of the finite element model (KEM) of the ring gear, the external load model and the boundary conditions simulating the fastening of this cogwheel to the drum, the following sequence was performed.

Creating 3D model (figure 5) was carried out in CAD program KOMPAS module Shaft on the geometric parameter am calculated in the paper.

When creation of the calculation model, a fragment of the cogwheel was cut out, in order not to waste the resources of the machine, since the stresses will be localized over the area of the crown's tooth of a ring gear.

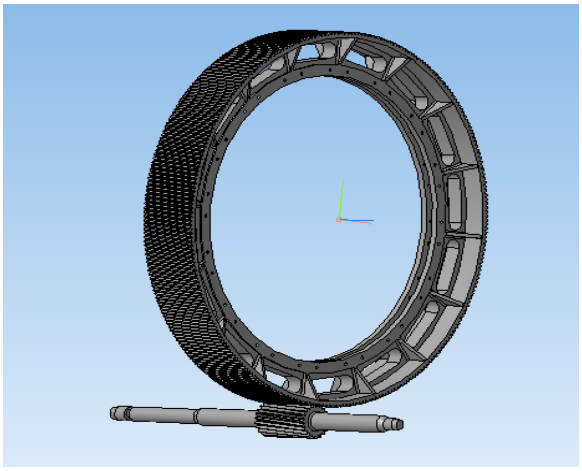


Figure 5 – 3D model of assembly of a cogwheel and gear wheel

The model created in the Russian CAD system was successfully imported through the exchange of files in the CAE system NASTRAN. Partitioning into finite elements is modeled by volume elements of the type tet. The calculation scheme for determining the operating voltages is shown in figure 6. The requirements for the type of elements and the quality of the grid should be increased, since for calculating the fatigue strength it is necessary to calculate the local stresses taking into account their concentration.

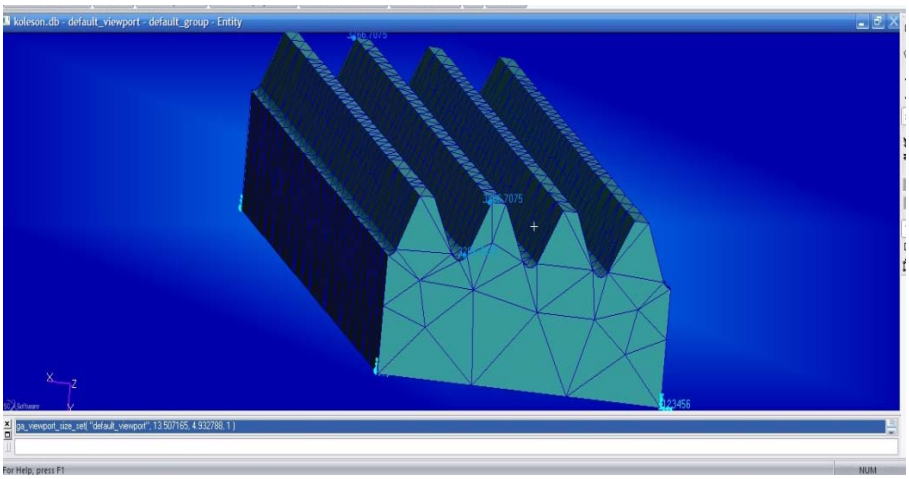


Figure 6 – The generated grid

Taking into account the specific features of the design, the calculated loading scheme is shown in figure 7.

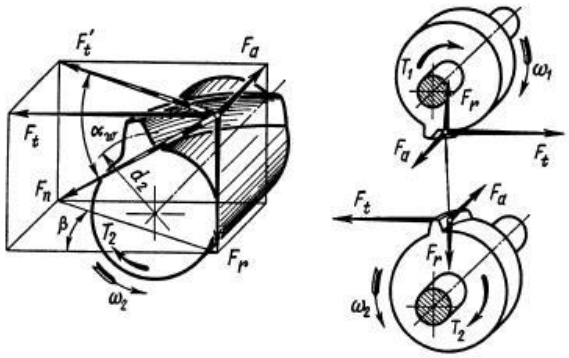


Figure 7 – Scheme of loading

Data on the forces acting in the gearing ring gear and gear shaft were calculated [9, 10].

- circumferential force: F_t = 5362315 H;
- radial force in the gearing: F_t = 195,972 H;
- Axial force: F_a = 49333 H.

The mechanical design scheme included a rigid anchorage, presupposing a superposition of the coupling along six degrees of freedom and loading as a resultant distributed load along the tooth edge. The axle load module was calculated using the following formula:

$$q_x = \frac{F_t}{s} = \frac{536231}{1.9141} = 280114\frac{H}{м}, \tag{8}$$

$$q_y = \frac{F_t}{s} = \frac{195972}{1.9141} = 102388\frac{H}{м}, \quad q_z = \frac{F_\alpha}{s} = \frac{49333}{1.9141} = 25773\frac{H}{м}.$$

Thus, for definition by means of the MSC/Nastran program of a ring gear the static problem (figure 8) was solved. The stress calculation results are saved in one file with the extension*. xdb.

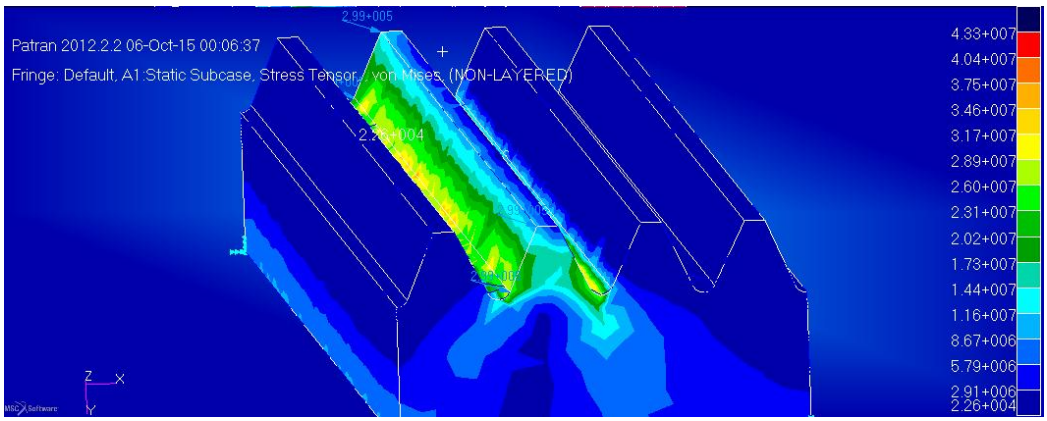


Figure 8 – Distribution of equivalent tension in a ring gear

After the program MSC/Nastran has successfully completed the solution of the problem "coleso.bdf ", the results of calculation for each step of the load application stored in one file "coleso.xdb" will be available for estimating the longevity. The distribution of equivalent stresses, calculated by the Mises formula. The voltage scale in Figure 8 corresponds to the dimension [Pa].

The stress results show a sufficient supply of static strength. Results in the diagram has a value of maximum stress σ_{max} = 44,3 MPa allowable stress [σ] = 600 MPa, the strength of the static coefficient is determined by the formula:

$$k = \frac{[\sigma]}{\sigma} = 1{,}72 \tag{9}$$

The stress distribution pattern shows good resistance to the bending of the profile teeth with evolvent stress.

However, it is known from practical observations that the failure of wheels occurs not because of an insufficient coefficient of static strength, but because of surface disruptions such as chipping, spalling, etc.

Fracture of the tooth occurs in the zone of maximum stress (at the fillet of the tooth) along the longitudinal section and has a curvilinear transverse contour which, depending on the type of load and heat treatment, can be either concave or convex. The fatigue fracture has a concave profile, that is, directed into the body of the wheel. For cogwheels improved or volume-hardened - without a step, for cogwheels with surface hardening with a step.

Statistical fracture, which occurs less frequently, has a convex contour, also without a step and with a step. In the case of surface hardening, the initial crack at the depth of the hardened layer is formed from the action of normal stresses, and further damage occurs under the influence of tangential stresses.

A fatigue fracture is preceded by a fatigue crack, which begins to form on the loaded side at the base of the tooth, more often on the edge of the butt; Further, the crack develops along the tooth's leg along the normal to the transition curve in the direction of the compressed side.

The pattern of stress isolines confirms these conclusions - the places of stress concentration at the base of the tooth are visible (figure 9). To assess the level of shearing stress influence on the fatigue strength of the tooth, it is advisable to estimate the values of the stress tensor components, which allows us to make the NASTRAN program.

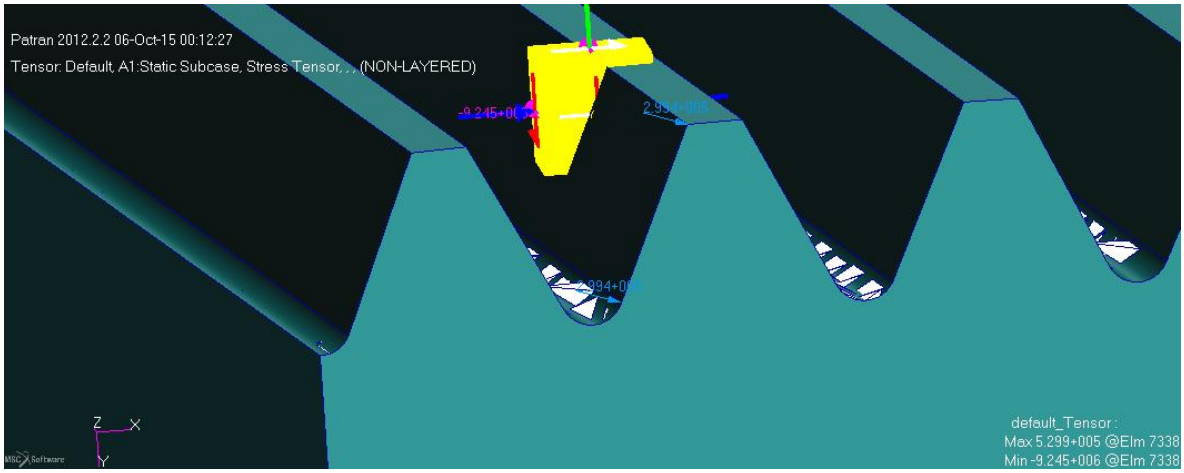


Figure 9 – Elementary volume on the tooth surface

An elementary volume was extracted from the tooth surface and all components of the stress tensor were visualized.

Figure 10 shows the components of the stress tensor in the elementary volume of the evolvent gearing tooth.

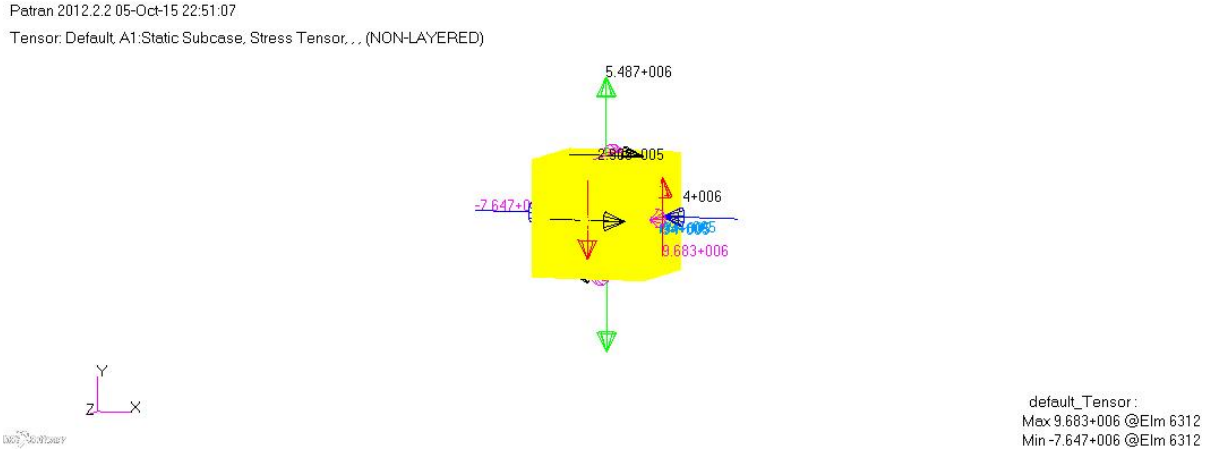


Figure 10 – Components of a stress of tension in the elementary volume of tooth of evolvent gearing

The diagram shows that the shearing stresses τ_{ig} on the areas of the linear contact has values greater than the values of normal stresses σ_i, (perpendicular vectors). It is known that macrocracks on contacting surfaces develop under the action of tangential stresses.

On the surface of the fatigue fracture, more often because of the small size of the tooth, one can observe not five, but three zones of development of the crack:

- smooth, where the origin of the crack and its slow growth occurred;
- Rough , where crack growth accelerates;
- rough , where there was a brittle fracture of the tooth.

The strained state in the dangerous section of the tooth depends on the geometric parameters of the tooth.

In order, to evaluate the load capacity and resistance to surface damage wheels with Novikov's gearing, according to GOST 15023-76 were counted geometric parameters of the teeth and solid model constructed in KOMPAS Russian program.

Figure 11 presents the 3D gearing model of a part of the Novikov's gearing of cogwheel.

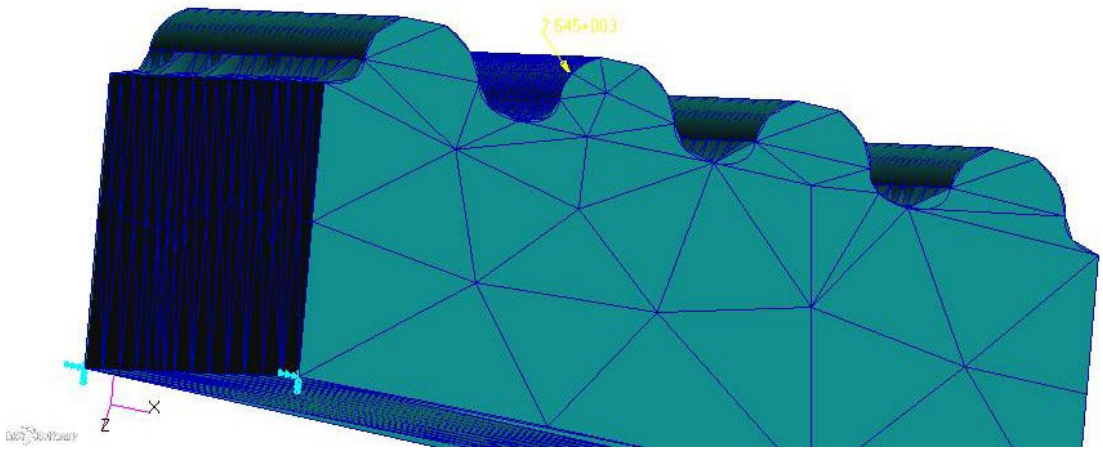


Figure 11 – 3D model of gearing of a part of a cogwheel of Novikov's tooth gearing

The load on the tooth was simulated as being equal in absolute value $F_n = \sqrt{F_t^2 + F_r^2 + F_a^2}$ and directed perpendicular to the tangent to the profile of the tooth, applied at the point of contact of the Novikov's gearing.

The fastening was modeled as a five-way link and a rotation around the axis Z.

The static calculation parameters were selected and the following results were obtained (figure 12).

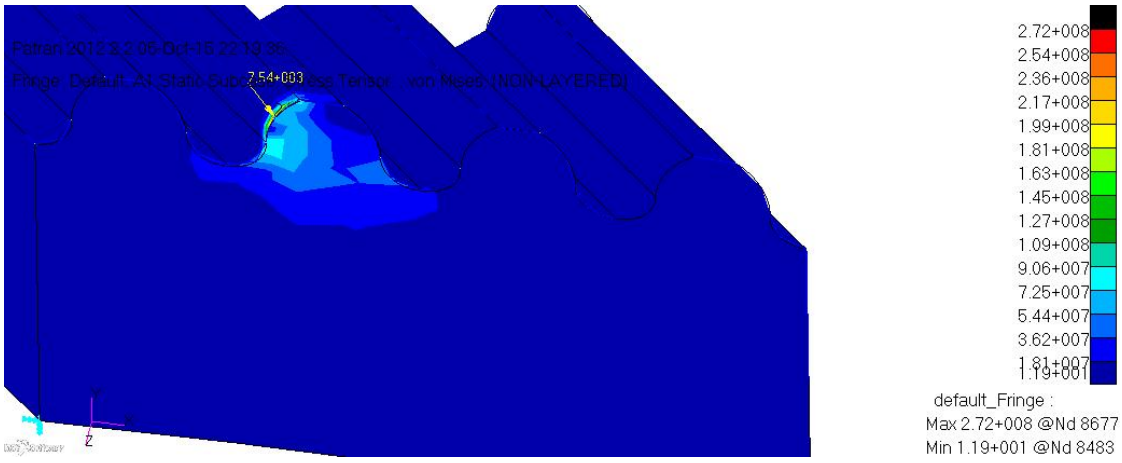


Figure 12 – Stress distribution diagram

The diagram shows that the limit of the maximum equivalent stresses is much higher in the Novikov's gearing than in the evolvent gearing.

σ_{max} = 272 MPa for the Novikov's gearing

σ_{max} = 44.3 MPa for gears with evolvent gearing

Which explains the best resistance of deformation to the bending of the evolvent teeth.

To assess the possibility of plastic deformations and physical causes of tangential stresses at the contact site, the capabilities of the NASTRAN program were used, which allows to decompose the stress tensor into components and visualize this result.

Figures 13 and 14 show the elementary volume on the surface of the tooth of cogwheel the Novikov's gearing and the components of the stress tensor.

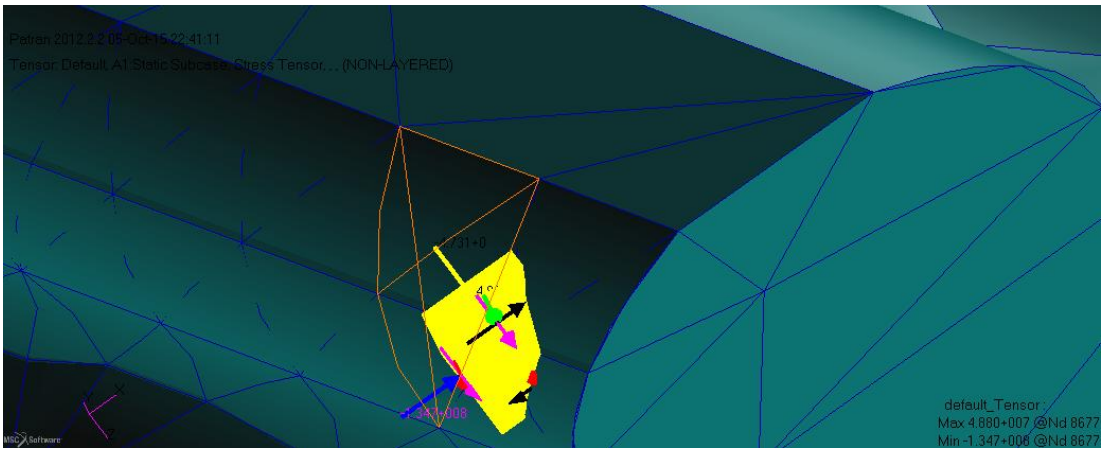


Figure 13 – Elementary volume on the surface of tooth of a cogwheel of Novikov

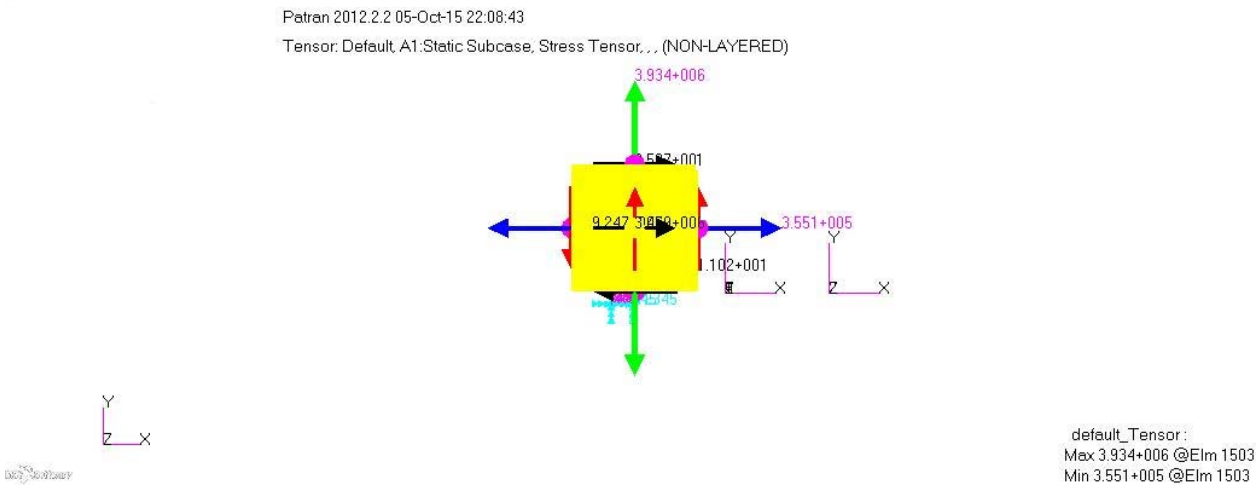


Figure 14 – Components of the stress tensor

The results show that tangential stresses located in the contact plane have very small values. Indeed, in case of point contact or contact of bodies with approximately equal radiuses of curvature of the body, they undergo uniaxial compression where the tangential stress should be absent on the main areas, ie, perpendicular to the force vector, which is approximately reflected in the results of the program, the value of τ_{xy} = 10 Pa.

Based on a comparison based on computer modeling, we can draw the following conclusions:

- the load capacity of Novikov's gearing from the conditions of contact endurance of the active surfaces of the teeth is higher than that of gears with evolvent gearing, with the same overall dimensions, due to the large reduced radius of curvature of the contacting teeth;

- the strength of the teeth of Novikov's gearing is lower in bending than in gears with evolvent gearing.

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ЭВОЛЬВЕНТТІ ІЛІНІС ЖӘНЕ НОВИКОВ ІЛІНІС ТІСТІ БЕРІЛІСТЕРІН КОМПЬЮТЕРЛІК МОДЕЛЬДЕУ АРҚЫЛЫ САЛЫСТЫРМАЛЫ ТАЛДАУ

Аннотация. Мақалада Герц шешімдерін ескере отырып әртүрлі авторлардың әдістеріне сәйкес максималды байланыс кернеулерінің есептелген мәндері берілген, шарлы диірмендер мен жетектерге арналған Новиков ілініс тісті берілісімен пайдаланылатын беріліс элементтердің жүктемелік қабілетін кернеуге салыстыру арқылы зерттеу жүргізілді. MSC/Patran, MSC/Nastran бағдарламаларының көмегімен есептелінетін тісті берілістің шекаралық жағдайда сандық соңғы элементтердің моделі (СЭМ), сондай-ақ СЭМ кернеулі-деформацияланған күйін есептеу жүргізілді. Зерттеу нәтижесінде белсенді тіс беттерінің контактілерге төзімділігі жағдайында Новиков іліністің жүктемелік қабілеті анықталды, бұл байланыстағы тістің келтірілген үлкен қисықтық радиусы салдарынан бірдей жалпы өлшемдерімен эвольвентті тісті берілістерге қарағанда жоғары болып табылды.

Түйін сөздер: тісті беріліс, Новиков ілінісі, эвольвентті ілінісі, тіс модулі, соңғы элементтік моделі, деформация, кернеу.

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СРАВНИТЕЛЬНЫЙ АНАЛИЗ КОМПЬЮТЕРНОГО МОДЕЛИРОВАНИЯ ЗУБЧАТЫХ ПЕРЕДАЧ С ЭВОЛЬВЕНТНЫМ ЗАЦЕПЛЕНИЕМ И ПЕРЕДАЧИ НОВИКОВА

Аннотация. Приведены расчетные величины максимальных контактных напряжений по методикам различных авторов с учетом решений Герца, рассмотрены исследования по сравнению нагрузочной способности элементов передач с эвольвентным зацеплением, применяемых в приводах шаровых мельниц и передач с зацеплением Новикова. Разработаны численные конечно-элементные модели (КЭМ), рассчитываемой зубчатой передачи и граничных условий, а также расчет напряженно-деформированного состояния КЭМ с помощью программ MSC/Patran, MSC/Nastran. В результате исследовании, установлена нагрузочная способность передачи Новикова из условий контактной выносливости активных поверхностей зубьев, которая выше, чем у передач с эвольвентным зацеплением, с теми же габаритными размерами, вследствие большого приведенного радиуса кривизны контактирующих зубьев.

Ключевые слова: зубчатые передачи, зацепления Новикова, эвольвентное зацепление, модуль зуба, конечная элементная модель, деформация, напряжения.

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PROSPECTS OF GRAPE MARC APPLICATION IN BREWING

Abstract. The paper presents studies results of practical aspects of dry grape marc use in brewing with humidity of 8.5%, obtained in laboratory on horizontal type dryer. In course of research work performed in laboratory, samples of unfiltered top-fermented beer were obtained, both without using and using dry grape marc. Finished beer was analyzed using standard methods, adopted in brewing, as well as using modern methods of high-performance liquid and gas chromatography for organic acids, carbohydrates and glycerin, volatile components, phenolic and furan compounds determination, that determine fermented drinks organoleptic profile. The potential of expanding special varieties range of brewing products with high consumer properties with the addition of raw material in the form of dry grape marc was revealed. Analysis of presented experimental data allows to conclude, that the technology of special beer sorts does not require additional production costs, since it can be carried out on existing production lines. The article makes assumptions about additional motivation of lean manufacturing system development in wine industry through grape marc use in brewing.

Key words: grape marc, special beer varieties, organoleptic profile, organic acids, sugars, glycerin, volatile components, phenolic and furan compounds.

Introduction. At the present stage of food market saturation with new food products, including alcoholic and non-alcoholic drinks, following areas should be highlighted:

- satisfaction (expansion) of consumer demand, taking into account product quality requirements [1-4].
- creation of new products and products with use of food components not previously used in them [5-8];
- accounting of food intake in the diet and at the same time in-depth study of basic technological processes influence on product quality, etc. [9, 10].

At the same time, it should be noted, that the development trend of new innovative technologies application in food production, based on use of secondary products [11].

Currently, wine industry has developed technological and production issues for wine waste processing and secondary winemaking products (SWP) production. This problem has not lost its relevance and finds new application aspects.

According to the experts of Russian National Research Institute of Viticulture and Winemaking "Magarach" of RAS, the use of secondary winemaking resources is of great importance both in terms of economic feasibility in obtaining a number of new and useful natural products for national economy needs, and to solve the problem of complex winemaking waste processing and safe disposal [12, 13].

The idea of grape marc use in brewing was formulated in works of N.I. Razuvaeva and Z.N. Kishkovsky in 80s of XX century, in which it was stated, that grape marcs freed from seeds could be used for grape beer production [14-16].

According to the works of A.O. Chursina data, grape marcs by their mass take largest part of the secondary raw materials of winemaking from 7 to 17% [12].

With average annual volume of processed grapes by winemakers in our country at the level of 540 thousand tons, there is reason to believe that grape marcs can become a full-fledged product, used in beer industry with additional technological processing.

Due to the currently insufficient use of secondary resources of wine industry processing enterprises, search for directions and ways of researching, developing and creating new products from secondary winemaking raw materials is of particular relevance.

Such direction could be the use of non-fermented grape marc as a raw material in special beer varieties and beer drinks production with high consumer properties.

The grape marc contains 1.2-3.6 % minerals of mass. Potassium and phosphorus predominate among the ash elements. Mass fraction of sugars in sweet grape juice ranges from 5 to 10%, tartrate compounds - 0.5 to 2.0%. At the same time, tartrate compounds mainly consist of free tartaric acid (40%) and potassium bitartrate (10-12%), as well as malic acid. In addition to the listed chemical compounds, marcs contain pentosans (1.0–4.5%), pectin (0.5–3.8%) and phenolic (up to 11%) substances. The extract from grape marcs isolated and identified lupeol, oleanolic acid, quercetin and glucoside b-sitosterol, as well as dietary fibers [17, 18].

Given the seasonality of obtaining sweet grape marc with humidity of at least 80%, it is necessary to process it by drying or extraction to preserve useful substances.

The use of dried grape marc or extracts from it will expand beer drinks and special beer varieties range.

Currently known beer varieties with use of grape juice, such as Italian grape ale, as well as drinks in the form of beer and grape juice mixes. Let us give some examples to illustrate the individual characteristics of such drinks.

In the description of the Italian grape ale (red and white), production of which uses different grape varieties, the following characteristics of drink aroma, color and taste are indicated:

- aroma with noticeable aromatic characteristics of a certain grape variety, but they should not overshadow other flavors. The malt character is usually restrained, and the hop character can vary from medium-low to absent.

- color from gold to dark brown. Ruby reddish color is usually due to red grapes use. Beer foam from white to reddish.

- many interpretations of taste are permissible. As in aroma, must be present grape character (resembling grape mash or wine), it can vary from delicate to medium-intensive. Grape varieties can affect taste sensations in different ways.

Typical ingredients of Italian grape ale:

The base is light malt or pils with a small amount of special malts or unmalted raw materials. Grape can be up to 40% of milled. Grape or wine mash (sometimes additionally boiled) can be used at various stages - during cooking, primary/secondary fermentation or aging. Ale or wine yeast may produce neutral character (more common) or fruit profile (English and Belgian strains). A wide range of hop varieties can be used, but in small quantities, so as not to give the beer an excessive character [19].

Experimental beer drinks made with grape juice addition have widest distribution geography - from European countries to China, including Russia. According to Czech Republic specialist's opinion, due to fresh grape juice added to beer, it acquires a reddish tint and has refreshing taste and pleasant sourness [20].

Research methods. The main organoleptic and physicochemical indicators of unfiltered beer using grape marc were made according to GOST 31711-2012. The mass concentration of organic acids was determined according to GOST 33410-2015. The mass concentration of sugars and glycerol was determined according to GOST 33409. The mass concentration of volatile components was determined according to GOST R 57893-2017. Determination of phenolic and furan compounds was carried out according to GOST 33407-2015.

Research results. To study grape marc influence on quality of finished beer in brewing technology department of All-Russian Scientific Research Institute of Brewing, Non-Alcoholic and Wine Industry at the BRUMAS (Germany) micro-brewery, samples of control and experimental beer were prepared using

grape marc from Moldova grapes variety. The original grape marc was pre-dried at a temperature of 60-80 °C for 12 hours on a horizontal dryer to a moisture content of 8.5%. Dried marc was made by mashing malted barley malt with water in infusion method in amount of 20% by weight of mashed malt. The hopped 11% wort was fermented with use of dry, pure culture of top-fermenting yeast of race S-04 (France). After ripening, finished unfiltered beer was analyzed by standard methods. Results are presented in table 1.

Table 1 – Organoleptic and physicochemical indicators of control and experimental unfiltered beer with use of grape marc

Indicator name	Control sample	Experimental sample with use of grape marc
Transparency	nontransparent foaming liquid without foreign inclusions not inherent in beer	nontransparent foaming liquid without foreign inclusions not inherent in beer
Aroma	Fermented malt, with yeast-flavored hop aroma	Fermented malt, with yeast-flavored hop aroma and grape aroma
Taste	Fermented malt, with hop bitterness, yeast flavor	Fermented malt, with hop bitterness, yeast flavor and wine tones
Volume fraction of alcohol, %	4,4	4,9
Acidity, a.u.	2,3	2,5
pH	4,0	4,2
Color, c.u.	2,0	2,4 (with reddish tint)

Finished beer analysis allows to conclude, that researched beer samples corresponded to requirements of current standards for main organoleptic and physicochemical parameters.

Currently, additional research methods are used to identify and assess the quality of brewing products, such as organic acids content, differential sugars composition, glycerin, volatile components, phenolic and furan compounds, that have significant effect on organoleptic fermentation product. In this regard, prepared beer samples were analyzed by above indicators (tables 2–5).

Table 2 – Organic acids mass concentration in control and experimental samples of unfiltered beer

Organic acid	Organic acids mass concentration, g/dm^3	
	Control Sample	Experimental sample with use of grape marc
Oxalic	0,1	0,2
Tartaric	0,3	0,9
Malic	0,4	0,4
Lactic	0,6	0,5
Citric	0,8	0,6
Succinic	0,4	0,8

Obtained experimental data indicate, that in unfiltered beer samples under study, the range of organic acids is identical. In unfiltered beer using grape marc, the content of oxalic, tartaric and succinic acids is 2-3 times higher than level of their content in control sample.

Table 3 – Sugars and glycerin mass concentration in control and experimental samples of unfiltered beer

Sugars and glycerin	Sugars and glycerin mass concentration, g/dm^3	
	Control Sample	Experimental sample with use of grape marc
Glycerin	2,6	2,8
Fructose	–	0,9
Glucose	1,1	0,7
Maltose	1,0	0,5

The data, presented in table 3 shows, that content of glycerin formed in the process of wort fermentation is almost at the same level. The content of fructose in control sample is absent, and the content of glucose and maltose is 1.5-2.0 times higher than in experimental sample. The fructose content in experimental beer sample can be explained by its presence in original grape marc.

Table 4 – Volatile components mass concentration in control and experimental samples of unfiltered beer

Volatile components name	Volatile components mass concentration, mg/dm^3	
	Control sample	Experimental sample with use of grape marc
Acetaldehyde	24,5	54,3
Formosol	1,0	1,3
ethyl acetate	6,9	8,0
2-propanol	0,3	0,4
Diacetyl	0,1	0,4
2-butanol	1,9	3,8
Isobutanol	6,6	19,0
Isoamyl acetate	0,2	0,4
1-butanol	0,1	0,2
Isoamilol	33,1	61,6
Phenethyl alcohol	11,9	29,2

It should be noted, that the volatile components nomenclature, presented in Table 4 is characteristic for beer and fermented drinks. However, in experimental beer sample, obtained using grape marc, an increased content of acetaldehyde, ethyl acetate, diacetyl, 2-butanol, isobutanol, isoamylol, and phenylethyl alcohol is typical, which is typical to grape-based fermented drinks.

Table 5 – Phenolic and furan compounds determination in control and experimental samples of unfiltered beer

Phenolic and furan compounds	Phenolic and furan compounds mass concentration, mg/dm^3	
	Control sample	Experimental sample with use of grape marc
Gallic acid	0,9	3,3
5- hydroxymethylfurfural	–	1,2
Furfural	0,5	3,7
Vanillic acid	2,2	3,3
5- methylfurfural	0,6	–
Syringic acid	0,9	7,0
Vanillin	0,4	0,4
Syringic aldehyde	–	0,2
Sinapic acid	0,6	0,7
Coniferyl aldehyde	0,3	0,5

Obtained experimental data on phenolic and furan compounds content in studied samples of unfiltered beer indicate, that there is no content in the control sample 5-hydroxymethylfurfurol, as well as syringic aldehyde.

No content of 5-methylfurfural was detected in experimental beer sample. At the same time, it noted an increased, compared with control sample, content of gallic acid, furfural and syringic acid. In our opinion, this is due to fermentation of extract from dried grape juice with top yeast during drink production.

Analysis of presented experimental data allows to conclude, that use of dried grape marc in brewing allows to expand the range of finished products with original organoleptic properties.

However, in connection with the adoption of Eurasian Economic Union Technical Regulations "On safety of alcoholic products" (EAEU TR 047/2018), these beers can be classified as special beer or beer drinks. The list of raw materials standards for these products will need to take into account the use of grape marc, as well as develop on them all the necessary regulatory documentation. Currently, studies are underway on grape marc drying modes selection for calculating the cost of its production.

Production technology of special beer varieties and beer drinks based on grape marc does not require additional production costs, since it can be carried out on existing production lines.

Organization of such production in traditional winemaking regions of Russia will ensure demand growth for grape marc as secondary winemaking product and will be additional motive for application of lean production management system at enterprises.

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СЫРА ҚАЙНАТУДА ЖҮЗІМ СЫҒЫНДЫСЫН ҚОЛДАНУДЫҢ БОЛАШАҒЫ

Аннотация. Жұмыста зертханалық жағдайда көлденең түрдегі кептіргіште алынған ылғалдылығы 8,5% құрғақ жүзім сығындысын сыра қайнату кезінде қолданудың тәжіриебелік аспектілерін зерттеудің нәтижелері келтірілген. Зертханада жағдайында жүргізілген ғылыми-зерттеу жұмыстарының барысында жоғарғы ашыту кезінде құрғақ жүзім сығындысы қосылған және қосылмаған сүзілмеген сыра үлгілері алынды. Дайын сыра оны қайнату кезінде қабылданған стандартты әдістермен талданады, сондай-ақ ферменттелген суындардың органолептикалық көрсеткіштерін анықтайтын, органикалық қышқылдарды, көмірсуларды және глицеринді, ұшқыш қосылыстарды, фенол және фуран қосылыстарын анықтау үшін жоғары сапалы сұйық және газ хроматографиясының заманауи әдістері қолданылды. Құрғақ жүзім сығындысы түріндегі шикізатты қосып, жоғары тұтынушылық қасиеттері бар сыра қайнату өнімдерінің арнайы сұрыптарын кеңейту потенциалы анықталды. Ұсынылған тәжіриебелік деректерді талдау арнайы сыра сұрыптарының технологиясы қосымша өндірістік шығындарды қажет етпейді, себебі оны қолданыстағы өндіріс желілерінде жүзеге асыруға болады. Мақалада жүзім сығындысын сыра қайнатуда қолдану есебінен шарап өнеркәсібінде үнемді өндіріс жүйесін дамытудың қосымша мотивациясы туралы болжамдар жасайды.

Түйін сөздер: жүзім сығындысы, сыраның арнайы сұрыпы, органолептикалық профиль, органикалық қышқылдар, қант, глицерин, ұшқыш қосылыстар, фенол және фуран қосылыстары.

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ПЕРСПЕКТИВЫ ПРИМЕНЕНИЯ ВИНОГРАДНОЙ ВЫЖИМКИ В ПИВОВАРЕНИИ

Аннотация. В работе представлены результаты исследований практических аспектов применения сухой виноградной выжимки в пивоварении с влажностью 8,5%, полученной в лабораторных условиях на сушилке горизонтального типа. В ходе выполненных научно-исследовательских работ в лабораторных условиях были получены образцы нефильтрованного пива верхового брожения как без использования, так и с использованием сухой виноградной выжимки. Готовое пиво анализировали стандартными методами, принятыми в пивоварении, а также с использованием современных методов высокоэффективной жидкостной и газовой хроматографии для определение органических кислот, углеводов и глицерина, летучих компонентов, фенольных и фурановых соединений, определяющих органолептический профиль напитков брожения. Выявлен

потенциал расширения ассортимента специальных сортов пивоваренной продукции с высокими потребительскими свойствами с добавлением несоложеного сырья в виде сухих виноградных выжимок. Анализ представленных экспериментальных данных позволяет сделать вывод о том, что технология специальных сортов пива не требует дополнительных производственных издержек, поскольку ее можно осуществлять на действующих технологических линиях. В статье выдвинуты предположения о дополнительной мотивации развития системы бережливого производства в винодельческой промышленности за счет использования виноградной выжимки в пивоварении.

Ключевые слова: виноградная выжимка, специальные сорта пива, органолептический профиль, органические кислоты, сахара, глицерин, летучие компоненты, фенольные и фурановые соединения.

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VALIDATION OF MICROWAVE INSTALLATION PARAMETERS WITH MOBILE RESONATORS FOR HEAT TREATMENT OF NONEDIBLE EGGS

Abstract. The use of hatching eggs rejected in the candling process as a protein feed after heat treatment and disinfection is relevant. The aim of the work is to develop and to validate the parameters of the installation, which provides heat treatment and disinfection of rejected hatching eggs, to obtain high-quality protein feed at reduced energy costs. The following objectives were solved: to develop a flow chart of the installation for the impact of the electromagnetic ultrahigh frequency field on a raw material with a cidal effect and providing selective heating of a two-component raw material in a dielectric shell; to develop the constructional design of the ultrahighfrequency installation with resonators having high basic Q-factor and providing high electric field intensity and continuous operation with maintaining electromagnetic safety; to conduct a technical and economic assessment of the use of the worked out installation in farms for processing rejected hatching eggs. The technical problem of the development is to ensure the duty cycle of a continuous process of exposure of the electromagnetic ultrahigh frequency field (EMUHFF) less than 0.5 and electromagnetic safety with a sufficiently high basic Q-factor of the resonator, forming a resonator-beam electrodynamic system. A distinctive feature of the resonators from the known mobile resonators is the use of a biconvex lens made of fluoroplastics to form a uniform field on the object of influence. The installation contains the bezel in the shielding case attached to the ring gear, coupled with the driving gear. To the bezel, the lower hemispheres are attached with the possibility of tipping. Emitters are directed into the upper hemispheres, which are rigidly fixed on the body. With a power consumption of 4.08 kW and a capacity of 12 kg/h, the specific energy costs are 0.34 kW·h/kg, i.e. it is 32% reduction in energy costs compared with the prototype.

Keywords: electromagnetic field, mobile spherical resonators, fluoroplastic lens, rejected hatching eggs, heat treatment and disinfection.

Introduction. Improving the efficiency of microwave installations that provide heat treatment and disinfection of nonedible animal waste with an increase in the forage value of the protein supplement and identifying patterns of the impact of the electromagnetic ultrahigh frequency field on high-humidity multicomponent raw materials to determine the effective operating modes of microwave installations in the food industry are relevant.

It is known that the average percentage of chicken output under current conditions is 84-85% [1]. Analysis of the research results showed that the percentage of rejection of hatching eggs in Russia is 6-10%. Each hatching egg loses 80% of its value if sold as a table egg. In farms, the waste of hatching eggs can reach up to 3%. Such a high percentage of early embryonic mortality is usually associated with

improper storage of hatching eggs.During the entire incubation period, egg candling is performed several times. Biological control of hatching eggs before setting to the incubator and after candling of the hatching eggs after 3 and 7 days makes it possible to identify rejected eggs suitable for use as protein feed after disinfection and cooking. Hatching eggs are rejected in case of:

- disturbances in the development of the embryo and separation of the inner shell membrane;
- appearance of blood rings and frozen foetuses;
- when the yolk exploded and mixed with white;
- marble shell structure (abundance of calcium in the shell);
- shell damage (light streaks);
- large air cell or cell is located on the side;
- the presence of blood clots;
- free movement of yolk, etc.

Such material after candling hatching eggs on average is accumulated in the amount of 3%. The use of hatching eggs rejected in the candling process as protein feed after heat treatment and disinfection is relevant. Therefore, we suggest that the listed incubation wastes should be boiled and disinfected in the electromagnetic ultrahigh frequency field (EMUHFF) at high electric field intensity for the use as a feed additive.The calculation of the number of eggs requiring processing for use in the form of protein feed in farms was carried out. If there are 12 incubation cabinets and 4 hatchers in the hatching egg workshop, each of which has 104 trays, and the average number of eggs in each tray is 120 pieces, then the capacity of one incubation cabinet for 19 days is 12,480 pcs. of eggs, and of 12 incubation cabinets - 149760 pcs. of eggs.According to the fact that 3% of eggs set in the incubator belong to the category of "rejected", therefore, 4493 eggs from 12 cabinets can be processed for the production of protein feed. This means that an average of 1123 pcs should be recycled throughout the day. Therefore, the designed microwave installation with a capacity of 200 pcs/h can process this amount of raw materials in 5.6 hours, and the installation will work 22.5 hours per month.

The specific properties of electromagnetic radiation contribute to the emergence of new field of application of microwave technology, that is the creation of a previously impracticable process of cooking eggs without water.

There is a method and microwave installation for cooking eggs without water. For example, a microwave egg boiler contains a rotating fluoroplastic rotor with cells inside a cylindrical shielding body for transporting eggs through the chambers of microwave ovens [2]

The power consumption of the microwave installation (ultrahigh frequency installation) with four sources and transport mechanism is 5.0 kW; the speed of eggs movement is 1.8 cm/s, the productivity is 150-165 pieces/h, the specific energy cost is 0.5 kW · h/kg [3]. The author proved that with a process duty cycle of close to 0.5, the cooking time is the shortest; when the temperature in the yolk reaches about 70 °C, the shell breaks.With such a constructional design of the working chamber, in the form of a tetrahedral prism with a slit for transporting eggs through the electromagnetic ultrahigh frequency field, the Q-factor of the resonators is very low, therefore, the energy costs are high.

There is a device for sanitizing hatching eggs by the complex effect of electromagnetic radiation [4]. The device contains infrared sources and ultrasonic frequency generators (22 kHz or 110 kHz) located above the dielectric disk with cells for transporting eggs. This device allows to disinfect eggs in a continuous mode, but it does not cook them to get protein feed.

Therefore, the aim of this work is to develop and validate the parameters of the installation, which provides heat treatment and disinfection of the rejected hatching eggs to obtain high-quality protein feed at reduced energy costs.

The following objectives were solved:

1. To develop a flow chart of the installation for the impact of the electromagnetic ultrahigh frequency field on a raw material with a cidal effect and providing selective heating of a two-component raw material in the dielectric shell.

2. To develop the constructional design of the ultrahigh frequency installation with resonators having high basic Q-factor and providing high electric field intensity and continuous operation with maintaining electromagnetic safety.

3. To conduct a technical and economic assessment of the use of the worked out installation in farms for processing rejected hatching eggs.

There are proven technologies and technical means for heat treatment of non-food animal waste in the electromagnetic ultra-high frequency field of (EMUHFF) to increase the forage value of the protein supplement. For the implementation of this technology, installations with ultrahigh frequency (microwave) power supply has been developed [5].

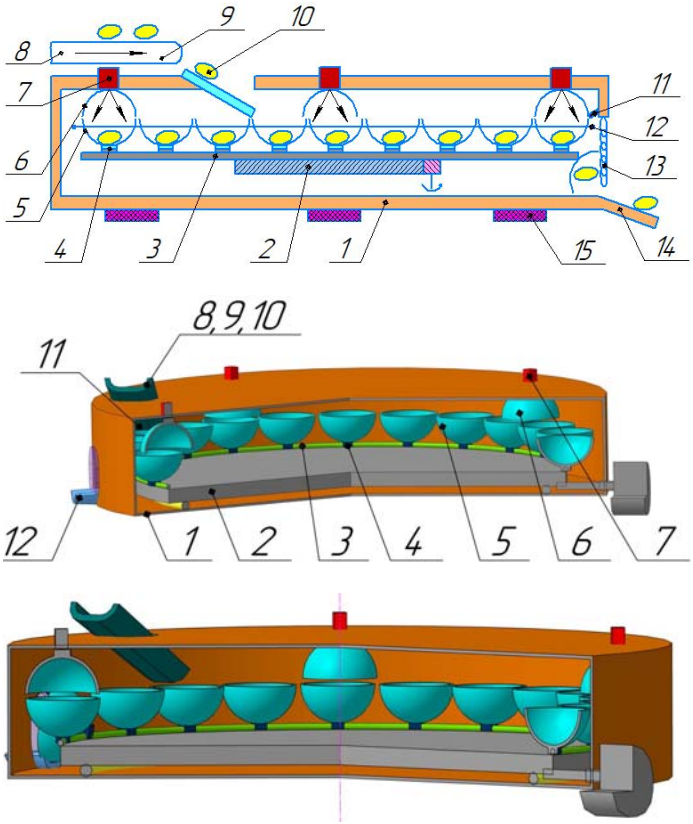
Materials and research methods. Based on the analysis of the constructional design of existing installations that provide cooking eggs without water in continuous mode, working with the use of electromagnetic radiation energy of ultrahigh frequency (EMUHFF), new working chamber with spherical mobile resonators was developed, which allows to reduce the specific energy costs for the process of egg heat treatment.

Research results and discussion. It is known the microwave (ultra-high frequency) emitters that direct the energy to the part of the raw material, which has large dimensions. For this purpose the H - shaped waveguide with an open end is used. There are horn antennas with a corrective dielectric lens in its aperture to create a flat wave or focus the radiation on the raw material. Using fluoroplastic biconvex lens it is possible to form a uniform field on the side of the targeted object.

We propose the microwave installation with low-power magnetrons, air cooling for cooking eggs without water in continuous mode, by repeated exposure of the electromagnetic ultrahigh frequency field in the “heating-pause” mode.

The technical problem of the development is to ensure the duty cycle of continuous process of exposure of the electromagnetic ultrahigh frequency field (EMUHFF) less than 0.5 and electromagnetic safety with a sufficiently high basic Q-factor of the resonator, forming a resonator-beam electrodynamic system.

Microwave installation (figure) for heat treatment of eggs in continuous mode: inside a cylindrical shielding body 1 installed on the mounting rack 15, coaxially, along the perimeter of the lower base there is the dielectric bezel 3 attached to the ring gear 2, coupled with the driving gear mounted on the shaft of the electric drive.



Microwave installation for heat treatment of nonedible eggs in continuous mode:
a) schematic illustration;
b, c) spatial image from different angles;
1 – shielding body; 2 – ring gear; 3 – bezel;
4 – pivot hinge; 5 – lower hemisphere;
6 – upper hemisphere;
7 – magnetron with emitter; 8 – conveyor;
9 – charging tray; 10 – charge hole; 11 – tipper;
12 – dielectric fishing line; 13 – shield grid;
14 – discharge tray; 15 – mounting rack

Lower non-ferromagnetic hemispheres 5 are attached to the bezel 3 using the hinges 4 convexity down, diameter multiple of half the wavelength, covered with guide line 12, the ends of which are connected with the inner side surface of the shielding body 1, where there is a window with shielding grid 13. There is also a tipper 11 in the form of a dielectric rack fixed to the upper base of the shielding body 1 with the possibility of contact and tripping of the lower hemispheres 5 towards its side surface and discharge tray 14.The upper non-ferromagnetic hemispheres 6, equal in diameter to the lower hemispheres 5, rigidly fixed under the upper base of the shielding body 1 convexity up, have opening in the upper points for guiding the emitters of the magnetrons 7 located along the perimeter on the upper base of the shielding body. The upper hemisphere 6 is covered with a *fluoroplastic lens*. On the upper base of the body 1, there is an inspection window and a charge hole, under which the dielectric charging tray 9 is located. The distance between the radiators 7 should be at least two diameters of the hemispheres 6.

The technological process of eggs heat treatment in continuous mode is under the following way. Turn on the driving gear, providing rotation of the gear ring 2 and the dielectric bezel 3 with the lower hemispheres 5. Turn on the conveyor 8, for feeding eggs through the charge hole 10 and the charging tray 9 into the mobile hemispheres 5.

Turn on the microwave generators, after that the rays of electromagnetic waves using the upper hemispheres will be directed to the lower hemispheres, where the eggs stand. In this case, the microwave generator operates in a resonant-beam electrodynamic system. That is, the upper hemispheres 6 contain fluoroplastic lenses and operate in the mode of the beam electrodynamic system. Fluoroplastic lens with a diameter equal to the diameter of the hemisphere 6, provides radiation focusing.At the moment when the upper 5 and lower 6 hemispheres are situated coaxially relative to each other, a spherical resonator is formed. Herewith, electromagnetic rays from the emitters 7 are sent to the lower hemispheres 5, bounce back off their surface, a standing wave is formed, there is a heat treatment of raw materials. The presence of several microwave generators and their non-synchronous operation give an averaging out of the total waves reflections, which leads to a good degree of distribution of the electric field in the working chamber and, consequently, to the uniform heating of the raw material.

Moreover, in effective rotation speed of the electric motor, the eggs in the lower hemispheres fluctuate, which also increases the uniformity of heating of the eggs components. By placing the magnetrons at regular intervals, taking into account the fact that these intervals should be much larger than the diameter of the hemispheres, it is possible to achieve wave interference and prevent the eggshell from breaking. Studies show that the best distribution of the electric field intensity in spherical mobile resonators with a slit is achieved at hemisphere diameter of 12.24 cm and interval of up to 1.0 cm.

Such a constructional design of spherical resonator with mobile hemisphere and stationary sphere with fluoroplastic lens allows to transfer up to 80% of the energy emitted by the magnetron to the raw material, and up to 55% without fluoroplastic lens.

Technical specifications of the microwave (ultrahigh frequency) installation are shown in table.

Technical specifications of the microwaveinstallation

Item	
Capacity, pcs/h kg/h	 200 12
Magnetron power, kW	3.2
Fan power for magnetron cooling, kW	0.25
Drive power of the ring gear, kW	0.63
Microwave installation power, kW	4.08
Specific energy costs, kW·h/kg	0.34

Technical and economic assessment of the use of the developed installation in farms for processing rejected hatching eggs was carried out. Operating costs for heat treatment of eggs in microwave installation in continuous mode for 1 month according to the conceptual design include the costs of wages, energy, maintenance and repair of the installation, depreciation allocations, other expenses.

Accordingly, the mathematical model is developed for the latter, matrices of product markers from genuine to falsified are proposed. Variants of poor-quality, and also surrogate products as possible intermediate links are considered for completeness of the information [6].

The microcontroller synchronizes with the external network and calculates the sine period [7].

Taking into account the average salary of the operator servicing this installation, in the Nizhny Novgorod region, the salary will be 106.25 rubles/hour. Taking into account the payment of personal income tax and contributions to the PFR, the FCMIF,and the SIF and the working time of 32 hours, the *wages* will be 4,862 rubles.

The power consumption of the developed microwave installation is 4.08 kW, then the cost of *electricity* per month will be 4.08 kW · 22.5 h · 7.3 rub/kW*h = 670.14 rubles. *Depreciation* for 1 month from the book value of the construction (72 thousand rubles) is 1,200 rubles, and deductions for *current repairs* - 1,440 rubles.

Taking into account other expenses of 408.6 rubles/month, general production costs of 1287 rubles/month, the total amount of operating costs is 4862 + 670.14 + 1200 + 1440 + 408.6 + 1287 = = 9867.74 *rubles/month*.

The producing cost of the operating costs for heat treatment of rejected hatching eggs in the microwave installation is 9867.74 / 4493 = 2.2 *rub/pcs.*

The price of the hatching eggs is 25-35 rubles/pcs. Taking into account the fact that eggs rejected after candling after 3-7 days lose 80% of their value, the wholesale price of raw materials on 03.10.2018 averaged 3-5 rubles per piece. Then the cost of raw materials will be 4493 pcs/month · 4 rubles/pcs = = 17 972 rubles/month. The cost of heat-treated and decontaminated rejected eggs according to the conceptual design will be 4+2.2 = 6.22 rubles/piece. If the heat treatment of eggs weighing 60 g, an average of 270 kg/month, the producing cost of protein feed is 6.22/0.06 = 104 rubles/kg. The wholesale price of egg feed for chickens is 400 rub/kg. When selling produced protein feed from rejected hatching eggs by means of exposure to EMUHFF at a price below the market - 250 rubles/kg, the additional income will be 150 rubles/kg.

Conclusion. When using spherical resonators with mobile hemispheres and fluoroplastic lenses in stationary hemispheres, forming the resonator-beam electrodynamic system, the specific energy costs are reduced by 32% compared to the prototype with the use of one fan for cooling four magnetrons mounted directly to the resonators, with the electronic units located in the control cabinet. The producing cost of the heat-treated rejected eggs is 104 rubles/kg.

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ТАҒАМДЫҚ ЕМЕС ЖҰМЫРТҚАЛАРДЫ ТЕМПЕРАТУРАЛЫҚ ӨҢДЕУГЕ АРНАЛҒАН ҚОЗҒАЛМАЛЫ РЕЗОНАТОРЛАРЫ БАР МИКРОТОЛҚЫНДЫ КОНДЫРҒЫНЫҢ СИПАТТАМАЛАРЫН НЕГІЗДЕУ

Аннотация. Термиялық өңдеуден және залалсыздандырудан кейін ақуызды жем ретінде овоскопиялық процесс барысында жарамсыз инкубацияланған жұмыртқаны пайдалану маңызды болып табылады. Жұмыстың мақсаты инкубация жұмыртқаларын термиялық өңдеу және дезинфекциялауды қамтамасыз ететін, төмендетілген энергия шығынын азайтқан жоғары сапалы протеинді азық алуға мүмкіндік беретін қондырғының параметрлерін әзірлеу және негіздеу болып табылады. Міндеттер шешілді: бактерицидтік әсері бар шикізатқа жоғары жиілікті электромагниттік өрісіне әсер ету және диэлектрлік қабықшасында екі компонентті шикізатты іріктеп алуды қамтамасыз етудің технологиялық схемасын жасау; жоғары электр өрісінің

беріктігі мен электромагниттік қауіпсіздікті сақтай отырып үздіксіз жұмысын қамтамасыз ететін жоғары сапалы, жоғары деңгейлі резонаторлармен микротолқынды қондырғылардың конструкциялық конструкциясын әзірлеу; шаруа қожалықтарында жарамсыз жұмыртқаларды қайта өңдеу қондырғыны пайдалануды техникалық-экономикалық бағалау жүргізу. Дамудың техникалық міндеті электронды-магниттік өрістегі (ЭМПСВЧ) 0,5-тен кем және резонатор-сәулелі электродинамикалық жүйені қалыптастыратын резонатордың жеткілікті жоғары өзіндік сапасымен электромагниттік қауіпсіздіктің үздіксіз технологиялық үрдісінің жұмыс циклын қамтамасыз ету болып табылады. Белгілі жылжымалы резонаторлардан резонаторлардың айырықша ерекшелігі әсер ету объектісінде біртұтас өріс қалыптастыру үшін фторопласттан жасалған қосдөңес линзасын пайдалану болып табылады. Қондырғы қорғау корпусында алдыңғы тегершігімен тісті тәжге байланысқан сақинасы бар. Сақинаға төменгі жартысферамен бекітілген, олардың аударылуға мүмкіндігі бар. Сәуле таратқыш денеге қатаң бекітілген жоғарғы жарты шарға бағытталған. Энергияны тұтыну кезінде 4,08 кВт және сыйымдылығы 12 кг/сағ, нақты энергия тұтыну - 0,34 кВт/сағ, яғни, прототибімен салыстырғанда энергия шығынын 32% төмендету.

Түйін сөздер: электромагниттік өріс, жылжымалы сфералық резонаторлар, фторопластикалық линза, жарамсыз инкубациялық жұмыртқа, термиялық өңдеу және заласыздандыру.

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ОБОСНОВАНИЕ ПАРАМЕТРОВ МИКРОВОЛНОВОЙ УСТАНОВКИ С ПЕРЕДВИЖНЫМИ РЕЗОНАТОРАМИ ДЛЯ ТЕРМООБРАБОТКИ НЕПИЩЕВЫХ ЯИЦ

Аннотация. Использование отбракованных в процессе овоскопирования инкубационных яиц как белкового корма после термообработки и обеззараживания актуально. Целью работы является разработка и обоснование параметров установки, обеспечивающей термообработку и обеззараживание отбракованных инкубационных яиц, для получения качественного белкового корма при сниженных энергетических затратах. Решены задачи: разработать технологическую схему установки для воздействия электромагнитного поля сверхвысокой частоты на сырье, обладающего бактерицидным эффектом и обеспечивающим избирательный нагрев двухкомпонентного сырья в диэлектрической оболочке; разработать конструкционное исполнение сверхвысокочастотной установки с резонаторами, обладающими высокой собственной добротностью, обеспечивающими высокую напряженность электрического поля и непрерывный режим работы при сохранении электромагнитной безопасности; провести технико-экономическую оценку применения разработанной установки в фермерских хозяйствах для переработки отбракованных инкубационных яиц. Технической задачей разработки является обеспечение скважности непрерывного технологического процесса воздействия в электромагнитном поле сверхвысокой частоты (ЭМПСВЧ) менее 0,5 и электромагнитной безопасности при достаточно высокой собственной добротности резонатора, образующего резонаторно-лучевую электродинамическую систему. Отличительной особенностью резонаторов от известных передвижных резонаторов является использование двояковыпуклой линзы из фторопласта для формирования равномерного поля на объекте воздействия. Установка содержит в экранирующем корпусе ободок, прикрепленный к зубчатому венцу, сцепленному с ведущей шестерней. На ободок прикреплены нижние полусферы с возможностью опрокидывания. В верхние полусферы, которые жестко закреплены на корпусе, направлены излучатели. При потребляемой мощности установки 4,08 кВт и производительности 12.кг/ч. удельные энергетические затраты составляют 0,34 кВт·ч/кг, т.е. на 32% происходит снижение энергетических затрат по сравнению с прототипом.

Ключевые слова: электромагнитное поле, передвижные сферические резонаторы, фторопластовая линза, бракованные инкубационные яйца, термообработка и обеззараживание.

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NUMERICAL SOLUTION STRESSED DEFRESSED CONDITION OF MULTILAYER COMPOSITION BLADES IN THE FIELD OF CENTRIFUGAL FORCES

Abstract. One of the main tasks of the mechanics of composite materials (CM) is the calculation of the effective characteristics of the elasticity of CM based on information about the physicomechanical properties of their components and the laws of the distribution of components over the volume of the material. The possible scattering of the properties of a layer of multilayer CM is not taken into account when constructing models of structurally inhomogeneous media and when calculating their effective characteristics. Therefore, it is necessary to assess the influence of the properties of the layer on the effective characteristics of the material, as well as on the reliability of the structure as a whole.

The paper considers program, allowing numerically determine stress and strain state of a layered composite blade in the centrifugal force field, has been compiled using proved engineering torsion theory of the random section composite layered rod. The naturally twisted layered composite blade lies under combined action of stretching forces, bending and twisting moments or under the influence of centrifugal forces. The program has solved engineering problem on cutting of the blade to leaves (these leaves appear in a result of variable section along the blade length) in planes, parallel to the rod axis. The blade, studied in this paper, is presented by eight sections.

Keywords: blade, torsion, stretching, bend, deformation, strain, cutting.

Introduction. Rotodynamic machine blade outline in potential engines becomes more complex. There is a change from outlines, close to the rods with twist and high relative elongation, to outlines like plates with low relative elongation, high twist and flexure, in the blade structures of fans, compressors and turbines. Intermetallic compounds, metal-matrix composites and ceramic-matrix composites come into use instead of modern metal alloys. With development of analysis methods of modern jet engines, geometrical characteristics, aerodynamic and thermal loads of bladed disks and drums become more specific. This allows use numerical method to determine the blades' stress and strain state [1, 6-21].

Research. Prospective models of air screws have blades with high sweep angle, twisted by the span and bended towards the axis of rotation. These blades should function in rather complicated and heavy aeromechanic conditions.

Similar designs are known for a long time, however, up till now there were no methods for their calculation and materials for their manufacture. Currently, the emergence of high-performance computers and complicated engineering software, as well as the availability of modern composite materials allow carry out more thorough and detailed analysis of the prospective turboprop engine blades. Therefore, using materials, received in [1], the analysis computer program, allowing numerically determine stress and strain state of the blades from the composite material, has been compiled.

The program is designed for investigation of the stress and strain state of naturally twisted layered rod structures, which lie under combined action of stretching forces, bending and twisting moments or under the influence of centrifugal forces. Each layer of the rod section under the investigation consists of

orthotropic material with 9 independent elastic constants. At that, purposeful general property regulation of the specific material can be carried out by choice of both fiber pattern in a separate layer and layer arrangement with known properties in section. This is achieved by alteration of angles φ_i between the material elastic symmetry principal directions in the layer and axes, where the body's stress and strain state is investigated. At that, amount of independent elastic constants (elastic modulus, shearing modulus, Poisson's constants, etc.) of the layer material in the general case will be equal to 13 [1].

The relevant rod structure cross section is arbitrary. The input program parameters are coordinates of the line, limiting separate arbitrary plane section, usually set in the working drawings of projects. This line is divided into two parts (further conditionally called "back" and "backet"), to which two outer lines are adjacent in the layer section. Coordinates of the layers' superficies are specified. Proceeding from these data, with the help of special procedure, the arbitrary configuration section is divided into separate layers by defined thickness t_c of the monolayer [3]. At that, numbers of each layer origin and end are formed. Such designs are carried out for a series of following one after another rod sections (figure 1). As dimensions of the section may vary along the rod length, then number of the layers in each section can be different. This predetermines the emergence of short layers inside the section. Taken from different sections, the coordinates of origin and end of one layer determine the leaf length in the current rod section.

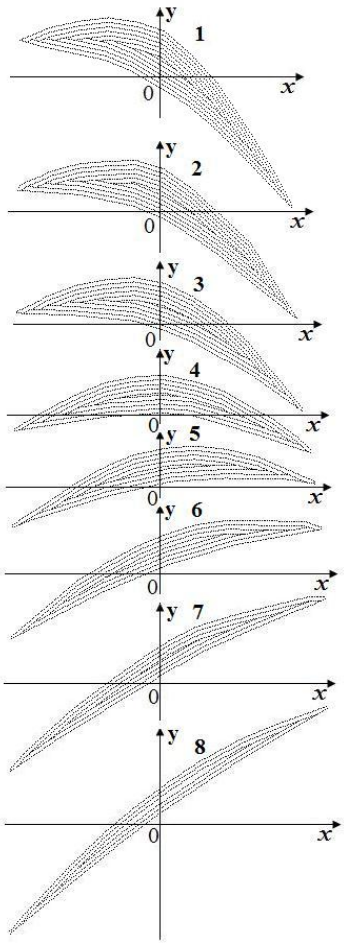

Figure 1 –
The compressor blade cross section set layers; numbers of the blade sections correspond to the sections, distant from its root section

Therefore, the program has solved the engineering problem of "cutting" of each rod layer on the leaves in planes, parallel to the rod axis.

Basic relations of the developed engineering theory on layered rods [1-6] are used to investigate the layered rod stress and strain state. Based on this theory, stretching strain ε, curvature changes χ_1, χ_2 and unwinding τ, as well as strains $\sigma_{11}^i, \sigma_{22}^i, \sigma_{33}^i, \sigma_{23}^i, \sigma_{13}^i, \sigma_{12}^i$ in separate points of the layer i are calculated for each section.

The input program parameters are stretching force P, bending M_1, M_2 and twisting M_t moments, as well as 13 elastic constants of each layer [1] for the current layer. The layers' set points coordinates and numbers are also input parameters for the current section.

To investigate the rod stress and strain state in the centrifugal force field, stretching force, applied in the current section, is calculated by formula:

$$P_r = P = \omega^2 \int_r^R \left(\int_{F(r_1)} \rho dF \right) r_1 dr_1 , \tag{1}$$

where $F(r_1)$ – cross sectional area; r, R – distance from the rotational axis to the gravitational center of the current r and peripheral R section respectively (figure 2); $\omega = \pi \cdot N/30$ – angular velocity (rad.turns/sec.), where N – rotational velocity (turns/min); r_1 – integration variable; ρ - the section layer material density.

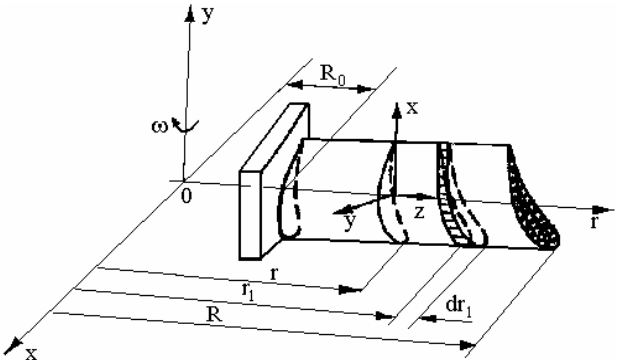

Figure 2 – The distance from the rotation axis to the center of gravity of the current r and peripheral R section

Thus, the force P in the current section r is equal by the centrifugal inertial force value, to the developed layered rod part, concluded between the considered section r and peripheral section R [22].

Data about geometrical characteristics of all sections are necessary to calculate the centrifugal effort by formula (1) and the current section gravity center coordinates. To this end, with the help of special procedure, 15 geometrical characteristics and set densities of all sections are calculated at first [22].

The centrifugal effort for the current section r by the approximate value for (1) is calculated by formula:

$$P_r = \omega^2 \sum_{i=1}^{R} \int_{r_i}^{r_{i+1}} F \rho r_1 dr , \tag{2}$$

where the current section area and density are measured linearly towards the previous section. i.e.

$$\begin{aligned} F &= F_i + (r_1 - r_i)(F_{i+1} - F_i)/(r_{i+1} - r_i), \\ \rho &= \rho_i + (r_1 - r_i)(\rho_{i+1} - \rho_i)/(r_{i+1} - r_i). \end{aligned} \tag{3}$$

Further, the layered rod stress and strain state is studied for the current section. The stretching strain ε, curvature changes χ_1, χ_2 and unwinding τ are determined, physical and geometrical characteristics of the layer and the whole section are calculated.

The program for described lower calculations is currently used to analyze the blade stress and strain state at the preliminary design stage.

1. The studied blade description. The considered blade model is a reduced version of the full scale compressor blade. This blade has been designed and manufactured with a view to follow the real blade structural and aerodynamic equivalency. The blade, studied in the paper, is presented by eight sections (figure 1). Figure 3 presents changes in the area (curve 2 on figure 3), in the highest thickness (curve 1 on figure 3), in the chord в (curve 3 on figure 3) of the blade and relation $c_{max}/в$ depending on r/R_0. The root

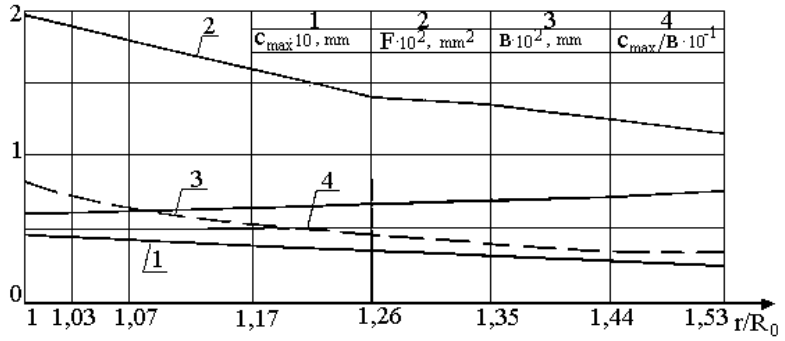

Figure 3 – Change of c_{max} , area F, chord в and $c_{max}/в$ by the compressor blade length

blade section consists of 12 layers of uniform thickness t_c=0,4 mm, however, the peripheral section consists of 6 layers. The reference swirl angle per one unit of the blade length τ_0 – is equal to 0.006 rad./mm.

2. Calculation variants. As an example, the blade from the composite material in the centrifugal force field has been calculated by the described program. At that, investigation for three different combinations of the elastic constants in the package of the composite blade layers has been carried out.

The blade consisting of boron aluminum (BAL) layers interstratified from the side of back and backet has been considered.

3. Calculation result analysis. The stretching force P in the blade rotation has been calculated by formula (1) for each its section r/R_0. Averaged values of the tension stresses σ_{cp} in the conditional untwisted blade achieve the highest value in the third section. This is related to the fact that the force P in the third section differs from the force in the root section on 17%, while their areas differ on 45%.

W, U, V displacement pattern isograms by the blade length for the back and backet (figure 4) have been drawn by the calculation results. As is clear from the Figure, normal displacements W on the peripheral section have maximal values (MX point). W displacements rise on 4-5 times on the entry edge of the back from the root section to the third section. They rise on 10 times on the feathered entry edges. W normal displacement and U, V displacement patterns on the back are more proportional in comparison with the blade backet. On the backet, concentration of the high displacements W is already observed in the fourth blade section. Therefore, to increase the blade strength, it is necessary to change the layers from the backet side by materials more rigid in the stretching.

Figure 5 gives deformation of the blade U_x, V_y, W_z towards the axis 0x, 0y, 0z. The highest changes occur in the second blade section. The compressing deformation value towards the axis 0x on the trailing edge on 3-4 times higher than on the entry blade edge. As a consequence, local strength loss may occur in the tailing feathered layers' edge. Therefore, these layers should be changed by materials with higher compression-resisting properties. The highest blade deformation changes towards the axis 0y occur on the third blade section. The stretching strain value towards the axis 0y in the trailing edge is 2 times higher than in the entry edge of the second blade section and by its value is 3 times higher than the compressing deformation towards the axis 0x. Consequently, to avoid the strength loss from the compressing and stretching strains in the tailing feathered layers' edge, these layers should be changed by materials with higher tensile and compression-resisting properties.

Figure 6 gives distribution of stresses σ_{xx}, σ_{yy}, σ_{zz} on the back and backet by the blade length. The highest normal stress is distributed on the root blade section (MX point), as the root blade section is rigidly fixed. If not to consider it, then the maximum stress is achieved on the third blade section and concentration of the normal stresses on the backet is higher on 1.5-2 times in comparison with the normal stresses on the back. Concentration of the normal stresses on the third section is lower on 4-5 times in comparison with its values on the root section. The compression stresses, conditioned by bending, twisting and stretching interconnectivity, occur on the peripheral back sections. The average stresses in comparison with the stresses σ_{xx}, σ_{yy}, σ_{zz} on 1.5-2 times higher and it is impossible to determine the compression stresses' fields by them (figure 7). Therefore, to determine the blade stress and strain state it is necessary to calculate all components of the stresses σ_{xx}, σ_{yy}, σ_{zz}.

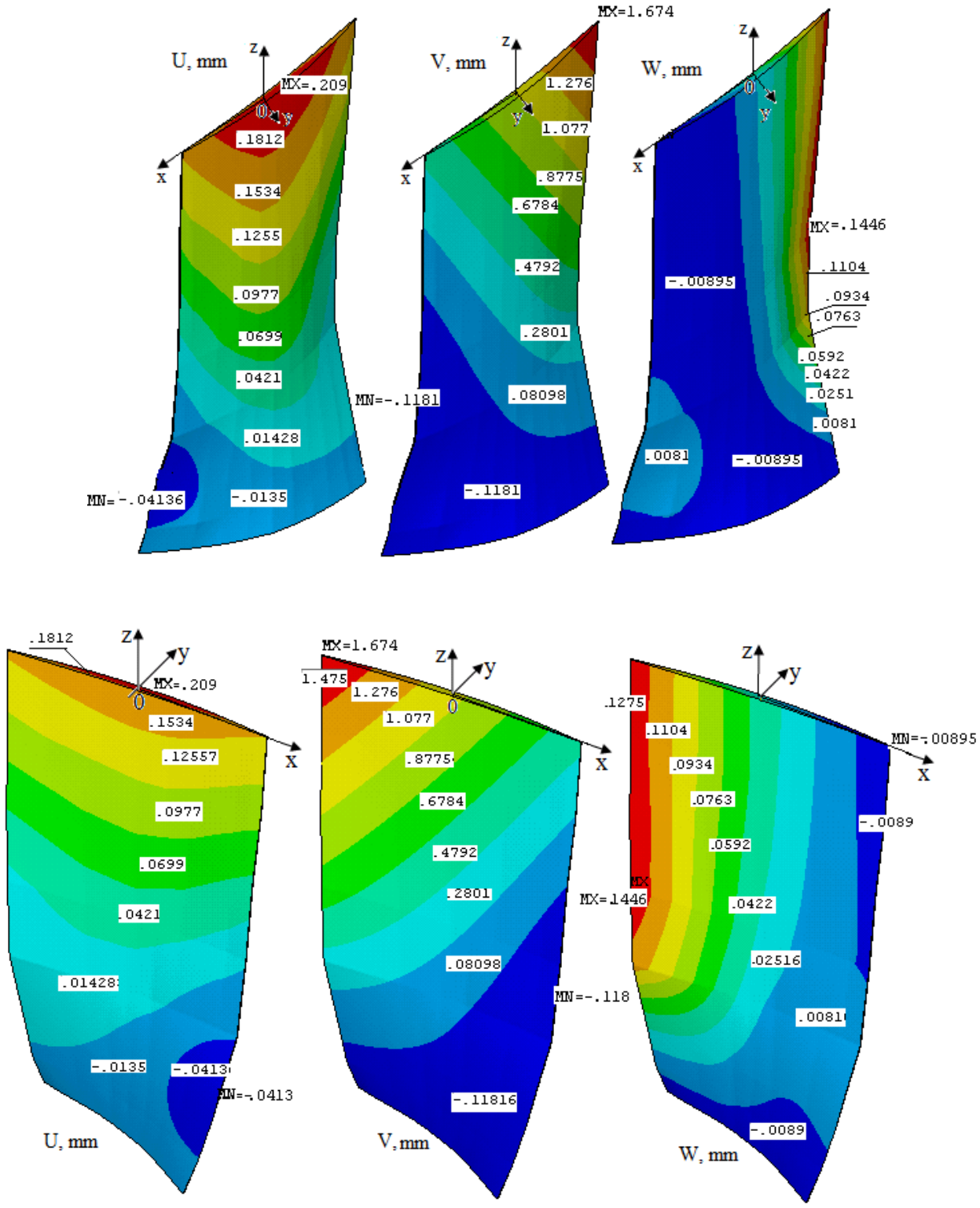

Figure 4 – U, V, W displacement patterns on the back and backet by the boron aluminum blade length

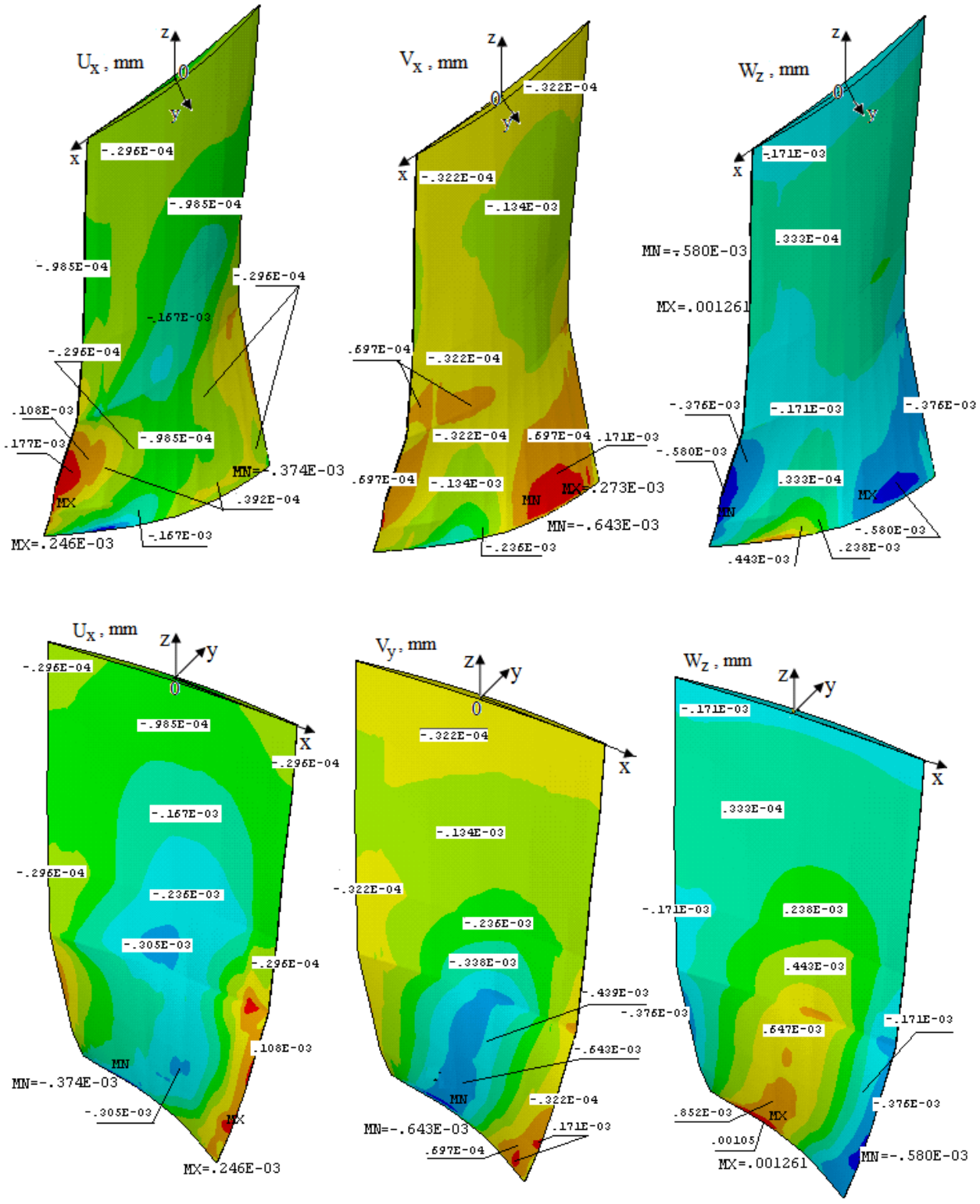

Figure 5 – U_x, V_y, W_z displacement patterns on the back and backet by the boron aluminum blade length

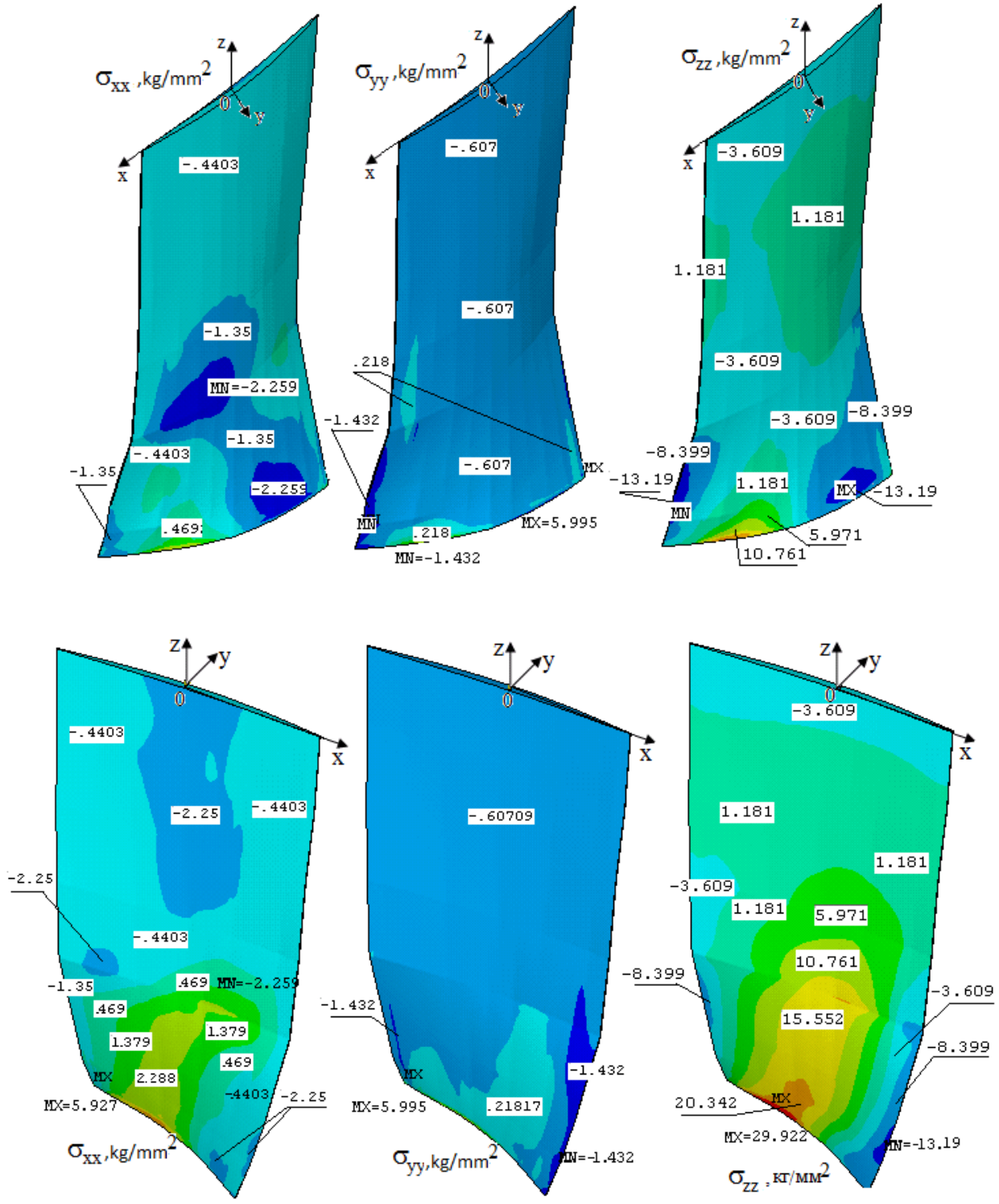

Figure 6 – Distribution of the stresses σ_{xx}, σ_{yy}, σ_{zz} on the back and backet by the boron aluminum blade length

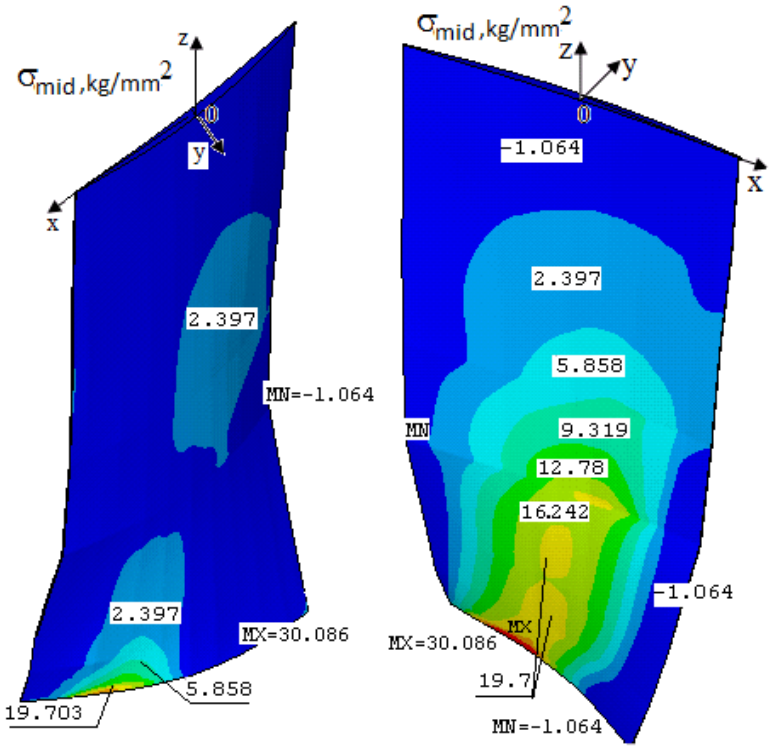

Figure 7 – Distribution of the averaged stress σ_{avg} on the back and backet by the boron aluminum blade length

Figure 8 gives distribution of tangential stresses σ_{xz}, σ_{yz}, σ_{xy} on the back and backet by the blade length. The highest tangential stress is distributed on the third blade section. The local highest tensile tangential stress σ_{xz} is achieved on the third section near the entry back edge, and the compression one – on the tailing backet edge and its value (MN point) is higher on 2 times in comparison with values of σ_{xz} near the entry back edge (MX point). As is known, in the feathered layers such concentration of the tangential stresses may result in the blade's local strength loss. As a consequence, the emergence of the above values of the tangential stresses in the blades may be inadmissible. It has been deduced from the experiments that the strength margin by the tangential stresses between the layers currently should not be less than 3 [3]. The tangential stress σ_{yz} by the value is 2 times lower than the tangential stress σ_{xz} and is distributed respectively on the thick back and backet layers. Therefore, in comparison with the tangential stress σ_{xz}, its influence on the general blade strength is insignificant. The highest value of the tangential stress σ_{xy} is achieved in the third section (MX point) (figure 8). In comparison with the values of the tangential stresses σ_{yz}, σ_{xz} the tangential stress σ_{xy} is insignificant. Therefore, it may not be considered in the calculations.

Figure 9 gives the displacement pattern isograms on the fourth blade section. As is seen from the Figure, displacement area on the backet is higher by its value on 25% from displacement on the back. The highest displacements occur in the middle of the blade back section. The highest displacement U occurs in the back layers neighboring to the gravitational center. V, W displacements occur on the tailing blade edge (MX point). Consequently, it is necessary to select materials of the layers neighboring to the gravitational center and tailing section edges with the tensile properties.

Figure 10 gives distribution isograms of the stresses σ_{xx}, σ_{yy}, σ_{zz} on the fourth blade section. As is seen from the figure, displacement area of the normal stress σ_{zz} on the backet is higher by its value on 20 times from the normal stress σ_{zz} on the back. The highest normal stresses occur in the middle of the blade backet section. The highest normal stress σ_{zz} occurs in the points neighboring to the backet layers' gravitational center and comparable to the values of the average stress (figure 12). Consequently, it is necessary to select materials of the layers neighboring to the gravitational section center with the tensile properties.

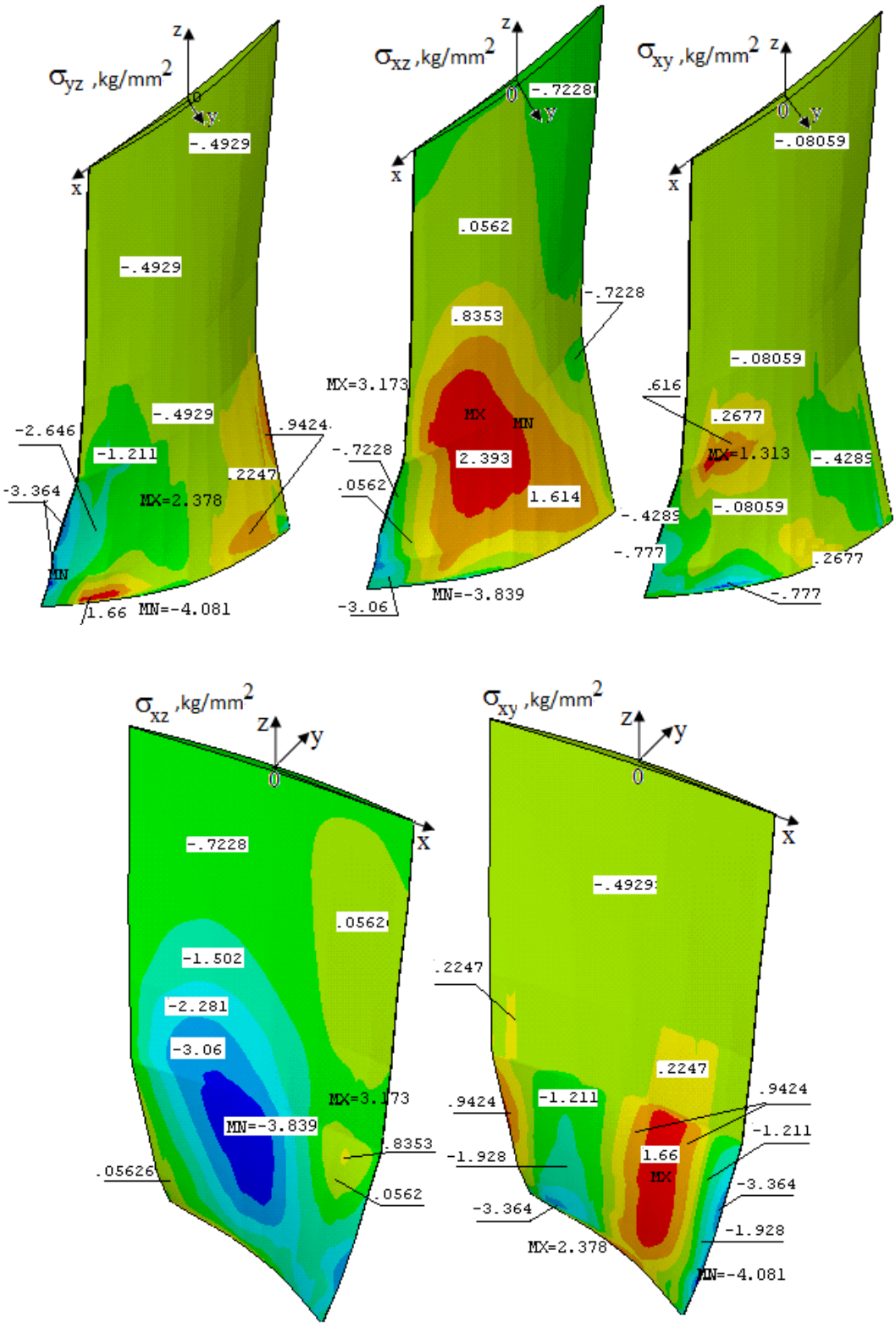

Figure 8 – Distribution of the tangential stresses σ_{xz}, σ_{yz}, σ_{xy} on the back and backet by the boron aluminum blade length

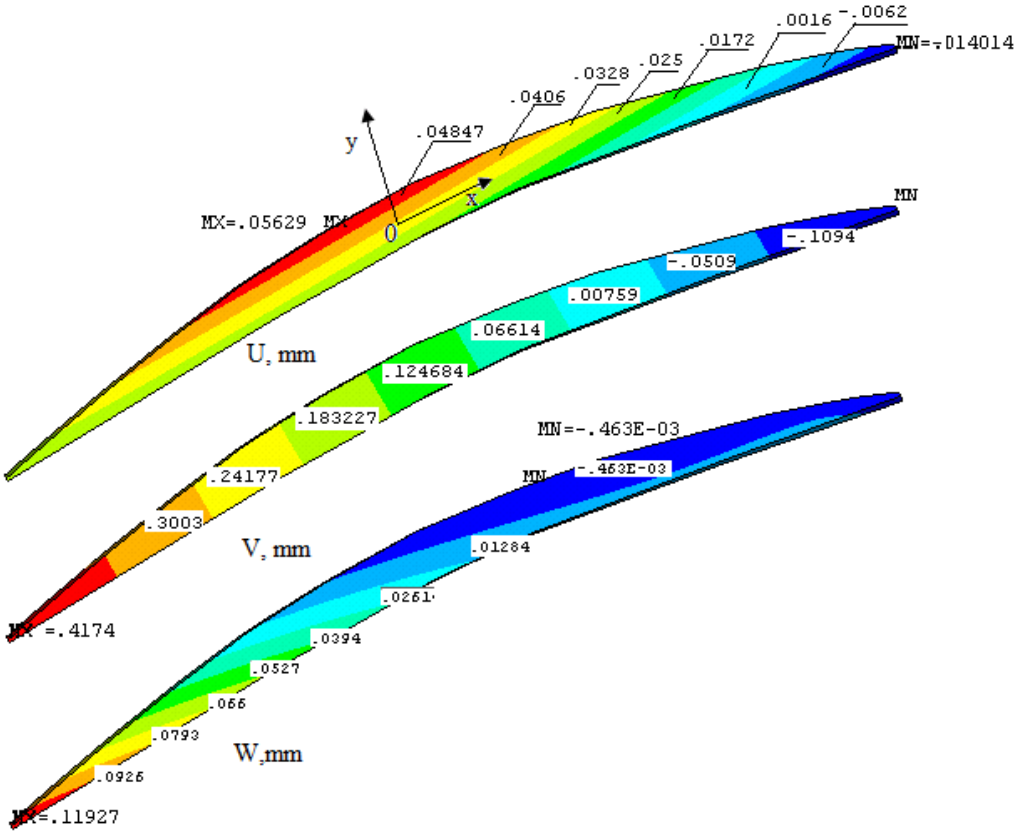

Figure 9 – U, V, W displacement patterns on the fourth boron aluminum blade section

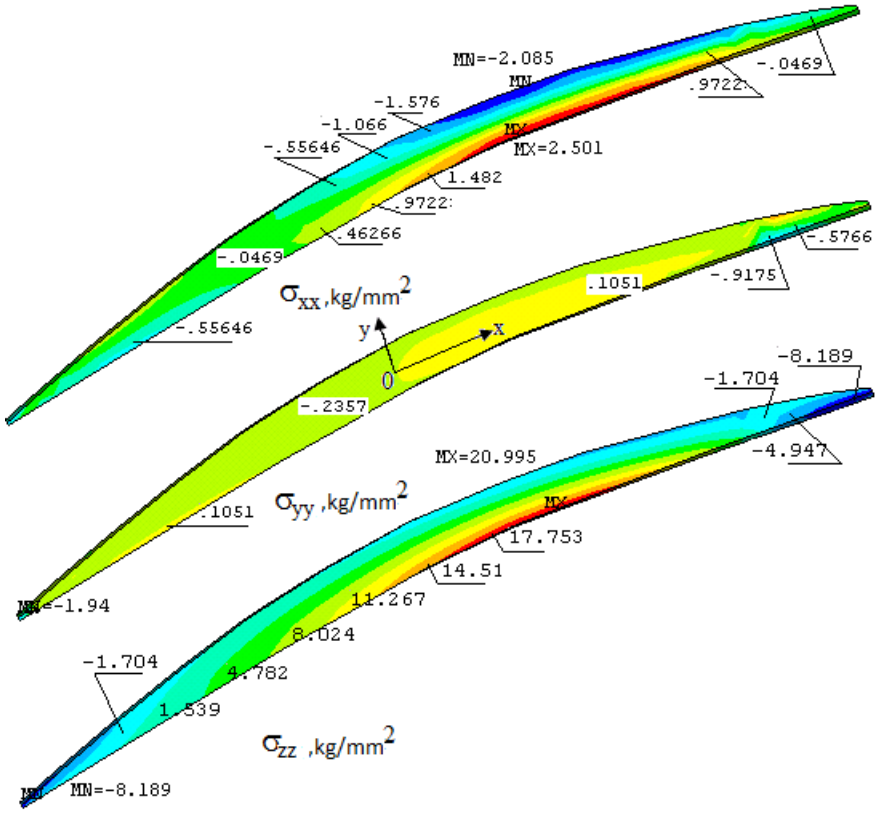

Figure 10 – Distributions of the stresses σ_{xx}, σ_{yy}, σ_{zz} on the fourth boron aluminum blade section

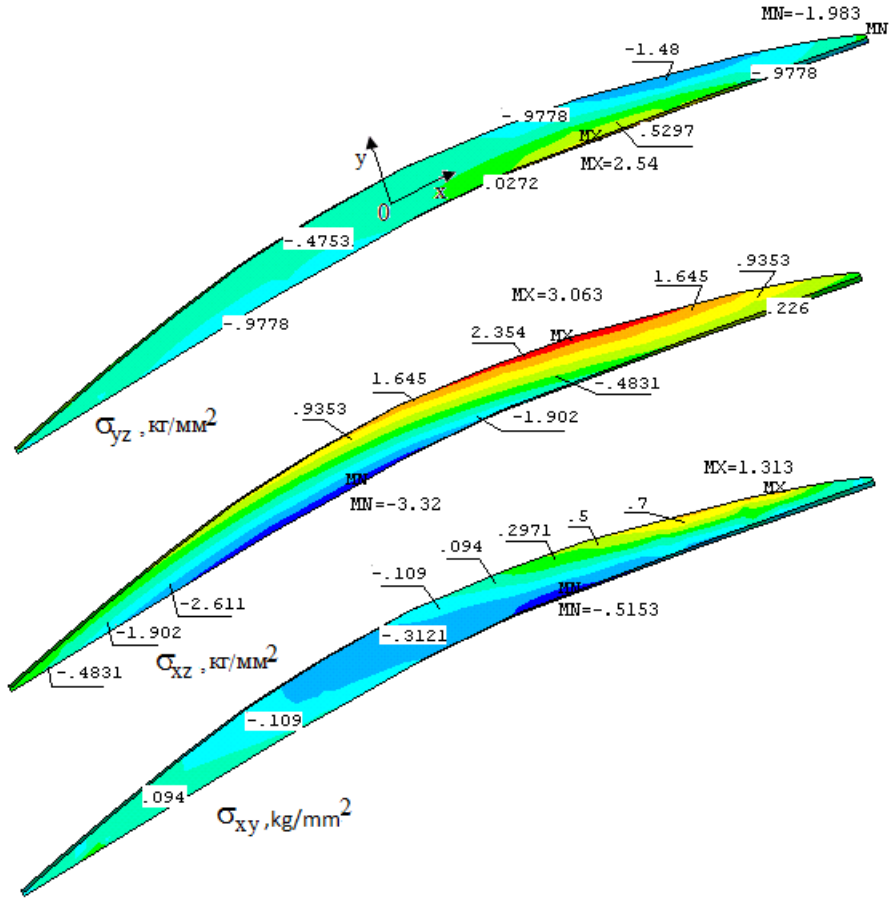

Figure 11 – Distributions of the stresses σ_{yx}, σ_{xz}, σ_{xy} on the fourth boron aluminum blade section

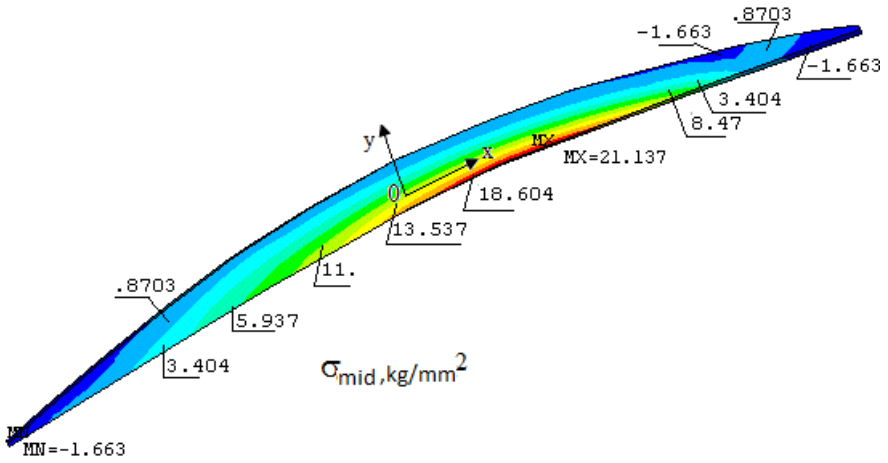

Figure 12 – Distributions of the stress σ_{avg} on the fourth boron aluminum blade section

In the same manner, distributions of the tangential stress σ_{xy} (figure 11) on the fourth blade section show that the tangential stress σ_{xy} concentration area is lower by its value on 200%-300% from the normal stress σ_{zz}. The highest tangential stress σ_{xy} occur in the backet layers neighboring to the gravitational center. In the feathered layers (4^{th} section) of the entry and tailing blade edge, the compression tangential stresses are equally distributed. Values of the tangential stress σ_{xy} in the concentration areas are comparable with values of the stresses σ_{yz}, σ_{xz}. Therefore, materials in the layers, neighboring to the gravitational center should have higher tensile and compression-resisting properties.

The tangential stress σ_{yz} distribution isograms on the fourth blade section show that the tangential stress σ_{yz} distribution area is lower by its value on 15-20 times from the normal stress σ_{zz}. The highest tensile tangential stress σ_{yz} is distributed in the layers of the entry blade edge and is insignificant by its value.

The tangential stress σ_{xz} distribution isograms on the fourth blade section show that the tangential stress σ_{xz} distribution area is lower by its value on 5-7 times from the normal stress σ_{zz}. The highest tensile tangential stress σ_{xz} is distributed in the layers in the middle back part, and the compression tangential stress – on the backet. In the feathered layers (4^{th} section) of the tailing blade edge, the compression tangential stresses are equally distributed and insignificant by their value. The highest tangential stress σ_{xz} by its value is higher on 4-6 times in comparison with values of the tangential stress σ_{yz} and from value of the normal stress is lower on 5-7 times. Therefore, it is necessary to consider influence of the tangential stress σ_{xz} for the layered thin rods.

Conclusions. Thus, the studied examples show that selecting material for the separate layers or reinforcing in them, it is possible over a wide range regulate the level of stress and deformation in the same physical rotor cycles. There is no such wide regulation opportunity for the isotropic material blades.

Thus, in the given geometrical blade form, selected from aerodynamic considerations, by two-way reinforcement of its layers, the level of stress σ_{zz} may be reduced, at the same time avoiding high compression stresses on the profile edges and achieving their more uniform distribution (σ_{zz}) by the section.

The carried out calculations of the blades of specific types showed that the peripheral blade section unwinding angle may be reduced both by increasing the torsional stiffness by the layers' two-way reinforcement and using the stiff material layers in the package of materials. When increasing the layers' rigidity curve ratio level (the layers' curve ratio (elastic modulus, shearing modulus, etc.), difference of the normal stresses in the cross section and value of the tangential stresses between the layers increase. The high tangential stresses between the layers occur due to the different rigidity of the contacting layers. Continuous transition of the material properties from layer to layer is required.

The multilayer composite materials' operation analysis in conditions close to the working conditions of the blades allowed determine a series of the stress distribution features in reinforced materials. It is found that increase in the normal stresses on 2-4 times in comparison with their average values occurs when stretching the blades from the composite materials in the centrifugal force field in external layers.

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КӨПҚАБАТТЫ КОМПОЗИТТІК ҚАЛАҚШАЛАРДЫҢ ОРТАЛЫҚ ТЕБУ КҮШТЕРДІҢ ӘСЕРІНЕН КЕРНЕУ ДЕФОРМАЦИЯЛАНҒАН КҮЙІН САНДЫҚ АНЫҚТАУ

Аннотация. Композиттік материалдардың (КМ) механикасының негізгі мәселелерінің бірі, оның құрамдас бөліктерінің физика-механикалық қасиеттеріне және олардың материал көлеміндегі таралу заңдылығына сүйене отырып КМ тиімді серпімділік сипаттамаларын есептеу. Көп қабатты КМ қабатының қасиеттерінің ықтимал шашырауы құрылымдық біркелкі емес орталар үлгілерін құру кезінде және олардың тиімді сипаттамаларын есептеу кезінде ескерілмейді. Сондықтан қабат қасиеттерінің материалдың тиімді сипаттамаларына, сондай-ақ тұтастай құрылымның сенімділігіне әсерін бағалау қажет.

Жұмыста, кез келген қимадағы композиттік қабатталған дене бұралуының техникалық теориясын пайдалана отырып, орталықтан тепкіш күштердің әсеріндегі қабатты композиттік қалақшаның кернеу деформацияланған күйін сандық анықтауға мүмкіндік беретін бағдарлама құрастырылды.

Табиғи бұралған көпқабатты композитті қалақша созылғыш күштердің, иілу және бұралудың біріктірілген әрекеті сәттерінде немесе орталықтан тебу күштердің әсерінде қарастырылады. Бағдарламада, қалақша осіне параллель орналасқан жазықтықта, қалақшаны қабаттардың жапырақшаларына пішудің технологиялық мәселесі шешілді (бұл қалақшаның ұзындығы бойымен әртүрлі қималары болғандықтан

қалақшаның ұзындығы бойынша жапырақтары пайда болады). Бұл жұмыста зерттелген қалақша сегіз қимадан тұрады.

Түйін сөздер: қалақша, бұру, созу, майыстыру, деформация, кернеу, бороаллюминий, қима.

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ЧИСЛЕННОЕ РЕШЕНИЕ НАПРЯЖЕННО-ДЕФОРМИРОВАННОГО СОСТОЯНИЯ МНОГОСЛОЙНЫХ КОМПОЗИЦИОННЫХ ЛОПАТОК В ПОЛЕ ЦЕНТРОБЕЖНЫХ СИЛ

Аннотация. Одной из основных задач механики композиционных материалов (КМ) является вычисление эффективных характеристик упругости КМ на основе информации о физико-механических свойствах их компонент и законах распределения компонент по объему материала. Возможное рассеяние свойств слоя многослойного КМ не учитывается при построении моделей структурно-неоднородных сред и при вычислении их эффективных характеристик. Поэтому необходима оценка влияния свойств слоя на эффективные характеристики материала, а также на надежность конструкции в целом.

В работе, используя полученную техническую теорию кручения композиционного слоистого стержня произвольного сечения, составлена программа, позволяющая численно определить напряжено-деформированное состояние (НДС) слоистой композиционной лопатки, находящейся в поле центробежных сил. Естественно-закрученная слоистая композиционная лопатка находится под объединенным действием растягивающих сил, изгибающих и скручивающих моментов или под влиянием центробежных сил. В программе решена технологическая проблема раскроя лопатки на лепестки (эти лепестки по длине лопатки появляются в результате переменного сечения по длине лопатки) в плоскостях, параллельных оси стержня. Лопатка, исследованная в данной работе, представлена восемью сечениями.

Ключевые слова: лопасть, кручение, растяжение, изгиб, деформация, напряжение, бороаллюминий, сечение.

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WATER GEOCHEMISTRY ON AKDALA RICE IRRIGATION SYSTEMS

Abstract. In the rice system produced discharges of water from rice fields that rice farmers is explained by the increase of water mineralization in rice bays influencing a reduction in rice yield. Given the Geochemistry of water Akdala irrigation system. The physics of negative influence of salts in water of rice bays on development of plants of rice and its productivity is proved. The critical threshold indicators of salinity and pH of water of rice bays and the frequency of discharges, providing a decrease in the rate of water consumption and sanitation by 15 %, increasing the yield of rice by 12 %, the profitability of production by 11%.

Key words: management, water, rice irrigation systems, rice, rice bay, salinity, change of water, irrigation rate, yield.

Introduction. Rice irrigation systems of Kazakhstan are situated on terraces in basins of rivers Syrdarya, Ile, Karatal on the area 200 thousand hectares. Soils are alluvial-sierozemic, takyr, weakly, moderately and strongly saline, climate is extremely continental arid, summer is hot 30-45^{0}C. Rice is cultivated on rice bays, which area is from1,5 ha to 3,0 ha. Periodical water discharges from rice bays are performed in rice-planting cooperatives and farm, growing rice during irrigation period, which necessity is related to increase of water salinity in bays, affecting on reduction of rice yield.

Disadvantage of this method of water resources management on rice irrigation systems is that there is insufficiently studied water geochemistry rice bays, no adequate substantiation of necessity of water discharge from rice bays during irrigation period. Unnecessary water discharges from rice bays overfill drain discharge channels, decrease their drainage effect, and lead to soil water head, secondary salinization and genesis of bog soils of rice systems. About 20-30% of mineral fertilizers, herbicides is removed by discharge outflow resulting in reduction of rice yield. In the result of application of this method of rice planting, rice yield has reduced to 46 c/ha, and irrigation norm has increased to 26,800 thousand m^3/ha, anddischarge outflow is 20-30% of irrigation norm.

Usage of water resources on rice systems in terms of restricted water access requires new approaches to water management and usage on rice irrigation systems, where nowadays there are hundreds of cooperatives and farms, which are water consumers and have equal rights on irrigation water in accordance with the Water Code of the Republic of Kazakhstan [1]. But there are a lot of problems due to water supply deficit, caused by application of obsolete method of rice growing and t1chnology of regulation and usage of irrigation water in rice irrigation systems. According to literary sources [2, 3] threshold values of water quality in rice bays, affecting rice yield and necessity in periodical water discharges are salinity and pH of water layer in water consumption rate rice bays. Dynamics of salinity and pH of water level during irrigation period, its impact on rice yield, water consumption and water discharge rates, water resources the frequency of water discharges from rice bays, efficiency use on rice irrigation systems is presented in this work.

Methods. Researches were conducted in Akdala rice system of Ile river basin, on rice fields of “Birlik” Agricultural Company of Balkhash region, Almatinskaya oblast. Water resources management in

Akdala rice system and necessity in water discharge from rice bays during irrigation period due to increase of salinity and pH of water layer has been studied on 20 bays of rice field with area 155 ha (figure 1). Chemical composition of salts in soils was determined at spring prior to rice planting, salinity and pH of water layer during irrigation and their impact on growth and development of rice, yield, water consumption and water discharge rates. Lands of rice bays 10 and 11 were very salted, with salt content more 1,0%, lands on other bays were slightly saline with salt content in soils 0,3%.

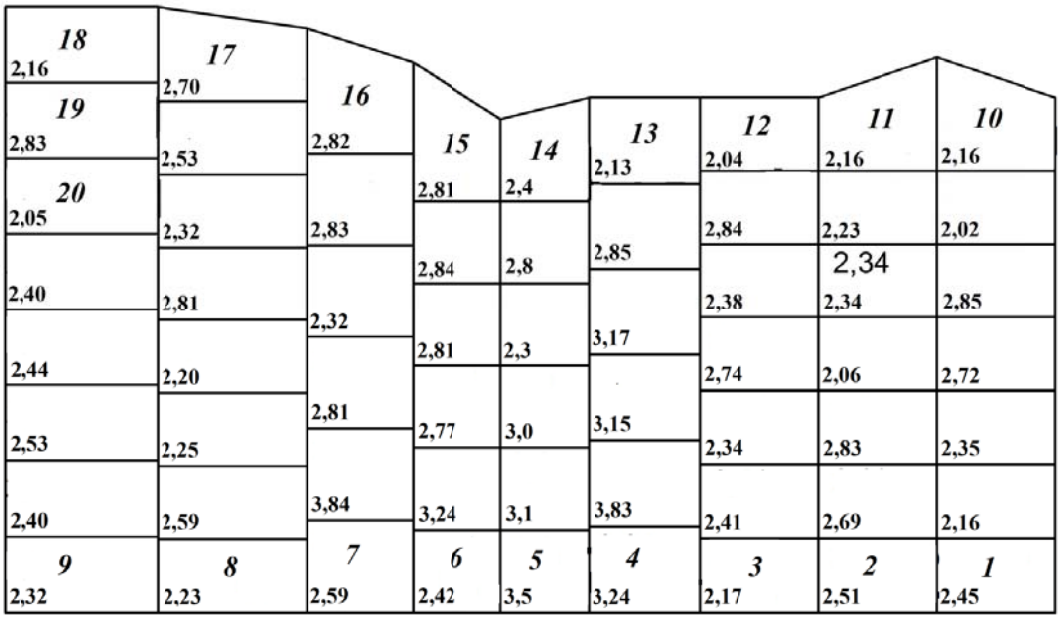

Figure 1 – Plan of rice field 155 ha of second agricultural area of "Birlik" Agricultural Company:
1-20 – rice bays, where salinity and pH of water layer were determined during irrigation period;
10 and 11 – rice bays, where water was discharged during irrigation period, 2.16 – area of rice bays hectares

Using the chemical content of water in rice bays, the irrigation coefficient SAR [4] was calculated, which was later used for assessment of water suitability for growth and development of rice plants, we were observing the condition of rice plants as well. With increase of SAR > 18 and appearance of first signs of wilting or delays in growth and development of rice plants, the water was discharged (changed) from rice bays immediately, and the "new" water was supplied from irrigation channel. Water supply into rice bays of experimental section of the fields was defined using Ivanov water release systems.

Results. Irrigated land of Akdala rice system are irrigated using water from Ile river. Since 2018, salinity of water within irrigation channels of production cooperative of "Birlik" Agricultural company was as follows: in May – 319 mg/l, in June – 339 mg/l, in July – 433 mg/l, in August – 476 mg/l, acid environment – pH – was not exceeding the level of 8.54 (table 1). In terms of chemical content, the water from Ile river is considered to be hydrocarbonate and calcium water suitable for domestic purposes and irrigation. In terms of irrigation coefficient SAR, the water is of a very good quality.

Irrigation coefficient – is the ability to rock and dust distribution within soils, which evaluated by the value of coefficient of potential sodium absorption and it is equal to 0.63 for water in Ile river.

$$SAR = Na : \sqrt{\frac{Ca+Mg}{2}} = 0.85 \sqrt{\frac{3.70}{2}} = 0.63. \quad (1)$$

According to SAR index, the water from Ile river falls under the class with low salinity rate.

Chemical content of water in rise bays is not only condition by the initial chemical content of irrigation water, but by the content of water-solvable salts within the upper layer of soils, method of filling up the rice bay and the water layer. In terms of chemical content, water in rice bays transfers from being hedrocarbonate and sulphate water to natrium and magnesian water. Among acid ions present in rice bay

water, sulphates are the main part of it; among positive ions, main parts compose of natrium and potassium.

During the irrigation period, salinity level of water was not exceeding 917 mg/l in 18 bays out of 20 (table 1). During May and June, salinity of water in 18 bays was 319-442 mg/l and was characterized by the sulphate-hydrocarbonate-calcium content. During July and August, salinity of water in all bays was increasing up to 657-917 mg/l, chemical content of water during this period was sulphate-hydrocarbonate-calcium-magnesium. Alkaline condition of water in rice bays was considered to be satisfactory and the pH level was not exceeding 9.24 units (table 1).

Table 1 – Salinity and pH level of water within rice bays of experimental field section

№ of bays	Salinity rate				pH rate			
	May	June	July	August	May	June	July	August
Irrigator	319	339	433	476	7.5	7,8	8,54	7,0
Rice bays without water release								
1	319	377	511	407	7.5	7.7	7.97	8.3
2	319	319	461	404	7.7	7.6	8.02	8.3
3	319	363	431	515	7.7	7.3	7.65	7.9
4	319	397	448	500	7.5	7.7	7.67	7.9
5	319	393	503	400	7.3	7.5	6.95	8.3
6	319	326	437	312	7.4	7.5	8.05	8.8
7	319	407	495	444	7.85	7.3	7.79	8.2
8	319	–	–	541	7.4	7.7	–	7.7
9	319	381	537	917	7.3	7.1	7.15	8.7
12	319	281	554	516	7.5	7.4	8.06	8.1
13	319	442	657	454	7.4	8.6	7.81	8.0
14	319	–	573	423	7.5	7.8	8.01	7.8
15	319	338	581	506	7.7	7,8	9.29	7.6
16	319	364	543	592	7.6	7.9	8.23	8.0
17	319	–	357	523	7.4	7.9	7.94	7.8
18	319	279	321	523	7.5	7.8	7.86	7.6
19	319	293	–	476	7.5	8.3	–	–
20	319	359	–	433	7.4	7.8	–	–
Rice bays with water release								
10	319	1.381	2.490	2.520	7.7	8.2	7.58	8.8
11	319	1.520	2.510	2.56	7.4	8.6	7.60	8.9

According to irrigation coefficient SAR, the water in 18 rice bays during the irrigation period was considered to be of a good quality, suitable for production of rice and other cultures. Water was not released from these bays for the whole irrigation period (figure 2). In land within these rice bays had low salinity rate with only 0.2-0.3% content of salts in 0-100 cm layer.

In two bays (10 and 11) out 20, salinity of water during the irrigation period was increasing and by the end of May was 1.381-1.520 g/l, by the end of second decade of July – 2.490-2.510 g/l (table 1). Having the water salinity rate of 2,5 g/l and above, the chemical content of water becomes sulphate-magnesium-sodium, and the coefficient calculated by the chemical content of water exceeds 18 units, which means that such water considered to be of poor quality and unsuitable of production of agriculture plants, including rice. The water in rice bays was released and then substituted with the fresh water from irrigation channel that has salinity level of 339 mg/l. Alkane water in rice bays, with salinity level of up to 2.5 g/l was considered to be satisfactory, and pH level was 8.2-9.29 units.

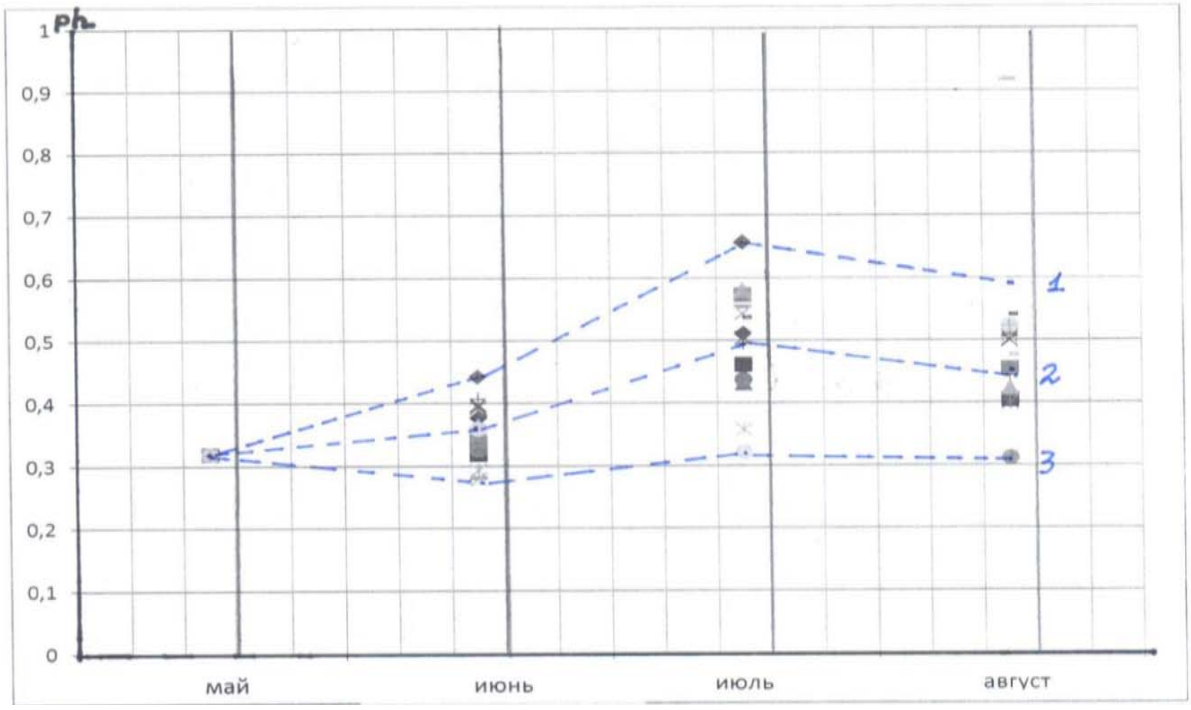

Figure 2 – Salinity of water layer on rice bays where water was not discharged during the irrigation period:
1 – maximum, 2 – average, 3 – minimum value

The second water release from two rice bays 10 and 11 was performed in first decade of August, when salinity level of water in bays was 2,520-2,560 g/l (figure 3).

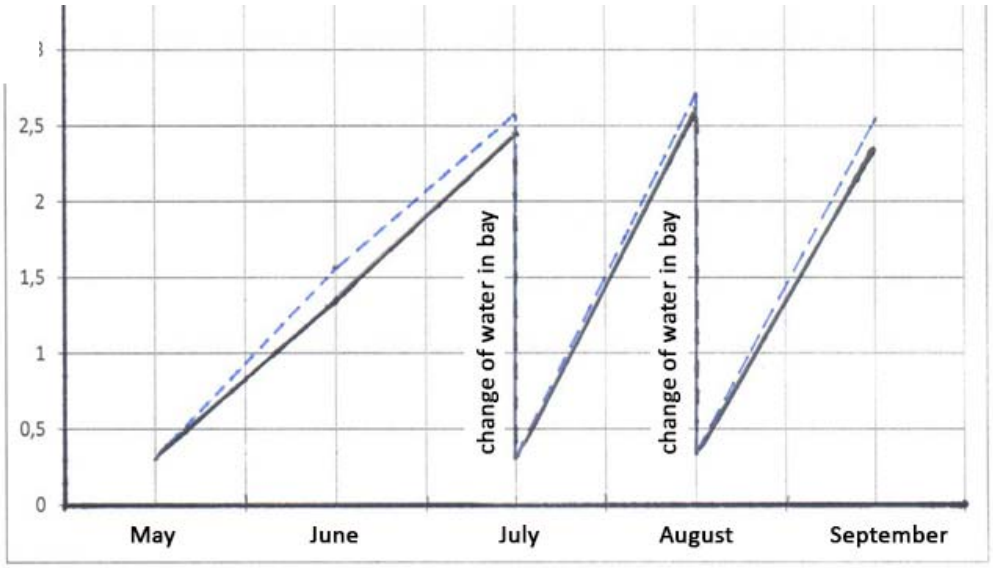

Figure 3 – Salinity of water on rice bays with water release during the irrigation period:
- - - - - – rice bay №10, _____ – rice bay № 11

Irrigation norm during the mineralization of water in rice bays is 0.7-0.9 g/l and without water release during the irrigation period is 21396 m^3/ha, in case of water salinity in rice bays of 2.5 g/l and above with water being released in July and August – 23448 m^3/ha (tables 2, 3). Hydromodule of filling up the rice bays is equal to 6.4-7.8 l/s.ha, during the period of maintaining the water level – 1.9-4.6 l/s.ha (table 2, 3).

Table 2 – Water supply to rice bays without water release systems during the irrigation period

Month	Decade	Water layer on the bay, cm	Water layer in water release system, mm	Water consumption, l/sec	Specific water consumption, l/sec ha	Water supply. m^3/ha
May	2	12.2	476	200.0	78.0	6723
	3	12.4	83	22.8	8.9	766
	Total per month					7489
June	1	4.9	125	42.0	16.3	1412
	2	3.3	37	6.1	2.4	205
	3	2.7	30	5.0	1.9	168
	Total per month					1785
July	1	2.5	137	47.9	18.6	1610
	2	9.8	126	42.3	16.5	1422
	3	14.0	126	42.4	16.5	1425
	Total per month					4457
August	1	11.0	79	21.0	8.2	706
	2	10.2	212	89.0	34.6	2992
	3	9.4	280	118.0	46.0	3967
	Total per month					7665
Water supply during the irrigation period						21396

Table 3 – Water supply to rice bays with water release systems during the irrigation period

Month	Decade	Water layer on the bay, cm	Water layer in water release system, mm	Water consumption, l/sec	Specific water consumption, l/sec ha	Water supply. m^3/ha
May	2	12.2	367	152.5	64	5525
	3	8.6	111	33.3	14.0	1209
	Total per month					6734
June	1	14.9	157	57.6	24.2	2091
	2	8.95	109	34.6	14.5	1256
	3	4.75	51	18.4	7.7	668
	Total per month					4015
July	1	2.33	45	9.0	3.8	327
	2	10.7	241	101.6	42.7	3688
	3	9.6	140	50.4	21.2	1830
	Total per month					5845
August	1	8.5	169	60.6	25.5	2200
	2	12.0	160	63.3	26.6	2298
	3	12.0	170	66.0	28.0	2396
	Total per month					6894
Water supply during the irrigation period						23488

Yield rate of rice in tested 18 bays, where water salinity level during the irrigation period was 0.339-0.917 g/l and water discharges were not performed, is 52.4 metric center/ha, and in two rice bays (10 and 11), where two water discharges were performed – 47.2 c/ha. Rice yield is 46.0 c/ha, irrigation norm is 26800 m3/ha in rice planting cooperative, where researches were performed, at unrationed water discharge from rice bays with area 100 ha. Along with discharged water, there are minerals being washed

out from fields as well, which had a certain effect on growth and development of rice plants and their yield rate, in other words, yield rate in bays with discharged water was 5,2 metric centners lower in comparison with rice bays with no water discharges performed and 6,4 c/ha as compared to data of rice-planting cooperative, where unreasonable water discharges are performed (table 4).

Table 4 – Efficiency of rice plants and their yield capacity on experimental-production field of "Birlik" Agriculture company

№ of bays	Amount of rice plants before harvest	Amount of effective rice straws, pcs/m^2	Tillering coefficient	Yield capacity, metric centner/ha
Rice bays without water release				
1	142	195	1.37	50.30
2	152	206	1.45	53.30
3	142	197	1.39	50.15
4	142	196	1.41	50.0
5	155	197	1.36	55.65
6	157	193	1.31	54.30
7	150	197	1.44	51.90
8	146	189	1.39	54.0
9	148	185	1.30	49.54
12	149	194	1.40	53.80
13	153	185	1.39	48.90
14	149	188	1.35	51.11
15	158	194	1.31	53.50
16	152	194	1.36	54.20
17	148	191	1.37	52.0
18	149	197	1.38	52.76
19	151	201	1.41	53.94
20	148	194	1.41	53.85
Area 48,2 ha	149	194	1.40	52.4
Rice bays with water discharge				
10	141	183	1.34	48.1
11	137	178	1.31	46.3
Area 6,8 ha	139	180	1.32	47.2
Rice-planting cooperative, 100 ha	136	129	1.30	46.0

Rather close relation of yield rate (Y) (r=0.983) to water salinity within rice bays was defined

$$У = (2.6+4.8C) – 0.5C. \quad (2)$$

In case of $C \leq 2.5$ g/l during the irrigation period.

Discussion. Physics of negative influence of salts on development of rice plants lays in the fact that mineral salts increase osmotic pressure of soil solvents, decrease transpiration rates, inhibit ionization of mineral fertilizers, part from which remains in unionized condition and thus is not available for plants, cells receive less water and mineral elements dissolved in this water. Chemical elements that are not required for process of biomass formation, such as natrium, chlorine, magnesium and others, settle down in vacuoles, which, in their turn, grow and cause the decrease of cytoplasm volume [2-4]. Besides, all valuable agricultural properties of soil degrade – structural condition, water retention ability, aeration porosity, alkalinity, mobility of organic compounds. Excess of natrium causes the swilling of soil colloids, degradation of coagulation and other negative effects.

The influence of water salinity in rice bays on the development of rice plants may be described by the following analytical dependence:

$$C = \frac{\chi_A}{1 + Y_A} \ . \tag{3}$$

Such equation describes development of rice plant: changes in environmental conditions (concentration of salts in water of rice bays (χ) and leads to the fact that relation of work modes, vegetation organs (A), cone of increase (Y_A) and environmental conditions becomes uneven (C). Rice plants try to restore the lost balance, therefore change the physiological and biochemical mode of their regulation center of increase cone, which causes that very change of physiological and biochemical mode of vegetative organs that we may observe on rice bays in case of water salinity increase up to 2.5 g/l, rice plants have delay in growth, thus, in order to improve development conditions for rice plants, it is necessary to improve the environment – decrease the salinity level in water of rice bays, and in order to do so, it is necessary to perform water release and change of water.

Conclusions. Saline soil in Akdala rice system is 15 % of irrigating area, but rice on rice is grown with water discharge from rice bays, charges are performed when salinity of water layer is 2.5 g/l, irrigation norm on these lands is 23480 m^3/ha, rice yield – 47.2 c/ha. Rice is cultivated without water discharge on slightly saline lands, which are 85% of irrigated area, salinity of water layer in bays during irrigation period is 1.0 g/l, irrigation norm is 21396 m^3/ha, rice yield – 52.4 c/ha. In rice-planting cooperatives water is discharged in all rice bays resulting in increase of irrigation norm of rice by 3945 m^3/ha and decrease of rice yield on 5.4c/ha. Introducing this method of water use on Akdala rice system, saving of irrigation water will be 39.450 thousand m^3, additional harvesting of rice – 5.2 thousand ton.

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АҚДАЛА КҮРІШ СУҒАРУ ЖҮЙЕСІНДЕ СУДЫҢ ГЕОХИМИЯСЫ

Аннотация. Күріш суғару жүйесінде күріш атыздарынан су тасталулар жүргізіледі, мұны күрішшілер күріш атыздарындағы судың жоғары минерализация және осыған орай күріш өнімділігі азаюымен байланыстырады. Ақдала суару жүйесі суының геохимиясы берілген. Күріш атыздарындағы су тұздарының күріш өсімдіктерінің дамуына және оның өнімділігіне теріс әсер ету физикасы негізделген. Су тұтыну және су бұру нормаларын 15%-ға төмендетуді, күріштің өнімділігін 12%-ға арттыруды, өндірістің рентабельділігін 11%-ға арттыруды қамтамасыз ететін күріш атыздарының минерализациясы мен pH суының шектік көрсеткіштері мен төгінділердің мерзімділігі анықталды.

Түйін сөздер: басқару, су, күріш суару жүйелері, күріш, күріш атыздары, судың минерализациясы, суару нормасы, өнімділік.

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ГЕОХИМИЯ ВОДЫ НА АКДАЛИНСКОЙ РИСОВОЙ ОРОСИТЕЛЬНОЙ СИСТЕМЕ

Аннотация. На рисовых системах производятся сбросы воды из рисовых чеков, необходимость которых рисоводы объясняют повышением минерализации воды в рисовых чеках, влияющей на снижение урожайности риса. Дана геохимия воды Акдалинской оросительной системы. Обоснована физика негативного влияния солей в воде рисовых чеков на развитие растений риса и его урожайность. Определены критические пороговые показатели минерализации и pH воды рисовых чеков и периодичность сбросов, обеспечивающие

снижение нормы водопотребление и водоотведение на 15%, повышение урожайность риса на 12%, рентабельность производства на 11%.

Ключевые слова: управление, вода, рисовые оросительные системы, рис, рисовые чеки, минерализация воды, оросительная норма, урожайность.

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PARAMETERS OF THE DISTRIBUTED DATABASES OF INFORMATION SYSTEMS WHEN SPLITTING DATA WITH APPLICATION OF ALGORITHMS OF MULTIDIMENSIONAL PARITY

Abstract. So far the standard method of prevention of loss of information is a repeated reservation that leads to huge material inputs. Big Data security system developed by authors of the article with an application of the algorithms of multidimensional parity steady against partial losses of places of storage, showed the increased safety level, in particular when using in a cloud computing. In this algorithm data, it is split on a large number of files, each of which does not may contain even one bit of the initial information dispersed in a cloud. The system realized by authors does not demand additional expensive infrastructure of reservation, easily is scaled, extends, and in process of increase in the sizes of infrastructure from the addition of units of storage safety and reliability of data storage automatically increases. Results of testing of parameters of the safety of the main basic subsystems of a technology of the distributed storage with a splitting of data are received. Results showed compliance of parameters of safety to modern requirements and, respectively, a possibility of reduction of domination of expensive infrastructure of reservation and Backup. The technology of the distributed storage with splitting of data personifies the new paradigm of safety opening a possibility of effective counteraction to numerous threats to the stored information and big calculations.

Key words: safety of information, cloud computing, the distributed storage, splitting of data.

Introduction. Safety of big data and calculations in clouds represents a problem which value only increases in the process of increase of external threats over time [1]. According to Brookings Institution, safety is the main obstacle for the federal U.S. Government in plans to transfer more functions to cloud platforms. The government of Kazakhstan, in general, was forced to issue Resolution No. 965 of September 14, 2004 "About some measures for ensuring information security in the Republic of Kazakhstan" according to which "processing and storage of the data making the state secrets, office information of limited distribution are carried out on the computer aids which are not connected to the international (global) data transmission networks, the Internet and/or to the information networks, communication networks having an exit in the international (global) data transmission networks, the Internet". Moreover, the possibilities of practical realization of optical neural networks with a small number of elements is considered [2, 3].

How in such a situation to strengthen the reputation of public clouds?

Only by ensuring reliable safety of the stored information. Badly operated infrastructures of storage of cloudy data threaten any business, any governmental activity in case of catastrophic failure. Therefore, the main objective is the creation of cost-effective architecture with extremely safe storage, scalability and seamless integration between local and cloudy ways of data storage.

We offered for the solution of security of cloudy systems technology of the distributed storage of information with splitting of data [4]. Originally this technology was approved in local networks [5], then established and passed tests in cloudy systems [6].

The essence of the offered technology consists in what the stored data is split on considerable number of files, each of which does not may contain even one bit of initial information. The divided files are distributed on a set of the servers programmed on self-recovery and self-preservation that ensures constant safety of data and safety [4].

The algorithm is not enciphering [7] therefore it cannot be deciphered. The complex structure of safety and resistance to damages of places of storage provides increased protection against the hacker attacks. Thanks to the innovative hierarchical protocol of access, the system prevents unauthorized access to data and plunder of information by insiders. At last, the system guarantees 100% of safe data transmission through open Internet channels and private networks.

It is possible to tell that in a sense our technology of the distributed storage of information with splitting of data is entered in the theory of universal objects in a class of the positive preorders considered a rather computable reducibility [8].

In the real work results of testing of parameters of safety of the main basic subsystems of technology of the distributed storage with splitting of data with application of algorithms of multidimensional parity which have to show the high level of protection and recovery of data in technology of the distributed storage of information with splitting of data are presented. The preliminary tests which are carried out on prototypes guarantee safety level which does not have now analogs in the world.

Method. The method of the distributed storage of information applied by us with splitting of data is intended for ensuring unique protection of databases and large-scale calculations in cloud systems. The method delivers new hybrid the object/block architecture which easily integrates optimal solutions for storage of the structured and unstructured data. In principle, the formulation and solution of the problem of optimal allocation of program modules and database arrays to the nodes of computing systems of a given topology is considered in a number of works [9-11]. But as a result of application of our method the new class of codes splits Big Data in a large number of files, each of which does not may contain even one bit of initial information. The divided files are distributed on a set of the servers programmed on self-recovery and self-preservation that ensures constant safety of data and safety. The separate split data in itself do not bear intelligent information. Another aspect is connected with the fact that the configuration of splitting/restoration can be made so that recovery of data could be executed with application only of a part of the split data, that is it is possible to provide resistance to loss of data.

The frontend of a system is realized on web technologies and uses the simple protocol of hypertext references of HTTP together with interactive technologies on AJAX/PHP (WEB 2.0). The basic control system of content of a web part is realized on CMS Word Press. The website is located on dedicated the server of Internet PS Company LLP, under the Linux Ubuntu Server operating system and the Apache 2.25 web server with PHP 7.0. As the database is used MySQL 5.0.

Technology. The technology offers seamless integration between local and cloud storages. Guarantees unprecedented safety of data and safety and also high scalability. The multilayered infra-structure of safety the system of the false IP addresses provides protection against the attacks of external hackers. Flexible hierarchical protocols of access convince that system administrators, service providers and other strangers have no access to the stored data that excludes need of personal safety, execution of protocols and promotes cost reduction. The technology also guarantees 100% of safe data transmission through open Internet channels and private networks.

In the developed technology patent algorithms of parity with resistance to multiple refusals are applied. The target platform on which the system functions, – MS Windows XP/Vista/7/8 with .NET Framework v.4/4.5.

Structurally the system of the distributed storage of information consists of knots with the installed software of NODE connected among themselves by a confidential communication channel and the software of CLIENT working with these knots. Such multi-agent systems are well known [12]. Many such systems are the basis of decentralized systems with autonomous components [13]. The platforms used are as follows: Java Agent Development Framework [14], JACK Intelligent Agents [15], Multi-Agent Development Kit [16], Agent Builder [17], Cognitive Agent Architecture [18], Agent Building Tool-kit [19], etc.

The main modules of a system, the user interface, server a component, knots of storage are subordinated to a program complex according to the card of interaction of components (figure 1).

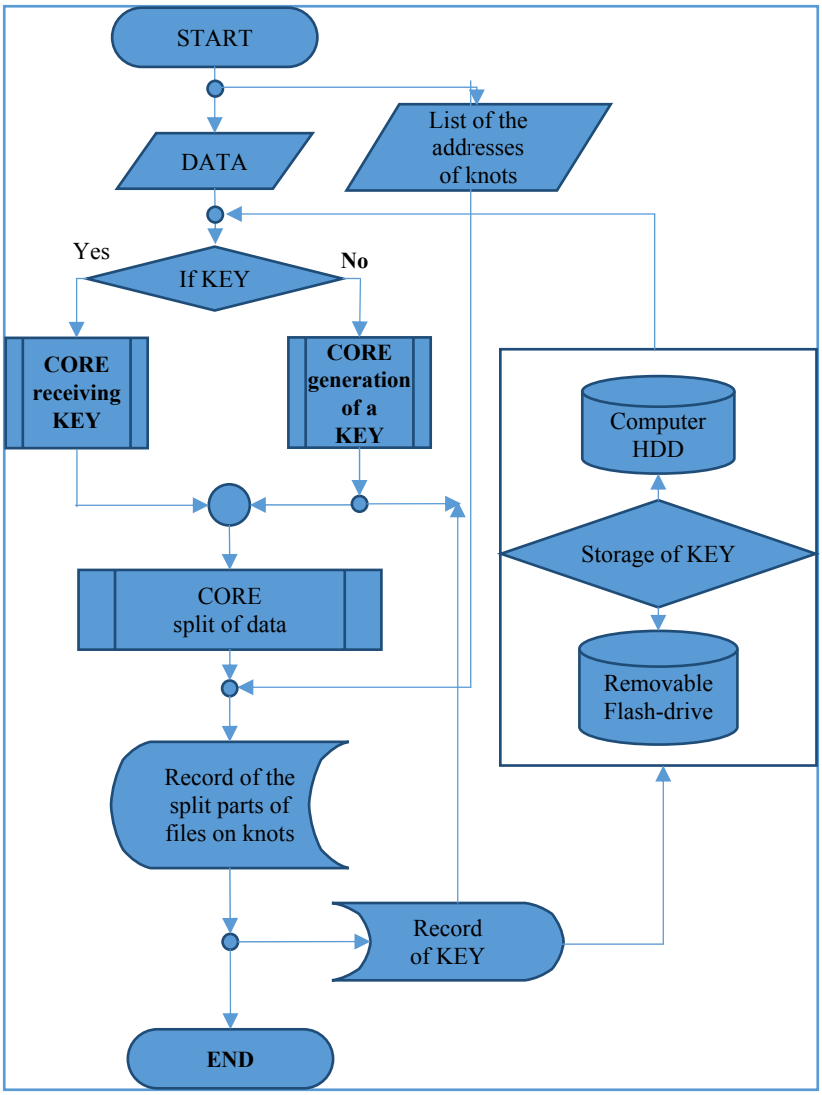

Figure 1 – The card of interaction of components of a system of the distributed storage of information

The client application is responsible for the breakdown of the file on blocks of data and distribution of blocks of data between knots. For storage of the file system and the distributed block, the client application is used by the metafile. Thanks to a tree-like system, the metafile describes file structure and arrangement of blocks of data. The metafile at completion of work is divided into blocks and is also distributed between knots. Only a unique key of the client of CID together with data of authorization (the account, the password) can collect the metafile.

The user establishes a client part of the application and will become authorized in the Distributed Cloud System system, receiving at the same time a unique key of CID which serves for formation of the metafile. Having chosen the file necessary to it, the client starts the Put in a Cloud function. At the same time, this file is blocked, both in the background divided into blocks and distributed on system knots. In need of obtaining the file, the client starts the Receive from a Cloud function, and to it from a cloud blocks of data of its file arrive and by means of an algorithm are packed in the file. The client can also give access to the directory to other users.

The server part of the application (figure 2) serves for storage and processing of information arriving from the client. Storage is carried out in data files which are broken into clusters. The cluster is in turn

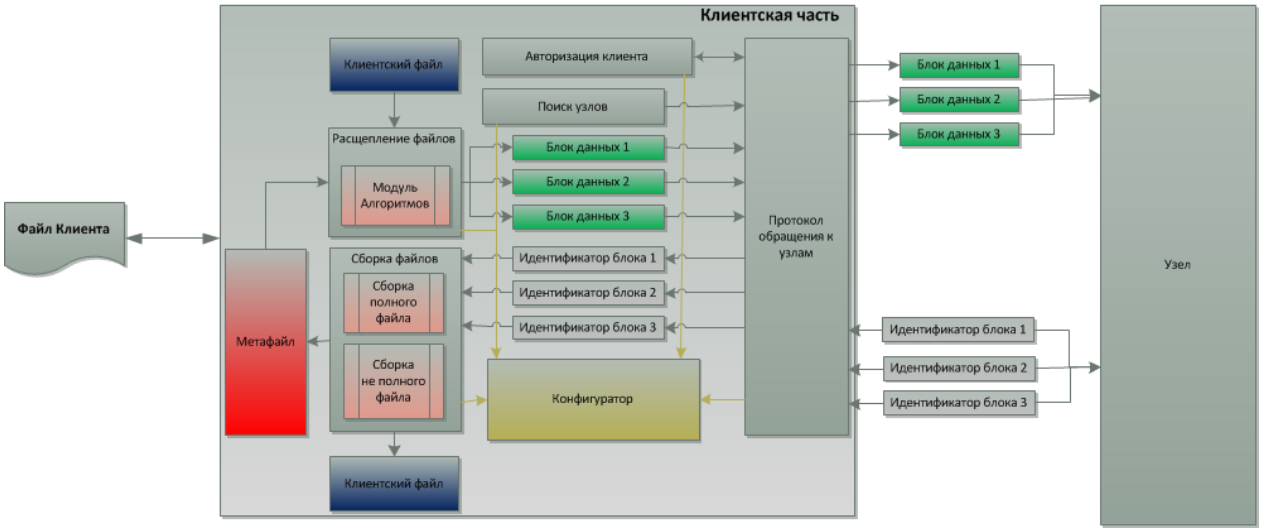

Figure 2 – Scheme of work of a server part of a system

broken into pages which are ranged on a 2-fold system. The size of a cluster is configured in settings of a system, the cluster contains multiple two the number of pages. For example, if the cluster consists of 32 megabytes, then it contains 256 pages of 128 kilobytes in size. In the process of receipt of new information the system creates new clusters for data storage with various dimension of pages.

All arriving data register in turn which monitors all processes of data recording. After successful completion of receiving the client block of data the system writes down this block in the data file and sends to the client the notice of successful receiving the block of data in the form of UID.

"Client" is an ordinary computer device in the form of the personal computer, the server or any other intelligent device on which the software of "CLIENT" is installed. The client serves as a lock for login.

"Knot" is a server with the installed software of "NODE".

"Client" works with a system as with an abstract cloudy subsystem. Interaction of "Client" with the massif of knots is carried out under the one-to-many protocol (one to many).

Any act of recording information into the system is pre-processed by a special algorithm that: a) splits information into unreadable components; b) adds dynamically generated redundant data to increase resistance to partial loss of split parts; c) generates a service metafile describing the created array.

The act of record of set of the created data is implemented by their distribution on system Knots. Any act of reading information by "Client" from "System" is possible only by means of processing of data array received from "Knots" by an algorithm which can restore it, only knowing its metadata. The system knots making the distributed massif know only the limited number of the neighbors. No knot can know all system and knots making it. Knots can dynamically be connected and be disconnected in a system that does not affect operability of all system. Knots can exchange data and automatically update the gone parts of the stored information on the teams of the client.

The client can become authorized on any knot of a system for work with all system.

All information exchange between components of a system is carried out by means of channels in the form of virtual tunnels.

The system is capable to sustain mass shutdowns and damages of Knots, up to 50% and more, depending on the size of a system and configuration parameters of an algorithm.

The system does not demand certification regarding use crypto - algorithms as it does not use enciphering for protection of the stored data. It is possible to read data, having only restored them from the parts of information "smeared" in a system on "Client". Only the owner of a system (creator) or the one to whom the rights were delegated by him can restore data. Delegation of the rights does not mean transfer of rights to possession. The owner always has complete control over any changes in its files.

Node is the software of knot installed on servers in local network of Datacenter I form network of storage of SAN. Knots interact with each other, updating information on the user database of a cloud and notifying neighbors on changes in structure of knots. Thus the transparent scalability of a system is provided.

Figure 3 – Scheme of work of the file system

The system is designed in such a way that all main innovative part of the functionality providing privacy of the stored data and resistance to mass losses of files on knots is implemented only in the client software (figure 3).

In the current version, the mode of access to data on the individual keys developed by the splitting module used in the only place namely at the time of reception/data transmission by the client to knots is realized. Thus, outside the client application with initialized by the user key access to data is impossible, and in a cloud, they are stored in the split unreadable look.

Testing of a security system. The considered security technology in cloud systems is installed by the author on the servers of Kazakhstan hosting company LLP "Internet company PS". 3 servers are used, each of which runs three services in SaaS (Software as a Service) mode. As a result of the use of such a configuration, the goal of a full-fledged layout of the system of 9 nodes has been achieved [20].

The configuration of 9 nodes corresponds to the second level of splitting, which allows achieving resistance to losses of parts from 3 to 5. As shown by the testing of the security system under consideration, conducted by the British company Locked Space Technology, Ltd (figure 4), the loss of 3 pieces of

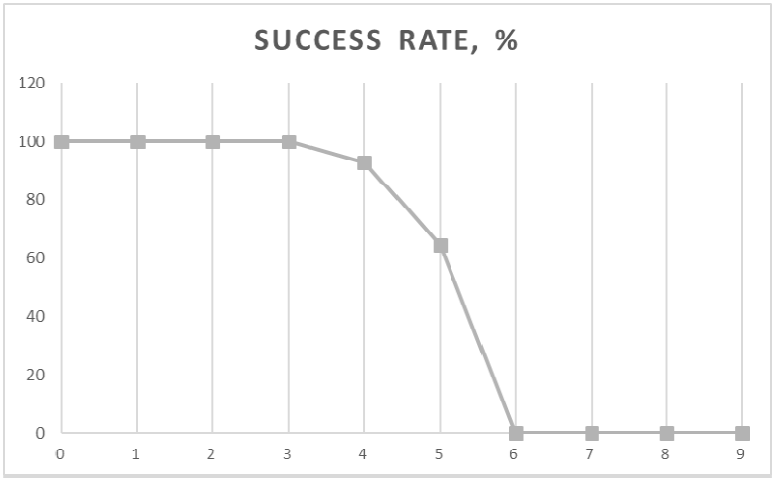

Figure 4 – The results of testing the security system (Locked Space Technology, Ltd)

split files allows you to restore the original file with a probability of 100%. That is, the system has an absolute resistance to file losses up to 33%. Loss of 4 files out of 9 (44.4%) allows you to recover a file with a probability of 92.8%. Even the loss of 5 parts of the split file (55.5%) still has a fairly high probability of 64.3% recovery.

The servers are joined by an internal network of 100 MB/sec. As shown by the preliminary performance tests of the system conducted at the stage of research and development, the speed of splitting/Assembly processes in this implementation depends mainly on the performance of the disk subsystem and the level of splitting. For the second level of splitting, the download and read speeds are between 80-100 MB/sec. Taking into account the existing network capacity of 70-80%, the utilization of the channel can be considered satisfactory. Given the speed of external access from the Internet to the cluster of nodes on average no more than 2-5 MB/s, we can assume that the speed of data access will not be limited to the splitting/Assembly subsystem. The utilization rate of the external access channel to the internal SAN:

$$K_{eff} = \frac{V_{IO}}{\left(\frac{V_{SAN}}{9}\right)} \cong 45\%,$$

where V_{IO} – the speed of Internet access and V_{SAN} – speed of access to nodes in the internal network.

External testing. Modern security methods are implemented by encrypting data, providing security around the perimeter and at the end points, verification protocols and control of employees. A system that stores data in a split form does not need additional protection from unauthorized access since split files do not carry any meaningful content.

The Swiss company Equivalence AG, which is interested in our results of studies on the security of distributed systems with data splitting, has independently tested the security parameters of the main basic subsystems of our technology. In particular, various types of cryptographic attacks on data stored in a split form and on traffic circulating in the system were simulated. The test results are shown in table 1.

Table 1 – The testing results of the distributed storage of information with a breakdown of the data conducted by an Equivalence AG

No	Name of test element	Test parameter	Amount	Results
1	Traffic	Attempt to determine the type of document: docx/odt, jpg, pdf, mp3, txt.	~15GB	Not recognized
2	Traffic	Search in the stream of recognizable symbols	~15GB	Not recognized
3	Login Process	Attempt to intercept the password	10 000 tests	No success
4	Login Process	Trying to Client software spoofing (MITM attack)	10 000 tests	No success
5	Split Files/Metafiles	Brute Force	8760 hours	No success

Of particular interest is the Brute Force attack on split files in the conditions of a specially created on the servers of the company "sandbox", in the form of an isolated virtual machine with a processor pool in 48x10 cores, with a clock frequency of 3.6 GHz. For the organization of attack, the split files of the 3rd level of splitting were selected. As can be seen from the above table of the test Protocol (5th line), the attack lasted 8760 hours, i.e. 1 year of continuous search of bits in 480 parallel streams, which did not give any results.

As you know, the number of search combinations **n** for each level will be equal to the number **k** of ordered sets from the array **j** elements, i.e. it will be equal to the placement A_j^k:

$$n = A_j^k = \frac{j!}{(j-k)!}$$

The number of possible bit permutations is: $s = P_\tau = \tau!$, where τ – the length of the bit sequence.

If you need to choose a sequence of bits in the i files from which you want to collect the original file, we get:

$$m = s1 \cdot s2 \cdot s3 \ldots \cdot si,$$

where m the resulting number of combinations and permutations of the bits in the file.

In our algorithm, the split parts are equal to each other, so

$$m = s1 \cdot s2 \cdot s3 \cdot \ldots si = s^i$$

And with the minimum required number of k parts for assembly of the file obtained the dependence of the level splitting λ:

$$k = 2^{\lambda}, m = (\tau!)^k$$

Get the General formula for calculating the number of combinations:

$$n \cdot m = \left\{\frac{j!}{(j-k)!}\right\} \cdot \{(\tau!)^k\}$$

Here, the total number of files and the minimum required number of file parts are related to the split level λ relations: $j = 3^{\lambda}$ and $k = 2^{\lambda}$ – when the length of the sequence of bits to be rearranged = 16 ($\tau = 16$, $\tau! = 20\ 922\ 789\ 888\ 000$).

The number of search combinations at the 3rd level is for a file with the length of 16 byte $1.35 \cdot 10^{213}$ (table 2). For example, in AES 256 the number of combinations of key search is 10^{77}.

τ = 16 (2 bytes)	*k*	*m*
1 level	2	$\sim 4.38 \cdot 10^{26}$
2-level	4	$\sim 1.92 \cdot 10^{58}$
3-level	16	$\sim 1.35 \cdot 10^{213}$
4-level	32	$\sim 1.82 \cdot 10^{426}$

Table 2 – The number of search combinations

Discussion. The deployed distributed storage and information exchange system is easily scalable by simply adding servers with NODE software installed. Infrastructure expansion is easy and inexpensive. In addition, as the size of the infrastructure increases with the addition of storage units, the security and reliability of data storage automatically increase. And as you know, reliability should always be taken into account when deciding on operation and maintenance: "Reliability is the ability of technical devices to perform certain functions, maintaining their operation within the specified limits for the required period of time or the required operating time in certain operating conditions" [21].

Thus, it can be concluded that the parameters of information security in the cloud with distributed storage using the method of splitting data meet modern requirements for the security of cloud technologies.

To date, the most common method of preventing data loss is multiple backup and replication (real-time copying), i.e. creating multiple copies of the source file. Implemented the system requires no additional costly infrastructure of redundancy and Backup, and can be used, in particular, in the field of processing of large amounts of data on the Mapreduce model [22].

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КӨП ӨЛШЕМДІ ЖҰПТЫҚ АЛГОРИТМДЕРІН ҚОЛДАНА ОТЫРЫП, ДЕРЕКТЕРДІ ЫДЫРАТУ КЕЗІНДЕ АҚПАРАТТЫҚ ЖҮЙЕЛЕРДІҢ ТАРАТЫЛҒАН ДЕРЕКТЕР ҚОРЫНЫҢ ПАРАМЕТРЛЕРІ

Аннотация. Қазіргі уақытта ақпараттың жоғалуын болдырмаудың жалпы қабылданған әдісі көп мәрте резервтеу болып табылады, бұл үлкен материалдық шығындарға әкеледі. Мақала авторлары әзірлеген Big Data қауіпсіздік жүйесі сақтау орындарының ішінара жоғалуына төзімді көп өлшемді айқындық алгоритмдерін қолдана отырып, жоғары қауіпсіздік деңгейін көрсетті, атап айтқанда бұлтты технологияларда пайдалану кезінде. Бұл алгоритмде деректер файлдардың көп санына бөлінеді, олардың әрқайсысы бұлтта

шашыраған бастапқы ақпараттың бір битін де қамтуы мүмкін емес. Авторлар іске асырған жүйе қосымша қымбат резервтеу инфрақұрылымын талап етпейді, оңай масштабталады, кеңейтіледі, әрі сақтау бірліктерін қоса отырып, инфрақұрылым көлемінің ұлғаюына қарай деректерді сақтаудың қауіпсіздігі мен сенімділігі автоматты түрде артады. Деректерді ыдыратумен үлестірілген сақтау технологиясының негізгі базалық кіші жүйелерінің қауіпсіздік параметрлерін тестілеу нәтижелері алынды. Нәтижелер қауіпсіздік параметрлерінің қазіргі заманғы талаптарға сәйкестігін және тиісінше қымбат резервтеу инфрақұрылымы мен Backup басымдығын азайту мүмкіндігін көрсетті. Деректерді ажыратумен үлестірілген сақтау технологиясы сақтаудағы ақпараттың көптеген қатерлеріне және үлкен есептеулерге тиімді қарсы әрекет ету мүмкіндігін ашатын қауіпсіздіктің жаңа парадигмасын өзіне көрсетеді.

Түйін сөздер: ақпараттық қауіпсіздік, бұлыңғыр технологиялар, деректерді үлестірілген сақтау, ажырату.

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ПАРАМЕТРЫ РАСПРЕДЕЛЕННЫХ БАЗ ДАННЫХ ИНФОРМАЦИОННЫХ СИСТЕМ ПРИ РАСЩЕПЛЕНИИ ДАННЫХ С ПРИМЕНЕНИЕМ АЛГОРИТМОВ МНОГОМЕРНОЙ ЧЕТНОСТИ

Аннотация. К настоящему времени общепринятым методом предотвращения потери информации является многократное резервирование, что приводит к огромным материальным затратам. Разработанная авторами статьи система безопасности Big Data с применением алгоритмов многомерной четности, устойчивых к частичным потерям мест хранения, показала повышенный уровень безопасности, в частности при использовании в облачных технологиях. В этом алгоритме данные расщепляются на большое число файлов, каждый из которых не может содержать даже одного бита рассредоточенной в облаке исходной информации. Реализованная авторами система не требует дополнительной дорогой инфраструктуры резервирования, легко масштабируется, расширяется, причем по мере увеличения размеров инфраструктуры с добавления единиц хранения автоматически увеличивается безопасность и надежность хранения данных. Получены результаты тестирования параметров безопасности основных базовых подсистем технологии распределенного хранения с расщеплением данных. Результаты показали соответствие параметров безопасности современным требованиям и, соответственно, возможность уменьшения доминирования дорогой инфраструктуры резервирования и Backup. Технология распределенного хранения с расщеплением данных воплощает в себе новую парадигму безопасности, открывающую возможность эффективного противодействия многочисленным угрозам хранимой информации и большим вычислениям.

Ключевые слова: безопасность информации, облачные технологии, распределенное хранение, расщепление данных.

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THE PROBLEMS OF LITHOSPHERIC GEODYNAMICS

Abstract. The mechanics of viscoelastic lithosphere where the dynamic source of its development determined forces of inertia of internal asynchronous rotation and viscous forces from a spherical current of Kuett in asthenosphere is constructed. These forces define the nature of internal geodynamic pressure and tangential tension. It is found that depending on a difference of angular speeds of internal covers of Earth lithosphere can be in conditions of comprehensive expansion or compression. The mechanism of local changes of thickness of a lithosphere as a result of instability of deformation of a lithospheric cover of Earth under the influence of the internal pressure and volume forces of inertia of rotation is found. Stability of deformation is investigated by a Leybenzon-Ishlinsky method. The main stressed and deformed state is considered at an invariable form of border of a body, and revolted taking into account turns of elements of borders of a body in the course of transition to an adjacent form of balance. Asymmetric forms of the indignations leading to loss of stability of an ellipsoid of rotation are defined. Exponential growth of components of indignations in time, accompanied by oscillatory changes takes place. Within a viscoelastic rheology of a lithosphere the stress-strain state of lithospheric plates at bilateral compression is analyzed. Investigated the formation of folds, arising from the interaction of the plates in the zones of inter-plate boundaries. The interaction of the lithosphere with the underlying asthenosphere with bilateral compression plates. The critical effort of loss of stability of the non-isotropic plate lying on the resilient basis at its bilateral compression is found. The swelling of a viscoelastic earth's plate on a viscid astenosphere at values of compressive forces, larger critical, grows under the exponential law eventually until the condition of applicability of model of a reference linear body is violated. When material of an earth's plate is modelled by a viscid body the deflection also grows in time under the exponential law.
Key words: stress-strain state, deformation, viscoelastic, lithosphere, asthenosphere, Earth.

Introduction. In Kazakhstan, many problems in the mechanics of the Earth in its unified inter-pretation set by academician Zh. S. Erzhanov and solved by his pupils [1, 2]. In researches of deep geody-namics to the fore a problem with the study of the structure and the processes occurring in the boundary between the mantle and the core layer [3]. The mechanism of interaction between the internal and external layers of the Earth is based on the dynamics of the Earth's axial rotation. Influences of endogenous processes apply to all external covers of the Earth.

Works [4-20] from a position of mechanics of a deformable solid body are devoted to research of tectonic development of Earth. Here on elastic, viscoelastic and viscoplastic models of a lithospheric cover of Earth global and local regularities of tectonic movements are studied.

The basis of the modern concept of tectonics of lithosphere's plates is made by the following provisions:

- the precondition about division of the top part of firm Earth into two covers, a lithosphere and an asthenosphere, significantly differing viscous properties;
- the lithosphere is subdivided into limited number of the plates, seven large and as much the small;
- divergent, convergent and transform borders between plates define nature of mutual movements of plates;

- movements of lithosphere's plates submit to laws of spherical geometry;
- the seduction completely compensates spreading;
- the reason of movement of plates in mantle convection.

The most part of earthquakes, volcanic eruptions and orogeny processes occurring on a planet is dated for area of borders between plates. Thus concentration of epicenters of the strongest earthquakes on the globe in rather accurately limited belts defines outlines of borders of lithosphere's plates.

The problem of delimitation of lithosphere's plates by mechanic-mathematical methods is unresolved and actual.

Theoretical fundamentals of tectonics of plates are based on two essentially important prerequisites. First, the most external cover of Earth called by a lithosphere directly lies on the layer called by an asthenosphere which is less strong, than a lithosphere. Secondly, the lithosphere is divided into rather small number of plates on which borders almost all tectonic, seismic and volcanic activity takes place [21-23]. Plates move relatively each other therefore form zones of expansion, thrusts, under thrusts and shifts. In tectonics of plates of methods of mechanics of a deformable solid body and the theory of stability of deformable systems the powerful impulse gives the efforts on introduction which have increased now to further development of science about Earth.

Main results. The case of unmatched rotation of the Earth's lithosphere and mantle is considered. The nature of internal geodynamic pressure and tangential stresses determines by the Cuetta's spherical flow in asthenosphere layer. The equilibrium problem of visco-elastic lithosphere was formulated and solved. The lithosphere is under operating of volumetric centrifugal forces of inertia and forces of viscosity of asthenosphere layer on its base surface. The new qualitative properties of an external display of visco-elastic deformations in lithosphere of the Earth was detected and shown. The process of their stabilization was studied. The distributive mechanism of disturbances with depth along a meridian and parallel was found. The mechanism of formation three axes of Earth's figure was obtained.

$$u_R = \frac{\gamma\omega_1^2}{60\overline{G}g(\overline{m}-1)}\left[\frac{(\overline{m}-2)R}{2}\left(\frac{3\overline{m}-1}{\overline{m}+1}R_0^2 - R^2\right) + \frac{2(\overline{m}-2)(3\overline{m}-1)R_1^2(e_1^2-1)R}{(e_1^3-1)} + \right.$$
$$\left. + \frac{(3\overline{m}-1)e_1^3R_1^5(e_1^2-1)}{(e_1^3-1)R^2}\right] + \frac{\gamma\omega_1^2}{84\overline{G}g(\overline{m}-1)}\left[4(\overline{m}-2)R^3 + \frac{12}{\overline{m}}K_8R^3 + \right.$$
$$\left. + 2K_{10}R_1^2R + \frac{2(5\overline{m}-4)R_1^5}{\overline{m}R^2}K_9 - \frac{3e_1^2R_1^7}{R^4}K_7\right]P_2(\cos\theta);$$

The Earth's lithosphere can be under conditions of comprehensive dilating or compression depending on a difference in rotation with mantle was shown. For a viscoelastic lithosphere the field of movements under the influence of centrifugal forces of inertia is received:

$$u_\theta = \frac{\gamma\omega_1^2}{84\overline{G}g(\overline{m}-1)}\left[(\overline{m}-2)R^3 + \frac{7\overline{m}-5}{\overline{m}}R^3K_8 + \right.$$
$$\left. + K_{10}R_1^2R + \frac{2(\overline{m}-2)R_1^5}{\overline{m}R^2}K_9 + \frac{e_1^2R_1^7}{R^4}K_7\right]\frac{dP_2}{d\theta};$$

and the field of the movements caused by forces of viscosity of a secondary current in an asthenosphere layer:

$$u_R = \frac{1}{\overline{\overline{G}}}\left\{\left[\frac{4\overline{\nu}-2}{1+\overline{\nu}}\frac{RR_1^3}{4(R_0^3-R_1^3)} - \frac{R_0^3R_1^3}{4R^2(R_0^3-R_1^3)}\right]\sigma_0^{(i)}P_0(\mu) + \right.$$
$$\left. + \left[\overline{\nu}\left[(56-40\overline{\nu})\frac{1}{R_0^8} + 40(1+\overline{\nu})\frac{1}{R_0^5R_1^3} - \frac{96}{R_0^3R_1^5}\right]6R^3 - \right.\right.$$

$$-\left[(80\overline{\nu}^2 - 560)\frac{1}{R_0R_1^5} + (168 + 168\overline{\nu} - 24\overline{\nu}^2)\frac{1}{R_0^3R_1^3} + \right.$$

$$\left. + (392 - 168\overline{\nu} - 56\overline{\nu}^2)\frac{R_1^2}{R_0^8}\right]R + (5 - 4\overline{\nu})\left[(56 + 40\overline{\nu})\frac{R_0^2}{R_1^5} + (196 + 80\overline{\nu})\frac{1}{R_0^3} - \right.$$

$$\left. - (140 + 40\overline{\nu})\frac{R_1^2}{R_0^5}\right]\frac{1}{R^2} + \left[(-28 - 48\overline{\nu} - 20\overline{\nu}^2)\frac{R_0^2}{R_1^3} + (168 + 48\overline{\nu})\frac{R_1^2}{R_0^3} - \right.$$

$$\left. - (140 - 20\overline{\nu}^2)\frac{1}{R_0}\right]\frac{3}{2R^4}\Bigg]\times\Bigg[(304\overline{\nu}^2 - 784)\left(\frac{R_0^2}{R_1^8} + \frac{R_1^2}{R_0^8}\right) + (2800 - 240\overline{\nu}^2)\times$$

$$\times\left(\frac{1}{R_0^5R_1} + \frac{1}{R_0R_1^5}\right) - \frac{4032}{R_0^3R_1^3}\Bigg]^{-1}\sigma_2^{(i)}P_2(\mu) +$$

$$+\left[\overline{\nu}\left[(-112 + 80\overline{\nu})\frac{1}{R_0^8} + 80(5 - \overline{\nu})\frac{1}{R_0^5R_1^3} - \frac{288}{R_0^3R_1^5}\right]6R^3 + \left[(240\overline{\nu}^2 - 336\overline{\nu})\frac{R_1^2}{R_0^8} + \right.\right.$$

$$\left.\left. + (336\overline{\nu} - 1680)\frac{1}{R_0^3R_1^3} + (1680 - 240\overline{\nu}^2)\frac{1}{R_0R_1^5}\right]R - (5 - 4\overline{\nu})\times\right.$$

$$\times\left[(-168 - 120\overline{\nu})\frac{R_0^2}{R_1^5} + \frac{168}{R_0^3} + 120\overline{\nu}\frac{R_1^2}{R_0^5}\right]\frac{1}{R^2} - \left[(280 + 144\overline{\nu} - 40\overline{\nu}^2)\frac{R_0^2}{R_1^3} - \right.$$

$$\left. - 144\overline{\nu}\frac{R_1^2}{R_0^3} + (40\overline{\nu}^2 - 280)\frac{1}{R_0}\right]\frac{3}{2R^4}\times\Bigg[(304\overline{\nu}^2 - 784)\left(\frac{R_0^2}{R_1^8} + \frac{R_1^2}{R_0^8}\right) +$$

$$\left. + (2800 - 240\overline{\nu}^2)\times\left(\frac{1}{R_0^5R_1} + \frac{1}{R_0R_1^5}\right) - \frac{4032}{R_0^3R_1^3}\Bigg]^{-1}\tau_2^{(i)}P_2(\mu)\right\};$$

$$+ (392 - 168\overline{\nu} - 56\overline{\nu}^2)\frac{R_1^2}{R_0^8}\Bigg]R + (2 - 4\overline{\nu})\left[(56 + 40\overline{\nu})\frac{R_0^2}{R_1^5} + (196 + 80\overline{\nu})\frac{1}{R_0^3} - \right.$$

$$\left. - (140 + 40\overline{\nu})\frac{R_1^2}{R_0^5}\right]\frac{1}{R^2} - \left[(-28 - 48\overline{\nu} - 20\overline{\nu}^2)\frac{R_0^2}{R_1^3} + (168 + 48\overline{\nu})\frac{R_1^2}{R_0^3} - \right.$$

$$\left. - (140 - 20\overline{\nu}^2)\frac{1}{R_0}\right]\frac{1}{R^4}\Bigg]\times\Bigg[(304\overline{\nu}^2 - 784)\left(\frac{R_0^2}{R_1^8} + \frac{R_1^2}{R_0^8}\right) + (2800 - 240\overline{\nu}^2)\times$$

$$\times\left(\frac{1}{R_0^5R_1} + \frac{1}{R_0R_1^5}\right) - \frac{4032}{R_0^3R_1^3}\Bigg]^{-1}\sigma_2^{(i)}\frac{dP_2}{d\theta} + \Bigg[(7 - 4\overline{\nu})\Bigg[(-112 + 80\overline{\nu})\frac{1}{R_0^8} + \Bigg.$$

$$\Bigg. + 80(5 - \overline{\nu})\frac{1}{R_0^5R_1^3} - \frac{288}{R_0^3R_1^5}\Bigg]R^3 + \Bigg[(240\overline{\nu}^2 - 336\overline{\nu})\frac{R_1^2}{R_0^8} + \Bigg.$$

$$\Bigg. + (1680 - 240\overline{\nu}^2)\frac{1}{R_0R_1^5} + (336\overline{\nu} - 1680)\frac{1}{R_0^3R_1^3}\Bigg]R -$$

$$-(2-4\bar{\nu})\left[(-168-120\bar{\nu})\frac{R_0^2}{R_1^5}+\frac{168}{R_0^3}+120\bar{\nu}\frac{R_1^2}{R_0^5}\right]\frac{1}{R^2}+$$

$$+\left[(280+144\bar{\nu}-40\bar{\nu}^2)\frac{R_0^2}{R_1^3}-144\bar{\nu}\frac{R_1^2}{R_0^3}+(40\bar{\nu}^2-280)\frac{1}{R_0}\right]\frac{1}{R^4}\Bigg]\times$$

$$\times\left[(304\bar{\nu}^2-784)\left(\frac{R_0^2}{R_1^8}+\frac{R_1^2}{R_0^8}\right)+(2800-240\bar{\nu}^2)\left(\frac{1}{R_0^5R_1}+\frac{1}{R_0R_1^5}\right)-\frac{4032}{R_0^3R_1^3}\right]^{-1}\tau_2^{(i)}\frac{dP_2}{d\theta}\Bigg\},$$

where R_0, R_1 - radiuses of external and internal surfaces of a lithospheric envelope; $P_0(\mu)$, $P_2(\mu)$ - polynoms of Legendre; $\sigma_0^{(i)}, \sigma_2^{(i)}, \tau_0^{(i)}$ - the sizes answering to forces of viscosity of an asthenosphere layer.

$$u_\theta=\frac{1}{2\bar{G}}\Bigg\{\Bigg[(7-4\bar{\nu})\left[(56-40\bar{\nu})\frac{1}{R_0^8}+40(1+\bar{\nu})\frac{1}{R_0^5R_1^3}-\frac{96}{R_0^3R_1^5}\right]R^3-$$

$$-\left[(80\bar{\nu}^2-560)\frac{1}{R_0R_1^5}+(168+168\bar{\nu}-24\bar{\nu}^2)\frac{1}{R_0^3R_1^3}+\right.$$

The mechanism of emergence of global tectonic breaks on which there is a splitting of a lithospheric cover into lithosphere's plates, is investigated by mathematical methods of the theory of stability of deformable systems.

The main stressed-deformed state of an elastic and viscous ellipsoid of rotation is investigated. The equation of elastic balance and the main ratios are defined in degenerate elliptic coordinates of *s, μ, φ*.

The ellipsoid rotates round its pivot-center symmetry with a constant angular speed ω and is under the influence of the uniform pressure q attached to its surface in the positive direction to a normal.

The balance equations in movements look like:

$$\frac{1}{1-2\nu}\,grad\ div\,\bar{u}+\nabla^2\bar{u}=\frac{1}{G}\,grad\,\Phi,$$

where $\Phi=-\frac{1}{2}\frac{\gamma}{g}\omega^2r^2$ - potential of centrifugal forces, $\bar{u}$ - movement vector, G - shift module, ν - Poisson's coefficient, $j=\rho g$ - specific weight, g - gravity acceleration, ρ - density.

The common decision of the equations of balance is defined through the biharmonic functions expressed by means of tesserae spherical functions

$$P_n^m(s)P_n^m(\mu)\cos m\varphi,\quad P_n^m(s)P_n^m(\mu)\sin m\varphi.$$

Asymmetric forms of the indignations leading to loss of stability of an ellipsoid of rotation are defined.

Components of indignations are expressed through three any constants which are found from boundary conditions.

Let's consider stability of a non-isotropic plate of length a, of thickness H subject to bilateral compression and lying on the deformable elastic basis.

Let's define reaction of the basis at loss of stability of a plate. Equilibrium equations in movements u,w of the indignant condition of the basis have an appearance:

$$\frac{G_0}{1-2v_0}\frac{\partial\theta}{\partial x}+G_0\nabla^2u=0,\qquad \frac{G_0}{1-2v_0}\frac{\partial\theta}{\partial z}+G_0\nabla^2w=0, \tag{1}$$

where $\nabla^2=\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial z^2}$ – Laplacion, $\theta=\frac{\partial u}{\partial x}+\frac{\partial w}{\partial z}$, G_0 - shift modulus, v_0 - basis Poisson's ratio.

We will take the solution of equilibrium equations (1) meeting a limitation condition on infinity in a look

$$u(x,z)=\varphi_1(z)\cos m_1 x,\qquad w(x,z)=\varphi_2(z)\sin m_1 x, \tag{2}$$

where

$$\varphi_1(z)=(A_1-A_2 z)\exp(m_1 z),\quad \varphi_2(z)=\left(A_1+A_2\frac{3-4\nu_0-m_1 z}{m_1}\right)\exp m_1 z,$$

A_1, A_2- the arbitrary constants, $m_1=\dfrac{n\pi}{a}, n-$ integer.

Expression for a rated stress has an appearance:

$$\sigma_z=2G_0\left[A_1 m_1-A_2\left(2\nu_0-2+m_1 z\right)\right]\exp(m_1 z)\sin m_1 x. \tag{3}$$

We will also define constants A_1 and A_2 from a condition of rigid coupling of a plate with the basis:

$$w\big|_{z=0}=w_0\big|_{z=0}, u=-\frac{h_1}{2}\frac{\partial w}{\partial x}\bigg|_{z=0}=u_0\big|_{z=0}, \tag{4}$$

where u,w- horizontal and vertical movement of a plate,, u_0, w_0- movements of the basis on border $z=0.$ Let's say that vertical movements of a plate at $z=0$ has an appearance:

$$w=\ell\sin m_1 x,$$

where $\ell-$ maximal deflection.

Then from a condition (4) we will define:

$$A_1=-\frac{1}{2}m_1 h_1\ell,\qquad A_2=-\frac{(2-m_1 h_1)m_1}{2(3-4\nu_0)}\ell. \tag{5}$$

Substituting values A_1, A_2 in expression (3), we will determine the size of normal pressure on border $z=0$:

$$q=\sigma_z\big|_{z=0}=-2G_0\left[\frac{2m_1(1-\nu_0)}{3-4\nu_0}+\frac{1-2\nu_0}{2(3-4\nu_0)}h_1 m_1^2\right]\ell\sin m_1 x=-\frac{4G_0 m_1(1-\nu_0)}{3-4\nu_0}w-\frac{(1-2\nu_0)h_1 G_0}{3-4\nu_0}\kappa, \tag{6}$$

where $\kappa=-\dfrac{\partial^2 w}{\partial x^2}-$ curvature of a plate at $z=0$.

We investigate the equation of neutral equilibrium of a plate

$$\frac{\partial^4 w}{\partial x_1^4}-\left(K_1^2-K_3^2\right)\frac{\partial^2 w}{\partial x_1^2}-K_2^2\frac{\partial^2 w}{\partial z_1^2}=0. \tag{7}$$

where

$$K_1^2=\frac{12G_2(1-\nu_1^2)}{E_1\rho^3(1-\rho)},\quad K_2^2=\frac{12E_2(1-\nu_1^2)}{E_1\rho^3(1-\rho)},\quad K_3^2=\frac{12(1-\nu_1^2)P}{E_1\rho^2}=K^2P,$$

$\rho=\dfrac{h_1}{h}$, $h=h_1+h_2$, E_1- elastic modulus, ν_1- Poisson's ratio, h_1- thickness of a rigid layer; $E_2=\dfrac{2G_2(1-\nu_2)}{1-2\nu_2}$- transversal module, G_2- shift modulus, ν_2- Poisson's ratio, h_2- thickness of the weak layer; $x_1=\dfrac{x}{h}$, $z_1=\dfrac{z}{h}$; u,w- horizontal and vertical movements, $P=ph_1-$ regional pressure.

Boundary conditions have an appearance:

$$w=0,\frac{\partial^2 w}{\partial x_1^2}=0 \text{ at } x_1=0 \text{ and } x_1=\frac{a}{h}, \tag{8}$$

$$\frac{\partial w}{\partial z_1} = 0 \text{ at } z_1 = \frac{H}{h} = r, \tag{9}$$

$$\frac{\partial w}{\partial z_1} = -q^*(x_1) = K_0^2 \left[4(1-v_0)w - \frac{\rho(1-2v_0)}{m} \frac{\partial^2 w}{\partial x_1^2} \right] \text{ at } z_1 = 0,$$

where

$$K_0^2 = \frac{(1-2v_2)(1-\rho)mG_0}{2(3-4v_0)(1-v_2)G_2},$$

$m = m_1 h -$ the pure wave number.

We will find value of critical effort:

$$P_{kp} = \frac{1}{K^2} \left\{ m^2 + K_1^2 + \frac{3K_2^2}{m^2 r^2} \left[1 + \frac{rK_0^2}{2} \left(4\left(1-v_0\right) + \rho m \left(1-2v_0\right) \right) \right] - \right.$$

$$\left. - \sqrt{1 + \frac{r^2 K_0^4}{4} \left[4\left(1-v_0\right) + \rho m \left(1-v_0\right) \right]^2 + \frac{rK_0^2}{3} \left[4\left(1-v_0\right) + \rho m \left(1-2v_0\right) \right]} \right\}. \tag{10}$$

When material of an earth's plate is modelled by a viscid body the deflection grows in time under the exponential law.

Recommendations. It is discovered that action of centrifugal force of inertia causes following geodynamic phenomena: with time and at value change of Poisson's constant the zero value of radial movement displaces along a meridian and is a possible disturbance and a trigger mechanism of tectonic stresses; with increase of Poisson's constant the compression close to a pole increases, and the expansion in the field of equator decreases and meridian movement increases. The mechanic-mathematical model of process of emergence of global tectonic breaks is presented by local changes of thickness of a lithosphere as a result of loss of stability of deformation of an ellipsoidal lithospheric cover of Earth under the influence of the internal pressure and volume forces of inertia of rotation. The lithospheric cover is rigidly linked to an adjacent continuous ellipsoid of rotation. The critical effort of loss of stability of the non-isotropic plate lying on the resilient basis at its bilateral compression is found.

Conclusion. It is shown that the account of the secondary flow in asthenosphere layer results in following properties: the positive value of radial movement increases with time and with depth, i.e. the lithosphere has a state of comprehensive expansion. With increase of a difference between angular velocities of lithosphere rotation and a mantle the value of radial and meridian movements reverses their mark and the lithosphere passes converts to the state of comprehensive compression. It is established that the main reason of emergence of global tectonic breaks on which there is a splitting of a lithospheric cover into lithosphere's plates, loss of stability of a lithospheric cover of Earth under the influence of the internal pressure and volume forces of inertia of rotation is. The swelling of a viscoelastic earth's plate on a viscid astenosphere at values of compressive forces, larger critical, grows under the exponential law eventually until the condition of applicability of model of a reference linear body is violated. When material of an earth's plate is modelled by a viscid body the deflection also grows in time under the exponential law.

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ЛИТОСФЕРАЛЫҚ ГЕОДИНАМИКАНЫҢ ПРОБЛЕМАЛАРЫ

Аннотация. Тұтқыр-серпімді литосфераның механикасы жасалған, оның дамуының динамикалық негізінен ішкі асинхронды айналу инерциялық күші мен сұйық астеносферадағы Куэтта сфералық ағымнан тұиқыр күштер анықталған. Ол күштер ішкі геодинамикалық қысымның табиғатын және жанама кернеулерді

анықтайды. Жердің ішкі қатпарларының келісілмеген айналуына сәйкес литосфераның тең жақты өсуі немесе сығылуы табылған. Ішкі қысым және көлемді айналу инерция күштер әсерінен Жер литосералық қабатының тұрақсыздық нәтижесінен литосфераның қалыңдығының тетігі жергілікті өзгерістер табылды. Лейбензон-Ишлинский әдісімен тұрақтылық деформациялау зерттелген. Дене шекара нысаны өзгермейтін кезінде негізгі кернеулі-деформациялық күй қаралды және ауытқу жағдай дене шекара бұрылыстар элементтерінің қосымша тепе-теңдік нысан үдерісінде көшу ескере отырып. Айналу эллипсоид орнықтылығын жоғалтуға әкеп соғатын қалыптан асимметриялық нысандар анықталған. Уақыт қалыптан ауытқу компоненттерінің экспоненциалдық өсуі орынды сүйемелденетін ауытқуы өзгерістермен. Тұтқыр-серпімді реология шеңберінде екі жақты сығу литосфера плиталардың кернеулі-деформациялық күйлері талданады. Плиталар шекара аймақтар өзара іс-қимыл арқылы қатпарлар құрылу процестер зерттелді. Литосфера плиталар екі жақты сығу кезінде литосфера мен астеносфера өзара іс-қимыл қаралды. Екі жақты сығу кезінде серпінді негізі жататын анизотроптық плитаның тұрақтылық жоғалу құдікті күш табылған. Қысым күш құдікті күштен үлкен кезінде тұтқыр-серпімді литосфералық плитаның дөңістену уақыт бойынша экспоненциал заңмен өседі стандартты сызықты дене моделі қолдану шартқа сәтке дейін. Егер литосфералық плитаның материалы тұтқыр дене болған кезде уақыт бойынша экспоненциал заңмен дөңістік сондай-ақ өседі.

Түйін сөздер: кернеулі-деформациялық күй, деформация, тұтқырсерпімділік, литосфера, астеносфера, Жер.

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ПРОБЛЕМЫ ЛИТОСФЕРНОЙ ГЕОДИНАМИКИ

Аннотация. Построена механика вязкоупругой литосферы, где динамическим источником ее развития определены силы инерции внутреннего асинхронного вращения и вязкие силы от сферического течения Куэтта в астеносфере. Эти силы определяют природу внутреннего геодинамического давления и тангенциальных напряжений. Найдено, что в зависимости от разности угловых скоростей внутренних оболочек Земли литосфера может находиться в условиях всестороннего расширения или сжатия. Найден механизм локальных изменений толщины литосферы в результате неустойчивости деформирования литосферной оболочки Земли под действием внутреннего давления и объемных сил инерции вращения. Устойчивость деформирования исследована методом Лейбензона-Ишлинского. Основное напряженное и деформированное состояние рассмотрено при неизменной форме границы тела, а возмущенное с учетом поворотов элементов границ тела в процессе перехода к смежной форме равновесия. Определены асимметричные формы возмущений, приводящих к потере устойчивости эллипсоида вращения. Имеет место экспоненциальный рост компонентов возмущений во времени, сопровождаемый колебательными изменениями. В рамках вязкоупругой реологии литосферы анализируется напряженно-деформированное состояние литосферной плиты при двустороннем сжатии. Исследованы процессы образования складок, возникающие в результате взаимодействия плит в зонах межплитных границ. Рассмотрено взаимодействие литосферы с подстилающей астеносферой при двустороннем сжатии литосферной плиты. Найдено критическое усилие потери устойчивости анизотропной плиты, лежащей на упругом основании, при ее двустороннем сжатии. Выпучивание вязкоупругой литосферной плиты на вязкой астеносфере при значениях сжимающих усилий, больших критического, с течением времени растет по экспоненциальному закону до тех пор, пока не нарушается условие применимости модели стандартного линейного тела. Когда материал литосферной плиты моделируется вязким телом, прогиб также растет во времени по экспоненциальному закону.

Ключевые слова: напряженно-деформированное состояние, деформация, вязкоупругость, литосфера, астеносфера, Земля.

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ARCHITECTURAL TECHNIQUE FOR SMOG ELIMINATION IN ALMATY

Abstract. The weather of Almaty is calm for more than 200 days a year, which results in a steady smog in an urban environment. This phenomenon is associated with the terrain of Almaty. The increase in development density and temperature inversion over the city, which prevents both horizontal and vertical air displacement. For this situation of stagnant smog in valley the authors of the article propose architectural and town-planning techniques for forced aeration of the city territory. The article discusses their authorial projects using contrast zones, as well as water properties to reduce the harmful effects of polluted air in Almaty and other cities.

Keywords: architecture, smog, aeration, atmospheric physics.

The problem of smog has been known for a long time. Millions of people on the planet get poisoned from pollution every day! Millions of people die of smog every year. However, toxic substances in the atmosphere continue to increase. Environmental pollution has penetrated the soil and water resources [1]. The existing biodiversity and of forest ecosystems has been diminished [2]. Scientists have been raising alarm for the pending environmental disaster for several decades in a row.

Smog is the product of urban civilization; it covers many cities, including Almaty. According data of the World Health Organization (WHO), almost 92% of the population on Earth lives in places with polluted air [3]. It is associated with about 3 million deaths per year. The level of air pollution due to the development of industry and vehicles has increased dozens of times from year to year. Referring to these facts, Kazakhstan scientists come to the conclusion that European countries before the others began to apply various environmental standards [4]. The high level of environmental pollution in Almaty was noted compared with the world leaders in pollution [5].

The active growth of the city leads to an increase in development density, an increase in the number of private cars and bus routes, and growth of private housing and high-rise residential compounds. According to studies, 80% of Almaty's air pollution comes from motor vehicles. There are 800 thousand cars in the city, which annually emit about 260 thousand tons of harmful substances into the air. The studies also show CHP-2 and CHP-1, located within the city boundaries and burning coal and fuel oil are the major reason for the formation of smog. In 2014, CHP-2 feed 32 880 tons of hazardous chemicals into the atmosphere. The private sector, often heated by coal, makes an enormous contribution to air pollution [6]. In February, a snapshot of a black curtain over Almaty was published in the article “One Day in the Life of a Suffocating Planet” in The Guardian. In the article, journalist Chris Michael made a selection of photographs of the dirtiest cities in the world [7]. “Today, our daily MPC is exceeded by eight times. All day long, we are absorbing air that is hazardous when you are breathing it for more than half an hour”, - says Pavel Alexandrov, the author of the airkaz.org website [8].

It seems like the mountain-valley circulation and the west-eastward flowing wind directions flushes toxic air out of the city. But in real the situation is quite different. The following key reasons result in such a situation: firstly, the terrain of Almaty, which is located in the piedmont basin, delays the ventilation;

secondly, the increase in the development density associated with the active growth of the city has worsens the aeration of residential area; thirdly, the temperature inversion over the city, which not only prevents the vertical displacement of air masses, but in addition it acts like a screen and throws the entire torch of hazardous substances back to the ground, increasing their concentration on the surface of the atmosphere multiple times. Thus, we can assume that residents of Almaty live in a tightly closed container filled with toxic gas.

Inadequate registration of the aeration mode is one of the problems of today's urban planning. Employees of the newly established «AlmatyGenPlan» Research Institute deem it necessary to address this problem. The results of the theoretical studies and researches conducted by Institute are reflected in the reports and articles [9-12]. Institute is trying to find out the options for financial opportunities for the further scientific research for the improvement of the air environment in Almaty, the implementation of experimental design and subsequent practical application of the results in urban design and development.

It is known that urban development makes significant changes in the wind pattern. Hence it appears that aeration is a controlled process. Consequently, the task is to conduct an in-depth study of the dependence of the velocity and direction of movement of air currents in the territory of the projected development on the relative position of buildings and their location in relation to the winds. The geographical position of Almaty and its development forms more than 200 days a year of calm weather, which results in smog stagnation. Thus, in order to disperse this stagnant air, it is first necessary to create conditions for the wind generation, which in turn will provide the city with forced aeration.

Consider town planning methods of wind flows generation. The simplest ones are the creation of contrasting zones in the building, such as "water-land", "sun-shadow", "cold-heat", "black-white", "oasis-desert", "open-closed spaces", "low - high pressure zones". In this, formation of various "transitional", "connecting" spaces between them in the form of through openings, arches, terraces, courtyard, and supported buildings, is important. This will ensure the flow of air masses, and transformation of negative environmental factors, such as intense insulation, high wind velocity, into positive ones. In some cases, they can be enhanced, while in other situations they can be reduced, depending on the goal.

Contrast zones ensure non-uniform heating of the underlying surface, which creates an uneven distribution of atmospheric pressure, due to which air masses are displaced. The air masses movement occurs in the direction from high to low pressure. The greater the pressure difference, the faster the air moves, the stronger the wind. It should be noted that there is also feedback - the long-term air movement, which transports some air from some districts to another, affects the difference in atmospheric pressures in these districts.

Today, many demand to eliminate high-rise buildings in Almaty for the aeration of the city. But does a high-rise building always prevent the city from airing? The authors of this article believe that it all depends on their design. High-rise buildings not always hinder aeration, but if designed properly also can initiate the movement of the air flow and can also act as filter (figure 1a, 1b). This can be achieved by creating an atrium inside a building, in accordance with Bernoulli's law - this will draw air currents from the surrounding territory pushing them up, and turning carbon dioxide into oxygen using a specially developed technology that has already been tested and licensed [13].

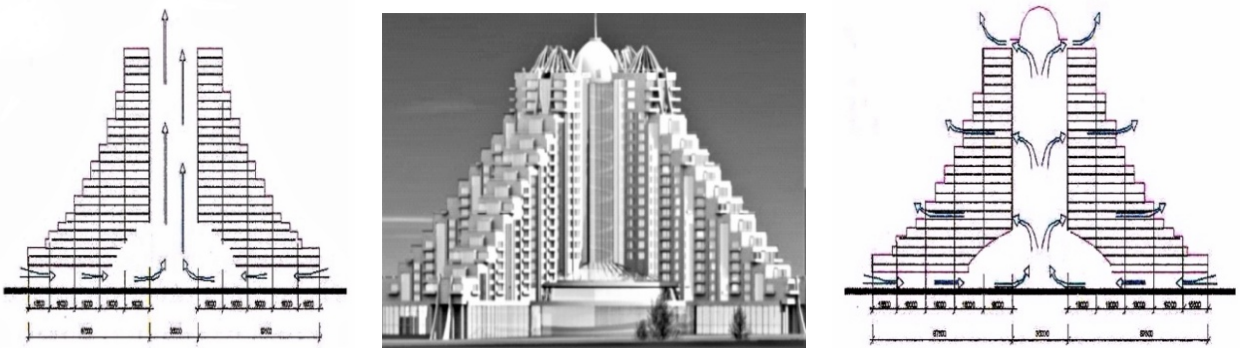

Figure 1a – Design of "Tau Samal" multifunctional residential complex at the intersection of Zhandosov and Navoi Streets. Changes in the aeration of the central building, depending on the upper floor structure of the atrium

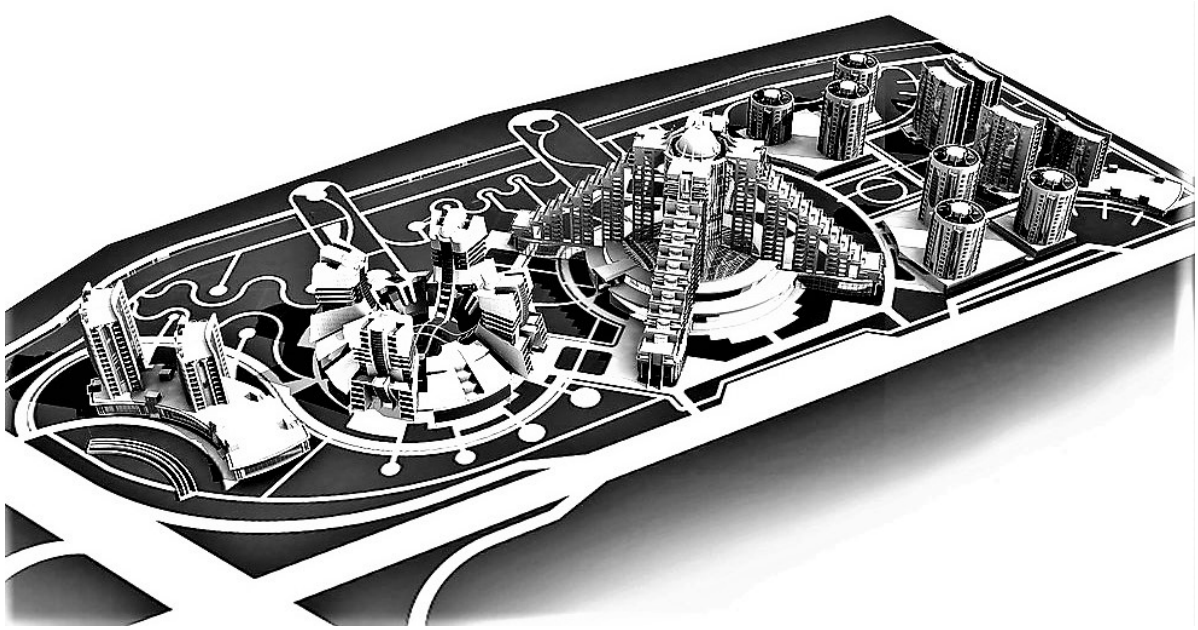

Figure 1b – Design of "Tau Samal" multifunctional residential complex at the intersection of Zhandosov and Navoi Streets. 3D image of a residential building

This technique that was proposed in Tau-Samal pilot project at the intersection of Navoi and Zhandosov streets, created under the authorship of the candidate of architecture, L. Rakhimzhanova (figure 1a, 1b). Preliminary studies have shown that this method will work even with zero wind levels at ground level. However, to determine more accurate atrium proportions, a special calculation of atmospheric physicists is needed in order to avoid uncomfortable human stay when air flows through the building and its surrounding territory.

Virtually any through atrium creates an updraft. But our project, as noted above, transforms the air quality: in the process of pushing it up, it purifies it using specially developed technology, turns carbon dioxide into oxygen, and also generates additional energy.

The Tau Samal project has also used water properties to improve air quality. An artificial channel created would be filled from Big Almatinka River and flowed by gravity through the center of the residential complex, sometimes even flowing it into the interiors of buildings. In addition for comfortable conditions the water was intended to create a variety of visual and psychological effects. The channel would play a public and social role, being the core of various social and youth activities.

The role of water in the elimination of smog in urban environments is enormous. It cleans the air pool, improving air quality [14]. Moreover, it performs two fundamental functions, namely: 1) a modifier of the external environment able to transform negative factors into positive ones; 2) a source of comfort and (figure 2).

Depending on the relief of the underlying surface, water changes the speed and direction of the wind. Its abilities to absorb, refract, disperse environmental factors (sun, wind) depending on its thickness, texture, position in space, allowing to regulate low and high pressure zones, which in turn contributes to the wind strength for aeration of the territory. Water properties of being still, falling, splashing, cascading, allow for its use as screens and barriers in improving microclimate. At the same time, its properties vary depending on the position of water surfaces in space: to be vertical, inclined, to serve as the upper screen or middle screen inside streets, centers and complexes. The authors refer to water screens as “shielded systems”.

Ability of water to improve air environment of the most polluted district of Tastak were proposed for the entertainment and business center on Lake Sairan (figure 5, 6). This is another project with an atrium, but of a spherical shape, inscribed in a conical one. Here, the use of water has been fully developed. First of all, for the most part it bases directly on the water; it has an underwater part with a museum and a surface part with various water effects.

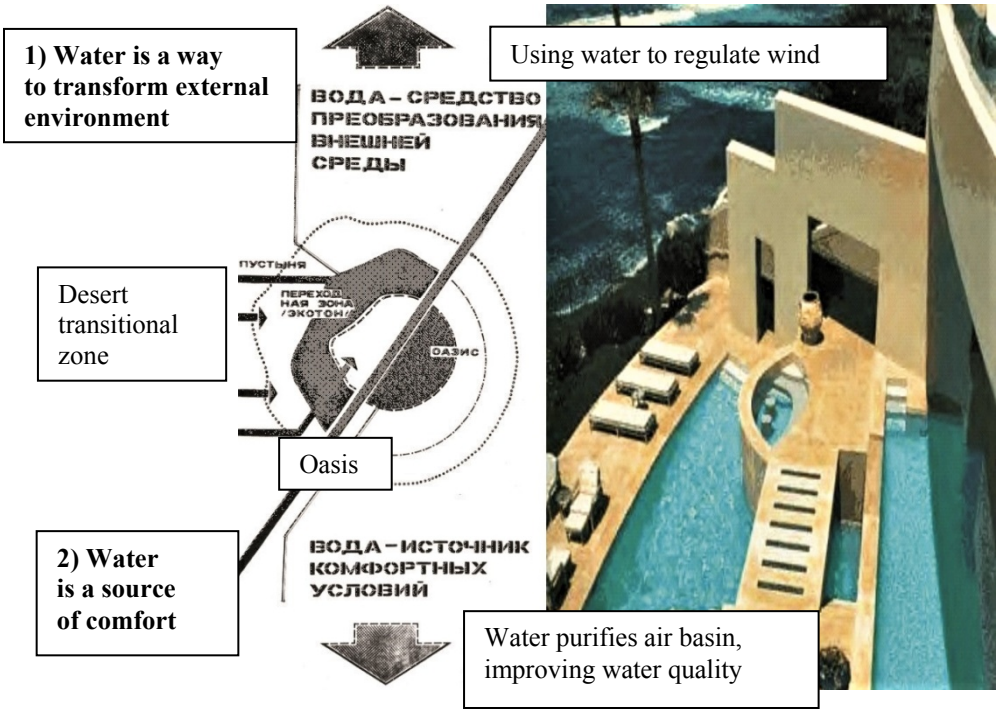

Figure 2 – Two functions of water: to be a source of comfort and a modifier of the external environment

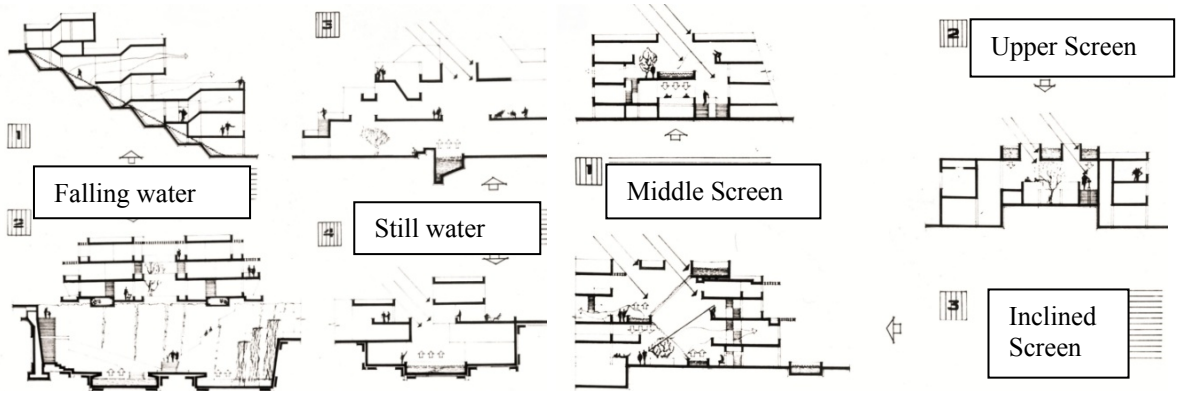

Figure 4 – Demonstration of various water properties to improve microclimate in its various positions

5

6

Figure 5, 6 – Entertainment and Business Center on Lake Sairan

Noteworthy is the fact that the projected center had various fog and cloud-forming installations (figure 7), which were already proposed to be used in the urban environment in the dissertation of Rakhimzhanova L.Sh. back in the 80's, where various nozzles and water curtains were carefully studied in industrial workshops [14]. Today, the use of some nozzles can already be seen in street restaurants of Almaty to provide a cool microclimate on hot days.

Figure 7 – Examples of the use of fog for the elimination of smog in the urban environment

Figure 8 –
Water-drip curtain project of Serik Burkutbvayev

There are other suggestions for Almaty in using water to eliminate smog, for example, the Almasagyn water cascades project (*Alma* is Almaty, *as* is pouring, and *agun* is water) by Serik Burkutbvayev, Doctor of Physics and Mathematics (figure 8). This is something like a Roman aqueduct, from where a water droplet curtain forms, drops (asagyn) are dripping and water is naturally sprayed in the air [15].

It should be mentioned that today China began to use fog guns to purify its cities from smog [16]. These mechanisms are installed on machines that are commonly used to combat dust in factories and construction sites (figure 9). As is well known, China took up a serious fight against smog and intends to spend $277 billion to do it. Sprinklers are going to be installed on high buildings in Chinese cities, which are able to suppress smog and bring the level of hazardous elements in the atmosphere to the recommended level in just a few hours (figure 10).

Figure 9 – Fog Guns

Figure 10 – High-Rise Sprinklers

The authors of this article from AlmatyGenPlan are aware of projects to purify the air basin of Almaty and of other authors of the world, in connection with which they intend to unite uncoordinated scientific forces and make air in Almaty other cities clean. The strong established mechanism of the country in the field of engineering will be useful to combine with the developed concepts such as air ozonation [17], air purification and disinfection systems of tenre-aerolife LLP [13], as well as artificial creation of clouds and fogs.

The results of the research presented in the article can be used in the development of the master plan, the development of detailed plans, as well as in the development of regulatory and technical documents in the field of urban planning, architecture and construction of Almaty.

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АЛМАТЫНЫҢ ТҮТІНТҰМАНЫН СӘУЛЕТТІК ЖОЮ АМАЛДАРЫ

Аннотация. Алматыда жылына 200 тәуліктен артық уақыт бойына желсіз тымық ауа-райы орнап, қалалық ортада тұрақты түтінтұманды қалыптастырады. Бұл құбылыс Алматы қаласының жер бедеріне, құрылыс салу тығыздығының артуы және қаланың үстіндегі температура инверсиясының ұлғаюымен тығыз байланысты болып табылады, бұл жайлар ауа массасының көлденең және тік қозғалысына кедергі келтіреді. Туындаған жағдайға байланысты, мақаланың авторлары қаланың аумағын мәжбүрлеп желдендіру үшін сәулеттік- қала құрылыстық амалдарды ұсынады. Мақалада контрасттық аймақтарды, сондай-ақ Алматы қаласында газданған ауаның зиянды әсерлерін жою үшін судың қасиеттерін пайдаланатын олардың авторлық жобалары қарастырылады.

Түйін сөздер: сәулет, түтінтұман, аэрация, атмосфера физикасы..

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АРХИТЕКТУРНЫЕ ПРИЁМЫ ЭЛИМИНАЦИИ АЛМАТИНСКОГО СМОГА

Аннотация. В Алматы более 200 дней в году безветренная погода, что формирует устойчивый смог в городской среде. Это явление связано с рельефом местности Алматы, увеличением плотности застройки и температурной инверсией над городом, что препятствует как горизонтальному, так и вертикальному перемещению воздушных масс. В связи с создавшейся ситуацией авторы статьи предлагают архитектурно-градостроительные приёмы принудительного проветривания территории города. В статье рассматриваются их авторские проекты, использующие контрастные зоны, а также свойства воды для погашения вредного воздействия загазованного воздуха в Алматы и других городах.

Ключевые слова: архитектура, смог, аэрация, физика атмосферы.

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CREATION OF DAMPING ALLOYS WITH OPTIMUM PHYSICAL-MECHANICAL PROPERTIES FOR GEOLOGICAL EXPLORATION EQUIPMENT PARTS

Abstract. One of the effective methods of reducing noise is to quench it at the source of occurrence. Such methods include replacement of percussion mechanisms with without impact ones, replacement of gears with V-belts, etc. The most acceptable method of reducing noise at the source of occurrence is the use of damping materials. Non-metals (plastics, wood, polyethylene, etc.), non-ferrous metals can be used. However, the most relevant to reduce noise at the source of occurrence in geo-exploration production is the use of iron-based damping metallic materials. In this work, the task was to assess the acoustic and vibration characteristics of standard steels 15ХГН2ТА, 15Х2Н2ТА, 15Х2ГН2ТРА, 20ХГНТР, 25Х2ГНТА, which are used to manufacture parts of geo-exploration equipment, new damping alloys GGR-1, GGR-2, GGR-3. The choice of the chemical compound of the GGR-1 alloy made it possible to obtain an anti-vibration damping alloy having a quenching martensite structure. It is recommended to use it for exploration equipment parts (drilling rigs, drill rod, drilling blade, adapters for drilling head, drill pipe, etc.).

Keywords: noise, vibration, damping, geological exploration, mechanical properties, acoustic and vibration characteristics, chemical compound, equipment, experimental alloys.

Introduction. The noise of impact origin is the most common and harmful industrial factor of industry.

One of the high-performance and efficient production is geological exploration production. The equipment for geological exploration production is characterized by intense vibration and increased radiated noise (drilling rigs, drill rod, drilling blade, adapters to the drill head, drilling pipe, etc.). Industrial noise and sound vibration worsen working conditions, negatively affect the health of workers. Intense vibration is the cause of damage to the structures of machines and mechanisms and reducing their service life. All these problems pose to designers and technologists the task of reducing the parameters of noise and vibration.

Frequently, geological explosive production is dominated by percussion and final noise, characterized as the most harmful to workers health. At short impulses the likelihood of hearing loss increases.

Very often, intense noise is emitted by parts made of 15ХГН2ТА, 15Х2Н2ТА, 15Х2ГН2ТРА, 20ХГНТР, 25 Х2ГНТА steels (standard steels) (gear wheels, gear rims, connecting rods, shaped castings and other parts of geological explosive equipment) [1, 13].

One of the effective methods of reducing noise is to quench it at the source of occurrence. Such methods include replacement of percussion mechanisms with without impact ones, replacement of gears with V-belts, etc. The most acceptable method of reducing noise at the source of occurrence is the use of damping materials. Non-metals (plastics, wood, polyethylene, etc.), non-ferrous metals can be used.

However, the most relevant to reduce noise at the source of occurrence in geo-exploration production is the use of iron-based damping metallic materials.

The aim of the work is the development and research of new grades of damping steels for castings, reducing the noise of impact origin, generated in parts and assemblies during the operation of geological prospecting equipment.

Research objectives:

- to evaluate the vibration and physical-mechanical properties of well-known steels (15ХГН2ТА, 15Х2Н2ТА, 15Х2ГН2ТРА, 20ХГНТР, 25 Х2ГНТА) used for parts subjected to shock loads;
- to develop new alloys for parts subjected to shock loads, differing in chemical composition, but not inferior in terms of mechanical and technological characteristics to known standard grades of alloyed steels.

As an object, both standard and newly smelted alloys were considered. The purpose of these steels is given in table 1. Table 2 presents the chemical compounds of the investigated steels. The acoustic characteristics (sound level, level of sound pressure) and vibration (vibration acceleration level, overall vibration acceleration level) characteristics of the alloys were investigated.

For the study, standard alloy steels were selected for castings of grades 15ХГН2ТА, 15Х2Н2ТА, 15Х2ГН2ТРА, 20ХГНТР, 25 Х2ГНТА and melted alloyed alloys GGR-1, GGR-2 and GGR-3, whose mechanical characteristics are shown in table 3.

In this work, the task was to assess the acoustic and vibration characteristics of standard steels 15ХГН2ТА, 15Х2Н2ТА, 15Х2ГН2ТРА, 20ХГНТР, 25Х2ГНТА, which are used to manufacture parts of geo-exploration equipment, new damping alloys GGR-1, GGR-2, GGR-3.

Standard alloyed casting steels 15ХГН2ТА, 15Х2Н2ТА, 15Х2ГН2ТРА, 20ХГНТР, 25 Х2ГНТА in the form of a plate were investigated.

The damping ability of metallic materials is characterized by a combination of vibration and physical-mechanical characteristics, such as vibration acceleration level, internal friction, electrical resistivity, density, shear modulus, Young's modulus and a number of metallographic features. In the present study, a series of experiments were aimed at establishing patterns that determine the relationship of structurally sensitive factors and microstructure with the optimization parameter – the level of vibration acceleration of low-alloy structural steels, the composition of which was specified by the experiment planning matrix.

Experimental alloys were smelted in a crucible induction furnace with a capacity of 12 kg with the main lining. The source material was sheet metal of steel 10. Doping was carried out with 97,6% metallic manganese, 77,5% FeSi and 99,98% metallic nickel. Carbonaceous additive served as synthetic cast iron with a carbon content of 3,9%. Steel was cast into a metal mold with dimensions of 210x115x115 mm.

Samples before forging were heated in a laboratory oven to a temperature of 1200 °C with a holding time of 1 hour. Ingots were forged using a forged hammer to stripes with final dimensions of 700x90x10 (12) mm. After each pass, the strips were placed in an oven to achieve a temperature of 1200 °C.

One of the objectives of this work is the development of new damping metallic materials based on iron. In this regard, by adding alloying elements to the chemical compound of standard steel grades, new alloys with enhanced damping properties were obtained. The principles of alloying of alloys in the work are based on the study of the phase diagrams of Fe – C, Fe – Si, Fe – Mn, Fe – Cr, Fe – La, Fe – Ca, Fe – V, Fe – Ni. State diagrams determine in equilibrium the phase composition of the alloy depending on the temperature and concentration of the components and allow qualitatively characterizing many physical-chemical, mechanical and technological properties of the alloys.

Casting was made in the chill mold. Casting in the chill mold compared with the sand form has several advantages: the relative durability of the form and accelerated cooling of the casting in it, a sharp reduction or almost complete elimination of the consumption of molding materials; an increase in the removal from the molding site by 2-6 times, an increase in labor productivity by 1.5-6 times, a decrease in surface roughness, an increase in the accuracy of castings, an increase in the density of castings, a reduction in profit margins and often even their elimination [15].

Based on the analysis of installations for the study of vibration (level of vibration acceleration, total level of vibration acceleration) properties of the alloys, the device “KazNTU” -2 was selected for a comprehensive study of the vibration properties of plate steel samples [6] (figure 1).

Table 1 – Purpose and general characteristics of standard steels [7]

Steel	Purpose
15ХГН2ТА 15Х2ГН2ТА 15Х2ГН2ТРА	Disks, sprockets, gears, connecting rods, crosses, forks, fingers, gears, shafts, cam couplings, covers and other parts of geological exploration techniques.
20ХГНТР 25 Х2ГНТА	Responsible details of exploration equipment, gears, crosses, levers, etc.

Table 2 – The chemical compound of the investigated steels

Mark of steels, alloys	Chemical compound, %								
	C	Si	Mn	Cr	Ni	Ti	S	P	Fe
							no more		
15ХГН2ТА	00,13-0,18	00,17-0,37	10,7-1,0	≤0,7-1,0	–	–	0,035	00,035	The rest
20ХГНТР	00,18-0,24	00,17-0,37	10,8-1,1	≤0,4-0,7	–	–	0,035	00,035	The rest
GGR-1	00,2	00,2	00,8	11,0	00,35	00,15	0,045	00,04	The rest
GGR-2	00,3	00,3	00,75	11,0	00,45	00,18	0,045	00,04	The rest
GGR-3	,0,3	00,3	11,0	11,0	00,55	00,20	0,045	00,04	The rest

Table 3 – The mechanical properties of the investigated steels

№	Mark of steel	$\sigma_в$	Impact strength KCU, J/cm^2	δ_5	ψ	$\sigma_т$, MPa
				%		
				not less		
1	15ХГН2ТА	1330	127	11,5	59,5	1180
2	20ХГНТР	1200	80	9	50	1000
3	15Х2ГН2ТА	1380	127	12	58	1190
4	15Х2ГН2ТРА	1320	120	14	62	1190
5	GGR-1	1400	140	13	25	1300
6	GGR-2	1350	145	14	30	1250
7	GGR-3	1400	140	12	35	1320

The installation works as follows. The ball-drummer 6 was installed on an inclined plane 5. The ball-drummer 6 rolls down from the inclined plane 5 and makes a free fall into the geometric center of the plate sample 3. The ball-drummer 6 rebounds from it and enters the receiver of the balls 11. The noise from the impact of the striker ball 6 and sample 3 is recorded by the OCTAVE-101A sound level meter 12. Sample (plate) 3, oscillating in the interweaving of nylon yarns 1 creates a vibration, which is estimated by the device model "Bruel & Kjer" model 22048. The tension of the sample nylon threads 1 is always constant, since the load 10 controls this tension. The height of the fall of the ball can be changed using the screw mounting rack drummer 15. The entire system of mounting the sample 3 and the ball-striker 6 is installed on the frame 2, which with the help of the uprights 13 is located at a certain height above the floor.

In the measurements, steel (ШХ15) impact balls of the following diameters were used: 9,5 mm; 12,7 mm; 15,2 mm; 15,8 mm and 18,3 mm (mass of balls, shock, respectively: 2,5 g; 5 g; 9 g and 25 g).

At the installation, steel lamellar (50x50x5 mm) specimens were examined.

The vibration acceleration levels were measured in the range of 31,5-31500 Hz, the total vibration acceleration level - according to the "Lin" characteristic.

The mass of the ball, the density of the sample, the distance from the point of impact to the sample, the thickness of the sample are interrelated according to [8]:

$$m \langle 4{,}6 \cdot \rho \cdot l \cdot h^2, \quad (1)$$

where m – mass of lamellar-sample, g; ρ – density of material lamellar-sample, g/cm^3; l – distance from impact point to nearest edge of sample plate, cm; h – thickness of material lamellar-sample, cm.

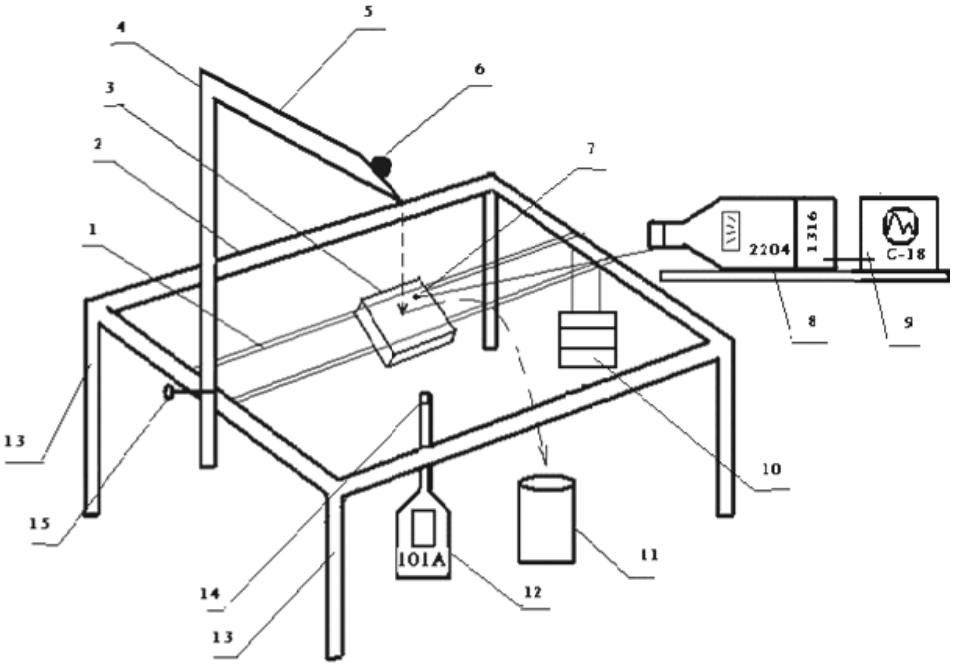

Figure 1 – Device "KazNTU-2" for the study of the vibration properties of solid plate (lamellar) samples [6, 18]:
1 – nylon thread; 2 – frame; 3 – lamellar (50x50x5 mm) sample; 4 – frame stand; 5 – inclined plane; 6 – ball-drummer;
7 – Vibration sensor of "Bruel&Kjer" vibrometer model 2204; 8 – vibrometer "Bruel&Kjer" model 2204;
9 – oscilloscope C-18; 10 – load; 11 – ball receiver; 12 – noisemeter "OCTAVE -101A"; 13 – frame stands;
14 – microphone of noise meter "OCTAVE -101A"; 15 – fastening pin rack screw

The correction for the change in the vibration signal from atmospheric pressure was carried out using a pistonphone of the brand PF-101. The air temperature and humidity in the laboratory were kept constant. Vibration measurements were found as the average of five measurements.

We also carried out mathematical processing of the experimental results and the determination of confidence intervals in accordance with the method [9]. Before starting, the adjustment of the measuring path was carried out by checking the sound pressure levels of the reference sample.

Vibration characteristics of the investigated standard steels 15ХГН2ТА, 20ХГНТР, 15Х2ГН2ТА and new damping alloys GGR-1, GGR-2 and GGR-3 are presented in tables 4, 5 and in figures 2, 3.

Table 4 presents the vibration characteristics of the samples (plates with size 50x50x5 mm) from standard steel 15ХГН2ТА, 20ХГНТР, 15Х2ГН2ТА, 15ХГН2ТРА after collision with impact balls with diameters d = 9,5 mm, d = 12,7 mm, d = 15,5 mm and d = 18,3 mm of steel ШХ15.

The nature of vibration acceleration levels (VAL) of standard steel 15ХГН2ТА, 20ХГНТР, 15Х2ГН2ТА, 15Х2ГН2ТРА has the following features:

- vibration acceleration levels of the samples studied vary in the range of 61-128 dB;
- maximums of vibration acceleration levels are observed at frequencies of 31,5 Hz, 63 Hz and 125 Hz;
- minimum levels of vibration accelerations of samples are typical for frequencies of 250-31500 Hz (61-68 dB);
- maximum values of the vibration accelerations of the compared samples are characteristic in collisions with a hammer-ball with a diameter of d = 18,3 mm;
- minimum values of the vibration acceleration levels of the compared samples are typical in collisions with impact balls with diameters d = 9,5 mm and d = 15,2 mm;
- maximum levels of vibration acceleration according to the "Lin" characteristic for samples 15ХГН2ТА, 20ХГНТР, 15Х2ГН2ТА, 15Х2ГН2ТРА are observed during collision with impact balls with diameters d = 12,7 mm and d = 18,3 mm (125-129 dB).

In the study of the sound emission characteristics of alloys, amplitude-dependent damping of vibration acceleration was found. Amplitude-dependent damping of vibration acceleration (ADDV) consists in the fact that when a ball striking a larger mass hits a sample, it generates a level of vibration acceleration of a smaller value than when a ball striking a smaller mass collides.

Table 4 – Vibration characteristics of standard steels (plates 50x50x5 mm) after casting

Mark of steel	Diameter of ball-drummer, d, mm	Vibration acceleration levels, dB, in octave bands with geometric average frequencies, Hz											TVAL, dB
		31,5	63	125	250	500	1000	2000	4000	8000	16000	31500	
15ХГН2ТА	9,5	85	104	86	65	64	63	61	64	65	70	68	105
	12,7	90	106	88	68	69	65	65	63	68	69	70	107
	15,2	88	106	90	67	75	68	67	62	67	68	71	108
	18,3	91	109	88	68	77	69	68	63	68	69	72	110
20ХГНТР	9,5	91	108	85	71	75	68	65	64	61	62	72	110
	12,7	91	114	82	73	76	69	69	65	62	64	77	115
	15,2	93	116	88	75	77	70	70	66	64	68	78	118
	18,3	94	122	85	78	75	72	72	67	68	70	80	124
15Х2Н2ТА	9,5	88	104	78	62	69	70	62	67	66	65	64	106
	12,7	85	109	89	72	71	69	66	68	67	64	66	110
	15,2	86	117	91	66	74	65	68	68	69	66	68	118
	18,3	90	120	96	67	73	64	69	70	70	66	71	122
15Х2ГН2ТРА	9,5	91	117	92	70	66	71	60	62	66	71	72	118
	12,7	97	122	96	71	72	68	64	69	67	72	73	125
	15,2	98	126	98	72	77	66	65	70	67	73	74	128
	18,3	98	128	100	74	78	65	69	72	68	74	77	129

In steel 15ХГН2ТА ADDV it is observed at frequencies of 31,5 Hz (drummers 12,7 mm and 15,2 mm); 63 Hz (drummers 12,7 mm and 15,2 mm); 125 Hz (drummers 15,2 mm and 18,3 mm); 250 Hz (drummers 12,7 mm and 15,2 mm); 4000 Hz (drummers 9,5 mm and 12,7 mm); 8000 Hz (drummers 12,7 mm and 15,2 mm); 16,000 Hz drummer 9,5 mm; 12,7 mm; 15,2 mm; 18,3 mm).

In steel 20ХГНТР ADDV is observed at frequencies of 31,5 Hz (drummers 9,5 mm and 12,7 mm); 125 Hz (drummers 9,5 mm; 12,7 mm; 15,2 mm and 18,3 mm); 500 Hz (drummers 15,2 mm and 18,3 mm).

In steel 15Х2ГН2ТА ADDV it is observed at frequencies of 1000 Hz (drummers 9,5 mm and 12,7 mm); 500 Hz (drummers 15,2 mm and 18,3 mm); 4000 Hz (drummers 12,7 mm and 15,2 mm); 16,000 Hz (drummers 9,5 mm; 12,7 mm; 15,2 mm and 18,3 mm).

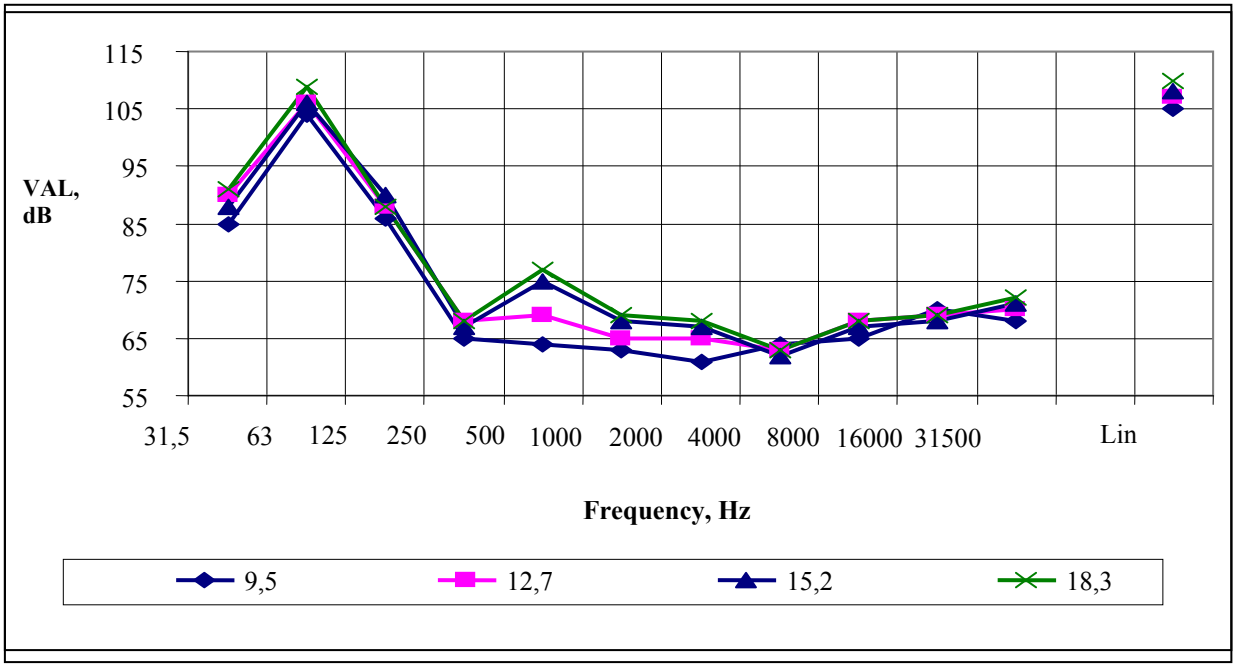

Figure 2 – Characteristics of vibration accelerations of the sample 15ХГН2ТА at impact

In steel 15Х2ГН2ТРА ADDV it is observed at frequencies of 31,5 Hz (drummers 15,2 mm and 18,3 mm); 1000 Hz (drummers 12,7 mm; 15,2 mm and 18,3 mm); 8000 Hz (drummers 12,7 mm and 15,2 mm).

Figure 2 shows the characteristics of the vibration accelerations of the 15ХГН2ТА sample at impact. In accordance with figure 2, it is maximum at a frequency of 31,5 Hz, 63 Hz, 125 Hz at impact 15ХГН2ТА sample with a hammer-ball with a diameter of d = 15,2 mm and 18,3 mm VAL = 90-109 dB, and minimal with a 15ХГН2ТА impact with a ball-drummer with a diameter of d = 15,2 mm VAL = 62 dB.

In figure 3 shows the characteristics of the vibration accelerations of the developed alloy sample GGR-1 at impact.

Table 5 – Vibration characteristics of the developed steels (plates 50x50x5 mm) after casting

Mark of steel	Diameter of ball-drummer, d, mm	Vibration acceleration levels, dB, in octave bands with geometric average frequencies, Hz											TVAL, dB
		31,5	63	125	250	500	1000	2000	4000	8000	16000	31500	
GGR-1	9,5	80	99	81	65	65	62	62	65	66	68	64	100
	12,7	82	100	79	66	68	64	65	68	69	70	65	102
	15,2	83	104	82	68	70	66	67	69	71	71	66	105
	18,3	85	107	83	70	72	67	68	71	72	73	68	108
GGR-2	9,5	81	100	80	66	66	64	65	64	68	70	67	102
	12,7	83	102	82	68	69	65	67	66	70	71	68	103
	15,2	85	106	83	69	71	66	67	66	70	71	69	108
	18,3	86	108	85	70	73	68	69	67	71	78	70	110
GGR-3	9,5	80	109	79	67	65	63	66	66	69	71	68	110
	12,7	79	111	79	69	66	65	67	68	70	73	69	112
	15,2	82	113	80	70	67	68	69	70	72	74	70	115
	18,3	85	117	82	72	69	70	71	71	73	75	72	119

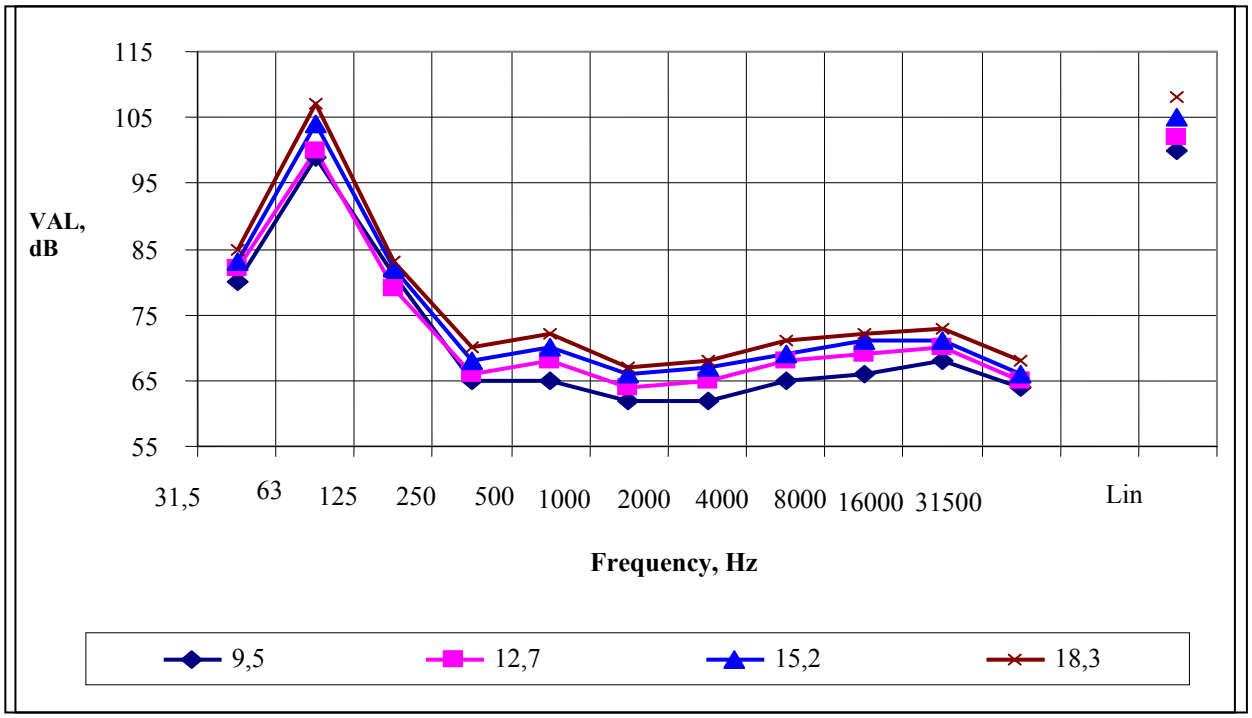

Figure 3 – Characteristics of vibration accelerations of the sample GGR-1 at impact

Conclusion. The choice of the chemical compound of the GGR-1 alloy made it possible to obtain an anti-vibration damping alloy having a quenching martensite structure. It is recommended to use it for exploration equipment parts (drilling rigs, drill rod, drilling blade, adapters for drilling head, drill pipe, etc.).

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ГЕОЛОГИЯЛЫҚ БАРЛАУ ЖАБДЫҚТАРЫНЫҢ БӨЛШЕКТЕРІНЕ АРНАЛҒАН ТИІМДІ ФИЗИКАЛЫҚ-МЕХАНИКАЛЫҚ ҚАСИЕТТЕРГЕ ИЕ ДЕМПФЕРЛІК ҚОРЫТПАЛАРДЫ ДАЙЫНДАУ

Шуды бәсеңдетудің ең тиімді жолдарының бірі ол шуды пайда болу көзінде төмендету. Мұндай әдістерге соққылы механизмдерді соққысыз түрге алмастыру, тісті берілістерді ременді берілістерге ауыстыруды жатқызуға болады. Шуды пайда болу көзінде бәсеңдету тәсілдерінде демпферлік материалдарды қолдану ұтымды болып табылады. Бейметалдар да (пластмассалар, ағаш, полиэтилен және т.б.), түсті металдар қолданылуы мүмкін.

Бірақ та, геологиялық барлау саласында шуды пайда болу көзінде бәсеңдету үшін темір негізіндегі демпферлік металды материалдарды қолдану өзекті болып табылады.

Жұмыста келесі негізгі міндеттер қойылды: геологиялық барлау жабдықтарының бөлшектерін дайындауда қолданылатын 15ХГН2ТА, 15Х2Н2ТА, 15Х2ГН2ТРА, 20ХГНТР, 25 Х2ГНТА стандартты болаттардың, сонымен қатар ГГР-1, ГГР-2, ГГР-3 жаңа демпферлі қорытпаларының акустикалық және дірілдік қасиеттерін бағалау көзделді.

ГГР-1 қорытпасының химиялық құрамы шынықтыру арқылы мартенситті құрылыммен дірілге қарсы демпферлік қорытпа алуға мүмкіндік берді. Аталған қорытпаны геологиялық барлау жабдықтары бөлшектеріне (бұрғылау құрылғылары, бұрғылау штангасы, бұрғылау күрегі, бұрғылау басының өткізгіштері, бұрғылау құбыры және т.б.) қолдануға ұсынылады.

Түйін сөздер: шу, діріл, демпферлеу, геологиялық жабдықтар, механикалық қасиеттер, акустикалық және дірілдік қасиеттер, химиялық құрам, жабдық, тәжірибелік қорытпалар.

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СОЗДАНИЕ ДЕМПФИРУЮЩИХ СПЛАВОВ С ОПТИМАЛЬНЫМИ ФИЗИКО-МЕХАНИЧЕСКИМИ СВОЙСТВАМИ ДЛЯ ДЕТАЛЕЙ ГЕОЛОГОРАЗВЕДОЧНОГО ОБОРУДОВАНИЯ

Аннотация. Одним из эффективных методов снижения шума является гашение его в источнике возникновения. К таким методам следует отнести замену ударных механизмов на безударные, замену зубчатых передач на клиноременные и т.п. Наиболее приемлемым методом снижения шума в источнике возникновения является использование демпфирующих материалов. Могут быть использованы неметаллы (пластмассы, древесина, полиэтилен и др.), цветные металлы.

Однако наиболее актуальным для снижения шума в источнике возникновения в геологоразведочном отрасле является применение демпфирующих металлических материалов на железной основе.

В настоящей работе была поставлена задача – оценить акустические и вибрационные характеристики стандартных сталей 15ХГН2ТА, 15Х2Н2ТА, 15Х2ГН2ТРА, 20ХГНТР, 25 Х2ГНТА , которые используются для изготовления деталей геологоразведочного оборудования, новых демпфирующих сплавов ГГР-1, ГГР-2, ГГР-3.

Выбор химического состава сплава ГГР-1 позволил получить демпфирующий антивибрационный сплав, имеющий структуру мартенсита закалки. Его рекомендуется использовать для деталей геологоразведочного оборудования (буровые установки, буровая штанга, буровая лопатка, переходники на буровую головку, труба буровая и др.).

Ключевые слова: шум, вибрация, демпфирование, геологоразведочные оборудования, механическое свойства, акстические и вибрационные характеристики, химический состав, установка, экспериментальные сплавы.

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DYNAMIC ANALYSES OF A CLUTCH OF CRANK PRESS

Abstract. The paper studies the dynamic of a clutch of crank press. At present, the dynamic study of clutch of the crank presses, with account of interaction with other blocks, is a priority. The crank press contains movable parts and assemblies, the mass of which is from one hundred kilograms to several tons. These parts and assemblies are connected cyclically by clutch of crank press with high speeds and they are subject to large dynamic loads. To simulate and analyze the movement of crank press with clutch, a software package: SimulationX is used. SimulationX is a software package for modeling and analyzing the dynamics and kinematics of cars, industrial equipment, electric, pneumatic and hydraulic drives, hybrid engines, etc. As a result of dynamic calculation, important dynamic parameters of the crank press clutch and working slide are determined. It is shown that dynamic loads sharply increase almost in all blocks of the crank press when the clutch is switched on.

Key words: dynamics, crank press, clutch, slide, moment, oscillations, SimulationX.

Introduction. Crank press is a machine with a slide-crank mechanism, designed for stamping various parts [1-5]. During the work of crank press, significant dynamic loads occur in blocks and mechanisms, especially when it is turned on. These dynamic loads are associated with operational feature of the crank press, which includes shock cyclic loads with sudden, almost immediate stops. In this connection, the study of the dynamics of clutch of the crank presses, is of great interest. Figure 1 shows block diagram of the press [1].

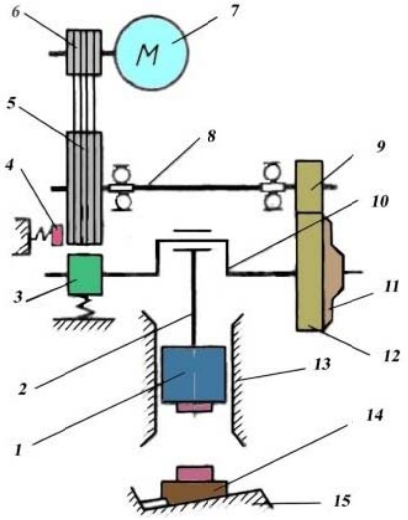


Figure 1 –
Block diagram of crank press:
1 - slide, 2 - crank rod,
3 - brake of crank mechanism,
4 - flywheel brake, 5 - flywheel,
6 - sheave, 7 - electric motor,
8 - drive shaft, 9 - drive gear,
10 - crank shaft, 11 - clutch,
12 - driven gear, 13 - crosshead guide,
14 - wedge-type platten,
15 - press board

Operating principle of the crank press (see figure 1): the crankshaft 10 rotates about an axis and activates through the crank rod 2 a slide 1 with punch. The press drive consists of an electric motor 7, a V-belt drive and a flywheel 5. The press clutch 11 is located on the end of the crankshaft 10. Brake 4 serves to stop the press. Brake 3 serves to stop the crank mechanism of the press.

The drive of the press is carried out from an electric motor with a flywheel. Since the parameters of motion of the actuating link – tool slide, depend only on the kinematic links of the main working mechanism, crank presses are referred to uncontrolled machines with limited movement of the tool slide, equal to the double radius of the crank or double eccentricity of the eccentric. Asynchronous electric drive accelerates with power flywheel and all the guide links with the corresponding moment of inertia to the steady angular velocity during the technological cycle and dispatches kinetic energy of the rotational motion of the flywheel to it. In this case, the crank shaft and all driven members of the crank-slider mechanism are fixed, the slide is in the upwardmost (initial) position. When the clutch 11 is turned on, the crank shaft (cranked axel 10) is rotated, driving and driven members move together, the slide with fixed upper die make a working stroke. After completion of the working stroke, the slide makes a return stroke. If the press works by single stokes, then when the slide reaches its initial position, the clutch 11 is turned off and at the same time the brake 3 is turned on. The slide stops in the upper (initial) position and the work cycle is completed.

Feed clutch of the crank press. Coupling clutches and brakes are provided in the press drive system, which make it possible to transmit motion to the actuator (operating mechanism) from the drive, but at the right time, vice versa, to stop the slide of mechanism without turning off the electric motor [1].

Switching on and off, and interlocking of the clutch and brake are performed using the control system [1]. The clutch, brake and control system form the so-called press start system, on the performance of which the reliability and safety of operation of the press as a whole is depended. The press start system works under difficult conditions – a large number of turning on per unit of time, on-off limited time (<0.1c), absolute security in operation.

Crank press's clutches should transmit moment of rotation up to 16 MNm and at the same time ensure the life of the structure and dampen vibrations, arising during the coupling [2]. The presses start systems and friction disc clutches most fully meet these requirements.

Disc clutches may be – single and multiple disc. Single-disc compact clutches with friction inserts are widely used, manufactured from retinax ФК-16А, ФК-24А or ferodo (figure 2). In pair with inserts, discs of steel 5, cast iron СЧ25 are working.

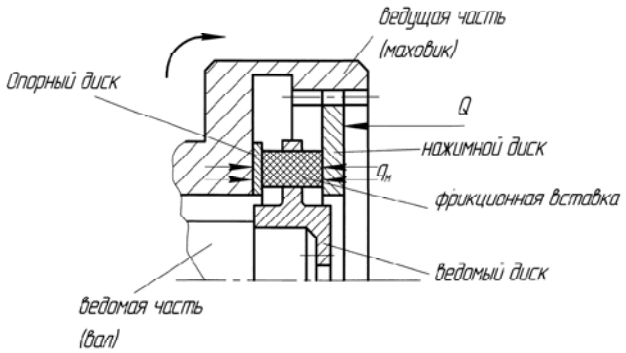


Figure 2 – Scheme of a single-disc friction clutch

The moment transferred by the one-disk frictional clutch (figure 2):

$$M_m = 2f \cdot q_m \cdot R_{cr} \cdot n \cdot F_{bc},$$

where f – friction coefficient f = 0.35; q_m – friction surface pressure q_m = 0,6-1,2 Мпа; R_{cr} – average insert radius; n – number of inserts; F_{bc} – work surface area of insert. Single-disc clutches transfer moment up to 140000 Нм, multiple-disc – up to 100 MNм with ferodo coverings.

The scheme of the multi-disc friction clutch is shown in figure 3.

Moment, transferred by the clutch:

$$M_m = \int_{R_2}^{R_1} 2\pi f \cdot m\rho \cdot d\rho \cdot \rho q_m = \frac{3}{2}\pi(R_1^3 - R_2^3) f q_m m$$

where q_m=0.4-0.6 Мпа (at n_m<180 об/min); q_m=0.3Мпа (at n_m>180 об/min); f =0.35; m

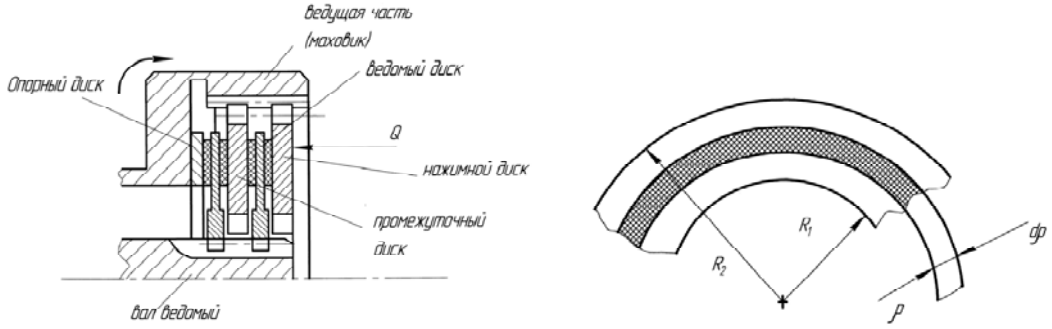


Figure 3 – Scheme of the multi-disc friction clutch

Calculation of disc friction clutches. Calculation of disc friction clutches made on the transmitted torque, specific force on the rubbing surfaces and the value of the wear rate (calculation for heating).

Original for the calculation is the nominal moment M_K^H, operating on the main shaft, which is driven to the clutch shaft. The required torque transmitted by the clutch [1]:

$$M_m^{mp} = \frac{\beta M_K^H}{i_m \eta_m}$$

where β = 1.1-1.3 is a factor of safety, taking into account the inertia and oscillation of the coefficient of friction;

$$M_K^H = m_K^H \cdot P_H,$$

m_K^H - reduced (modified) shoulder corresponding to the nominal angle α_H; P_H - nominal force; $i_m \eta_m$ - gear ratio and transmission efficiency from the coupling shaft to the main shaft (when installing the coupling on the main shaft $i_m \eta_m$ = 1).

It is necessary that the torque transmitted by the coupling $M_m \geq M_m^{mp}$. Based on the moment (torque) transmitted by the clutch (coupling) press M_m, determine the force (effort) on the slider:

$$P_m = \frac{M_m}{m_K}$$

The results of the calculation P_m are entered in the table and build a graph of efforts on the slider based on the moment transmitted by the clutch $P_m = f(\alpha)$. When the clutch is turned on, part of expended energy goes into heat, causing heating of parts, friction inserts and linings. As an indirect thermal calculation, a performance calculation is applied in terms of wear. For this, the work balance is made when the clutch is turned on (at the initial moment, the speed of the driven disks due to slippage is somewhat less). Over a period of turn-on of the coupling t - the leading part transmits the moment M_m, moreover, during this time it turns for angle α_1. The balance of work when the clutch is turned on is as follows:

$$M_m \alpha_1 = \frac{I_{bm} \omega_H^2}{2} + M_c \alpha_2 + A_{mp},$$

where I_{bm} – moment of inertia of clutch's driven parts, reduced to clutch (coupling) shaft; M_c – moment of resistance of the driven parts; α_2 – the angle of rotation of the driven parts in a time t; A_{mp} – work spent on friction in the clutch (coupling). Angles α_1 and α_2 can be determined from the equation of dynamics for the driven parts.

$$I_{bm}\frac{d\omega}{dt}+M_m-M_c$$

take up I_{bm}, M_m, M_c as a constant for the period *t* (turn-on):

$$I_{bm}\omega_M=(M_m-M_c)t$$

from where:

$$t=\frac{(M_m-M_c)}{I_{bm}\omega_M}$$

Angular rotational rate of the driven part (at a known time *t*):

$$\omega_M=\frac{(M_m-M_c)t}{I_{bm}}$$

Turning angle of driven disks (substituting instead *t* its value):

$$\alpha_1=\omega_M t=\frac{I_{bm}\omega_M^2}{M_m-M_c}$$

Turning angle of driven part:

$$\alpha_2=\int_0^t\omega_M t=\int_0^t\frac{M_m-M_c}{I_{bm}}\cdot tdt=\frac{M_m-M_c}{I_{bm}}\cdot\frac{t^2}{2}=\frac{I_{bm}\omega_M^2}{2(M_m-M_c)}$$

substituting in the equation of the balance of work α_1 и α_2 will get:

$$A_{mp}=\frac{M_m}{M_m-M_c}\cdot\frac{I_{bm}\omega_M^2}{2}$$

Taking $\frac{M_m}{M_m-M_c}=\alpha_M$ = 1,05-1,16 (coupling on the main shaft) α_M =1,25-1,35 (coupling on a transmission shaft).

If the friction work is divided by the area of friction surfaces *F* [m^2] and multiplied by the actual number of turn-ons per minute, we get the wear rate [1]:

$$K_{izn}=\alpha_M\cdot\frac{I_{bm}\omega_M^2}{2F}\rho\cdot n_H\le\left[K_{izn}\right],$$

where ρ - use factor of number of moves, n_H - calculated speed of the press, the values are given in table 1.

Table 1

Type of equipment	n_H	ρ
1. Sheet-plate stamping press, ventilating, bending, high capacity cutoff	<15	0.7-0.85
2. Also of average capacity	20-40	0,50-0,65
3. Horizontal forging machine, plate cutter (sheet metal shears), shearing and multi-function, sheet metal press of average capacity	25-60	0,55-0,70
4. Hot forging crank driven press, embossing, high capacity varietal shears	70-110	0,30-0,45
5. Also of average capacity	40-70	0,45-055
6. Multi-operated sheet-plate stamping and shearing presses, high speed	90-120	0,20-0,45

[K_{izn}] = 0.7-0.8 M J/м^2 min – single disk clutches with retinax inserts.
[K_{izn}] = 0.4-0.5 M J/м^2 min – multi disk clutches with ferodo plates.

Formula shows that with decreasing ω the wear is reduced (but the moment is growing). After checking the wear rate, the piston diameter is selected based on the pressure in the pneumatic cylinder. p_c = 0,3-0,4MPa.

To improve the operation of the clutch, two-stage feed is made, and the pressure increases until the time of the working operation. [1].

Dynamic model of a crank press with feed clutch. When modeling the dynamics of a crank press with the feed clutch and simulation of the operation of the feed clutch, various software systems are used [6-17].

To simulate and analyze the movement of a crank press with the feed clutch, this work uses a software package: SimulationX [18].

SimulationX – is software for modeling and analyzing the dynamics and kinematics of automobiles, industrial equipment, electric, pneumatic and hydraulic actuators, hybrid engines, etc. It is used for the design, modeling, simulation, analysis and virtual testing of complex mechatronic systems. It simulates the behavior and interaction of various physical objects of mechanics (1D and 3D), driving equipment, electrical, hydraulic, pneumatic and thermodynamic systems, as well as magnetism and analog and digital control systems. It performs the following tasks: system modeling in the time and frequency domains; simulation of transient processes in linear and nonlinear systems or stationary simulation to calculate a model in a periodic state (nonlinear or linear). Model libraries are divided by simulated physical applications. Tools and interfaces complement SimulationX for integrated analysis of systems and structure.

Figure 4 shows dynamic model of a crank press with feed clutch on the SimulationX software package [19-22].

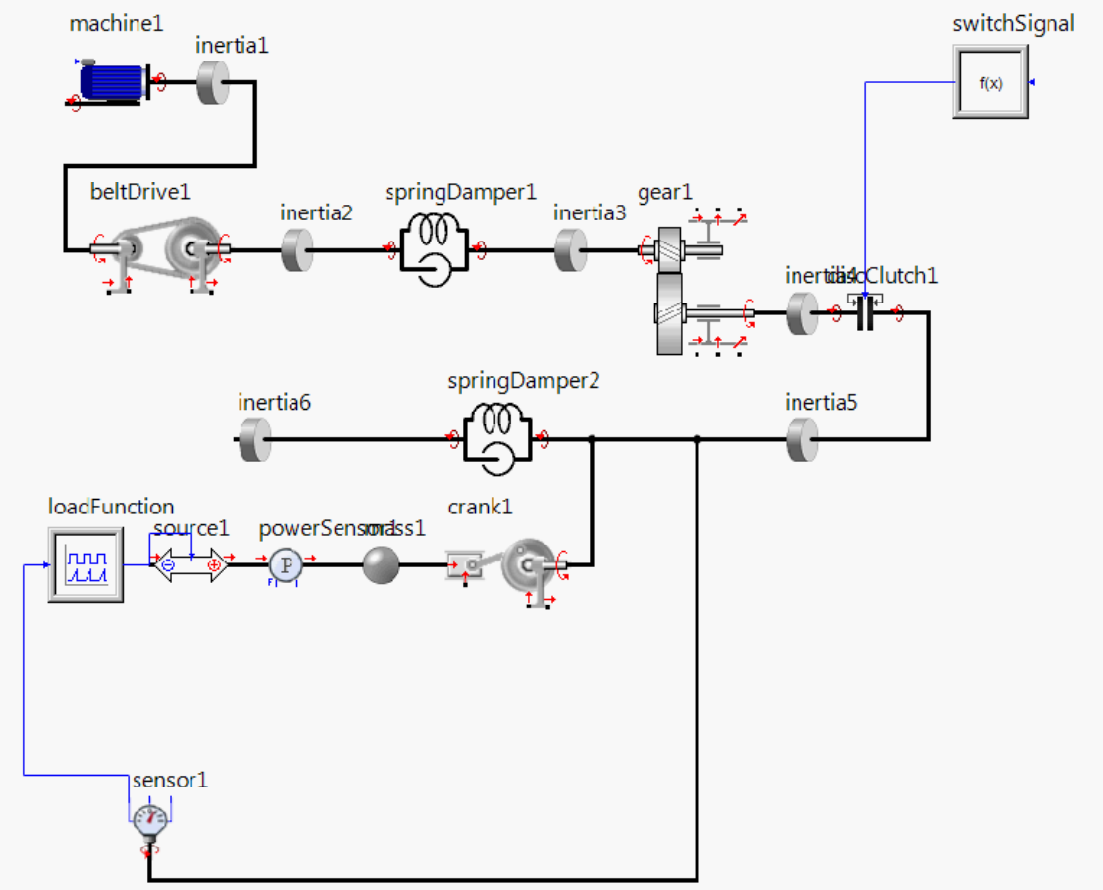


Figure 4 – Dynamic model of a crank press with feed clutch on the SimulationX software package

The elements of the SimulationX library that were used to compile the model are shown in figure 5.

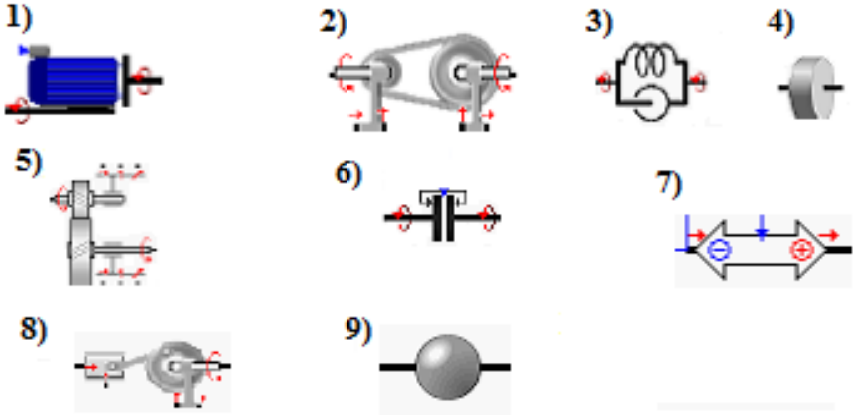


Figure 5 – The elements of the SimulationX library

List of symbols (see figure 5) and description of the elements of the SimulationX library:

1 – Asynchronous motor. This element simulates the simple asynchronous motor. The model is based on the stationary characteristics of the motor. This element models the asynchronous motor with sufficient accuracy when simulating the drive of a machine. It simulates engine starting, transient and steady-state processes, depending on the load and the speed of rotation of the shaft.

2 – Belt drive. This element models the operation of belt transmission, with the account of elastic-dissipative characteristics. The model takes into account the reactions and movements in the bearings of the pulleys of the belt drive that allows you to simulate the interaction of the transmission with the base.

3 – Spring - Damper – backlash. The model represents elastic and / or damped behavior between the rotational links, with the possibility of taking into account backlash. Springs always acts in parallel with the dampers.

4 - Inertia. This element models the moment of inertia of a rotary link. It is also possible to simulate a variable moment of inertia.

5 – Gear. The Transmission element is an ideal converter of rotational movements and forces operating between two components in a rotating mechanical system. It works as an ideal converter without taking into account dissipation and, fulfills the specified gear ratio or the conditions of power balance in input and output. The Transmission element allows you to model fixed and variable ratios for angles or velocities in input and output.

6 – Disc clutch. The Model Disc Clutch is a component that turns on or interrupts the flow of torque (and therefore power transmission) between the drive components. The model can be used to simulate multi-plate clutch of machines or gearboxes. In addition, it is possible to simulate the friction of the brakes (for example, an automatic transmission). Elasticity, damping and clutch friction parameters can be considered. In transmission of the models, the clutch can be activated by a signal from the switch.

7 – External force. This type of element allows you to simulate the forces between two components, or only on one component of the mechanical model. It provides universal, functional power transfer in the mechanical model.

8 – Crank mechanism. The element models a slide-crank mechanism, taking into account the backlash in the hinges, the elastic-dissipative properties of the connecting rod.

9 – Mass. This element models the mass of a linear link. Variable mass modeling is also possible.

Initial parameters of the model:

Crank press motor power W=0.5 кВт, rated engine speed n=450 rpm. The numerical values of the dimensions, moments of inertia of the nodes of the crank press and the stiffness of the shafts are taken from [1].

The nominal force developed by the slide of the slide-crank working mechanism in the area before the extreme low point of the slide's stroke is modeled by a sine-wave signal generator (loadFunction) and linear force (load) (figure 6). This load force depends on the angle of the crank. The maximum force is reached at the lower point of the slide’s stroke and is equal to 4000n.

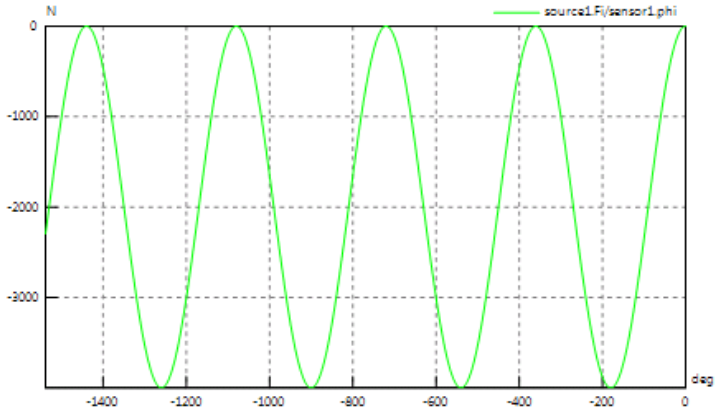


Figure 6 – The nominal force, developed by the slide of the slide-crank working mechanism

Parameters of the feed clutch of the crank press are shown in figure 7.

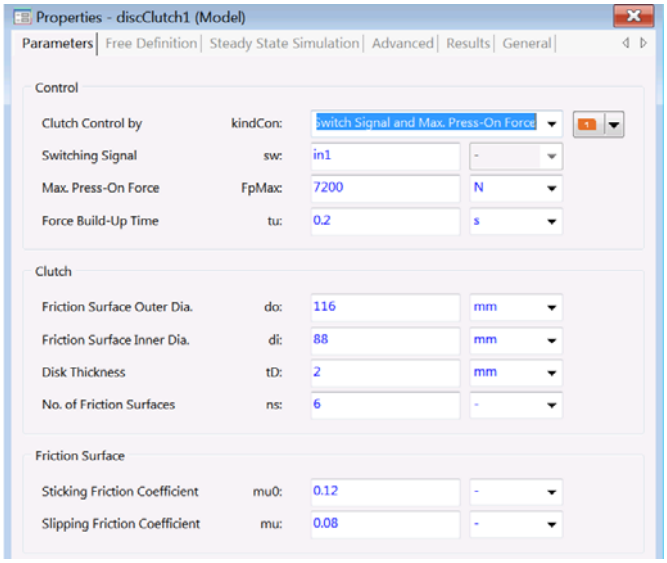


Figure 7 – Parameters of the feed clutch of the crank press

Simulation results: Feed clutch of the crank press is activated on the 10th second and connects the moving flywheel to the actuator. Figure 8 shows the moment transmitted by the feed clutch.

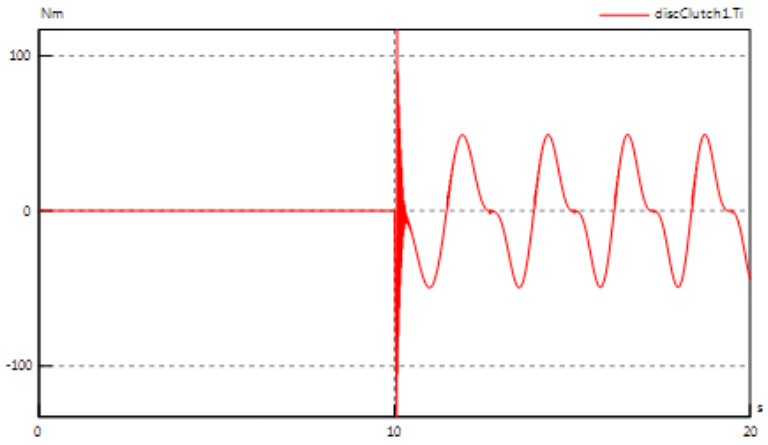
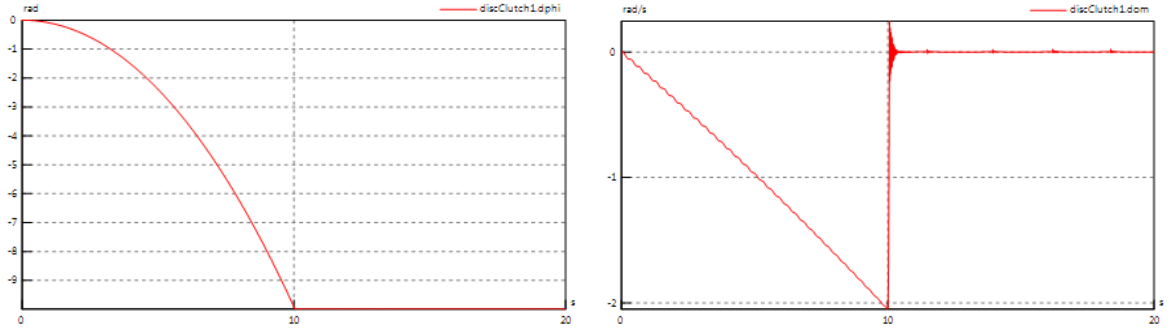


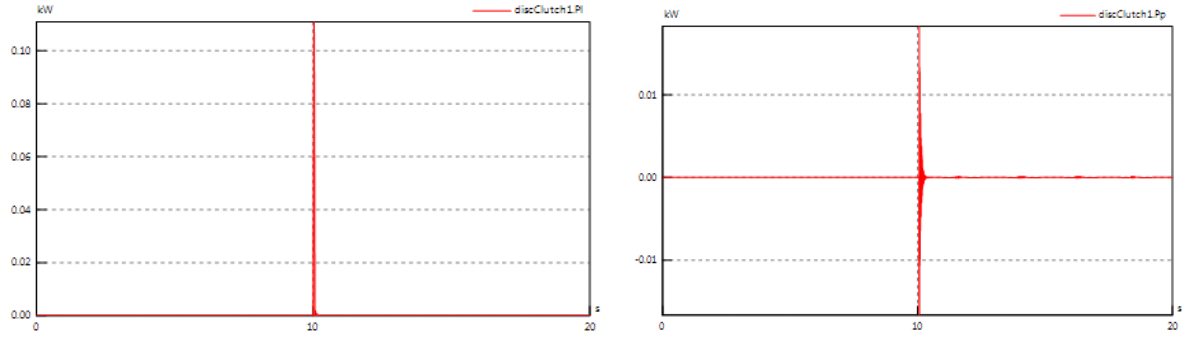
Figure 8 – moment transmitted by the feed clutch

Figures 9 and 10 show the various data of the feed clutch of the crank press



(а) (б)

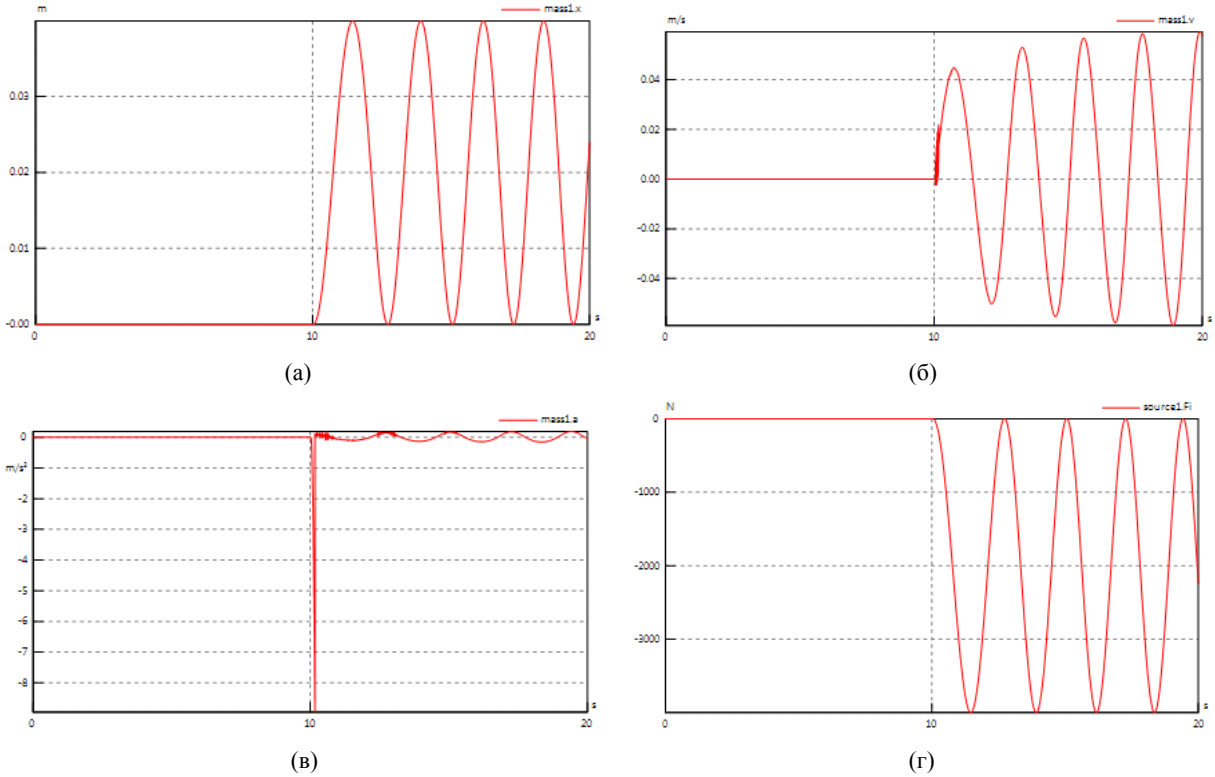
Figure 9 – Calculated data of the feed clutch a) relative angular displacement of the discs; b) relative angular velocity of the disks



(а) (б)

Figure 10 – Calculated data of the feed clutch a) turn-on power loss; б) potential energy change of the clutch

Figure 11 a, b, c shows movement, speed, acceleration and load of the press slide.



(а) (б)

(в) (г)

Figure 11 – Estimated data of the press slide a) movement; б) speed; в) acceleration; г) load

Conclusion.

1. The SimulationX software package allows one to simulate the dynamics of the feed clutch of the crank press, taking into account its design parameters as part of the crank press, and the interaction with all its nodes.

2. As the result of the dynamic calculation following is determined; moment transmitted by the feed clutch, relative angular displacement of disks, relative angular velocity (speed) of the disks, turn-on power loss and potential energy change of the clutch. The displacement, speed, acceleration, and load of the slide of the crank press are determined at the moment of clutch turn-on and after movement.

3. Dynamic loads in the nodes of the crank press sharply increase at the moment of clutch turn-on.

4. When studying the dynamics of a crank press, it is necessary to take into account the design features of the feed clutch, especially plate wear and adjustment, which requires further research of this unit.

5. Visibility of the models and graphical results are especially useful for students and engineers in the study of the feed clutches of the crank presses.

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ҚОСИІНДІ БАСПАҚҚА ҚОСЫЛҒАН ЖАЛҒАСТЫРҒЫШТЫҢ ДИНАМИКАЛЫҚ ЗЕРТТЕУІ

Аннотация. Жұмыста қос иінді баспаққа қосылған жалғатырғышты динамикалық түрде зертелді. Қазіргі кезде басқа түйіндердің өзара әсерін ескеріп, қос иінді баспаққа қосылған жалғастырғышты динамикалық зерттеу маңызды мәселе болып отыр. Қос иінді баспақ массасы 100 килограммнан бірнеше тоннаға дейін болатын қозғалмалы бөлшектер мен түйіндерден тұрады. Үлкен динамикалық жүктememен үлкен жылдамдықпен әсер ететін қос иінді баспаққа қосылылған жалғастырғышқа осы бөлшектермен түйінде циклді түрде қосылып отырады. Қосылылған жалғастырғышты қос иінді баспақтың қозғалысын моделдеп және талдау үшін SimulationX бағдарламалық комплекс қолданылды. SimulationX бағдарламалық комплексі - өнеркәсіптік жабдықтар, электр,- пневмо,- гидрожетектер, гибридті қозғалтқыш, автокөліктердің кинематикасы мен динамикасын талдап және моделдеу үшін пайдаланылды. Динамикалық есептеу нәтижесінде жұмысшы бұлғақтың және қос иінді баспаққа қосылылған жалғастырғыштың маңызды динамикалық параметрлері анықталды. Жалғастырғышты қосқан сәтте қос иінді баспақтың барлық түйіндерде динамикалық жүктеме ұлғая бастағаны көрсетілген.

Түйін сөздер: динамика, қосиінді баспақ, жалғастырғыш, бұлғақ, момент, тербеліс, SimulationX.

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ДИНАМИЧЕСКОЕ ИССЛЕДОВАНИЕ МУФТЫ ВКЛЮЧЕНИЯ КРИВОШИПНОГО ПРЕССА

Аннотация. В работе исследуется динамика муфты включения кривошипного пресса. В настоящее время динамическое исследования муфт включения кривошипных прессов с учетом взаимодействия с остальными узлами является актуальной задачей. Кривошипный пресс содержит подвижные детали и узлы, масса которых от ста килограмм до нескольких тонн. Данные детали и узлы циклически подключаются муфтой включения кривошипного пресса с большими скоростями и на них действуют большие динамические нагрузки. Для моделирования и анализа движения кривошипного пресса с муфтой включения используется программный комплекс: SimulationX. SimulationX – программный комплекс для моделирования и анализа динамики и кинематики автомобилей, индустриального оборудования, электро-, пневмо- и гидроприводов, гибридных двигателей и т.д. В результате динамического расчета определены важные динамические параметры муфты включения кривошипного пресса и рабочего ползуна. Показано, что динамические нагрузки практически во всех узлах кривошипного пресса резко возрастают в момент включения муфты.

Ключевые слова: динамика, кривошипный пресс, муфта, ползун, момент, колебания, SimulationX.

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ENVIRONMENTAL ANALYTICAL CHARACTERISTICS OF GAS EMISSIONS FROM THE SOLID DOMESTIC WASTE LANDFILLS OF TURKISTAN OBLAST

Abstract. The work is devoted to the study of the state of 2 urban and 22 rural landfills of Turkistan oblast (Turkestan and Otyrar districts). Based on the conducted morphological analysis of SDW, it was determined that about 50% of waste in the landfills of Turkistan and Kentau towns can be attributed to a potential source of secondary raw materials. Chemical and analytical studies have been carried out to identify the content of harmful gas components in the atmospheric air on the territory of landfills under normal conditions and under ignition of solid domestic waste (SDW). Al hazard classes' compounds presence was detected in the composition of landfill gas. A significant part of the urban landfills' territories in contrast to rural areas, can be attributed to the fire hazard zone. It has been determined that during fumigation or fire, the content of toxic compounds in gas emissions is higher many times than the maximum permissible concentrations both in the working area and outside the landfills.

Keywords: solid domestic waste, urban and rural landfills, ignition, gas emissions, toxic compounds.

Introduction. At the present time the destiny of solid domestic waste (SDW), the quantity of which is increasing with speed, anticipating their recycling and utilization, belongs to pending important problems in all countries [1, 2]. The main part of generated solid domestic wastes are stored in the landfills of various type and numerous unauthorized landfills. They mainly adjoin the settlements or are located in the territory of residential areas.

Ownerless accumulation of SDW has huge environmental, economic and social damages. Such waste management can be referred to one of the main factors, which hinders stable development of the cities and villages.

Permanent growth of generated waste quantities leads not only to littering, but also to increase of recallable valuable lands under SDW disposal landfills in the economic respect. SDW consists of toxic gases and not less toxic products of their decomposition, representing various harmful substances in the form of gaseous, solid and liquid connections. Accordingly places of SDW accumulation acts as the essential pollution sources of environmental medium, more specifically of atmosphere, soil, surface and underground water. which in turn have a negative impact on the biological resources, including population [3, 4].

For protection and enhancement of the environment, ensuring environmental safety it is necessary to focus on solution of a problem with minimization of SDW impact on the environment and population health, decrease of accumulated SDW volume by implementing effective measures on collection, sorting, treatment and recycling with obtaining valuable market products, reclamation and rehabilitation of disturbed lands. Occupied under landfills and unauthorized landfills. In light of specified problems, a solution of the problem, ensuring environmental improvement on a broad scale and in a concrete region is topical.

The objective of this work was to identify existing landfills and landfills of Turkistan oblast (for example, Turkistan and Otrar districts) and conduct chemical and analytical studies to determine the ecological condition of atmospheric air under normal conditions of storage of SDW and their fire.

Objects and methods of study. 24 polygons of Turkistan oblast, namely, in two districts (Turkistan and Otrar) and in the towns - Turkistan, Kentau (table) served as objects of research. Apart from that, several hundreds of unauthorized landfills located in the studied areas were examined.

The landfills under study of Otyrar district (Akkol, Akkum, Arys, Baltakol, Bestam, Bestorangyl, Koksarai, Kosterek, Mayakum, Otyrar, Syrdarya), the area occupied by them is 60 ha (17 922 people). Total quantity of waste in the landfills of Otyrar district (actual) is 41 355,144 tons. Total area occupied by 10 rural landfills of Tukistan district (Zhibek zholy, Ushaiyk, Shornak, Sauran, Zhuynek, Zhana Ikan, Eski Ikan, Babaikorgan, Orangai) is 22 ha (87 957 people). Total quantity of buried waste in the landfills of Turkistan district (actual) is 155 780,662 tons. Urban lanfdfill of Turkistan occupies 18 ha (263 000 people). Quantity of waste of Kentau town (actual) is 239 175 tons. Area of the landfill of Kentau town is equal to 33 ha (7115 people), total quantity of waste in it is 20 020 tons. Average quantity of SDW for 1 person is from 200 to 250 kg/year.

In order to perform the foreseen works, a comprehensive analytical analysis of landfills' condition, determination of SDW morphological composition in different periods of the year, the study of gaseous products' composition released under normal conditions and spontaneous combustion were carried out. Measurement of gas composition above the landfill surface was carried out in favorable meteorological conditions, in particular, on a windless day and in the absence of precipitation. And to establish the distribution of gas flows in space and their effects on environmental objects, measurements were taken both in calm and in windy weather, but in the absence of precipitation.

As is known, the value of gas flow from the body of waste into ground air of landfill surface in different sections are different [5, 6]. Irregularity is observed not only in area, but also in depth. It is connected with heterogeneity of solid domestic waste both in composition and capacity of landfill masses. In this regard, to establish the intensity of the gas flow from the landfill masses and SDW morphological composition in them, the sampling was carried out using a well-known "envelope" method [7]. Used "envelope" method for sampling by us was not difficult, since SDW in the studied landfills and disposal fields are in piles (no more than 2-3 meters high) and there are free passages between them.

All analytical studies were carried out in an accredited laboratory of "Environmental Control and Chemical Analysis" by certified methods, and field observations were conducted in the territories of landfills using well-known classical methods [8-10].

Using the universal gas analyzer ГАНК-4 (measurement height up to 2 meters from the ground), we regularly measured emissions of harmful gaseous substances. While using the gas analyzer "ГАНК-4" the chemical cassettes or a built-in sensor are used. The cassette is designed for approximately 1000 counts for working area air and/or for atmospheric air. The built-in pump sucks in analyzed air through the inlet piece of a gas analyzer and passes it through the sensor or tape of a chemical cassette. Changing the cassette is done manually and takes at most 1 minute.

Results and discussion. The outcomes of monitoring studies in the territories of districts under consideration show that there are not only 24 landfills, but also hundreds of unauthorized landfills, about 20 landfills in the territory of Turkistan and Kentau towns. It is impossible to determine an exact number of unauthorized landfills, as they are like mushrooms after rain, appear in unpredictable places especially in rural areas. SDWs are piled in the ravines, pit places and areas adjacent to private solid fuel-heated houses (about 70% of ash and construction waste).

The studied 24 landfills of Turkistan oblast on average occupy a total area equal to 133 hectares. Only 5% of these landfills meet the requirements of sanitary standards. The most common method of waste management is depositing the solid domestic waste at disposal fields and landfills in the territory under consideration. The results of field surveys (visual assessment) showed that the waste is disposed systemless in many SDW landfills (at least 80%). Waste is delivered to the entire area without mapping and observing the established sequence for waste. Proper compaction and backfilling of waste with soil is also not performed.

As the results of on-site surveуы have shown, over time, the geometric characteristics of landfill sites is changed with accumulated waste. Namely, there is a subsidence of SDW and sometimes, on the

contrary, a height increase of burials due to refill of heaps with new batches of various wastes. It accordingly leads to a change not only in shape, but also to a change in the mechanical, chemical, biochemical, and other characteristics of SDW. Changing the areal and volumetric configuration of the landfill body requires periodic monitoring of atmospheric gas pollution state in the territories of a landfill and in the territories of a residential part adjacent to the landfill. The data from monitoring studies will allow establishing the impact of landfills on natural environmental objects' state in both normal and extreme (fire, smoke, etc.) conditions.

One of the important indicators characterizing the SDW composition is their morphological composition. These data are necessary not only for identifying the landfill impact on the environment, but also for effective selection of decontamination technology, methods of SDW disposal and recycling [11]. In connection with this, we have conducted studies on establishment of a morphological composition in all existing landfills and dumps of the studied area.

Table presents an average morphological composition of SDW at various types of landfills, depending on season (2018).

An average morphological composition of solid domestic waste located in rural and urban landfills of Turkistan oblast (12 landfills of Turkistan district, Kentau town, 11 rural landfills of Otyrar district)

Name of components	Average content of SDW components in rural and urban landfills by seasons of a year, %					
	winter-spring			summer-autumn		
	rural	Turkistan	Kentau	rural	Turkistan	Kentau
Food waste	5-7	23-30	15-20	8-10	36-37	35-45
Paper, cardboard	9-12	13-16	10-12	7-9	20-22	5-6
Tree	~0,4	2-3	0,5-1	~0,5	3-4	1-2
Ferrous and nonferrous scrap metal	≤1	≤3	до 1	≤2	≤3	1-3
Textile	4-6	4-5	3-5	4-6	4-5	2-4
Bones	5-7	6-8	1-2	4-6	5-6	1-2
Glass	3-5	7-8	2-5	10-12	10-15	9-11
Leather, rubber	6-9	2-5	10-11	5-7	2-5	2-3
Construction materials: stone, plaster, asbestos sheeting and others	8-9	19-23	5-7	10-15	20-26	6-8
Polymers	7-10	20-24	10-20	20-25	26-29	15-20
Manure, poultry droppings, wool and others	10-15	2-3	5-10	8-10	2-3	1-2
Other waste (ash, coal, residue)	Remaining			Remaining		
SDW physical and mechanical composition for urban landfills						
Ash content to working mass, %					10-21	
Ash content to dry mass, %					20-32	
Organic substance to dry mass, %					48-60	
Humidity, %					15-20	
Density, kg/m^3					190-200	
Heating value as fired, kJ/kg					5000-8000	
Agrochemical factors, % to dry mass (rural landfills)						
Total Nitrogen					0,8-1	
Phosphorus (P_2O_5)					0,7-1,1	
Potassium (K_2O)					0,5-0,7	
Calcium (CaO)					2,3-3,6	

As can be seen from the data presented in Table 1, solid domestic waste is a complex heterogeneous mixture, determined by living standard of population, degree of home improvement, habits and characteristics of residents. The content of food waste is unstable, their content in the total waste stream increases in the summer-autumn period, which is associated with an increase in consumption of vegetables and fruits, preparation for storage and absence of the need to use them as food for animals and birds. Food waste is not thrown away in the winter-spring period, because it used for feeding animals. An increase in the content of glass and plastic containers is associated with an increased use of various beverages in hot summer months. An increase in construction waste by almost 2 times is due to the intensified repair and other construction works in summer-autumn months. The remaining fractions are practically little changed. Many waste components belong to IV and V hazard classes, average waste density is ≤ 0.2 t/m^3.

Based on a deep morphological sorting, solid domestic waste can be divided into the following 3 groups: biodegradable (food, wood, sawdust, textiles, leather), inert (stone, sludge, resuduals) and recyclable (paper, cardboard, polymeric materials, metal, glass).

Morphological analysis of waste of Turkistan and Kentau towns showed that at least 50% of SDW are potential secondary raw materials. Under the existing waste management system, about 100 000 tons of SDW are placed annually in two town landfills, including over 7 thousand tons of glass, ~ 4-6 thousand tons of polymeric materials, at least 8 thousand tons of paper and cardboard and about 5 thousand ton of metal. There is a constant increase in the content of non-ferrous and ferrous metals in SDW composition. It is connected with additional recharge of non-ferrous metals due to emergence of aluminum cans from beer, water and other beverages, as well as iron packaging cans. The content of plastic packaging materials, including bottles made of polyethylene terephthalate, is also increasing every day in all landfills.

The survey results of landfills' state show that the construction materials, large furniture, refrigerators, microwave ovens, other kitchen appliances, car tires, chemical current sources (batteries, batteries) and similar household items constitute a significant part in the structure of waste stored at landfills and dumps. The disposal of these materials is not only a significant force on the environment, but also the loss of valuable materials and energy contained in them.

Involvement of such valuable components as paper, cardboard, glass, polymeric materials, metals in the secondary circulation will lead to a significant reduction in the need for material and energy resources, as well as to reduce their negative impact on the environment. In addition, an extraction of recycled materials from waste and their sale, use of biogas energy will allow for additional income.

Recycling of organic waste will provide an opportunity to return carbon to the circulation of substances, naturally increasing soil fertility through the production of compost, vermicompost and use the waste energy value through use of energy and heat produced.

Since 2019, taking into account the feasibility of reusing the valuable components of SDW as a secondary raw material, Kazakhstan has banned the export and deposit of paper, cardboard, plastic bottles and other polymeric materials, glass in landfills [12].

Considering the experience of Germany and other countries in collection and sorting of waste [13-15] the implementation of pre-sorting has commenced in Turkistan with active participation of students, undergraduates, doctoral students and staff of International Kazakh-Turkish University named after Khoja Ahmed Yasavi. At the same time the following is used for separate collection of waste: *yellow* containers designed for plastic packaging and plastic films; *red* - for food and other biological waste; *blue* - for waste paper; *brown* - for glass products; *black* - for collecting other waste.

Sorted waste from special containers having different colors will fall under further processing. This approach allows not only to obtain an economic effect, but also to improve the environment by reducing the amount of waste which does not fall under biodegradation.

But, unfortunately, used batteries and accumulators that have a multicomponent chemical composition get into the composition of other waste. There are practically no enterprises involved in their processing in Kazakhstan as in many other countries [16–19]. In this regard, they have to be disposed of in landfills along with other waste. In a mixed environment, they enter into chemical reactions, are destroyed and begin to act as a dangerous source of environment contamination.

Worries in the cities are caused by food waste, their collection and separate storage in containers does not solve the environmental problem. They quickly decompose with release of bad smelling compounds, and are also a cumulative environment for rapid development of harmful microorganisms and

other representatives of biota. Their destroying by burning does not solve the problem, although this method is used in many countries [20-22].

A perspective and strenuously developing method of biochemical transformation of organic waste with production of useful products - compost or biohumus serves as an alternative to the burning method. But, however, to recommend their use in agriculture is limited, which is associated with possibility of heavy metals in their composition. They can only be suitable for fertilizing lawns and industrial crops that are not used to produce food.

At the present, there is no option of comprehensive optimal solution of SDW disposal issues, which would allow processing of secondary raw materials and energy resources in a significant amount both economically and environmentally efficient. The system for SDW management that exists in Kazakhstan and in local regions requires further improvement based on development and implementation of more rational ways to minimize the SDW impact on the environment and public health.

The presented paper provides the observation results of atmospheric air state directly in the territories of 24 polygons under consideration and in nearby areas up to 1 km. Field observations made it possible to note elevated concentrations of greenhouse gases (methane and carbon dioxide) and toxic gases — hydrogen sulfide, sulfur dioxide, nitrogen oxides and carbon in the surface air on the landfill body during fumigation moments. It has also been determined that significant air pollution of the landfill working area and the adjacent territory with carcinogenic compounds - benzpyrene, formaldehyde, benzene and other hazardous substances is as a result of waste ignition (figure).

The quantity of these of those gases in the surface air over different parts of the landfill sections was very different from each other. Such uneven content of gases in the atmospheric air first of all, during the fire, apparently, is related to the heterogeneity of composition and capacity of the waste landfill masses. And under normal conditions, the value of emission and the dynamics of gas volume changes over time depend on the nature of processes occurring in the landfill body.

Fumigation or fire development, especially during summer periods at the landfill, is more associated with artificial burns and, probably, to a lesser degree with facts of spontaneous combustion.

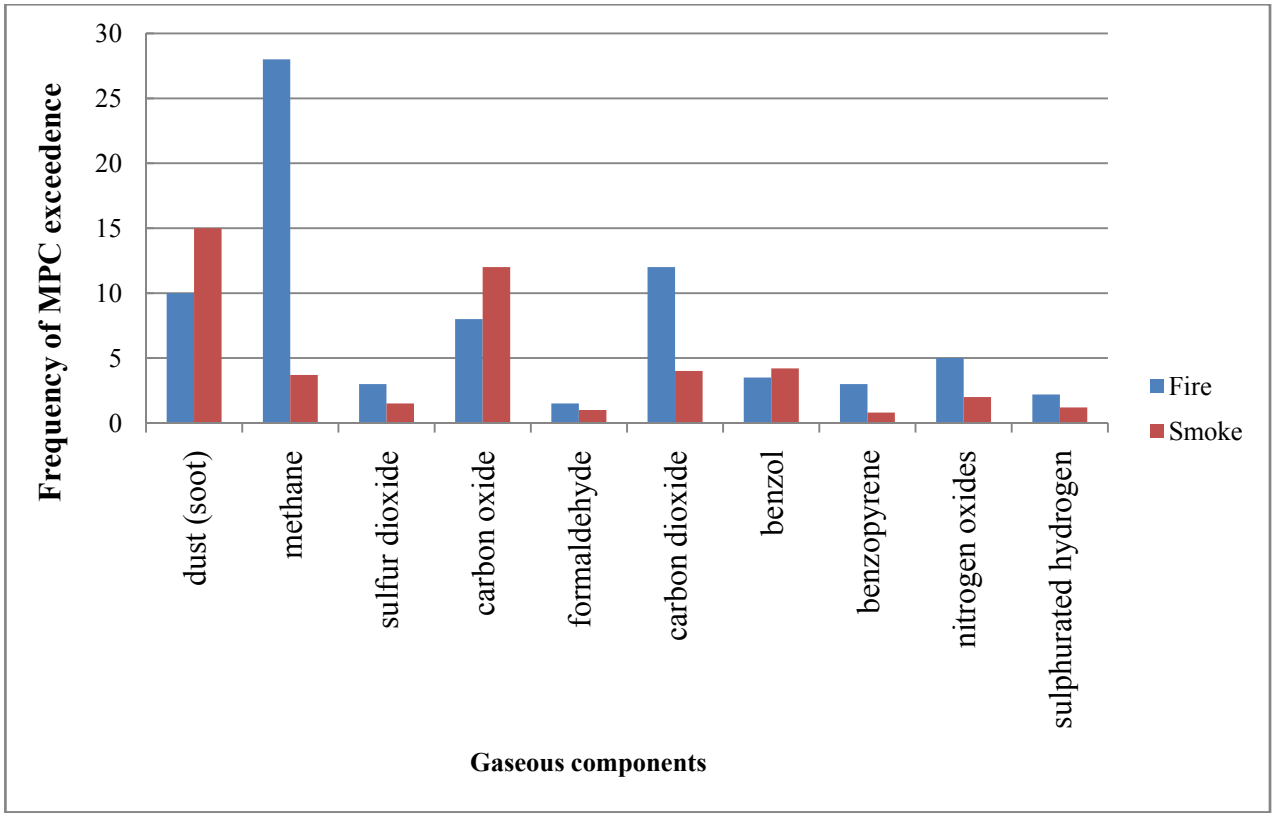

Figure 1 – Frequency of exceeding the maximum permissible concentration of individual compounds content in the composition of gas emissions (gas emissions) generated during fire

The results of experimental studies on determination of gas components released into the atmospheric air during ignition indicate to possibility of deterioration in the quality of population life in the nearby territories.

The presence of substances of all hazard classes was detected in the landfill gas composition. In addition, in urban landfills as opposed to rural areas, a significant part of the landfill territory belongs to the potentially fire-hazardous zone.

The considered qualitative and quantitative composition of landfill gas emissions testifies to presence of hazardous, fire-hazardous, toxic and carcinogenic gases of all hazard classes in the composition of gas emissions. In nature of impact on the human body, harmful substances can be divided into groups: irritants (chlorine, ammonia, hydrogen chloride, etc.); suffocative (carbon monoxide, hydrogen sulfide, etc.); narcotic (nitrogen under pressure, acetylene, acetone, carbon tetrachloride, etc.); somatic, causing organism disorder (lead, benzene, methyl alcohol, arsenic).

Thus, in order to reduce a negative impact on the environment and human health, it is necessary to take measures to minimize the risk of fires or fumigation on time.

Conclusions.

1. Monitoring studies on the state of 24 solid waste landfills in Turkistan oblast were carried out. It has been determined that, until now, the priority method of waste disposal from Turkistan and Kentau towns, as well as from the villages of Otrar and Turkistan districts is their removal for burial to landfills.

2. A morphological composition of waste deposited at the landfills was studied and, based on the results of these studies, the SDW components were classified into 3 groups: biodegradable (food, wood, sawdust, textiles, leather), inert (stone, sludge, residues) and recyclable (paper, cardboard, polymeric materials, metal, glass).

3. On the basis of experimental studies, generation of toxic compounds has been determined, the contents of which in gas emissions from fumigation or fire are many times higher than the maximum allowable concentrations both in the working area and outside the landfills (or disposal fields).

4. To enable the operation of solid waste landfills without a negative impact on the environment, it is proposed to carry out a regular analysis of entering waste. This will make it possible to identify types of waste that cannot be buried in ordinary SDW landfills, for example, availability of radioactive substances, hazardous medical and other wastes, and also to identify the sources of their generation.

Work «Environmental analytical characteristics of gas emissions from the solid domestic waste landfills of Turkistan oblast» authors G.A. Sainova, M.O. Baikhamurova, A.D. Akbasova, Zh.Zh. Yessenbayeva., Mehmet Ali Ozlerdone with the financial support of the Ministry of Education and Science of the Republic of Kazakhstan on the program AP05130297, registration №0118RK00358 «Development and implementation of environmentally efficient and effective technologies for processing of solid domestic and industrial waste with obtaining secondary raw materials and marketable products (by the example of the territory of Turkestan-Kentau-Otyrar)».

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ТҮРКІСТАН ОБЛЫСЫНЫҢ ҚАТТЫ ТҰРМЫСТЫҚ ҚАЛДЫҚ САҚТАҒЫШТАРЫНАН БӨЛІНЕТІН ГАЗ ШЫҒАРЫНДЫЛАРЫНЫҢ ЭКОЛОГИЯЛЫҚ-АНАЛИТИКАЛЫҚ СИПАТТАМАЛАРЫ

Аннотация. Мақала Түркістан облысының (Түркістан және Отырар ауданы) 2 қалалық және 22 ауылдық полигондарының жағдайын зерттеуге бағытталған. Қатты тұрмыстық қалдықтарға жүргізілген морфологиялық талдау нәтижелері көрсеткендей, Түркістан және Кентау қалалық полигондарында орналастырылған қалдықтардың шамамен 50% екінші реттік шикізат көзі ретінде қолданысын таба алады. Полигондардағы жинақталған қатты тұрмыстық қалдықтардан қалыпты жағдайда және де олардың өртенетін кезінде атмосфералық ауаға бөлінетін уытты газдардың құрамын анықтау мақсатында химиялық-аналитикалық зерттеу жұмыстары жүргізілген. Қоршаған ортаға бөлінетін газдардың құрамында барлық қауіптілік

сыныпқа жататын қосылыстар болатыны айқындалды. Ауылдық қалдық сақтағыштармен салыстырғанда қалалық полигондардағы қалдықтардың ауқымды көлемі өрт қауіптілігі жоғары екені анықталды. Өртеніп немесе түтіндеп жататын кезеңдерде полигондардың жұмыс аймағында да санитарлық шекарасының сыртында да улы қосылыстардың мөлшері шектік рауалы мөлшерден анағұрлым асып жататыны дәлелденді.

Түйін сөздер: қатты тұрмыстық қалдықтар, қалалық және ауылдық полигондар, өртену, газ шығарындылары, уытты қосылыстар.

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ЭКОЛОГО-АНАЛИТИЧЕСКАЯ ХАРАКТЕРИСТИКА ГАЗОВЫХ ВЫБРОСОВ С ПОЛИГОНОВ ТВЕРДЫХ БЫТОВЫХ ОТХОДОВ ТУРКЕСТАНСКОЙ ОБЛАСТИ

Аннотация. Работа посвящена исследованию состояний 2 городских и 22 сельских полигонов Туркестанской области (Туркестанский и Отрарский районы). На основе проведенного морфологического анализа ТБО установлено, что около 50% отходов в полигонах городов Туркестан и Кентау можно отнести к потенциальному источнику вторичного сырья. Проведены химико-аналитические исследования по определению содержаний вредных газовых компонентов в атмосферном воздухе на территории полигонов при обычных условиях и при возгорании твердых бытовых отходов (ТБО). В составе свалочного газа обнаружено присутствие соединений всех классов опасности. Значительная часть территорий городских полигонов в отличие от сельских можно отнести к пожароопасной зоне. Установлено, что при задымлении или пожаре содержание токсичных соединений в газовых выбросах многократно превышают предельно допустимые концентрации как в рабочей зоне, так и за пределами полигонов.

Ключевые слова: твердые бытовые отходы, городские и сельские полигоны, возгорание, газовые выбросы, токсичные соединения.

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RADIATION-ECOLOGICAL MONITORING OF COAL MINES OF NOVOVOLINSK MINING AREA

Abstract. The recent restructuring of the mining industry causes a significant detrimental effect on environment and population. Operating of coal mining enterprises of the Lviv-Volyn coal basin and the restructuring of the mining industry led to the accumulation of waste possessing technogenically-increased natural radioactivity. Radiation safety on these coal mines is associated with natural radionuclides in coal and associated rock (γ-rays). The main contribution to the radiation dose of underground workers and the general radiation background.

Keywords: restructuring, radon, uranium, thorium, monitoring of radioactivity.

Introduction. Sustainable socio-economic development of modern society is impossible without an assessment of the technogenic impact on the environment. Nowadays, the peculiarities of development of various regions of Ukraine are the course of anthropogenic processes that lead to environmental pollution. Particular attention needs to be paid to the study of the regions where the coal industry is developed.

During the period of coal mining and coal processing in the territory of the Lviv-Volyn coal basin, the geoecological environment has undergone significant changes. This is primarily due to the change in the natural landscape, the impact of coal-processing waste on the environment, as well as the change in the geochemical indicators of the environment as a result of additional inflow of chemical and mineral compounds into it [1, 2].

One of the main sources of ecological danger for the region are dumps of mine rocks. Thus, during the extraction of coal from the rock mass that enters the surface, more than 75% of the raw material goes into the waste. In this regard, an important issue when developing environmental measures to minimize the impact of dumps mine rock to the environment is a reliable assessment of their toxicity [3].

Novovolynsk mining area belongs to the Lviv-Volyn coal basin, which is located on the border of the Lviv and Volyn regions of Ukraine and covers the right and left banks of the Bug. The total geological coal reserves are estimated at 2 billion tons, while the balance reserves are 1.4 billion tons [4]. In the landscape of the investigated area the arable land occupies more than 60% of the territory, in the north the surface is hilly, with a height of 244-270 m, which contains many ravines and beams. On its territory 28 mine dumps are formed (figure 1).

Along with weathering, which is widespread in the outer part of shaft waste heaps, because within them there are favorable conditions for oxidation and subsequent burning. The leading role in this belongs to the activities of microorganisms. The study of the conditions for the development of microorganisms in the zones of oxidation of sulfide deposits shows their stability at temperatures from 2 to 70 ° C, and pH of the medium - from 1 to 8. In this, the development of bacteria occurs in conditions of high humidity of the rock mass. In support of these findings, the fact that within the boundary parts of the mine waste dumps there are local focal ignition and there is a selection of vaporous sulfate acid [5-7].

The oxidation and burning of the waste heaps described above is accompanied by a significant evolution of water vapor, which is a mineral-forming medium for most of the minerals: sulfates, hydrocarbons, carbonates, phosphates, arsenates. In addition, oxidation produces carbon dioxide, nitrogen

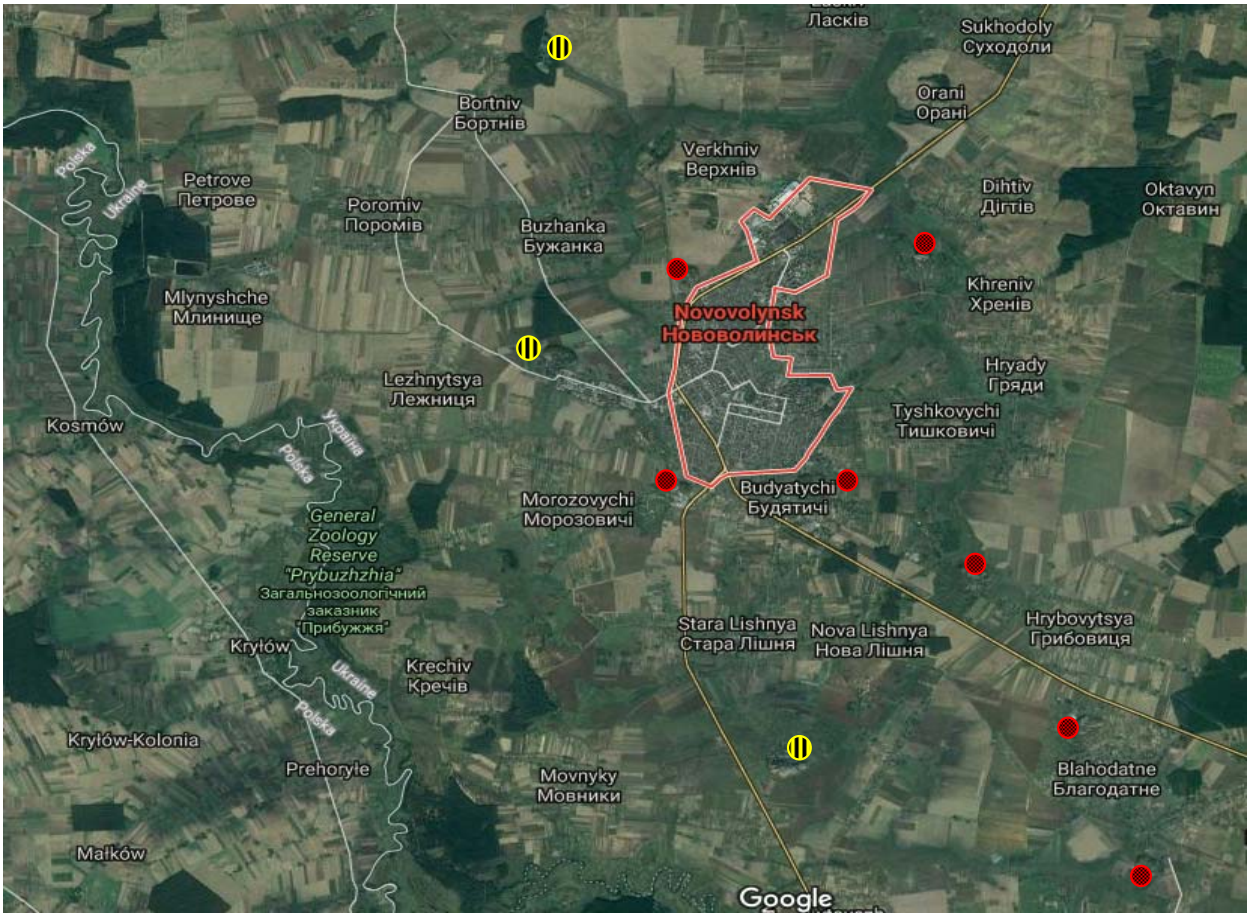

Figure 1 – Satellite image mines on the territory of Novovolynsk mining area (Ukraine).
Legend: yellow tag producing mines, red tag recultivated or under recultivation

oxide (IV), which forms nitric acid with water. In the absence of oxygen in the burning cells in the vapor-gas emissions contain hydrogen sulfide, hydrocarbons, ammonia, carbon monoxide (II). When leaving the surface of the rock dump form raids, crystalline or spherulite aggregates of new minerals, which predominate sulphates, sulfides and carbonates. The other part of the oxidized compounds evaporates into the atmosphere, filling it with harmful substances [9-11].

Modern mining operations are accompanied by an intense change in natural energy and mass transfer, as huge deposits of coal, rocks and underground water reach the surface of the earth causing the development of many negative phenomena that leads to environmental degradation of the region. For the Novovolynsk mining area, a significant transformation of the hydrogeology conditions, the change in the balance and regime of groundwater, the subsidence of the earth's surface, the formation of highly mineralized acid waters are characteristic [12, 13].

Purpose, tasks and methods of research. The purpose of this investigation is measurement of radiation background of mining waste heaps by MKS–05 "TERRA" dosimeter-radiometer. The permissible dose of background radiation is 0.3 μSv/h.

According to the purpose the following tasks are set: currently there are only few investigations made on coal mines, although they are extremely important for monitoring the health of mine personnel, as well as for the analysis of the radon level. The change of radon content may signal a fire breaking-out in the unworked coal.

The change of radon content may signal a fire breaking-out in the unworked coal. Presently 3 mines are operating on the territory of the Novovolynsk Mining Area, one is being built and 7 mines are being reclaimed or recultivated.

Radiation safety on these coal mines is associated with natural radionuclides in coal and associated rock (γ-rays). The main contribution to the radiation dose of underground workers and the general radiation background is made by radon products, as well as radionuclides of uranium and thorium series, and the radioactive isotope of potassium - 40, which are present in the form of aerosols in mine atmosphere. As is commonly known, gamma rays has a high penetrating power and therefore creates an external irradiation of the body of miners. Gamma-radiation intensity is directly proportional to the content of γ-emitting radionuclides in the walls of mining workings [14-16].

The greatest amount of radon emission is observed in areas where rocks contain high concentrations of uranium. Migration of radon is facilitated by long term deformation of rocks, vertical fault zones and porosity of rocks. It is believed that the greatest intensity of migration of radon from rocks can be expected in conditions of combination of geological factors such as the presence of a rock enriched with uranium; intense deformation of sub-vertical rocks that don't contain quartz, carbonate or clay, and a soil cover consisting of gravel or sandy eluvium.

Results and their discussion. The radiation situation in the coal mines of the Novovolynsk mining area depends on the intensity of its ventilation. Most coal mines are intensively ventilated (the time of air exchange is more than 2500 seconds), the average content of uranium and thorium in coal and rocks rarely exceeds 40 Bq/kg^{-1}. If such mines adhere a standard for dust contamination (10 mg/m^{-3}), then the average level of total radionuclides exposure on the lungs is within the range of 0.5– 0.7 exposure limit for miners of non-uranium mines and the radiation state is quite favorable. The annual dose for these categories of workers is 5mSv/year.

Mining conditions in coal mines, as a rule, differ significantly from the conditions for the ore deposits. Coal mines are characterized by a narrower range of the content of radium – 226 (Ra^{226}) and thorium – 232 (Th^{232}), coal and enclosing rocks, a small number of horizons that are in operation, shallowness of coal beds and the release of methane. Taking into account these differences, one can make the following assumptions about the radon emission features in the coal mines of the Novovolynsk mining area:

1. radon emission per unit volume or per unit surface of mine working is more or less uniform throughout the mine;
2. high intensity of radon emission may occur in the places with significant amount of methane released, as well as in mine workings, adjacent to the abandoned place;
3. on mines with a exhaust ventilation, higher radon emission should be expected, especially at a shallow workings;
4. radon emission intensity will be higher compared to the wingway due to the radon filtration release from the coal bed between them.

During complex studies in the region it is determined that the most dangerous for the environment are the workings in coal beds with radioactivity of 0.01-1.3 mSv/year (an average of 0.06 mSv/year), and for field workings of 0.05-0.8 mSv/year (an average of 0.12 mSv/year). The significance of such doses can be estimated by comparing them with the average external radiation dose obtained during the year by the staff working in the premises on the surface (0.23 mSv), with the average external radiation dose by the natural background of 0.8 mSv/year [17, 18].

It can be expected that the annual average external dose of staff in a coal mine will be 2.4 times less than the dose received during the same period by the workers on the surface and 6.12 times less than the annual dose due to the average value of the natural rediation background on the surface. From the foregoing, it follows that external gamma radiation is not a significant radiation hazard and that systematic monitoring and accounting of external doses of underground workers is required only in mines where the average content of natural radionuclides exceeds the content of radium (Ra^{226}) - 200 Bq/kg^{-1}, and thorium (Th^{232}) - 150 Bq/kg^{-1}. Measurement of the exposure-dose rate of photon-ionizing radiation in coal mines of the investigated area was carried out only in the producing mines.

As a result of the measurements of photon-ionizing radiation in the cities of Lviv-Volyn coal basin and in the coal dumps, it was established that:

1. The exposure-dose rate of photon-ionizing radiation in the Novovolynsky mining area is higher than in other cities of the basin.
2. The results of radioecological investigations have shown that the concentration of cesium - 137 in coal mines is 18-55 kBq/m^2 (0.5-1.5 Ci/km^2). The usual concentrations of cesium - 137 for this area are

0.1-0.2 Ci/km². Thus, the level of exposure dose of mining objects in the area exceeds the background in 1.2-1.6 times. The average index of radioactive contamination of 137Cs is higher than the background in 1.3-1.7 times, and 90Sr - in 2.0-5.0 and this causes their high concentrations in food in the area. In mines, the average content of natural radionuclides is: Ra^{226} - 3240 Bq/kg, Pb^{210} - 930 Bq/kg, Po^{210} - 1700 Bq/kg, Th^{232} - 1700 Bq/kg, Th^{228} - 1100 Bq/kg, Pa^{230} - 1300 B/kg.

3. The content of radon in the air of coal mines reaches 0.3-6.0 Bq/m³ (background content), high values of radon content are observed in the places of the former settling basins of the mine (on the surface of 22-35 Bq/m³, and at a depth of 0.3 m to 180 Bq/m³), and in the places of sediment ponds in the mine field, the radon content reaches several hundred Bq/m³ (MPC per radon of 100 Bq/m³ for mine production facilities) (figure 2).

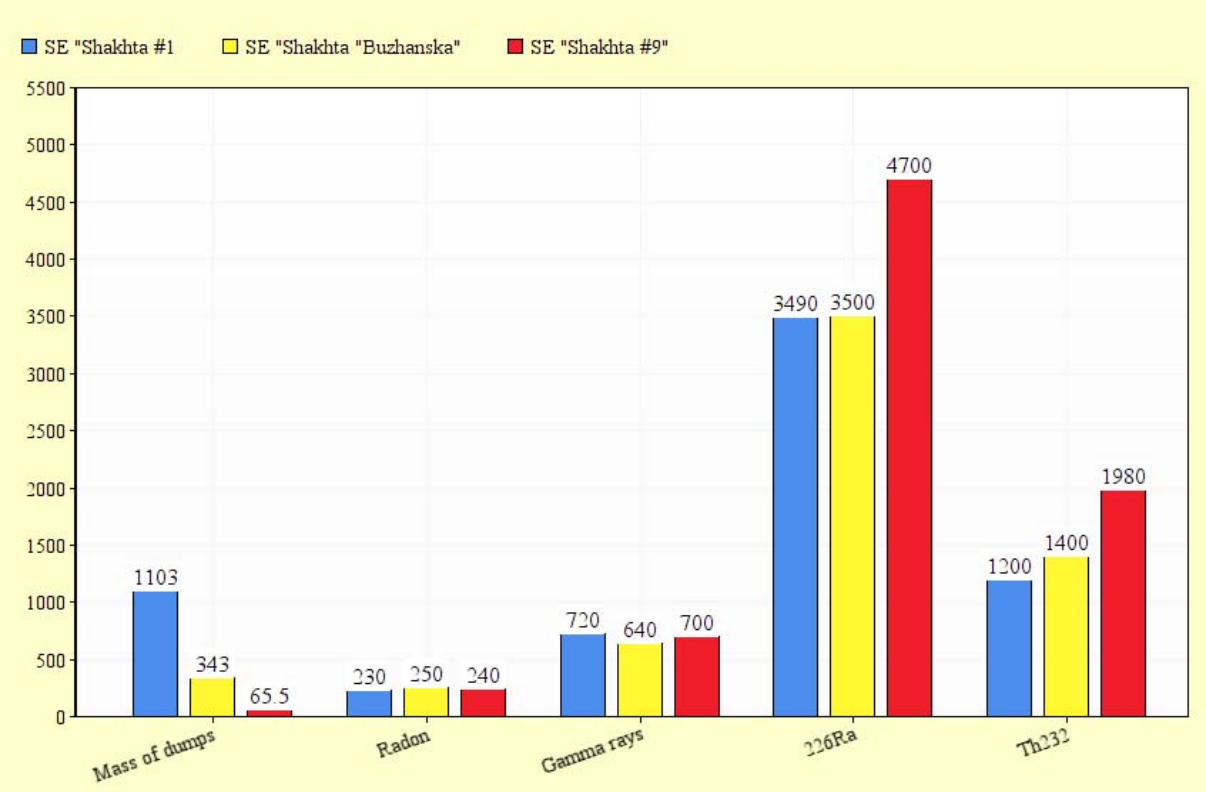

Figure 2 – Graphic representation of the radioactivity level (^{226}Ra and Th^{232}) on the producing coal mines of the Novovolynsk mining area

^{226}Ra, Th^{232}, specific activity of rocks does not exceed 4900 Bq/kg. High radioactivity is observed in loamy-sludge sediments of sediment ponds of coal mines. Here, the rate of gamma radiation dose from the surface is 640-720 mR/g, at the depth this index is 750 mR/g. The density of beta-rays from the surface - 80 cpm/cm², and alpha-rays 4 cpm/cm². It was established that in other mines of the area, the gamma-rays exposure rate does not exceed the values of 21-25 μR/g. The total specific activity at more than 90% is determined by the presence of ^{226}Ra and is equal to 3490-13000 Bq/kg.

Conclusions. It should be emphasized that the control of the concentration (volume activity) of radon in the atmosphere, which is necessary for determining the sources of its emission, the calculation of the needs of the mine in the air and the rational distribution of the latter. In the mine roadway mines of Novovolynsk mining area, the assessment of radioactive contamination of residential and industrial premises, measurements of individual expositions, plays a special role in ensuring radiation safety of the area. Ways of radioactive wastes burial are developed in the special literature and based on the requirements of "Norms of radiation safety of Ukraine". Now the main goal of radioactive waste burial is to reduce the total dose of all radiation sources to a rate that does not exceed the maximum allowable dose for the environment and population of the city (region). Therefore, this topic is worth special attention and further monitoring.

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НОВОВОЛЫН ТАУ-КЕН ӨНЕРКӘСІБІ АУДАНЫ КӨМІР ШАХТАЛАРЫНЫҢ РАДИАЦИЯЛЫҚ ЭКОЛОГИЯЛЫҚ МОНИТОРИНГІ

Аннотация. Соңғы кездегі тау-кен өнеркәсібін қайта құрылымдау қоршаған ортаға және халыққа зиянды әсер етуде. Львовск көмір өндіруші кәсіпорындарының жұмысы- Волын көмір бассейні мен тау-кен өнеркәсібін қайта құрылымдау техногендік жоғары табиғи радиоактивтілігі бар қалдықтардың жиналуына әкелді. Радиациялық қауіпсіздік бұл көмір шахталарында көмірдегі және байланысты жыныстардағы табиғи радионуклидтермен (γ-сәулелер) байланысты. Радон өнімдері, сондай-ақ бірқатар уран, торий радионуклидтері және калий-40 радиоактивті изотопы, -аэрозоль түрінде пайда болған шахталық ауадағы радионуклидтер аясында пайда болады. Львовско-Волын көмір бассейнінің мәселелері қоршаған ортаны Нововолин тау-кен өнеркәсіб ауданында көмір шахталарын жабу, жұмыс істеп тұрған шахталардың экологиялық және радиациялық қауіпсіздігін арттыру кезінде сақтау жолдарын зерттеу қажеттілігінен туындады.

Түйін сөздер: қайта құрылымдау, радон, уран, торий, радиоактивтілік мониторингі.

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РАДИАЦИОННО ЭКОЛОГИЧЕСКИЙ МОНИТОРИНГ УГОЛЬНЫХ ШАХТ НОВОВОЛЫНСКОГО ГОРНОПРОМЫШЛЕННОГО РАЙОНА

Аннотация. Недавняя реструктуризация горнодобывающей промышленности оказывает значительное пагубное воздействие на окружающую среду и население. Работа угледобывающих предприятий Львовско-Волынского угольного бассейна и реструктуризация горнодобывающей промышленности привели к накоплению отходов с техногенно повышенной природной радиоактивностью. Радиационная безопасность на этих угольных шахтах связана с естественными радионуклидами в угле и связанных породах (γ-лучи). Продукты радона, а также радионуклиды ряда урана, тория и радиоактивный изотоп калия-40, присутствующие в форме аэрозолей, образуются на фоне радионуклидов в шахтном воздухе. Проблемы Львовско-Волынского угольного бассейна обусловили необходимость изучения путей сохранения окружающей среды при закрытии угольных шахт, повышения экологической и радиационной безопасности действующих шахт Нововолынского горнопромышленного района.

Ключевые слова: реструктуризация, радон, уран, торий, мониторинг радиоактивности.

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THEORETICAL BASES FOR THE IMPLEMENTATION OF THE PROCESSES TO REDUCE VISCOSITY IN THE CONDITIONS OF NATURAL RESERVATION

Abstract. A matrix of space-time interactions occurring at the phase interface for films of different origin has been developed. It shows the types of controlled processes and methods of influence on the phase boundary to obtain the specified properties.

Key words: phase boundary, oil, water, quartz, matrix, space-time.

The fact of the predominance of high viscosity oils in modern oil fields makes it necessary to search for new geotechnologies that will reduce the cost of hydrocarbons (HC). Therefore, our work develops the idea of using the field as a natural reactor. For the first time this hypothesis was expressed by Lomonosov [1]. Then it was convincingly substantiated [2-4, 11-16] by other researchers in different parts of the globe [5-8, 17-23]. In our work, laboratory studies have shown the viability of this hypothesis for two and three component phase boundary. In industrial conditions at the Embamunaygas field, the processes of hydrogenation under conditions of natural occurrence were carried out by the authors [5] in 2017. Here, the decomposition of water was carried out chemically using hydro-reactive substances based on activated aluminum. Positive results of laboratory [6] and industrial tests require theoretical substantiation to explain the mechanisms of hydrocarbon hydrogenation under conditions of natural occurrence. Due to the fact that all processes begin at the phase boundary of this state, special attention is paid, as the phase boundary has the properties of both phases that it shares.

For the nano-level consideration, a matrix of basic interactions within the space-time responses of various forms of fluid to external influences has been developed.

Table 1 shows the main responses (processes) for films of organic and inorganic compounds.

Table 1 – Software module of interaction on phase boundary (3x3) (nano-level consideration)

Consideration levels, m	Frequency range, $(Hz)s^{-1}$			
	Films of liquid metal melts10^{-12} -10^{-15}	Liquid film 10^{-12} -10^{-9}	Films of organic compounds 10^{-9} -10^{-6}	Type of controlled process
Electronic $> 10^{-12}$	Elastic and inelastic scattering (exo emission)	Ionization	Radiation chemical reactions (radiolysis)	Phase nonequilibrium
Crystallographic $> 10^{-9}$	PhotoTransformation	Surface active processes	Structuring, oxidation, reduction	Concentration disequilibrium
Textural $> 10^{-6}$	Heat generation	Sorption	Polymerization (synthesis, destruction)	Interfacial disequilibrium
The method of controlling the state of phase boundary	Changes in contact conditions for heterogeneous phases	Resonant interaction mode	Capacitive parameters of contacting phases	

The developed matrix, made in the coordinates of the space-time parameters of interfaces of different composition, has 3 consideration nano-levels:

- electronic, for scales>10^{-12} m;
- crystallographic, for scales characteristic of the crystalline state;
- structural - for the size of the molecular level of consideration.

Three types of interfaces, differing in the frequency of responses to external influences, are considered:

- films of liquid melts;
- films of liquids of inorganic substances;
- films of organic substances.

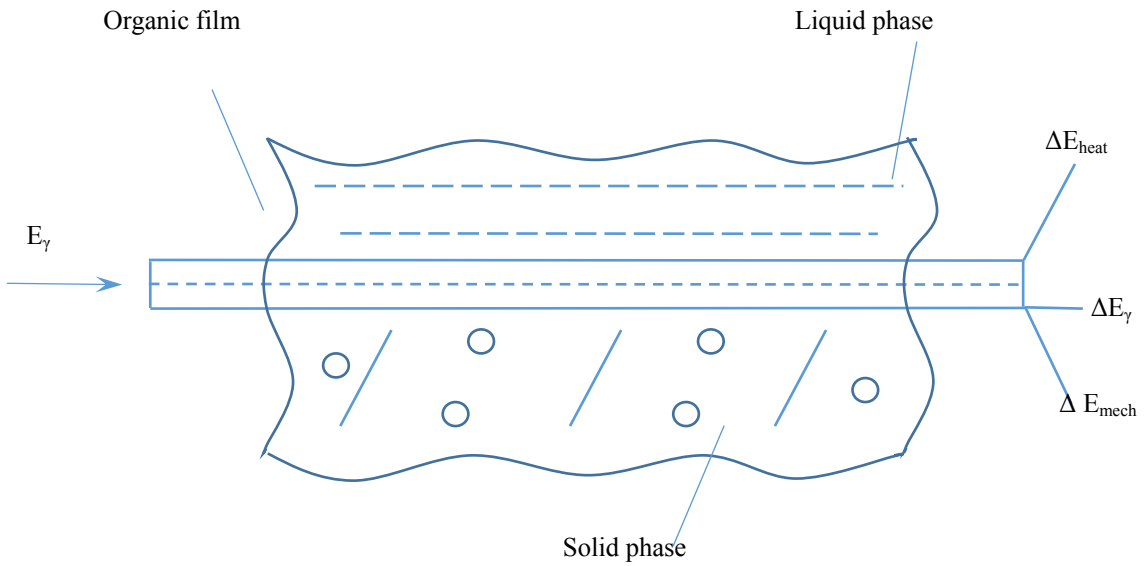
For each state of the phase boundary, the type of process it controls is defined, which are listed in response types.

In addition, methods for controlling the phase boundary were identified.

So according to the spatial attribute of the electronic level of consideration (horizontal row of the matrix), the types of response to external influence are exoemission, ionization and radiolysis. The driving force for the implementation of these processes is the intraphase disequilibrium that occurs when exposed, which can be controlled using 3 types of changes in the state of the film itself (the bottom row of the matrix). This can be done by low-energy methods such as:

- changes in the contact conditions of heterogeneous phases, for example, taking into account the effects of focusing;
- by changing the resonant parameter of one of the components of the boundary;
- the change in capacitive ratios separated by phase boundaries.

As an example, we consider the transforming potential of a film of an organic compound (HC) for the listed levels of consideration. Here, the types of external response are radiolysis, redox and polymerization-depolymerization reactions (vertical column for organic films). Here, at the electronic level of consideration, the frequency of external influence is within 109 ÷ 106 Hz. This means that intraphase nonequilibrium (activation of the boundary) can be accomplished with the help of electromagnetic or mechanical vibrations. In the specified frequency range, γ-rays, thermal oscillations, and ultrasonic waves have such capabilities.In the course of the resulting valuable reaction, they will ensure a change in concentration between the separated phases and within the film itself according to the scheme:



The scheme of film interactions (HC) at the phase boundary

Figure shows a diagram of the appearance of responses at the interface of a fluid-containing system under an external exposure on an organic film by the γ-radiation frequency. These high-frequency vibrations, passing through the film, are partially transformed under the influence of its structure and at the output we have:

$$E_\gamma \rightarrow E_{heat} + E_{mech} + E`_\gamma , \quad (1)$$

where E_γ – γ-radiation energy; ΔE_{heat} – energy of the IR spectrum of mechanical vibrations; $E`_\gamma$ – unabsorbed gamma rays energy.

Here it can be seen that as the scale of structural elements decreases during the response, new forms of external energy conversion from γ-radiation of the electromagnetic spectrum to mechanical vibrations of the thermal (IR) and ultrasonic (US) ranges appear. In the absence of resonance manifestations, these responses have a linear dependence on the frequency of conversion.

To do this, it is enough to know the space-time relations of the acting flow, which are interconnected with the speed υ by the universal linear relationship:

$$\upsilon = \lambda\nu, \quad (2)$$

where λ – the wavelength; ν – the frequency.

The response parameters depend on the speed properties of the perceiving medium and, depending on their nature, have linear and power relations [8]:

- for electromagnetic oscillations:

$$\upsilon = \frac{c}{n}; \quad (3)$$

- for mechanical waves in a solid (speed of sound):

$$\upsilon^2 = \frac{E}{\rho}; \ \upsilon^2 = \frac{G}{\rho}; \quad (4)$$

- speed of sound in liquids:

$$\upsilon_{ж}^2 = \frac{\sigma}{\rho}; \quad (5)$$

- surface wave velocity in fluid:

$$\upsilon_{П}^2 = gh , \quad (6)$$

here E is Young's modulus, ρ is density; G is the shear modulus; σ – surface tension.

The interaction mechanism in each case is determined by the speed parameters of the phases in contact with each other. Thus, the state of the phase boundary will change. Thus, by changing the state of the phase boundary (film), it is possible to control the response processes in the contacting media (in this example, at the boundary of the organic film).The quantitative ratios in the course of interaction obey A. P. Smirnovs law. [9].

The obtained experimental results on the study of the spectral parameters of the response to external influence showed a good convergence of the obtained data with a theoretical ratio.

To solve the problems of digitalization of technological processes, it is necessary to have knowledge of all types of external response for nano and macro levels of consideration. These responses should contain information that is distributed over spatial-temporal characteristics, each of which reflects the energy potential of the manifestation capabilities of a particular process depending on the scale of the structural elements and the frequency (temporal sign) of their oscillations around the equilibrium position.

For this case, a matrix table 2 of the matching of processes has been developed inherent in all types of reactions to external influences for four levels of consideration, differing from each other by three orders of magnitude:

- intraatomic;
- interatomic;
- intramolecular;
- intermolecular.

Table 2 – General view of the matching matrix for the selection of resonant conditions for the interaction of dissimilar substances

Reaction type / Level of consideration	Solid phase	Liquid phase (petrochemistry)	Gas phase (pyrolysis, polymerization)	Phase boundary (energy converters)
Intraatomic	Ionization potential, electron work function	Refractive index	Polarization	Atomic heat capacity electrode potential
Interatomic	Breaking energy, communication atmosphere	Dissociation energy	Sound speed	Electrodependence, sorption
Intramolecular	Molecular breaking energy	Specific heat, sound speed, density	Molar heat capacity	Thermal conductivity electrical conductivity
Intermolecular	Lattice parameter	Ion radius	Covalent radius, free path length	Diameter pairs, interfacial surface contact potential difference

Energy ratios are determined by the type of chemical reactions:

- solid phase;
- liquid phase
- gas-phase;
- phase boundary.

Thus, the developed correspondence matrix for selecting resonant interaction modes covers a wide range of phenomena inherent in all substances in different states. Practical use of such a matrix allows to:

- select the type of resonant interaction;
- determine catalytically - active substances;
- use the necessary scale features to achieve the conditions of multiplicity;
- harmonize the electrical and mechanical methods of converting external energy to obtain given properties.

After creating such matrices for nano and macro levels of consideration, it becomes possible to implement digitalization processes using the following algorithm:

- determination of the interaction mechanism at the phase boundary;
- identification of the level of consideration by frequency;
- identification of the level of consideration by spatial attribute;
- determination of the prevailing process;
- selection of a specific process control method.

According to the results of the analysis of the types of interaction at the phase boundary between the phases, the following conclusions:

1. The mechanisms of interaction at the phase boundary of the phases it separates depend on the space-time ratios of the boundary itself and the substance of the neighboring phases. The types of responses to external forcings are determined for three levels of consideration: electronic, crystallographic and structural (molecular).

2. As a response to an external effect, there are corresponding to each level types of disequilibrium: intraphase, concentration, and interphase. It provides the appearance of driving forces (transformation) of a specific response, the mechanisms of which are developed by mathematical and physical models.

3. It is shown that, depending on the type of film coating, there are 3 types of control processes during which the state of the phase boundary changes. Such methods are: changing contact conditions, resonant interaction mode and changing capacitive parameters of the contacting phases.

4.A mathematical equation is proposed to determine the quantitative parameters of the interaction with external influences for nano-levels of consideration.

5. An algorithm has been developed for the digitalization of all types of response to external influences according to space-time features.

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ТАБИҒИ ЖАҒДАЙ ШАРТТАРЫНДАҒЫ ТҰТҚЫРЛЫҚТЫ ТӨМЕНДЕТУ ПРОЦЕССТЕРІН ІСКЕ АСЫРУҒА АРНАЛҒАН ТЕОРИЯЛЫҚ НЕГІЗДЕР

Аннотация. Фазалардың бөліну шекарасында өзара болып жатқан шығу тегі әртүрлі пленкалар үшін, кеңістік-уақыт матрицасыәзірленді .Берілген қасиеттерді алу үшін фазалардаың бөліну шекарасынаәсер ету әдістері және басқарылатын процесстердің түрлері көрсетілген.

Түйін сөздер: бөліну шекарасы, мұнай, су, кварц, матрица, кеңістік-уақыт.

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ТЕОРЕТИЧЕСКИЕ ОСНОВЫ ДЛЯ РЕАЛИЗАЦИИ ПРОЦЕССОВ СНИЖЕНИЯ ВЯЗКОСТИ В УСЛОВИЯХ ПРИРОДНОГО ЗАЛЕГАНИЯ

Аннотация. Разработана пространственно-временная матрица взаимодействий, происходящих на границе раздела фаз для пленок разного происхождения. Показаны виды управляемых процессов и способы воздействия на границу раздела фаз для получения заданных свойств.

Ключевые слова: граница раздела, нефть, вода, кварц, матрица, пространство-время.

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THE INVESTIGATION OF THE INTERNET OF THINGS (IoT) IN ELECTRIC POWER SYSTEMS

Abstract. In recent years, with the continued growth of energy demand, intelligent energy systems have become a common choice for the world's energy to meet the challenges of the future. Currently, the rapid development of the Internet of Things leads to the use of new, advanced solutions in various fields. One of the target markets for IoT is electric power systems. This article presents the current state of electric power systems based on IoT. The architecture of the Internet of Things and its components, as well as its importance in electric power systems, have been studied. The methodology and structure of the application of the Internet of Things in the electric power industry are shown.

Keywords: Internet of Energy (IoE), The Internet of Things (IoT), electric power systems, power systems control.

Introduction. Currently, experts are already talking about concepts such as the Internet of Energy [1] and the Internet of Things [2]. One example of the implementation of these concepts is the so-called Smart Grid which assesses the need for electricity and redirects it to the place where the need for electricity is maximum at the moment. The Internet of things (IoT) is considered to be the third digital revolution after the computer and the Internet, and it offers significant benefits of an intelligent network. Predicting and preventing natural disasters of power lines is one of the most difficult problems for power transmission companies. Advanced IoT detection and communication technologies can effectively prevent or reduce disaster damage to power lines and, consequently, increase the reliability and stability of power transmission [3].

Internet of Energy (IoE) is a network of energy producers and consumers integrated into the common infrastructure and exchanging its surpluses. The implementation of this methodology also implies the introduction of the Internet of Things (IoT) concept, which involves the creation of a computer network of physical objects that have the ability to interact with each other and with the external environment.

The Internet of Things (IoT) provides the ability to build multi-agent, machine-based interaction and coordinated work, power system control, which is aimed at the formation and regulation of the transmission of electricity and its parameters, as well as the economic optimization of the power system and its power equipment pools.

At power plants, IoT systems also provide real-time information on the operation of equipment and timely decisions on its repair. This technology helps to optimize the stopping time of generating equipment and minimize the risk of accidents. Taking into account the existing regulatory framework, the equipment will be repaired according to the regulations in the foreseeable future. However, the IOT in the electric power industry makes it possible to understand not the routine, but the real condition of the equipment, the parameters of its operation after the planned repair (and they should ideally correspond to the factory ones) [4, 5].

The Internet of Things (IoT) system in electric power industry. The purpose of the IoT system, the architecture of which is shown in figure 1, is to provide machine-to-machine interaction between power equipment control systems, including various power conversion devices, by means of which power equipment of users is integrated into electrical networks, as well as load control systems [6].

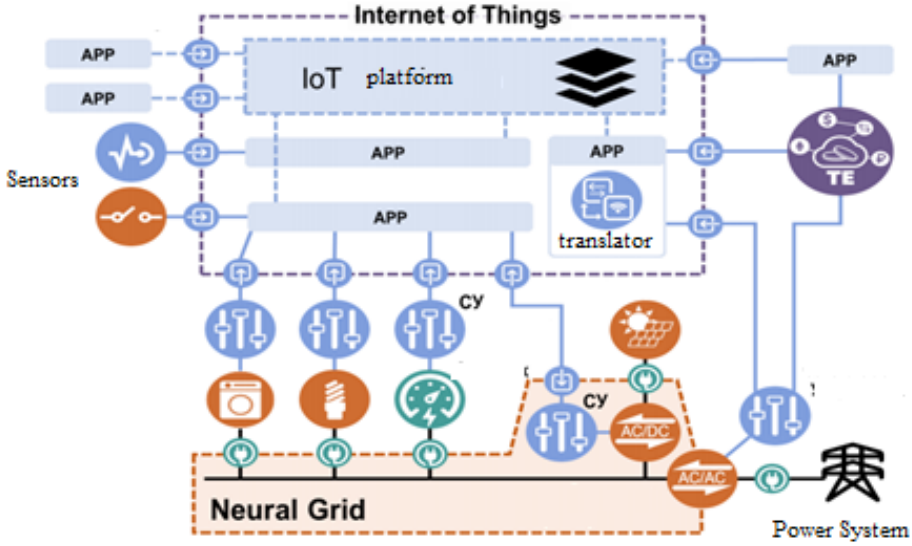

Figure 1 – Functional diagram of the Internet of Things (IoT) in Power Systems

As a result of machine-to-machine interaction between these control systems of various power equipment occurring in the IoT system, an environment for multi-agent control of distributed power equipment pools is created [7, 8]. Interaction in the IoT system makes it possible to make the operation of this equipment consistent and thus, firstly, to form the mode of transmission of electricity, controlling its generation, accumulation and consumption, and secondly, to carry out various functions of operational control associated with the secondary and tertiary power balance control and ensuring the specified quality of electricity from users [9].

Components of the IoT system are [10-12]:

- digital interfaces with control systems of various power equipment - power converting devices through which generation and storage are integrated into electrical networks, as well as controlled load;
- digital interfaces with measurement tools required to obtain current data on mode parameters;
- various sensors required to obtain information that is not data on the parameters of the power transmission mode, but necessary for the economic and technical management of power equipment pools;
- various actuators required to support the management of power equipment pools, but are not control systems of this equipment;
- proprietary system applications that ensure the efficiency and reliability of the system, including embedded and implemented in the logic of IoT energy management systems (EMS);
- information interfaces with custom applications;
- IoT platform is a digital environment for interaction of applications, equipment control systems, sensors and actuators with each other.

The IoT system enables user applications to build a multi-agent, based on machine-to-machine interaction and coordinated work, power system control, which is aimed at the formation and regulation of the power transmission mode and its parameters, as well as the economic optimization of the power system and its energy equipment pools. The IoT system allows to build economic self-organization, mutual adjustment and economic optimization of such pools.

The key areas in all elements of the power industry that will be affected by the introduction of IoT are:

technologies, including their reliability will be increased;

efficiency, including costs will be reduced;

the emergence of new markets, the creation of new properties and businesses.

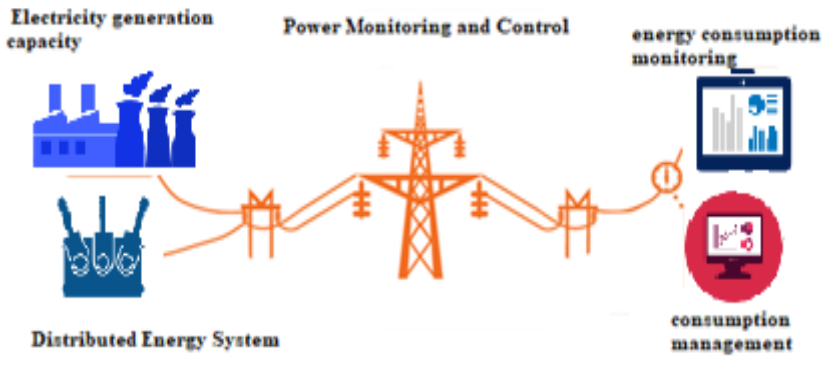

Figure 2 – Applications of IoT in electric power industry

Architecture of energy internet and its components. Internet energy is such a decentralized power system in which intelligent distributed control is implemented, carried out at the expense of energy transactions between its users. The architecture of energy Internet should provide, on the one hand, the ability to implement energy transactions, on the other - the ability to control energy cells through machine-to-machine interaction and, finally, to provide the possibility of such distributed mode control in real time, which allows to maintain the power balance in the power system and its static and dynamic stability [13, 14].

Energy Internet is a system of systems (SoS), the architecture of which is based on a special combination of three systems, the boundaries and interactions of which are shown in figure 3 [6]:

- Systems of formation, control of execution and payment of smart contracts of Transactive energy (TE);
- System of machine-to-machine interaction and exchange of control actions between energy cells and energy equipment of the Internet of Things (IoT);
- System of regime control, maintaining the power balance and ensuring the static and dynamic stability of the Neural Grid power system (NG).

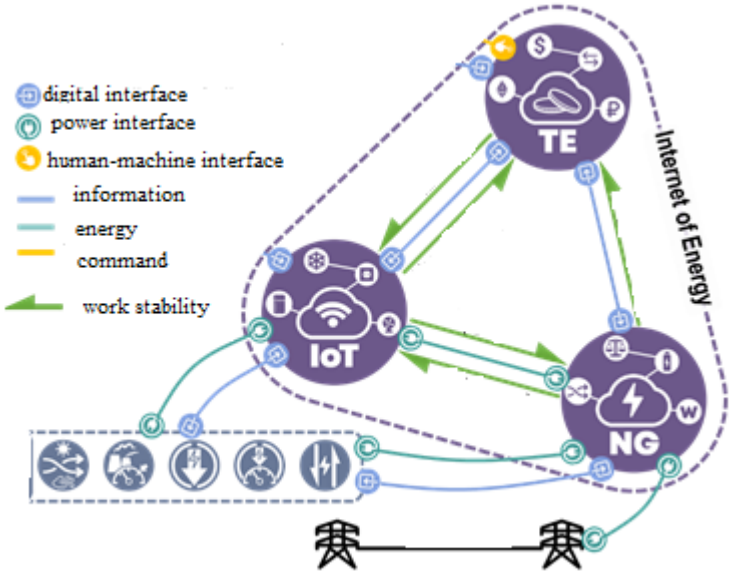

Figure 3 – The architecture of the Internet energy as systems of systems

Each of these systems can be deployed independently and perform its function independently of other systems, but only a set of interconnected and interacting by special protocols TE, IoT and NG systems forms the Internet of energy.

The interconnection and interaction between the systems is ensured during the implementation of energy transactions between users and the corresponding energy cells. The smart contract of energy

transaction is formed in the TE system, the information on obligations under the smart contract is transmitted to the IoT system, and this smart contract is implemented in the form of coordination of the work of energy cells (setting power flow parameters) due to their machine-to-machine interaction. At the same time, the NG system receives the parameters of the regime formed due to the implementation of a set of energy transactions, i.e. due to the operation of energy cells, and ensures its stability, maintaining the balance of power both at the level of energy cells and at the level of power flows between them. Control the execution of the smart contract and payment are carried out in the TE system. In case the NG system cannot ensure the maintenance of the power balance within any boundaries, where it is necessary, on its own (only with the help of the NG system components), it requests the power reserve through the TE system, i.e. initiates the energy transaction necessary to ensure the reserve of the regulating power [1].

Energy Internet users interact with the TE system, participating, if necessary, in defining the parameters of smart contracts and in transactions with financial assets through appropriate human-machine interfaces.

The main thing for Internet energy users is interaction with user applications (Application, App), which provide the formation and conduct of energy transactions (relevant smart contracts in the TE system and control actions on energy cells and energy equipment through the IoT system). Therefore, user applications (App) on information channels interact with these two systems.

Interaction of users and energy cells with external to the Internet energy information and control systems of traditional, centralized power system or local control systems, standing in power supply systems, such as SCADA, DMS, EMS, OMS, is also carried out through user applications (App) of energy in digital.

Reduction of energy consumption by the end user at certain economic signals of the electricity market with the receipt of revenue for the implementation of such a reduction in consumption.

Lifecycle management of power equipment condition. Grid companies use the Internet of Things technology through RFID, GPS and other sensors to monitor and collect all aspects of power equipment information (including the environment, conditions, accounting, testing, defects, a reasonable choice of statistical methods), analyze the current state of equipment, the law on the future development and the main influencing factors to form a method for assessing the risk of equipment based on the Internet of Things technology, this system can dynamically update added, distributed, serving, inactive, unnecessary, and other historical data. In this system, equipment status information and asset management information are effectively integrated, supervision management is unified [15]. Lifecycle management of power equipment condition.The IOT-based energy equipment lifecycle management system is shown in figure 4.

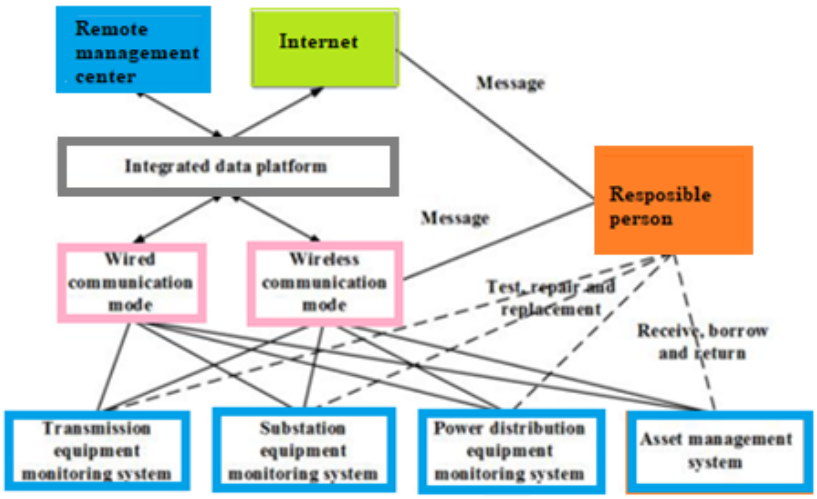

Figure 4 – Power equipment lifecycle management system based on the Internet of things [16]

To check the effectiveness of the system, a simulation test will be conducted on the performance of power equipment [17]. The system can real-time detect the operating status of power equipment in order to increase management efficiency and realize intelligent and digital control of the energy industry figure 5.

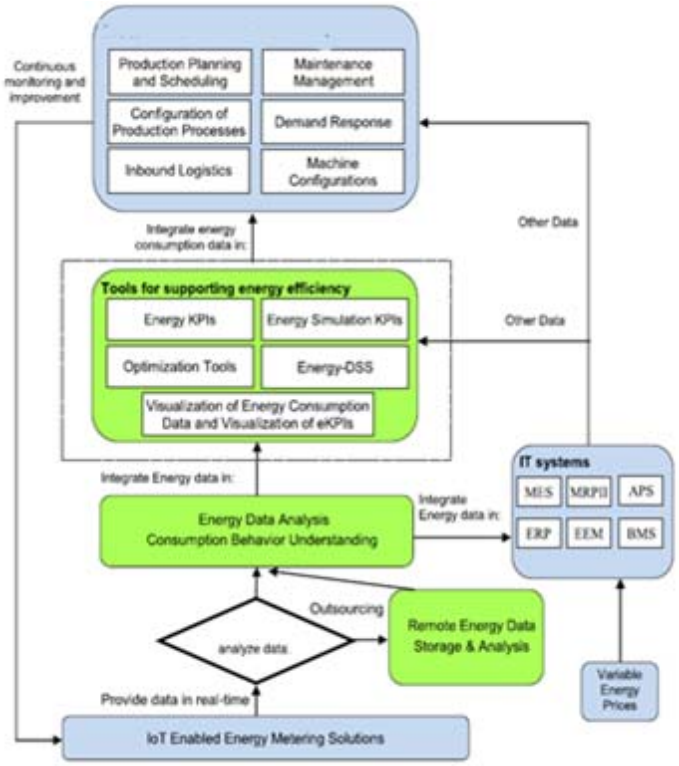

Figure 5 – The structure of energy data integration based on the Internet of Things in industrial control solutions

The Internet of things has been an integral part of the transformation towards smart grids. Examples of IoT technologies that are currently used in intelligent electric power systems include Advanced Metering Infrastructure and Supervisory control and data acquisition (SCADA)[18]. There are several advantages to deploying IoT into intelligent electrical systems:

- Increased reliability, fault tolerance, adaptability and energy efficiency;
- Reduced number of communication protocols;
- Networking and extended work with information scope;
- Improved control over household appliances;
- Enable on-demand access and end-to-end provision of services;
- Improved sensory capabilities;
- Improved scalability and compatibility;
- Disaster Damage Reduction;
- Decreased physical attacks (for example breaking into substation).

Conclusion. As an inseparable technology to support an intelligent system, the Internet of Things technology has become a center of research in the field of energy.

To achieve a high degree of integration of the intelligent system and the Internet of things, this article proposes a system of energy equipment management throughout the lifecycle, based on the Internet of things. Based on the study of the functional characteristics of the Internet of things and the state of its application in the power system, the basis for managing the entire life cycle of power equipment is created. This system provides a research base for improving the application of Internet of things technology in power systems and achieving a high degree of integration of intelligent networks and network technologies. The intelligent system further optimizes network management at all levels, provides panoramic information about the power system through a combination of centralization and decentralization, and integrates various types of production and processing information to provide comprehensive and complete reference information for decision-making for operation and management.

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ЭЛЕКТРОЭНЕРГЕТИКАЛЫҚ ЖҮЙЕЛЕРДЕ ИНТЕРНЕТ ЗАТТАР (IoT) ТЕХНОЛОГИЯСЫН ЗЕРТТЕУ

Аннотация. Соңғы жылдары энергияны тұтыну сұранысы жоғарлағандықтын, жалпы әлемдік энергетика үшін интеллектуалдық энергетикалық жүйені таңдау болашақ мәселесі болды. Қазіргі таңда Интернет заттардың (IoT) дамуы алуан түрлі аймақтарда алдығы қатарлы шешімдерді қолдануға мүмкіндік береді. Электроэнергетикалық жүйе үшінде IoT қолдану қарқындады. Мақалада IoT негізіндегі электроэнергетикалық жүйелердің қазіргі жағдайы көрсетілген. Интернет заттар архитектурасы мен оның құрамдасбөліктері, электроэнергетикалық жүйелердегі мәні зерттелген. Интернет заттардың - электроэнергетикадағы қолдану құрылымы мен әдістемесі қарастырылған.

Түйін сөздер: Интернет Энергия (IoE), Интернет заттар(IoT), Электроэнергетикалық жүйелер, Энергожүйені басқару.

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ИССЛЕДОВАНИЕ ТЕХНОЛОГИИ ИНТЕРНЕТА ВЕЩЕЙ (IoT) В ЭЛЕКТРОЭНЕРГЕТИЧЕСКИХ СИСТЕМАХ

Аннотация. В последние годы, в условиях продолжающегося роста спроса на энергию, интеллектуальные энергосистемы стали общим выбором для мировой энергетики для решения задач будущего. В настоящее время бурное развитие Интернета вещей (IoT) приводит к использованию новых передовых решений в различных областях. Одним из целевых рынков для IoT являются электроэнергетические системы. В статье представлено современное состояние электроэнергетических систем на основе IoT. Исследована архитектура Интернета вещей и ее компоненты, а также ее значимость в электроэнергетических системах. Показана методология и структура применения Интернета вещей в электроэнергетике.

Ключевые слова: Интернет Энергии (IoE), Интернет вещей (IoT), электроэнергетические системы, управление энергосистемами.

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DEVELOPMENT OF BIOLOGICALLY ACTIVE COMPLEXES TAKING INTO ACCOUNT TECHNOLOGICAL REQUIREMENTS

Abstract. Nutrition during pregnancy is one of the main conditions for the healthy fetal development, favorable course of pregnancy and its outcome. One of the ways for optimization of the nutritional status of pregnant and breastfeeding women is using specialized foods with the optimized chemical composition in a diet. The V. M. Gorbatov Federal Research Center for Food Systems of Russian Academy of Sciences (Gorbatov Research Center for Food Systems) developed the biologically active additives (BAAs) intended for the use in production of the specialized cooked sausages for nutrition of pregnant and breastfeeding women. With consideration for the requirements of the body in nutritional and biologically active substances and technological peculiarities of cooked sausage production, the composition of additives was substantiated, their medico-biological assessment was carried out and the parameters of their addition were established. The BAAs correspond to the established norms by the sanitary-chemical indicators, which will ensure safety of an enriched meat product. Using the developed BAAs, the biologically full-value sausages were produced, which correspond to the medico-biological requirements specified for this consumer group. Addition of the BAAs into a meat product in the recommended dose ensures meeting the daily requirement for biologically active substances (vitamins and calcium) by 15-28%, recommended ratio of omega-6:omega-3 fatty acids (5:1) and the calcium: phosphorus ratio (1:1.5).

Keywords: sausage, specialized nutrition, pregnant women, vitamins.

Introduction. Intake of **t**he necessary amount of nutrients and energy by pregnant women and breastfeeding mothers is, largely, ensured by a correspondent range of products in a diet. Balanced nutrition should be accomplished due to the use of different product groups - meat (beef, lean grades of pork and mutton, chicken, turkey, rabbit), fish, bread, cereals, pasta, butter, vegetable oil, vegetables, and fruit. It is necessary to exclude from a diet products that contain preserving agents, coloring agents and artificial flavoring agents. It was established that for support of active lactation, the optimal composition of breast milk and health of a breastfeeding mother, her daily diet should additionally include vitamins and minerals, as well as up to 40 g of protein and carbohydrates, up to 15 g of fat, which bring into a diet of about 500 kkal [1-5].

Meat and meat products in nutrition of a pregnant and breastfeeding woman are a source of full value protein, fat, B-group vitamins and, more importantly, easily assimilable iron.

Insufficient protein consumption is dangerous during pregnancy, especially in its second half, and during breast feeding, when the need for protein increases almost by 1.5 times from 66 to 96 g per day, which is conditioned by its increased expenditure for the growth of the placenta, uterus, fetus, mammary glands and later for production of breast milk [6]. All women during pregnancy (especially those in the risk group of the development of iron deficiency anemia) need mainly the prophylaxis to prevent the development of this condition. The prophylaxis of the development of iron deficiency anemia should be

carried out beginning from the earliest period of pregnancy. It consists largely in administration of a full value diet that ensures increasing iron requirements of pregnant women. In case of detection of latent iron deficiency or diagnosis of anemia, a woman needs not only dietetic therapy but also pharmaceutical treatment. When making one or another recommendation, it is necessary to take into account the peculiarities of iron metabolism in the body, mainly, the peculiarities of its absorption in the gastrointestinal tract. It is known that heme ferrous iron is utilized most successfully in the digestive tract. The sources of this iron form are, primarily, meat products [7-9].

The main aspect of a balanced diet of a pregnant woman as well as a woman during breast feeding of a baby is a sufficient content of vitamins and minerals in a menu. Analysis of the actual nutrition of pregnant and breastfeeding women carried out in different Russian regions gives evidence about the significant alimentary imbalance of their diets. It does not seem possible to satisfy increasing requirements of a future mother in these substances only with foods in her diet. Therefore, it is necessary to correct a diet of pregnant and breastfeeding women using specialized foods that contain the main macro- and micronutrients in quantities that, to a large extent, can meet the requirements of women in this important period of their life, achieve the optimal composition of breast milk and ensure the adequate development of a child [10-19].

Table 1 highlights the key micronutrients influencing the fetal development, which a woman has to intake both before and during pregnancy.

Table 1 – An effect of several disorders of the nutritional status of pregnant women on the fetal development

Nutrition disorders	Disorders of fetal development
Deficiency of protein and energy	Intrauterine hypotrophy, arrest of the brain development
Deficiency of PUFA; imbalance of the ω6: ω3 PUFA ratio	Disorders in the development of neuroretina and brain
Deficiency of folic acid (especially, in combination with deficiency of vitamins C, B6, B12)	Defects of the neural tube development (anencephalia, cephalocele)
Deficiency or excess of vitamin A	Congenital malformation
Deficiency of vitamin D3 and Ca	Disorders of calcium and phosphorus metabolism in the bone tissue
Deficiency of iron (Fe)	Leads to iron deficiency anemia

The aim of the work was to develop the biologically active additives for specialized meat products for pregnant and breastfeeding women and to carry out their medical and biological assessment.

Materials and methods. The content of calcium in BAAs was detected by the complexometric method based on formation in the alkaline medium of the slightly dissociated complex compounds of calcium cations with disodium salt of ethylenediaminetetraacetic acid (trilon B). The content of vitamin D3 was detected according to GOST 30624-98, biotin (vitamin H), vitamins B5, B9, B12 using the high performance liquid chromatography. The content of the dietary fibers was detected using the enzymatic method, which consists of hydrolysis and elimination of protein and starchy substances by enzymes that are analogous to the enzymes of the human digestive tract. The general content of omega-3 PUFA was detected by the method of gas chromatography with the use of a packed column or a capillary column to detect qualitative and quantitative composition of the mixture of fatty acids in a form of methyl esters obtained according to GOST 31665. Heavy metals were detected by the following methods: lead and cadmium by the method of inverse voltammetry, mercury and arsenic by the method of atomic absorption spectrometry. Pesticides were detected by the chromatographic methods; antibiotics were detected using the test-system RIDASCREEN® Chloramphenicol (for chloramphenicol) and by the screening method using enzyme immunoassay (for the tetracycline group). The melamine content was detected by the method of high resolution liquid chromatography, aflatoxins by thin-layer and high performance liquid chromatography.

The obtained results of investigations were processed by the methods of mathematical statistics. Statistical processing was carried out using the software package Statistica 10.0. The results are presented as a weighted average ± standard deviation.

Results. The Gorbatov Research Center for Food Systems developed the biologically active additives (BAAs) intended for the use in manufacture of cooked sausages for nutrition of pregnant and breast-feeding women, substantiated their composition and technology of production and addition. The ingredient composition and dosage of additives are presented in table 2.

Table 2 – Ingredient composition of biologically active additives

Additive	Ingredient composition	Dosage, kg/100 kg
BAA (mixture No. 1)	Dry nonfat milk, wheat fiber, calcium lactate, calcium carbonate, dry egg mélange, calcium D-pantothenate, folic acid, D-biotin, D3 cholecalciferol, cyanocobalamin	7.84
BAA (mixture No. 2)	Dry nonfat milk, wheat fiber, calcium citrate, dry egg mélange, omega-3 polyunsaturated fatty acids (eicosapentaenoic acid, docosahexaenoic acid), calcium D-pantothenate, folic acid, D-biotin, D3 cholecalciferol, cyanocobalamin	7.87

The choice of components is conditioned by their compatibility and an effect on normalization of processes occurred during pregnancy. Addition of dietary fibers is determined by their function of improvement of intestinal peristalsis; addition of dry milk and mélange is conditioned by an increase in the biological value due to the balanced amino acid composition. Vitamin D, which participates in the calcium and phosphorus metabolism, facilitates ossification of the fetal skeleton and thereby prevents the development of rachitis, while folic acid (B_c) plays an important role in formation of the placenta tissue and new blood vessels in the uterus, therefore, the vitamin deficiency during pregnancy can lead to its premature termination. The presence of ω_3 PUFA in the mixture is conditioned by their effect on the normal course of pregnancy and prevention of premature delivery, the development and function of the organ of vision and fetal nervous system, formation of new tissues during pregnancy [3, 11, 17, 19]. As a source of calcium, calcium salts (carbonate and lactate) were used in the mixture composition. The effective concentration of calcium salts was selected that ensured the required content of the element in the product and at the same time positively affected the functional properties of minced meat [20]. The use of phosphates in production of meat products for pregnant and breastfeeding women is impermissible as it is known that the calcium and phosphorus ratio in meat is about 1:10; as a result of phosphate addition, the imbalance increases leading to elimination of calcium from the body of a mother and a child. The optimal assimilation of calcium (70-72%) requires the calcium and phosphorus ratio of 1:1÷2.

The quantitative ratio of the ingredients in the mixtures was established with consideration for degradation of the enriching components in the process of thermal treatment and storage, mutual compatibility and so on.

Medico-biological assessment of the developed BAAs was carried out in the Federal Research Centre of Nutrition and Biotechnology. Table 3 presents the values of the nutritional value indicators of the developed additives and the content of the biologically active substances.

Table 3 – Actual values of the indicators of the nutritional value and biologically active substances in BAAs

Indicator	Units of measurement	Actual content	
		BAA (mixture No. 1)	BAA (mixture No.2)
Biotin (vitamin H)	mg/100 g	0.240±0.036	0.240±0.036
vitamin B12	μg /100 g	11.0±2.0	11.0±2.0
vitamin B5	mg /100 g	20.7±1.0	21.7±1.1
vitamin B9	mg /100 g	1.85±0.09	1.91±0.10
Calcium	g/100 g	4.80±0.28	3.80±0.23
vitamin D3	μg/100 g	54.80±0.54	52.60±0.52
Sum of omega-3 fatty acids	mg /100 g	–	694.0±138.8
Dietary fibers (sum)	g/100 g	28.0±2.8	28.40±2.84
Protein	g/100 g	19.7±0.3	17.4±0.3
Fat	g/100 g	3.50±0.42	5.64±0.67

Along with the solution to the task of increasing the nutritional value of meat products, an important factor is its hygienic safety, including microbiological safety, which to a large degree depends on raw material quality and recipe components [21-25].

Pregnant women are one of the population groups that are most sensitive to the content of chemical contaminants and biological agents in foods. Taking into consideration the purpose of the product, for which production the BAAs are used, sanitary-chemical safety of the additive and its correspondence to the existing norms (TR TS 021/2011 "On food safety") are of great importance. Table 4 presents the values of the sanitary-chemical indicators.

Table 4 – Actual and regulatory values of the sanitary-chemical indicators

Indicator	Actual value of the indicator		Regulatory value of the indicator
	BAA (mixture No.1)	BAA (mixture No.2)	
Lead	≤0.001 mg/kg		Not more than 1.0 mg/kg
Cadmium	≤0.001 mg/kg		Not more than 1.0 mg/kg
Mercury	not detected (limit of detection 0.0025 mg/kg)		Not more than 0.2 mg/kg
Arsenic	0.048 mg/kg (±35%)	0.012 mg/kg (±35%)	Not more than 1.5 mg/kg
Hexachlorocyclohexane (α,β, γ-isomers)	not detected (limit of detection 0.001 mg/kg)		Not more than 0.1 mg/kg
dichlorodiphenyl trichlorome-thyl methane and its metabolites	not detected (limit of detection 0.001 mg/kg)		Not more than 0.1 mg/kg
Aldrin	not detected (limit of detection 0.0025 mg/kg)		Not allowed
Heptachlor	not detected (limit of detection 0.0025 mg/kg)		Not allowed
Aflatoxin M1	<0.00002 mg/kg		Not more than 0.0005 mg/kg
Melamine	not detected (less than 1 mg/kg)		Not allowed (less than 1.0)
Chloramphenicol	0.00015 mg/kg (±8%) (limit of detection 0.00008 mg/kg)	not detected (limit of detection 0.00008 mg/kg)	Not allowed (less than 0.0003)
Tetracycline antibiotics	not detected (limit of detection 0.0015 mg/kg)		Not allowed (less than 0.01)
Streptomycin	not detected (limit of detection 0.1 mg/kg)		Not allowed (less than 0.2)
Penicillin	not detected (limit of detection 0.004 mg/kg)		Not allowed (less than 0.004)

By the sanitary-chemical indicators, the BAAs correspond to the established norms, which will allow ensuring safety of an enriched meat product.

According to the results of the medico-biological assessment, the mixture is recommended for the use in the food industry for enrichment of specialized sausages intended for nutrition of pregnant and breastfeeding women. The Gorbatov Research Center for Food Systems developed the technologies of specialized meat products intended for nutrition of pregnant and breastfeeding women [20].

Cooked sausages are one of the most popular meat products of industrial production in Russia. Their significant drawback is a high content of saturated fats, salt, the use of phosphoric acid salts that lead to imbalance of the calcium:phosphorus ratio, and other food additives.

Particular requirements are specified for sausages intended for nutrition of pregnant and breastfeeding women: they have to be balanced by the macro- and micronutrient composition, have restrictions regarding the content of salt, sodium nitrite and fat, do not contain phosphates, hot spices, synthetic coloring and flavoring agents. With that, all raw materials and used components should strictly correspond to the Russian effective regulation regarding the allowable levels of toxic elements and microbiological indicators. The balance of protein and fat composition is ensured by selection of combinations of animal and plant raw materials. The recipe composition of cooked sausages includes: option 1 - rabbit meat, pork, soybean oil, BAA (mixture No. 1), curing mixture, ascorbic acid, sugar, spices; option 2 - beef, pork, turkey meat, BAA (mixture No.2), curing mixture, ascorbic acid, sugar, spices.

Addition into a meat product (sausage) of BAAs in the recommended dose will ensure meeting a daily requirement in biologically active substances (vitamins and calcium) by 15-28%, as well as the favorable ratio of omega-6/omega-3 fatty acids.

BAAs are added at the final stage of minced meat preparation not less than 3-5 minutes before the end of cutting.

Table 5 presents the indicators of the nutritional value of cooked sausages produced with the use of the developed BAAs and intended for nutrition of pregnant and breastfeeding women.

Table 5 – Physico-chemical indicators of cooked sausages produced with BAAs and intended for pregnant and breastfeeding women

Indicator	Content in sausage with BAA (mixture No. 1)	Content in sausage with BAA (mixture No. 2)
Mass fraction of protein, %	14.5	14.0
Mass fraction of fat, %	19.0	18.5
Mass fraction of edible salt, %	1.75	
Mass fraction of sodium nitrite, %	0.0018	
Ratio of ω-6 : ω-3 PUFA	7:1	5:1
Mass fraction of vitamins and minerals in 100 g		
B_9, mg	0.12/25*	
B_5, mg	1.4 /23,3*	
B_{12}, μg	0.5/14,3*	
H, μg	10.0/ 20*	
D_3, μg	3.5 /28*	
Ca, mg	250.0/19*	
Ca:P ratio	1:1.5	
Dietary fibers, %	2.0	
*Percent of daily norm upon consumption of 100 g of a product.		

Conclusion. Therefore, the biologically full value sausages that corresponded to the medico-biological requirements for the products intended for this group of consumers were produced using the developed BAAs. Introduction into a diet of pregnant and breastfeeding women of the specialized sausages enriched with physiologically beneficial ingredients instead of traditional products will provide them with quality products without sharp changes in food stereotypes.

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ТЕХНОЛОГИЯЛЫҚ ТАЛАПТАРДЫ ЕСЕПКЕ АЛУ ЕСЕБІНЕН БИОЛОГИЯЛЫҚ БЕЛСЕНДІ КЕШЕНДІ ӘЗІРЛЕУ

Аннотация. Жүктілік кезінде тамақтану ананың құрсағындағы баланың толыққанды дамуының, жүктіліктің қолайлы ағымының және оның нәтижесінің ең басты шарттарының бірі болып табылады. Жүкті және бала емізетін әйелдердің тағамдық мәртебесін оңтайландыру жолдарының бірі рационда оңтайландырылған химиялық құрамды арнайы тамақ өнімдерін пайдалану болып табылады. ФМБҒМ " В. М. Горбатов атындағы азық-түлік жүйелерінің федералдық ғылыми орталығы" РҒА жүкті және бала емізетін әйелдерді тамақтандыруға арналған арнайы пісірілген шұжық өнімдерін өндіру кезінде қолдануға арналған биологиялық белсенді қоспалар (ББҚ) әзірленді. Ағзаның тағамдық және биологиялық белсенді заттарға қажеттілігін және пісірілген шұжықтарды өндірудің технологиялық ерекшеліктерін ескере отырып, қоспалар құрамында негізделіп, олардың медициналық-биологиялық бағасы жүргізілді, енгізу параметрлері белгіленді. Санитарлық-химиялық көрсеткіштер бойынша ББҚ белгіленген нормативтерге сәйкес келеді, бұл байытылатын ет өнімінің қауіпсіздігін қамтамасыз етуге мүмкіндік береді. Әзірленген ББҚ-ны қолдана

отырып, тұтынушылардың осы тобына қойылатын медициналық-биологиялық талаптарға сәйкес келетін биологиялық толыққанды шұжық өнімдері алынды. Ет өніміне ББҚ ұсынылатын дозада енгізу биологиялық белсенді заттарға (дәрумендер мен кальций) тәуліктік қажеттілікті 15-28%-ға қанағаттандыруды қамтамасыз етеді, омега-6:омега – 3 (5:1) тұқымдас май қышқылдарының ұсынылатын арақатынасы, кальций арақатынасы: фосфор-1:1,5.

Түйін сөздер: шұжық, арнайы тамақтану, жүкті әйелдер, дәрумендер.

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РАЗРАБОТКА БИОЛОГИЧЕСКИ АКТИВНЫХ КОМПЛЕКСОВ С УЧЕТОМ ТЕХНОЛОГИЧЕСКИХ ТРЕБОВАНИЙ

Аннотация. Питание во время беременности является одним из самых главных условий полноценного развития плода, благоприятного течения беременности и ее исхода. Одним из путей оптимизации пищевого статуса беременных и кормящих женщин является использование в рационе специализированных пищевых продуктов оптимизированного химического состава. В ФГБНУ «ФНЦ пищевых систем им. В.М.Горбатова» РАН разработаны биологически активные добавки (БАД), предназначенные для использования при производстве специализированных вареных колбасных изделий для питания беременных и кормящих женщин. С учетом потребностей организма в пищевых и биологически активных веществах и технологических особенностей производства вареных колбас обоснован состав добавок, проведена их медико-биологическая оценка, установлены параметры внесения. По санитарно-химическим показателям БАД соответствуют установленным нормативам, что позволит обеспечить безопасность обогащаемого мясного продукта. С применением разработанных БАД получены биологически полноценные колбасные изделия, соответствующие медико-биологическим требованиям, предъявляемым к продуктам для данной группы потребителей. Внесение в мясной продукт БАД в рекомендуемой дозе обеспечивает удовлетворение суточной потребности в биологически активных веществах (витаминах и кальции) на 15–28 %, рекомендуемое соотношение жирных кислот семейств омега-6:омега-3 (5:1), соотношение кальций: фосфор – 1:1,5.

Ключевые слова: колбаса, специализированное питание, беременные женщины, витамины.

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CAMBRIAN OF THE NORTH-WESTERN BALKHASH AREA

Abstract. For the first time in recent decades, the revision of the Cambrian sequence of the northwest Balkhash area was carried out, basing on a comprehensive study of the observed earlier and newly acquired field and archived data, as well as on information, published in professional geological literature. The stratigraphic correlation of different facies of terrigenous-carbonate-siliceous deposits was established utilizing both the collected fossil marine fauna and flora and the lithological characteristics. The sections were measured, and the lithostratigraphic units (suites) specified and incorporated within the modern International Stratigraphic Scale.

Key words: cambrian, stratigraphy, suite, section, carbonate and terrigenous, siliceous, trilobite, conodont, Balkhash.

Research history. The Early Paleozoic successions dated by the Cambrian are known in the northwest of the Balkhash lake. This vast area was named the Atasu-Zhamshi watershed [1], that is, the area located between the rivers Atasu and Mointy. In geological literature, one can find also another naming of the Atasu-Mointi watershed. Starting from the 1980s, 40 km west of the Balkhash town, near the Sarykum railway station, a section was studied in full sequence, dated by the interval from the middle Cambrian to the middle Ordovician, lying on dolomites and limestones of the Bosaga suite conditionally dated to the undifdferentiated Vendian to Lower Cambrian. The Bosaga dolomites were also studied in the original outcrops to the south from the Gulshad gore. These facts expand the presence of geologically homogeneous deposits to the east, up to the longitude of the Balkhash town, and this area is limited to the drying-up valley of the Zhamshi River (figure 1A).

The history of the stratigraphic study of the Atasu-Zhamshi watershed successions is described by E.V.Alperovich [1] and D.V.Voznesensky [32]. The Lower Paleozoic formatuions here are known since long ago. For long, their stratigraphic age and volume were conditional. The first finds of the Early Paleozoic trilobites were made in 1952 by A.G. Gokoev, and then in the 1950s, basing on results of the first systemic geological survey and academic studies, the so-called "Silurian Carbonates" were divided into the Cambrian and Ordovician sediments [6, 17, 32].

Until the mid-1980s, sites with fossil fauna of the Cambrian trilobites and brachiopods were known in the mid-reaches of the Shazhagai river (figure 1B), in the carbonates of the Kyzylzhar suite [1] and in the Shundy mountains (fig. 2A) - these are the sections near the mount Aksuran and the Zhaksybulak spring in the terrigenous sandstone units of the Aksuran suite [1, 29, 32]. Definitions of the faunistic remnants were made: for trilobites by G.K.Ergaliev, N.V.Pokrovskaya, N.K.Ivshin, L.N.Kraskov and M.K.Apollonov, and for brachiopods by E.A.Balashova, I.F.Nikitin and L.E.Popov [1, 29, 32, 33].

The first recorded on Late Cambrian trilobites and inarticulate brachiopods of the Sarykum railway station are in publication A.V.Zaichkina et al. [33], with reference to definitions of the fossil fauna collection by L.N.Kraskov and L.E.Popov. In 1984-86, in the territory of the Sarykum block, geologists of the Balkhash Geosurvey Expedition I.I.Kolesnikov and D.K.Muratbekov carried out prospecting works for lead and zinc. Several trenches were dug out there, also small exploratory wells drilled, so that in two trenches no.11 and no.20, V.G.Zhemchuzhnikov discovered Cambrian trilobites in 1985 [34]. He collected rock samples for the microfauna study, where S.V.Dubinina and L.E.Popov [4, 9, 19] discovered the

conodonts and inarticulate brachiopods. The first definitions of Cambrian and Ordovician fauna of trilobites from the Sarykum section were made by M.K.Apollonov [4] and A.V.Zakharov (1989, not published data).

In 2004, T.E.Pirogova and N.A.Azerbaev, under the guidance of the academician G.K.Ergaliev, carried out thematic works in sections of the Kyzylzhar suite along the Shazhagay river and the Aksuran suite of the Shundy mountains. As a result, trilobite fauna collections were repeated from the known sites, and in 2018, under the paid thematic works T.E.Pirogova and V.G.Zhemchuzhnikov, guided by G.K.Ergaliev, repeated collections of trilobite fauna from the trench no.20 at the Sarykum railway station and in the area of the Aksuran mount.

The current work was financed by the grant of the Ministry of Education and Science of the Republic of Kazakhstan AP05134181 titled "Compilation and issue of the Atlas of basic geological sections and stratotypes of Kazakhstan's Phanerozoic".

Geological settings. The complexity of the geological framework of the area is explained by the tectonics and the fact that the Lower Paleozoic sediments are covered by the Upper Paleozoic ones. This fact and the fragmented nature of the outcrops do not allow establishing the initial configuration of the basin through direct observations. Having stratigraphic and facial features of the Lower Paleozoic sediments, obtained in late 1980s [4, 34], three facial zones of Shazhagai, Sarykum and Kiik were individuated in the paleobasin from east to west (figure 1A).

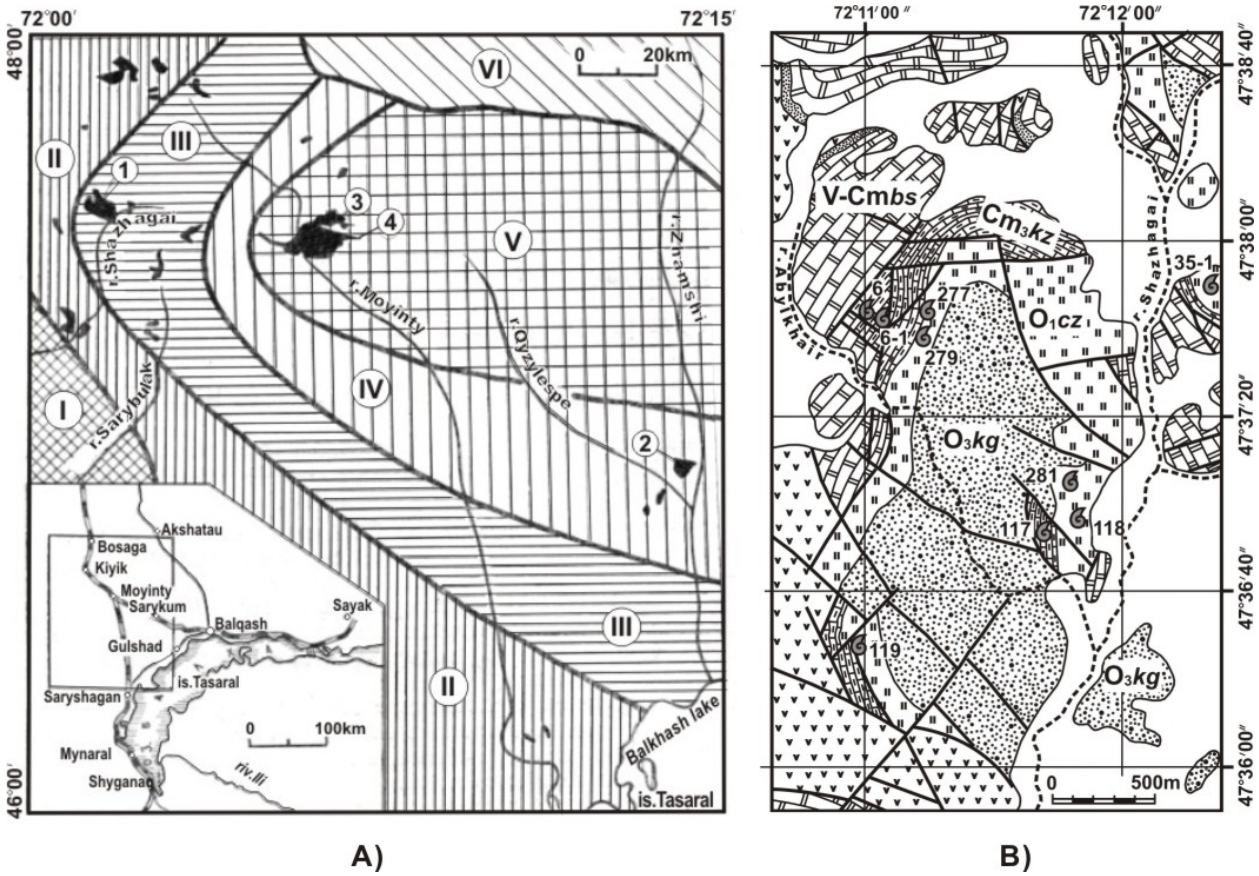

Figure 1A – Regional geological subdivisions of Cambrian deposits of the North-West Balqash area:
I. the Buryntai zone, II-V. the Atasu-Zhamshi zone; subzones: II. Kyzyltau, III. Shazhagai, IV. Sarykum, V. Kiik;
VI. Agadyr-Qyzyl-Yespe zone. Stratotype section: 1. Shazhagai, 2. Sarykum, 3. Zhaksybulak, 4. Aksuran.
Figure 1B – Geological scheme of the Shazhagai site (figure 2: the legend).

Generally, the boundaries of the Early Paleozoic paleobasin coincide with the outlines of the Vendian and Early Paleozoic folded structure and to some extent repeat the outlines reconstructed by A.E.Alperovich [1], but are more detailed. Main criteria to determine the facial zones are the nature and completeness of the sections, composition and facial features of the Lower Paleozoic beds (see figure 3).

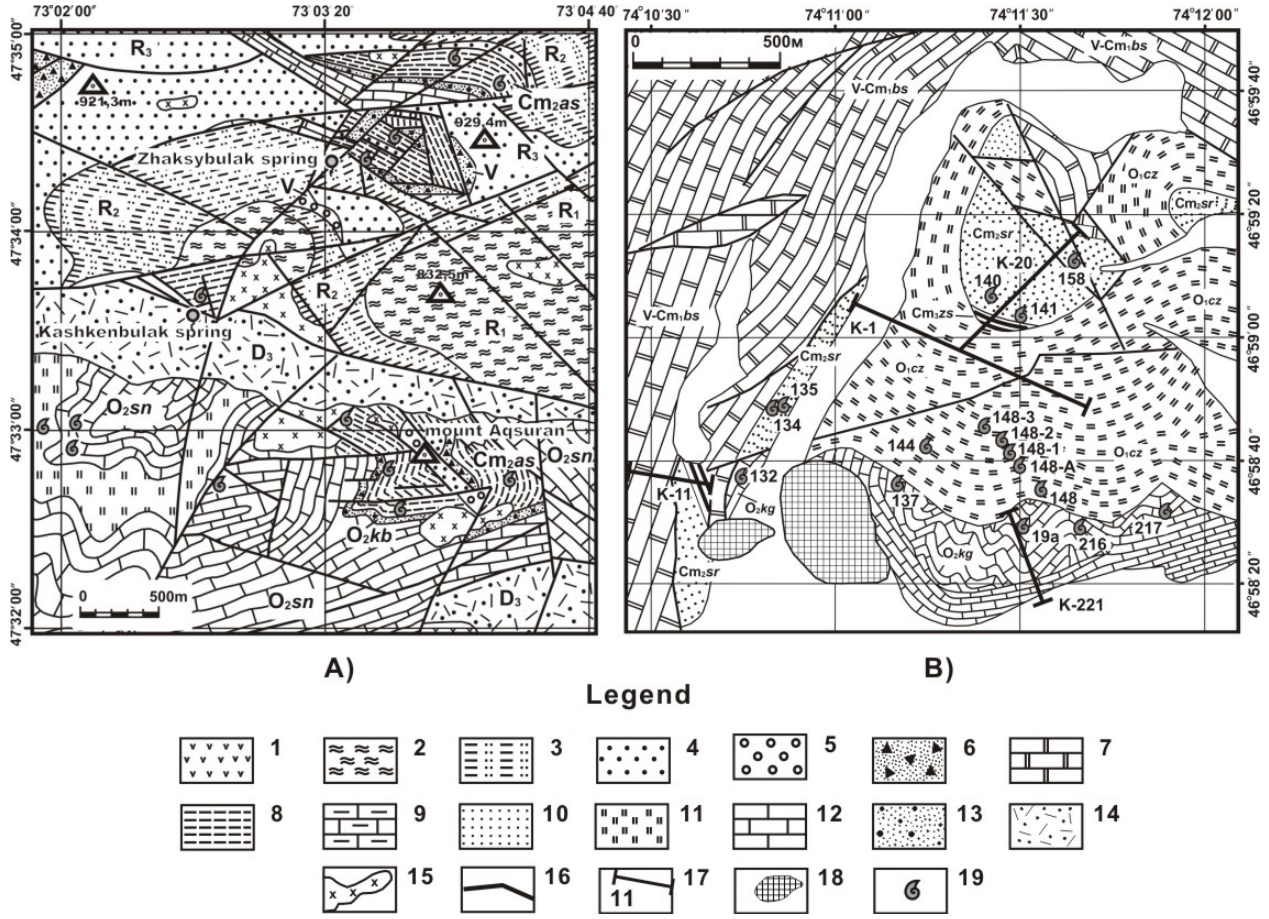

Figure 2A – Geological scheme of Kiyik location. (Pupyshev and others, 1973).
Figure 2B – Geological scheme of Sarykum location [30].

Legend: 1 - Vendian porphyric granite, Upper Riphean suites; 2 - shales, 3- carbon-rich-shales & carbonate-terrigenous shales, 4 - quartzite sandstone; 5 - Vendian conglomerate and sandstone, 6 - Vendian tillite, sandstone and dolomite, 7 - dolomites of Bosaga suite, 8 - thin bedded and fine grain terrigenous rock, 9 - thin bedded detrital limestone, 10 - alternating carbonate-terrigenous beds, 11 - black chert, 12 - Ordovician limestone, 13 - Ordovician conglomerate, 14 - Devonian acidic volcanic rock, 15 - Devonian acidic intrusive rock, 16 - fault, 17 - exploration trench and sequential number, 18 - carbonate quarry, 19 - fauna locality. Suite symbol on the map: bs – Bosaga, sr – Sarykum, zh – Zhamshi, cz – Shazagai, kc – Kurshilik, kg – Kogedei, ak – Aksuran, kb – Kashkenbai, sn – Shundy.

In the Kiik facial zone, the Lower Palaeozoic succession is represented by a terrigenous units with interlayers of limestones and phosphorites, dated to the Middle-Late Cambrian. Above are carbonate deposits of the Llandeilian-Caradocian. The sequence of the upper Cambrian and lowermost Ordovician deposits is not proved here by fauna dating.

The succession of the Sarykum zone is the most complete one [4]. There is a continuous sedimentary sequence from the Middle Cambrian to Llanvirnian inclusive. The section's structure is the most complit. It is composed of successive terrigenous, carbonate and siliceous beds. Proven by fauna Cambrian units are underlain by the carbonate beds of Bosaga suite, conditionally dated to the Vendian-Lower Cambrian and composed of massive dolomites, with oncolites and stromatolites.

The succession of the Shazhagai facial zone is represented by carbonates and flints covering the interval from the Middle Cambrian to the Llanvirnian. There are also no proven deposits of the Upper Cambrian and Tremadocian in this subzone. The Middle Cambrian part of the section is also underlain by Bosaga suite dolomites.

Cambrian Stratigraphy. Cambrian units of the Atasu-Zhamshi area are reliably studied on the Shazhagai, Aksuran, Zhaksybulak and Sarykum locations (figure 3). In the west, in the middle course of the Shazhagai river, they are composed of multifacial rocks, massive thin-bedded limestones of grey and

dark-grey colour, and at several localaties trilobites of the Mayan stage of the uppermost Middle Cambrian were collected. Further to east of the railway station Kiik, in the central part of the region in the Shundy mountains, in the section near the Aksuran town, they are replaced by thin-bedded terrigenous siltstones and fine-grained sandstones also with trilobites of the Mayan stage of the Middle Cambrian. In the section near the Zhaksybulak spring they are underlain by terrigenous sandstones, which contain Amgian stage trilobites. In the same place, Middle Cambrian phosphorites were explored in trenches. Here, the section concludes with the Upper Cambrian terrigenous Zhaksybulak suite with carbonate interlayers, where trilobites of the lowermost Upper Cambrian were found.

At the Sarykum railway station, trenches opened an intermediate section represented by interlayered terrigenous green and brownish sandstones and massive dark-grey bedded limestone, referred to the Sarykum suite with trilobites and inarticulate brachiopods of the Mayan stage of the uppermost Middle Cambrian. Above they are replaced by interlayered massive brecciated limestone and thin-bedded fine-grain detrital limestone with layers of black cherts of the Zhamshi suite with trilobites and conodonts of the Upper Cambrian.

In the Shazhagai and Sarykum zones, the lowermost complex is represented by the Bosaga suite, which has no reliable faunal dates. It consists of two sub-suites; the first one is composed of oolitic, brecciated and massive thin-layered dolomites, which reach a thickness of 800-2500 m, and the second one is the same massive carbonates, mainly dolomites, with columnar stromatolites up to 1400 m thick. Of these, B.Sh.Klinger described: oncolites *Osagia caudate* Kor., *O.gigantea* Kor., *O.granulata* Kl., *O.senta* Z.Zhur., *O.kingbreensis* Zabr., *Volvatella gigantean* Kl., *V.lancea* Kl., as well as catagraphies *Nubecularites punctatus* Z.Zhur., *N.catagraphus* Reitl., *N.parvus* Z.Zhur., *Hieroglyphites mirabilis* Reitl., *H.rotundus* Z.Zhur. [1, 32]. In the east part of the district, near the Sarykum railway station, on the right bank of the Zhamshi river and the Akkirek mountains, the pattern was also observed here, when the Bosaga suite is split in two parts: the lower part, darker, with the thin-layered structure and oncolites, and the upper one, of lighter colour, with black cherts interlayers, the lower part with columnar stromatoliths, often forming biohermes and biostromes, stretched for 200m and 5-25m thick. Oncolites and catagraphies here were studied by N.S.Krylov, with marking of some of them: *Osagia ukka* N.Kryl., *O.monolamellosa* Z.Zhur., *O.carticosa* Nar., *O.balchashensis* Kryl., *Volvatella vadosa* Z.Zhur., *V.zonalis* Nar., *Nubecularites* sp., *Vesicularites bothrydiaformis* (Krasnop.), *V.*cf. *šubinensis* Zabr., *Medullarites lineolatus* Nar., *Conferta* sp. [32].

The middle part of section the Bosaga carbonates contains stromatolites: layred, columnar and domal, of which K.N.Konyushkov defined: *Linella* sp., *Stratifera* sp., *Jurusania* sp., *Paniscollenia emergens* Komar?, *Boxonia* sp. [33].

The above stromatolites and microphytolites belong to the Upper Proterozoic-Lower Cambrian intermediate complex [1, 29, 32], so the stratigraphic volume of the Bosaga suite is still defined as the Vendian to Lower Cambrian one.

The Bosaga suite in the Shazhagai zone lies on fornmations which N.A.Pupyshev attributed to the Bylkyldak suite, composed of interlayered dolomites and sandstones, among which there are layers of fine pebble conglomerates. It reaches thickness of 20-250 m. This suite, in turn, is underlain by the Kazan-Syngan suite 400-850 m thick, dominated by coarsely clastic terrigenous sediments: crossbedded sandstones, gravelites, and fine pebble conglomerates [29]. The age of this pair of suites was conventionally dated by the Vendian, which is consistent with the regional model of the Uppermost Proterozoic formations, when the section is coarsened by the "tillite-like" conglomerates of the Baikonur suite in the Big Karatau and Ulutau, as well as the Kyrshabakti suite of the Lesser Karatau. This coarse-clastic complex of the Upper Proterozoic everywhere covers by fauna proven Cambrian sediments [10, 11, 23, 24].

The stratigraphic interval overlying the Bosaga carbonates is represented by the Kyzylzhar suite formed by gray and dark-grey thin-layered limestone, their more granular detrital and brecciated differences. The most complete section of this suite, up to 460 m thick, is exposed on the western part of the Shazhagai syncline (fig. 1A). Trilobites collected by N.A.Pupyshev [29], among which G.K.Ergaliyev and M.K.Apollov identified *Acrocephalus sp., Lisania sp., Fuchouia sp., Goniagnostus sp, Dorypyge sp., Solenopleura sp., Hypagnostus sp., Peronopsis sp., Nepeidae and Anomocaridae,* dating these sediments by the Mayan stage of the Middle Cambrian age.

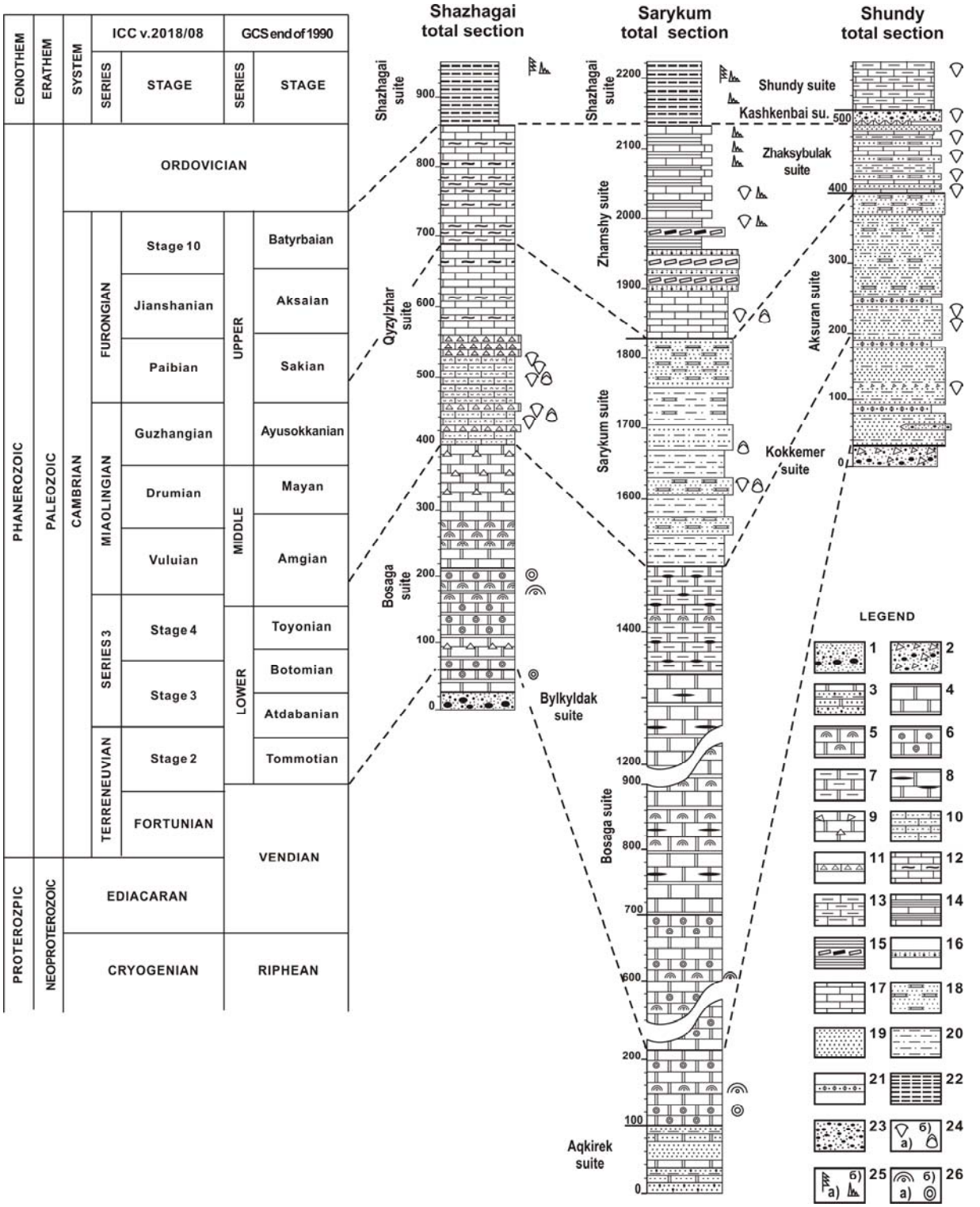

Figure 3 – Correlation of stratigraphic columns of Cambrian deposits of the North-Western Balkhash area.

Legend: 1 - coarse grain conglomerate, 2 - tillite, 3 - alternation sandstone, glauconitic sandstone and dolomites, 4 - massive dolomite, 5 - stromatolitic dolomite, 6 - oncolitic and coated grain dolomite, 7 - thin-bedded dolomite, 8 - dolomite with black chert nodules, 9 - brecciated dolomite, 10 - detrital limestone, 11 - carbonate breccia, 12 - thin wavy-laminated limestone, 13 - thin parallel-laminated limestone, 14 - alternation of shales and parallel bedded limestones, 15 - braccia with carbonate and chert fragments, 16-carbonate turbidite, 17 - thin-bedded dark grey limestone, 18 - terrigenous sandstone with carbonate matrix, 19 - sandstone, 20 - siltstone, 21 - phosphorites, 22 - cherts, 23 - basal conglomerate, 24 - trilobite(a) and inarticulate brachiopod(b), 25 - graptolite(a) and conodont(b), 25 - stromatolite(a) and oncolite(b).

The coordinates of the beginning of the Shazhagai section: 47°37'52.5" N, 72°10'20.29" E. In 2004, at the location of 47°37'52.2" N, 72°10'20.4" E, trilobites were re-collected in grey, fine-grained limestone with prevailing fine horizontal and sparsely cut undulating layering of 3.1 m from the base of the ditch: *Peronopsis sp., Ptychagnostus sp., Doryagnostus sp., Bailiella sp., Agraulos ? sp., Amphoton sp.*, the inarticulates *Obolellidae gen. et sp. indet., Prototreta? sp. Botsfordia ? sp.*, and at 5,25 m above the section, found were the trilobites *Ptychagnostus sp., Elyx? sp., Bailiaspis sp*.

Then, at the point of 47°37'51,9" N, 72°10'24,2" E, in dark-grey fine-grained organogenic clastic limestone, an abundant fauna of trilobites was gathered: *Doryagnostus sp., Peronopsis sp., Ptychagnostus sp*., *Bailiella sp.* and the rare inarticulates: *Obolellidae gen. et sp. indet., Acrotretidae gen. et sp. indet.*, the rare inarticulates *Prototreta sp., Anabolotreta? sp., Botsfordia? sp., Obolellidae gen. et sp. indet.* the conodonts of *Phakelodus tenuis* (the fauna P-2163). 22.85 m to south found were the trilobites *Doryagnostus sp., Peronopsis sp., Amfoton sp*. at the locatiion of 47°37'51,9" N, 72°10'24,54" E.

The coordinates of the end of the section: 47°37'51,84" N, 72°10'28,2" E.

A different Cambrian section represented by the Sarykum suite of interlaying terrigenous and carbonate rocks [2, 19, 34] was found to east of the Sarykum railway station in the trench no.20 (figures 2B and 3). The coordinates of the beginning of this trench are 46°59'14,45 "N and 74°11'40,72 "E, and the end of the trench is 46°58'54,20" N and 74°11'20,40 "E. The suite structure includes interlayered packages of siltstones, polymytictic and feldspar quartz medium-fine sandstones, interlayers of thin-bedded sandy limestone. The upper part is dominated by limestone breccias and detrital limestone of packstone. The rocks' limestone content increases noticeably in the upper part of the section. The feldspar-quartz sandstones can be divided to very, medium and slightly calcareous ones. The colour of the rocks varies from brownish red and grayish-brown to yellow-green, light and dark grey.

The Sarykum suite can be divided into two sub-suites.

The lower subsuite is characterized by a rhythmic interlayering beds. Each rhythm at the base is composed of coarser layers of limestone sandstones, and on the top, the rhythms are represented mainly by siltstones. The brownish-red and red polymictic sandstones and siltstones at the base above are changing for yellow differences. Turbidites with gradational layering are also noted here. In such beds one can distinguish the chanal forms of base. The upper part of the lower subsuite has a coarser up composition, i.e., different granular turbidite sandstones of green and yellowish-green colour. Packages of siltstones are typical. The thickness of the subsuite is 320 m.

The upper subsuite is composed mainly of limestone. Terrigenous sandy material is present in turbidites in the Buma rhythm Ta. Limestones are mainly represented by fine grain differences. In the lower part they are of light tones with red, yellow or brown tincture. At the top of the interlayers are small unsorted pebble-flat polyclast breccias represented by fragments of limestone turbidite beds, which alternate the fine-grained dark grey limestone. The thickness of the subsuite is 100 m.

The lower boundary of the suite is sharp and is lined-up along the first layer of terrigenous rocks, overlaying of the Bosaga dolomites. The upper boundary of the suite is determined by the first appearance of black and dark grey chert layers with layers of breccias, relating to the Zhamshi suite.

The age of the Sarykum suite has been established by trilobites found here and inarticulate brachiopods as the Middle Cambrian [34]. Among trilobites, A.V.Zakharov (1989) determined *Hypagnostus parvifrons* Linnarsson, *Goniagnostus (Allodochus) buckleyi Tago, G.bicanes Zhen*, *Pseudophalacroma praecox* (*Öpik), Lejopyge aff. calva Robins., L. armata (Linnarsson), L.laevigata (Dalman), Kormagnostus* sp. et al. Inarticulate brachiopods are represented in the lower part of the section by such forms as *Linnarssonia ophirensis (Walcott), Anabolotreta diversa Koneva, Stilpnoreta magna Henderson and MacKinnon, Treptotreta cf. jucunda Henderson and MacKinnon*, which correspond to the Mayan stage of the Middle Cambrian [19]. In the section's tops, in the upper subsuite M.K.Apollonov [4] defined *Pseudagnostus* sp. и *Parakoldinia* sp., and L.E.Popov determined inarticulate brachiopds *Anabolotreta diversa Koneva, Stilpnoreta minuta Canthilotreta tenuis sp.nov., Dactylotreta septata sp.nov., Picnotreta karakichiensis sp.nov*. They referred this faunistic complex to base of the Upper Cambrian [19].

The total thickness of the suite reaches 420 m.

The Zhamshi suite overlies of the Sarykum suite units and is studied in the trenches 20 and 11. It has also been opened with shallow wells. The suite is composed of interlayered packs of various dark thin-

layered chert, grey limestone, and sometimes carbonate-siliceous brown rocks on the weathered surface, but of dark grey colour of fresh chips. The suite is characterized by an upward decrease in the granularity of deposits. There are siliceous limestone breccias and large-plated gradation detrital limestone in the lower reaches. Among cherts, the most common are thin-layered and massive black phthanites. The uppermost suites are characterized by lime-siliceous shales.

The trilobite fauna, revealed in sediments of the suite, is represented by: *Rhaptagnostus sp., Neoagnostus sp., Lotagnostus (Eolotagnostus) scrobicularis* Ergaliev*, Lotagnostus asiaticus* Lu*, Lotagnostus hedini (*Troedson*), Hedinaspis sp., Charchaqia sp.* [4, 34]. Here also have been found the conodonts *Cordylodus lindstromi* Druce et Jones*, Cordylodus prion* Lindström*, Cordylodus proavus* Müller*, Eoconodontus notchpeakensis (*Miller*), Prooneotodus rotundatus (*Druce et Jones*), Phakelodus tenuis (*Mùller*)* [4, 9]. It is necessary to note that the entire faunistic complex is currently considered as confined to the Upper Cambrian and establishes the 10 terminal Cambrian stage of the Upper Furongian series [5].

Immediately above this complex, or 3m below, under the black Shazhagai flints, in the well 51 at depth of 84 m, in the carbonate-siliceous rocks, trilobites Micragnostus sp., et Koldiniodia sp., were found together with conodonts *Chosonodina herfjurti* Mùller, *Rossodus manitouensis* Repetski et Ethington, *Cordylodus rotundatus* Pander, *Acanthodus linearis* (Furnish), *Scalapodus* sp., *Drepanoistodus* sp., *Hertzina* sp., *Phakelodus* sp., which is currently considered as confined to the most bottoms of the Tremadocian stage of the Ordovician period [8]. Immediately above them there are the flints of the Shazhagai suite, where found in the 148, 148-A, 148-1, 148-2 and 148-3 were high Tremadocian and Lower Arengian conodonts *Drepanoistodus deltifer* (Lindström), *D.proteus* Lindström, *D.acuatus* Pander, *Paracordylodus gracilis* Lindström et al. [4]. Close conodont complexes corresponding to the Cambrian tops and Ordovician base were studied by T.Yu.Tolmacheva [31] on the western shore of the lake Balkhash in several siliceous sections of the Burubaital suite.

Below the Sarykum suite there is the Bosaga suite, which already described. This suite is underlain by the Vendian-Lower Cambrian carbonate-terrigenous unit, which is considered in this article as a new Akkirek suite, composed of brown, gray, greenish-gray quartz and oligomitic sandstones, siltstones, clay shales, glauconite sandstones, sandstones with lime-dolomite cement, limestone, clayish and sandy dolomites. The rocks are mainly thin-bedded, and sandstones are often bimodal cross-bedded. Its thickness is estimated at 100-500 m. The given suite by structure and stratigraphic position can correlate with Kyrshabakti suite of the Lesser Karatau [28] which is dated by the upper Vendian and where available the absolute age dating of 570 million years, received on glauconites from sandstones.

A completely different Cambrian section was studied in the Kiik subzone (figure 3), which is represented by terrigenous rocks of argillites, siltstones and sandstones, and where the fossil fauna of trilobites was studied at several levels corresponding to the Middle and Upper Cambrian. As elsewhere, the section at the base of the Cambrian is underlain by a coarse-clastic "tilloid" Akkelenti suite with conglomerates of sandstones and dolomites, dated to the Upper Vendian and is preceded by the Keneli suite of the Lower Vendian, composed of boulder conglomerates and sandstones. Just above them, deposits belonging to the Kokkemer suite formed by phosphate-bearing siltstones, sandstones and gravelites have been studied, but there is no phosphate material at the base of the suite. Only sponges were found here from organic remnants [21]. The thickness of this suites is 10-50 m and maximally measured at 73 meters; it is compared to the Chulaktau suite, which is represented by carbonate-siliceous phosphate thickness with well-proven micro- and skeletal fauna of the Lower Cambrian age [11, 24].

The Aksuran suite deposits lay stratigraphically higher and conformably to the phosphorite sandstones.

The bottom part of the Aksuran suite is fully distributed around the Zhaksybulak water source (figure 2A) and is represented by siltstones, phosphate-bearing sandstones and phosphorites. Found were trilobites *Schistocephalus sp., Olenoides sp., Chondagraulos sp., Dawsonia sp., Pseudanomacarina sp., Peronopsis (Acadagnostus) sp. Pokr.,* which allowed G.K.Ergaliyev, N.V.Pokrovskaya and N.K.Ivshin give a conclusion about their belonging to the Amgian stage of the Middle Cambrian [29]. Here the Aksuran suite bottoms reach 170 m.

The coordinates of the beginning of the section are 47˚ 34' 26.04" N., 73˚ 04' 31.56" E.

The upper part of the Aksuran suite is fully represented in the section to the west of the Aksuran town (figure 2A). Here it is composed of siltstones, mudstones, clayey and siliceous clayey shales. Sandstones and limestones are rarer. Numerous trilobites have been collected here and, according to L.N.Kraskov's conclusion, they are represented by trilobites of the Mayan stage, such as *Lejopyge laevigata (*Dalm*.), Hypagnostus sulcifer (*Wall*.), Goniagnostus nathorsti (*Brogg*.), G.spinifer* Wgard*, Ptychagnostus aculeatus (*Ang*.), Triplagnostus sp., Cotagnostus* ex gr. *confuses (*Wgard*)*. Locations of this trilobite complex were also found at the Zhaksybulak spring and the Kokkemer gorge [29].

Coordinates of the beginning of the section are 47˚32' 52.3" N, 73˚ 03' 36.2" E.

The Upper Cambrian Zhaksybulak suite completes the Cambrian section of the Kiik subzone and is composed of sandy dolomites, limestone, clay shale, polymytictic and limestone sandstones. At its base, a marker horizon of glauconite limestones and sandstones can be traced. Trilobites were found in the suites' deposits, which L.N.Kraskov defined as *Agnostus aff. simplexiformis* Ros*. and Phaldagnostus longus sp.nov.* Kras*., Agnostoglossa* aff*. bassa* Opik*., Onchonotellus sp., Agnostus sp., A.inexpectans* Kob*.* associated with the lower Upper Cambrian. The thickness of the suite is 82-104m.

Cambrian deposits are uncomformably covered by the Lower Ordovician sediments of the Kashkenbai suite, overlaid by the Ordovician limestone of the Shundi suite [4].

Conclusion. The International Sub-Commission on the Cambrian Sratigraphy is currently working to establish global stratigraphic standards for the Cambrian system and to define the global stratotype and boundary points (GSSP) for its series and stages [18, 30]. After many years of work and analysis of biostratigraphy of the Cambrian unites on separate continents, and discussion in the mid-2000s, researchers of this Sub-Commission decided that the Cambrian system should be divided into four series, as opposed to the classical three series division, for details see discussion in [27]. It was also recommended that series should be divided into ten stages: two stages in the two lower series and three tiers in the two upper series. Index-species of the levels of the first appearance of taxons for stages [5, 18, 30] were also established. These data were published as International Chronostratigraphic Scale of the International Stratigraphy Commission (www.stratigraphy.org). There are also cross-references to the relevant literature. The current status of study of the Cambrian Stratigraphy, as well as the representation of the hierarchy of stratigraphic units at different levels, can be found on the same site, more over representation such information can also be seen on the site of the Sub-Commission on Cambrian Stratigraphy at (www.paleontology.geo.uu.se). Both of these resources are regularly updated, so it is possible to follow the progress made so far.

To date, the International Cambrian Sub-Commission has identified three series that have already been ratified and officially approved by the International Commission on Stratigraphy. It is the lowest Terraneuvian series, as well as the third series called Miaolingian and the upper fourth series called Furongian. Out of the 10 stages, already individuated, ratified and approved for use in the International Stratigraphic Scale, six stages include the lowest Fortunian stage, at the base of which determined was the boundary of the basis of the Phanerozoic Eonothema. The lower boundary of the Cambrian system and he entire Phanerozoic was determined by the first appearance datum (FAD) of ichnofossil *Trichophycus pedum* in the section near the Fortune town in Newfoundland, Canada [7, 23].

This boundary will determine the so-called "the Cambrian explosion" or "the Cambrian radiation", the practically instant and sudden appearance, blossoming and spread of marine skeletal fauna. The work on the second, third and fourth stages continues and should be completed in the near future. The Vuliuan, Drumian and Guzhangian stages, belonging to the Miaolingian series have been ratified and approved, as well as the Paibian and Jiangshanian stages, belonging to the Furongian series; and there remains a vacancy for the set-up of a global stratotype and naming of the last 10th terminal Cambrian stager. The upper boundary of the Cambrian system or the base of the Ordovician system was established in 1998, ratified and approved by the ISS on the first appearance of the conodontic species *Iapetognatus fluctivagus* [8].

In Kazakhstan, Cambrian deposits became known with the discovery in 1932 by the R.A.Borukaev in the Boschekul district (North-East Central Kazakhstan) in the well core of the Upper Cambrian trilobites. In South Kazakhstan, the first trilobites *Kootenia* sp. in the Karatau mountains have been known since the late 1930s, but originally they were erroneously defined as Middle Cambrian. In 1960s, these locations

G.K.Ergaliev re-tested and in the Tamdy limestone a more representative collection of trilobite fauna was obtained just above the Chulaktau phosphorites and defined as Lower Cambrian [11]. At the same time, in base of Chulaktau phosphoritic beds the "small shelly fossil" was found, which made it possible to date the base of Chulaktau suite to the lowermost Cambrian, and the underlying "Lower dolomites" of Burkuti suite to the topmost of Vendian [24].

Reliably, the Archaeocyatha fossil fauna of the Lower Cambrian deposits dated as top of the Aldanian stage was discovered in 1965, in the North-East Kazakhstan, in the Chingiz range, close to the Balkibek river. Thus, by early 1970s, Cambrian sediments had been established in many areas of northern, central, southern and eastern Kazakhstan. The work carried out in the 1960-80s by Kazakhstan stratigraphers was successful and its achievements were expressed in general adoption of the Upper Cambrian Ayusokkanian, Sakian and Aksai stages, singled out by G.K.Ergaliev in the Lesser Karatau [12, 13, 14], supplemented in the late 1990s by the Batyrbaian terminal stage, proposed by M.K.Apollonov, also singled out in the Lesser Karatau [26].

Already in the 1980s and 1990s, specialized work was carried out to establish the upper boundary of the Cambrian system [2, 3, 14], which made it possible to develop in the sections of the Small Karatau and Atasu-Zhamshi a biostratigraphic sequence based on conodonts from the index species of *Cordylodus proavus* to *Cordylodus lindstromi* [4, 9]. Later, the same sequence of the transient conodontic fauna was found in flints in the Zhalair-Naiman zone, in the north-east of Central Kazakhstan and in the Chingiz range [31].

In recent years, new collections of Lower and Middle Cambrian trilobites were collected in the Chingiz range by G.K.Ergaliev and T.E.Pirogova [15, 16], and these data were published.

In the Atasu-Zhamshi region in the North-West of the Balkhash area, the Cambrian deposits are reliably established only for its upper part, that is, there is a sequence, limited to the Cambrian and Ordovician boundary, somewhere in the interval of the conodontic zone of *Cordylodus lidstrome*, which in practical terms almost coincides with the base of flints of the Shazhagai suite and the bottom interval of the Aksuran suite, with trilobites of the Amgian stage. The base of the Cambrian can be assumed as based by presence of a coarse-clastic terrigenous-carbonate level with "tillite-like" conglomerates, which now should be correlated with the tops of the Neoproterozoic or a new individuated system of Cryogeny, corresponding to the lower Vendian, previously widely used in the Kazakhstan geology. This interval is interrupted by thick Bosaga dolomites, at base of which there is a terrigenous-carbonate package with glauconite sandstones, which can be correlated with the Kyrshabakta suite of the Lesser Karatau and is represent by deposits of the Ediacaran system, previously called the Upper Vendian.

Thus, we can conclude that within the Atasu-Zhamshi region there is the Cambrian sequence of deposits (fig. 3), which should be further detailed for the upper half and studied in detail to detect fauna and proofs of the lower half of the Cambrian in the Bosaga suite and base of the Aksuran suite.

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СОЛТҮСТІК-БАТЫС БАЛХАШ ӨҢІРІНІҢ КЕМБРИЙ

Аннотация. Соңғы онжылдықта алғаш рет ерте және жаңа далалық және қор деректерін кешенді зерттеу, сондай-ақ ашық басылымда жарияланған геологиялық әдебиеттерді кешенді зерттеу негізінде Солтүстік-Батыс Балқаш өңірінің кембриялық бірізділігіне тексеру жүргізілді. Жиналған қазба теңіз фаунасы мен флорасын анықтау негізінде де, литологиялық белгілері бойынша да әртүрлі фациальды терригендік-карбонатты-кремнийлі шөгінділердің корреляциясы орындалды. Тіліктерді бөлу жасалды, литостратиграфиялық бірліктер (свиттер) орнатылды және олар қазіргі Халықаралық Стратиграфиялық Шкаламен біріздендірілген.

Түін сөздер: кембрий, стратиграфия, свит, разрездер, карбонатты және терриген шөгінділері, кремний, трилобиттер, конодонттар, Балқаш.

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КЕМБРИЙ СЕВЕРО-ЗАПАДНОГО ПРИБАЛХАШЬЯ

Аннотация. Впервые за последние десятилетия на основе комплексного изучения ранних, новых полевых и фондовых данных, а также опубликованной в открытой печати геологической литературы проведена ревизия кембрийской последовательности Северо-Западного Прибалхашья. Выполнена корреляция разнофациальных терригенно-карбонатно-кремнистых отложений как на основе определения собранной ископаемой морской фауны и флоры, так и по литологическим признакам. Сделано расчленение разрезов, установлены литостратиграфические единицы (свиты), и они унифицированы с современной Международной Стратиграфической Шкалой.

Ключевые слова: кембрий, стратиграфия, свита, разрезы, карбонатные и терригенные отложения, кремни, трилобиты, конодонты, Балхаш.

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THE ROLE OF THREE-DIMENSIONAL MODELS OF DEPOSIT AND THERMODYNAMIC CONDITIONS OF ITS FORMATION AT SELECTING AND EVALUATING RESOURCES OF PERSPECTIVE SITES

Abstract. The state program "Digitalization of Kazakhstan" considers the accelerated introduction of modern information technology in various spheres of our life. In the geological industry, particularly in geological science, these technologies allow creating an accurate, geo-referenced spatial database of geological objects of various scales, and it represents a necessary condition for consistent, holistic, system-differentiated research of objects, which allows efficient and rational solve practical problems.

The introduction of modern digital information technology to the geological study of the bowels of Kazakhstan presents new opportunities, and the ways of solving the tasks posed require the improvement of the methodological basis of modern geological research. The basis for the improvement of this methodology is the creation of a single interconnected (with local and regional geographical coordinates) digital scientific information base of the studied mineral resources (including minerals) of Kazakhstan, regardless of the scale of geological research.

Below, the example of the Bakennoye deposit will show the creation of its scientific and information base, and on this basis, the improvement of the methodology of geological research will be shown.

Keywords: GIS-technology, *ArcGIS–10, Micromine,* 3Dmodels of deposit, ore-controlling factors, ore-bearing environment, rare metal deposits, pegmatite field, tantalum pentoxide, perspective area.

The expansion of the mineral and raw materials base of the most important stratigraphic elements such as tantalum and niobium is a topical task for the Republic of Kazakhstan, because they define innovative progress in the field of high technology.

All industrial deposits of tantalum-niobium ores are concentrated in the Eastern region of our Republic.One of the brightest representatives of such objects is the **Bakennoye deposit**, located in the ore pegmatite field Ognevsko-Bakennoye.

The deposit is located in the East Kazakhstan region. The first pegmatite veins of the deposit were discovered in 1948 by VA Filippov, subsequent - a group of geologists under the leadership of Yu.A.Sadovsky. The ore field is located on the northern flank of the central block of the Kalba-Narym zone and is confined to the Gremyachinsko-Kiinsky regional fault of the 2nd order, in the endo-exocontact of the Irtysh granite massif. The sedimentary-metamorphic deposits of the upper Devonian and the Lower Permian granitoids of the Kalbinsk complex take part in the geological structure of the deposit. The host rocks consist of siltstones, sandstones and carbonaceous shales.They are crumpled into linearly extended folds, undulating in the general structure of transverse kinks. Granitoids are represented mainly by biotite medium-coarse granites of the first phase (granite-granodioritesub formation) and their vein derivatives: aplite, aplite-pegmatites and pegmatites. With granites of the I phase, rare metal-pegmatite mineralization is genetically associated (figure 1) [1-3].

In structural terms, the Bakennoye and Ognevskoye deposits are a single whole, separated by the specificity of mineralization: the first one is complex-tantalum and the second is columbite-beryl, non-industrial [6].

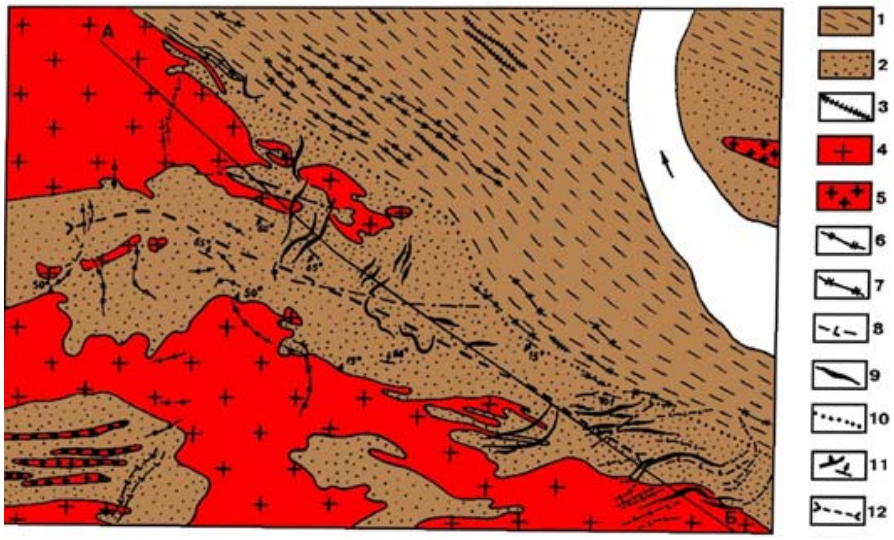

Figure 1 – Ognevsko-Bakennoyeore field. According toYu.A. Sadovskiy [7].

1 – hornfels; hornfelsed shale and 2 – magmatized rocks of the Takyr suite; 3 – granite-porphyry, plagiogranite-porphyry of the Kunushsky complex: (?); 4-9 Kalba complex: 4 – medium-coarse-grained granites of phase Iand 5 – fine-medium-grainedgranites of phase II; 6 – aplite veined granites; 7 – aplites, aplite-pegmatites; 8 – pegmatitesoligoclase-microcline non-ore; 9 – rare metal pegmatites; 10 – boundary of gradual rock transitions in the metamorphism zone; 11 – elements of occurrence of contacts of granites(a), sedimentaryrocks (б); 12 – axis of longitudinal folds.

Three-dimensional models of the Bakennoye deposit. The digital three-dimensional model of the deposit is constructed using the computer program **Micromine** [4, 5].

The geo-information database consisted of 730 pieces of information entered into the computer base for the I, II, III and VI veins[7].

Wireframe model (figure 2). The obtained skeleton model fully visualizes the structural-morphological feature of the deposit, where all the formations of the ore field have a "stepped" wedging to a depth at the horizons of 200 and 300 m, with a small approach one by one. The concentration of pegmatite veins decreases in the sections between the suites, and they themselves are insignificant in size. The predominant form of the veins is irregularly plate-shaped, in some cases plate-shaped, some lenticular. There are more than 100 pegmatite veins on the deposit, 21 of them carrying industrial mineralization. The main industrial reserves of the field are concentrated in the formations I (Spodumenovaya I vein) and II (Spodumenovaya IV vein), since they contain a high concentration of pegmatite ore veins [6].

Blockmodel (figures 3, 4). It visualizes the distribution of tantalum pentoxide contents within the deposit, since the main ore mineral is columbite-tantalite.

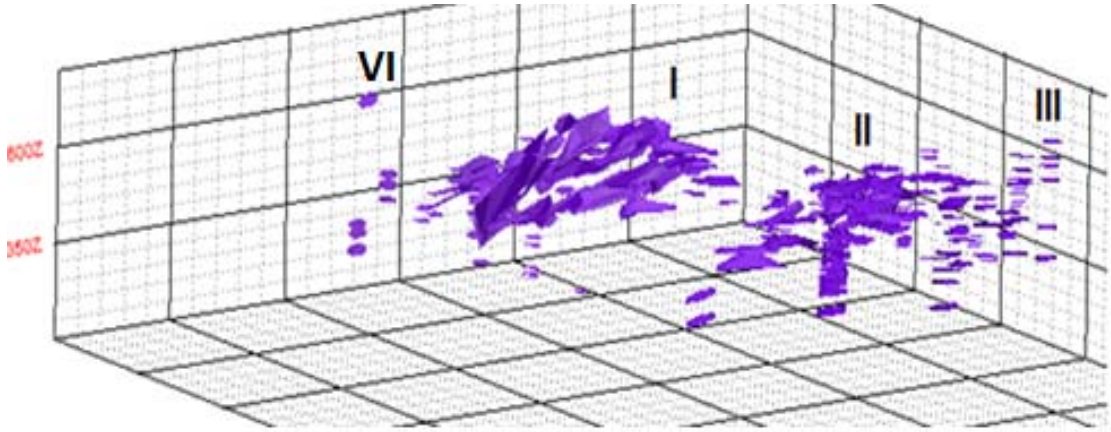

Figure 2 – Three-dimensional frame model of the deposit Bakennoye
(I, II, III, VI – numbers of suits)

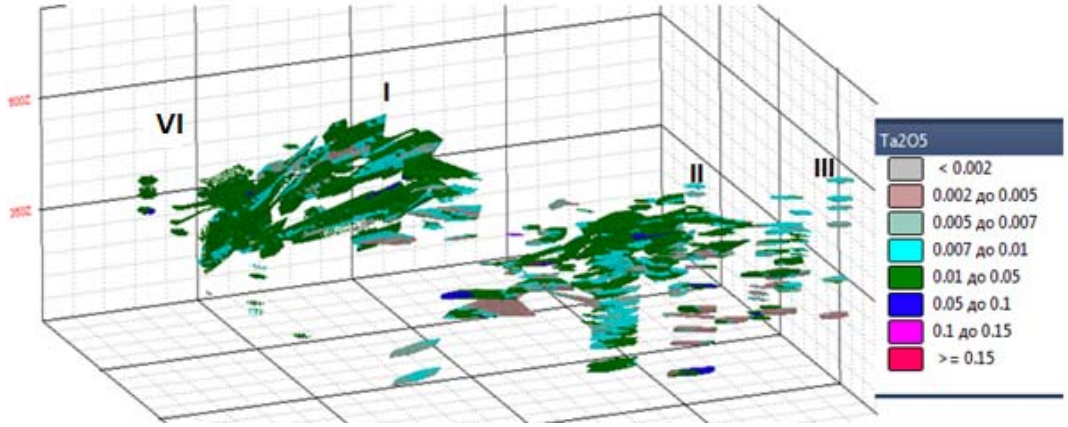

Figure 3 – Three-dimensional block model of the Bakennoye field (I, II, III, VI – numbers of suits)

In general, the following conclusions are drawn:

- the content of tantalum pentoxide varies in the range from 0.002 to 0.15%;
- the most common deposit in the deposit is tantalum pentoxide from 0.007 to 0.05%;
- a rather distinct tendency is observed for decreases in the content of tantalum pentoxide to the peripheral parts of the veins to 0.007% and lower.With the drop in the concentration of mineralization, wedging out of ores is observed, and pegmatites are almost completely transferred to non-ore veins with ore contents below them extracted;
- individual maxima of tantalum contents in the range from 0.10 to 0.15% are located both in the lower parts of the fall and in the upper parts of the I, II upwelling strata;
- areas with a low tantalum content from 0.002 to 0.005% occur in the lower horizons of the pegmatite veins of all the suites;
- especially the III suite, where in its upper part a low content of tantalum is visualized, and in the lower parts it reaches 0.10%.This is due to the fact that the upper part of this formation belongs to the Ognevskoe deposit by columbite-beryl mineralization, the lower horizons, which enter the vein after the second stage, bear the mineralization of tantalum, tin, beryllium, lithium;
- the first vein of the Kamenushinskaya (VI) suite is represented by albitizedpegmatites, the content of tantalum pentoxide reaches 0.013%.
- the average content of tantalum pentoxide according to the calculation of computer simulation was determined within0,01184%;

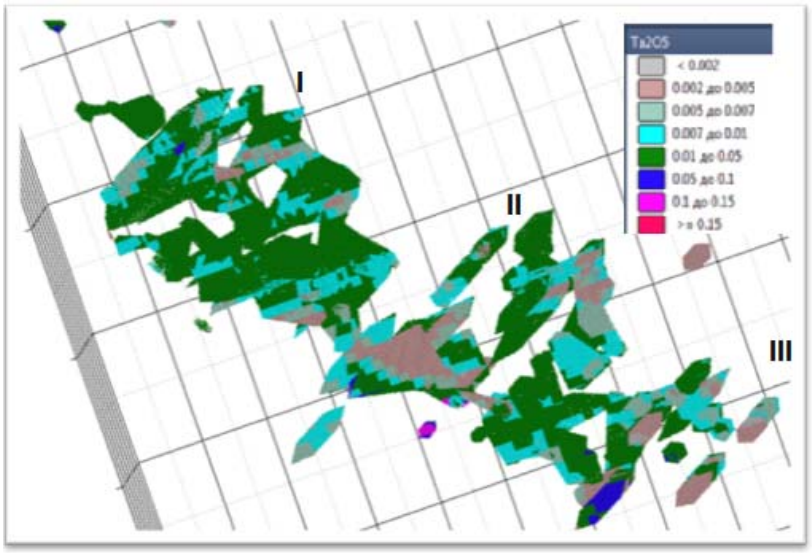

Figure 4 – Three-dimensional block model of the Bakennoye field, bottom view.

An analysis of the visualization of the distribution of tantalum mineral content resulted in a predominance of tantalum pentoxide from 0.007 to 0.05%.Its high contents (from 0.10 to 0.15%) have a limited distribution, but they can occur both in the upper and lower horizons of some deposits in the field (figure 4).

Since the actual problem is the evaluation of the prospects of the deep horizons of the deposit, the results of its three-dimensional models are compared with the data of thermometry and quantitative modeling of ore-forming systems [8].

The Bakennoye field is confined to the western part of the Irtysh pluton, which in this area is a granite plate with a thickness of more than 7 km.The introduction of an intrusive massif with a thickness of up to 6-7 km and a temperature in the range of 850-900^{0}C will lead to a redistribution of the temperature in the host environment, leading to warming of the exocontact layers of the rocks, and to a decrease in the temperature of the endocontact part of the massif [8, 9]. Therefore, a sharp decrease in temperature in the endocontact area of the ore-bearing massif contributes to the formation of structural elements, where the stage of pegmatite formation is associated with the appearance of a gently sloping fault system, and the free pegmatites (700-560°C) at the Bakennoye field were formed in this *progressive stage* of cooling the intrusion.

In addition, this stage of cooling of the intrusion is characterized by the development of contact metamorphism processes, where hornfels are formed, at temperature intervals of 640-450°C (based on the temperature of deposition of cordierite, garnet). Halo of hornfelsed rocks reaches up to 750 m vertically, and its position can contour the area of ore formation.

The thermal field of the ore-bearing massif is gradient, and it contributes to the formation of ore zoning in the deposit. According to thermometry data, ore formation occurred in the temperature ranges of 480-260°C. Not only rare and rare earth ores, but also rare metals were formed (tin, beryllium). The deposition ofrare earths, niobium and tantalum proceeded at intervals of 480-390°C, and are concentrated in the dermal contact zones, where the ore-forming and ore-localizing systems were under thermal equilibrium conditions. Rare metal ores (tin) were deposited at temperatures of 380-260°C in the above-dump zone of the ore-bearing intrusion, where the thermal nonequilibrium between ore-forming and ore-localizing systems was established.

Analysis of the thermodynamic conditions of the formation of the deposit is considered in the context of the deposit. As is known, the deposit is composed of gently sloping veins located within one hundred meter weakened zone along the contact. Raremetal pegmatites are distributed unevenly in the field and are grouped in six formations separated by sections with a much lower concentration of veins, of which three belong to the Bakennoye deposit (I, II, VI) and three to Ognevsky (III, IV, V).Stretching of veins varies from sublatitudinal (Ognevka) to submeridional (formation Kamenushinskoye Bakennoye deposit) (figure 5).

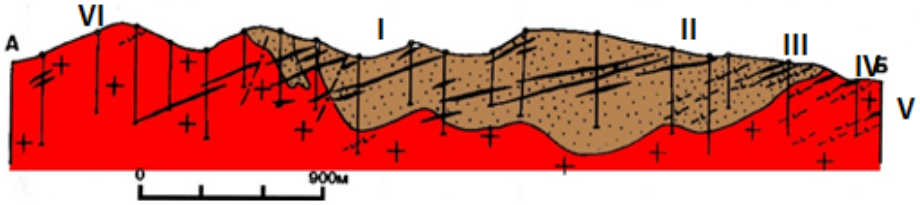

Figure 5 – Geologicalsection of Ognevsko-Bakennoyeore field (I, II, III, IV, V, VI formations)

This geological section of the Ognevsko-Bakenny ore field shows that ore pegmatite veins in some formations are localized only in the dusk, but also in the endocontact zones of the ore-bearing massif (VI, IV, V part I), and in some formations (II, III and Part I) pegmatite veins occupy only its dusk zones (figure 5).

If we take into account that the most favorable thermodynamic condition for the deposition of high-temperature ore elements is created in the endocontact region of the ore-bearing massif, the deep horizons of the suites II, III and I are of practical interest for the detection of rare metal mineralization.In addition, the deposition temperature of the main ore minerals indicates the metasomatic nature of rare metal mineralization in pegmatites, and the metasomatic nature of the formation of rare metal minerals suggests the possibility of detecting rare metal mineralization outside the pegmatite veins.

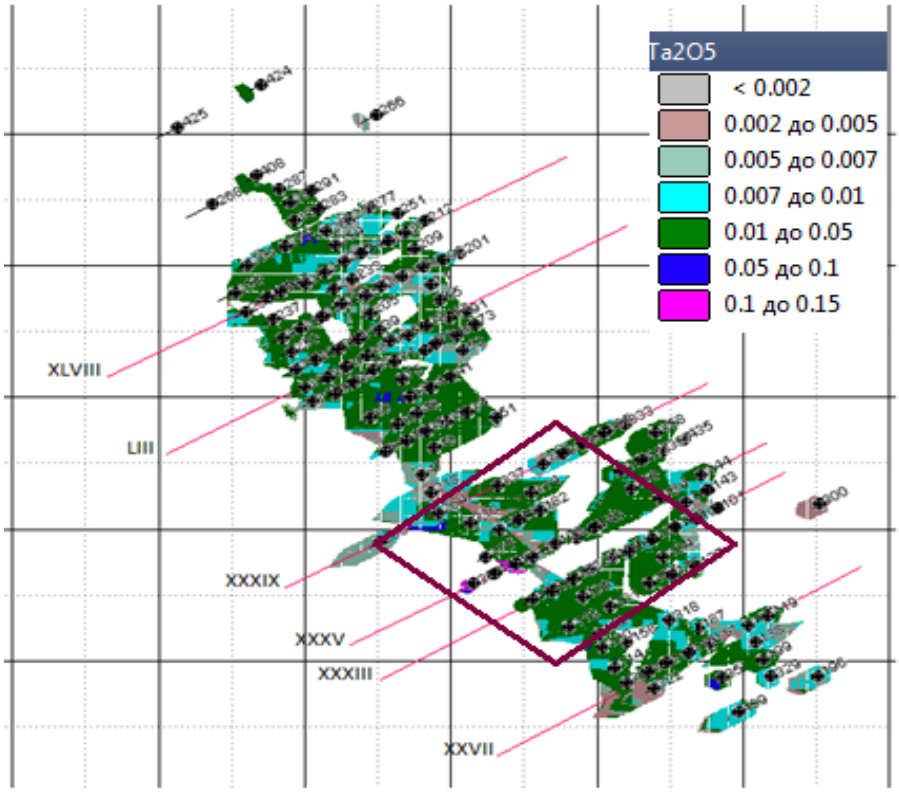

Figure 6 – Allocating a prospective site on the block model of the Bakennoye field

Thus, the analysis of the three-dimensional models of the deposit and the thermodynamic conditions of its formation make it possible to identify two prospective sites in the vicinity of the Bakennoye deposit and confirm them with geological data.

The first section is the deep horizons of the II formation between the profiles XXVIII and XXXIX, covering the veins of the deep horizons of the III formation.The parameters of the site are 500 meters long, 500 meters wide, 5 meters deep (figure 6). The allocated site corresponds to the position of the productive areas allocated on the geological and industrial model of the field [10, 11].

The second section is the deep horizons of the I formation between the LXVIII and LX profiles, it is confirmed by testing wells №283,260,254 and 245. Parameters of the site length – 500 m, width 200 m, depth 20 m (figure 7).

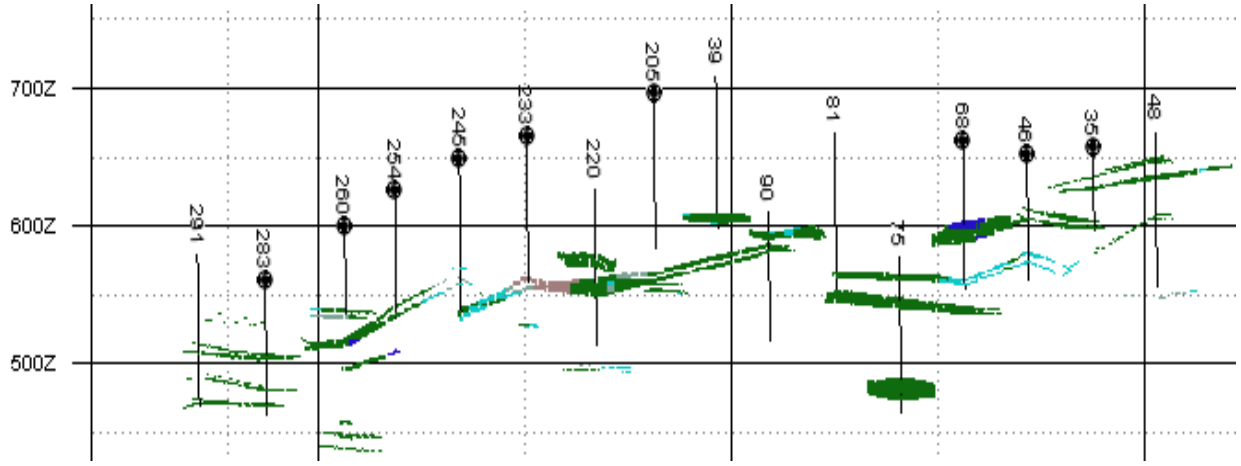

Figure 7 – Longitudinal 2D slice of the block model along the line №8 (Bakennoye deposit)

At the deep horizons of the formation, a vein№ 100is identified, which in composition refers to the lepidolite type of pegmatites, the content of tantalum pentoxide in it according to geological data is more than 200 g/t, and the stretching of veins are submeridional, which suggests that lithium pegmatites in the lower horizons are present in it (figure 8).

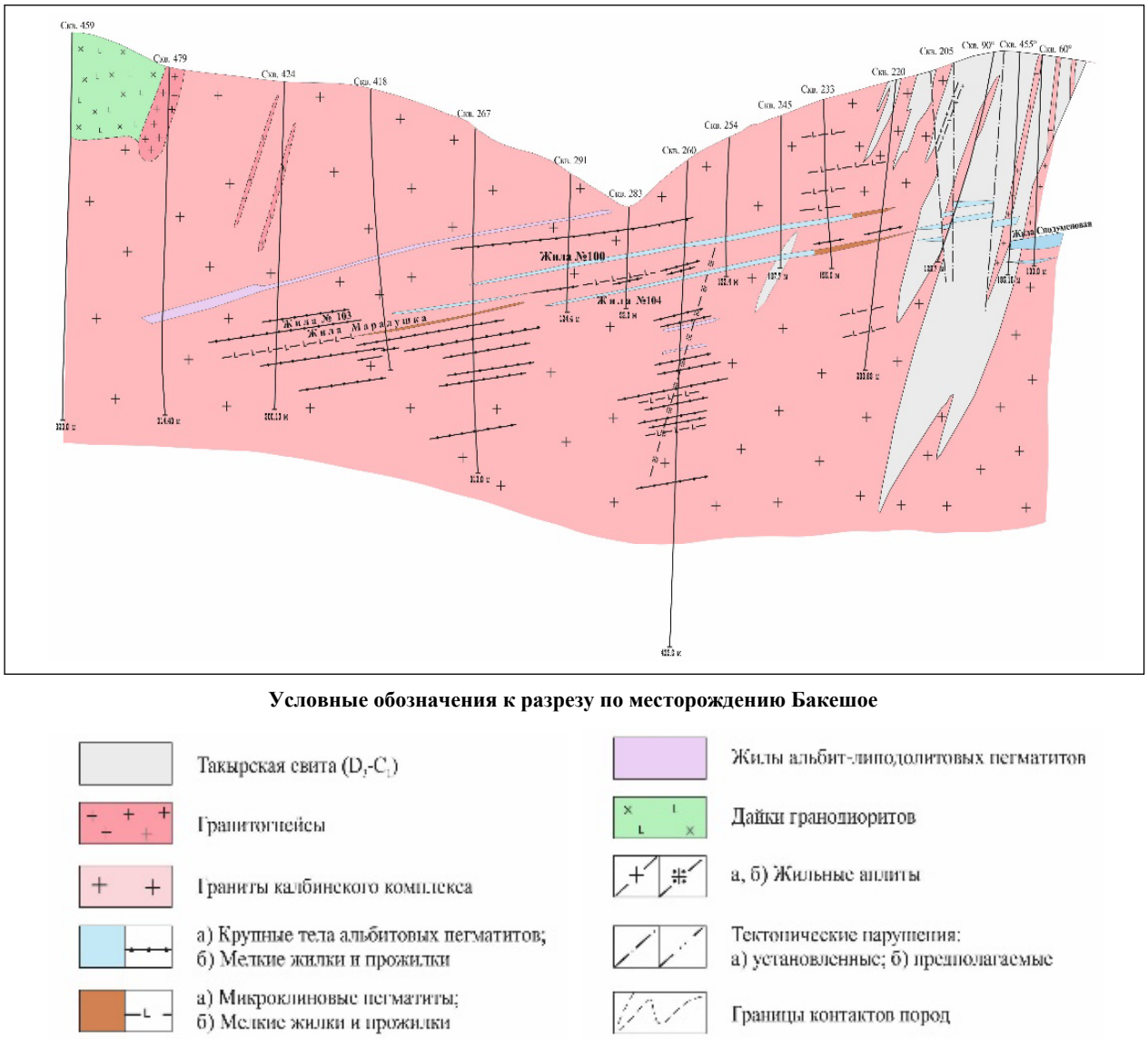

Figure 8 - Longitudinal geological section along the line№8 (Bakennoye deposit)

Reasonable views on the size and conditions of occurrence of promising areas within the Bakennoye deposit allowed quantitative assessment of their potential resources (table).

Calculation of the forecast resources of promising areas of the Bakennoye deposit

The position of ore zones, deposits, sites	The size of the forecast sites			Bort content, g/t	Resource category	Size of resources, t
	Length, m	Width, m	Depth of calculation, m			
Section Transitional between profiles XXVIII and XXXIX	500	500	5	125 g/t Ta_2O_5	P_1	284,375
First suit between profiles LVIII and LX	500	100	20	125 g/t Ta_2O_5	P_1	227,5

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ПЕРСПЕКТИВТІ УЧАСКЕЛЕРДІҢ ҚОРЫН АНЫҚТАУДА ЖӘНЕ БАҒАЛАУДА КЕНОРЫННЫҢ ТЕРМОДИНАМИКАЛЫҚ ЖАҒДАЙЛАРЫНЫҢ ҚАЛЫПТАСУЫ МЕН ҮШӨЛШЕМДІ МОДЕЛЬДЕРІНІҢ РӨЛІ

Аннотация. «Қазақстанның цифрландыру» мемлекеттік бағдарламасы біздің заманымыздың түрлі салаларында заманауи ақпараттық технологияларды жедел енгізуді қарастырады. Геологиялық салада, әсіресе геологиялық ғылымдарда, бұл технологиялар түрлі масштабтағы геологиялық объектілердің кеңістіктік, геоэкологиялық деректер базасын құруға мүмкіндік береді және бұл объектілерді дәйекті, біртұтас, жүйелік-дифференциалды зерттеуге қажетті жағдайды білдіреді, бұл тиімді тәжірибелік мәселелерді ұтымды шешу.

Қазақстанның жер қойнауын геологиялық зерттеуге заманауи цифрлық ақпараттық технологияларды енгізу жаңа мүмкіндіктерді ұсынады және қойылған міндеттерді шешу жолдары заманауи геологиялық зерттеулердің әдіснамалық негізін жетілдіруді талап етеді. Осы әдіснаманы жетілдірудің негізі геологиялық зерттеулер масштабына қарамастан зерттелетін минералды ресурстардың (соның ішінде минералдардың) сандық ғылыми-ақпараттық базасының бірыңғай өзара байланысын (жергілікті және аймақтық географиялық координаттары бар) құру болып табылады.

Төменде Бакенное кен орнының үлгісі оның ғылыми-ақпараттық базасын құруды көрсетеді және осы негізде геологиялық зерттеулер әдіснамасын жетілдіретін болады.

Түйін сөздер: ГАЖ-технологиясы, ArcGIS-10, Micromine, кенорындардың 3D моделі, кенбақылаушы факторлар, кенсиыстырушы орта, сирекметалл кенорындары, пегматитті өріс, болашағы бар аймақтар.

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РОЛЬ ТРЕХМЕРНЫХ МОДЕЛЕЙ МЕСТОРОЖДЕНИЯ И ТЕРМОДИНАМИЧЕСКИХ УСЛОВИЙ ЕГО ФОРМИРОВАНИЯ ПРИ ВЫДЕЛЕНИИ И ОЦЕНКЕ РЕСУРСОВ ПЕРСПЕКТИВНЫХ УЧАСТКОВ

Аннотация. Государственная программа «Цифровизация Казахстана» рассматривает ускоренное внедрение современной информационной технологии в различные сферы нашей жизни. В геологической отрасли, в частности в геологической науке эти технологии позволяют создать точной, привязанной к геологической среде пространственной цифровой базы данных об изучаемых геологических объектахразличных масштабов и она представляет необходимое условия для последовательного, целостного, системно-дифференцированного исследования объектов, позволяющие эффективно и рационально решать практические задачи.

Внедрение современной цифровой информационной технологии в геологическое изучение недр Казахстана представляет новые возможности, и пути решения поставленных задач требует совершенствования методологической основы современных геологических исследований. Основой совершенствования указанной методологии является создание единой взаимосвязанной (с местными и региональными географическими координатами) цифровой научно-информационной базы (основы) изучаемых объектов недр (в том числе, полезных ископаемых) Казахстана, вне зависимости от масштаба геологических исследований.

Ниже на примере месторождения Бакенное будет показано создание его научно-информационной базы, и на этой основе будет показано совершенствование методологии геологических исследований.

Ключевые слова: ГИС-технология, ArcGIS–10, Micromine, 3D модели месторождения, рудоконтролирующие факторы, рудовмещающая среда, редкометалльные месторождения, пегматитовое поле, пятиокисью тантала, перспективная площадь.

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SYNTHESIS OF CARBON NANOTUBES BY THE CVD METHOD ON THE SURFACE OF THE HYDROPHOBIC SHALE ASH

Abstract. The paper presents a procedure for the synthesis of carbon nanotubes (CNTs) by the CVD (Chemical Vapor Deposition) method with the decomposition of carbon monoxide at a pyrolysis temperature of 800 ° C. Cobalt particles were used as the catalyst, and hydrophobic ash of the oil shale (Kendyrlik field) based on superhydrophobic soot was used as the support for the catalyst. The chemical composition was determined and the morphology of the surface of the samples was studied by using the methods of energy-dispersive X-ray spectroscopy, electron microscopy and Raman scattering. The optimum condition for obtaining CNTs by a catalytic method was established, where the holding time was 120 min at a pyrolysis temperature of 800^0C. The yield of carbon nanotubes per unit mass of catalyst was ~ 30%.

Keywords: CNT, catalyst, pyrolysis, shale, ash, soot, CVD method.

Introduction. The last decades were marked by a burst of scientific activity in the development and the study of carbon materials (CM). This was reflected in the purposeful synthesis of allotropic forms of carbon (carbines, fullerenes, nanotubes, circulites, etc.), as well as in the creation of a wide range of porous materials in a series of mixed (transitional) forms of carbon, of practical interest as adsorbents, catalysts and supports for catalysts [1].

The discovery in 1991 of carbon nanotubes (CNTs) has caused a large number of studies devoted to the properties and applications of this modification of carbon in a wide range of fields of science and industry. The improved mechanical characteristics (tensile strength ~ 300 GPa, Young's modulus ~ 1000 GPa) combined with low density (~ 1.8 g/cm^3) and nanometer sizes make it possible to consider carbon nanotubes as a promising reinforcing component [2]. Recently, in connection with their unique properties, the greatest interest among nanomaterials is attracted by carbon nanotubes - carbon allotrope with a cylindrical nanostructure.

A cylinder formed from a single graphite sheet is known as a single-walled carbon nanotube and usually has a diameter of about one nanometer to several tens of nanometers (about 30 to 50) and has a length that can be many orders of magnitude greater than the diameter. Multi-walled carbon nanotubes are carbon compounds with layers consisting of coaxially embedded tubes of different diameters (2÷100 nm) or rolled in the form of a scroll from one or more graphene sheets. Due to their structure, CNTs have a number of unique physical properties compared to traditional carbon-based materials. In particular, they are characterized by high tensile strength (exceeding the strength of steel), flexibility, thermal and electrical conductivity. The most interesting property of carbon nanotubes is that they can have conductivity in metallic or semiconductor types, depending on their diameter and chirality [3].

Unique properties of carbon composite have caused their wide distribution in the chemical industry, due to heat resistance, thermal strength, high chemical resistance and specific strength. They are used for

obtaining high-temperature composite materials [4, 5], modified electrodes [6, 7], sorbents, catalytic systems [8-10], as well as in medicine, security and defense devices, power generation and storage devices, transport, communication, computer technology, building materials. Among the most important properties of CNTs, the connection between the geometric structure of a nanotube and its electronic characteristics should be mentioned first [11, 12]. The use of these materials in the electronics industry is explained by the properties of carbon nanotubes, such as mechanical ductility and significant thermal conductivity. Biocompatibility with human and animal tissues causes the possibility of their use in medicine as a carrier for targeted delivery of medicinal agents to target tissues under directed therapy.

The developed surface and structure of CNTs determine their unique electrochemical and sorption properties, when realizing the conditions for their filling with gaseous or liquid substances. The distance between the layers in the multilayer carbon nanotube is close to the corresponding value for crystalline graphite (3.4 nm). This distance is sufficient for placing another substance inside the CNT, and the graphite shell provides a sufficiently good protection of the material contained in it from external chemical or mechanical action. Therefore, CNTs can be considered as a unique storage tank for substances that are in gaseous, liquid or solid state [13].

The prospect of modified CNTs due to the possibility of their effective use as reinforcing fillers of various composites, elements electronic and energy-saving devices, as well as the creation of biocompatible materials in medicine [14].

Methods for synthesizing nanotubes can be divided into non-catalytic and catalytic methods. In the non-catalytic method, carbon nanotubes are synthesized in helium by thermal spraying of a graphite electrode in arc discharge plasma. Alternative methods are the evaporation of a mixture of carbon and transition metals by a laser beam from a target (consisting of a metal alloy with graphite), methods of thermal chemical deposition, plasma-chemical deposition, etc. The catalytic methods are based on the pyrolysis of CO or hydrocarbons in the presence of metallic catalysts [1].

In the catalytic method of CNT synthesis, small particles of different transition metals, for example, elements of group 8, 6B, 5B or a mixture of two, three, four or more elements (including scandium, titanium, vanadium, chromium, manganese, iron, cobalt , nickel, copper, zinc, yttrium, zirconium, niobium, molybdenum, etc.). Non-volatile metal oxides (magnesium, calcium, zirconium, aluminum, lanthanum, silicon, titanium), some salts (calcium carbonate, spinel, perovskite), zeolite, silica gel, airgel, natural clay, amorphous carbon are used as the catalyst support [15].

During the synthesis, nanotubes begin to appear from the catalyst bed, and their thickness directly depends on the size of the catalyzing metal. The surface is heated to high temperatures, and then the carbon-containing gas is supplied (methane, acetylene, ethylene, ethane, propylene, propane, ethyl or propyl alcohol, etc.). As a diluent gas, nitrogen or argon is used. This method of obtaining nanotubes is the most widespread [16, 17].

The main disadvantage of modern catalytic methods for the production of carbon nanotubes is that they consist of several stages. In addition, the catalyst is usually applied in the form of a powder on a substrate, where the main problem is separation from the last nanotubes. In this connection, there is a need to improve the catalytic process for the production of carbon nanotubes, as well as the need for a low-cost method of rapidly obtaining large quantities of high-quality pure CNTs of uniform dimension that would ensure a high yield. Also studies aimed at developing of various catalysts for the complex treatment of gas emissions of industry under more favorable conditions, are strategically important [18].

The purpose of this work is the synthesis of carbon nanotubes (CNTs) by CVD (Chemical Vapor Deposition) method with the decomposition of carbon monoxide in argon, at a pyrolysis temperature of 800 ° C on the surface of the catalyst (10% Co / 5% soot / 85% ash of shale) and study physicochemical properties of the obtained samples. In the CVD method occurs pyrolysis of carbon-containing gas and the dissolution of carbon in the catalyst nanoparticles, which often there are materials with high solubility of carbon (Fe, Co, Ni) [19].

Research method. Samples of carbon nanotubes (CNTs) were obtained in LLP "Institute of Coal Chemistry and Technology» (Astana, Kazakhstan). A catalyst based on cobalt, which was obtained from 0.5 M $CoCl_2$ in an alcoholic solution in an ultrasonic bath, was used as a stationary layer. The ash part of the oil shale of the Kendyrlik deposit (Kazakhstan) and soot was used as a carrier. To obtain samples of shale ash, the sample was pre-crushed on a hammer mill (Molot-200) to a fraction of 0.1 mm, and then

subjected to heat treatment in a muffle furnace at a temperature of 900 ° C in a current of air for 60 minutes. Samples of carbon black were obtained by electrochemical gassing in an electric field of high voltage on an electrochemical aeroion installation of the series B0-B9 at JSC "Company Absolute Kazakhstan" (Karaganda, Kazakhstan) under the guidance of prof. A.V. Borisenko. The catalyst was then dried in a muffle furnace at 100 ° C for 15 minutes, treated in an inert argon medium at 400 ° C for 1 hour.

The CNT synthesis by gas phase deposition (CVD) was carried out at atmospheric pressure in argon at 800 ° C for 60 and 120 minutes in a horizontal tubular quartz reactor (figure 1).

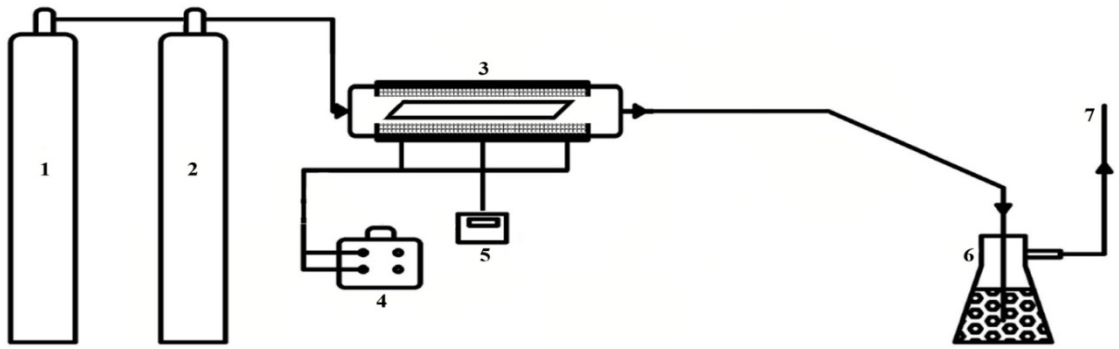


Figure 1 – Schematic diagram of a laboratory installation for the synthesis of CNT:
1 - gas cylinder (argon); 2 - carbon monoxide (CO); 3 - quartz reactor; 4 - LATR;
5 - temperature sensor; 6 - a flask for controlling the gas outlet; 7 - gas outlet

The quartz reactor was heated and cooled in an inert argon medium at a gas velocity of 80 cm^3/min. Carbon monoxide was used as the carbon source (carbon-containing raw material), the feed rate was 80-100 cm^3/min. 7 g of catalyst was charged to a horizontal cylindrical quartz reactor (3) (with an internal diameter of 30 mm). The reactor is wrapped in a nichrome spiral and insulated with asbestos to heat the furnace. The temperature in the reactor was set by means of a heating element (LATR) (4) and monitored according to the indications of a digital thermal sensor "Aries TRM1" (5) equipped with a thermocouple of the chromel-alumel type introduced into a special pocket of the reactor. The temperature in the reactor was maintained with an accuracy of ± 0.2 °C. Up to 150 °C, the temperature increases at a rate of 2°C/min, after 150°C increases at a rate of 1°C/min.

Element composition, structure and dimension of the catalyst of CNTs were studied on a SEM Phenom XL device (the Netherlands), SEM device (Quanta 3D 200i) with an attachment of energy-dispersive spectrometry (EMF), also on a portable X-ray fluorescence spectrometer S1 Titan (Germany).

Raman spectroscopy was measured using a Solver Spectrum (NT-MDT) apparatus, using a 100x objective and exciting radiation in the visible range from a semiconductor laser λ = 473 nm. The accumulation time for all spectra was 30 seconds. The original spectra were processed in the Origin Lab program.

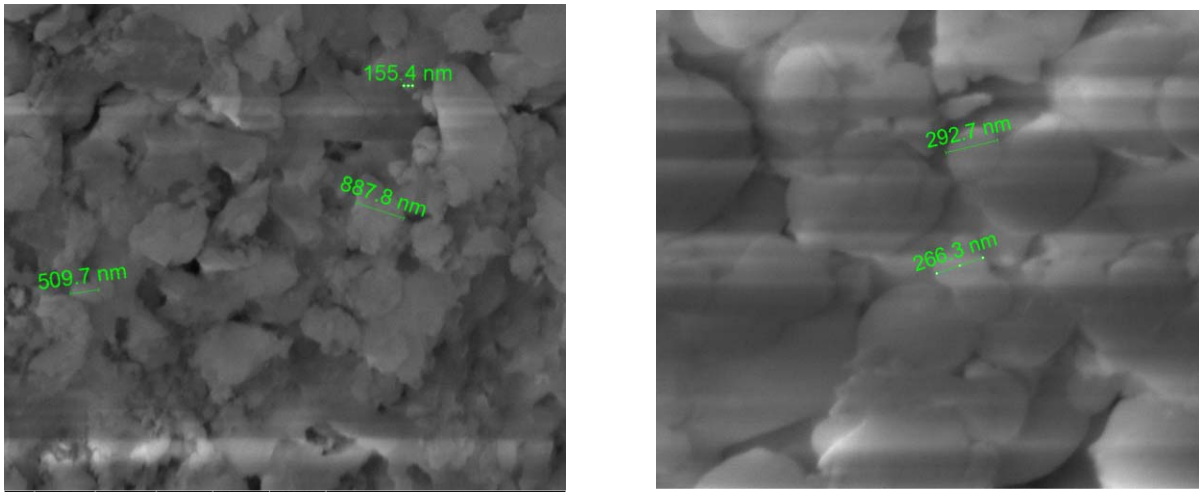
Results and discussion. The results of the elemental analysis, presented in table 1, show that the ash part of the shale contains the main compound of silicon, aluminum, calcium and iron, and the carbon content is only 4.6%, due to the intensive release of volatile organic compounds after heat treatment. The elemental composition of the carbon soot indicates the presence of C, O and Ca, which confirms the results of studying the components of soot obtained by the electronic microprobe JCXA 733 by the scientists of Absolute Kazakhstan Company (Karaganda), where the composition (%): C - 87.88; O - 8.85; Al is 1.08; Si - 2.01; S = 0.15 [17].

Electron microscopic images of Kendyrlyk shale ash and soot are presented in figures 2 and 3. Analysis of the the surface morphology of the samples showed that the cleavage surface is represented by structural heterogeneity and has dense formations with strong agglomerates with particle sizes of ~ 155 ± 900 nm. In some places, the cleavage surface is plate-stepped.

Based on the analysis of microphotographs and elemental composition of the soot, it can be concluded that the basis is a structured carbon matrix composed of particles with dimensions of ~80 - 800 nm, which are indicated in micrographs. The spherical shape is due to the fact that the liquid-like particles

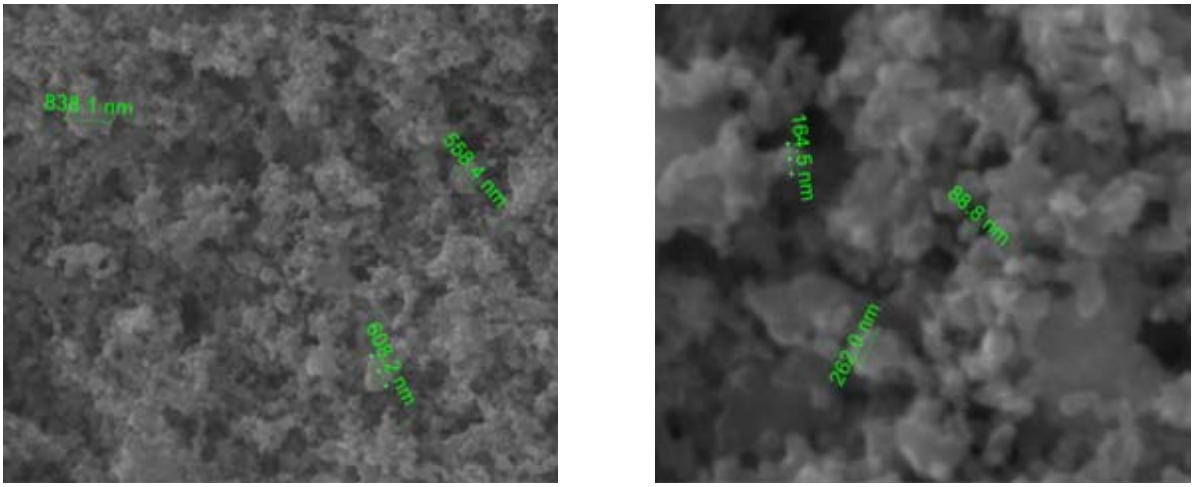
Table 1 – Elemental composition of ash from the Kendyrlyk oil shale and soot

Element	Wt. %	
	Shale ash	Soot
C	4.59	83.67
O	37.33	11.09
Na	0.68	–
Mg	1.37	–
Al	6.99	–
Si	29.91	–
K	2.37	–
Ca	10.54	5.24
Fe	6.20	–



x30 000 x100 000

Figure 2 – Electron microscopic images of ash from the Kendyrlyk oil shale

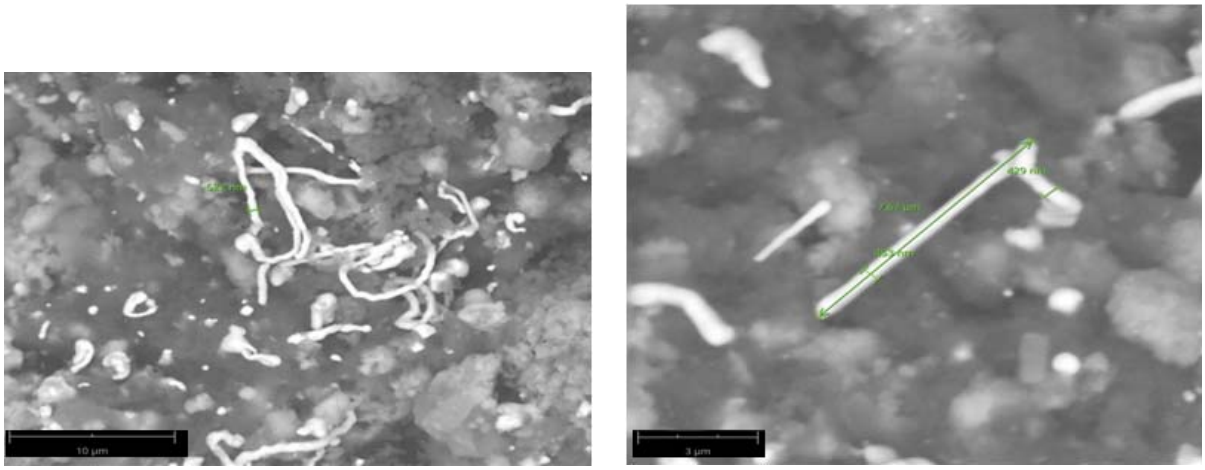


x30 000 x100 000

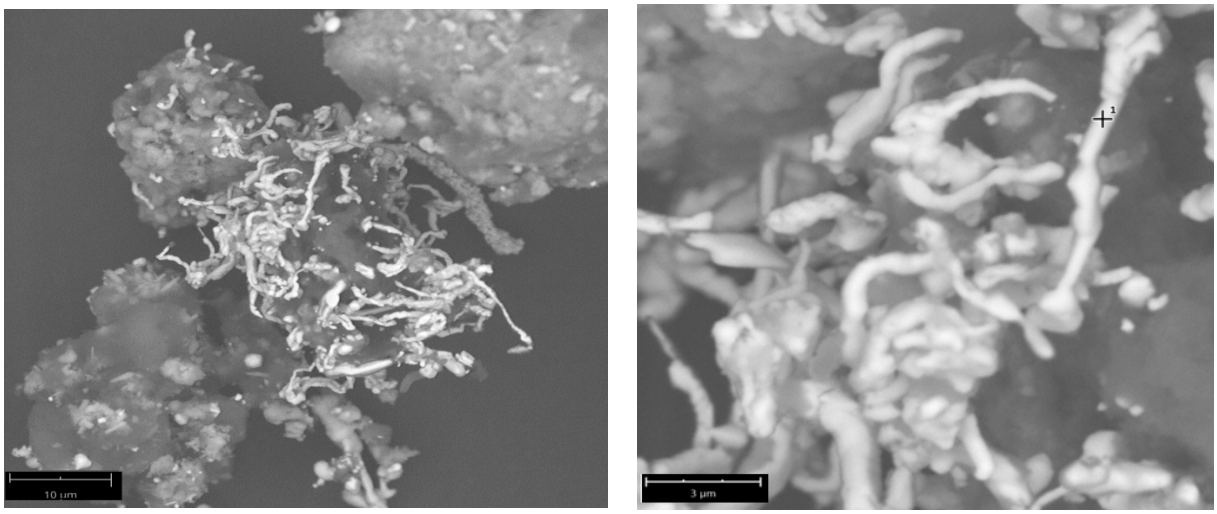
Figure 3 – Electron microscopic images of soot

formed by the associates of the graphene clusters are assembled into droplets that are self-compacted by the action of capillary forces [1]. Different microstructural models of the organization of primary particles suggest that in the near-surface layer a part of graphenes is located parallel to their outer surface. As noted [1], primary globules of carbon soot are usually grouped in fairly strong formations of a certain form (primary aggregates), from which less strong secondary aggregates (or agglomerates) are formed. Depending on the method of packing the primary carbon globules in the aggregates, spherical, ellipsoidal, linear and branched carbon soot particles are classified.

Figure 4 shows SEM photographs of the catalyst (10% Co / 5% soot/ 85% ash of shale) after synthesis by the CVD method at a temperature of 800^0C, the synthesis time of 60 (a) and 120 (b) min.



a



b

Figure 4 – SEM images of the catalyst after synthesis of CVD, synthesis time:
a – 60 min; b – 120 min

As can be seen from the data obtained on the surface of hydrophobic shale in the presence of Co-particles, carbon filaments (filaments) were formed after the synthesis and a carbon material known as CFC-catalytic fibrous carbon is produced. The process of forming filaments includes the following successive stages: the complete decomposition of the hydrocarbon on one of the faces of the metal with the adsorption of carbon atoms on it, their dissolution and diffusion through the volume of the metallic crystallite, followed by the release and formation of graphene on the other face. In this case, the formed graphene exfoliates from the surface of the metal, giving way to the growth of the next. The scheme of the process of obtaining the CFC from carbon monoxide using the kobolt catalyst is shown in figure 5.

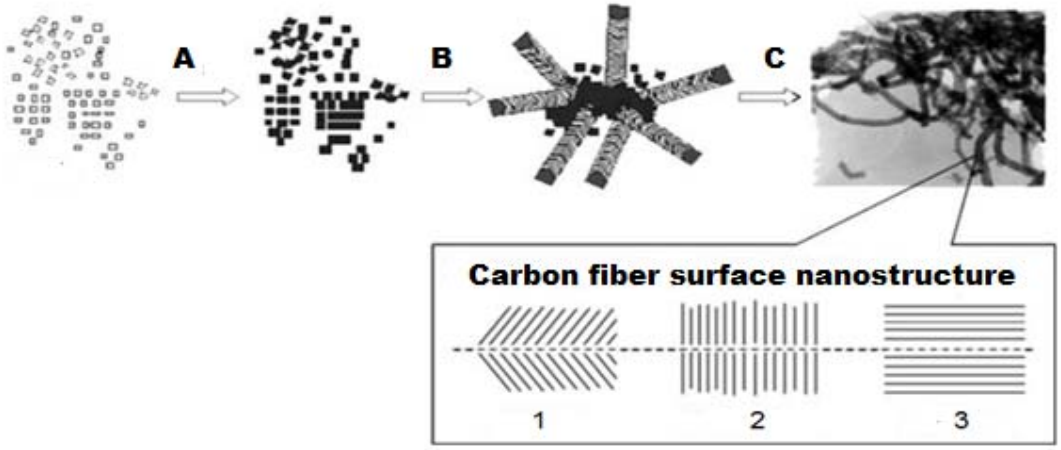


Figure 5 – Scheme for the production of CFC based on Co-catalyst

In stage A, the carbon monoxide decomposes on the surface of the cobalt particles dispersed on the surface of the hydrophobic ash of the oil shale. Carbon is dissolved in metallic cobalt particles to form Co_3C. As a result of the growth of the fibers (stage B), the catalyst particles are separated from one another. Growing fibers (stage C), interwoven into dense tangles, occupy an increasing volume. Note that this feature can be used to produce products of the desired shape from carbon materials. Carbon fibers are known to be graphite-like layers. In this case, the nature of the packing of the layers is determined by the mutual orientation of the faces in the crystallites of the catalyst used. There are three main types of packing layers: 1 - layers in the form of nested one in the other cones - "fish bone"; 2 - layers located perpendicular to the axis of the fiber - "deck of cards"; 3 - nested in one another cylinders, oriented along the axis of the fiber - nanotubes [1]. The derivation of certain types of CFCs depends on the catalytic systems and the synthesis conditions. From the literature data it is known that when using a Co catalyst, nanotubes oriented along the fiber axis are formed, which represent extended structures folded into single or multilayer tubes with a diameter of 100 to 500 nm and a length of about 8 μm. The morphology of the grown CNT is a tubular, curved shape (figure 5). Experimentally it is extremely difficult to synthesize HLCs of the same type with ideal packing of layers.

Table 2 shows the chemical composition of the catalyst after synthesis (10% Co/5% carbon soot/85% ash of shale), which is determined on a portable X-ray fluorescence spectrometer S1 Titan (Germany). The elemental composition confirms the content of the active metal (Co) in the catalyst (9.53%).

Table 2 – Chemical composition of catalyst (wt%)

t, min	SiO_2	Co	Fe_2O_3	CaO	MgO	Al_2O_3	K_2O	MnO	TiO_2	P_2O_5	Cl	S^{daf}	C^{daf}
60	9.97	9.53	4.53	3.09	1.36	0.70	0.31	0.16	0.16	0.03	0.25	0.30	69,55
120	9,58	10,02	4,68	2,81	1,03	0,65	0,22	0,10	0,18	0,01	0,12	0,08	76,68

Figure 6 shows the Raman spectra of the catalyst after synthesis (t = 60 min) in the wave interval 200-3200 cm^{-1}. The sample mainly contains carbon in the amorphous state (a) and in the form of graphite (b) [20]. The peak in the 2730 cm^{-1} region indicates the possibility of containing polycrystalline graphite structures - carbon nanotubes (b). The sample contains cobalt oxide (470, 512 cm^{-1}) (c) [21]. A peak in the region of 455 cm^{-1} in figure 6 (d) indicates the presence of compounds containing SiO_4 groups.

Figure 7 shows the Raman spectra of the catalyst after synthesis (t = 120 min). As the results showed, the sample is heterogeneous, consists of several components. The main part is carbon in the phase of defective graphite (a). In addition, there are regions containing crystalline graphite structures (possibly carbon nanotubes), as evidenced by narrow peaks at 1360, 1575, 2720 and 2940 cm^{-1} (b). Less intense peaks in the low-frequency region of the spectrum (190, 470, 510, 675 cm^{-1}) shown in figures (b) and (c) may indicate the presence of traces of Co_3O_4 cobalt oxide [22].

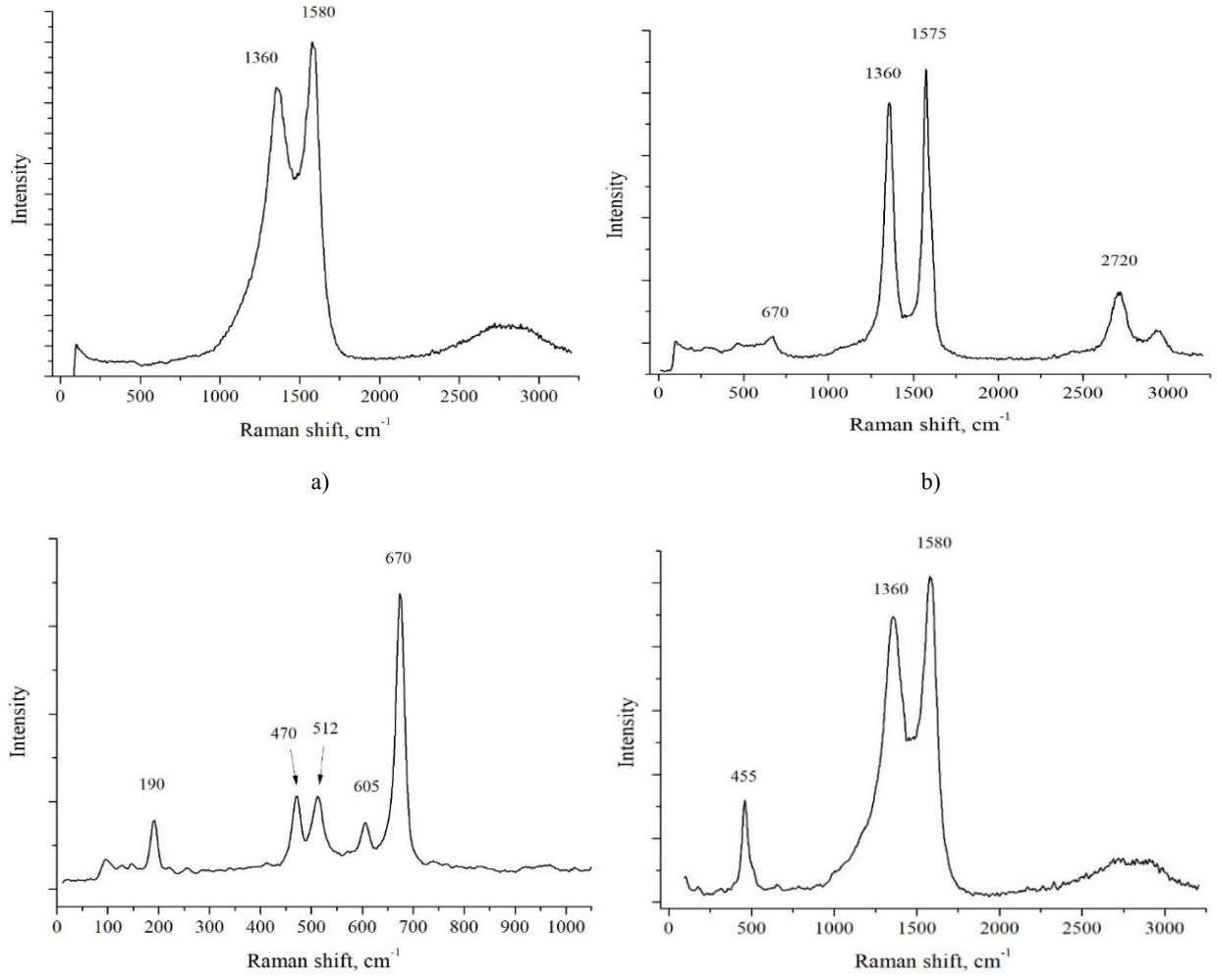
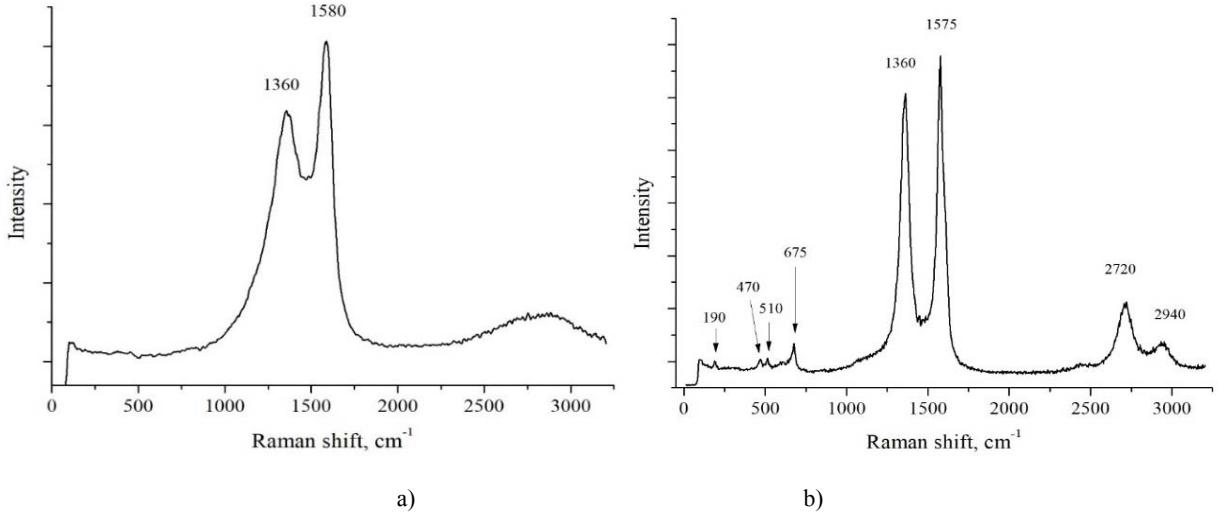
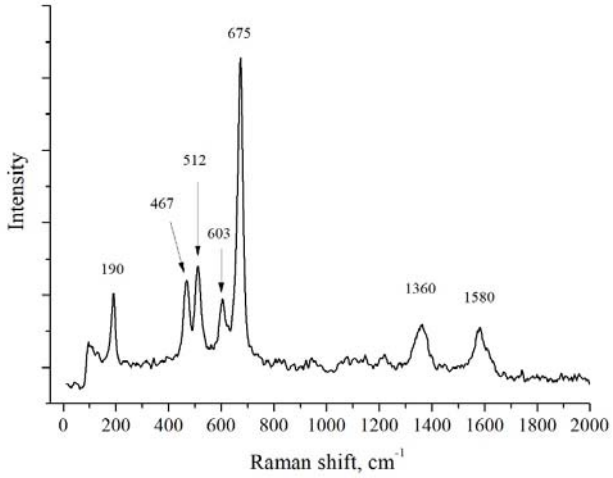


Figure 6 – Raman spectra of the catalyst after CVD synthesis at t = 60 min





c)

Figure 7 – Raman spectra of the catalyst after CVD synthesis at t = 120 min

After synthesis, carbon materials in the form of a film were formed on the walls of the reactor. The elemental composition of the carbon material showed the presence of 100% pure carbon (figure 8).

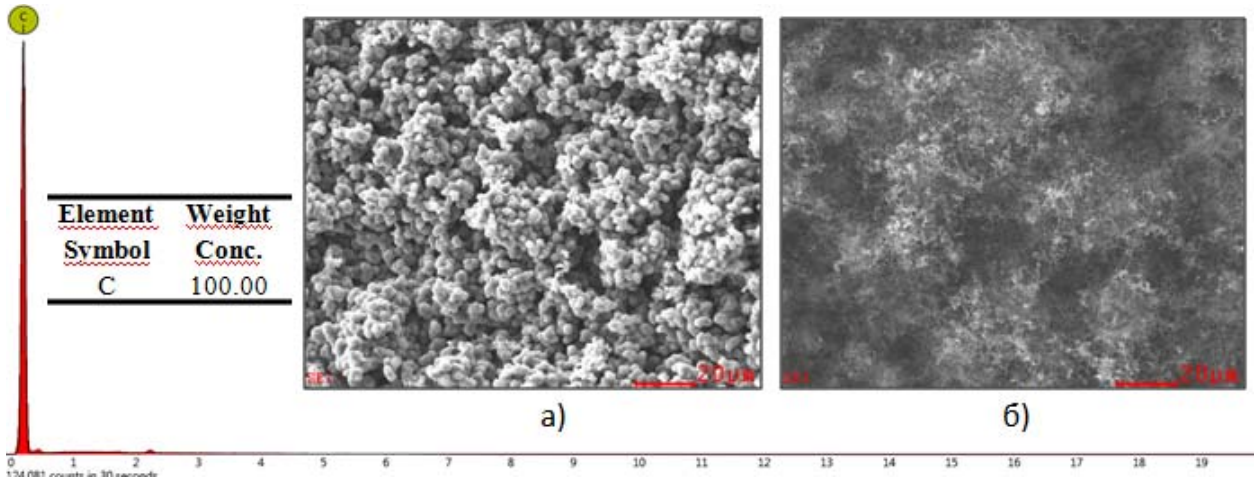
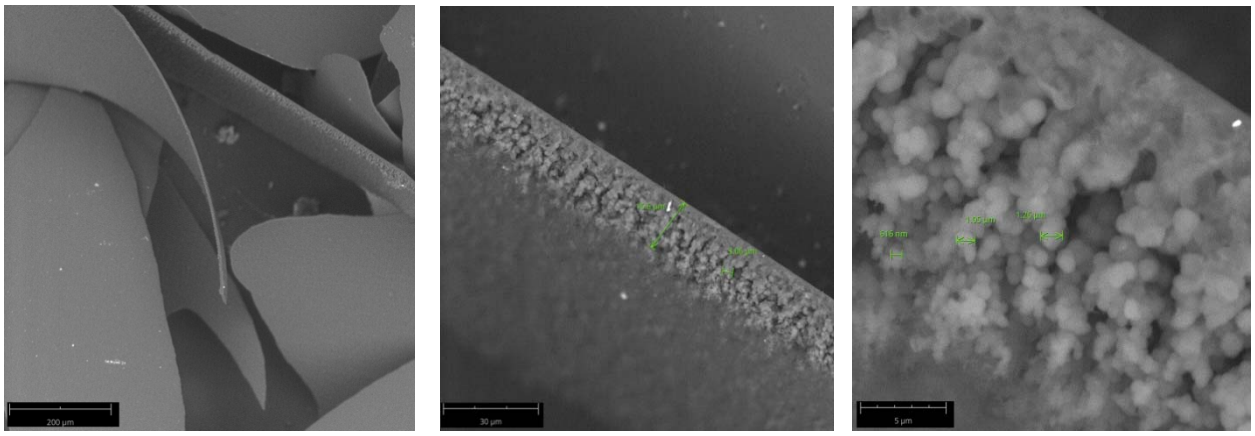


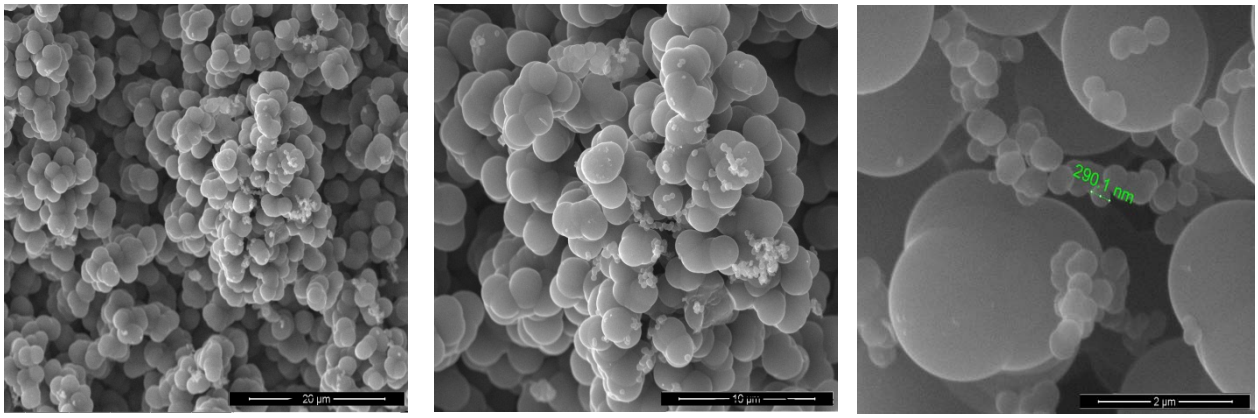
Figure 8 – Elemental composition of the film after synthesis (T = 800^0C) with a holding time: a - 60 min; b - 120 min

Figure 9 shows SEM photographs of carbon films on the walls of a quartz tube after synthesis by the CVD method at a pyrolysis temperature of 800^0C, the synthesis time being 60 min. Carbon material was formed as graphite sheets (also known as graphene), in which the carbon atoms are ordered into sheets with a thickness of 10 to 20 μm. As can be seen from figure 9 (b) the material consists of spherical forms of carbon with dimensions from 200 nm to 1.0 μm. This is due to the fact that during gas-phase thermal decomposition of hydrocarbons, the reaction can proceed through a heterogeneous mechanism with product deposits - pyrolytic carbon (PC) on the equipment walls or other porous materials introduced into the reaction zone.

In this case, the PC is produced in the form of a dense film with a metallic sheen that reproduces all the details of the surface. The process of pyrocarbon formation can be considered as the crystallization of carbon products from the gas phase on the substrate. Growth centers are the embryo of carbon formed from graphenes and their clusters on the surface. During the growth process, carbon atoms from the gas phase interact with the embryos, forming a dense mass. When the pyrolytic layer reaches 10 nm, the influence of the nature of the substrate on the process of its isolation disappears, and the rate of pyrocarbon formation becomes proportional to the surface of the film. Depending on the pyrolysis temperature, the growing carbon layers can form either a turbostratic or graphite-like structure. Pyrocarbon, as a carbon



a)



b)

Figure 9 – Electron microscopic images of the film after synthesis at t = 60 min,
on the device: a - SEM Phenom XL (Netherlands); b - SEM (Quanta 3D 200i)

material, has properties that make it attractive enough for industrial use. However, in view of the fact that it is formed only on free heated surfaces, making any products based on pyrolytic carbon is very difficult. In recent decades, the direction associated with the preparation of carbon-carbon composites has been rapidly developing [1].

An electron microscopic image of a fragment of a carbon material containing CNTs is shown in figure 10, where the retention time of the synthesis was 120 min. Particles of CNT with diameters from 50 to 500 nm are clearly visible, which are folded into a single, seamless seam cylinder. The length of nanotubes can reach tens of micrometers, the end of such a tube can be an open or closed fullerene-like hemisphere. The cylindrical surface of the tubes is formed by hexagons. In real nanotubes, due to the existence of penta- and heptagons, structural defects, the formation of bridges and the sparking of a cylindrical surface are observed [1].

Figure 11 (a) shows the Raman spectrum of the film after synthesis (t = 60 min). The sample is homogeneous in structure, a spectrum characteristic of amorphous carbon is observed. Comparison of the Raman spectrum of the investigated sample with Raman spectra for various forms of carbon [1] reveals a similarity (in terms of structural closeness) of the spectrum to nanocrystalline carbon with different quasi-graphite crystallite sizes.

Figure 11 (b) shows the Raman spectrum of the film after synthesis (t = 120 min), which is the most typical for carbon nanotubes of a rather high degree of ordering, as evidenced by the peak at 2730 cm^{-1}.

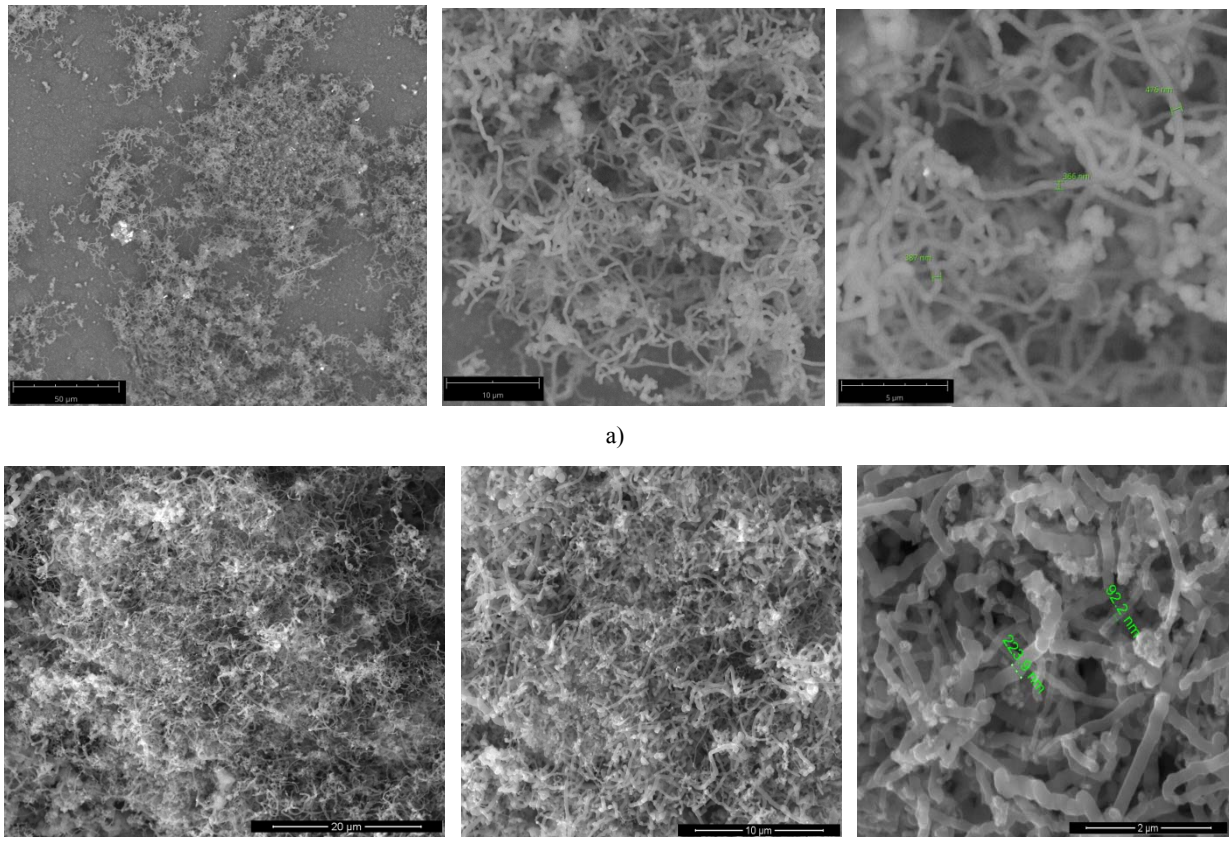


Figure 10 – Electron microscopic images of the film after synthesis at t = 120 min,
on the device: a - SEM Phenom XL (Netherlands); b - SEM (Quanta 3D 200i)

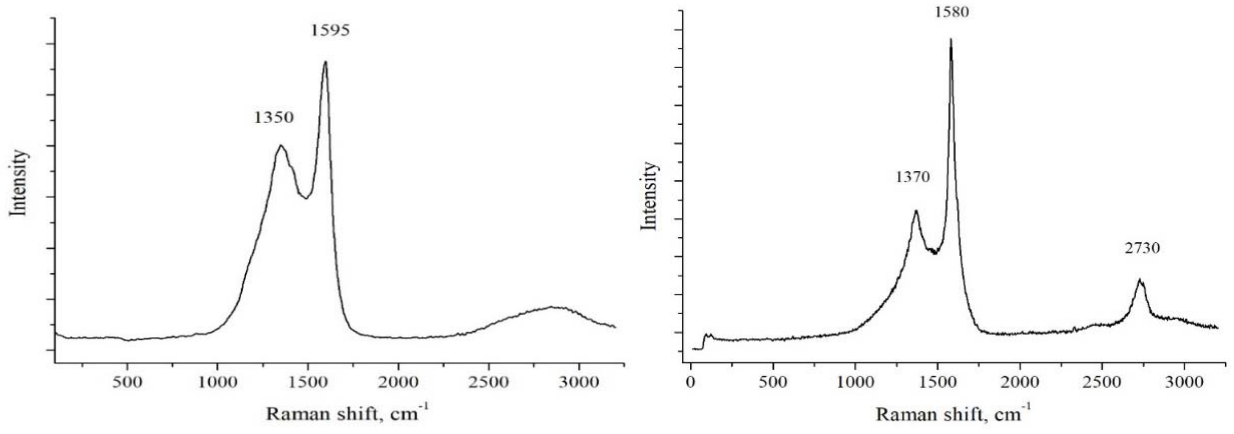


Figure 11 – Raman spectra of the film after CVD synthesis: a - t = 60 min; b - t = 120 min

Conclusions. Thus, the proposed method of carbon nanotubes is based on the method of chemical (catalytic) vapor deposition, which is the most promising method of industrial production and provides a product with a relatively high multilayeredness and homogeneity of the fraction, which determines the achievement of the strength characteristics required for structural materials. As a result of the high-temperature process, carbon nanotubes (CNTs) were obtained at 800^0C (in an inert atmosphere) by the CVD method (chemical Vapor Deposition) with the decomposition of monoxide on the Co catalyst surface, where the hydrophobic ash of the Kendyrlik (Kazakhstan) based on soot. The optimum condition for obtaining CNTs by a catalytic method was established, where the holding time was 120 min at a

pyrolysis temperature of 800 ^{0}C. The yield of carbon nanotubes per unit mass of catalyst was ~ 30%. The carbon nanotubes obtained by this method can be used as a power filler in the production of composite and heat-insulating materials.

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КӨМІРТЕКТІ НАНОТҮТІКШЕНІ CVD ӘДІСІМЕН ГИДРОФОБТЫ СЛАНЕЦ КҮЛІНІҢ БЕТІНДЕ СИНТЕЗДЕУ

Аннотация. Жұмыста көміртекті нанотүтікшені (КНТ) CVD (Chemical Vapor Deposition) әдісімен көміртегі монооксидінің 800 °С пиролиз температурасында ыдырауы нәтижесінде синтездеуге негізделген. Катализатор ретінде кобальт большектері, ал катализаторға тасымалдағыш ретінде супергидрофобты күйе негізіндегі гидрофобты сланец күлі («Кендырлык» кеніші) қолданылды. Энергодисперсионды рентгенді спектроскопия, электронды микроскопия және комбинациялық шашырау әдістері арқылы зерттелген үлгілердің химиялық құрамы және беттік морфологиясы анықталды. КНТ каталитикалық әдіспен алудың оптимальді шарттары анықталды, пиролиз температурасы 800 ^{0}С, ұсталу уақыты 120 мин. Катализатордың массасына салыстырғанда көміртекті нанотүтікшенің шығымы ~30 % құрады.

Түйін сөздер: КНТ, катализатор, пиролиз, сланец, күл, күйе, CVD әдісі.

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СИНТЕЗ УГЛЕРОДНЫХ НАНОТРУБОК МЕТОДОМ CVD НА ПОВЕРХНОСТИ ГИДРОФОБНОЙ ЗОЛЫ СЛАНЦА

Аннотация. В работе представлена методика синтеза углеродных нанотрубок (УНТ) методом CVD (Chemical Vapor Deposition) при разложении монооксида углерода при температуре пиролиза 800 °С. В качестве катализатора были использованы частицы кобальта, а в качестве носителя для катализатора применялась гидрофобная зола сланца (месторождения «Кендырлык») на основе супергидрофобной сажи. С использованием методов энергодисперсионной рентгеновской спектроскопии, электронной микроскопии и комбинационного рассеяния определен химический состав и изучена морфология поверхности исследуемых образцов. Установлено оптимальные условие для получения УНТ каталитическим способом, где время выдержки составил 120 мин при температуре пиролиза 800^{0}С. Выход углеродных нанотрубок на единицу массы катализатора составил ~30 %.

Ключевые слова: УНТ, катализатор, пиролиз, сланец, зола, сажа, метод CVD

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SIMULATION OF THE SOLAR SYSTEM

Abstract. The article offers calculations and visualization of trajectories of solar system planets done by using the MATLAB software. It contains materials such as Kepler's laws, orbital parameters of planets, formulation of the problem, listings of programs, the model of the solar system and the trajectory of the planet Mars motion in a heliocentric frame of reference during the observation time of one year and ten years. The submitted drawing of the solar system model shows that all planets move along an ellipse, in one of the foci of which there is the Sun as the center of gravity.

From the presented trajectory of Mars in Copernican heliocentric system it is seen that one year observation reveals practically no retrograde motion of the planet but ten years observation makes such motion noticeable. Usually planets move in the sky in a forward direction from the West to the East. Near the opposition the planet changes the direction of its motion and moves in inverse direction from the East to the West, i.e. Mars is in a retrograde (backward) motion. The retrograde motion of Mars with respect to Earth is explained on the base of heliocentric model of the solar system.

Results of this article are used on the practical classes on theoretical mechanics and on the laboratory classes on the discipline "Modeling the physical phenomena".

Key words: solar system, Kepler, trajectory, ellipse, retrograde (backward) motion.

Nowadays all educational institutions of Kazakhstan are provided with computer hardware and software, interactive boards and internet. Almost all teachers have completed language and computer courses for professional development. Hence the educational institutions have all conditions for using computer training programs and models for performing computer laboratory works. In recent years the new computer system of carrying out mathematical calculations MATLAB is being widely used in many universities and engineering institutions throughout the world [1-7]. Unfortunately, the numerical calculations carried out by students are often done by means of the calculator. Modern computers are frequently used only for presentation of the work. Actually students should be able not only to solve these or other engineering problems, but also do it by using modern methods, that is, using personal computers.

Students of the physics specialties 5B060400 and 5B011000 successfully master the discipline “Computer modeling of physical phenomena” which is the logical continuation of the disciplines “Information technologies in teaching physics” and “Use of electronic textbooks in teaching physics”. The aim of this discipline is to study and learn the program language of the MATLAB system, acquaintance with its huge opportunities for modeling and visualization of physical processes.

In our early works [8-23] we used the MATLAB system for modeling and visualization of physical processes related with mechanics, molecular physics, electromagnetism and quantum physics. This software has enabled us to solve ordinary differential equations (ODE), visualize equipotential lines of charged conductors system, describe the motion of charged particles in electric, magnetic and gravitational fields and etc.

The present article is devoted to calculation and visualization of trajectories of solar system planets, the motion path of Mars in the heliocentric system of reference by using the package of MATLAB applied programs.

Formulation of the problem. The heliocentric model of the solar system based on the idea that the Earth and planets move around the Sun was presented by the Polish astronomer Nicolas Copernicus in his book "About Rotation of Celestial Spheres" in 1543. Before him the ideas about heliocentric system were found in the works of a number of the Greek, Arab and Indian scientists. Johannes Kepler in his work "New astronomy" written in 1609 formulated the laws of motion of planets, defined the shape of their orbits and established mathematical relationship between their geometrical parameters and periods of their motion.

Orbital parameters of planets

Name	Semimajor axis [a.u]	Eccentricity	Inclination to the ecliptic [degrees]	Revolution period [days]	Axis tilt [degrees]	Orbital speed [km/s]
Mercury	0.38709831	0.205631752	7.004986389	87.96843362	0.00	47.87
Venus	0.72332982	0.006771882	3.394661944	224.6954354	177.36	35.02
Earth	1.000001018	0.016708617	0	365.24218985	23.45	29.79
Mars	1.523679342	0.09340062	1.849726389	686.92970957	25.19	24.13
Jupiter	5.202603191	0.048494851	1.303269722	4330.595765	3.13	13.06
Saturn	9.554909596	0.055508622	2.488878056	10746.94044	25.33	9.66
Uranus	19.21844606	0.046295899	0.77319611	30588.74035	97.86	6.8
Neptune	30.11038687	0.008988095	1.7699522	59799.90046	28.31	5.44
Pluto	39.5181762	0.245938782	17.12259917	90738.995	122.52	4.74

The laws of motion of planets were obtained as a result of a large number of precise astronomical observations. Let's consider three laws of Kepler:

1. The orbits of the planets are elliptical with the Sun at one focus of the ellipse.
2. The radius vector of each planet sweeps out equal areas in equal time.
3. The ratio of the square of each planet's sidereal period to the cube of the semimajor axis of its orbit is a constant for all the planets.

Here is the listing of the program:

```
>> Planet= zeros(9,3);
>> % Semimajor axis (a.u.) Eccentricity; Revolution period (days)
>> Planet(1,:)=[0.38709831; 0.205631752; 87.96843362]; % Mercury
>> Planet(2,:)=[0.72332982; 0.006771882; 224.6954354]; % Venus
>> Planet(3,:)=[1.000001018; 0.016708617; 365.24218985]; % Earth
>> Planet(4,:)=[1.523679342; 0.09340062; 686.92970957]; % Mars
>> Planet(5,:)=[5.202603191; 0.048494851; 4330.595765]; % Jupiter
>> Planet(6,:)=[9.554909596; 0.055508622; 10746.94044]; % Saturn
>> Planet(7,:)=[19.21844606; 0.046295899; 30588.74035]; % Uranus
>> Planet(8,:)=[30.11038687; 0.008988095; 59799.90046]; % Neptune
>> Planet(9,:)=[39.5181762; 0.245938782; 90738.995]; % Pluto
>> Cg= {'m', 'b', 'g', 'r','k'};
>> % drawing the orbits of planets
>> figure('Color',[1 1 1]);
>> ksi=linspace(0,2*pi,500);
>> hold on;
>> plot(0,0,'ok');
>> for iCurP=1:9
>> a=Planet(iCurP,1);
```

```
>> e=Planet(iCurP,2);
>> T=Planet(iCurP,3);
>> t=(0.5*T/pi)*(ksi-e.*sin(ksi));
>> x=a.*(cos(ksi)-e);
>> y=a*sqrt(1-e^2).*sin(ksi);
>> plot(x,y);
>> %plot(x,y,Cg{iCurP-4});
>> %pause(2)
>> end
```

The result is presented in the figure 1.

Figure 1 presents the model of the solar system. The diagrams show that each planet moves along the ellipse with the Sun at one focus of the ellipse. The Sun is the center of gravity and any such model is always developed with violation of the scale.

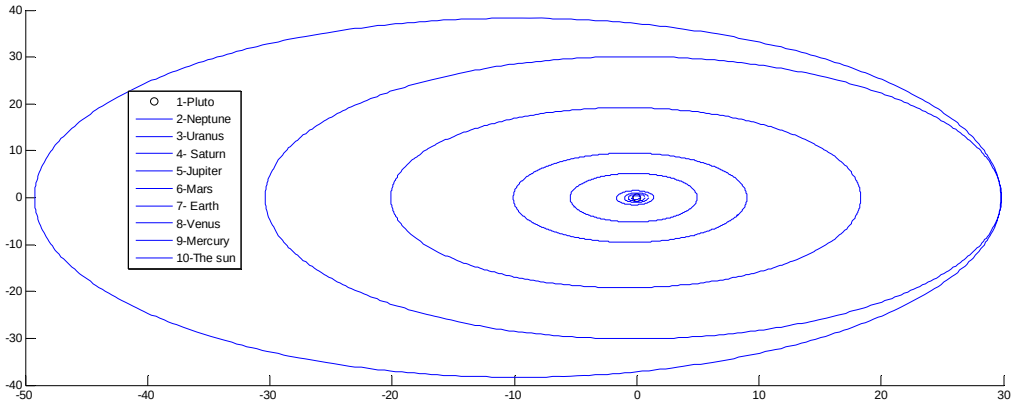

Figure 1 – Trajectories of motion of solar system planets

Calculation and visualization of Mars trajectory in the heliocentric system. Since the ancient times the astronomy tried to solve the mystery of retrograde motions of planets. Such motions are especially noticeable for outer planets. Usually planets move in the sky in a forward direction from the West to the East. Near the opposition the planet changes the direction of its motion and moves in inverse direction from the East to the West. The retrograde motion of the Mars is shown in figure 2.

Figure 2 – The retrograde motion of the Mars

Let us draw the trajectory of the Mars in the geocentric reference system being at the same time within a heliocentric system. In other words we will answer the question: what will be the path of the Mars in the sky for the observer on the Earth? The position vectors describing the motion of the Earth and Mars in the heliocentric system and the position vector describing the motion of the Mars in the geocentric system are connected by a simple relationship:

$$\vec{r}_{SE} + \vec{r}_{EM} = \vec{r}_{SM}$$

The abbreviation in the subscript SE means the Sun and Earth, EM means for the Earth and Mars, SM means for the Sun and Mars. Knowing the position of planets at the same time, it is possible to define the position vector of Mars in the geocentric reference system:

$$\vec{r}_{EM} = \vec{r}_{SM} - \vec{r}_{SE}$$

The listing of the program is:

```
>> R1=1.496*10^8;% input the radius of the Earth's orbit
>> T1=365.24; % input the period of the Earth revolution round the Sun in days
>> Am=2.28*10^8; % input the radius of Mars's orbit
>> Tm=689.98; % input the period of Mars revolution round the Sun in days
>> E=0.093; % eccentricity of Mars's orbit
>> Np=1000; % number of points for one revolution of Mars round the Sun
>> K=9; % number of revolutions of Mars round the Sun
>> dski=(2*pi)/Np*K; % calculation of the step Δϵ of the variable parameter ϵ
>> ksi=0:dski:2*pi; % calculation of values of vector coordinates ϵ_i, % calculation of values of coordinates T_i = r(ϵ_i)
>> T=Tm/(2*pi)*(ksi-E*sin(ksi)); % calculation of instantaneous values of the % Mars's radius-vector Ox component
>> Xm=Am*((1-E.^2).^0.5)*sin(ksi); % calculation of instantaneous values of % the Earth's radius-vector Ox component
>> Xz=R1*cos(2*pi*T/T1); % calculation of instantaneous values of the Earth's % radius-vector Oy component
>> Yz=R1*sin(2*pi*T/T1); calculation of instantaneous values of Mars's % radius-vector Oy component in the reference system connected with the Earth.
>> Xotn=Xm-Xz; % calculation of instantaneous values of the distance between % the Earth and Mars
>> Ym=Am*((1-E.^2).^0.5)*sin(ksi);
>> Xm=Am*(cos(ksi)-E);
>> Xotn=Xm-Xz;
>> Yotn=Ym-Yz;
>> plot(Xotn,Yotn,...% the orbit of Mars
>>'k',...% the initial position of Mars 'MarkerEdgeColor','b','MarkerFaceColor','g','MarkerSize',5);
```

The result is presented in the figure 3.

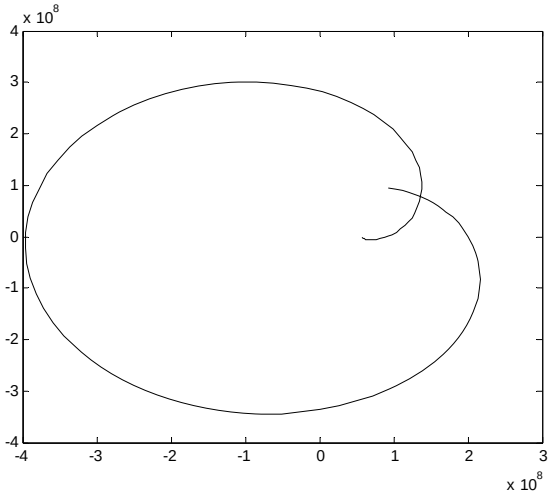

Figure 3 – The trajectory of the Mars (observation time is one year)

During one year observation the retrograde motion of Mars is imperceptible therefore for obtaining this retrograde motion we will increase the observation time up to 10 years.

The listing of the program is:

```
>> R1=1.496*10^8;
>> T1=365.24;
>> Am=2.28*10^8;
>> Tm=689.98;
>> E=0.093;
>> Np=10000;
>> K=9;
 dski=(2*pi)/Np*K;
 ksi=0:dski:2*pi;
T=10*Tm/(2*pi)*(ksi-E*sin(ksi));
Xm=Am*((1-E.^2).^0.5)*sin(ksi);
Xz=R1*cos(2*pi*T/T1);
Yz=R1*sin(2*pi*T/T1);
Xotn=Xm-Xz;
Ym=Am*((1-E.^2).^0.5)*sin(ksi);
Xm=Am*(cos(ksi)-E);
Xotn=Xm-Xz;
Yotn=Ym-Yz;
plot(Xotn,Yotn,...% the orbit of Mars
'k',...% the initial position of Mars
'MarkerEdgeColor','b','MarkerFaceColor','g','MarkerSize',5);
>> Np=10000;
>> K=9;
 dski=(2*pi)/Np*K;
 ksi=0:dski:2*pi;
T=10*Tm/(2*pi)*(ksi-E*sin(ksi));
Xm=Am*((1-E.^2).^0.5)*sin(ksi);
 Xz=R1*cos(2*pi*T/T1);
 Yz=R1*sin(2*pi*T/T1);
 Xotn=Xm-Xz;
 Ym=Am*((1-E.^2).^0.5)*sin(ksi);
 Xm=Am*(cos(ksi)-E);
 Xotn=Xm-Xz;
Yotn=Ym-Yz;
 plot(Xotn,Yotn,...% the orbit of Mars
'k',...% the initial position of Mars
'MarkerEdgeColor','b','MarkerFaceColor','g','MarkerSize',5);
```

The result is presented in the fig.4.

The figure presents the motion of the planet in the sky in the forward direction from west to east and then near the opposition the planet changes the direction of its motion for inverse and moves from east to west (the retrograde motion), i.e. Mars moves along a loop made near the opposition.

Conclusion. Calculations and visualization of trajectories of solar system planets are presented using the MATLAB software. The materials such as Kepler's laws, orbital parameters of planets are applied for simulation the solar system and the trajectory of Mars motion in a heliocentric frame of reference during the observation time of one year and ten years. The submitted drawing of the solar system model shows that all planets move along an ellipse, in one of the foci of which there is the Sun as the center of gravity.

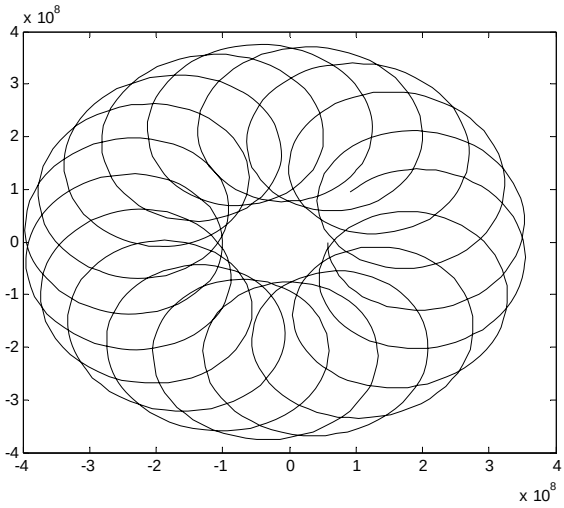

Figure 4 – The trajectory of the Mars (observation time is ten years)

From the presented trajectory of Mars in Copernican heliocentric system it is seen that one year observation reveals practically no retrograde motion of the planet but ten years observation makes such motion noticeable. Usually planets move in the sky in a forward direction from west to east. Near the opposition the planet changes the direction of its motion and moves in inverse direction from east to west, i.e. Mars is in a retrograde (backward) motion. The retrograde motion of Mars with respect to Earth is explained on the base of heliocentric model of the solar system.

Results of this article are used on the practical classes on theoretical mechanics and on the laboratory classes on the discipline "Modeling the physical phenomena".

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КҮН ЖҮЙЕСІНІҢ МОДЕЛІН ҚҰРУ

Аннотация. Күн жүйесінің планеталарының қозғалысын MATLAB бағдарламалық ортасында есептеу мен бейнелеу ұсынылады. Кеплер заңдары, планеталардың орбиталық параметрлері, есептің шарттары, бағдарламаның кодтары, күн жүйесінің моделі және Марс планетасының гелиоцентрлік санақ жүйесіндегі 4 жыл және 10 жыл бақылау кезіндегі қозғалыс траекториялары келтірілген. Келтірілген суреттерден күн жүйесінің моделін байқаймыз-барлық планеталар бір фокусында тарту центрі-Күн орнасқан эллипс бойында қозғалаынын байқаймыз.

Марстың қозғалған траекторысының 1 жылдығында оның кері қозғалысы байқалмайды, ал оның кері қоғалысы уақытты 10 жылға дейін ұзартқанда байқалады. Әдетте планета аспанда батыстан шығысқа қарай тікелей қозғады. Ал қарсылас тұсқа жақын жерде ол қозғалыс бағытын кері өзгертіп шыңыстан батысқа қарай қозғалады, яғни кері қозғалыс жасайды. Марстың осындай кері қозғалысын күн жүйесінің моделі бойынша түсіндіріледі.

Мақаланың нәтижелері теориялық механиканың практикалық сабағында және «Физикалық құбылыстарды молелдеу» пәнінің зертханалық сабақтарында қолданылады.

Түйін сөздер: Күн жүйесі, Кеплер, траектория, эллипс, кері қозғалыс.

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МОДЕЛИРОВАНИЕ СОЛНЕЧНОЙ СИСТЕМЫ

Аннотация. Предлагается расчеты и визуализация траекторий движения планет солнечной системы в программной среде MATLAB. Приводятся законы Кеплера, орбитальные параметры планет, постановка задачи, листинги программ, модель солнечной системы и траектория движения планеты Марс в гелиоцентри-

ческой системе отсчета за время наблюдения 1 год и 10 лет. Из представленного рисунка – модели солнечной системы видно, что все планеты движутся вдоль эллипса, в одном из фокусе которого находится Солнце – центр притяжения.

Из представленной траектории Марса в гелиоцентричесой системе за время наблюдения 1 год незаметно попятное движение планеты и при увеличении времени наблюдения до 10 лет такое движение становится заметным. Обычно планеты движутся по небосклону в прямом направлении с запада на восток. Вблизи противостояния планета меняет направление движения на обратное и движется с востока на запад, т.е. наблюдается попятное (возвратное) движение Марса. Попятное движение Марса на небосводе Земли находит свое объяснение в рамках гелиоцентрической модели солнечной системы.

Результаты данной статьи используются на практических занятиях по теоретической механике и на лабораторных занятиях по дисциплине «Моделирование физических явлений».

Ключевые слова: Солнечная система, Кеплер, траектория, эллипс, попятное движение.

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IMPLEMENTATION OF COVERING ALGORITHM FOR THE ROBOT WITH PARALLEL STRUCTURE

Abstract. The paper considers a 3RPR robot with a parallel structure. One of the main tasks in robotics is to determine the working area of the robot. Algorithms for solving systems of this type are given. The properties and accuracy estimates of the obtained approximations are proved. As an approach to determining the work area, the method of non-uniform coatings was used in this work, which allows one to determine the external and internal approximation of the set of solutions of the system with a given accuracy.

Keywords: parallel structure robot, non-uniform covering, work space, system of nonlinear inequalities.

Robots of a parallel structure are widely used due to a number of design advantages compared with serial mechanisms. For example, less load on the load-bearing elements and better positioning accuracy of the end-effector could be achieved. These robots are formed by a series of parallel kinematic chains connecting the base of the robot and the end-effector.

In this paper considered a parallel robot, having 3 degrees of freedom (figure 1). The given robot type has 3 link rods A_iB_i, which execute forward movements and B_iC, fulfilling two-dimensional motion [1].

For the given robot type the actuators coordinates are positions of B_i, that is, the link rods lengths A_iB_i. B_i, points, that are link roads of A_iB_i. Let's assume, that link rods lengths B_iCi =1,2,3 cannot be random and limited from above and below with some magnitudes l_{min}, l_{max}, with one and the same for all three rods depending on actuators. The C working organ position in the operational space is assigned with masses center coordinates (x,y) and platform tilting angleφin the plane Oxy. Let's denote through DB_iC link rod length, which is a constant value for the given robot, h_i height of lift point B_i from the C levelvia φ_i tilts A_iB_iC between the rod and B_iC and verticalbar A_iB.

Let's recordlimitations in the platform center coordinates, connected with the link rods lengths in the plane Oxy:

$$l_{min} \le |B_iC\sin\varphi_i| \le l_{max}, i = \overline{1,3},$$

or, in expanded form

$$(x - x_{Bi})^2 + (y - y_{Bi})^2 - l_{imax}^2 \le 0, \quad (1)$$
$$l_{imin}^2 - (x - x_{Bi})^2 - (y - y_{Bi})^2 \le 0,$$

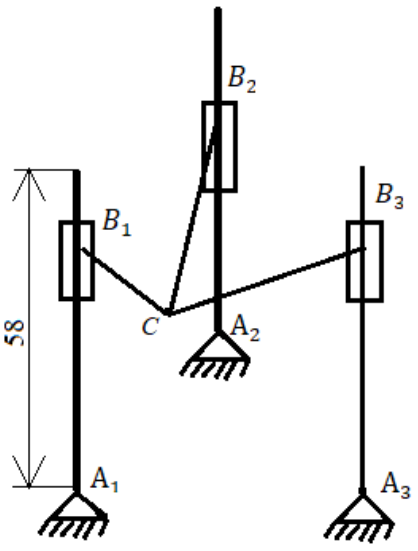

Figure 1 – Inematic diagram

$$i = \overline{1,3}.$$

hereby

$$l_i = D\sin\varphi_i,$$

$$\varphi_i = \arccos\frac{h_i}{D},$$

$$l_i = D\sin\left(\arccos\frac{h_i}{L}\right) = \sqrt{D^2 - h_i^2}, \quad (2)$$

$$\left|\frac{h_i}{D}\right| < 1{,}0 < h_i < D.$$

As it can be seen, the limitations on the given robot have the same formas for the 3RPR type plain robot. It means, that the robot's kinematic diagramis given in the same diagram, which is similar to 3RPR robot, having been considered at the research's previous stages [2].

Numerical outcomes. As we see, at the fixed limitation actuators the heights (1) are assigned with circumference equations in the variables planes (*x,y*). Inourre search we applied anon-uniform coverings concept for constructing the robot's working area based on limitations, which were formed with six inequations (1) on variables (x,y) and limitation (2). In the below given examples we have assigned the fixed values of maximum and minimal height s$h_{max} = 21\ cm, 27\ cm, h_{min} = 7\ cm, 4\ cm$ and computed the possible limitations covering and internal working area. To take in to account the feasible allowances in the minimal and maximum link rods lengths possible values, we have included the allowance for the link rod length asε>0.

Non-uniform covering algorith m (figure 2) for the limitation case in the form of inequation might be formulated as [3, 4]:

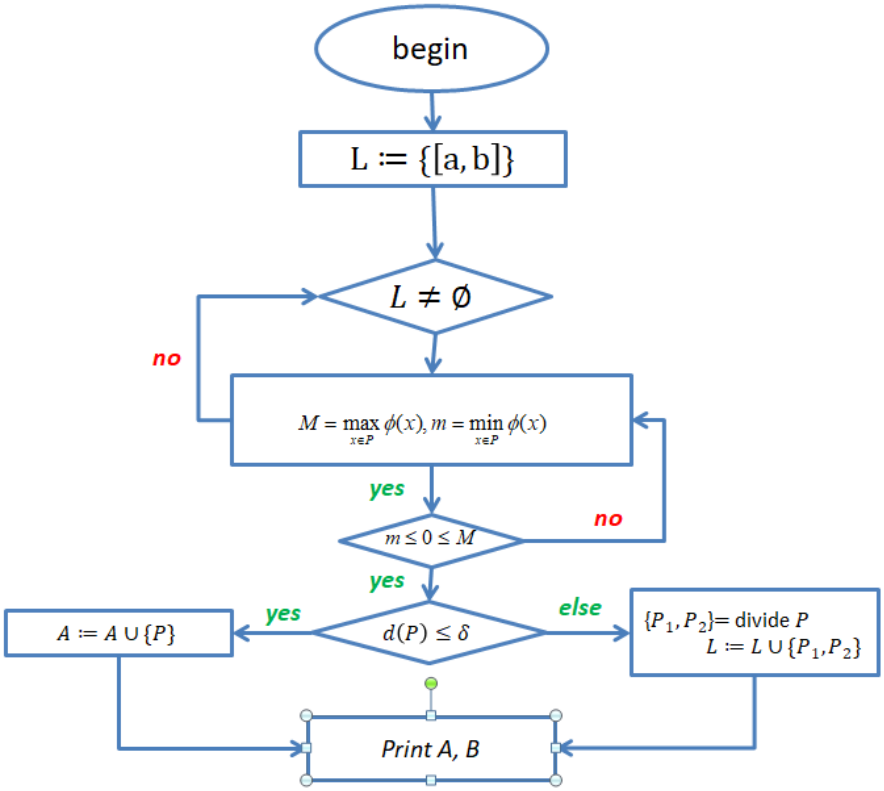

Figure 2 – Covering algorithm

Numerical modeling has been conducted for the following geometrical parameters of the robot: D =B_iC = 22 cm, A_iB_j≤ 58 cm, A_1A_2 = 28 cm.

Table 1 – Operating are a volume for specified actuators height

	$h_{max} = 21\ cm,$ $h_{min} = 7\ cm$	$h_{max} = 27\ cm,$ $h_{min} = 4\ cm$
S(cm^2)	57,81	9,38

Covering the working area and its borders are shown in figure 3 and 4.

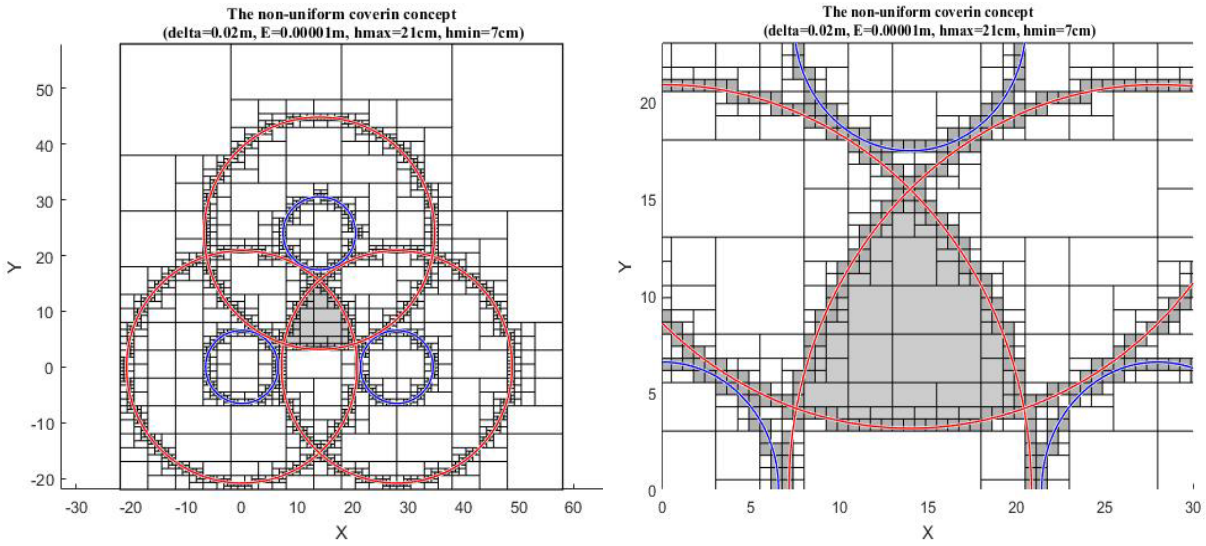

Figure 3 – Covering the working area and its borders, having been constructed
with the non-uniform covering concept at maximum and minimal height values$h_{max} = 21\ см, h_{min} = 7\ cm.$

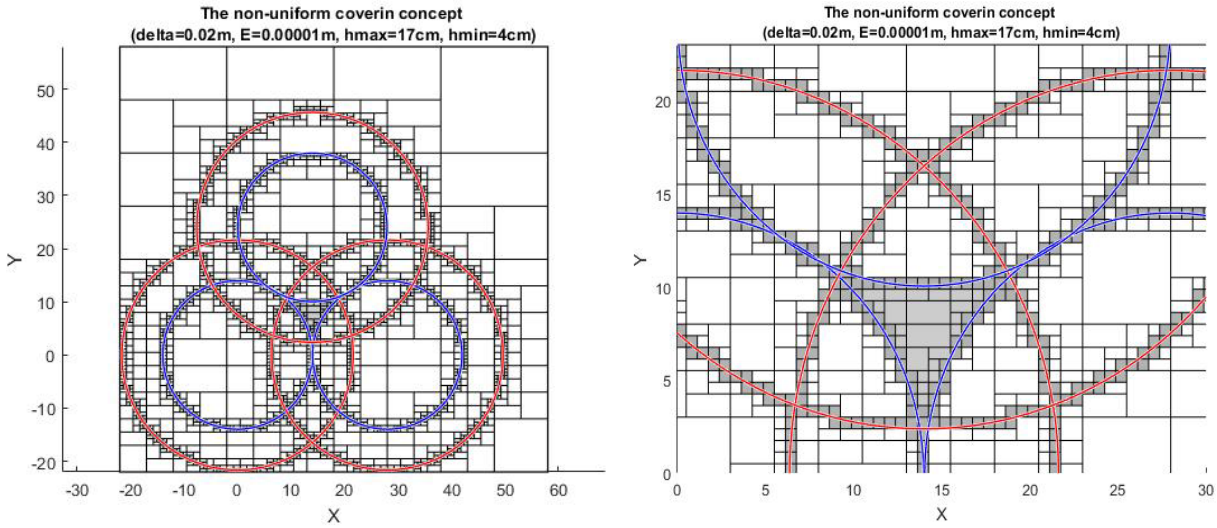

Figure 4 – Covering the working area and its borders, having been constructed
with a non-uniform covering concept at maximum and minimal height values $h_{max} = 27\ cm, h_{min} = 4\ cm.$

Computations have been done on the personal computer in the language C++, the outcomes visualization has been executed in Matlabs of t ware.

Table 2 – Amount of the rectangles, processed in the algorithm to prove the computations different accuracy and ε (figure 5)

δ/ ε (м)	0.02 / 0.0001	0.015/0.0001	0.01/0.0001	0.005/0.0001
Rectangles quantity in the working are a covering	48	72	112	245
Rectangles quantity in borders covering	988	1476	2006	3565
Rectangles quantity in processing	2483	3447	4883	9672

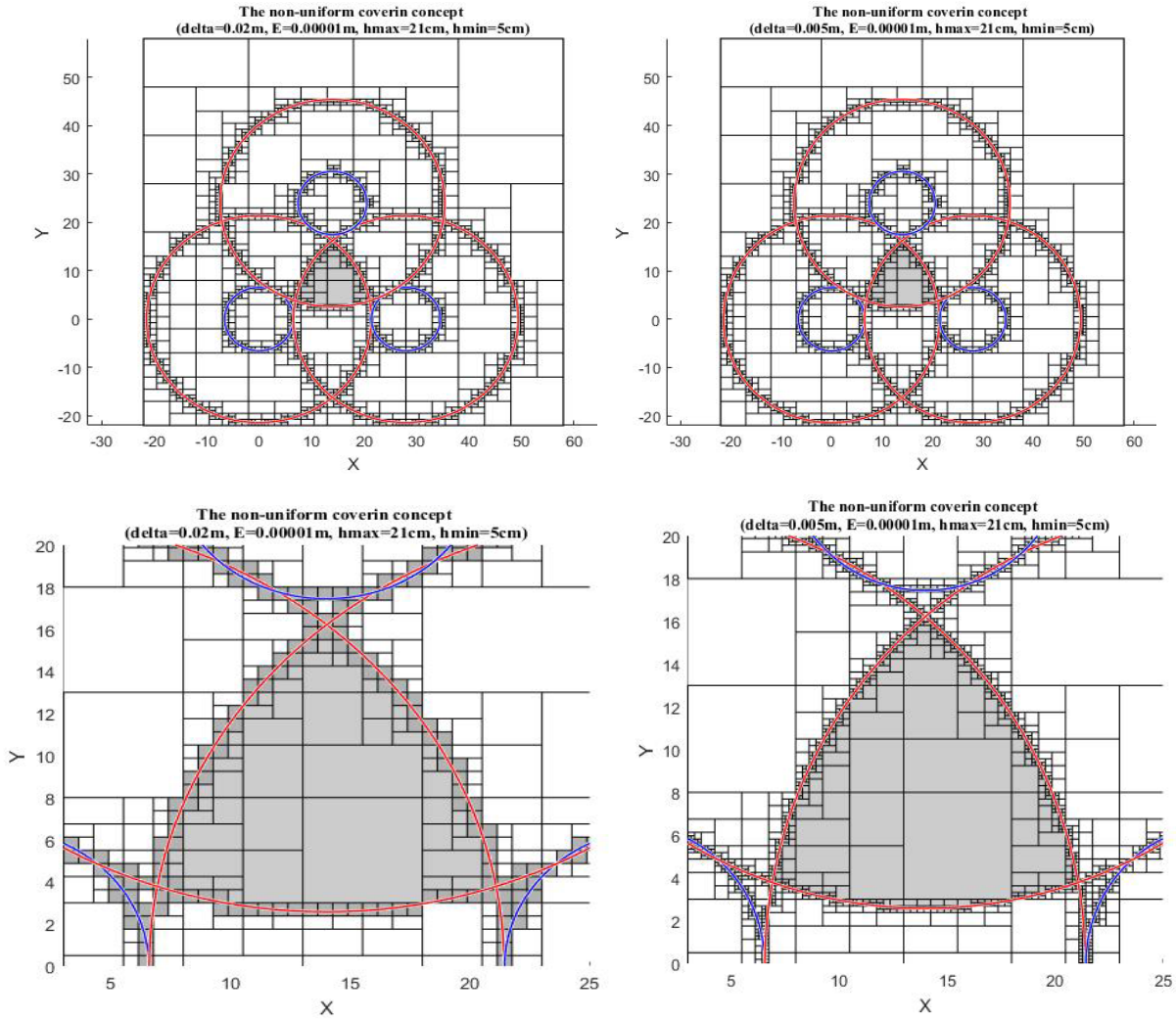

Figure 5 – Covering of the working area and its borders, having been constructed with the non- uniform covering concept for different computation accuracy

Conclusion. At this stage, a numerical implementation of the method of non-uniform coatings was performed for a number of model examples. Numerical calculations showed that the method of non-uniform covering can be applied to models of robots of parallel structure, in particular, for a flat robot with three degrees of freedom 3RPR. In the future, systematic calculations will be performed for different types of constraints and other types of robots. Covering of the working area and its borders, having been constructed with the non- uniform covering concept for different computation accuracy. To prove the computations different accuracy and ε amount of the rectangles, processed in the algorithm. The problem of approximating the solution set of a system of equalities or inequalities is considered. A practical example is given that can be formulated in one of these forms.

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РЕАЛИЗАЦИЯ АЛГОРИТМА ПОКРЫТИЯ ДЛЯ РОБОТА С ПАРАЛЛЕЛЬНОЙ СТРУКТУРОЙ

Аннотация. В статье рассматривается робот 3RPR с параллельной структурой. Одной из основных задач в робототехнике является определение рабочей зоны робота. Приведены алгоритмы решения систем этого типа. Доказаны свойства и оценки точности полученных приближений. В качестве подхода к опреде-

лению рабочей зоны в данной работе использовался метод неравномерных покрытий, который позволяет определить внешнюю и внутреннюю аппроксимацию множества решений системы с заданной точностью.

Ключевые слова: робот параллельной структуры, неравномерное покрытие, рабочаяобласть, система нелинейных неравенств.

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ПАРАЛЛЕЛЬ ҚҰРЫЛЫМЫ БАР РОБОТТЫҢ ҚАМТУ АЛГОРИТМІН ІСКЕ АСЫРУ

Аннотация. Мақалада параллель құрылымы бар 3RPR роботы қарастырылады. Робот техникасындағы негізгі міндеттердің бірі роботтың жұмыс аймағын анықтау болып табылады. Осы типтегі жүйелерді шешу алгоритмдері келтірілген. Алынған жуықтаулардың қасиеттері мен дәлдіктері дәлелденді. Осы жұмыста жұмыс аймағына нықтауға тәсіл ретінде біз жүйенің шешімдер жиынтығын берілген дәлдікпен сыртқы және ішкі жақындастыруды анықтауға мүмкіндік беретін бір келкі емес қамту әдісін қолдандық.

Түйін сөздер: параллель құрылым роботы, біркелкі емес қамту, жұмыс аймағы, сызықты емес теңсіздіктер жүйесі.

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CONDITIONS OF EXTREME STRESS STATE

Abstract. In continuum mechanics, the theory of stresses contains the spreading of Newton's laws for point masses to a continuous medium, and the theory of deformations contains a geometric description of the changes that occur when the points of the body move. Stress is a concept used to determine how loads are transmitted through a solid body. In the three-dimensional coordinate system x, y, z, stresses acting on planes with normals parallel to the coordinate axes are known as components of the stress tensor. To calculate the stability of open and underground mines, it is necessary to know the conditions in which the destruction occurs. The mechanical theory of strength is devoted to the analysis of the boundaries of the stress state at which stability loss and destruction occur.

Key words: stress theory, continuous medium, rocks, stability, nonlinear dependence.

Cohesive rocks up to a certain level of stress and strain generally retain their properties. Any small change in shear strain dγ corresponds to a change in the shear stress dτ of the same sign $d\tau/d\gamma > 0$ (figure 1). The deformed state at the point B is characterized by a plastic component γ^p and an elastic component γ^y of general deformation. The unloading of material from point B will be accompanied by the restoration of elastic deformations, and upon repeated loading to the achieved level τ_B, it will occur purely elastic, without the appearance of additional plastic deformations. Thus, the achieved stress level during reloading after preliminary unloading will serve as the boundary of the elastic state region and is called the yield stress. The stress $\tau_{пр}$ at point C (figure 1) is called the ultimate strength. As long as the level of τ does not exceed $\tau_{пр}$ the loading process is accompanied by an increase in the yield strength, called hardening, after reaching $\tau_{пр}$ in the rock, the process of reducing resistance ($d\tau/d\gamma < 0$), called softening, begins.

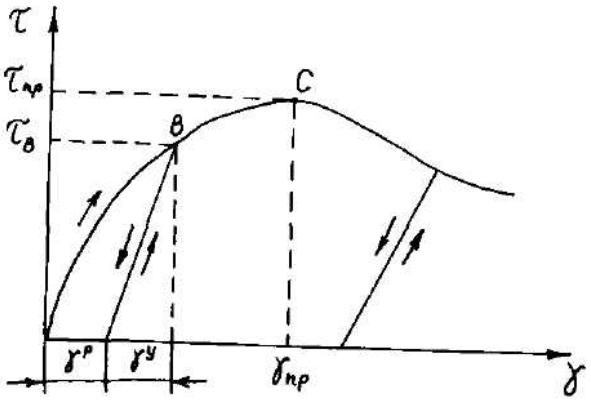

Figure 1 – Nonlinear dependences of stresses and strains in axes γ-τ

In the space of principal stresses, the yield strength will form a certain surface, which is called the yield surface. The equation of this surface is the symmetric function of the principal stresses, in general terms it is written as follows:

$$F(\sigma_1, \sigma_2, \sigma_3) = K, \quad (1)$$

where K is a constant associated with ultimate strength.

Since the basic symmetric functions of the stress components are its invariants, then equation (1) can be represented as:

$$F(J_1(T_\sigma), J_2(T_\sigma), J_3(T_\sigma)) = K, \quad (2)$$

where

$$J_1(T_\sigma) = \sigma_1 + \sigma_2 + \sigma_3 = 3\sigma,$$

$$J_2(T_\sigma) = -(\sigma_1\sigma_2 + \sigma_2\sigma_3 + \sigma_3\sigma_1),$$

$$J_3(T_\sigma) = \sigma_1\sigma_2\sigma_3$$

– are the linear, quadratic, and cubic invariants of the stress tensor.

Concretization of dependence (2) leads to one or another criteria of strength. For rocks, it is of interest to consider the mechanical theories of Tresca, Coulomb, and Mohr [41].

The Tresca criterion states that the ultimate tangential stress in the body is equal to some constant value C:

$$\tau_{пр} = C. \quad (3)$$

Since $\tau_{пр} = (\sigma_1 - \sigma_3)/2$ then we have

$$\sigma_1 - \sigma_3 - 2C = 0. \quad (4)$$

Formula (4) describes a plane parallel to the hydrostatic axis. If we consider all the main stresses to be equal, then the Tresca criterion describes a regular hexagonal prism in the space of the main stresses.

The Coulomb criterion is based on the assumption that the rock's resistance to shear in the fracture plane is equal to the adhesion C plus a value proportional to the normal stress in this plane:

$$|\tau| = C + f\sigma, \quad (5)$$

where $|\tau|$ - the absolute value of the ultimate shear stress; f is the coefficient of proportionality.

The coefficient f is called the coefficient of internal friction, since the expression $f\sigma$ is similar to the dry friction force.

We write criterion (5) in terms of the principal stresses σ_1 и σ_3.

For this, the normal σ and tangent τ stress on the considered site are expressed in terms of the principal stresses:

$$\sigma = \frac{\sigma_1 + \sigma_3}{2} + \frac{\sigma_1 - \sigma_3}{2}\cos 2\beta$$
$$\tau = \frac{1}{2}(\sigma_1 - \sigma_2)\sin 2\beta \quad (6)$$

Where the angle β between the normal N to the site and the direction of stress σ_1 (figure 2).

Putting (6) into (5) gives

$$C = |\tau| - f\sigma = \frac{1}{2}(\sigma_1 - \sigma_3)(\sin 2\beta - f\cos 2\beta) - \frac{1}{2}(\sigma_1 + \sigma_3)f. \quad (7)$$

This expression has a minimum value as a function β when

$$tg2\beta = -\frac{1}{f}. \quad (8)$$

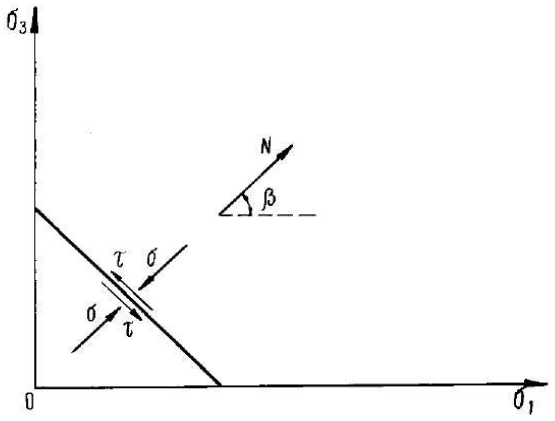

Figure 2 – Graphical representation of stresses on an inclined plane

Since tg 2β< 0, obviously that the angle β lies within 45^0- 90^0 and

$$\sin 2\beta = \left(f^2+1\right)^{-1/2}, \qquad \cos 2\beta = -f\left(f+1\right)^{-1/2} \tag{9}$$

Putting (9) into (7), we obtain the Coulomb criterion expressed in terms of principal stresses:

$$\sigma_1\left[\left(f^2+1\right)^{1/2}-f\right]-\sigma_3\left[\left(f^2+1\right)^{1/2}+f=2C\right]. \tag{10}$$

Concerning (10) it implies that if the left side of the equation is less than 2C, then destruction will not occur; if more - then it will happen.

In the coordinates σ_1,σ_3 the equation (10) describes the line BSC (figure 3).

The uniaxial compression strength S is obtained if we put in equation (10)

σ_3= 0:

$$\sigma_1 = S = 2C[(f^2+1)^{1/2}+f]. \tag{11}$$

The criterion assumes $\sigma_1 > \sigma_3 > 0$, i.e., it corresponds to the conditions of volume compression.

In the tensile site, we supplement the Coulomb criterion with the durability condition at tension:

$$\sigma_3 = T, \tag{12}$$

where T is a durability for tension (T< 0).

The segment ATV corresponds to the formula (12) in figure 3.

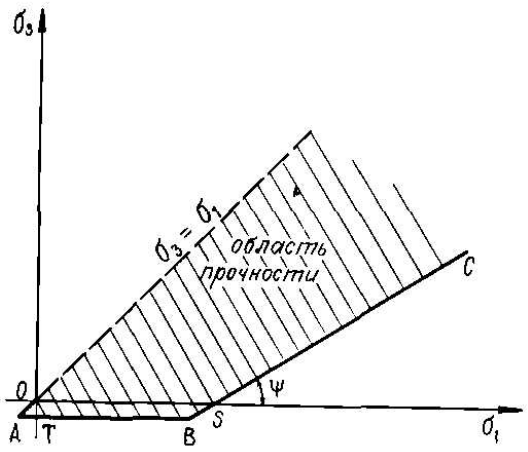

Figure 3 – Coulomb criterion on the axes of principal stresses

Equation (10) can be written by introducing the notation f= tg φ and after simple trigonometric transformations we obtain

$$\sigma_1 = S + \sigma_3 ctg^2\left(\frac{\pi}{4} - \frac{\varphi}{2}\right), \quad (13)$$

where φ is the angle of internal friction.

The slope angle Ψ of the straight line BSC to the axis σ_1 is determined by the ratio:

$$ctg\psi = ctg^2\left(\frac{\pi}{4} - \frac{\varphi}{2}\right) = \frac{1+\sin\varphi}{1-\sin\varphi}. \quad (14)$$

The Coulomb criterion in the space of three principal stresses is a hexagonal pyramid, in which the axis $\sigma_1 = \sigma_3 = \sigma_3$ is the axis of symmetry.

Mohr's criterion states that the resistance to shear along the site is a function of the normal stress on it:

$$/\tau/ = F(\sigma). \quad (15)$$

If the function F is linear, then the Mohr's and Coulomb's criteria coincide. The form of the function F (σ) is determined by the test results under conditions of triaxial compression. In the space σ_1, σ_2, σ_3 the Mohr criterion will describe a surface resembling the Coulomb pyramid, but with curved boundaries.

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АҚЫРЛЫ КЕРНЕУЛІ ЖАҒДАЙДЫҢ ШАРТТАРЫ

Аннотация. Тұтас орта механикасында кернеу теориясы нүктелі массалар үшін Ньютон заңдарының тұтас ортаға таралуынан тұрады, ал деформация теориясы дененің нүктелерін ауыстыруда болатын өзгерістердің геометриялық сипаттамасынан тұрады. Кернеу бұл тұтас дене арқылы жүктемелердің қалай берілуін анықтау үшін қолданылатын ұғым. x, y, z координаттарының үш өлшемді жүйесінде нормалармен, параллель координаттық осьтерге параллель жазықтықта әрекет ететін кернеу тензорының компоненттері ретінде белгілі. Ашық және жер асты тау-кен қазбаларының тұрақтылығын есептеу үшін тау-кен қазбаларының күйреу жағдайларын анықтау қажет. Мақала орнықтылықтың жоғалуы және күйреуі орын алатын кернеулі күй шекарасын талдау кезіндегі беріктіктің механикалық теорияларына арналған.

Түйін сөздер: кернеу теориясы, тұтас орта, тау жыныстары, тұрақтылық, сызықсыз тәуелділік.

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УСЛОВИЯ ПРЕДЕЛЬНОГО НАПРЯЖЕННОГО СОСТОЯНИЯ

Аннотация. В механике сплошной среды теория напряжений содержит распространение законов Ньютона для точечных масс на сплошную среду, а теория деформаций- геометрическое описание изменений, происходящих при перемещениях точек тела. Напряжение это понятие, используемое для определения того, как передаются нагрузки через сплошное тело. В трехмерной системе координат x, y, z напряжения, действующие на плоскостях с нормалями, параллельными координатным осям, известны как компоненты тензора напряжений. Для расчета устойчивости открытых и подземных горных выработок необходимо знать условия, в которых происходит разрушение. Анализу границы напряженного состояния, на которых происходят потеря устойчивости и разрушение, посвящены механические теории прочности.

Ключевые слова: теория напряжений, сплошная среде, горные породы, устойчивость, нелинейная зависимость.

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ABOUT ONE MODEL OF PUMPING OIL MIXTURE OF DIFFERENT VISCOSITIES THROUGH A SINGLE PIPELINE IN AN UNSTEADY THERMAL FIELD

Abstract. The paper discusses the calculation of the flow of oil mixture of different viscosity with decreasing temperature, produced under the action of the classification of loads with I-III types. Flows of the volume of oil mixture of different viscosity can be reduced as much as possible by desalination and separation of impurities.

Keywords: viscous oil, pumped liquid, pipeline, flow rate, differential equation, flow calculation.

Introduction. The study of the prospects of development of the oil refining industry on the example of the Western Kazakhstan oil features allows to determine one of the urgent problems of refining – a high percentage of paraffin-containing and high-sulfur oils. The presence of such impurities indicates a large percentage of high-viscosity oils, which in turn poses the task of analyzing the flow of oil through the pipeline, taking into account the increased viscosity of the medium. **The purpose of the study:** development of the most effective analysis of the model of pumping oil mixtures of different viscosity through a single pipeline in an unsteady thermal field, which allows the refining process to be facilitated with the most economical energy consumption.The considered model allows, in order to be economical and to benefit the region's ecology, to use certain conditions where it is advisable to pump any oil of different viscosity through a single pipeline in order to minimize the volume of the mixture depending on the flow regime of each of them under assumptions.

Methods. For analysis purposes, the following **methodological assumptions** are introduced:

- Mixing at the interface of pumped liquids is negligible, although the number of collisions between elements in the allocated volume is large, compared with the number of collisions of elements with a limiting surface volume, depending on the energy desiccation, flow velocity, distance from solid walls, the geometric shape of the filler cross section, the velocity of the free jet placed in the flow with a longitudinal direction.

- The pressure at the end section of the pipeline remains constant throughout the change of liquids, heavy liquid flows out along the lower tinder forming, the light rises along the upper forming at an unsteady temperature effect in the pipeline system.

- The splitting of the flow velocity allows to obtain a correct viscous solution in one main passage in the direction of flow, where the viscous friction stress is due to the molecular momentum transfer, and the viscosity coefficient of the mechanical system depends on the friction stress itself.

- There are some laminar sublayers between movements in the boundary layer and in the pipe, as a result of which the methods of warm and hydraulic pressure of the oil mixture and the transfer phenomenon make it possible to find the limiting amount of heat and mass according to the Euler integral theorem.

$$k_{in} - k_{out} = \sum(q_k + p_k),$$

where k_{in} – amount of inflowing liquids; k_{out} – amount of outflowing liquids; q_k – impulse of active forces; p_k – impulse of reactive forces.

Results. Under the above assumptions of the flow of petroleum liquids of different viscosities through a single pipeline under unsteady temperature field 80 °C ≥ T ≥ 30 °C can be represented as a mechanical-physical-mathematical model [1-3]:

$$\frac{\partial^2}{\partial x^2}\left[\varepsilon(x)\frac{\partial^2 w}{\partial x^2}\right] = q_k \diagup D\ \lambda^2\ \frac{c\rho}{k} c(w)\frac{\partial w}{\partial t}, \tag{1}$$

where $\varepsilon(x)$ is the coefficient of liquid of the cross-sectional area of the tubular structure, depending on the temperature; k – coefficient of thermal conductivity,

$$q_k \diagup D = \lambda_k \frac{N}{Q}\gamma^2 \frac{1}{1+\lambda_k^{'}\gamma^2}\left(\frac{h}{R}\right)^{5/2}\left(R/2\right) -$$

active external load (impulse) $c(w) = \beta$ – heat capacity per unit volume; k – coefficient of thermal conductivity; c – heat capacity; ρ – density. $W(x,t)$ – displacement function in OZ axis direction and

$$W(x,t) = W(x)T(t), \tag{2}$$

then

$$\frac{d^2}{dx^2}\left[\varepsilon(x)\frac{\partial^2 w}{\partial x^2}\right]\cdot T(t) = \frac{q_k}{D}\frac{c\rho}{k}\beta W(x)\frac{dT}{dt}, \tag{3}$$

where

$$\frac{\dfrac{d^2}{dx^2}\left[\varepsilon(x)\dfrac{\partial^2 w}{\partial x^2}\right]}{\dfrac{q_k}{D}\dfrac{c\rho}{k}\beta W(x)} = \frac{1}{T}\frac{dT}{dt}; \tag{4}$$

$$\frac{d^2}{dx^2}\left[\varepsilon(x)\frac{\partial^2 w}{\partial x^2}\right] = -\lambda^2\ \frac{q_k}{D}\frac{c\rho}{k}\beta W(x); \tag{5}$$

$$\left.\begin{array}{l} \dfrac{dT}{dt} + \lambda^2 T = 0, \dfrac{d^2T}{dt^2} + CO_4^2 T = \dfrac{Q}{a_0} \\ Q = \displaystyle\int_0^l q_k(x,t)W(x)dx, \lambda^2 = \dfrac{n\pi h}{L} \end{array}\right\}. \tag{6}$$

The ordinary differential equation (6) is easily solved, the expression of potential, kinetic energy is written and the Lagrange equation is involved, and the ordinary differential equation (5) is the Euler equation.

$$\left[\varepsilon(x)\frac{d^4W}{dx^4} + 2\varepsilon^{'}(x)\frac{d^3W}{dx^3} + 2\varepsilon^{''}(x)\frac{d^2W}{dx^2}\right] + aW = 0, \tag{7}$$

where $a = \dfrac{q_k}{D}\lambda^2\beta\dfrac{c\rho}{k}$.

In particular:

$$\varepsilon(x) = Dx^4. \tag{8}$$

Then

$$\left[x\frac{d^4W}{dx^4} + 8x^3\frac{d^3W}{dx^3} + 12x^2\frac{d^2W}{dx^2} \right] + aW = 0. \tag{9}$$

The following cases are possible:

A) for 0 < a < 1, for example $a = \frac{3}{4}$, then ($a = \frac{q_k}{D}\lambda^2\beta\frac{c\rho}{k}$)

$$W(x) = x^{-1/2}\left(C_1x^{m_1} + C_2x^{m_2} + C_3x^{m_3} + C_4x^{m_4}\right), \tag{10}$$

where

$$m_{1,2} = 5/4 + \sqrt{1-a}. \tag{11}$$

B) for $a = 1$, then

$$W(x) = x^{-1/2+m_1}\left(C_1 + C_2\ln x\right) + x^{-1/2+m_2}\left(C_3 + C_4\ln x\right), \tag{12}$$

where

$$m_{1,2} = \pm 1/2 + \sqrt{5}. \tag{13}$$

C) for a > 1, for example $a = 5$, 1< x < 4 $\beta = 1/2\sqrt{1/2\left(\sqrt{89}-5\right)}, \alpha = 1/2\sqrt{1/2\left(\sqrt{89}+5\right)}$

$$W(x) = x^{-1/2}\left[\left(C_1x^{\alpha} + C_2x^{-\alpha}\right)\cos(\beta\ln x) + (C_3x^{\alpha} + C_4x^{-\alpha})\right], \tag{14}$$

where $\alpha = \sqrt{2}\cos(\varepsilon/2), \beta = \sqrt{2}\sin(\varepsilon/2), r = a + \frac{9}{16}$;

$$\sin\varepsilon = \frac{\sqrt{a-1}}{r}, \cos\varepsilon = \frac{5}{4r}. \tag{15}$$

Since we have considered the tubular structure under the action of an external active force, it is necessary to further consider the nonhomogeneous equation of the form

$$\frac{d^2}{dx^2}\left[x^4\frac{d^2W}{dx^2} \right] + om = x^2 - 2x + 2. \tag{16}$$

A particular solution of which is

$$W^*(x) = \frac{1}{a+24}x^2 - \frac{2}{a}x + \frac{2}{a}. \tag{17}$$

Then, on the basis of formulas (10) – (15), we have:

Case A).

$$W(x) = x^{-1/2}\left(C_1x^{m_1} + C_2x^{m_2} + C_3x^{m_3} + C_4x^{m_4}\right) + \frac{1}{a+24}x^2 - \frac{2}{a}x + \frac{2}{a}, \tag{18}$$

where $0 < a < 1, m_{1,2} = \frac{5}{4} \pm \sqrt{1-a}; a = \frac{q_k}{D}\lambda^2\beta\frac{c\rho}{k}$.

The general solution of the differential equation (6) we write in the form

$$T(t) = T_0 e^{-\lambda^2 t}, \tag{19}$$

where $T(0) = T_0$.

Consequently:

$$W(x) = T_0\left[x^{-1/2}\left(C_1 x^{m_1} + C_2 x^{m_2} + C_3 x^{m_3} + C_4 x^{m_4}\right) + \frac{1}{a+24}x^2 - \frac{2}{a}x + \frac{2}{a}\right] e^{-\lambda^2 t}. \tag{20}$$

Case B)

$$W(x) = x^{-1/2+m_1}\left(C_1 + C_2 \ln x\right) + x^{-1/2+m_2}\left(C_3 + C_4 \ln x\right) + \frac{1}{a+24}x^2 - \frac{2}{a}x + \frac{2}{a}, \tag{21}$$

where $a = 1; m_{1,2} = \pm\frac{1}{2}\sqrt{5}$.

The general solution of the differential equation (6) we will write in the form:

$$T(t) = T_0 e^{-\lambda^2 t}$$

then

$$W(x) = T_0\left[x^{-1/2+m_1}\left(C_1 + C_2 \ln x\right) + x^{-1/2+m_2}\left(C_3 + C_4 \ln x\right) + \frac{1}{a+24}x^2 - \frac{2}{a}x + \frac{2}{a}\right] e^{-\lambda^2 t} \tag{22}$$

$$\lambda^2 = \frac{n\pi h}{L}, T_0 = \{1,2,3,4,5\}.$$

Case C) similarly:

$$\begin{aligned} W(x) = T_0 \{ & x^{-1/2}\left[C_1 x^{\alpha} + C_2 x^{-\alpha}\right)\cos(\beta \ln x) + \left(C_3 x^{\alpha} + C_4 x^{-\alpha}\right)\sin(\beta \ln x)\right] + \\ & + \frac{1}{a+24}x^2 - \frac{2}{a}x + \frac{2}{a}\} e^{-\lambda^2 t} \end{aligned} \tag{23}$$

where $\alpha = \sqrt{r}\cos(\varepsilon/2), \beta = \sqrt{r}\sin(\varepsilon/2); r^2 = a + \frac{9}{16};$

$$\sin\varepsilon = \frac{\sqrt{a-1}}{r}; \cos\varepsilon = \frac{5}{4r}. \tag{24}$$

Static deflection is determined from natural oscillations

$$\frac{d^2}{dx^2}\left[\varepsilon(x)\frac{d^2 W}{dx^2}\right] = 0. \tag{25}$$

A particular solution of which is

$$W(x) = c_1 + c_2 x + \int_a^x \frac{x-t}{\varepsilon(t)}\left(c_3 + c_4 t\right)dt, \tag{26}$$

or

$$W(x) = c_1 + c_2 x + c_3\varphi(x) + c_4\varphi(x), \tag{27}$$

where

$$W(x)=\int_a^b \frac{|x-t|}{\varepsilon(t)}dt, \quad \varphi(x)=\int_a^b \frac{|x-t|^t}{\varepsilon(t)}dt\,. \tag{28}$$

On an interval [*a*,*b*], on which $\varepsilon(x)\neq 0$ and twice continuously differentiable.

Fundamental solution

$$g_1(x,\xi)=\int_a^b \frac{|x-t||\xi-t|}{4\varepsilon(t)};$$

$$g_2(x,\xi)=\frac{|x-\xi|}{|x-\xi|}\int_\xi^x \frac{(x-t)(t-\xi)}{2\xi(t)}dt\,. \tag{29}$$

In the case of transverse vibrations of the tubular structure, the following right conditions are encountered:

$$\text{A)}\ \ \mathrm{W(x)}\Big|_{\substack{\mathrm{x=0}\\ \mathrm{x=L}}}=0;\ \ \frac{dW}{dx}\Big|_{\substack{\mathrm{x=0}\\ \mathrm{x=L}}}=0; \tag{30}$$

stringently

$$\text{B)}\ \ \mathrm{W(x)}\Big|_{\substack{\mathrm{x=0}\\ \mathrm{x=L}}}=0;\ \ \frac{d^2W}{dx^2}\Big|_{\substack{\mathrm{x=0}\\ \mathrm{x=L}}}=0; \tag{31}$$

$$\text{C)}\ \ \frac{\mathrm{d}^2W}{dx^2}\Big|_{\substack{\mathrm{x=0}\\ \mathrm{x=L}}}=0;\ \ \frac{d^3W}{dx^3}\Big|_{\substack{\mathrm{x=0}\\ \mathrm{x=L}}}=0; \tag{32}$$

free boundary conditions.

Possible mixed boundary conditions.

We introduce the notations

$$D)\ \alpha=\int_a^b \frac{dt}{\varepsilon(t)};\ \ \beta=\int_a^b \frac{tdt}{\varepsilon(t)};\ \ \gamma=\int_a^b \frac{t^2dt}{\varepsilon(t)}; \tag{33}$$

Then, in the accepted notation for the Green function of various boundary value problems, we have:

$$\text{I)}\quad \Gamma^{\mathrm{I,I}}=g_1(x,\xi)+\frac{1}{4(\alpha\gamma-\beta^2)}\{\varphi(x)[\beta\varphi(\xi)-\gamma\varphi(x)]+\varphi(x)[\beta\varphi(\xi)-\alpha\varphi(\xi)]\}, \tag{35}$$

where $\alpha\gamma-\beta^2\neq 0.$

$$\text{II)}\quad 4\Gamma^{\mathrm{II,II}}=4g_1(x,\xi)+\gamma+(\beta-2\gamma)\xi-\varphi(\xi)+[\beta-2\gamma+(\alpha-4\beta+4\gamma)\xi+ \\ +2\varphi(\xi)-\varphi(\xi)]x-\xi\varphi(x)+(2\xi-1)\varphi(x) \tag{35}$$

for $a=0,b=1;0\le t\le 1.$

III) $\Gamma^{\mathrm{III,III}}$ – does not exist. In these cases, it is possible to construct generalized Green's functions, since the boundary value problems have a nonzero solution c_1+c_2x.

IV) $$N\Gamma^{\mathrm{I,II}} = Ng_1(x,\xi) + (x-b)[(\xi-b)(2\gamma-\beta^2) + (\gamma-b\beta)\varphi(x) + (b\alpha-\beta)\varphi(x)] - \varphi(x)[(\xi--b)(b\beta-\gamma) + b^2\varphi(\xi) - b\varphi(\xi)] + \varphi(x)[(\xi-b)(b\alpha-\beta) + b\varphi(\xi) - \varphi(\xi)] \quad (36)$$

where $N = 4(b^2\alpha - 2b\beta + \alpha) \neq 0.$

V) $$4\Gamma^{\mathrm{I,III}} = 4g_1(x,\xi) + \gamma - \beta\xi - \varphi(\xi) + [\alpha\xi - \beta + \varphi(\xi)]x + \xi\varphi(x) - \varphi(x). \quad (37)$$

VI) $\Gamma^{\mathrm{II,III}}$ – does not exist, since it has a nonzero solution. We can construct a generalized Green's function $c(x-\alpha)$.

Graphs 1–3 show the flow of the oil mixture with different viscosities when changing the shear modulus $\mu(T)$, the Poisson's ratio $\upsilon(T)$ and the linear expansion coefficient $\alpha(T)$ for the elastic-viscous region according to figures 1, 2.

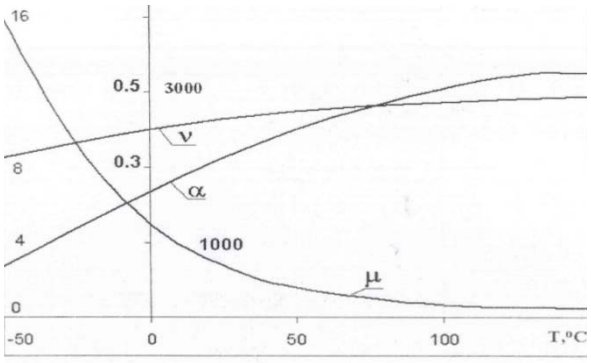


Figure 1 – Dependence of the shear modulus, the Poisson's ratios and the linear expansion on temperature

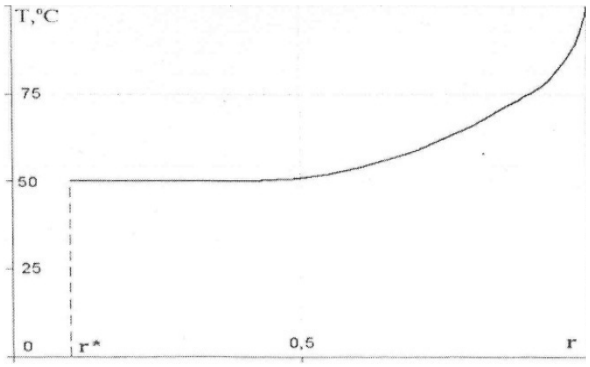
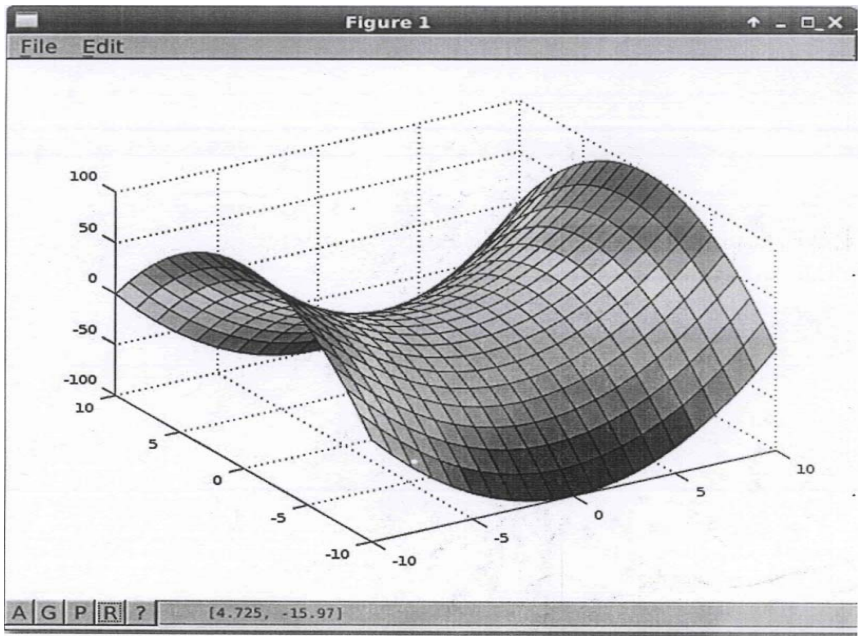
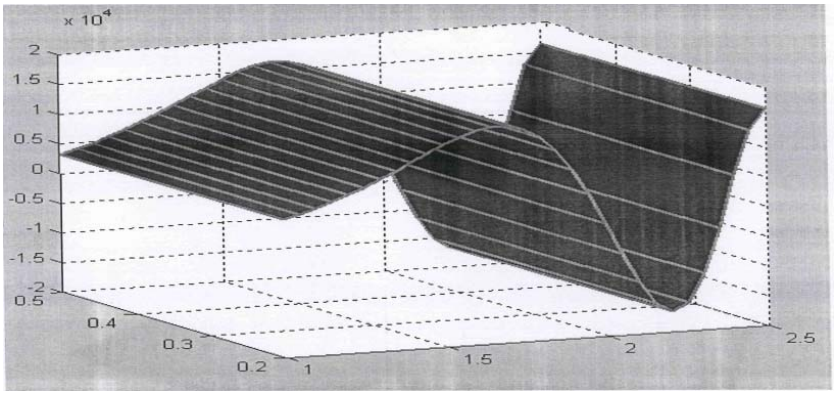


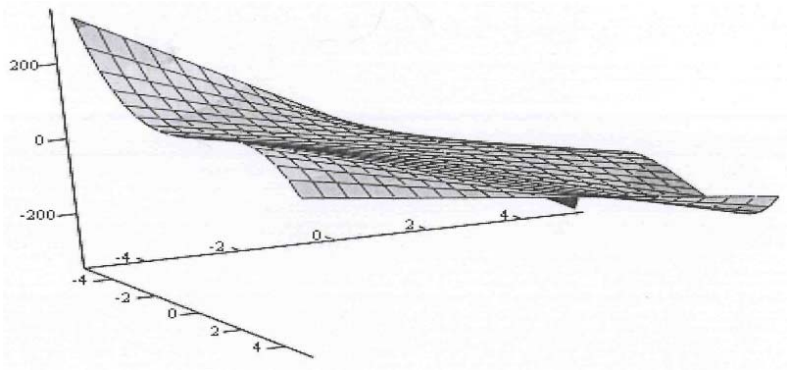
Figure 2 – The temperature distribution over pipe thickness



Graph 1 – The flow of oil mixture of different viscosities with decreasing temperature from 80 °C to 60 °C, when $a = \frac{3}{4}$



Graph 2 – The flow of oil mixture of different viscosities
with decreasing temperature from 60 °C to 30°C, when $a = 1$



Graph 3 – The flow of oil mixture of different viscosities
with decreasing temperature from 29 °C to 23 °C, when $a = 5$

Conclusion. As a result of the study, the following calculations have been analyzed and obtained:

– The calculation of the flow of the oil mixture of different viscosities with a decrease in temperature from 80 °C to 60 °C is performed under the classification of loads of 1-type

– The calculation of the flow of the oil mixture of different viscosities with a decrease in temperature from 60 °C to 30°C is performed under the classification of loads of 2-type

– The calculation of the flow of the oil mixture of different viscosities with a decrease in temperature from 29 °C to 23 °C is performed under the classification of loads of 3-type.

The dependencies have been determined, i.e. depending on the flow regime, the volume of the oil mixture of different viscosities can be reduced as much as possible by desalination and separation of impurities, heavy sediments and stratification, under the influence of combined power factors on the type of classification of loads of the 1st –III types. In this case, depending on the power factors, the original equation is reduced to an equation of the Riccati and Weber type, and in some cases to the Bessel and Euler equations.

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ӘР ТҮРЛІ ТҰТҚЫРЛЫҚТАҒЫ МҰНАЙ ҚОСПАЛАРЫНЫҢ АҒЫНЫН ЕСЕПТЕУ

Жұмыста I–III-типтегі жүктемелердің жіктелуінің әсерінен өндірілетін температураның төмендеуімен әр түрлі тұтқырлықтағы мұнай қоспаларының ағынын есептеу қарастырылған. Әр түрлі тұтқырлықтағы мұнай қоспасының көлемін ағынды тұзсыздандыру және қоспаларды бөлу арқылы азайтуға болады.

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РАСЧЕТ ТЕЧЕНИЯ НЕФТЯНОЙ СМЕСИ РАЗНОЙ ВЯЗКОСТИ ПРИ УМЕНЬШЕНИИ ТЕМПЕРАТУРЫ

Аннотация. В работе рассматривается расчет течения нефтяной смеси разной вязкости при уменьшении температуры, производимые под действием классификации нагрузок с I–III-видов. Течения объема нефтяной смеси разной вязкости можно максимально снизить путем опреснения и разделения примеси.

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THE ESTABLISHMENT OF THE BASIC ELEMENTS OF MODELING AND DIGITALIZATION IN THE DESIGN OF PARTS OF AN OBJECT

Abstract. The regularity defining the organization of the General composition creating integral perception is established. Due to this, the efficiency and integrity of the composition is achieved, which contributes to the establishment of a relationship between the shape of the product, the compositional expression of the figure and the overall design. Based on the unification model of the elements of the ornaments, the options of forming non-standard ornamental compositions from the standard patterns, the considered methods and performance techniques, types of finishes and guidelines for placement of designs. We have also developed an algorithm of modern methods of designing clothes based on the traditional Kazakh costume. this is based on the analysis of the formation of the traditional Kazakh costume, structural analysis of the most characteristic costumes-images and the structure of the general code. The basic elements of their modeling and digitization in the design of object parts are considered.

Key words: composition, object, national, ornament, technique, design, Kazakh, clothing.

World practice requires specialists with a narrow specialization and knowledge of the technology for manufacturing light industry products, including products made on the basis of a traditional national costume [1], but also able to use the knowledge gained in the field of digitalization.

Time proves that national clothing was created by wise and practical creators. A feature of Kazakh national clothing is that the processes of their design and manufacture must be carried out with the mandatory observance of the requirements, canons and traditions of the Kazakh people [2]. Scientific developments in this direction are practically absent. Some information on the types of Kazakh national clothing is contained in some scientific papers. But they lack any information on the methods of designing and manufacturing national clothes.

Therefore, we identified the types of clothing of Kazakhs of the XYIII- beginning of the XX centuries, analyzed the use of Kazakh national traditions in modern clothing, developed a method for forming a rational structure of the assortment of Kazakh clothing taking into account national traditions.

On the basis of a specially developed structure of a unified system analysis of national clothes, developed by Dr. Parmon, and the result of a retrospective analysis revealed the most characteristic Kazakh national costumes-images and the structure of the common code of Kazakh national clothes [3].

Since the form of national clothes is being improved with each subsequent step, there is a need to study the connection of national clothes with modern ones.

The methodology of designing modern clothes based on the traditional Kazakh costume leads to the development of graphic design of ornaments of Kazakh national clothes.

The decor of Kazakh national clothing is a rich heritage in the field of ornamental art. Separate motifs of the ornament, elements of Kazakh national clothing, rooted in ancient times, are now indispensable sources for the design of modern clothing. A retrospective analysis of the artistic and graphic features of the ornament contributes to the preservation of the traditions of the Kazakh ornament, the design on their

basis of new compositions for modern clothes with the mandatory preservation of national traditions. This will enrich and reveal the artistic qualities of modern clothing.

The results of the analysis of Kazakh national ornamentation show that the real idea of the world is generalized and stylized in the form of ornaments. The design of Kazakh national ornaments consists of geometrically regular standard elements. This contributes to the use of modern computer technology, dictated by the onset of a new stage in the improvement of modern clothing design.

The development of a computer graphic sketch of Kazakh ornaments is carried out using the Corel Draw X6 vector graphics package. In this way, there are great opportunities for creating an ornament by filling the background and contour with various colors, as well as moving from one shade to a completely different one in a given direction.

Based on a number of completed works, we proposed the creation of non-standard ornaments from standard ones to create completely new artistic and constructive solutions to models of modern clothes based on traditional Kazakh costume, inherent in the era of the 21st century.

Thus, the proposed technique contributes to the identification of groups of ornaments of plant, zoomorphic, cosmogonic, geometric origin used in the design of modern clothing based on traditional Kazakh costume; the creation of a variety of non-standard ornaments from existing standard (primary sources), leading to the expansion of the product range.

It has been established that, with the development of the market, the demand for ornamented products increases, since decor contributes to the expansion of the possibilities of artistic solutions to clothing and the diversity of its assortment.

The results obtained are recommended to be used in the development of artistic and constructive solutions of modern clothing based on the traditional Kazakh costume. Variants of shaping non-standard ornamental compositions from standard ornaments have been developed.

In the preparation of engineer-teachers in the study of Kazakh national clothing, it is necessary to give training, including courses in engineering and computer graphics. Students in this case will receive the necessary information in the field of using modern information technologies, get acquainted with the capabilities of graphic packages.

The skills gained in the study of computer graphics contribute to their use in independent work. High quality of sketches and short terms of their creation confirm the prospects of this direction.

The development of a computer graphic sketch of models of modern clothing based on a traditional Kazakh costume consists of the following steps.

Stage 1 - creating a graphic base of a human figure.

This is the first and crucial stage on which the appearance and perception of the model ultimately depend. Using the simplest elements (rectangles, polygons, ellipses), a color palette for lines and contours, build a frame of the figure.

2-stage creation of graphic databases of product parts.

The second stage involves the development of sketches of details of modern clothes based on the traditional Kazakh costume for this figure. Modern graphic editors provide a powerful tool for this (from the editor of nodes and contours to intersections and associations of graphic images), which allows you to quickly create large collections of parts, decorative stitches and perforations that give the product a certain aesthetic appearance that matches the fashion direction.

Stage 3 - filling with texture and giving volume to models of modern clothes based on traditional Kazakh costume.

The next step in the outline design of clothing models is to fill in the details with a specific color or texture.

Graphic editors provide ample opportunities for decorating objects, including the ability to fill objects and its outline with the same or different colors, the transition of one color (shade) to another in a given direction. Many of the editors allow you to include in your library of textures your textures of materials entered from a scanner or camcorder. Of special interest are special tools for creating highlights, shadows, transparency. Having neither experience nor knowledge about the center of perspective (entry point) or light source, it is possible to turn a two-dimensional object into a three-dimensional using a computer. The specialist's task is to use all of the above effectors, to transfer the characteristic features of the model's shape, using the traditions and canons of the Kazakh costume.

Stage 4 - creating catalogs of models of modern clothes based on the traditional Kazakh costume.

This is the final stage and, as the bases replenish the human figure and details, it becomes the main one when developing new models. The process of preliminary design at this stage boils down to combining the elements of the parts bases on the selected human figure. Using the capabilities of creating multi-layer drawings and setting various sequences of parts in the model, it is possible to create and design several guide collections in a short time.

Designing new models of modern clothes based on the traditional Kazakh costume is a comprehensive solution to the artistic, technical, technological, economic and other problems in the process of developing sketches, layouts, drawings, manufacturing techniques and product samples.

We found that the appearance and location of the ornament have a great influence on the artistic and decorative design of clothing details. Based on this, a group of ornaments was developed depending on the location along the edge and corner elements of clothing.

Based on the use of typical elements of ornaments, options for shaping non-standard ornamental compositions from typical ornaments, the methods and techniques for performing the types of decoration and principles for placing ornaments, the types of ornament that are most significant for designing clothes are established.

We have identified options for different locations of ornaments on the shelf, as well as options for the location of various ornaments. In order to select the types of ornament in the details of the designed clothing, a questionnaire was conducted among specialists, using the example of a female camisole. To determine the most significant type of ornament when designing clothes, factors are established that affect the artistic and decorative design: types and location of the ornament. At the same time, the types of ornament (zoomorphic, floral, geometrical, cosmogonic, and derivative) are taken for variables — and the location and location of the ornament (edge of the neck, neck, bottom, side cut, armhole) for a constant.

Based on this, a fragment of the drawing is proposed in the questionnaire, where, with the same location of the ornament, different types of crucible, zoomorphic, geometric, cosmogonic and platoon (plant and zoomorphic) ornaments are recommended. The influence of each factor is estimated by the value of the rank - the place that is assigned to the specialist in ranking all the factors. In the objective processing of personal data obtained as a result of the survey, the method of a priori ranking of factors is used.

The sum of the ranks by the factors is

$$\sum_{i}^{m} a_{ij}$$

The difference between the sum of each factor and the average sum of ranks

$$\Delta_i = \sum_{i}^{m} a_{ij} - \frac{\sum_1^k \sum_1^m a_{ij}}{k} = \sum_{i}^{m} a_{ij} - T. \quad (1)$$

Sum of squared deviations

$$s = \sum(\Delta_i) = 19\ 374, \quad (2)$$

where α_{ij} – rank of each *i*-th factor in the *j*-th specialist; m – number of specialists (100); *k* – the number of factors (5); *T* – average amount of ranks.

The concordance coefficient shows the degree of coordination of the opinions of all specialists.

$$\omega = \frac{12 \cdot s}{m^2(k^2 - k) - m\sum_1^m T_i} = 0,699, \quad (3)$$

where $T_j = \sum\left(t_j^3 - t\right) = 342,$ where t_j – number of identical ranks in the jth ranking.

Since the value of the concordance coefficient differs significantly from zero, there is a significant relationship between the opinions of specialists. The value of ω differs markedly from unity, therefore, experts unequally rank factors. Using special tables, the significance of the concordance coefficient is evaluated. The value of x^2 – the criterion is determined by the following formula

$$x^2 = \frac{12 \cdot s}{mk(k+1) - \frac{1}{k-1}\sum_1^m T_j} = 79,7. \quad (4)$$

We have given a ranking matrix based on the data of interviewed specialists. From the known static distributions we find that for a 5% significance level, with the number of degrees of freedom $f = 5–1 = 4$, $x^2 = 9.5$.

Since this value is less than the calculated one, it can be argued with 95% confidence that the opinion of experts regarding the degree of influence of factors is consistent with the coefficient of concordance. Based on a priori ranking, an average ranking diagram is constructed for the factors considered in accordance with figure 2.

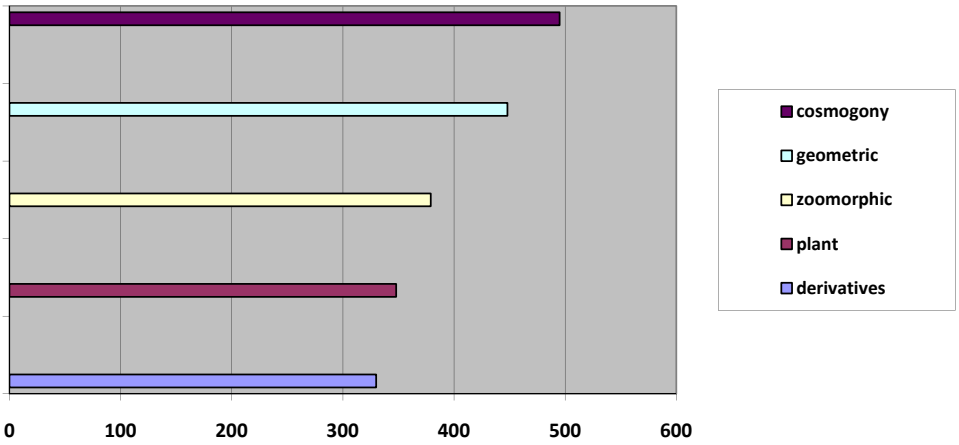

Figure 1 – Average prior ranking chart

The diagram shows that according to the results of a survey of specialists, the types of derivative, floral, zoomorphic and geometric ornaments have the greatest influence on the artistic and decorative design of a female camisole. Since the cosmogonic form of the ornament scored the highest amount of points, which makes it possible to exclude the use of this type in the artistic and decorative design of the camisole. Studies of the artistic techniques of clothing based on typical ornaments and their derivatives, used in combination with its various types, have made it possible to preserve the stylistic link between the existing ornament and the newly created one.

Thus, we have identified a relationship that allows you to establish a pattern that determines the organization of the overall composition of clothes, creating a holistic perception, due to which the design and integrity of the compositional solution are implemented, which helps to establish the relationship of the form of clothing, compositional expressiveness of the ornament, and the whole design.

On the basis of the developed methodology, variants of artistic and decorative design of the main and structurally decorative parts for the developed model designs of national costumes are offered.

The effectiveness of design procedures, assessed by the timing and quality of the development of the project, increases when specialists use modern methods for creating clothes of various shapes, silhouettes and cuts. Improvement of clothing design methods is currently aimed at digitalization.

Kazakh national pockets on the upper female products (camisole, beshmet) have a curly neckline in the form of a parabola, therefore they have their own characteristics [3].

The line of entry into the pocket was determined in the old-fashioned way: the contour of the pocket was drawn at the ends of the five fingers (fingers should be placed freely, without tension). The ends of the pocket were determined by the little finger and thumb. The middle finger showed the place of the greatest bend of the line.

To automate the process of transforming various lines of clothing designs using the example of a pocket entry line (figure 2), we have developed a method for using information technologies. We suggest expressing the line of entry into the pocket as a function (figure 3). The initial function was the entry line into the pocket for size 46, length 20.6 cm. The length of the pocket was measured by a parabola.

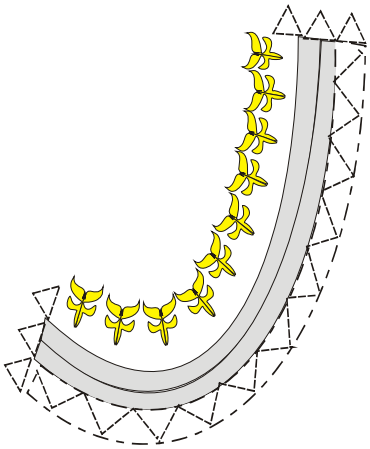

Figure 2 –
The appearance of the pocket

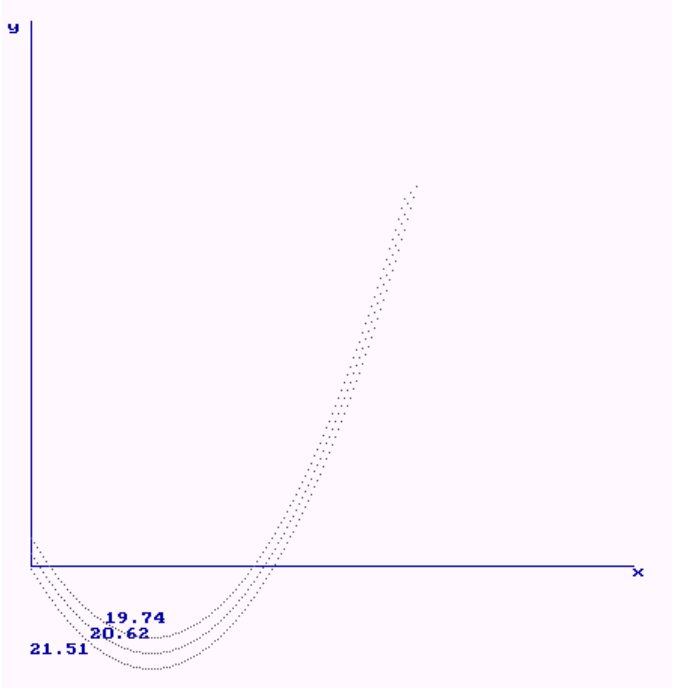

Figure 3 –
Entrance lines
to the camisole pocket
for three sizes

To build the line of entry into the pocket (figure 4), we used a program in the Turbo Pascal language:

```
program pocket (input, output);
  uses Crt, Graph;
    var Gd, Gm: Integer;
        l,l1:real;
      function St(I: real): String;
        var
         S: string[6];
        begin
          Str(I:0:2, S);
          st := S;
        end;
      procedure rr(a1:real;y,x:integer);
        var k,a:real;
        begin
         K:=1;
```

```
        a:=0;
        while (a<=a1+0.1) do
        begin
          l:=(1/4)*(a-2)*(a-2)-1;
          l1:=(a-2)/2*sqrt(1+(a-2)*(a-2)/4)+ln((a-2)/2+sqrt(1+(a-2)*(a-2)/4))-sqrt(2)-ln(-1+sqrt(2));
          putpixel(90+round(10*(a+a*SIN(pi/2))),450-y-round(8*(l-l*COS(5*pi))),15);
          a:=a+0.1;
          K:=K+0.05;
        end;
       outtextxy(50+x,450-y,st(l1));
  end;
begin
  Gd := Detect;
  InitGraph(Gd, Gm, '');
  if GraphResult <> grOk then
    Halt(1);
  setcolor(2);
  line(50,50,50,400);
  line(50,400,450,400);
  outtextxy(35,50,'y');
  outtextxy(450,400,'x');
  rr(10.8,0,0);
  rr(10.6,10,40);
  rr(10.4,20,50);
  readln;
  CloseGraph;
 end.
```

Since such a pocket on the upper female products has a curved neckline in the form of a semicircle, they also have their own characteristics in processing. Before processing the pockets, it is necessary to embroider, which is usually located above the top line of the slot of the pocket in the form of a semicircle.

Based on a retrospective analysis, it was found that the following factors play a big role in choosing the location of an ornament: the purpose of the clothes; artistic expressiveness of the model; material used; variety of clothing item.

It has been established that the forms of ornamental techniques have a huge impact on the aesthetic properties of modern clothing based on the traditional Kazakh costume: appearance, technique, location of the ornament, as well as a combination of materials with various physical and mechanical properties. Therefore, depending on the form of ornamental reception, ornaments were divided into the following categories:

1. Edge - along the edge of the side, bottom of the sleeves, bottom of the product, collars and other edges of clothing.

2. Ornaments are circular in shape - in the center of large and small planes, backs, sleeves, upper part of the skullcap and other details allowing to determine the compositional center.

3. Ornaments to fill certain parts of the plane - the corners of the parts - the bottom corner of the shelf, the design of the side cuts.

This arrangement of ornaments allows you to express very simple details of the clothes of the national costume, transforming it, and emphasizing its ethnic differentiation.

Based on the developed unification of typical elements of ornaments, options for shaping non-standard ornamental compositions from standard ornaments, the methods and techniques for performing decoration types and principles for placing ornaments, as well as an analysis of the formation of a traditional Kazakh costume, a structural analysis of the most characteristic costumes-images and the structure of a common code, we developed an algorithm for designing modern clothes based on a traditional Kazakh costume.

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НЫСАН БӨЛШЕКТЕРІН ЖОБАЛАУ КЕЗІНДЕ МОДЕЛЬДЕУ МЕН ЦИФРЛАНДЫРУДЫҢ НЕГІЗГІ ЭЛЕМЕНТТЕРІН АНЫҚТАУ

Аннотация. Объектінің жалпы композициясын ұйымдастыруды анықтайтын заңдылықтарды анықтауға мүмкіндік беретін тәуелділік анықталды. Осының есебінен композициялық шешімді безендіру және оның бүтіндігі жүзеге асырылады, бұл бұйымның пішінінің, ою-өрнектің композициялық мәнерлілігінің және жалпы конструкцияның өзара байланысын орнатуға ықпал етеді. Ою-өрнектің типтік элементтерін, стандартты ою-өрнектің стандартты емес композицияларын қалыптау нұсқаларын әзірленген біріздендіру негізінде ою-өрнектің өңдеу түрлері мен орналасу принциптерін орындау тәсілдері мен техникасы қарастырылған. Сондай-ақ, біз дәстүрлі қазақ костюмінің қалыптасуын талдауға, неғұрлым тән костюм-бейнелердің құрылымдық талдауына және жалпы кодтық құрылымға негізделе отырып, дәстүрлі қазақ костюмінің негізінде заманауи киімді жобалау әдістемесінің алгоритмін әзірленді.

Түйін сөздер: композиция, объект, ұлттық, ою-өрнек, әдістеме, жобалау, қазақ, киім.

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УСТАНОВЛЕНИЕ ОСНОВНЫХ ЭЛЕМЕНТОВ МОДЕЛИРОВАНИЯ И ЦИФРОВИЗАЦИИ ПРИ ПРОЕКТИРОВАНИЯ ДЕТАЛЕЙ ОБЪЕКТА

Аннотация. Определена зависимость, которая позволяет установить закономерность, определяющую организацию общей композиции объекта, создающая целостное восприятие. За счёт этого осуществляется оформление и целостность композиционного решения, что способствует установлению взаимосвязи формы изделия, композиционной выразительности орнамента, и в целом конструкции. На основе разработанной унификации типовых элементов орнаментов, вариантов формообразования нестандартных орнаментальных композиций из стандартных орнаментов, рассмотренных способов и техники исполнения видов отделки и принципов размещения орнаментов. А также нами разработан алгоритм методики проектирования современной одежды на основе традиционного казахского костюма на основе анализа формирования традиционного казахского костюма, структурного анализа наиболее характерных костюмов-образов и структуры общего кода.

Ключевые слова: композиция, объект, национальная, орнамент, методика, проектирование, казахская, одежда.

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CHARACTERISTICS OF ROAD BITUMEN MODIFIED WITH CARBON NANOPOWDER

Abstract. In the paper the improvement of low temperature properties of blown road bitumens by means of modification with a carbon nanopoweder is shown. The bitumens of grade BND 70/100 and BND 100/130 have been produced by the Pavlodar petrochemical plant. The nanopowder has been obtained from a coal in the "Saryadyr" deposit ("ON-Olzha" corporation). Stiffness of the bitumens has been measured by a bending beam rheometer. Group chemical composition of the bitumens has been determined by the "Gradient" chromatograph. It was found that the Fraas point of the modified bitumens after short term aging on the RTFO method is not less than of the bitumen in non-modified and non-aged condition. Stiffness of the modified bitumen is considerably decreased at low temperatures (44%, 38% and 28% at the temperatures of -24 ^{o}C, -30 ^{o}C and -36 ^{o}C respectively). It has been stated that modification of the bitumens with the crbon nanopowder transforms the resins into compacted asphaltenes and decompacted oils consuming little energy for the process.

Key words: bitumen, carbon nanopowder, Fraas point, bending beam rheometer, stiffness, group chemical composition.

Introduction. The results of numerous investigations [1-10] show that conventional bitumens produced in plants do not practically always satisfy the requirements of operational conditions (including climatic ones) in many countries of the world, especially in the regions with sharp continental climate. As a rule to improve bitumens quality they are modified with polymers. Addition of polymers varies considerably the characteristics (physical and mechanical, rheological, etc.) of bitumens [11-13].

Due to what the abovementioned variations occur for bitumens characteristics at their modification with polymers? The answer should be searched, first of all, in variation of chemical composition of binders. Usually the researchers confine themselves only to physical and mechanical and rheological characteristics at the analysis of polymer type and content effect on bituminous binders properties, i.e. their chemical composition is not considered.

Table 1 represents the results for determination of group chemical composition of the neat bitumen of grade BND 100/130 and polymer bitumen binders manufactured by addition of various polymers into the bitumen. The neat bitumen has been produced by Pavlodar petrochemical plant (PPCP) from crude oil of Western Siberia by method of direct oxidation. The group chemical compositions of the basic neat bitumen and the polymer modified bitumens were determined in the laboratory of the Kazakhstan Highway Research Institute (KazdorNII) by method of adsorptive chromatography on Gradient M chromatograph [14, 15].

As the data of the table 1 show, without dependence on type and content of polymers, the bitumen modification is followed by the decrease of light components content (oils) and the increase of heavier components content (resins and asphaltenes). The increase of asphaltenes content due to the decrease of oils in the composition of the bitumen of grade BNS 70/100 (PPCP) at short-term and long-term aging has been determined in the work [14].

Table 1 – Group chemical composition of the neat bitumen of grade BND 100/130 and the polymer bituminous binders

Name of chemical compounds	Bitumen BND 100/130	Name and content of polymers				
		Bitumen BND 100/130 + KUMHO KTP (SBS) (Korea) – 6.0%	Bitumen BND 100/130 + Interchi-mica SBS – 4%	Bitumen BND 100/130 + SBS (L 30-01 A) – 3%	Bitumen BND 100/130 + Elvaloy AM – 2%	Bitumen BND 100/130 + Butonal NS 198 – 3%
Parafinonaftenes	21.9	16.7	16.35	15.6	16.1	14.45
Aromatics light	8.0	8.2	9.1	6.95	7.55	8.35
Aromatics middle	3.51	8.1	7.6	5.5	6.0	5.75
Aromatics heavy	22.1	21.3	18.5	21,8	23.7	25.15
Resins 1	6.6	7.5	6.7	8.45	9.05	8.35
Resins 2	24.1	24.0	27.4	21.7	22.3	21.35
Asphaltenes	13.8	15.2	15.4	20.0	15.3	16.65
Group chemical composition						
Oils	**55.51**	**54.3**	**51.5**	**49.85**	**53.35**	**53.7**
Resins	**30.7**	**31.5**	**34.1**	**30.15**	**31.35**	**29.7**
Asphaltenes	**13.8**	**15.2**	**15.4**	**20.0**	**15.3**	**16.65**

Thus, one can conclude that as at thermal aging as well as at polymer modification the following variation for group chemical composition of bitumen occurs: content of more light components (oils) is decreased and the content of heavier components (asphaltenes) is increased, and the content of intermediate components (resins) remains constant or it is also increased.

At present the possibility has been shown for application of nanoparticles of different structure as functional additives for bitumens [16]. Meanwhile, carbon nanoparticles are the closest to bitumen, as a component of petrol. It is considered that in this case the effect of modification will be a maximal one [17-19].

Materials and methods. Bitumens of grades BND 70/100 and BND 100/130 produced by PPCP have been taken for investigation of the impact of carbon nanopowder content on a group chemical composition. Nanopowder has been manufactured from a coal of 'Saryadyr" deposit belonging to "Corporation "ON-Olzha" LLP (Akmola region, Kazakhstan), and it has dimensions of 150-200 nm.

For the purpose of provision of the uniform distribution of the nanopowder particles in bitumen the nanopowder has been first dispersed in kerosene through the action of ultrasound with the frequency of 20 kHz for 5 minutes at a room temperature. Then the dispersed solution (kerosene+nanopowder) has been added to the bitumen at the temperature of 160 °C and constant stirring for 30 minutes. In such a way the samples of the nanocarbon bituminous binder (NCBB) have been prepared with the content of the carbon nanopowder from 0.1 to 2.0 % by weight.

Rational quantity of the nanopowder was determined according to the indicators of the bitumen resistance to aging. Bitumen "is aged" in the process of preparation of a hot asphalt concrete mix, light fractions are volatilized, bitumen becomes more brittle, less frost resistant.

The following main standard indicators for NCBB have been determined by appropriate methods of laboratory tests: needle penetration depth at the temperature of 25 °C under the standard ST RK 1226 [20], softening point on ring and ball under the standard ST RK 1227 [21], ductility at the temperature of 25 °C under the standard ST RK 1374 [22], Fraas point under the standard ST RK 1229 [23].

Aging of a binder at stirring of an asphalt concrete mix in a mixing device and during its laying occurs in conditions of a high temperature and air inflow. To model this form of aging the method of rolling of a thin film in the oven (RTFO) is used under the standard ST RK 1224 [24] and AASHTO T 240 [25].

To model the aging in the process of operation the accelerated method of aging is used in the device PAV under high pressure and at a high temperature for 20 hours under standard ASTM D 6521 [26]. The samples of a binder aged in PAV have already been subjected to aging under method RTFO. Binder

residue after aging under method PAV represents the binder subjected to the action of all the factors of the environment which it has during production of an asphalt concrete mix and operation of an asphalt concrete pavement.

In accordance with the Technical system Superpave the low temperature stability of bituminous binders is evaluated under the stiffness modulus value, determined at load duration of 60 seconds under the standard ASTM D 6648 [27] on a bending beam rheometer (BBR). In this work the stiffness modulus of the neat bitumen and NCBB was determined at the temperatures of -24 °C, -30 °C and -36 °C.

Group chemical compositions of the original and the nanomodified bitumens were determined on the chromatograph "Gradient".

Results and discussion.

Standard indicators. Main standard indicators of the bitumen and NCBB, determined under the abovementioned standards, are represented in table 2.

Table 2 – Main standard indicators of the neat bitumen and NCBB

Indicators	Content of nanopowder, %								
	Neat bitumen	Neat bitumen after aging (RTFO)	0.1	0.2	0.3	0.5	0.7	1.0	2.0
Depth of needle penetration at 25°C, 0.1 mm	75	55	47	61	62	59	59	64	61
Softening point, °C	47.5	51	55	53.5	53	53	52	51	51
Ductility at 25°C, cm	118	69	41	53.5	45	32	54	31	51
Fraas point, °C	-28.5	-24.5	-27.1	-27.2	-26.9	-28.5	-28.0	-24.3	-27.6

The results of table 2 data analysis have shown that adding of the nanocarbon powder decreases ductility to 26 %; softening point is practically not changed, and depth of the needle penetration is increased for 16 %.

It should be specially noted that bitumen aging under the method RTFO increases Fraas point for 4°C from -28.5°C to -24.5°C, and adding of the nanocarbon powder reduces Fraas point and already with the nanopowder content of 0.5 % the Fraas point of the neat bitumen is recovered, i.e. becomes equal to -28.5°C.

Stiffness. Table 3 gives stiffness modulus values for the neat bitumen and NCBB at lower temperatures, obtained by testing at BBR.

Table 3 – Stiffness modulus of the neat bitumen and NCBB at low temperatures

Temperature, °C	Content of nanopowder, %		
	0	0.5	2.0
-24	104.21	-24	104.21
-30	220.11	-30	220.11
-36	322.50	-36	322.50

As it is seen the nanopowder decreases considerably the stiffness modulus of the bitumen, i.e. increases low temperature stability. Modification effect is especially clearly shown with the content of the nanopowder of 0.5 %. So, the stiffness modulus of the bitumen with such concentration of the nanopowder at the temperatures of -24 °C, -30 °C and -36°C is 46 MPa (44.1 %), 83 MPa (37.7 %) and 91 MPa (28.2 %) respectively.

Thus, one can conclude that modification of the bitumen of grade BND 70/100 by the nanocarbon powder increases considerably its low temperature stability.

Group chemical composition. The obtained data on group chemical composition of the original bitumen and its modified samples have been tabulated into table 4.

Table 4 – Group chemical composition of the neat bitumen and NCBB

Bitumen	Asphal-tenes, %	Resins, %			Oils, %				
		Petrol-benzol	Spiritus-benzol	Sum of resins	Paraffin-naphthene	Light aromatic	Middle aromatic	Heavy aromatic	**Sum of oils**
BND 100/130 RTFO	**11.8**	24.5	20.4	**44.9**	20.6	3.6	4.3	14.9	**43.4**
BND 100/130 RTFO + 0.5% NANO	**17.0**	15.2	19.2	**34.4**	23.3	5.1	4.5	15.7	**48.6**
BND 100/130 RTFO + 0.7% NANO	**17.8**	17.0	16.6	**33.6**	23.6	4.3	4.6	16.1	**48.6**
BND 100/130 RTFO + 2.0% NANO	**20.8**	10.7	18.0	**28.7**	23.1	5.5	5.3	16.7	**50.6**

Progressing decrease of resins content with aggregate portion increase from 0.5% to 2.0% is seen from Table 4. At 2.0% of the added nanopowder portion the resins content is decreased for 16.2% by weight and the content of the asphaltenes and oils is increased for 9.0% and 7.2% by weight respectively.

Conclusion.

1. The possibility has been shown for considerable improvement of low temperature characteristics for road bitumens by their modification with a nanopowder from a coal: Fraas point of the modified bitumen after short-term aging under the RTFO method is not lower than for the original (non-aged) bitumen; stiffness is considerably decreased (at the temperatures of -24°C, -30°C and -36°C for 44%, 38% and 28% respectively).

2. Phenomenon previously unknown has been determined for differently directed weak energetic transformation of bitumen resins into compacted asphaltenes and non-compacted oils cumulatively forming a nanostructured bitumen with increased low temperature resistance during heating up to +160°C with addition of a nanopowder from a coal into a original bitumen.

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КӨМІР НАНОҰНТАҒЫ ҚОСЫЛҒАН ЖОЛ БИТУМЫНЫҢ СИПАТТАМАЛАРЫ

Аннотация. Мақалада тотыққан жол битумына көмір наноұнтағын қосу арқылы оның төменгі температуралық сипаттамаларын жақсарту мүмкіндігі көрсетілген. МЖБ 70/100 және МЖБ 100/130 маркалы битумдары Павлодар мұнай-химия зауытында өндірілген, ал өлшемі 150-200 нм наноұнтақ «ОН-Олжа» корпорациясының көмірінен алынды. Битумдардың төменгі температурадағы (-24 ºС, -30 ºС, -36 ºС) қаттылығы иілгіш білікті реометрмен өлшенді, топтық химиялық құрамы «Градиент» хроматогрофында анықталды. Наноұнтақ қосылған битумның RTFO әдісімен қысқа мерзімді ескірген күйіндегі морттық температурасы бастапқы (ескірмеген) битумдікінен кем еместігі көрсетілген.

Наноұнтақ қосылған битумның қаттылығы елеулі (-24 ºС, -30 ºС және -36 ºС температураларда тиісінше 44%, 38%, 28 %) төмендейтіндігі анықталды. Бұрын белгісіз, битумға көмір наноұнтағын қосқанда шайырлардың тығыздалған асфальтендерге және қопсыған майларға аз энергия шығынымен айналу құбылысы анықталды.

Түйін сөздер: битум, көмір наноұнтағы, морттық температурасы, иілгіш білікті реометр, қаттылық, топтық химиялық құрам.

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ХАРАКТЕРИСТИКА ДОРОЖНОГО БИТУМА С НАНОЧАСТИЦАМИ УГЛЯ

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CHARACTERISTICS AND PROPERTIES OF PHYSICAL AND QUANTUM FIELDS OF NANOCARBON AND THEIR APPLICATIONS

Abstract. It is theoretically justified, characteristics have been determined for physical (electric, magnetic) and quantum (wave corpuscle) fields of surface nanocarbon electrons.Validity and preserving have been specified for their numerical values of field characteristics for nanopowders of solid bodies. It has been proved that quantum-dimensional effect of nanopowders is the surface activity of a substance, the essence of field actions. Actions of physical and quantum fields and the proposed model of electron can influence considerably on the development of nanotechnology and nanophase materials science.

Key words: nanopowder, electric and magnetic fields, wave-corpuscle characteristics, quantum-dimensional effect, Compton effect, wave length.

Introduction. A large number of qualitatively new indicators and properties of substance nano-particles uncharacteristic of the macrostates of the latter have been experimentally discovered [1]. Nano-particles of many solids significantly change their optical, electrical, magnetic and electromagnetic properties, acquire high thermal and radiation stability, become ultra-light and super-strong, extremely hard and wear-resistant, stand incredible impact forces and show flexibility to large loads without loss of continuity. Nanoparticles made from nanoparticles significantly change Young's modulus, Poisson's ratio, shear modulus, compressibility, and other properties.

The experimenters [1] note the unusually high "free valency" of nanoparticles, allowing them to form new nanomaterials with unimaginable qualities for macro substances. For example, silicon and tantalum nanoparticles form tantalum silicide (practically non-oxidizing in the open air) with a melting point of + 5500 °C, a record low electrical resistance. Nanopowders of aluminosilicate, iron or cobalt, magnesium or manganese form an alloy with an anomalously high magnetocaloric effect, which made it possible to create new cryogenic devices and revise the fundamentals of magnetic material science.Free-valence surface electrons occupy high energy levels with a large reserve of absorbed energy during crushing and abrasion of a substance to a nanopowder, unattainable in ordinary ion-radical reactions and characteristic only of extreme effects. As an example, let us note our experiments [2-4] of modifying road bitumen with the addition of nanocarbon up to 200 nanometers in the amount of up to 2% of mass, where a new phenomenon of low-energy transformation of bitumen resins into asphaltenes and oils, providing it with high strength and growth, has been discovered low temperature stability. In nanocarbon a catalyst property was observed that promoted the mutual transformations of the structural elements of bitumen and increased their reaction rate up to phase transitions of solid nanoparticles into ***liquid hydrocarbon molecules***.

The main reason for nanoparticles to acquire the properties of surface active substances (SAS), a catalyst, and a promoter is the quantum-dimensional effect (QDE), i.e. commensurability of nanoparticle size and de Broglie wavelength λe of an electron [5]:

$$\lambda_e \approx h / \sqrt{m_{эф} E_{ф}} \ , \tag{1}$$

where $m_{эф}$ – effective mass, $E_ф$ – Fermi electron energy,$h = 6{,}625 \cdot 10^{-34} J{\cdot}sec$ – Planck constant. Known that $m_{эф}$ may turn out to be by an order, sometimes two orders of magnitude, less than its real mass [6]. The Fermi electron energy also differs from its total energy by one or two orders of magnitude [6,7]. Consequently, the length calculated by (1) is a random variable, and the QDE is a doubtful factor in the acquisition of the properties of SAS, catalyst, and promoter by nanoparticles. In the theory of nanomaterials and physical nanochemistry, the energy and wave parameters of a nanoparticle are calculated using de Broglie relations[1-5]:

$$\lambda = h / mu, \tag{2}$$

where m – mass, u – nanoparticle velocity. Formulas (1) and (2) are widely used in determining the energy and wave parameters of a nanoparticle, the energy costs of producing nanomaterials, and the economic benefits of their industrial application. Using (1) and (2), the experimental values of the de Broglie wavelength from 0.1 to 10 nm for metals and from 10 to 100 nm for semiconductors, semimetals, and alloys of refractory metals are substantiated [5,7]. In our opinion, the real physical meaning and the physicochemical mechanism of the special qualities of nanoparticles and nanomaterials lie behind CDE.The purpose of this article is to build an adequate theoretical understanding and justification of the physical (field) and quantum-mechanical mechanisms of the quantum-dimensional effect. Considering the vastness of the nanoparticles class, we focus on nanocarbon of coal rocks [2-5], and summarize the results of its study on nanoparticles of solids and their alloys.

Characteristics of the physical fields of surface electrons of nanocarbon. Each nanocarbon particle is bounded by a surface in the form of a sphere of radius R of the order of 100 nm (10^{-7} m). It is inhabited by electrons of carbon molecules C_2 with a surface density ρ_e in the amount of 10^{15} units per cm^2 of the area: $\rho_e \sqcup 10^{15} e/cm^2$ [2-4]. Sphere with the area $S \sqcup 4\pi \cdot 10^{-14} cm^2$, is inhabited by about 10^6 electron units $\rho_e' \sqcup 10^6 e/S$[2-4]. The intensity $E\ (C2)$ and the density $U\ (C2)$ of the electric field, the induction $B_e$and the strength of the H_e magnetic field are defined in [2-4]:

$$E(C_2) = 1{,}04 \cdot 10^9 \ В/м \sqcap 10^7 \ В/см, \tag{3}$$

$$E_e = 1{,}442(10^7 \div 10^{10}) \ \ В/см, \tag{4}$$

$$U_e = (10^3 \div 10^5) \ В, \tag{5}$$

$$B_e = (0{,}3 \div 3 \cdot 10^3) \ T_e, \tag{6}$$

$$H_e = (1{,}6 \cdot 10^6 \div 1{,}6 \cdot 10^9) \ \ а/м. \tag{7}$$

The kinematic energy T_e and the electron velocity V_e are also determined [2-4]:

$$T_e = (10^3 \div 10^5) \ эВ, \tag{8}$$

$$V_e = (0{,}593 \div 1{,}875) \ 10^8 \ м/с. \tag{9}$$

Characteristics (3) - (9) of the electric and magnetic fields of the surface electron of nanocarbon have experimental confirmation in the materials of the scientific discovery of the corresponding member of the USSR Academy of Sciences B.V.Deryagin [8]. The tension (3) of an individual molecule C2 and the tension (4) of a nanocarbon are sufficient for emission of surface electrons [2-4, 8]. Let us consider the motion of the emission electron in the electric field with strength (5) and the magnetic field with the induction (6). As its average speed in the interval (9) with average energy (8) we take the velocity $V_e = 0{,}712 \cdot 10^8 m/sec$. The trajectory will be a helical orbit with a Larmor radius rL. Electron experiences precession with angular velocityω_L(cyclotron frequency) or Larmor frequencyν_L [9]with the values

$$r_L = 2 \cdot 10^{-7}; \quad \omega_L = 3,52 \cdot 10^{14}\, Гц; \quad v_L = 0,56 \cdot 10^{14}\, Гц, \tag{10}$$

where Гц = (1/c) – Hertz. The precession of a material point does not make sense. Academician of the USSR Academy of Sciences M.A. Markov [10] said: ***"... the fundamental difficulty of the theory ... is due to the fact that all particles in modern physics are regarded as point particles."***

Values (10) have no experimental evidence. Their reliability follows from the formulas for the relationship between the characteristics of the magnetic field and reliable values of the electric field. In addition, the academician of the USSR Academy of Sciences, Nobel Laureate V. L. Ginzburg, considering the problem of creating super-powerful quantum generators, wrote [6]: "... ***the creation of x-ray and gamma-ray analogs is one of the important fundamental physical problems ... All the proposals we know regarding the sizes and grasers belong to the field of energies not exceeding 10 keV (10^4 eV)*** ... "X-ray and γ-ray laser systems are called Raser and Graser respectively. The values of the electric field strength (5) and the coincidence of the Larmor radius (10) with the focusing radius of the field of existing high-power lasers indicate the reliability of the characteristics of the physical fields of nanocarbon. We determine the pressure *Qe* of the magnetic field with intensity ***He*** [9]:

$$Q_e = \frac{\mu_0 H_e^2}{2} = 3,217 \cdot 10^{12}\, \frac{H}{м^2}, \tag{11}$$

where *H* – Newton(power unit). Pressure (11) exerts a inhibitory effect on the motion and the electron experiences magnetic bremsstrahlung with a length λ_L:

$$\lambda_L = V_e / \nu_L = (0,712 \cdot 10^8) : (0,56 \cdot 10^{14}) = 1,271 \cdot 10^{-6}\ \ м. \tag{12}$$

Comparing (12) with the de Brogliewaveleng the mitted by world-famous power full asersystems [6, 7], we have their completecoincidence. This fact proves the reliability of the characteristics of the magnetic field of nanocarbon and indicates that our device for the nanopowder production in a rotating magnetoelectric field works as the powerfull asersystem. Its magnetoelectric field wave generator has a power of 4 kW and deserves much attention from the point of view of quantum generators. We consider the quantum field characteristics of nanocarbon.

Quantum field characteristics of surface electrons of nanocarbon. For a nonrelativistic electron, we write down [9, 11] the law of equivalence of the total energy ε_e and Einstein mass m_e and de Broglie relation:

$$E_e = m_e c^2; \quad c = 2,998 \cdot 10^8\ \ м / с, \tag{13}$$

$$\varepsilon_e = h\nu_e; \quad P_e = m_e \nu_e = h / \lambda_e; \quad \lambda_e \nu_e = c. \tag{14}$$

In the 2nd case, the common mass of electron is used. Takingitintoaccountusing (13) and (14) we determine the electron frequency ν_e

$$\nu_e = m_e c^2 / h = 1,236 \cdot 10^{20}\ \ Гц. \tag{15}$$

With the help of (15), we calculate electron wave length λ_e

$$\lambda_e = c / \nu_e = 2,426 \cdot 10^{-12}\ \ м. \tag{16}$$

The coincidence of the value (16) with the Compton wavelength of the electron expresses the essence of the Compton effect [9, 11]. Value (15) coincides with a theoretically determined electron frequency [12]. However, the method of calculating λ_e by the author [12] is very different from ours, which proves the possibility of calculating ν_e and λ_e in the classical way. In view of (16), we turn to the second formula from (14) and calculate the electron velocity V_e

$$V_e = c. \tag{17}$$

An equality (17) contradicts the Special Theory of Relativity (STR) and all modern physics based on it. This means that the meaning of the pulse in (14) differs from that implied in quantum physics (QPh). Therefore, abandoning the point model of the electron, we take its spatial model, where its arbitrary point A has an absolute velocity $\overrightarrow{u_A}$ from the sum of the translational velocity $\overrightarrow{u_0}$ of the center of massOand rotation of the electron around this center with the angular velocity $\overrightarrow{\omega_e}$ [13]:

$$\overrightarrow{u_A} = \overrightarrow{u_0} + \overrightarrow{\omega_e} \times \overrightarrow{r_A}, \tag{18}$$

where $\overrightarrow{r_A} = \overrightarrow{OA}$. Integrally the (18) gives the absolute velocity $\overrightarrow{u_A}$:

$$\overrightarrow{u_a} = \overrightarrow{u_e} + \overrightarrow{\omega_e} \times \overrightarrow{r_e}, \overrightarrow{u_e} = \overrightarrow{u_0} \tag{19}$$

With the free motion of the electron $\overrightarrow{u_e}, \overrightarrow{\omega_e}$ are constant in space and time, $\overrightarrow{r_e}$is rigidly connected with the electron and constant in module.It is orthogonal to $\overrightarrow{\omega_e}$ and changes a position in space according to the law of rotation. The impulse $P_e = m_e V_e$, included in (14), differs from the impulse $\overrightarrow{Q_a} = m_e \overrightarrow{u_a}$, i.e. $m_e V_e \neq m_e u_a$ ***This is the main difference between the point model of the electron of modern physics and its real spatial model.***

The values $\overrightarrow{u_e}$, $\overrightarrow{\omega_e}$, $\overrightarrow{r_e}$, in (19) are subject to determination. Referring to the QDE and the last equality (14), we take

$$r_e = \lambda_e / 2\pi; \quad \omega_e = 2\pi\nu_e; \quad r_e\omega_e = c, \tag{20}$$

where r_e – a radius of a minimal sphere centered at a point O, completely covering the electron. The unknown form of the electron remains to be determined. A rotating electron has a kinematic momentum $J_e\overrightarrow{\omega_e}$, where J_e - the main moment of inertia of the electron relative to the axis of its rotation, coinciding with one of the dynamic axes. Let the electron spin express its kinematic momentum [9, 11]:

$$k_e = \hbar / 2 \quad или \quad J_e\omega_e = \hbar / 2. \tag{21}$$

The kinetic energy of the electron rotation $T_{евр}$ is equal to [9,11]

$$T_{евр} = J_e\omega\frac{2}{e} / 2 = (J_e\omega_e) / 2 = \hbar\omega_e / 4. \tag{22}$$

According to (20) $\hbar\omega_e = \varepsilon_e$ and according to (13) the right side of (22) is equal to

$$T_{евр} = m_e c^2 / 4. \tag{23}$$

The kinetic energy of translational (figurative) movement $T_{епр}$ of the electronis equal to

$$T_{епр} = m_e u\frac{2}{e} / 2 = m_e c^2 / 2 - T_{евр} = m_e c^2 / 4. \tag{24}$$

Theequalities (23) and (24) allow to determine the effective velocities$u_{эф}$rotational (relative) and u_e translational (figurative) movements of the electron

$$u_{эф} = c / \sqrt{2}; \quad u_e = \nu_e = c / \sqrt{2} \tag{25}$$

From the equalities (22) and (23), taking into account the last relation (20), we get

$$J_e = m_e r_e / 2. \tag{26}$$

The equality (26) indicates the cylindrical shape (disk) of the electron with a base radius r_e and a relatively small height, much smaller than r_e. We accept the vectors $\overrightarrow{u_e}$, $\overrightarrow{\omega_e}$ as collinear, we fix an arbitrary point A on the rim of the disk and follow its movement. If $\overrightarrow{u_e}$, $\overrightarrow{\omega_e}$ are codirectional, then with the translational-rotational movement of the electron, point A will move along a helical line winding around a cylindrical surface with a radius r_e and an axis directed along the vectors $\overrightarrow{u_e}, \overrightarrow{\omega_e}$. In this case, they speak of the right helicity of the electron [9-12]. If $\overrightarrow{u_e}$, $\overrightarrow{\omega_e}$ have opposite directions, then the trajectory of point A will be a left-handed helix and speak of the left helicity of the electron. In both cases, starting from (25), we have

$$u_a = \left(u_{эф}^2 + u_в^2\right)^{1/2} = c. \tag{27}$$

Theelectron can be polarized $\overrightarrow{u_e}$, $\overrightarrow{\omega_e}$ mutually orthogonal, point A describe a cycloid with concavity up or down and for a right- or left-polarized electron with conservation (27). For polarization, efforts are needed and the most probable path will be a spiral with parameter *a* and pitch *d*:

$$a = 2\pi r_e = \lambda_e; \quad d = 2\pi r_e = \lambda_e. \tag{28}$$

The surface point A of the electron, describing the helix with the parameter and pitch (28), passes a distance of a length $l_e = c \cdot сек$ during translational movement with a velocity of (25) for $v_e$rotations. The pitch of the screw will be the de Broglie wavelength of the electron, and the number of rotations v_e, for which the electron travels a path of length l_e, – frequency of this wave. These are the geometric and physical meanings of the wave characteristics of the electron.

Such an electron model satisfies (13) the first and last expressions (14). The second of the de Broglie relations (14) contradicted SRT and CF, regardless of the indicated electron model. Taking $P_e = m_e u_a$ as the impulse, where u_a - the absolute velocity of the spatial electron model, we will have

$$P_e = m_e u_e. \quad P_e = m_e c. \quad P_e = \hbar\omega_e / c. \quad P_e = 2\pi\hbar / \lambda_e. \quad P_e = m_e u_a = h / \lambda_e. \tag{29}$$

The equality (29) is the second relation from (4), refined and consistent with SRT and CF, expressing the relationship of the total electron momentum with the characteristics of its de Broglie wave. This is logical from the point of view of Einstein's law (13), the wave form (14) of this law. This implies the law of conservation of the momentum of the total momentum

$$P_e \lambda_e = m_e u_a \lambda_e = m_e c \lambda_e = h. \tag{30}$$

From (30), there are consequences, which are important for the process of radiation and energy absorption by the electron. Radiating the energy, the electron lengthens and vice versa, absorbs energy, shortens the wavelength. According to (30), when the energy is emitted, the electron must lose a mass, and when it absorbs energy, increase it. Therefore, particles with masses should act as energy carriers, i.e. energy is inherent only in bodily and mass essence.Since the electron emits (absorbs) photons, x-ray and γ - ray, that they have mass. This contradicts SRT and CF, is not perceived by modern physics. However, it is experimentally proved the presence of mass in the photon [14].

Note that $\overrightarrow{u_a}$ - this is the group velocity of the electron. It is different from the velocity of the center of mass, $u_e < u_a$, shows the presence of electron rotation near the center of mass with a constant kinematic momentum. A number of corollaries can be drawn from the law (21) established experimentally. When the energy is radiated, the electron wavelength increases; therefore, the radiation frequency decreases according to (14). In accordance with the choice of (20), the angular velocity of rotation of the electron decreases. Then the moment of inertia J_e of the electron should increase. Turning to the expression (26), we see that

$$J_e = m_e r_e^2 / 2 = (m_e r_e) r_e / 2 = (m_e \lambda_e / 2\pi)(\lambda_e / 2\pi) / 2 = (h / c)(\lambda_e / 2\pi) / 2 = const \cdot \lambda_e. \tag{31}$$

From (31) the increase of J_e with λ_e follows.

In such a way, the electron model satisfies the basic postulate of STR and CF, experimentally established conservation laws and gives consistent results with the theory and experiments of radiation (absorption) of energy. The electron along with the form must have a structure and all that it emits is contained in its bowels. However, this is forbidden by modern physics and considers the electron to be the only mass particle without an internal structure [14]. Based on the act of electron production during the decay of a neutron that does not have an electron in the internal structure [14], we conclude that the electron is assembled from elements erupted from the bowels of the neutron during decay, has these elements in its internal structure, emits (absorbs) these same elements - photons, x-rays andγ - rays. Such a vision does not contradict anything, with the exception of the statement of modern physics about the absence of the internal structure of the electron. It should also be noted its electric charge and electron magnetism, expressed by Bohr magneton $\mu = 9,274 \cdot 10^{-24}$ *Дж / тл* [11]. In view of (26), we consider the expression (21) multiplied by the charge and transformed to the form:

$$\frac{er_e^2\omega_e}{2} = \frac{\hbar e}{2m_e} = \mu_e. \tag{32}$$

The left side of (32) can be called the electric kinematic momentum

$$\vec{q} = i_e\overrightarrow{\omega_e}, \quad i_e = er_e^2 / 2. \tag{33}$$

Accordingto (21) and (33) the kinematic momentum $\overrightarrow{k_e}$ and the electric kinematic momentum $\overrightarrow{g_e}$ are connected through the moment of inertia J_e and the electric moment of inertia i_e:

$$\overrightarrow{q_e} = \frac{e\overrightarrow{k_e}}{m_e}; \quad i_e = \frac{ej_e}{m_e}. \tag{34}$$

The Expression (34) shows that the electric kinematic momentum and the electric moment of inertia are very large quantities that differ from the mass of the kinematic momentum and the moment of inertia by a constant value e/m_e:

$$\frac{e}{m_e} = 1,759 \cdot 10^{11} \quad кл / кг \tag{35}$$

The equality (35) indicates that the charge mass is dispersed along the periphery of the electron, the ordinary mass is concentrated in its center of mass like an atom.

We hypothesize: *a Newtonian mass with a kg unit of measure is represented by a bipolar magnetic mass with the property of a magnet and orientational attraction.*

Combined field and quantum actions of nanocarbon on emission electrons. Each emission electron is accelerated by the voltage (5) of the electric field of the nanocarbon and, according to (10), makes a helical motion near the nanocarbon in its magnetic field with induction (6). We draw a plane through the center of mass of the nanocarbon, the hole from where the electron is torn, and the center line of the cylindrical surface (toroid) on which the helical trajectory of the center of mass of the electron is wound. The electron and the hole for man **exciton** [6, 12]. The electron makes three kinds of motions in space: helical motion with a portable velocity V_e, main rotation with an angular velocity ω_e, and precession. The precession is regular and is ensured by the moment of magnetic forces acting on the electron. orders of magnitude of angular velocities ω_L (1014 Hz) and ω_e (1020 Hz) indicate the applicability of the Zhukovsky rule [13] to them and the order of the moment of magnetic forces ensuring regularity of the precession, from 10^{-20} J to 10^{-18} J.The motion along a helical path differs from the motion in a circular orbit in that the interaction force of the electron and its hole, the centrifugal force of motion along a helical path will be equally oriented and directed into the hole at least once on each turn. As a result of the combined actions of these two forces, the electron falls on a nanocarbon and makes an exciton impact, causing a further collapse of the nanocarbon into smaller particles of a smaller nanoscale.

This is a real mechanism for the development of nanoprocesses; it is unnoticed and unexplored by anyone. Being an internal mechanism, it does not require large external energy forces and can explain the

phase transition of solid nanocarbon particles added to the liquid state in bitumen. This fact is confirmed by experiments conducted in the laboratory of Kazakhstan Highway Research Institute JSC [2-4].

Conclusions about the accepted electron model. Nanotechnology and processes for the production of nanomaterials, like all other technological operations, are the result of electromagnetic interactions of atoms, an atom and a molecule, a molecule with a molecule in a substance. The rupture of chemical and physical bonds between the indicated structural elements of a substance, the formation of the necessary bonds are chemical reactions. Connections form electrons, thanks to them, the material world exists.The surface electrons of a nanocarbon form its physical fields and determine their characteristics. Emission electrons, interacting with the physical fields of nanocarbon, decide its fate. These circumstances are associated with the spatial model of the electron. In formulating the electron model, Einstein's law (13) was substantially used, with an important clarification that the mass is constant and does not obey the Einstein-Lorentz law, and de Broglie relation (14) with the refinement of the meaning of the pulse.The Compton wavelength and spin of the electron, the laws of conservation of the kinematic momentum and angular momentum of the electron, and the value of Bohr magneton were used. It is shown that the Bohr magneton follows from the law of conservation of the kinematic momentum of the electron, as a derivative, does not make much sense. Its reason lies in Maxwell's classical electrodynamics, which reduces magnetism to electricity and excludes the independent essence of the electron and the entire material world.

The model revealed the essence of the wave properties of an electron, the propagation of which required a carrier medium. It was established that it is not the wave that propagates, but the electron itself moves and what is called the wavelength and frequency are the parameters of this movement. The model explains the precession of the electron in the magnetic field under the action of a moment of magnetic forces and establishes that due to the high angular velocity of rotation, the electron having a large gyroscopic moment obeys the Zhukovsky rule and uniquely determines the momentum of external forces ensuring the regularity of the precession. The kinematic momentum of rotation of the electron, the spin, is preserved.

It is proved that the surface activity of matter and nanocarbon is a consequence of the manifestation of the properties of surface electrons with free valency in nanomaterials and their special characteristics. These facts can serve the development of nanotechnology, nanoscience and nanomaterial science, which are the basis of the cyclical economy and its digitalization using additive 3D printing. The role and place of physical and quantum fields of nanocarbon and its surface electrons are shown, the basis of the theory of electron in nanotechnology and nanomaterial science, developed in the direction of structural elements and electron structure, is laid.

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НАНОКӨМІРТЕКТІҢ ФИЗИКАЛЫҚ ЖӘНЕ КВАНТТЫҚ ӨРІСТЕРІНІҢ СИПАТТАМАЛАРЫМЕН ҚАСИЕТТЕРІ ЖӘНЕ ОЛАРДЫ ҚОЛДАНУ

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Аннотация. Нанокөміртектің беттік электрондарының физикалық (электрлік, магниттік) және кванттық (корпускулярлық-толқындық) өрістерінің сипаттамалары теориялық тұрғыдан негізделді және анықталды. Қатты денелердің наноұнтақтары үшін өрістердің сипаттамаларының сандық мәндерінің ақиқаттығы және сақталуы анықталды. Наноұнтақтардың кванттық мөлшерлік эффекті заттың беттік белсенділігі, яғни электрон өрістерінің әсері екені дәлелденді.Физикалық және кванттық өрістердің әсерлері мен электронның ұсынылған моделі нанотехнологиялар мен наноматериалтанудыңдамуына елеулі әсер етуі мүмкін.

Түйін сөздер: наноұнтақ, электр және магнитөрістері, корпускулярлық-толқындық сипаттамалар, кванттық өлшеу әсері, комптон әсері, толқын ұзындығы.

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ХАРАКТЕРИСТИКИ И СВОЙСТВА ФИЗИЧЕСКИХ И КВАНТОВЫХ ПОЛЕЙ НАНОУГЛЕРОДА И ИХ ПРИЛОЖЕНИЯ

Аннотация. Теоретически обосновано, определены характеристики физических (электрического, магнитного) и квантового (корпускулярно-волнового) полей поверхностных электронов наноуглерода. Установленысправедливость и сохранение числовых значений характеристик полей для нанопорошков твердых тел. Доказано что квантоворазмерный эффект нанопорошковесть поверхностная активность вещества, суть действия полей электрона. Действия физических и квантовых полей и предложеннаямодель электрона могут существенно влиять на развитие нанотехнологии и наноматериаловедения.

Ключевые слова: нанопорошок, электрическое и магнитное поля, корпускулярно-волновые характеристики, квантоворазмерный эффект, эффект Комптона, длина волны.

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ANALYSIS OF ECOLOGICAL CONDITION OF THE NURA RIVER ACCORDING TO THE BASIC BIOGENIC ELEMENTS

Abstract. The Nura River is an important water artery of Central Kazakhstan, feeding the network of lakes of the Korgalzhyn Nature Reserve, normal functioning of which depends on the quality of incoming Nura river waters, since the river flows through the territory of two regions undergoing technogenic and anthropogenic pollution.

Assessment of quality of waters flowing into lakes is an important element in monitoring studies.

The article assesses the ecological state of the Nura River by biogenic elements in three observation points - the village of Romanovka, the village of Sabyndy, the village of Korgalzhyn during the period from 2015 to 2018. An analysis of the dynamics of receipt ofbasic biogenic elements, such as ammonium salt, nitrite nitrogen, nitrate nitrogen, and phosphates was carried out. The results of the analysis indicate pollution of the river in all the investigated points with ammonium salts and nitrite nitrogen. The content of nitrate nitrogen and phosphates does not exceed the maximum permissible concentrations (MPCs). The main source of pollution can probably be nearby settlements, the main activity of which is related to agriculture. The main periods of pollution are the summer seasons in all years. The investigated points on the degree of pollution belong to a moderate level of pollution.

Keywords: the Nura River,environmental monitoring, pollution, biogenic elements.

The Nura River is an important water artery of the Tengiz-Korgalzhyn depression, feeding the network of lakes inscribed in the UNESCO's World Heritage List in Kazakhstan and Central Asia - “Saryarka - Steppe and Lakes of Northern Kazakhstan”.

Nura is the river in Central Kazakhstan, the largest of the rivers of the Nura-Sarysu basin. Most of the Nura river runoff belongs to the internal drainage Aral-Caspian basin. In some high water years, part of the runoff overflows into the river Ishim, then in the river Irtysh, and further to the Ob River, which flows into the Kara Sea. The Nura River originates from the western spurs of the Kyzyltas mountains and flows into Lake Tengiz, where the Korgalzhyn Nature Reserve is located, normal functioning of which depends on the flow of the Nura River waters[1]. The length of the river is 978 km, the catchment area is 58.1 thousand km^2, and it flows within the Kazakh Upland [2]. The terrain relief varies from low-mountain to plain with some swamps.In the floodplain near the settlements, there are plantings of garden and melon crops; varieties of willow and rose grow near riverbed zone.Thewidthofthechannelis 15-80 m. The average water consumption is 19.5 m^3/s. The Nura River is characterized by sharp fluctuations in the level and consumption of water. High water occurs in the upper and middle reaches from mid-April, in the downstream - in May, duration is 1.5-3.5 months; a depth in this period is 3.1 m.

Mineralization of the NuraRiver water varies in the upper and down reaches from 0.2-1.6 mg/dm^3 to 0.2-1.2 mg/dm^3. During a period of high water, upstream water is characterized by hydrocarbonates, in the lowwater period – by sulfate-sodium composition, ranging from 0.1-0.3 mg/dm3 to 2 mg/dm^3.The sum of salts of the middle and down reaches varies in the range of 0.5-4.0 mg/dm^3.Thus, the composition of salts ensures softness of water in high water period and hardness in low water period [3].

Analysis of literature data on the quality of surface waters of the Nura River basin has revealed the presence of technogenic pollution associated with wastewater discharges by industrial and agricultural enterprises and settlements [4, 5]. Anthropogenic impact on river waters is provided by municipal and industrial effluents of cities and enterprises along the Nura river [3]. Pollution by manganese, iron, chlorides, phenols, nitrogen-containing substances and the most dangerous pollutants – mercury and its compounds occurs along with wastewater [6-10].

The purpose of our research is to analyze an ecological state of surface waters of the Nura River by the content of biogenic elements. Biogenic elements are part of organisms, formed in water and included in the process of life; ensure the existence of living organisms. An insufficient or excess amount of biogens in water reduces the biological productivity of aquatic biogeocenoses. Exceeding the MPC values for biogens is a sign of eutrophic pollution that causes water flowering and development of cyanobacteria that release toxic substances, which leads to poisoning of people and animals, killing of aerobic organisms due to oxygen deficiency and degradation of aquatic ecosystems in general [11, 12].

Sections of the Nura River with a length of 432 km, in three observation points – a village of Romanovka, a village of Sabyndy, and a village of Korgalzhyn, located outside the industrial zone, were analyzed (table 1).

Table 1 – Coordinates of investigated points

#	Investigated point	N	W
1	Romanovka Village	50°49'28.3"	71°21'31.6"
2	Sabyndy Village	50°49'43.8"	70°33'53.9"
3	Korgalzhyn Village	50°35'42.7"	70°01'04.1"

The Romanovka Village (Tselinograd district, Akmola region) is located on the left bank of the Nura River, a population is 1680 people, key economic sectors are meat and dairy production.

TheSabyndy Village (Korgalzhyn district, Akmola region), the population is 1775people. There are 40 enterprises of agroindustrial complex (ten limited liability partnerships (LLP), including seven agricultural, eight livestock, and 22 farms).

TheKorgalzhyn Village (Korgalzhyn district, Akmola region),the left bank of the Nura River, the population is4034people. There are 44 agricultural enterprises in the livestock and crop sectors: 4 LLPs, 2 social entrepreneurship corporations, 38 peasant farmings (figure 1) [13].

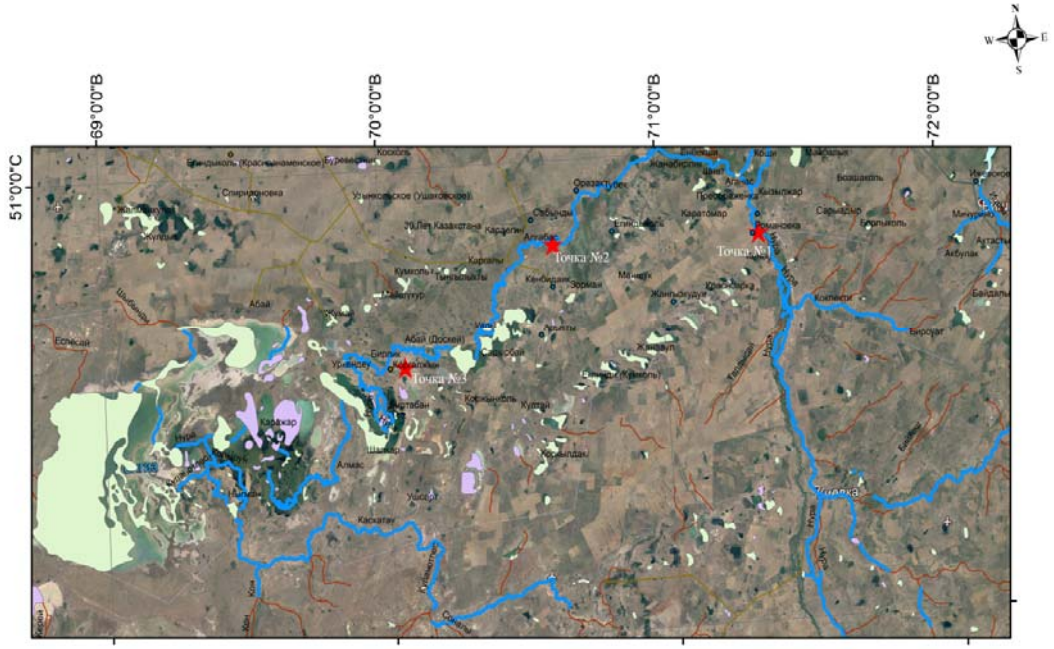

Figure 1 – Map-scheme of the study area:
1st point - Romanovka Village, 2nd point - Sabyndy Village, 3rd point - Korgalzhyn Village

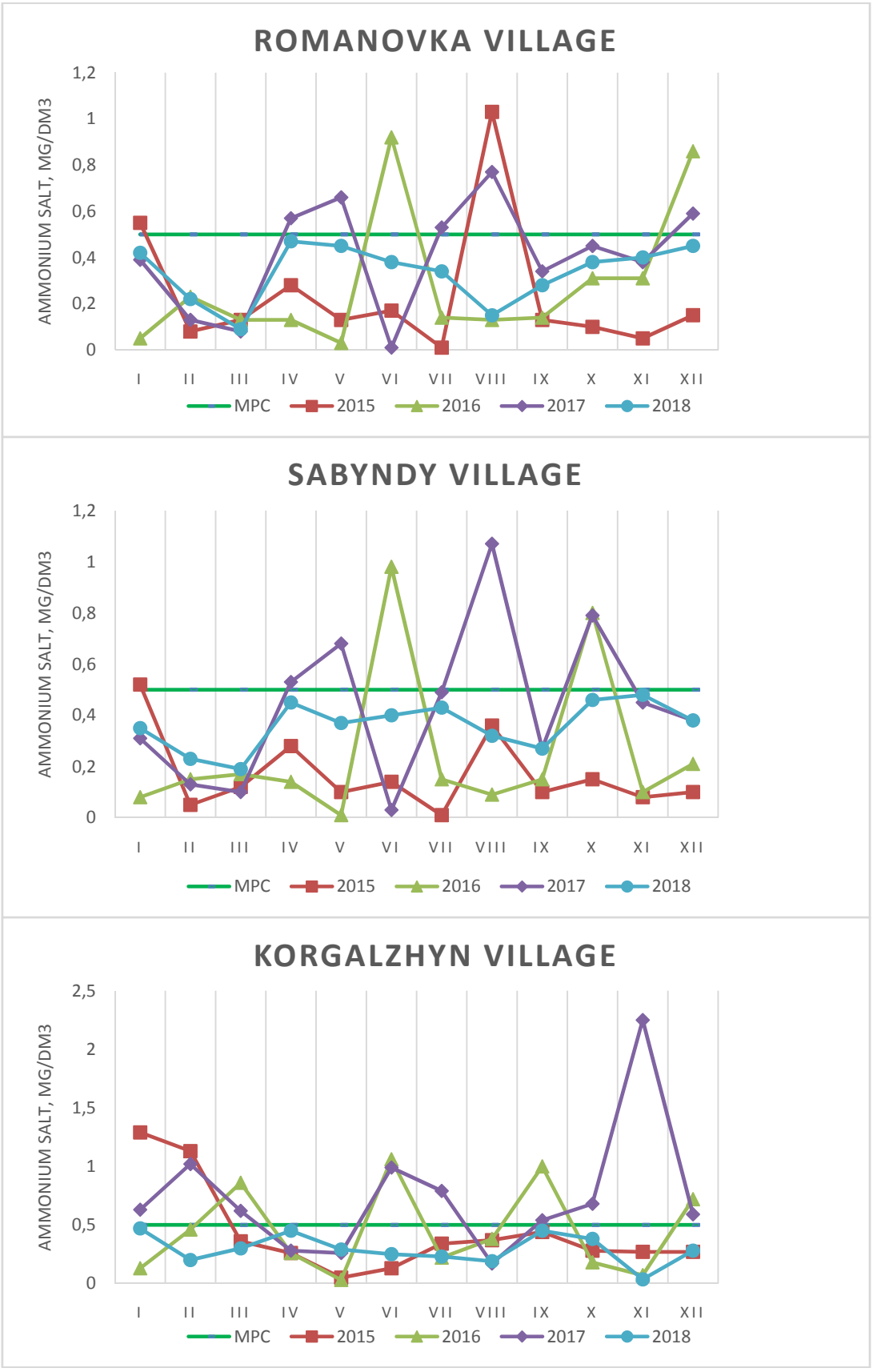

Figure 2 – Indicators of ammonium salt (NH_4^+), 2015-2018

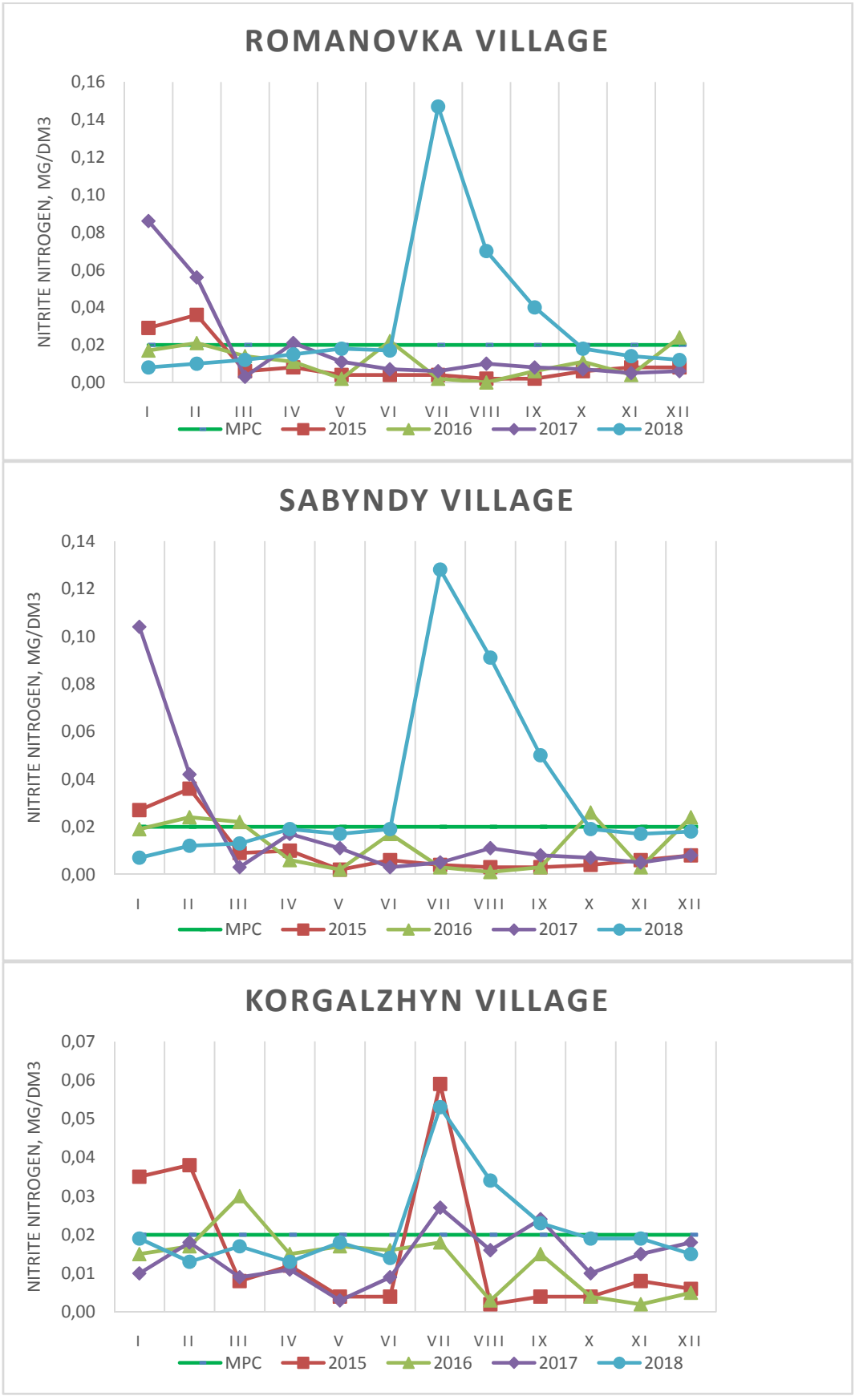

Figure 3 – Indicators of nitrite nitrogen (NO_2^-), 2015-2018

Using data from Kazhydromet, the content of basic biogenic elements: ammonium salt (NH_4^+), nitrites (NO_2^-), nitrates (NO_3^-), andphosphates (PO_4^{3-}) for the period 2015-2018,was taken into consideration [14- 17].

The results of the analysis of the content of biogenic elements at observation points are given below (figures 2, 3).

The content of ammonium salt (NH_4^+) (figure 2).

Analysis of the ammonium salt content in the Romanovka point shows the excess of the MPC values in 2015-2017. The range of indicators of the content of ammonium salt varies from 0.01 and above 1 mg/dm^3. The maximum values were noted in 2015 in August - 1.03 mg/dm^3. Also, the excess of MPC was noted in 2016 (June, December) and in 2017 (May, August). In other periods, the level of ammonium salts does not exceed the maximum permissible concentrations.

In the observation point of Sabyndy of the Nura River in 2015 and 2018, the MPC was not exceeded. Whereas in 2016 in June the excess of salt ammonia amounted to 0.9 mg/dm^3, in October - 0.8 mg/dm^3. Frequent and high excess rates were observed in 2017 in May, August, and October. The maximum values of ammonium salt for all years were noted in August 2017 - 1.07 mg/dm^3.

The control point in the Korgalzhyn area also noted an increase in the level of ammonium salts. So, if in 2015 an excess was noted only in winter (January, February), then in 2016 an excess of MPC was found in March, June, and September, in 2017 - in February, June, July, and a sharp increase in MPC in November - 2.25 mg/dm^3. In 2018, ammonia levels were not exceeded.

Analysis of the data on the content of ammonium salts showed that the most polluted year is 2017, becauseof excess is noted at all observation points. In 2018, the state of the river stabilized. Thus, starting from 2015, pollution with ammonium salts intensifies reaching a maximum in 2017.

The most polluted waterwas near the settlements. This indirectly proves that the intensive activity of agricultural enterprises, flushing fertilizers from fields and animal waste by rain wastewater can be sources of pollution.

The content of nitrite nitrogen (NO_2^-) (figure 3).

The presence of nitrite nitrogen in water and an increase in its level characterizes the ongoing oxidative processes of decomposition of organic substances as a result of the vital activity of microorganisms and is an indicator of pollution. The presence of nitrite nitrogen in large quantities indicates recent organic pollution, as well as ongoing processes of mineralization of organic matter [18].

According to the content of nitrite nitrogen at the Romanovka control point in 2015 and 2017 in the winter period (January, February), the MPC level is exceeded. In 2016, nitrite nitrogen pollution was not observed. 2018 is characterized by a sharp excess from the MPC level in the summer period (July, August).

At the Sabyndy point, an increase of the nitrite nitrogen content was insignificant in 2015 and 2016; in 2017 and 2018, there was a sharp excess of the MPC level by several times (January 2017, the third quarter of 2018).

The nitrite nitrogen content in the Korgalzhynpoint is marked by an excess of the MPC level for all studied years. The highest nitrite nitrogen values are observed in January, February and July 2015 and in July and August 2018.

The phosphate and nitrate contents are shown in table 2.

Table 2 – The content of phosphates and nitrates

Investigated point		2015		2016		2017		2018	
		min	max	min	max	min	max	min	max
Romanovka Village	NO_3^-	0,090	0,580	0,040	0,850	0,020	2,91	0,030	0,950
	PO_4^{3-}	0,006	0,102	0,003	0,137	0,008	0,091	0,005	0,100
Sabyndy Village	NO_3^-	0,09	0,55	0,04	0,87	0,02	3,39	0,07	1,87
	PO_4^{3-}	0,005	0,091	0,001	0,12	0,007	0,078	0,006	0,080
Korgalzhyn Village	NO_3^-	0,09	0,72	0,07	0,81	0,05	2,36	0,06	1,81
	PO_4^{3-}	0,008	0,075	0,0009	0,043	0,009	0,072	0,007	0,070

According to the list of maximum permissible concentrations of harmful substances for water of fishery reservoirs, MPC for nitrates is 9.1 mg/l, maximum concentration limit for phosphates is not established.

Analyzing the above data, it can be stated that the content of phosphates and nitrates at all observation points show values that do not exceed the maximum permissible concentrations.

According to published data, nitrates up to 10 mg/l do not adversely affect aquatic organisms [19-21].

Many factors affect river pollution, including the rural areas through which the river flows. Domestic water is supposedly discharged from settlements to the Nura River, and pollution is caused by organic residues from animal husbandry.

Analyzing the data, it can be noted that the Nura River at the observation points is polluted with organic residues. This is evidenced by the presence of periodically elevated ammonia values of salt and nitrite nitrogen. It can be explained by the location of nearby settlements, agricultural land and livestock farming.

Comparative analysis of nutrients through observation points has allowed to identify the main periods of pollution, which is the summer seasons in all years.

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БИОГЕНДІ КӨРСЕТКІШТЕР БОЙЫНША НҰРА ӨЗЕНІНІҢ ЭКОЛОГИЯЛЫҚ ЖАҒДАЙЫН ТАЛДАУ

Аннотация. Нұра өзені Қорғалжын қорығының көлдер торабын қоректендіретін маңызды су көзі болып табылады. Қорықтағы көлдердің қалыпты тіршілігі осы өзен суларының құйылуына тәуелді, себебі өзен техногендік және антропогендік ластануға ұшырап екі облыстың аумағы арқылы ағып өтеді.

Көлдерге құятын өзендердің сапасын бағалау мониторингтік зерттеулердің маңызды бөлігі болып табылады.

Мақалада Нұра өзенінің сапасын биогенді элементтер бойынша бағалау үш бақылау бекеттері – Романовка, Сабынды ауылдары мен Қорғалжын тұрғын елінде 2015-2018 жылдар аралығында жүргізілді. Аммоний тұзы, нитритті азот, нитратты азот, фосфаттар секілді негізгі биогенді заттардың түсу динамикасына талдау жүргізілді. Талдау нәтижелері өзеннің барлық зерттелген нүктелерінде аммоний тұздары мен нитритті азотпен ластанғандығын көрсетті. Нитратты азот пен фосфат мөлшері шекті рұқсат етілген концентрациядан (ШРК) аспайды. Ластанудың негізгі көзі жақын орналасқан елді мекендер болуы мүмкін, олардың негізгі қызметі ауыл шаруашылығымен байланысты. Негізгі ластану мерзімдері – бұл барлық жылдар бойынша жаз мезгілі. Зерттелген нүктелер ластану дәрежесі бойынша орташа ластану деңгейіне жатады.

Түйін сөздер: Нұра өзені, экологиялықмониторинг, ластану, биогенді элементтер.

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АНАЛИЗ ЭКОЛОГИЧЕСКОГО СОСТОЯНИЯ РЕКИ НУРЫ ПО БИОГЕННЫМ ЭЛЕМЕНТАМ

Аннотация. Река Нура является важной водной артерией Центрального Казахстана, питающей сеть озер Коргалжынского заповедника, нормальное функционирование которого зависит от качества поступающих речных вод Нуры, так как река, протекая по территории двух областей подвергается техногенному и антропогенному загрязнению.

Оценка качества впадающих в озера вод является важным элементом мониторинговых исследований.

В статье дана оценка экологического состояния реки Нура по биогенным элементам втрех пунктах наблюдения – село Романовка, село Сабынды, поселок Коргалжын в период с 2015 по 2018 гг. Проведен анализ динамики поступления основных биогенных элементов, таких как, аммоний солевой, нитритный азот, нитратный азот, фосфаты. Результаты анализа указывают на загрязнение реки во всех исследованных пунктах солями аммония и нитритным азотом. Содержание азота нитратного и фосфатов не превышает предельно допустимых концентраций (ПДК). Основным источником загрязнения вероятно могут являться близлежащие населенные пункты, основная деятельность которых связана с сельским хозяйством. Основные периоды загрязнения – это летние сезоны во все года. Исследованные точки по степени загрязнения относятся к умеренному уровню загрязнения.

Ключевые слова: река Нура, экологический мониторинг, загрязнение, биогенные элементы.

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PARTIAL DISCHARGES AND ELECTRIC BREAKDOWN IN COALS OF MAIKUBEN, EKIBASTUZ AND KORZHUNKOL BASINS

Abstract. The paper is devoted to the study of the possibility of underground pyrolytic conversion of coal from Kazakhstan into combustible gases and tar by heating with electric current. The purpose of this work is to study the patterns of electrical breakdown of coal as a result of long partial discharges action. The breakdown between the electrodes leads to the forming of a low-resistance channel which is supposed to be used as a resistive heating element for heating and pyrolysis of a part of the underground formation. The paper presents the dependences of the voltage of occurrence of partial discharges and the voltage of breakdown of coal. Coals of Maykubensky, Ekibastuzsky and Korzhunkolsky basins were used for research. Steel rods were used as electrodes, the interelectrode distance ranged from 5 to 30 cm. It was found that the average field of the occurrence of partial discharges and the average breakdown field decrease with increasing the electrode distance. It can be assumed that this tendency will be valid in the field conditions, which makes it possible to use electrothermal breakdown for underground heating and conversion of coal. Moreover, these dependences correlate with each other, which can be used to predict the breakdown voltage at a known voltage of the occurrence of partial discharges.

Key words: coal, partial discharges, electric breakdown, subterranean gasification, heating element, voltage, electric field.

Introduction. Recently, there has been a significant increase in attention to technologies for efficient processing of solid fossil fuels (black and brown coals, oil shale) and metamorphism research [1]. Underground conversion can claim to be one of the most efficient processing technologies. It does not require the extraction of rock to the surface, as well as the subsequent disposal of slag.

To date, a large number of different methods of underground conversion have been proposed. A number of them offer oxidative gasification by incomplete combustion of coal directly in the reservoir [2-4], heating of the reservoir with heat-transfer agent [5, 6], electromagnetic heating using radio frequency [7-9] or microwaves [10], heating with electric heaters [11, 12], heating with fuel cells [13], heating by electric current [14, 15].

The use of electric discharge technologies can give a new approach in the development of underground conversion methods. We have previously found that electric discharge processes, such as partial discharges and the electrical treeing caused by them, can lead to the breakdown of certain types of solid fuels at relatively low voltages. This effect can be used for electrical breakdown and subsequent heating of a part of a subterranean formation by using the breakdown channel as a resistive heating element [16].

In order to study the applicability of Kazakhstan coal for conversion in this way, we studied the characteristics of partial discharges and breakdowns in coal taken from the coal mines Maykuben (Maykuben basin), Bogatyr (Ekibastuz basin) and Saryadyr (Korzhunkol basin).

Partial discharges (PD) occur in dielectrics under the action of an applied external high voltage. PD is an incomplete breakdown of the dielectric, leading to the electric locking of the part of the interelectrode distance by discharge channel. The cause of partial discharges is the uneven distribution of the electric field inside the material. For an inhomogeneous substance having inclusions of different materials, the electric field in the interelectrode space will be distributed inversely proportional to the dielectric constant of materials [17]:

$$\frac{E_D}{E_I} = \frac{\varepsilon_I}{\varepsilon_D},$$

where E_D, E_I – electric field in main part of dielectric material and in inclusion correspondingly, ε_D, ε_I – permittivity of dielectric material and matter of inclusion correspondingly. Thus, the greatest field strength will be on elements with the lowest dielectric constant. As a rule, such are gas inclusions and pores. Moreover, the field on them will be the greater, the higher the dielectric constant of the rest of the dielectric.

PDs are characterized by a number of characteristics, the main of which are the voltage and field of occurrence, intensity, apparent charge. The voltage and field of occurrence reflect the threshold value of the applied field, at which the recorded partial discharges appear. This value characterizes the dielectric inhomogeneity of the material under study. The intensity of partial discharges is the number of PDs occurring in a dielectric per unit time. In the case of coal, the voltage of occurrence and the dependence of intensity on voltage reflect the dynamics of electric discharge processes in coals and can be used as indicators of the treeing beginning and the treeing breakdown. The apparent charge is the amount of charge that passed through the external electrical circuit at the moment of PD. Thus, this is the amount of charge that can be fixed by the measuring device, in contrast to the true charge, which passed inside the inclusion at the moment of PD. The name "apparent" is associated with the assumption that this characteristic is not equal to the true charge neutralized by a partial discharge. However, it is considered that this value indirectly reflects the value of the true charge.

In homogeneous insulating materials the apparent charge can be used as an indicator of critical PDs that lead to dielectric failure [18, 19]. To do this, calibration measurements for each specific material are carried out. In the case of coals, this approach is not applicable, as a large dispersion of the apparent charge of critical PDs can be expected because of a sharp material heterogeneity. So we have investigated the voltage of PDs occurrence and the breakdown voltage of the interelectrode gap in coals as a function of interelectrode distance.

Method of experiments. Measurement of the characteristics of partial discharges and voltage of the treeing breakdown is necessary to estimate the potential of applying these phenomena to develop underground pyrolysis technology. Thus, the low intensity of the PDs occurrence and the low voltage of the treeing breakdown indicate the possibility of producing a breakdown of a significant interelectrode distance at a technically realizable voltage value.

Samples for measuring of the PDs characteristics were made in the form of bars (figure 1) by cutting out from a solid fragment of coal on a stone-cutting machine with an abrasive-cutting disc with a diamond coating. The length of the bar was selected on the basis of the required interelectrode distance so that from the electrode to the edge of the bar remained at least 30 mm. Samples with an interelectrode distance from 5 cm to 30 cm were made from the target deposits coals. The width and height of the bar were selected in the range of 30-50% of the length.

Rod electrodes were used to supply voltage, since such an electrode configuration is a reduced model of the proposed technology for the breakdown and heating of an underground coal bed. The electrodes were rods of carbon steel with a 10 mm diameter, which are tightly inserted into the pre-drilled holes. The electrodes were deepened into the sample at 60–80% of the sample height.

The methods of measuring of the partial discharges characteristics are regulated by a number of normative documents [20, 21]. The measurement was carried out by applying a high voltage of industrial frequency to the sample and registering current pulses in an external circuit. Since the PD pulses have a higher frequency spectrum, in order to close PD current, a so-called coupling capacitor is switched on in parallel with the sample under test. Also in the circuit includes a recording device. The simplified electrical circuit diagram of the power and measuring parts of the equipment is shown in figure 2.

Figure 1 – A sample of coal for measuring of the characteristics of PD

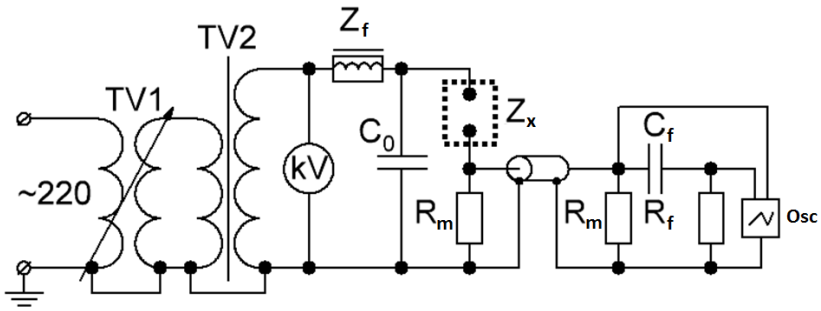


Figure 2 – The electrical circuit of the laboratory equipment for investigation of the characteristics of partial discharges

The equipment is supplied from an electrical network of alternating voltage of 220 V, which is fed to the regulating transformer TV1. This regulator with a rated power of 100 kW works as a variable magnetic coupling transformer. The voltage at its output can vary from 10 V to 220 V by moving the carriage placed inside the transformer. The voltage from the regulator output feed the step-up transformer TV2. This transformer with a rated power of 100 kW produces a voltage of 100 kV at an input voltage of 220 V. The voltage at the output of the TV2 transformer is monitored using a digital kilovoltmeter.

The element Z_f is used as a blocking impedance, which does not allow to high-frequency interference from the supplying network and transformers to flow into the measuring circuit. It also helps to ensure that the PD current pulses are closed in the circuit between the sample and the coupling capacitor. A highly inductive wire-wound resistor with a nominal resistance of 1 kΩ is used as Z_f. The resistor has the shape of a tube, and a set of ferrite washers was placed inside of them to increase its inductance.

Capacity C_0 performs the function of a coupling capacitor in the circuit. The high-frequency current pulse of partial discharges closes through this capacitance. C_0 was made from 5 220 pF ceramic capacitors connected in series. The total rated battery capacity is 44 pF, the maximum allowable voltage is 112 kV. According to international standard IEC 60270, the capacitance of the coupling capacitor was chosen close to the interelectrode capacitance of the sample under study.

The element Z_x is a test sample. Two resistors, designated in the circuit as R_m, work as current sensors, which are used for registration of partial discharge pulses. Physically measuring device (oscilloscope) removed a few meters from the sample under high voltage. The signal source is connected to the receiver by a shielded cable. To prevent interference, the cable line is matched by connecting resistors at both ends with a resistance equal to the cable impedance. In this case, these resistors simultaneously work as a shunt. Resistance of each R_m is 150 Ohms.

The signal from the output of the measuring shunt passes through a high-pass filter, in order to separate the low-frequency volume conductivity current from the current of partial discharges, whose frequency spectrum lies in the range of tens to hundreds of megahertz. Two signals come to the measuring device - directly from the shunt and from the output of the filter. The kilovoltmeter kV is a high-voltage resistive frequency-compensated divider, which is also connected to the oscilloscope.

The voltage applied to the sample during the experiment was gradually increased from zero to the moment of sample breakdown at a rate of 100 V/min. Using an oscilloscope, the presence of partial discharges was recorded and the voltage applied to the sample was measured.

Results and discussion. Samples of coal under the action of high voltage exhibit a capacitive-resistive reaction with a predominance of the resistive component (figure 3). The phase shift between current and voltage is 15-20 degrees. The phase of the PD at the moment of their appearance corresponds to the amplitude of the flowing current. As the voltage increases, the PD phase range expands.

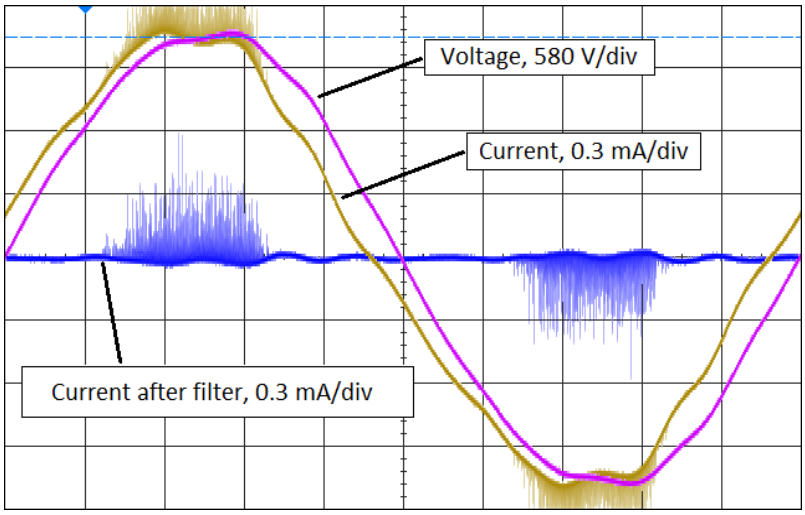


Figure 3 – Diagrams of voltage and current through the sample (horizontal scale 2 ms / div)

The pulses of partial discharges current have a front duration of 5-10 ns (figure 4). This is the time of discharge plasma action in the gas pore. Then the pulse has an exponential decay, indicating the process of recharging pore capacity.

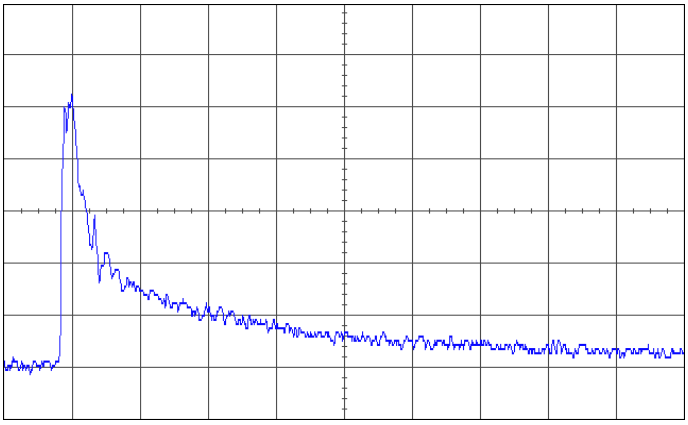
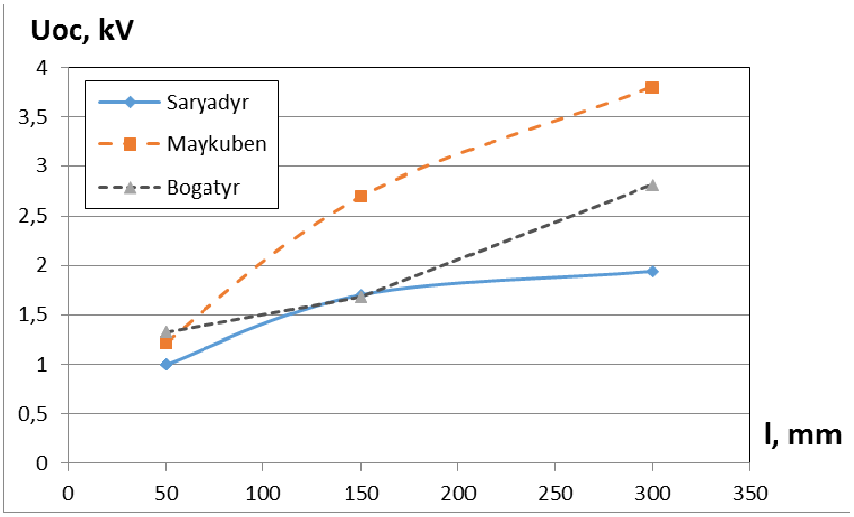


Figure 4 – Diagrams of a single PD current. The scale of the horizontal axis is 100 ns / div, the vertical axis is 27 μA/div

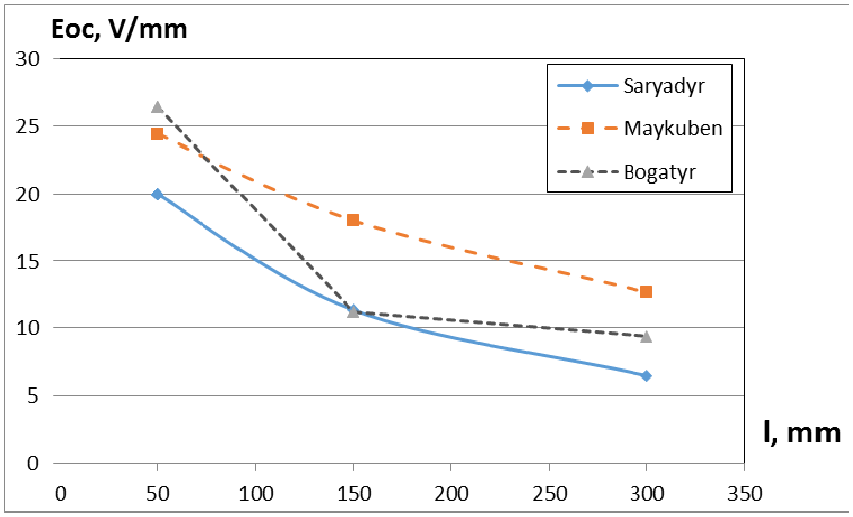
The voltage of occurrence of partial discharges U_{oc} is the smallest voltage at which the partial discharges appear. It can be assumed that the lower the voltage required for the occurrence of PDs, the lower the voltage cause the treeing and breakdown. Therefore, the voltage of PDs occurrence can be used as

indirect indicator of the breakdown voltage. When a voltage is applied to a real subterranean formation, knowledge of such a correlation may be highly helpful.

Figure 5,a shows the dependence of the voltage of the PDs occurrence U_{oc} on the distance between the electrodes l. For the coals under study, the U_{oc} varies up to 2 times, which is due to the different porosity and different composition of the mineral component of the coal.



a)



b)

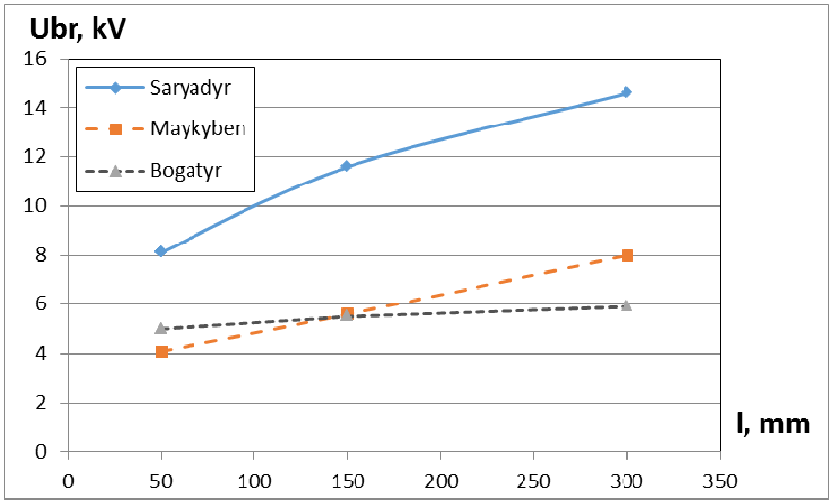
Figure 5 – Voltage (a) and field intensity (b) of the occurrence of the PD in coals depending on the distance

Curves show that increasing of interelectrode distance leads to increasing of the occurrence voltage. This is due to the fact that with the same voltage, but a greater interelectrode distance, the average field strength will be lower. However, it is also of interest how the average intensity of the occurrence of E_{oc} (figure 5,b), which was determined as follows, depends on the interelectrode distance:

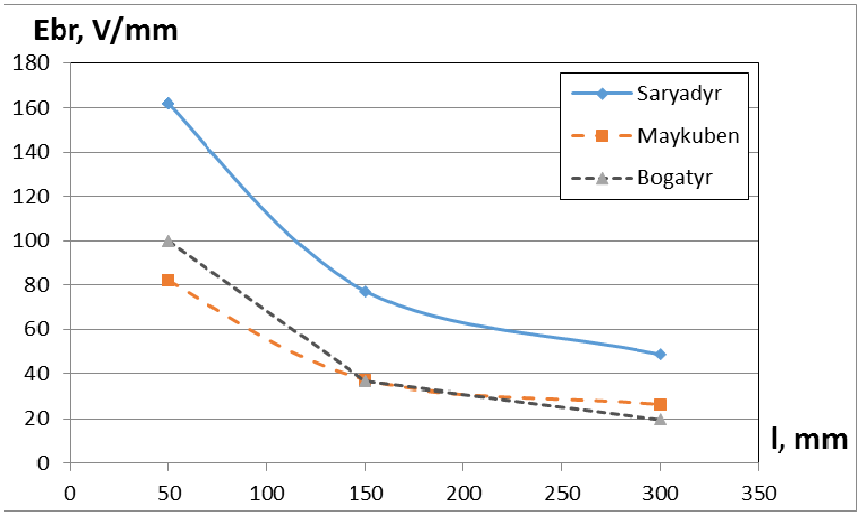
$$E_{oc} = \frac{U_{oc}}{l}.$$

It can be seen that the average intensity of partial discharges occurrence decreases with an increasing of the interelectrode distance. This suggests that the voltage of occurrence depends on the distance nonlinearly. Extrapolating the graphs to large distances, it can be assumed that E_{oc} will continue to decline further, that is, U_{oc} will increase more slowly with increasing of interelectrode distance.

The voltage U_{br} and the field E_{br} (figure 6) of the breakdown characterize the magnitude of the electromagnetic action at which the electrical resistance of the inter-electrode gap of the sample abruptly decreases in several hundred or thousand times. The reason for this is the forming of a through-channel breakdown between the electrodes, consisting of discharge plasma. The high temperature of this plasma causes thermal destruction and carbonization of the coal substance, so the resistance of the interelectrode gap retains its low value even after the voltage is turned off.



a)



b)

Figure 6 – Voltage (a) and field intensity (b) of coal breakdown versus distance

The behavior of the curves $U_{br} = f(l)$ and $E_{br} = f(l)$ is very similar to the dependencies $U_{oc} = f(l)$ and $E_{oc} = f(l)$, respectively, however, the breakdown occurs at voltages several times higher than the partial discharge voltage. It also shows that, in contrast to homogeneous dielectrics, in coals, the average breakdown voltage significantly decreases with an increasing of the interelectrode distance. The behavior of the curves suggests that a further increasing of the interelectrode distance will lead to slight increasing of the breakdown voltage. As a result, the breakdown of interelectrode distances of tens of meters in the conditions of a real underground reservoir may require technically realizable in field conditions voltage.

The correlation between the voltage of PD occurrence and the breakdown voltage may also be useful in the field. Knowing how many times the breakdown voltage exceeds the PD occurrence voltage for these coals, by fixing Uoc, we can predict Ubr at a given interelectrode distance.

Findings. The use of electric heating of underground coal beds may make it possible to create a new highly efficient technology for the processing of coal. Studies have shown the possibility of coal breakdown for using the breakdown channel as a heating element. The behavior of the dependence of the breakdown voltage on the interelectrode distance suggests that in field conditions the technically achievable voltage will allow to breakdown the interelectrode distance of tens of meters.

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МАЙКӨБЕН, ЕКІБАСТҰЗ ЖӘНЕ ҚОРЖЫНКӨЛ КӨМІРЛЕРІНДЕГІ ІШІНАРА РАЗРЯДТТАР МЕН ЭЛЕКТРЛІК БҰЗЫЛУЛАР

Аннотация. Мақала Қазақстан көмірін электр тогымен қыздыру арқылы жанғыш газдар мен шайырларды жерасты пиролиттік әдіспен қайта өңдеудеуін зерттеуге арналады. Бұл жұмыстың мақсаты ұзартылған ішінара шығарындылар нәтижесінде көмірдің электрлік бөліктерінің үлгілерін зерттеу болып табылады. Электродтар арасындағы бұзылудың нәтижесінде төменомды арна пайда болады, бұл жер асты түзілімін қыздыруға, пиролизге арналған резистивті қыздыру элементі ретінде қолданылады. Бұл мақалада ішінара разрядтардың пайда болу кернеуінің және көмірдің бұзылу кернеуінің тәуелділігі келтірілген. Зерттеулер үшін Майкөбен, Екібастұз және Қоржынкөл бассейндерінің көмірлері пайдаланылады. Электродтар ретінде болат құбырлар пайдаланылды және электрөткізуқашықтықаралығы 5-тен 30 см-ге дейін болды. Ішінара разрядтардың қашықтығы үлкендеуінен орташа қарқындылығы және электродтың аралық кеңеюімен, орташа сыну қарқындылығының төмендеуі анықталды. Бұл үрдіс жерасты жылыту мен көмірді қайта өңдеу үшін электротермальды бұзылуды қолдануға мүмкіндік беретін өріс үшін жарамды деп болжауға болады. Сонымен қатар, бұл тәуелділіктердің бір-бірімен байланысуы, ішінара зарядтардың пайда болу қарқындылығында бұзылу кернеуін болжау үшін пайдаланылады.

Түйін сөздер: көмір, ішінара разряд, электр тогының бұзылуы, жерасты газдандыру, қыздыру элементі, кернеу, қарқындылық.

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ЧАСТИЧНЫЕ РАЗРЯДЫ И ЭЛЕКТРИЧЕСКИЙ ПРОБОЙ В УГЛЯХ МАЙКУБЕНСКОГО, ЭКИБАСТУЗСКОГО И КОРЖУНКОЛЬСКОГО БАССЕЙНОВ

Аннотация. Статья посвящена исследованию возможности подземной пиролитической конверсии углей Казахстана в горючие газы и смолы путем нагрева электрическим током. Цель проведенной работы состоит в исследовании закономерностей электрического пробоя углей в результате продолжительного действия частичных разрядов. В результате пробоя между электродами образуется низкоомный канал, который предполагается использовать в качестве резистивного нагревательного элемента для нагрева и пиролиза участка подземного пласта. В статье приведены зависимости напряжения возникновения частичных разрядов и напряжения пробоя углей. Для исследований были использованы угли Майкубенского, Экибастузского и Коржункольского бассейнов. В качестве электродов использовались стальные стержни, межэлектродное расстояние составляло от 5 до 30 см. Обнаружено, что средняя напряженность возникновения частичных разрядов и средняя напряженность пробоя снижаются при увеличении межэлектродного расстояния. Можно предположить, что эта тенденция будет справедлива и в полевых условиях, что дает возможность использовать электротепловой пробой для подземного нагрева и конверсии углей. При этом данные зависимости

коррелируют между собой, что может быть использовано для прогнозирования напряжения пробоя при известной напряженности возникновения частичных разрядов.

Ключевые слова: уголь, частичные разряды, электрический пробой, подземная газификация, нагревательный элемент, напряжение, электрическое поле.

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