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ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫНЫҢ
Қ. И. Сәтпаев атындағы Қазақ ұлттық техникалық зерттеу университеті

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ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН
Қазақстан Республикасының Ғылым Академиясының
Қ. И. Сәтпаев атындағы Қазақ ұлттық техникалық зерттеу университеті

NEWS

OF THE ACADEMY OF SCIENCES
OF THE REPUBLIC OF KAZAKHSTAN
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NAS RK is pleased to announce that News of NAS RK. Series of geology and technical sciences scientific journal has been accepted for indexing in the Emerging Sources Citation Index, a new edition of Web of Science. Content in this index is under consideration by Clarivate Analytics to be accepted in the Science Citation Index Expanded, the Social Sciences Citation Index, and the Arts & Humanities Citation Index. The quality and depth of content Web of Science offers to researchers, authors, publishers, and institutions sets it apart from other research databases. The inclusion of News of NAS RK. Series of geology and technical sciences in the Emerging Sources Citation Index demonstrates our dedication to providing the most relevant and influential content of geology and engineering sciences to our community.

Қазақстан Республикасы Ұлттық ғылым академиясы "ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы" ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Web of Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді геология және техникалық ғылымдар бойынша контентке адалдығымызды білдіреді.

НАН РК сообщает, что научный журнал «Известия НАН РК. Серия геологии и технических наук» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК. Серия геологии и технических наук в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по геологии и техническим наукам для нашего сообщества.

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**ABOUT RATIO AND VALUES OF THE EMPIRICAL COEFFICIENT
OF ALKALI METALS (Na⁺ and K⁺) IN SURFACE WATERS
OF KAZAKHSTAN ON THE EXAMPLE OF THE ILE RIVER**

Abstract. Issues concerning to insufficient knowledge of such important aspects in the field of regional hydrochemistry, which are the patterns of formation of the regime and the dynamics of alkali metals (sodium and potassium) in surface waters are considered. It is pointed out the need for reliable analytical data on the separate concentration of sodium and potassium in natural waters to solve important practical problems in the field of assessing the suitability of the composition of the water of reservoirs for acclimatization of valuable forage organisms for fish, when choosing water sources for irrigated areas. Special attention is paid to the importance of the empirical coefficient (EC) of sodium and potassium, which is necessary in determining the total mineralization of natural waters, on which the level of their use for various household and drinking needs depends. On the state monitoring data, the nature of changes in the ratio of sodium and potassium along the Ile River was studied and the EC was established to calculate their absolute concentration (in mg/dm³) and total water mineralization. Based on the analysis of literature data and the results of our own research on the item under consideration, conducted in different years for a number of reservoirs and watercourses in Kazakhstan, it was concluded that: previously adopted for the entire territory of the former USSR, the EC equal to 25 for freshwater reservoirs can be used for waters of some river basins of the Republic of Kazakhstan with their mineralization up to 350-400 mg/dm³. A decisive role in the formation of the regime and the dynamics of the concentration of sodium and potassium in surface waters has a complex of regional physiographic conditions: climate, nature of the soil, groundwater, anthropogenic influences, etc. The necessity of establishing the EC for reservoirs and watercourses of different climatic zones of the Republic of Kazakhstan, especially for large transboundary basins, is recommended.

Key words: sodium and potassium, values of their ratio in surface waters, empirical coefficients of alkali metals.

Introduction. The sodium and the potassium are one of the main components of the chemical composition of natural waters. However, until now, due to the sufficient laboriousness of their separate chemical analysis and limited distribution of sensitive and relatively simple methods for determining these ions, they are often not determined separately, and the total content of Na⁺ and K⁺ is calculated from the difference between the sum of anions and cations. The data obtained in this case cannot be considered reliable, since the calculated value of the sum of Na⁺ and K⁺ contains errors of chemical determination of all major ions.

In terms of assessing the genetic conditions for the formation of the chemical composition of waters of different types of reservoirs, as well as to develop a number of methodological approaches in their study, it is very important to know about the content of water and migration characteristics of alkali metals – Na⁺ and K⁺. The study of the dynamics of Na⁺, K⁺ and their ratios is of great importance in determining

the characteristics of their migration in surface waters and other natural objects in different climatic and soil zones, in the characteristics of biological productivity and quality of natural waters, for search purposes, etc.

Literature review. The research of the content and dynamics of sodium and potassium in the lithosphere and natural waters are devoted to the works of a number of geochemistry classics, like F. Clark [1], V.M. Goldschmidt [2], A.P. Vinogradov [3, 4], E.D. Goldberg [5], J.P. Reilly and G. Skirrow [6]. Subsequently, these elements were studied in sufficient detail by A.A. Beus [7], G.S. Kononov and V.I. Koreneva [8, 9], A.M. Almazov and I.G. Enaki [10].

The scientific data on this issue for surface waters of Kazakhstan have until recently been found in the work of A.I. Mun and A.B. Bekturov [11]. A fairly wide range of issues related to alkali metals (Na^+ and K^+), we studied in some years in the water of a number of important and large brackish-water and fresh water objects in Kazakhstan [12-17].

It is known that a number of aquatic organisms that serve as a fodder basis for fishes can live and reproduce only at certain ratios of potassium and calcium concentrations in water. As the value of the $\text{K}^+/\text{Ca}^{2+}$ ratio (above 0,2) increases, unfavorable water properties for aquatic organisms increase. The toxic effect of potassium on organisms can neutralize calcium ions at certain ratios and concentrations [18-19].

A clear example that confirms these conclusions is the results of our experimental work on the survival of mysids in the water of in the water bodies in Kazakhstan. According to the results of a number of years of acclimatization works, the introduction of mysids (*Paramysis (Mesomysis) intermedia*, P (M).kovalevski) and other food items in the large brackish lake Alakol has failed. The reason was precisely in the high concentration of potassium in the water, unbalanced, respectively, by antagonist ions.

In the waters of Lakes Sasykkol and Koshkarkol, which are part of the Alakol lakes system, the concentration of potassium is low, according to average values of 3,9 and 9,4 mg/dm³, respectively. Mysids were successfully acclimatized to these lakes, the conditions were optimal for the life of invertebrate organisms, including the ratio of $\text{K}^+/\text{Ca}^{2+}$ is characterized by values of 0,06-0,16. The ratio of $\text{K}^+/\text{Ca}^{2+}$ in the water of lake Alakol, taken for experience, was 1,11-0,75. In some areas of the water area, the ratio of $\text{K}^+/\text{Ca}^{2+}$ in the water of this lake reached 4,1 and 5,6. In our experiments, the survivorship rate of mysids in the water of Lake Alakol was 14-16 %, and in the water of other reservoirs it reached 80 %. According to Yu.V. Epova [20], the mysids have not been found in the Lake Alakol so far.

Separate concentration of sodium is an important indicator in the agro-industrial sphere in assessing the irrigation quality of natural waters. Thus, when calculating the values of the irrigation (alkali) coefficient (K_a) proposed by H. Stabler using an equation $K_a = \frac{6620}{\text{Na}^+ + 2,6 \text{Cl}^-}$, as well as the sodium absorption ratio SAR (used by the Department of Agriculture US farms), which characterizes the danger of soil salinity

according to the equation $SAR = \frac{\text{Na}^+}{\sqrt{\frac{\text{Ca}^{2+} + \text{Mg}^{2+}}{2}}}$, the value of elemental sodium concentration is quite large.

Sodium and potassium have similar chemical properties, but on the earth's surface, their migration paths diverge. Na^+ leaches from hypergenic formations, while K^+ is trapped by soil colloids and living material.

The geochemical mobility of potassium is many times lower than that of sodium, which is explained by a number of reasons: slower destruction and greater persistence of primary potassium minerals in comparison with sodium; potassium adsorption by sedimentary rocks, soil, potassium absorption by living organisms, especially by plants. The difference in the behavior of sodium and potassium in the weathering crust is reflected in the peculiarities of the ratio of sodium and potassium in natural waters. Sodium prevails in the hydrosphere. About 65% of the total removal of sodium from the weathering zone to the ocean comes mainly in the dissolved state, most of the potassium is in the composition of suspended sediments [8, 21].

The intake of Na^+ and K^+ into natural waters is largely determined by the interaction of water with living organisms, especially with plants. Researches of N.A. Kudryatseva [22] showed that with the loss of aquatic vegetation a significant portion of alkali metals goes into water. From the dry plant mass, according to the results of experiments, on average, 79,2 % of potassium is extracted, and 77,9 % of their

total content is sodium. It turns out that aquatic plants are able to concentrate potassium selectively. For example, in the clasping-leaved pondweed and water persicaria, the potassium content was respectively 41,4 and 54,7 % of the sum of calcium, magnesium, potassium, and sodium.

Baseline data, research results and discussion. In this paper, based on data from the state monitoring of RSE «Kazhydromet», the dynamics of sodium and potassium in the water of the r. Ile, which is one of the main transboundary rivers of Kazakhstan. The features of the change in the ratio of these elements along the river were studied and empirical coefficients (EC) were established for recalculating the amount of Na⁺ and K⁺ from mg-eq/dm³ to mg/dm³.

The laboratory of hydrochemistry of RSE «Kazhydromet» (Almaty), the content of Na⁺ and K⁺ ions was determined by the ion-selective method. This method is the most accessible, since the determination takes place with the help of the portable ionomer «Anion-7051» and two electrodes for each element; this allows a series of definitions to be taken directly at the object in a short time [23, 24].

Baseline data for the study and calculation of these characteristics are presented in table 1. According to them, the average sodium concentration for 2009-2014 in the water of four hydrological posts located along the river from transboundary hydrological section to the delta (length of 815 km) varied from 22,1 to 27,0 mg/dm³, and potassium – from 3,0 to 2,5 mg/dm³ in the delta zone. At the same time, their maximum concentrations reached 31,6 and 4,8 mg/dm³, respectively. Average values of sodium in the water along the river gradually increase from 22,1 to 27,0 mg/dm³, while potassium remained at 3,0 mg/dm³, only at the top of the delta decreased to 2,5 mg/dm³. In changing the concentration of sodium in the water along the river can be traced dependence on the value of water mineralization. Average mineralization of river water for 2009-2014 varied in the range from 356 mg/dm³ in the border hydrological section to 386 mg/dm³ – at the top of the Ile river delta.

Table 1 – Mineralization (Σ_i) and the concentration of sodium, potassium in the water of the river Ile, mg/dm³

Hydrological post	Ingredient	Years						Average, mg/dm ³
		2009	2010	2011	2012	2013	2014	
Dobyn village (border)	Σ_i	342	340	362	374	358	368	356
	Na ⁺	20,0	25,7	20,7	24,8	19,0	22,9	22,1
	K ⁺	4,8	2,2	2,3	2,4	2,5	3,5	3,0
164 km above the dam of the Kapshagay hydroelectric station	Σ_i	348	345	345	370	360	395	361
	Na ⁺	20,3	23,7	21,8	24,6	20,3	27,9	23,0
	K ⁺	3,7	1,8	4,1	1,7	2,4	4,3	3,0
37 km below the Kapshagay dam	Σ_i	336	347	372	375	358	380	368
	Na ⁺	21,7	28,3	29,1	28,8	23,6	31,6	25,5
	K ⁺	3,0	2,2	3,9	1,4	2,7	4,0	3,1
Ushzharma village (the top of the r.Ile delta)	Σ_i	366	383	384	394	379	410	386
	Na ⁺	24,2	28,5	30,9	29,2	23,6	25,5	27,0
	K ⁺	3,3	1,9	2,9	1,3	2,7	3,1	2,5

Analysis of the change in the relative content of sodium and potassium from their sum shows (table 2) the increase in the relative proportion of sodium downstream from 88,2 to 91,3 % and the decrease in the proportion of potassium from 11,8 to 8,7 %. As is known, the relative content of sodium and potassium in waters of different salinities is not the same. In sea waters, the relative content of sodium is on average 96 %, potassium is 4 % of their total. In river waters, the potassium content increases to 12-20 %, and sodium decreases to 88-80 % [10].

According to J.P. Railey and G. Skirrow [6], when the salinity of seawater is 10, sodium concentration is 3,074 g/dm³, potassium is 0,111 g/dm³, and at salinity 41 ‰ their content increases to 12,603 and 0,454 g/dm³, respectively. When the salinity of seawater changes, the relative content of these elements remains constant – sodium 96,5 %, potassium – 3,5 %. In the literature there are data characterizing the close proximity of the content of sodium and potassium in the waters of the seas and oceans.

Thus, according to A.P. Vinogradov [4], in oceanic water, sodium is contained in the amount of 10 354 mg/dm³, potassium – 387 mg/dm³, and in the sea water by E.D. Goldberg [5], 10 500 mg/dm³ and 380 mg/dm³, respectively. At the same time, the relative proportion of these elements also remains unchanged.

Table 2 – The values of ratio and empirical coefficients (equivalents) of sodium and potassium in the water of the River Ile

Hydrological post	Na ⁺ , %	K ⁺ , %	Na ⁺ /K ⁺ , mg/dm ³	E _{Na⁺+K⁺}
Dobyn village (border)	<u>80,6-92,1</u> 88,2	<u>7,9-19,4</u> 11,8	<u>3,8-12,0</u> 8,3	<u>23,8-25,2</u> 24,2
164 km above the dam of the Kapshagay hydroelectric station	<u>84,2-93,5</u> 88,5	<u>6,5-15,8</u> 11,5	<u>5,3-14,5</u> 8,8	<u>23,6-24,6</u> 24,2
37 km below the Kapshagay dam	<u>87,9-95,4</u> 90,5	<u>4,6-12,1</u> 9,5	<u>7,2-20,6</u> 10,6	<u>23,4-24,2</u> 23,9
Ushzharma village (the top of the r.Ile delta)	<u>88,0-95,7</u> 91,3	<u>4,3-12,0</u> 8,7	<u>7,3-22,5</u> 12,1	<u>23,4-24,2</u> 23,9

According to our data, in the water of brackish reservoirs of Kazakhstan: in the Lake Alakol the relative content of potassium decreased to 1,5-1 %, sodium reached 98,5-99 % [15], in the brackish eastern part of Lake Balkhash the content of potassium decreased to 4 % [13].

Such significant differences in the content of these elements in natural waters are due to their different migration ability, although the Clarke content of these components is very close: according to A.P. Vinogradov [25] sodium – 2,64 %, potassium – 2,60 %, according to S.P. Taylor [29] – 2,36 and 2,09 %, respectively.

In accordance with the changing of the relative content of sodium and potassium, the values of the ratio Na⁺/K⁺ change. The high mobility of sodium compared to potassium (sodium ionization potential is 5,12, potassium is 4,32) is determined by its best leaching from sedimentary formations, potassium accumulates in weathering products, it is easily adsorbed by rocks, soils and their colloidal part, which greatly limits its migration.

Among natural objects, the highest values of the Na⁺/K⁺ ratio are characteristic of natural waters. As their mineralization increases, the ratio between these ions increases. In [8] were given the values of the ratio Na⁺/K⁺ for the main rivers of the Soviet Union. Depending on the physiographic conditions, they varied from 0,75 to 58. At the same time, the greatest significance is characteristic of the rivers of Central and Northern Kazakhstan, which are in arid climate.

The value of the ratio of Na⁺/K⁺ (mg/dm³) in the water of the Ertis River near the city of Pavlodar is on average 7,3. It gradually increases along the route of the Ertis-Karaganda canal. The highest values of the Na⁺/K⁺ ratio (from 34 to 160) are noted in the sections of the canal route, affected by groundwater [12]. In the water of the r. Syrdarya and Shardara water storage reservoir averaged 26,6 and 30,3, respectively [16], water storage reservoirs on the Tobol River from 15 to 51, on average of 27,8, and reservoirs on the Esil River from 3 to 19, on average of 13,8 [14]. In the waters of brackish reservoirs: in the Lake Alakol, it was in the range from 23,2 to 79,2, on average of 54,8 [15], in the Lake Balkhash – from 7,2 to 29,1, on average of 14,0 [13].

Directly the value of ratio Na⁺/K⁺ is defined by the EC (Na⁺ and K⁺), that are needed for the calculation of the sum of these ions from mg-eq/dm³ in mg/dm³. This indicator for waters of all reservoirs and watercourses studied by us was calculated using the equation $E_{Na^{+}+K^{+}} = \frac{A+B}{\frac{A}{E} + \frac{B}{E}}$, where A is the amount of Na⁺ in a sample, mg/dm³; B is the amount of K⁺ in the sample, mg/dm³; E_{Na⁺} is the equivalent of Na⁺, equal to 23, E_{K⁺} is equivalent of the K⁺, equal to 39,1.

The EC of Na⁺ and K⁺, established by us for a number of reservoirs and watercourses of Kazakhstan are shown in table 3. From the estimates, it follows that from among total surface waters studied on this subject, the EC equal to 25 was registered only for the water resources of the Ertis River and the Vyacheslavsky (Astana) water-storage reservoir, built in the Upper Esil River. The average coefficients equal to 24 and 24,8 are characteristic for the water of the Ile River and the Sergeevsky water-storage reservoirs located in the Middle Esil River. For waters of all other reservoirs and watercourses, the average values of the EC of Na⁺+K⁺ were in the range of 23,1-23,8, including the brackish reservoirs (Lake Balkhash and Alakol), as well as freshwater reservoirs such as the Syrdarya River, a cascade of water-storage reservoirs on the Tobol River, on the Ertis-Karaganda canal, Shardarinsky water-storage reservoir.

As is well known by definition of P.A. Kashinsky [26], the EC of Na⁺+K⁺ for the highly mineralized lake brine is close to 23,5; for the fresh water, as well as for water extraction of basic sediment and soil it is in cases in close to 24,5. In the practice of hydrochemical analysis to date, when calculating the total

content of Na^+ and K^+ from the difference mg-eq. of anions and cations, these values are rounded and are taken equal: for saline water is 24 and for fresh is 25 [27, 28].

These coefficients are also adopted in the system of RSE «Kazhydromet» and are used by those that are to some extent related to the chemical analysis of natural waters.

In this regard, the following should be noted. According to our research, in 1970-1984 the mineralization of water of the cascade of reservoirs on the Tobol River was in the range of 530-833 mg/dm³, the Sergeevsky reservoir in 1974-1984 from 365 to 489 mg/dm³ [14], Shardarinsky reservoir – 700-1000 mg/dm³ in 2003-2005 [16], in the water of the reservoir cascade on the Ertis-Karaganda canal the values of this indicator in 1969-1978 marked within 238-676 mg/dm³ [12]. The EC values for the waters of these reservoirs are from 23,3 to 24,8 (table 3). Consequently, the use of EC is 25 for these fresh reservoirs in accordance with the generally accepted scheme will be overvalued of the concentration of both the alkali metals themselves and the value of the total water mineralization. The limits of admitted errors will especially increase in the quantitative assessment of reserves of mineral salts in reservoirs, annual and long-term volumes of the flow of chemicals along rivers, salt balance and forecast calculations.

Table 3 – The value of ratio and empirical sodium and potassium coefficients established for waters of various types of water objects in Kazakhstan

Water objects	Na^+/K^+		$E_{\text{Na}^+/\text{K}^+}$		Source
	1	2	1	2	
Rivers:					
Ertis	4,2-12,3	7,3	24,2-26,1	25,0	[12]
Syrdarya	24,0-29,3	26,6	23,3-23,4	23,3	[16]
Ile	3,8-22,5	9,9	23,4-25,4	24,0	
Shiderty	89-111	92	23,1-23,2	23,1	[12]
Water-storage reservoir:					
Cascade on the River Tobyl	15-51	27,8	23,5-23,8	23,6	[14]
Vyacheslavsky Sergeevsky	3-18	12,9	24,3-26,1	25,0	[14]
Shardarinsky	6-19	14,6	24,1-25,2	24,8	[14, 12]
Cascade on the Ertis-	24,3-33,9	30,3	23,3-23,4	23,3	[16]
Karaganda canal	5,4-34,9	16,8	23,4-25,7	23,8	[12]
Brackish reservoirs:					
Lake Balkhash	7,2-29,1	14,0	23,3-24,2	23,6	[13]
Lake Alakol	23,2-79,2	54,8	23,2-23,5	23,3	[15]

Note: 1 – limits, 2 – average values.

One of the important conclusions resulting from our research is that the ratio of Na^+/K^+ and the EC value of these elements in surface waters largely depend on the complex natural conditions of the territory where the water object is located. The dependence of the dynamics of these characteristics on the value of the total water mineralization, of course, cannot be excluded, but the influence of this factor has a secondary role, if we consider the peculiarities of these characteristics in the regional aspect. The impact on the dynamics of the characteristics of water mineralization is mainly manifested only through the concentration of sodium ions, which increases with the growth of mineralization, and the potassium content within certain values of the latter does not change significantly.

According to research by A.M. Almazov and I.G. Enaki [10] in water objects of Ukraine, with the water mineralization in the range of 100-500, the EC was 27, and with 500-1000 – this indicator was in the range from 25 to 26,4. At the same time, the authors indicate that this coefficient for some fresh waters can reach higher values – 28-30.

As it was shown above, EC 25 was registered by us for Ertis River water with mineralization of 180-195 mg/dm³ and Vyacheslavsky reservoir with mineralization of 294-360 mg/dm³ [12,14]. When water mineralization above these values, even not reaching 1000 mg/dm³, the EC recorded in the range from 23 to 24. Indicators of the EC 23,5-23,7, according to studies [10], recorded when mixing of river and sea water in the Dniprobuzkiy Lyman with the mineralization of 1000-2000 mg/dm³.

The results obtained by us on the values of the EC of sodium and potassium for water reservoirs of various territories of Kazakhstan confirm the conclusions made by G.S. Konovalov and V.I. Koreneva [8,9,21], on the basis of detailed studies of the regime and the EC of sodium and potassium in the waters

of the rivers of the Soviet Union. In particular, they indicated the absence of a clear dependence of the EC on the mineralization of river waters. At the same time, it is concluded that this indicator is determined by the complex of physical and geographical conditions in the catchment area of the river basin, the degree of soil and rocks washing, the presence of underground inflow, the amount of precipitation and the balance of radiant energy. Several EC amounts of sodium and potassium have been proposed for rivers of different climatic zones, namely, for rivers in the mountainous region, in the flood – 28,0, in low water – 27,0, for the rivers of the steppe zone and forest-steppe – 25,0 and 24,0, respectively, for rivers of semi-desert and desert zones in the flood – 24, in the low water – 23,5.

From all that has been said in this work, in our opinion, it follows that it is necessary to establish the EC at least for large reservoirs and watercourses of various climatic zones of Kazakhstan, including especially water objects in the basins of the main transboundary rivers. This would allow to eliminate the inaccuracies that occur in the quantitative assessment of the level of water mineralization, especially in the objects of the country's large water basins. It is mineralization that is the determining component of the degree of suitability of natural waters for their use in all economic sectors and for safe drinking.

Conclusion. Sodium and potassium are among the insufficiently studied chemical elements in surface waters, particularly in Kazakhstan. To some extent, this is due to the extremely limited data on their separate concentration in the water of reservoirs and watercourses.

Along with the theoretical significance of knowing their dynamics and migration in nature, information about the separate concentration of sodium and potassium is necessary when solving the number of important practical problems in the use of water resources for various needs. For the water of the Ile River, the values of the empirical coefficient of sodium and potassium are set in the range of 23,9-24,2, on average 24,0. The empirical coefficient, which is 25, generally accepted for freshwater reservoirs, which is applicable to the waters of individual river basins of the Republic of Kazakhstan with mineralization up to 350-400 mg/dm³. The formation of the regime and the dynamics of the concentration of sodium and potassium are determined by regional physiographic conditions.

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ҚАЗАҚСТАН ЖЕР БЕТІ СУЛАРЫНДАҒЫ СІЛТІЛІК МЕТАЛДАРДЫҢ (Na⁺ ЖӘНЕ K⁺) ЭМПИРИКАЛЫҚ КОЭФФИЦИЕНТІНІҢ МӘНІ МЕН ҚАТЫНАСЫ ТУРАЛЫ, ІЛЕ ӨЗЕНІ МЫСАЛЫНДА

Аннотация. Аймақтық гидрохимия саласындағы аз зерттелген, маңызды аспектілердің бірі – жер беті суларындағы сілтілік металдар (натрий және калий) режимінің қалыптасу заңдылықтары мен динамикасы бойынша мәселелер қарастырылған. Әдебиетке шолу бөлімінде литосфера мен табиғи сулардағы Na⁺ и К миграциясына қатысты геохимия саласындағы бірқатар классик ғалымдардың еңбектерінен мәліметтер келтірілген. Табиғи сулардағы натрий мен калийдің жеке концентрациясы бойынша сенімді аналитикалық деректердің осы салада келесідей маңызды практикалық мәселелерді шешудегі қажеттілігі атап өтілді: суармалы массивтерге су көздерін таңдау кезінде; балық үшін құнды ағзаларды бейімдеу үшін суқойманың су құрамының жарамдылығын бағалау. Омыртқасыздарды акклиматизациялау мен су қоймаларының био-өнімділігін арттыру тәжірибесі кезінде судағы негізгі иондардың қатынасы туралы білімнің маңыздылығы тәжірибелік жұмыстардың нәтижелері бойынша нақты мысалда көрсетілген.

Өртүрлі тұрмыстық және ауызсу қажеттіліктеріне пайдалану деңгейін анықтайтын, табиғи сулардың жалпы минералдануын анықтауға қажетті натрий мен калийдің эмпирикалық коэффициентінің (ЭК) маңыздылығына ерекше назар аударылды.

Мемлекеттік мониторинг мәліметтері негізінде Іле өзенінің ағысы бойынша натрий мен калийдің концентрациясы мен қатынасының өзгеру сипаты зерттеліп, олардың абсолюттік концентрациясы (мг/дм³) мен судың жалпы минералдануын есептеу үшін ЭК анықталды. Өзен ағысы бойымен судағы натрий концентрациясының өзгеруінде судың минералдану мөлшеріне тәуелділігі анықталды. Натрий мен калийдің жалпы сомасындағы олардың салыстырмалы мөлшерінің өзгерісін талдау нәтижесі, өзен ағысы бойымен натрийдің

мөлшері 88,2% -дан 91,3% -ға дейін жоғарылауын және калийдің үлес салмағының 11,8%-дан 8,7%-ға дейін төмендеуін көрсетті.

Дж.П. Рейли, Дж. Скирроу, А.П. Виноградова, Е.Д. Гольдберг, С.П. Тейлордың іргелі ғылыми зерттеу жұмыстарынан теңіз бен мұхит суларындағы сілтілік металдардың қатынасы бойынша мәліметтер жинақталған түрде келтірілген. Қазақстанның су қоймалары бойынша өз материалдарымызға салыстырмалы талдаулар келтірілген.

Қазақстанның бірқатар су қоймалары мен су ағындары үшін әртүрлі жылдарда жүргізілген зерттеулер бойынша әдеби мәліметтер мен өзіндік зерттеулердің нәтижелерін талдау негізінде мынадай тұжырымдар жасалды: бұрынғы КСРО-ның барлық аумағы үшін тұщы су қоймаларына бұрын қабылданған ЭК 25-ке тең мәні ҚР кейбір өзен бассейндерінің сулары үшін, яғни олардың 350-400 мг/дм³ дейін минералдандыру кезінде пайдаланылуы мүмкін. Жер үсті суларындағы натрий мен калий концентрациясының режимі мен динамикасының қалыптастыруда аймақтық кешенді физикалық-географиялық жағдайлардың шешуші рөлі бар: климат, топырақ, жер асты суларының сипаты, антропогендік әсер ету және т.б. ҚР түрлі климаттық аймақтарының су қоймалары мен су ағындары үшін, әсіресе ірі трансшекаралық бассейндер үшін ЭК белгілеу қажеттілігі ұсынылған.

Түйін сөздер: натрий және калий, олардың табиғи сулардағы қатынасының мәні, сілтілік металдардың эмпирикалық коэффициенті.

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О СООТНОШЕНИИ И ВЕЛИЧИНАХ ЭМПИРИЧЕСКОГО КОЭФФИЦИЕНТА ЩЕЛОЧНЫХ МЕТАЛЛОВ (Na⁺и K⁺) В ПОВЕРХНОСТНЫХ ВОДАХ КАЗАХСТАНА НА ПРИМЕРЕ РЕКИ ИЛЕ

Аннотация. Рассмотрены вопросы, касающиеся недостаточной изученности таких важных аспектов в области региональной гидрохимии, какими являются закономерности формирования режима и динамики щелочных металлов (натрия и калия) в поверхностных водах. В развернутом литературном обзоре приведены некоторые данные из трудов ряда классиков в области геохимии, касающихся миграции натрия и калия в литосфере и природных водах. Указано на необходимость достоверных аналитических данных о раздельной концентрации натрия и калия в природных водах для решения важных практических задач в области: оценки пригодности состава воды водоемов для акклиматизации ценных кормовых для рыб организмов, при выборе источников водоснабжения орошаемых массивов. Важность знания о характере соотношений главных ионов в воде в практике акклиматизации беспозвоночных и повышение биопродуктивности солоноватых водоемов показано на конкретном примере по результатам опытных работ.

Особое внимание уделено важности эмпирического коэффициента (ЭК) натрия и калия, необходимого при определении общей минерализации природных вод, от которой зависит уровень использования их для различных хозяйственных и питьевых нужд.

На данных государственного мониторинга изучен характер изменения по течению р. Иле концентрации и соотношения натрия и калия и установлены ЭК для расчета их абсолютной концентрации (в мг/дм³) и общей минерализации воды. В изменении концентрации натрия в воде по течению реки прослеживается зависимость от величины минерализации воды. Анализ изменений относительного содержания натрия и калия от их суммы показывает рост относительной доли натрия вниз по течению реки от 88,2 до 91,3 % и снижение доли калия от 11,8 до 8,7 %.

В сконцентрированной форме представлены сведения из фундаментальных трудов Дж. П. Рейли и Г. Скирроу, А.П. Виноградова, Э.Д. Гольдберга, С.П. Тейлора по соотношению щелочных металлов в морских и океанических водах. Дается сопоставительный анализ собственными материалами по водоемам Казахстана.

На основе анализа литературных сведений и результатов собственных исследований по рассматриваемому вопросу, проведенных в разные годы для ряда водоемов и водотоков Казахстана, сделаны выводы о том, что: принятый ранее для всей территории бывшего СССР ЭК для пресноводных водоемов, равный 25, может использоваться для вод некоторых речных бассейнов РК при их минерализации до 350-400 мг/дм³. Решающую роль в формировании режима и динамике концентрации натрия и калия в поверхностных водах имеет комплекс региональных физико-географических условий: климат, характер почв, подземных вод, антропогенные воздействия и др. Рекомендовано установление ЭК для водоемов и водотоков различных климатических зон РК особенно для крупных трансграничных бассейнов.

Ключевые слова: натрий и калий, величины их отношения в поверхностных водах, эмпирические коэффициенты щелочных металлов.

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THE IMAGE PROCESSING ALGORITHMS FOR BIOMETRIC IDENTIFICATION BY FINGERPRINTS

Abstract. The article discusses image processing algorithms for biometric fingerprint identification. The identification features of the structure of papillary patterns on the fingers have been studied taking into account the fact that different pressure, speed, direction, ambient temperature and humidity level lead to different images. Due to various digital image processing and analysis algorithms such as: the SIFT descriptor, as well as the closest competitor, the SURF descriptor, it is possible to quickly obtain unique characteristics for each image. This study used a database of photographs obtained from open sources – the Fingerprint Verification Competition 2004 (FVC2004). As a result of the work, the graphic image of the matching key points, as well as the number of matched key points by fingerprints, have been investigated. Search key points is performed using the Hesse matrix. The determinant of the Hesse matrix (Hessian) reaches the extremum at the points of maximum variation of the brightness gradient. Fingerprints were obtained using the optical sensor "Cross Match V300". The experimental study showed that the developed software system has invariance to image rotations.

Key words: biometrics, fingerprints, identification signs, minute, papillary patterns, key point descriptors, image gradient, biometric personality identification, brightness gradient, digital processing algorithm, SIFT, SURF, BRIEF descriptors, database, Hessian matrix, CrossMatch V300 optical sensor, biometric scanner, FPM10A module, Adafruit Arduino library, optical scanner, password for passwords, invariance, uniqueness, volume precedents, Laplace pyramid, octave, key point estimates, Haar filter, Hamming distance sum, electronic fingerprint.

Introduction. Modern image processing algorithms are the main tools to improve performance in a variety of industries [1-3]. Criminology is one of those areas where the use of modern image processing algorithms provides a significant improvement in the results.

Since ancient times, a handprint was used to confirm the authenticity of a document. In VI-VII centuries in China a fingerprint was used to sign documents. The most famous use of the handprint as a confirmation of the document was the Ashtiname of Muhammad, also known as the Covenant or Testament of Muhammad, is a document which is a charter or writ ratified by the Islamic Prophet Muhammad granting protection and other privileges to the followers of Jesus the Nazarene, given to the Christian monks of Saint Catherine's Monastery. It is sealed with an imprint representing Muhammad's hand [4].

Traces of human fingers in their forensic significance occupy the first place in the group of methods of identification, which is explained as the frequency of their detection, and the fact that they can be used quickly enough to identify the person who left the fingerprints, also to identify the relation of this person with other incidents in which the same fingerprints were found. Such possibilities are associated with the features structure of skin on the fingers, namely the uniqueness of papillary patterns. Identification features of the structure of papillary patterns on fingers are divided into global and local signs: Global

signs include features that can be seen with unaided eye. These features include: the type and kind of papillary pattern; direction and steepness of the flow of papillary lines; structure of central pattern; structure of delta; the number of papillary lines between the center and delta and many other features. Another type of signs is local. They are also called minutia points (signs or special points) – unique features inherent only in a particular print, determining the points of change in the structure of papillary lines (ridge ending, bifurcation, short or independent ridge, etc.), the orientation of papillary lines and coordinates in these points. Each print can contain up to 70 minutiae or more. The analysis is based on mapping local features – minutia is the most popular approach to identify because of the widespread opinion that minutia are the most discriminating and reliable features [5]. However, this approach faces some serious problems related to large distortions caused by fingerprint matching with different rotation, an example of such matching is shown below (figure 1) distortions from the FVC2004 DB1 (102_3) base.tif and 102_5.tif).

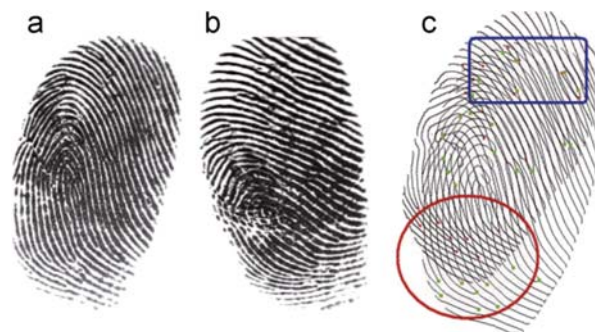


Figure 1 – The result of matching fingerprints with different rotation

The fingerprint of the same person will never look the same in any two readings. Different pressure, speed, direction, ambient temperature, skin moisture and moisture levels will result in different images. Also, in work [13] the example of age-related changes of fingerprints is given, with age fingerprints become less accurate and can change. To solve the above mentioned questions, the researchers proposed various methods of digital image processing and analysis, namely, the description of local vicinity of characteristic points - descriptor.

One of the main requirements for a special descriptor were:

Invariance – for the description of singular points to little change under different geometric and photometric transformations of the image.

Uniqueness – the descriptors of two different images should be markedly different from each other. These image requirements were formulated in [7] on the review of image matching methods.

Through various digital image processing and analysis algorithms such as: the SIFT descriptor, which was proposed in 1999 in article [8], as well as the closest competitor the SURF descriptor, which was proposed in 2008 in work [9], it became possible to quickly obtain unique characteristics for each image. However, none of the existing algorithms is universal, and therefore the search for solutions is an actual task.

The algorithms used to describe local features for biometric fingerprint identification, can be separated into several interrelated tasks:

1. Transformation the fingerprint image to a list of special points in the function (intersections, ridges, etc.), as well as their relative positioning and other parameters.
2. Converting the resulting function vector to a storage object in the database, which can be a row or a data series of column in a tuple.
3. Classification and comparison of the identified unique features of fingerprints with all the data that are already available in the system.

The objects of analysis are photos of fingerprints obtained from open sources, their unique features – a set of characteristics, and the output – comparison with other images and an indication of the coefficient of "similarity" with images that have already been previously identified in the database. Training takes place on a sufficient amount of precedents.

Research methods. In this research, we used a database of photos obtained from open sources - Fingerprint Verification Competition 2004 (FVC2004) [15-16], and the result: a graphical image of matching key points, as well as the number of matching key points on fingerprints. In FVC2004, emphasis is placed on distortion as well as on obtaining images of dry and wet fingerprints. Fingerprints were obtained using the optical sensor "Cross Match V300". Between the identification features of the structure of papillary patterns of the same person, obtained at different times, there are certain dependencies that need to be established. For this purpose, so-called precedents are used, that is, such sets of fingerprint images that are already identified using this algorithm. Such precedents are called training samples. In this study, several types of descriptors such as SIFT, SURF, and ORB descriptors were considered and used.

Descriptor SIFT. The SIFT (Scale Invariant Feature Transform) descriptor was proposed in 1999 by D. Lowe, University of British Columbia [8]. This descriptor is a local histogram of the image gradient directions. The following steps are required to build an image descriptor:

1. Finding the pyramid of image.
2. Keypoint finding.
3. Keypoint localization.
4. Keypoint orientation.
5. Local descriptor of image.

To find the pyramid of the image, we use the Laplace pyramid, in which we find high-frequency information about the image. The keypoints of the image are mainly located in these high-frequency parts of the image. In fact, the Difference of Gaussian (DoG) is an approximation to the Laplacians of the Gaussian (LoG). It is necessary to build several pyramids with different image scale, each pyramid is called an octave. Pyramids (octaves) is necessary for invariance to changes in scale and also to search for keypoints in different scales. For search keypoints to the DoG pyramid, it is necessary to find maximum / minimum in this scale as well as to find maximum / minimum in the neighboring scales. Refinement of keypoints after finding the maximum / minimum the next step is a detailed alignment with nearby data on the location, scale and ratio of the main curves. Keypoint orientation, gradient histograms are build for each keypoint, and the neighborhood of the special point is divided into four square sectors. In each pixel inside each sector, the gradient of image, direction and modulus are calculated. Next, the modules of the gradients are multiplied by the weight exponentially decreasing with distance from point of interest. For each sector, is created directions histogram of gradients, with each occurrence weighted by modulus of the gradient.

The local SIFT descriptor is a vector derived from the values of all elements of the histograms of directions and consists of 128 components (8 (number of bins) \times 4 \times 4 (number of squares)).

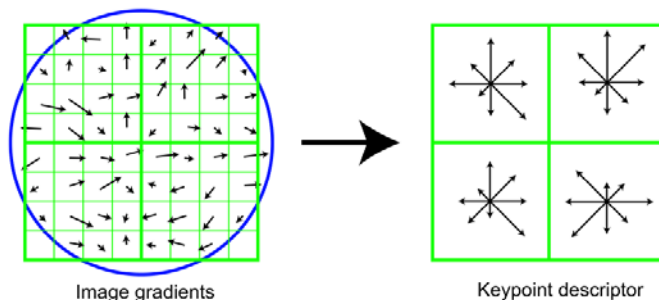


Figure 2 –
The construction of SIFT descriptor

The disadvantage of the system is that the descriptor vector consists of 128 real numbers, that is, it occupies at least 512 bytes per keypoint. That require significantly more processing power from the hardware especially if the image has a large resolution and a large number of details. Below (figure 3) an example of evaluation of key points using the SIFT algorithm is given.



Figure 3 –
Assessment the key points
of the SIFT descriptor

SURF descriptor. Descriptor SURF (Speeded up Robust Features) was proposed in 2008 [9] and is a further development of the SIFT technique. Its descriptor also refers to the number of descriptors that simultaneously search for singular points and construct their description invariant to scaling and rotation. The descriptor has proven itself in the tasks of searching for objects in images and comparing images.

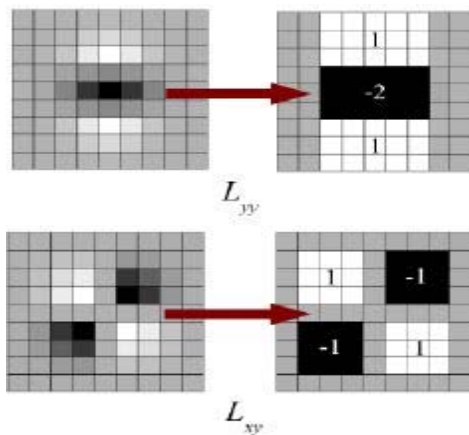
The SHIFT method uses the Difference of Gaussian (DoG) for building pyramids of the images. Different scales of Hessian masks are used to calculate the pyramid of the SURF image, while the scale of the image is always unchanged. This speeds up the calculation time without reducing the image.

Keypoints are searched using the Hesse matrix. The determinant of the Hesse matrix (Hessian) reaches the extremum at the points of maximum variation of the brightness gradient and its determinant is defined as follows:

$$H(f(x, y)) = \begin{bmatrix} \frac{\partial^2 f}{\partial x^2} & \frac{\partial^2 f}{\partial x \partial y} \\ \frac{\partial^2 f}{\partial x \partial y} & \frac{\partial^2 f}{\partial y^2} \end{bmatrix}$$

$$\det(H) = \frac{\partial^2 f}{\partial x^2} \frac{\partial^2 f}{\partial y^2} - \left(\frac{\partial^2 f}{\partial x \partial y} \right)^2$$

where H is the Hesse matrix and the $f(x, y)$ is brightness gradient change function. In this case, the SURF algorithm uses different-scale filters to find Hessians. For each keypoint, the gradient and scale are calculated. The gradient at a point is calculated using Haar filters. The filter size is taken to be $4s$ (where s is the scale of the singular point). An example of Haar filters is shown in figure 4. After finding the keypoints, the SURF method generates their descriptors. The descriptor for each key point is a set of 64 (or 128) numbers. These numbers represent the gradient fluctuations around the keypoint. Since the keypoint is the maximum of Hessian, thereby is guaranteed that there must be areas with different gradients in the in the neighborhood of the point. Thus, the dispersion (difference) of descriptors for different keypoints is provided, thereby achieving invariance of the descriptor with respect to rotation. The size of the area on which the descriptor is calculated is determined by the scale of the Hesse matrix, which provides invariance with respect to the scale.



(black areas have values of "-1", white "+1")
Figure 4 – Haar Filters



Figure 5 – Evaluation of keypoints of SURF descriptor

SURF. Advantages of the method: the SURF method has a higher accuracy and speed of recognition in comparison with the SIFT method. The disadvantages of the method are similar to the disadvantages of the SIFT method – it is a requirement for computing power, as well as method is patented and its use is prohibited for commercial purposes, without the consent of the owner. Below (figure 5) an example of evaluation of keypoints using the SURF algorithm is given.

ORB descriptor. The ORB descriptor (Oriented FAST and Rotated BRIEF) is a combination of the detector of keypoints FAST [10] and binary descriptors BRIEF [11], this method was proposed in 2011 [12] as an effective replacement for descriptor SURF/ SIFT.

The FAST detector is used to search for keypoints. To find corner points, comparing the brightness of the surrounding 16 pixels around each pixel p . All 16 pixels are then sorted into three classes (lighter than p , darker than p or similar to p). If more than 8 pixels are darker or brighter than p , this pixel is selected as the keypoint. Thus, the keypoints found with FAST detector give us information about the location of the edge (border) in the image. Selecting only 4 pixels on a circle allows you to quickly weed out the wrong points, but in some cases it is possible to determine different features in the same circle. However, the FAST algorithm does not have orientation component and multi-scale functions. A multi-level in image pyramid is used to solve this problem. By detecting keypoints at each level, the algorithm effectively finds key points at a different scale. Thus, the FAST detector is invariant of partial scale. In the ORB algorithm, the maximum number of special points by default is not more than 500, if there are more, then the Harris angle detector [11] is applied to them, to exclude the least significant ones.

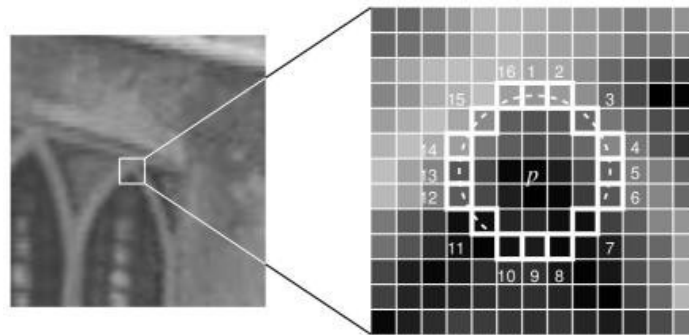


Figure 6 – The considered neighborhood of the p point of the FAST detector

After locating keypoints position, the FAST detector now assigns an orientation to each keypoint, such as left or right, depending on how the intensity levels change around that key point. The Ball uses a centroid of intensity for detect changes in intensity. The intensity centroid assumes that the intensity of an angle is shifted relative to its center, and this vector can be used to calculate orientation.

BRIEF descriptor. This descriptor takes all the keypoints found by the FAST algorithm and converts it to a vector of binary objects so that together they can represent the object. A binary objects vector, also known as a binary objects descriptor, is an object vector that contains only 1 and 0. In brief, each key point is described by a vector of objects, which is a string 128-512 bits long.

The BRIEF handle smoothes the image using a Gaussian kernel to prevent the handle from being sensitive to high-frequency noise. The BRIEF descriptor selects a random pair of pixels in a specific neighborhood around a key point. A certain neighborhood around a pixel is called a patch, which is a square of width and height equal to the selected pixel of the singular point. The first pixel in a random pair is taken from a Gaussian distribution centered around a key point with a spread of σ (Sigma). The second pixel in a random pair is taken from a Gaussian distribution centered around the first pixel with a spread of σ (Sigma)/2. Now, if the first pixel is brighter than the second, it assigns a value of 1 to the corresponding bit, otherwise 0, figure 7 shows an example of estimating the neighborhood of the keypoint.

This descriptor is represented as a 256-length vector consisting of binary tests results around a singular point. To achieve invariance to rotation, the descriptor computation area is oriented by the orientation of the singular point.

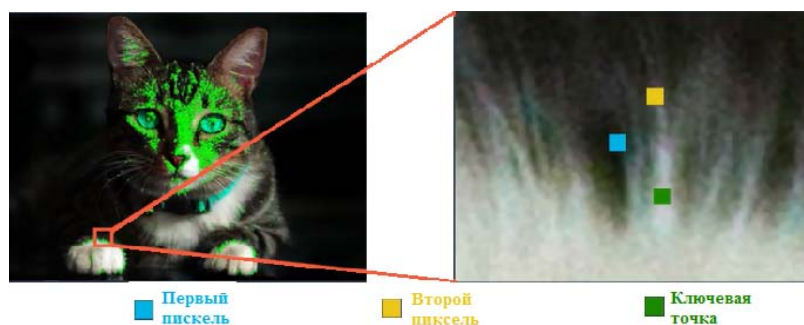


Figure 7 – Considered neighborhood of the keypoint

Advantages of the method: the ORB method has a high speed in comparison with the methods of SIFT/SURF. Disadvantages of the method: This method has a "lower" accuracy of recognition in comparison with the methods of SIFT/SURF. Below (figure 8) an example of evaluation of key points using the ORB algorithm is given.

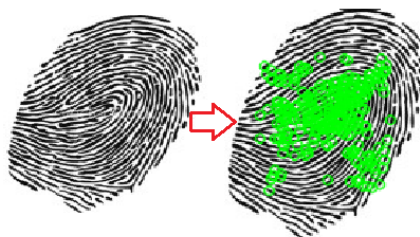


Figure 8 – Evaluation of keypoints of the ORB descriptor

Research results. The analysis of algorithms of search and identification on images showed that for the solution of a problem of identification on fingerprints it is effective to use descriptors of key points because they provide possibility of obtaining the classifier (descriptor) of a fingerprint with high degree of accuracy, and also have good function of identification on an incomplete fingerprint, the example of an assessment of 30 key points is shown on (figure 9).



Figure 9 – Score 30 key points descriptor ORB (left), SIFT (center), SURF (right)

The experimental research of biometric fingerprint identification, created on the basis of the proposed methods of searching for key points, showed that the developed software system has invariance to image rotations. Its software system is able to work in a large range of lighting changes up to 50-70% of the lighting level in the image, and has invariance to zoom and slight distortion.

Discussion. According to the results of the analysis of the efficiency and speed of methods and algorithms of biometric identification of persons, the following conclusions can be drawn:

Algorithms SURF/SIFT have better classifying ability in solving everyday tasks of finding textured images. Both algorithms are more demanding on the hardware and more suitable for other computer vision tasks, and both algorithms are patented and its use is prohibited on commercial use, without the consent of the owner for fingerprint identification task, they have "excess power".

The ORB algorithm has a higher speed in comparison with the above algorithms using SIFT/SURF techniques, and is more suitable for biometric fingerprint identification tasks. The algorithm is freely available. ORB algorithm descriptors are binary descriptors and the matching test for such descriptors is the sum of the Hamming distances for each byte of the descriptor. The use of this algorithm is more suitable for the tasks of searching for fuzzy fingerprint. An example of the use of forensic software systems in which fingerprints were marked out using the proposed algorithm.

Conclusion. In the course of the research work, the following tasks were performed: three algorithms for the identification of key points were investigated and analyzed to solve the problem of biometric identification by fingerprints. A promising area of application of algorithms is the addition into "classic" software products for the creation of electronic dactylocards, to search for incomplete fingerprint, because often in practice there is only a part of the fingerprint to search for matches.

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САУСАҚ ІЗДЕРІ БОЙЫНША ЖЕКЕ ТҮЛҒАНЫ БИОМЕТРИЯЛЫҚ СӘЙКЕСТЕНДІРУ ҮШІН АЛГОРИТМДЕРДІ ӨНДЕУ

Аннотация. Мақалада биометриялық саусақ ізін сәйкестендіруге арналған суретті өңдеу алгоритмдері қарастырылады. Олар көптеген салалардағы жұмысты жақсартудың негізгі құралы болып табылады. Тану жүйесі деректерді сақтауға, оны ары қарай өңдеуге, саусақ іздерінің суреттерін анықтауға және көрсетуге арналған. Криминалистика (сот сараптамасы) – кескіндерді өңдеудің заманауи алгоритмдерін қолдану және жұмыс нәтижелерін едәуір жақсартатын бағыттардың бірі. Мұнда тәжірибелік зерттеу әдісі қарастырылып, сәйкестендіру нәтижелерін өңдеу процесі сипатталған. Бұл жұмыста FPM10A модулін Adafruit Arduino кітапханасында биометриялық саусақ іздері жүйесін құру үшін пайдалану әдісі көрсетілген. Бұл мәселені шешу үшін деректерді сақтау, одан ары өңдеу, саусақ іздерінің суреттерін анықтауға және көрсетуге арналған тану жүйесі ұсынылды. Олар өте құпия жерлерде, сканерлеу және дерекқордың көмегімен саусақ іздерін тексеруге негізделген парольға қол жеткізу кілтінің бір түрі ретінде қолданылады. Саусақтардағы папиллярлы өрнек құрылымының сәйкестендіру ерекшеліктері әртүрлі қысымның, жылдамдықтың, бағыттың, қоршаған ортаның температурасы мен ылғалдылық деңгейінің әртүрлі кескіндерге әкелетінін ескере отырып зерттеледі. Олар әдетте жаһандық және жергілікті ерекшеліктерге бөлінеді. SIFT дескрипторы және SURF ең жақын бәсекелесі сияқты әртүрлі сандық өңдеу алгоритмдерінің арқасында әр кескінге ерекше сипат-тамаларды тез алуға мүмкіндік туды. Осы зерттеуде біз ашық көздерден алынған фотосуреттер базасын қолдандық. Ол Fingerprint Verification Competition 2004 (FVC2004) деп аталады. Жұмыс нәтижесінде сәйкестіктің негізгі нүктелерінің графикалық бейнесі, сонымен қатар саусақ іздері бойынша сәйкес келетін негізгі нүктелердің саны зерттелді. Бұл ерекшеліктер үшін әртүрлі мысалдар келтірілген, олардың алгоритмдерінің айырмашылықтары, артықшылықтары мен кемшіліктері көрсетілген. Саусақ іздерін сканер арқылы әртүрлі айналдырумен сәйкестендіру нәтижесі алынды. Негізгі нүктелер Гессе матрицасының көмегімен ізделеді. Гессе матрицасының детерминанты (гессиан) жарық градиентінің максималды өзгеру нүктелерінде экстремумға жетеді. Саусақ іздері «Cross Match V300» оптикалық сенсорының көмегімен алынды. Эксперименталды зерттеуден көргеніміздей, әзірленген бағдарламалық жасақтама кескіннің айналуына тұрақты емес.

Түйін сөздер: биометрия, саусақ іздері, сәйкестендіру белгілері, минуция, папиллярлық үлгілер, түйінді дескрипторлар, сурет градиенті, жеке басын биометриялық сәйкестендіру, жарықтылық градиенті, цифрлық өңдеу алгоритмі, SIFT, SURF, BRIEF дескрипторлары, мәліметтер базасы, Гессе матрицасы, CrossMatch V300 оптикалық сенсор, биометриялық сканер, FPM10A модулі, Adafruit Arduino кітапханасы, оптикалық сканер, парольге арналған кілт, инвариант, бірегейлік, векторлық функция, Лаплас пирамидасы, октава, негізгі нүктелерді бағалау, Хаар фильтри, Хэммингтің қашықтық сомасы, электронды саусақ ізі.

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АЛГОРИТМЫ ОБРАБОТКИ ИЗОБРАЖЕНИЙ ДЛЯ БИОМЕТРИЧЕСКОЙ ИДЕНТИФИКАЦИИ ЛИЧНОСТИ ПО ОТПЕЧАТКАМ ПАЛЬЦЕВ

Аннотация. Рассматриваются алгоритмы обработки изображений для биометрической идентификации личности по отпечаткам пальцев. Они являются основными инструментами по улучшению результатов деятельности в самых различных отраслях. Система распознавания предназначена для хранения данных, дальнейшей ее обработки, идентификации и отображении снимков отпечатков пальцев. Криминалистика

является одним из таких направлений, где применение современных алгоритмов обработки изображений дает значительное улучшение результатов работы. Рассмотрена методика экспериментальных исследований, описан процесс обработки результатов идентификации. В этой работе показано, как использовать модуль FPM10A с библиотекой Adafruit Arduino для создания биометрической системы отпечатков пальцев. Для решения данной проблемы была предложена система распознавания, которая предназначена для хранения данных, дальнейшей ее обработки, идентификации и отображении снимков отпечатков пальцев. Они используются в местах строгой секретности, как своего рода паролевый ключ доступа, основанный на сканировании и сверки отпечатков пальцев с базой данных. Исследованы идентификационные признаки строения папиллярных узоров на пальцах с учетом того, что различное давление, скорость, направление, температура окружающей среды и уровень влажности приводят к разным изображениям. Их принято подразделять на глобальные и локальные признаки. Благодаря различным алгоритмам цифровой обработки и анализа изображений таким как: дескриптор SIFT, а также ближайший конкурент дескриптор SURF, появилась возможность быстрого получения уникальных характеристик по каждому изображению. В данном исследовании использовалась база данных из фотографий, полученная из открытых источников – Fingerprint Verification Competition 2004 (FVC2004). В результате работы исследованы графическое изображение совпадающих ключевых точек, а также количество совпавших ключевых точек по отпечаткам пальца. Приведены различные примеры для этих признаков, показывающие их отличия, преимущество и недостатки использованных алгоритмов. Получен результат совпадения отпечатков пальцев с различным вращением через сканер. Поиск ключевых точек производится с помощью матрицы Гессе. Детерминант матрицы Гессе (гессиан) достигает экстремума в точках максимального изменения градиента яркости. Отпечатки пальцев были получены с помощью оптического датчика «CrossMatch V300». Проведенное экспериментальное исследование показало, что разработанная программная система обладает инвариантностью к поворотам изображения.

Ключевые слова: биометрия, отпечатки пальцев, идентификационные признаки, минуция, папиллярные узоры, дескрипторы ключевых точек, градиент изображения, биометрическая идентификация личности, градиент яркости, алгоритм цифровой обработки, дескрипторы SIFT, SURF, BRIEF, база данных, матрица Гессе, оптический датчик CrossMatch V300, биометрический сканер, модуль FPM10A, библиотека Adafruit Arduino, система распознавания, оптический сканер, паролевый ключ доступа, инвариантность, уникальность, объем прецедентов, пирамида Лапласа, октава, оценки ключевых точек, фильтр Хаара, сумма расстояний Хэмминга, электронная дактилокарта.

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**COGNITIVE SMART-TECHNOLOGY OF DISTANCE LEARNING
OF EXPERION PKS DISTRIBUTED CONTROL SYSTEM
FOR OIL AND GAS INDUSTRY USING ONTOLOGICAL APPROACH**

Abstract. The research is devoted to the actual problem of qualified engineering personnel training for the oil and gas industry of the Honeywell company industrial equipment. There has been developed a cognitive Smart-technology of distance learning of engineers in shared laboratories of Experion PKS distributed control system equipment, which is currently widely used to solve a set of tasks from data collection and processing to technological processes operating modes optimization at refineries. The application of the proposed technology allows to provide high-quality personalized distance learning using ontological models that are designed to analyze the structure of DL, to systematize the input and output data, as well as significantly to improve the quality of the developed complex software. The advantage of the proposed Smart-technology of DL is the use of cognitive methods for the dynamic presentation of educational information using cognitive-visual schemes depending on the type of central nervous system of the student: choleric, sanguine, melancholic or phlegmatic, as well as features of vision in order to improve learning efficiency. Taking into account the individual characteristics of the perception of educational information there was created a personalized learning trajectory. An important feature of the technology is the processing of multidimensional data using a bioinspired approach of artificial immune systems in order to predict learning results and prompt adjustment of the industrial equipment development process.

Key words: distance learning, Smart-technology, ontological approach, shared laboratories, Experion PKS industrial equipment, cognitive methods.

Introduction. Nowadays, the actual problem is qualified engineering personnel training in the oil and gas industry on modern industrial equipment. The development of innovative distance learning technologies for effective training of specialists in shared laboratories (SL) on industrial equipment of leading manufacturers is relevant. Since 1974, Honeywell company has been developing distributed control systems (DCS) and is currently a leading company in the Fortune 100 rating in the field of industrial equipment for various purposes [1]. Honeywell equipment is successfully used in the oil and gas and chemical industries, for the production of turbo compressors, in industrial automation, etc. The company pays special attention to training centers and training courses. There are a large number of colleges around the world: in Germany (Honeywell Process Solutions); in France (Honeywell French Automation College); in Russia (Honeywell Russia Automation College), etc. The company invests heavily the development of E-Learning and offers various virtual trainings. The platform Experion PKS (Process Knowledge System) by Honeywell, which is a set of high-tech tools for solving various automation tasks [2], is especially widely used and is often used at refineries.

The progress in the field of high technology and the creation of the Internet allowed to modernize the sphere of higher education and one of the promising direction is distance learning (DL). The purpose of implementation of distance learning technologies in the system of engineering education is to ensure the availability of obtaining knowledge for students, regardless of their place of residence, social status, health

status, distance from the training center [3], etc. Development and implementation of innovative distance learning technologies using modern approaches of artificial intelligence and telecommunication means, which provide a highly effective interactive method of obtaining knowledge, is a new level of interaction between the teacher and the student, aimed at improving the quality of training and development of complex technological equipment.

Literature analysis. Shared laboratories (SL) create a platform for research, technological and engineering activities and provide open access to expensive industrial equipment. For example, the researchers [4] consider various learning styles that determine the cognitive and psychosocial behavior of students, the knowledge perception, interaction and information processing in various learning environments. There is given an evaluation of the styles effectiveness for laboratory training through a web-platform. The work [5] is devoted to the issues of efficient maintenance of distributed remote laboratories.

The studies [6] consider the need to use the latest remote information technologies in educational process organization in the system of higher technical education, due to the fact that traditional approaches categorically do not meet the needs of a rapidly developing society, that contradicts the real needs of main consumers of educational services. The article [7] is devoted to the issues of the DL advantages in connection with the great adaptability to the needs of students, the wide possibilities of modern high technologies use, telecommunication and multimedia tools in order to improve the education quality. The research [8] raises the issue of the student training quality. The rapid development of online higher education leads to the fact that students are faced with certain barriers that affect the general DL quality. These problems are solved by the use and by the implementation of effective DL methods and by the latest information and communication technologies. Despite the advantages of DL there is a high percentage of student dropouts. The work [9] is devoted to the solution of this problem. There has been carried out the analysis and have been developed measures that help to reduce the dropout rate from the distance learning system on the basis of a deep level of personnel interest and learning process personalization. The conducted researches and available data confirm the effectiveness of their application. The article [10] presents a comparative analysis of the traditional system of education and distance education. The effectiveness of DL as a supplement to the traditional form of education is also shown.

The implementation of modern information Smart-technologies using the latest achievements of artificial intelligence in the field of DL contributes to the development of intellectual abilities of students and to the improvement of the education quality. The article [11] defines Smart-learning, based on the use of digital technologies and DL empowering. The development of various cognitive DL methods in order to take into account the characteristics of information perception by students is relevant. The article [12] proposes a Smart-technology of DL using cognitive learning tools that solves the problem of accessibility of education and is aimed at developing the mental abilities of students. The article [13] deals with issues of interactive learning in the intellectual environment. There are proposed various training scenarios that illustrate the implementation of new educational models aimed at the adaptation and individualization of knowledge acquisition. The general purpose of both learning scenarios is to improve learning for different groups, moving away from a teacher-based approach to a student-centered approach.

A great importance at the development of innovative Smart-systems of distance learning has the development and the use of ontological models, which allow to systematize and to structure the data [14]. Ontologies are widely used in solving problems of knowledge representation in various applied areas, including in the field of DL. Analysis of ontological models allows to take into account the peculiarities of functioning and interconnection during the work of various algorithms of artificial intelligence, reduces the time and computational costs on the development of software for the implementation of Smart-technologies of DL. The article [15] describes the ontological learning model, which contains the psychological characteristics and personality traits of the learner. The research [16] is devoted to the creation of ontological models that characterize students in the ontology editor Protégé. In the work [17], there is considered the problem of creation of the large-scale ontologies and their practical use. The article [18] presents the ontological student's network model for learning environments. This model is developed as a set of ontological resources that have been expanded, standardized, interconnected and adapted for the use in various learning environments.

The proposed researches are a continuation of the cycle of works devoted to distance learning of engineering specialties. For example, the work [19] considers the need to process a huge flow of

multidimensional data in real time arising from the operation of modern DL systems, problems associated with the huge number of unaccounted factors affecting the system and the ability to connect to real equipment. With DL there is a very large load on the eyesight [20], therefore, the development of a specialized DL system for people with visual disabilities is urgent.

Problem statement and solution methods. It is necessary to develop a cognitive Smart-technology of DL equipment for the Experion PKS distributed control system of Honeywell company for the oil and gas industry in shared laboratories using ontological models and an approach of artificial immune systems, taking into account students' perception of educational information depending on their psychotype and visual characteristics in order to improve learning process.

Figure shows the structure of the cognitive DL Smart-technology to the Experion PKS industrial equipment.

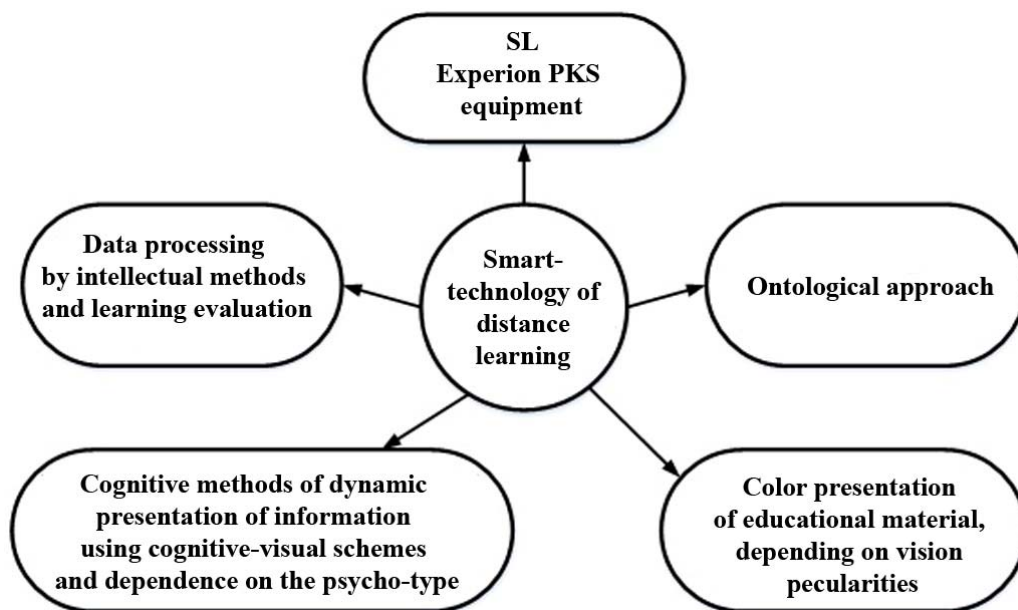
The main features of the proposed technology are:

1. Development of ontological models for structuring the information DL system, systematization of input and output data, identification of logical links, and development of software.

2. Introduction of cognitive methods of dynamic presentation of educational information using personalized cognitive-visual schemes depending on the student's psychotype (choleric, sanguine, melancholic or phlegmatic) and vision peculiarities (myopia and hyperopia).

3. Application of the modified Artificial Immune Systems (AIS) algorithm for processing individual characteristics (descriptors) of students and for prediction learning results, as well as operational control of the process of obtaining knowledge based on the learning evaluation.

4. Shared laboratories for solving the assigned task of distance learning should have a complete infrastructure: modern equipment, appropriate technical and software support.



Cognitive DL Smart-technology to the Experion PKS industrial equipment

The Experion PKS platform is a multi-layered architecture for solving complex tasks from collecting and processing information to optimization of operating modes of technological processes and is widely used in the oil and gas industry [2]. This platform largely interacts with a large amount of advanced control, planning and automation subsystems, alarms, security and access control subsystems, thereby providing the necessary level of integration and interaction between all components of the control systems. The use of a fault-tolerant industrial network (FTE) provides the connection of all control nodes, but at the same time has a number of characteristics that allow maintaining a high level of reliability and security, as well as the ability to work with equipment from other manufacturers. At connecting field devices via digital interfaces, not only the measurement channel error is reduced, but it also ensures the extended information obtaining. The use of a universal digital interface (HART protocol) allows remote

monitoring and configuration of communication channels. The main feature of Experion PKS is the built-in “server consolidation” technology - DSA (Distributed Server Architecture). DSA technology provides unified access not only to real-time data (configured points), but also to the trends and history logs. This makes it possible quickly to respond and to make decisions through access to the necessary information.

Ontological models. Table presents the following ontological models: shared laboratories with the use of the Experion PKS distributed control system equipment, the ontological model of teaching the Experion PKS equipment; ontological model of a student taking into account psychotypes and visual peculiarities.

Ontological models of DL in SL with Experion PKS equipment

Ontological models	Content
1	2
1. Ontological model of SL with the Experion PKS equipment of the Honeywell company	<i>Download and connection of software for the Experion PKS system.</i>
	<i>Creation of an operator account in the Station program:</i> - opening the operator panel using Enter System Menu and System Configuration; - creation of an operator account (selecting Operators) to Configuration Studio access; - log in to the system under the created operator account.
	<i>Creation of an enterprise model database (EMDB, Enterprise Model DataBase):</i> - download an EMDB system using Knowledge Builder program; - connection and loading of the configured server into the EMDB system; - creation and configuration of Asset Model in the Enterprise Model Builder application for the selected control object; - download the Asset Model to the EMDB system; - creation of an Alarm Group in the Enterprise Model Builder application and connection to the Asset Model; - download of Alarm Group to EMDB system.
	<i>Creation of a SCADA system:</i> - selection of Control Strategy command; - creation and configuration of a communication channel (Build Channels) in Quick Builder application; - connection of a communication channel using Ethernet in order to work with controllers using OPC technology; - checking the connection of the communication channel in the Station program, where statistical data are automatically recorded; - selection of the controller type (Modbus, UserScanTask, Allen-Bradley, FSC) and connection to the communication channel and download; - checking the connection of the controller in Station; - if the controller is not connected, then select “Controllers” in the System Configuration system and connection of the controller using the left mouse button on the “Enable” checkbox; - selection and configuration of the sensor "points" (Points) by signal type: Accumulator Point, Analog Point, Container Point, Status Point; -connection and loading Points: to the communication channel, controller, Asset Model (control object), Alarm Group; - checking the connection of Point in the Station; - in order to control the Point state, the name Point is entered in the Command Zone and by the left mouse button on Detail opens the created point through which it can be controlled; - point status control; - view the status of the Alarm Zone; - viewing time control in History from 1 hour to 1 minute.
	<i>Creation of an interactive operator display and setting up the information presentation from a display reflecting the front panel of the control circuit:</i> - a data structure of the display is compiled for several field values at one point with different parameters; - Analog Point for control circuit (PV, SP, OP, Mode, Aux1-4, Alarms). StatusPoint for valve (PV, OP, Mode, Alarms). Where PV (process value) is the process variable, OP (output) is the output variable, SP is the specified value of the measured parameter (setpoint), MD is the mode for loop changing from manual to automatic control; - creation of a working group display and of a trend for each point in the server database; - definition of Analog Point or Status Point and the display name in (Group Face Template Display) for working with the front panel of the operator; - creation of groups configuration Configure Groups in the application Trends and Groups in the field Title Definition;

	<ul style="list-style-type: none"> - point identification and point description (Point IDs and Point Descriptions) using the Point Browser window; - definition of the working group and observation of working data for each point from one display, if your server is connected to the controller and is in operation mode; - work with an interactive display that combines the characteristics of standard group and trends displays.
2. Ontological model of Experion PKS equipment learning	<p><i>Lectures:</i></p> <ul style="list-style-type: none"> - Lecture 1. Introduction to the Experion PKS platform; - Lecture 2. Work with the Station program. ...
	<p><i>Laboratory classes:</i></p> <ul style="list-style-type: none"> - Lab. 1. Access to the Station program using protection level data; - Lab. 2. Launch of Configuration Studio, which performs access configuration and system simulation tasks. ...
	<p><i>Independent work:</i></p> <ul style="list-style-type: none"> - Topic 1. Connection of the controllers to the server using communication channels, as well as determination of the controller type and communication line type; - Topic 2. Configuration of the trend in the application Configuration Studio. ...
	<p><i>Educational materials:</i></p> <ul style="list-style-type: none"> - Experion PKS. Product guide. 2004. Honeywell. ...
3. Ontological model of the student taking into account psychotypes and vision peculiarities	<p><i>The use of a cognitive approach in order to identify the physiological, intellectual and psychophysiological features of the perception and awareness of information:</i></p> <p>- questionnaire in order to determine the individual characteristics by the psychotype:</p> <ol style="list-style-type: none"> 1. choleric (strengths: active, confident, pragmatist, creative; weaknesses: domineering, irritable, hot-tempered); 2. sanguine: (strengths: enthusiastic, sociable, talkative; weaknesses: unorganized, undisciplined); 3. phlegmatic: ... 4. melancholic: ... <ul style="list-style-type: none"> - selection of the optimal training tactics, taking into account the individual vision peculiarities 1. with myopia; 2. with hyperopia; - development of a database of individual descriptors of students; - processing of multidimensional data on the basis of modified AIS algorithm; - formation of individual cognitive visual schemes; - dynamic presentation of information, taking into account the vision peculiarities and psychotype; - prediction of learning results and operational control of the knowledge obtaining process based on the learning evaluation.

The developed ontological models are implemented in the Protégé ontology editor.

Conclusion. The conducted researches on creating innovative cognitive Smart- technologies [21] of distance learning of engineering specialties in shared laboratories of distributed control equipment at Experion PKS of the Honeywell company using an ontological approach and artificial immune systems are relevant and are aimed at effective personalized distance learning, taking into account information perception features (depending on psychotype and visual acuity) and the preparation of highly professional specialists in the oil and gas industry [22].

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**МҰНАЙГАЗ САЛАСЫ ҮШІН ОНТОЛОГИЯЛЫҚ ТӘСІЛДІ
ҚОЛДАНА ОТЫРЫП
EXPERION PKS ЖАБДЫҒЫН ҚАШЫҚТАН ОҚЫТУДЫҢ
КОГНИТИВТІ SMART-ТЕХНОЛОГИЯСЫ**

Аннотация. Зерттеулер мұнайгаз саласындағы Honeywell (Honeywell) фирмасының өнеркәсіптік жабдығы үшін мамандандырылған инженерлік кадрларды дайындаудағы өзекті мәселеге арналған. Кешенді техникалық автоматтандырылған құрылғыларын өндіруден Honeywell компаниясы әлемдік көшбасшы болып саналды. Honeywell құрылғылары аэроғарыш, мұнай-газ және басқа да өндіріс салаларында сәтті қолданысқа ие. Автоматты түрде реттеуге, қашықтықтан басқаруға, жинақтау және деректерді өңдеуге, ақпараттарды графикалық бейнелеуге, есептерді қалыптастыруға, журналдарды мұрағаттауға, ақпарат алмасуға және т.б. функцияларды атқаратын қуатты Experion PKS реттелген басқару жүйесін Honeywell корпорациясы әзірлеген.

Қазіргі уақытта мұнайөңдеу зауыттарында ақпаратты жинау және өңдеуден бастап технологиялық үрдістердің жұмыс істеу тәртібін оңтайландыруға дейінгі міндеттердің жиынтығын шешу үшін кеңінен пайдаланылатын ұжымдық пайдалану зертханаларында инженерлерді Experion PKS жабдығын қашықтан оқытудың когнитивті Smart-технологиясы жасалды. Ұсынылған технологияларды қолдану – ҚО құрылысын талдауға, кіріс және шығыс деректерді жүйелеуге арналған онтологиялық модельдерді пайдалана отырып сапалы дербестендірілген қашықтан оқытуды қамтамасыз етуге мүмкіндік береді, сондай-ақ, жасалған күрделі бағдарламалық қамтудың сапасын айтарлықтай арттырады. Ұсынылып отырған ҚО Smart-технологиясының артықшылығы оқытудың тиімділігін арттыру үшін оқушының холерик, сангвиник, меланхолик немесе флегматик сияқты орталық жүйке жүйесінің типіне, сонымен қатар көру ерекшеліктеріне байланысты оқу ақпараттарын когнитивті-визуалды сызбалардың көмегімен динамикалық тұрғыда берудің когнитивті әдістерін қолданумен байланысты. Оқу ақпаратын қабылдаудың жеке сипаттамаларын ескере отырып, оқытудың дербестендірілген траекториясы тұрғызылады. Технологияның маңызды ерекшелігі оқытудың нәтижелерін болжау және өнеркәсіптік жабдықтарды игеру үдерістерін шұғыл түзету үшін жасанды иммундық жүйелердің биоинсперирленген тәсілін пайдалана отырып, көпөлшемді деректерді өңдеуде жатыр.

Түйін сөздер: қашықтан оқыту, Smart-технология, онтологиялық тәсіл, зертханаларды ұжымдық пайдалану, Experion PKS өнеркәсіптік жабдығы, когнитивті әдістер.

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**КОГНИТИВНАЯ SMART-ТЕХНОЛОГИЯ
ДИСТАНЦИОННОГО ОБУЧЕНИЯ
РАСПРЕДЕЛЕННОЙ СИСТЕМЫ УПРАВЛЕНИЯ EXPERION PKS
ДЛЯ НЕФТЕГАЗОВОЙ ОТРАСЛИ
С ПРИМЕНЕНИЕМ ОНТОЛОГИЧЕСКОГО ПОДХОДА**

Аннотация. Исследования посвящены актуальной проблеме подготовки квалифицированных инженерных кадров для нефтегазовой отрасли промышленному оборудованию фирмы Honeywell. Компания Honeywell является мировым лидером в области производства комплекса технических средств автоматизации. Оборудование Honeywell успешно применяется в аэрокосмической, нефтегазовой и других областях промышленности. Корпорацией Honeywell разработана мощная распределённая система управления Experion PKS, которая выполняет функции: автоматического регулирования, дистанционного управления, сбора и обработки данных, графического отображения информации, формирования отчетов, архивирования журналов, обмена информацией и т.д.

Разработана когнитивная Smart-технология дистанционного обучения инженеров в лабораториях коллективного пользования оборудованию распределенной системы управления Experion PKS, которое в настоящее время широко используется для решения комплекса задач от сбора и обработки информации до оптимизации режимов работы технологических процессов на нефтеперерабатывающих заводах. Применение предлагаемой технологии позволяет обеспечивать качественное персонализированное дистанционное обучение с использованием онтологических моделей, которые предназначены для анализа структуры ДО, систематизации входных и выходных данных, а также существенно повышают качество разрабатываемого сложного программного обеспечения. Достоинством предлагаемой Smart-технологии ДО является применение когнитивных методик динамической подачи учебной информации с помощью когнитивно-визуальных схем в зависимости от типа центральной нервной системы обучающегося: холерика, сангвиника, меланхолика или флегматика, а также особенностей зрения для повышения эффективности обучения. С учетом индивидуальных характеристик восприятия учебной информации строится персонализированная траектория обучения. Важной особенностью технологии является обработка многомерных данных с использованием биоинспирированного подхода искусственных иммунных систем для прогнозирования результатов обучения и оперативной корректировки процесса освоения промышленного оборудования.

Ключевые слова: дистанционное обучение, Smart-технология, онтологический подход, лаборатории коллективного пользования, промышленное оборудование Experion PKS, когнитивные методики.

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**MODERN GEOCHEMICAL STATE OF THE ENVIRONMENT
OF THE ADJACENT TERRITORIES
OF THE DOMODEDOVO MOSCOW AIRPORT**

Abstract. The main parameters of the geochemical state of the environment (E) and their change as a result of the functioning of the apron of the Domodedovo Moscow Airport are considered. The qualitative and quantitative composition of the polluting elements is presented. The features of elements of soil contamination are studied. The carried out theoretical and practical work allowed compiling tables of total and active forms of pollutants in the studied soils. Recommendations have been developed to prevent and reduce the negative environmental impact on the soil of the aerodrome and nearby natural-anthropogenic areas during the operation of transportation hub facilities by creating phytobuffers.

Key words: Domodedovo Airport, geochemical barrier, hyperaccumulants, apron complex, soil, pollutants, rare metals, phytobuffer, phytoremediation, environmental safety.

The relevance of the topic. At the present stage of social development, the Domodedovo Airport is becoming the most important link in the transportation system not only of the Russian Federation, but of the whole of Eastern Europe. Being a part of the Moscow aviation hub along with the Sheremetyevo and Vnukovo airports, it is one of the fastest-growing, innovative and attractive civil aviation facilities in Russia. The total passenger flow in 2018 amounted to about 29.4 million people [1], which is the second result in the Russian Federation after Sheremetyevo Airport (33.7 million).

The increase in the size of airport infrastructure due to the construction of a new runway (RWY), passenger and cargo terminals, transport interchange for 43 km of the A-105 highway causes an emphasis of anthropogenic pressure on nature. The transformation processes of the environment (E), related activities trigger the mechanisms of migration and redistribution of chemical elements, the occurrence of anthropogenic anomalies and increasing their background values.

The technogenic transformation of the airport landscape is a consequence of mechanical disturbances of the natural surface (a creation of the aerodrome, a construction of infrastructure, installation of heating mains and pipelines), hydrodynamic disturbances of the geological environment (changes in the level of ground and underground water) and the geochemical impact on individual components of landscapes [2]. One of the strongest influence on living organisms and the most common chemical pollution is entering the soil of heavy metal compounds.

The natural presence of metals in soils and plants is a reference point in determining ecosystem changes. Exceeding the level of natural content is a cause for beginning to determine the anomalies reason. They can have both a natural genesis and an artificial one. Transformations in the environment have a long accumulative effect and influence human health, so the determination of the geochemical situation of the territory is an extremely urgent issue.

Materials and methods of research. The study was conducted using the following materials: articles [3] and theses for the degree of candidate of science [4]; Volume 2 of the Master layout plan for the development of the Domodedovo district of the Moscow region for 2014 [5]; Volume 3 of the Master plan of the Domodedovo urban district for 2006 [6]; “Ecology and environment of the Domodedovo urban district for 2015-2019” municipal program [7], and the Information release annual report “On the state of natural resources and the environment of the Moscow region in 2018” [8].

At the first stage, samples and soil were collected nearby the airport, the coordinates of the collection point are [55.433993; 37.873778]. Then, as a result of the analyzes performed by the ELAN-6100 mass spectrometer using the methodology [9, 10] of the Academic Council for Analytical Techniques (ACAT) No. 499-AЭC/MC and ACAT No. 500-MC and Lumachrome liquid chromatograph, the data are shown in tables 1, 2. The gross content in the soils of the studied chemical elements above the maximum permissible concentration (MPC) is summarized in table 1.

Research results. The study revealed the presence of fifty metals, both heavy and rare, as well as radioactive ones. This fact should not set at a gaze since the activity of any aviation enterprise is associated with the use of high-tech alloys containing almost all known elements of the periodic table. Changes in the geochemical environment are influenced by diffusing emissions from stationary and mobile sources inside and outside the airport.

Table 1 – The content of gross forms of pollutants in the soil sample

Chemical element	Soil horizon, mg/kg		MPC, mg/kg
	A	B	
Copper	2.9	5.54	3.0
Nickel	3.26	6.52	4.0
Benzopyrene	0.0025	0.0025	0.002
Chromium	6.8	15.2	6
Arsenic	1.52	2.52	2.0

The increased pollutant values in horizon **B** are accounted for the actively ongoing process of introducing chemically aggressive substances. Nickel and chromium are important chemical elements in the production of aircraft engines and alloys that also contain arsenic. At high temperatures, the studied elements are emitted to the environment due to the wear of aircraft structures. Various compounds are formed due to the content of mineral impurities (ash) in the fuel composition.

Lead, zinc, and cadmium belong to a separate group. Their compounds are the most studied metallic ecotoxicants. It is worth noting that the research on technogenic soil pollution was conducted around the airport, in the zone of its influence [3].

Table 2 contains the results of recent measurements with primary data obtained by other researchers. The analyses indicate a decrease in the concentration of metals and their compounds.

Table 2 – The content of active forms of elements (mg/kg) in the soil in comparing 2007 and 2016

Chemical element	Soil horizon /year of investigation				MPC	Background content
	A ₂₀₀₇	A ₂₀₁₆	B ₂₀₀₇	B ₂₀₁₆		
Cadmium	0.13	0.0028	0.33	0.0168	1	1.97
Lead	2.34	0.72	4.33	1.3	32	3.4
Zinc	1.3	1.02	2.73	1.68	23	2.754

* 2007 data taken from source [3].

Recently, the main reason is a decrease in passenger traffic and, as a consequence, a decrease in the number of flights. A positive trend is also associated with a new type of aircraft engine and more environmentally friendly jet fuels.

The insertion of metal elements with gas and dust exhausts onto the surface of the soil, and then into the soil solution, leads to the formation of various compounds. A typical scheme of transformation and movement of the main ecotoxicant metals in the soil is presented in figure 1.

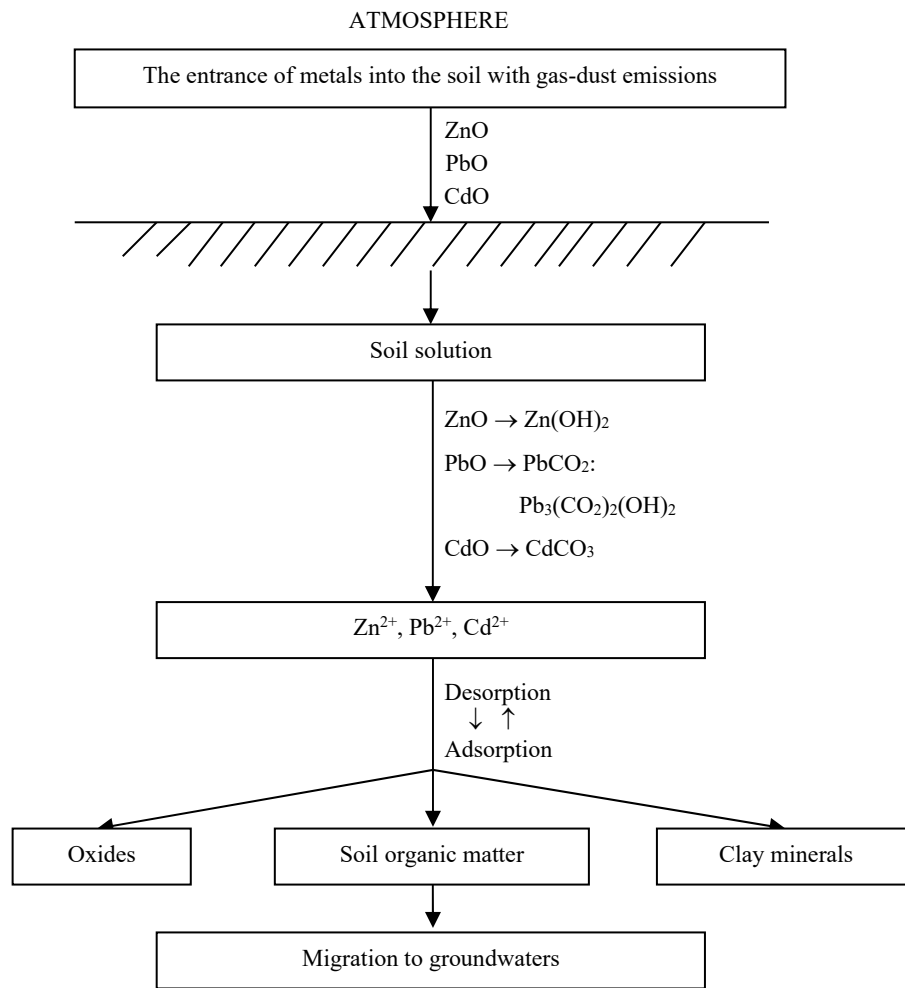


Figure 1 – Transformation and migration of heavy metals in soil [13]

Lead oxides are poisonous, belong to the 1st hazard class. In flora and fauna, bioaccumulation of lead carbonate may be observed. The substance affects the blood, bone marrow, central and peripheral nervous systems, kidneys. The result of this process is anemia, hemolysis, and encephalopathy. The toxic impact causes serious impairment of human reproductive function [17].

Cadmium oxide is the 1st hazard class substance. Inhalation of its vapor can be fatal and carcinogenic [16]. Cadmium carbonate is a water-insoluble compound. Due to its inertness, there is no strong interaction with the ecosystem, on the other hand, it removes cadmium from the cycle, which leads to its accumulation and the occurrence of geochemical anomalies.

To stabilize the geochemical situation near the airport, it is necessary to create an engineered barrier with calcium carbonate on the way of acidic waters, forming streams and ground flows through the drainage system. This will make a concentration of copper, zinc, cadmium and other pollutant metals at its border, thereby localizing pollution foci.

Engineering geochemical barriers can also belong to the oxidizing, hydrogen sulfide, gley, and sorption classes. The most promising way to neutralize the negative impact of the airport system on the geochemistry of the surrounding landscape is to create phytobuffers with high absorption capacity. Plants with significant sorption properties should be included in their composition.

Representative model objects can be zinc hyperaccumulants, represented mainly by plants of the mustard family (Brassicaceae). Over-accumulation of cadmium and lead is a very rare occurrence among higher plants. The ability to accumulate cadmium is known only about the glaucous pennycress (*Thlaspi caerulescens*), as well as the rockcress (*Arabidopsis halleri*). Brown mustard (*Brassica juncea*) can accumulate several heavy metals such as Cd, Cu, Ni, Pb, Se, Zn [14].

The reduced level of impact on the environment is associated primarily with a decrease in the number of takeoff and landing operations, which directly depends on the number of performed flights. Even though the airport experiences a difficult economic period, the environmental component of the enterprise is on the right track.

Thanks to this research, the following results were obtained:

- the geochemical environmental state of the surrounding area of Domodedovo Moscow Airport is described;
- the main pollutants of the soil cover of the landscape near the transport facility were identified;
- the content of gross forms of pollutants (copper, nickel, benzopyrene, chromium, arsenic) in the soil sample was established;
- the content of active forms of metal pollutants (cadmium, lead, zinc) in the soil sample was defined.

The obtained pollutant values were compared with the data of previous years, which made it possible to observe the dynamics of changes in the geochemical conditions of the territories around the aviation hub.

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"ДОМОДЕДОВО" МӘСKEУ ӘУЕЖАЙЫ МАҢЫНДАҒЫ ҚОРШАҒАН ОРТАНЫҢ ҚАЗІРГІ ГЕОХИМИЯЛЫҚ ЖАҒДАЙЫ

Аннотация. Қоғамның қазіргі даму сатысында «Домодедово» әуежайы тек РФ ғана емес, Шығыс Еуропаның да маңызды транспорттық тізбегі болып келеді. Сондай-ақ «Шереметьево» және «Внуково» әуежайларымен қатар, Мәскеу авиациялық торабының құрамындағы, Ресей аумағындағы тез дамушы, инновациялық азаматтық авиация нысаны. 2018 жылғы жалпы жолаушылар ағымы – 29,4 млн адам, бұл көрсеткіш РФ бойынша «Шереметьево» (33,7 млн) әуежайынан кейінгі екінші орынды білдіреді.

«Шереметьево» және «Внуково» әуежай инфрақұрлымының жаңа ұшып-қону жолағын (ҰҚЖ), жолаушы және жүк терминалдарын, А-105 тас жолының 43 км-де жол қиылыстарын салу табиғатқа түсетін антропогенді салмақты күшейтті. ҚО өзгерту прцестері және осыған байланысты іс-шаралар химиялық элементтердің көшуі мен қайта бөлінуі механизмін іске қосады. Антропогендік құбылыстардың орын алуы және олардың фондық мәндерінің ұлғаюы.

Әуежай ландшафтын техногенді өзгерту – табиғи жамылғыны механикалық бұзу (аэродром жасау, инфрақұрлым нысандарын салу, жылу құбырларын және құбыр желілерін өткізу), геологиялық ортаның гидродинамикалық бұзылуы (жер асты су деңгейлерінің өзгеруі) және ландшафттың жекелеген компоненттеріне геохимиялық әсер ету. Әсері бойынша тірі ағзаға күшті әсер ететін және кең таралған химиялық ластаушы ауыр металдардың қосындыларының топырақ жамылғысына түсуі болып табылады.

Экожүйедегі өзгерістерді анықтау үшін топырақта және өсімдікте металдардың болуы есеп нүктесі болып табылады. Өзіндік мөлшерінен асқан жағдайда ауытқу мөлшерін анықтауды бастау керек. Олар табиғи немесе жасанды генезистерге ие болуы мүмкін. ҚО орын алатын өзгерістер созылмалы аккумулятивті әсерге ие болғандықтан, адам денсаулығына әсер етеді, сондықтан аумақтың геохимиялық жағдайын анықтау өзекті мәселе.

Мәскеу «Домодедово» әуежайы комплексінің қызмет ету нәтижесіндегі қоршаған ортаның және геохимиялық параметрлердің негіздері қарастырылған. Ластаушы элементтердің сандық және сапалық құрамы келтірілген. Топырақ жамылғысын ластаушы элементтердің ерекшеліктері зерттелген. Өткізілген теориялық және практикалық жұмыстар топырақ жамылғысындағы жылдық және күнделікті ластаушы заттардың кестесін жасауға мүмкіндік берді. Фитобуфер жасау арқылы транспорттық байланыс нысандарын

эксплуатациялау барысындағы топырақ жамылғысына әсер ететін кері экологиялық әсерді төмендетудің ұсыныстары жасалды.

Әуежай маңындағы геохимиялық жағдайды тұрақтандыру үшін дренажды жүйе арқылы түзілетін қышқылды су, жерасты суларының жолына кальций карбонатынан жасанды бөгет жасау керек. Мыс, мырыш, кадмий және басқа да ластаушы – металдардың шекарасында мүмкіндік береді, осы арқылы ластаушы көздерді шоғырландырады.

Жасанды биохимиялық кедергілер тотықтырғыш, күкіртсутекті, глейлі, сорбционды класқа жатуы мүмкін. Әуежай жүйесінің маңайындағы ландшафтқа кері әсерін шектеудің айтарлықтай тиімді тәсілі сіңіру қабілеті жоғары – фитобуфер жасау.

Қоршаған ортаға әсер ету деңгейінің төмендеуі ұшып – қону іс-шараларының азаюымен байланысты. Әуежайдың экономикалық кезеңі айтарлықтай болмаса да, экологиялық жағдайында шешу керек мәселелер бар (сөйлем дұрыс құралмаған).

Жүргізілген зерттеулер барысында келесідей нәтижелер алынды: Мәскеу «Домодедово» әуежайына қарасты аумақтың ҚО геохимиялық жағдайы сипатталды; көлік нысандары маңындағы жерлердің топырақ жамылғысын ластаушы негізгі поллютанттар анықталды; топырақ үлгісіндегі поллютанттардың жылдық формалары (мыс, никель, бенз(а)пирен, хром, мышьяк, мырыш) мөлшері анықталды; топырақ жамылғысындағы жылжымалы металл ластаушылардың (кадмий, қорғасын, мырыш) мөлшері анықталды.

Поллютанттардың алынған мәндері алдыңғы жылғы мәліметтермен сәйкестендірілген. Әуежай маңындағы геохимиялық жағдайдың өзгеріс динамикасын бақылауға мүмкіндік берді.

Түйін сөздер: әуежай "Домодедово", геохимиялық кедергі, гипераккумулянттар, перрондық кешен, топырақ жамылғысы, поллютанттар, сирек металдар, фитобуфер, фиторемедиация, экологиялық қауіпсіздік.

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СОВРЕМЕННАЯ ГЕОХИМИЧЕСКАЯ ОБСТАНОВКА ОКРУЖАЮЩЕЙ СРЕДЫ ПРИЛЕГАЮЩИХ ТЕРРИТОРИЙ МОСКОВСКОГО АЭРОПОРТА «ДОМОДЕДОВО»

Аннотация. На современном этапе развития общества аэропорт «Домодедово» становится важнейшим звеном транспортной системы не только РФ, но и всей Восточной Европы. Входя в состав Московского авиационного узла наряду с аэропортами «Шереметьево» и «Внуково», является одним из самых быстроразвивающихся, инновационных и привлекательных объектов гражданской авиации на территории России. Общий пассажиропоток за 2018 года составил порядка 29,4 млн. человек, что является вторым результатом по РФ после аэропорта «Шереметьево» (33,7 млн).

Увеличение размеров аэропортовой инфраструктуры за счёт строительства новой взлетно-посадочной полосы (ВПП), пассажирского и грузового терминалов, транспортной развязки на 43 км трассы А-105 становится причиной усиления антропогенной нагрузки на природу. Процессы преобразования окружающей среды (ОС), связанные с ней мероприятия, запускают механизмы миграции и перераспределения химических элементов, возникновения антропогенных аномалий и повышения их фоновых значений.

Техногенная трансформация аэропортового ландшафта – следствие механических нарушений естественной природной поверхности (создание аэродрома, строительства объектов инфраструктуры, проведение теплотрасс и трубопроводов), гидродинамических нарушений геологической среды (изменения уровня грунтовых и подземных вод) и геохимического воздействия на отдельные компоненты ландшафтов. Одним из сильнейших по действию на живые организмы и наиболее распространенным химическим загрязнением является попадание в почвогрунты соединений тяжелых металлов.

Естественное присутствие металлов в почвах и растениях является точкой отсчёта при определении изменений в экосистеме. Превышение уровня природного содержания – повод для начала определения причин возникновения аномалий. Они могут иметь как естественный генезис, так и искусственный.

Преобразования в ОС имеют длительный аккумулятивный эффект и сказываются на здоровье человека, поэтому определение геохимической обстановки территории чрезвычайно актуальный вопрос.

Рассмотрены основные параметры геохимической обстановки окружающей среды (ОС) и их изменение в результате функционирования перронного комплекса московского аэропорта «Домодедово». Представлен качественный и количественный состав загрязняющих элементов. Изучены особенности элементов загрязнения почвогрунта. Проведенная теоретическая и практическая работа позволила составить таблицы валовых и подвижных форм поллютантов в исследованных грунтах. Разработаны рекомендации по предотвращению и снижению отрицательного экологического эффекта на почвогрунты аэродрома и близлежащих природных-антропогенных участков при эксплуатации объектов транспортного узла с помощью создания фитобуферов.

Для стабилизации геохимической обстановки вокруг аэропорта необходимо создать искусственный барьер из карбоната кальция на пути кислых вод, образующих ручьи и грунтовые потоки через дренажную систему. Это позволит концентрироваться меди, цинку, кадмию и другим металлам-поллютантам на его границе, тем самым, локализуя очаги загрязнения.

Искусственные геохимические барьеры могут относиться также к окислительному, сероводородному, глеевому, сорбционному классу. Наиболее перспективный способ нейтрализации отрицательного воздействия аэропортовой системы на геохимию прилегающего ландшафта – создание фитобуферов с высокой поглощательной способностью. В их состав должны быть включены растения со значительной сорбцией.

Снизившийся уровень воздействия на окружающей среды (ОС) связан, прежде всего, с уменьшением количества взлётно-посадочных операций, что напрямую зависит от количества выполненных рейсов. Несмотря на то, что аэропорт переживает не лучший экономический период, экологическая составляющая предприятия находится на верном пути.

Благодаря проведенному исследованию получены следующие результаты: описана геохимическая обстановка ОС прилегающих территорий московского аэропорта «Домодедово»; определены основные загрязнители почвенного покрова земель вблизи транспортного объекта; установлено содержание валовых форм поллютантов (меди, никеля, бенз(а)пирена, хрома, мышьяка) в почвенном образце; установлено содержание подвижных форм металлов-загрязнителей (кадмия, свинца, цинка) в почвенном образце.

Полученные значения поллютантов сопоставлены с данными предыдущих лет, что позволило наблюдать динамику изменений геохимической обстановки территорий вокруг авиационного узла.

Ключевые слова: аэропорт «Домодедово», геохимический барьер, гипераккумулянты, перронный комплекс, почвогрунты, поллютанты, редкие металлы, фитобуфер, фиторемедиация, экологическая безопасность.

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**EFFECT OF ELECTROPHYSICAL IMPACT
ON THE PHYSICAL AND CHEMICAL CHARACTERISTICS
OF COAL ASH FROM THE MAIKUBEN DEPOSIT**

Abstract. The paper studies the effect of electrophysical treatment of ash from coal of Maikuben deposit on its physical and chemical characteristics. The processing of coal ash was carried out on an electromagnetic apparatus (for fine grinding of ash particles) and on a high-voltage electric discharge installation (to change the properties of ash). The physical and chemical characteristics of coal ash were studied by multi-element instrumental neutron activation analysis (elemental analysis on the content of microelements), energy dispersive X-ray spectroscopy on a scanning raster electron microscope with an attachment for energy dispersive analysis (for studying the structure and size of ash and analyzing the content of macroelements), laser diffraction (for analyzing the volume distribution of ash particles size), Brunauer-Emmett-Teller (BET) (for determining the specific surface area and pore volume). It was established that after the electromagnetic treatment of coal ash, the surface of the samples acquires a more developed and porous structure and the particle sizes significantly decrease. This is especially observed for the average volumetric distribution of $D_v(50)$ (50% of particles of their total number), where the interval of change of particles is 129-7 micrometers. As a result of the electric discharge treatment of coal ash, additional mineral complex compounds are formed with the content of some rare metals Ga, Ge, Li. It was revealed that the electric discharge treatment of ash, like the electromagnetic treatment, leads to a decrease in the size of the particles of the original ash, but not so significantly (up to 1.3 times).

Key words: coal, ash, electromagnetic treatment, electric discharge treatment, chemical composition, physical and chemical characteristics.

Introduction. Ash and slag waste (ASW) of coal-fired thermal power plants can be considered as technogenic deposits of mineral substances suitable for cost-effective industrial use.

ASW are products of high-temperature (1200-1700°C) processing of the mineral part of the fuel [1]. The main ash-forming macronutrients in ASW (Si, Al, Fe, O, Ca, Ti, Mg, S, K, Na) make up 98-99%. Particularly all other elements (trace elements) are contained in the ash in a concentration of 0.1% or less. During the combustion of coal, part of the trace elements (Sr, Ba, Sc, Y, La, Ti, Zr, etc.) is concentrated in the slag. Other elements (Ga, In, Tl, Ge, Sn, Pb, etc.) at temperatures above 1000°C volatilize from the zone of high temperatures and settle in electrostatic precipitators and cyclones (at 110–120 °C) [1]. Moreover, the chemical properties of the ash and slag waste system vary greatly depending on the type of coal, combustion temperature, combustion technology, air / fuel ratio, and coal particle size [2].

All elements of ASW can be part of both the mineral part of the coal (i.e. form minerals) and in the form of compounds with the organic matter of the coal, forming the so-called organic-mineral components, which are the least studied forms. These include: salts of humic acids (K, Na, Ca, Mg, etc.), complex humates, characterized by a cyclic system of bonds, as well as organic compounds (i.e., C-E bond, where E is S, Si etc.) [3].

A significant accumulation of ash and slag waste due to coal combustion (in CHP, boiler houses) in ash dumps causes special attention to the study of the physical and chemical characteristics of coal ash.

For example, in [3-8], coal ash was studied using elemental, electron microscopic, X-ray phase analysis, and particle size analysis. These studies have shown that the ash contains mainly silicon dioxide, aluminum oxide and iron oxide and is a fine amorphous material consisting of particles with a size of 5-100 microns. Fly ash consists of glassy, hollow spherical particles, which are cenospheres (thin-walled hollow spheres). The mineralogical composition of ash is represented mainly by inorganic elements in the form of quartz, kaolinite group minerals, mullite, magnetite, siderite, hematite. The modulus of ash basicity is basically $MO < 1$, therefore, this ash is classified as acidic, which results in the absence of binding properties of these materials. Studies of the sorption properties of coal ash showed that the specific surface area of ash (measured by the BET method) can vary from 1.1 to 15.6 m^2/g , depending on the phase content and porosity [9-13]; while the total pore volume can vary from 0.004 to 0.022 cm^3/g [10,12].

The specific properties of ash and slag waste are used in the production of building materials (as additives in concrete, cement, bricks, etc.) [1,14,15], in the preparation of aluminosilicate and magnetic microspheres [1], silica [16] and alumina [17,18], in the extraction of rare metals [19-24].

The purpose of this work is to study the effect of electrophysical effects on the physicochemical characteristics of the ash of Maikuben coal. Experiments were performed in LLP "Institute of Coal Chemistry and Technology" (Astana).

As objects of research, ash was used in its original form, ash after processing on an electromagnetic device (hereinafter EM treatment) and ash after electric discharge treatment (hereinafter ED treatment) (except for samples for analyzing the size of coal ash particles, where the processing was carried out separately from friend to determine the impact of each influence). EM treatment of coal ash was carried out for its fine grinding, the ED treatment of ash to weaken and/or break chemical bonds in an aqueous solution of ash.

Research methodology. The preparation of ash samples was carried out in 3 stages. At the 1st stage, the ash was pre-crushed and an average sample (by chemical and particle size distribution) was prepared from the combined sample кварц by the quartering method. At the 2nd and 3rd stages, the EM processing and then the ED treatment were carried out, respectively.

EM processing of ash samples was carried out on an electromagnetic apparatus EMA-1 (figure 1), which consists of an inductor, a working chamber and a tripod. Electric parameters of EMA-1: rated current - 8 Amps; nominal electromagnetic field strength in the center of the inductor (at 220 V) – 40-45 kA/m; active power – 0.15-0.2 kW; the power and capacity of capacitors to compensate for $\cos\varphi$ is 400 microfarads.

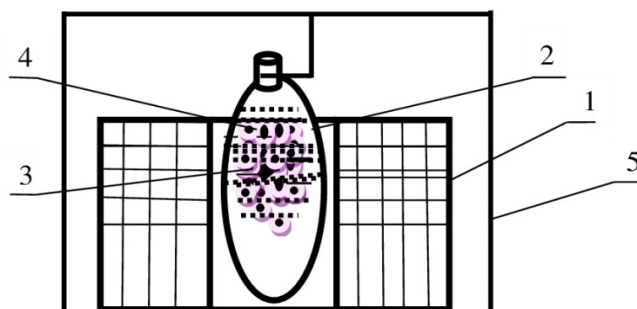


Figure 1 – Grinding of ash in EMA-1 in the periodic mode: 1 – inductor; 2 – working chamber; 3 – magnetic granules; 4 – crushed material; 5 – tripod

The treatment was carried out as follows:

– coal ash (100 grams) was mixed with magnetic granules (2-3 mm in diameter) (the ratio of the mass of the ground material to the mass of magnetic granules 1:10; magnetic granules occupied 70-80% by volume of the working chamber);

– a glass beaker was placed in the working chamber (about 1 l), in which an elastic material (rubber-fabric was preliminarily inserted inside) to prevent sticking of the crushed ash to the walls and the formation of cracks on the walls of the glass from the impact of magnetic granules);

- the resulting mixture of ash with magnetic granules was unloaded in the working chamber and closed (to prevent the ash from entering the atmosphere);
- the working chamber was installed inside the inductor (in the middle);
- electromagnetic processing in EMA-1 was performed 3 times for 8 minutes;

At the same time, during processing in the chamber thorough mixing and grinding of ash occurred due to the strong rotating and colliding actions of the magnetic granules, which is caused by the induction of the vortex electric field due to the action of the alternating electromagnetic field from the inductor.

Visually, it was found that the size of the ash particles after electromagnetic treatment decreased significantly compared with the particles of the original ash.

ED treatment of coal ash by high-voltage pulsed discharge was carried out in a laboratory electric discharge installation (figure 2), consisting of the following components: power regulator, capacitor bank, step-up transformer (from 220 V to 30 kV), reactor (200 ml capacity for coal water solution ash with 2 electrodes).

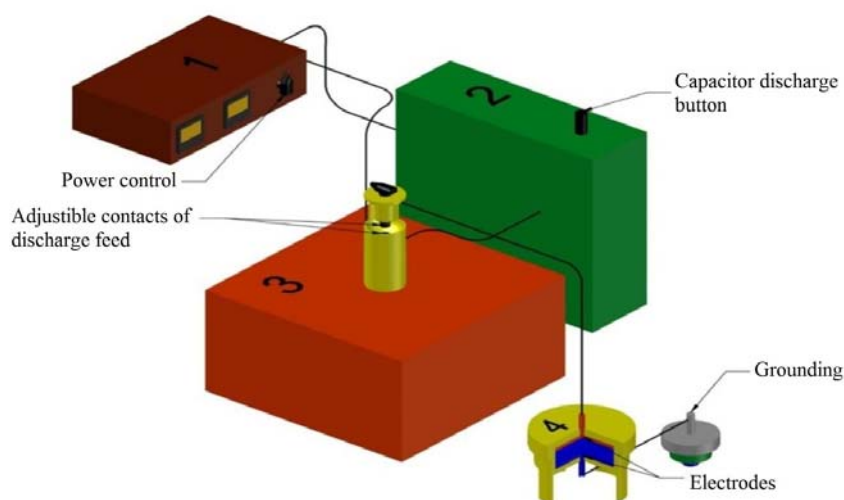


Figure 2 – Schematic diagram of the electric discharge installation

Experiments were performed as follows. The necessary technical parameters were pre-installed and adjusted (voltage 30 kV, the number of discharge into the reactor 5 times in 1 second, the distance between the upper electrode and the surface of the solution was 3-5 mm). The prepared ash weighing 40 g and 80 ml of water were thoroughly mixed and the resulting solution was poured into the reactor. The installation was turned on through a special remote control and arc-processed for 3 minutes. Next, the resulting solution was dried to a dry state (for the subsequent measurement of the electrophysical characteristics of coal ash).

Elemental analysis of the content of microelements in the Maikubensky coal was performed using multi-element instrumental neutron activation analysis on a multichannel amplitude pulse analyzer (KANBERRA) with a detector of pure germanium mark GX-3018 with a resolution of 1.8 keV using the Co60 line of 1333 keV and recording efficiency 30 %

The study of the elemental composition, structure and dimension of coal ash was carried out using energy dispersive X-ray spectroscopy on a scanning electron scanning microscope SEM (Quanta 3D 200i) with an attachment for energy dispersive analysis (EDAX). The samples were attached to a copper holder with conductive adhesive paper. Previously, a thin conducting layer of carbon was deposited on the surface of the samples in a special vacuum unit for better passage of charges. The energy of the exciting electron beam in the analysis was 15 keV, the working distance was 15 mm.

X-ray diffraction was used to identify the crystalline phases that make up the ash. X-ray phase analysis was performed on a Rigaku MiniFlex 600 diffractometer. The sampling mode: Fe, K β -radiation, voltage on the X-ray tube is $U = 40$ kV with a current $J = 15$ mA.

The adsorption characteristics of the ash (specific surface area, specific volume by limiting filling) were studied using the Brunauer – Emmett – Teller method (BET). The measurements were performed on a Sorbtometer M analyzer (CATACON company). Nitrogen was used as adsorbate gas, helium was used

as carrier gas. Before starting the measurement of the sample, a thermal training was performed, i.e. its degassing, which consists in heating the sample in a stationary gas flow at a given temperature in order to remove absorbed gases and vapors from the surface of the material under study.

To establish the degree of influence of electrophysical effects on the particle size of coal ash, an analysis of the volume distribution of particle sizes was carried out for various values of bulk density. At the same time, the processing of coal ash by an electric discharge and an electromagnetic method was carried out separately from each other, in order to exclude their mutual influence, and thus to conduct a comparative analysis of the effectiveness of each type of influence on the particle size. Analysis of ash particle sizes was performed by laser diffraction using a *Malvern Mastersizer 3000* instrument, designed to obtain information about the volume distribution of particle sizes in the range from 0.01 to 10 000 μm . Distilled water was used as a dispersant for all ash samples in the Hydro-MV mode.

Results and its discussion. The results of the elemental analysis show the presence of 31 microelements in ash samples of Maikuben coal (table 1).

According to the technical classification [23], the following groups of rare metals are present in coal samples: light – Cs, Li, Rb, Sr, Ba; refractory – Ta, Hf; rare earth metals – Sc, La, Nd, Eu, Tb, Yb, Lu, Sm, Ce; scattered – Ga, Ge, Cd; radioactive – U, Th.

As can be seen from the listed metals, predominantly rare earth metals are present in the coal.

Table 1 – Results of multi-element instrumental neutron activation analysis of the studied Maikuben coal

Sample number	Element	Content, g/t
1	Samarium (Sm)	10.5
2	Uran (U)	2.0
3	Ytterbium (Yb)	5.82
4	Bromine (Br)	<1
5	Lantan (La)	51.0
6	Cerium (Ce)	90.5
7	Terbiy (Tb)	2.47
8	Chromium (Cr)	82.5
9	Barium (Ba)	2341
10	Strontium (Sr)	1622
11	Silver (Ag)	<0.5
12	Rubidium (Rb)	45.4
13	Cobalt (Co)	33.6
14	Neodymium (Nd)	61.5
15	Gallium (Ga)	21.85
16	Zinc (Zn)	136.6
17	Thorium (Th)	8.5
18	Hafnium (Hf)	8.20
19	Tantalum (Ta)	0.1
20	Germanium (Ge)	16.48
21	Calcium (Ca)	3.54
22	Lutetium (Lu)	0.81
23	Gold (Au)	0.0089
24	Arsenic (As)	14.3
25	Sodium (Na)	0.08
26	Scandium (Sc)	31.1
27	Iron (Fe)	7.24
28	Europium (Eu)	3.30
29	Lithium (Li)	12.92
30	Cesium (Cs)	3.22
31	Cadmium (Cd)	5.72
Note: content of Fe, Ca, Na in %.		

Analysis of the obtained results shows the presence in the greatest amount (from 0.08 to 3.54%) of metals such as calcium, barium, strontium, sodium (in decreasing order of concentration), attracting a certain interest for industry. Their concentrations (in wt.%) Are: Sr (0.1622), Ba (0.2341), Na (0.08), Ca (3.54). The remaining elements are present in very small quantities (from 0.01% or less), especially silver, tantalum, gold, bromine, lutetium (to 0.0001%).

The results of elemental energy dispersive analysis (EDAX) on the content of macronutrients in the ashes of (initial) coals are shown in table 2.

Table 2 – The chemical composition of the mineral part of Maikuben coal

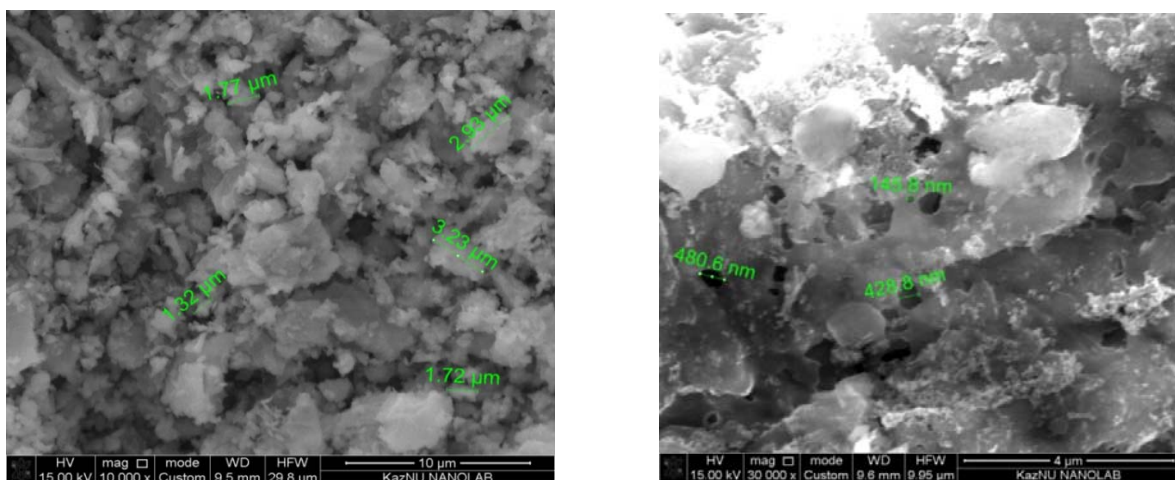
Indicators	Content, wt. %
SiO ₂ , %	50.16
Al ₂ O ₃ , %	26.63
Fe ₂ O ₃ , %	8.27
CaO, %	5.84
MgO, %	2.79
TiO ₂ , %	1.05
SO ₃ , %	0.93
P ₂ O ₅ , %	0.87
K ₂ O +Na ₂ O, %	1.16

The obtained data show that the main macroelements of coal ash are acidic and amphoteric oxides of silicon, aluminum and iron, the total concentration of which is 85 %, which is comparable with similar data obtained in [7] (90 %).

To characterize the ash activity of the studied coal and their stability during decomposition, the basicity modulus (M_0) was calculated using the known formula [25] as the ratio of the sum of the contents of basic alkaline earth metal oxides to the sum of silicon and aluminum oxides (in %): $M_0 = (CaO + MgO)/(SiO_2 + Al_2O_3)$.

The calculation results showed that the modulus of basicity is 0.112 which makes it possible to assign these samples to the class of acid ashes ($M_0 < 1$), which causes their absence properties [4].

Electron microscopic images of coal ash samples, presented in figure 3, demonstrate the morphological features of the samples, whence it is seen that the ash surface is heterogeneous and represents an amorphous and dense structure and is characterized in some places by flaky inclusions. Most ash particles have an irregular shape (flat, acute-angled). The surface relief of the particles has a high degree of roughness and pores of various geometric shapes with sizes up to about 500 nm (figure 3, b), which corresponds to macropores with sizes > 50 nm (according to the classification of pores adopted by the International Union of Theoretical and Applied Chemistry (IUPAC)).



a) $\times 10\ 000$

b) $\times 30\ 000$

Figure 3 – Electron microscopic images of the ashes of Maikuben coal: a) initial ash; b) ash after EM treatment

The results of the analysis of micrographs show that after the EM treatment, the ash acquires a more developed surface and porous structure.

The obtained data on X-ray phase analysis (table 3) show that the presence of two crystalline phases of the main ash-forming elements, α -quartz and mullite ($3\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$), is common to all the ash samples studied. This coincides with the literature data obtained in the study of the phase composition of coal ash from other deposits, where these minerals are also the main crystalline phases [4-6]. As a result of the ED treatment of the ashes, kaolinite and anhydrite are removed and mineral phases with the content of rare metals Ge, Li, Ga are additionally formed (table 3). This effect of the electric discharge is apparently due to the fact that when the pulsed high-voltage voltage is applied to the ashes, a simultaneous influence and a complex mechanism of all the effective factors of the electrohydraulic effect occur, which lead to the breaking of sorption and peripheral chemical bonds and the formation of new compounds.

Table 3 – Mineral composition of Maikuben coal

Phase name	Chemical composition		
	initial ash	ash after EM treatment	ash after ED treatment
α -Quartz	SiO_2	SiO_2	SiO_2
Mullite	$3\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$	$3\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$	$3\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$
Kaolinite	$\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$	$\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$	–
Hematite	Fe_2O_3	Fe_2O_3	–
Anhydrite	$\text{Ca}(\text{SO}_4)$	$\text{Ca}(\text{SO}_4)$	–
Aluminum Germanium Oxide Hydroxide	–	–	$\text{Al}_2\text{GeO}_4(\text{OH})_2$
Octalithium hexakis(gallosilicate)dibromide	–	–	$\text{Li}_8(\text{GaSiO}_4)_6\text{Br}_2$

Bulk density, pH of the aqueous extract, adsorption activities on iodine and methyl orange for samples of coal ash (in its original form, after the EM and ED treatments) were determined in accordance with [26,27]. The results of the analysis are shown in table 4.

Table 4 – Physical and chemical characteristics of the ashes of the Maikuben coal

Name of the indicator	Ash in its original form	Ash after EM treatment	Ash after ED treatment
Bulk density, g/cm^3	0.75	0.810	0.90
Methyl orange adsorption activity, %	65.00	70.10	69.50
pH of the aqueous extract	9.20	8.86	4.27

Highest values of bulk density and methyl orange adsorption activity has ash after EM and ED treatments, confirming the data obtained by microscopic analysis of samples (figure 3), where electromagnetic treatment leads to a more developed surface and porous structure.

Table 5 presents the results of measurements of specific surface area and specific pore volume (by limiting filling) of the studied coal ash samples.

Table 5 – Adsorption characteristics of coal ash

Name	Specific surface area, m^2/g	Specific pore volume, cm^3/g
Ash in its original form	23.876	0.036
Ash after EM treatment	37.914	0.055
Ash after ED treatment	38.639	0.057

The data obtained show that the coal ash is a porous material. EM treatment of ash samples contributes to a noticeable increase in the specific surface area (≈ 1.6 times) and the specific volume of pores (≈ 1.5 times). At the same time, the ED treatment of ash (after EM treatment) almost does not lead to a noticeable change in the values of the specific volume of pores and specific surface. The results of the analysis of adsorption characteristics of initial ash samples are approximately consistent with similar parameters obtained in [3,7].

The results of the analysis of the volumetric distribution of particle sizes for different values of bulk density $D_v(10)$, $D_v(50)$, $D_v(90)$ (10%, 50%, 90% of particles from the total amount respectively) are presented in table 6.

Table 6 – The results of the analysis of the particle size of Maikuben coal ash

Name of the indicator	Uniformity	Dv(10), μm	Dv(50), μm	Dv(90), μm
Ash in its original form	1.484	7.91	129	612
Ash after EM treatment	4.771	1.41	7.08	75.3
Ash after ED treatment	1.903	7.07	101	603

As can be seen from the results of the analysis, when exposed to coal ash by electric discharge, there is a slight decrease in particle size (1.1-1.3 times) ash for for all volumetric distributions. At the same time, the EM treatment of coal ash leads to a more significant decrease in the particle size of the ash as compared to the electric discharge treatment, especially for the average distribution of D_v (50), where the particle size decreases by 18.2 times (129-7.08 μm). The consequence of the effective influence of the EM treatment of coal ash on particle size reduction is an increase in the specific surface and specific pore volume. This fact is confirmed by the obtained data on the adsorption characteristics of the ash (table 5).

Conclusion. Thus, the study of the effects of electrophysical effects on Maikuben coal ash showed that EM treatment effectively mainly affects the particle size and adsorption properties of coal ash, while ED treatment mainly affects the mineralogical composition of coal ash. The use of electrophysical treatment of coal ash is of particular scientific and practical interest, since it allows for the qualitative preparation of this material for its further thermochemical processing in order to leach valuable components such as rare metals, silica, alumina.

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МАЙКУБЕН КЕН ОРНЫНЫҢ КӨМІР КҮЛІНІҢ ФИЗИКАЛЫҚ-ХИМИЯЛЫҚ ҚАСИЕТТЕРІНЕ ЭЛЕКТРФИЗИКАЛЫҚ ӘСЕРДІҢ САЛДАРЫ

Аннотация. Жұмыста Шоптыкөл кен орнындағы (Майкүбен бассейні, Қазақстан) көмір күлін электрофизикалық өңдеу барысында оның физика-химиялық қасиеттеріне тигізетін әсері зерттелген. Көмір күлі алдын ала электромагниттік аппаратта (күл бөлшектерін ұсақтау үшін) өңделді, одан соң магнит түйіршіктерімен араластырып (диаметрі 2-3 мм) жұмыс камерасына жіберілді (индуктор ішіне орнатылды), ал ұнтақтау процесі 8 минуттан 3 рет жүргізілді. Содан кейін сумен араласқан (1/2 массалық қатынаста) күлді кернеуі 30 кВ-қа дейін жоғары вольтты электр разрядты қондырғыда күл бөлшектеріндегі химиялық байланыстардың әлсіреуі және/ немесе бұзу мақсатында 3 минут өндейді. Электрофизикалық өңдеуге дейін және өңдеуден кейін көмір күлінің физика-химиялық сипаттамаларын көп элементті аспаптық нейтронды-активтендіруді талдау әдісімен көп каналды амплитудалық импульсті («Канберга»компаниясы) анализаторда (микроэлементтік құрамын элементтік талдау үшін), SEM электронды микроскопындағы энергодисперстік рентген-спектроскопиялық әдіспен SEM (Quanta 3D 200i) сканерлеуші растрлы электронды микроскопта (күлдің құрылымы мен күл бөлшектерінің өлшемін зерттеу және макроэлементтік құрамына талдау жасау үшін), RigakuMiniFlex 600 дифрактометрмен рентгендік дифракция әдісімен (минералды құрамды талдау үшін), лазерлі дифракция әдісімен MalvernMastersizer 3000 құрылғысында (күл бөлшектерінің өлшемі бойынша көлемдік таралуын талдау үшін), SorbtometerM анализаторында («Катакон»компаниясы) Брунауэр-Эмметт-Теллер (БЕТ) (нақты беттік ауданды және кеуектердің нақты көлемін анықтау үшін) зерттелді. Зерттелген көмірдің микроэлементін талдау нәтижелері кальций, барий, стронций, натрий сияқты металдардың көп мөлшерде (0,08-ден 3,54%-ға дейін), ал қалған элементтер өте аз мөлшерде (0,01% немесе одан аз) бар екендігін көрсетті, әсіресе күміс, тантал, алтын, бром, лютеций өте аз мөлшерде болады. Көмір күлінің макроэлементтік құрамын талдау нәтижелері көрсеткендей, негізгі макроэлементтер кремнийдің, алюминий мен темірдің қышқылдық және амфотерлі оксидтері болып табылады, олардың жалпы концентрациясы 85 %-ды құрайды. Зерттеліп отырған күл үшін есептелген негіздік модуль (M₀) 0,112 болды, бұл оны қышқыл күлге (M₀ < 1) жатқызуға мүмкіндік береді, бұл тұтқыр қасиеттердің болмауына себепкер болады. Күлдің электронды микроскопиялық талдауы бөлшектердің беттік рельефінің кедір-бұдырлығының жоғары екендігін және өлшемі 500 нм-ге дейін, бұл өлшемдері > 50 нм макрокеуектерге сәйкес келетін әртүрлі геометриялық формалардың бар екендігін көрсетті. Сонымен қатар, электромагниттік өңдеуден кейін күл

дамыған беткі және кеуекті құрылымға ие болады. Рентгендік дифракцияның нәтижелері күлдің негізгі элементтерінің екі кристалды фазасының, α -кварц пен муллиттің ($3\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$) болуы барлық зерттелген күл сынамаларына ортақ екенін көрсетті. Электрлік разрядты өңдеу нәтижесінде күлден каолинит және ангидрит жойылып, құрамында сирек кездесетін металдар Ga, Ge, Li бар минералды фазалары қосымша құрылатындығы анықталды. Бұл сорбциялық және перифериялық химиялық байланыстардың бұзылып, жаңа байланыстардың пайда болуына алып келетін электрогидравликалық эффекттің барлық әсер етуші факторларының бір уақытта әсер етуі мен күрделі механизмнің әсерінен пайда болады. Көмір күлінің метилоранж үлгілері бойынша сусымалы тығыздықты және адсорбциялық белсенділікті талдау нәтижелері электромагниттік және электр разрядты өңдеуден кейінгі параметрлердің мәні бастапқы күлмен салыстырғанда едәуір үлкен екенін көрсетті, бұл электромагниттік өңдеу неғұрлым дамыған бетке және кеуекті құрылымға алып келетіндігін көрсететін электронды микроскопия арқылы алынған мәліметтермен сәйкес келеді. Көмір күлінің зерттелген үлгілерінің меншікті бетінің ауданын және кеуектің меншікті көлемін (максималды толтыру бойынша) зерттеу нәтижелері көмір күлінің кеуекті материал екенін көрсетті. Күлдің сынамаларын электромагниттік өңдеу меншікті беттік ауданының (1,6 есе) және кеуектердің меншікті көлемінің (1,5 есе) артуына ықпал ететіндігін көрсетті. Сонымен бірге күлді одан әрі электрлі разрядты өңдеу (электромагниттік өңдеуден кейін) іс жүзінде кеуек көлемі мен меншікті бетінің мәндерінің айтарлықтай өзгеруіне әкелмейді. Бөлшектердің көлемдік тығыздықтың $D_v(10)$, $D_v(50)$, $D_v(90)$ әртүрлі мәндеріндегі (бөлшектердің жалпы мөлшерінен тиісінше 10%, 50%, 90%) өлшемдері бойынша көлемдік таралуының анализі көрсеткендей электр разрядымен өңдеуден кейін барлық көлемді таралулар үшін күлдің бөлшектерінің өлшемі жай азаятындығын көрсетті (1,1-1,3 есе). Сонымен қатар, көмір күлін электромагниттік өңдеу электр разрядты өңдеумен салыстырғанда тазартумен салыстырғанда күлдің бөлшектерінің өлшемінің едәуір азаюына әкеледі, әсіресе $D_v(50)$ орташа таралуы кезінде тиімді, онда бөлшектердің мөлшері 18,2 есе азаяды (129-дан 7 мкм-ге дейін). Осылайша, электрофизикалық әсер етудің көмір күліне әсерін зерттеу электромагниттік өңдеу күл бөлшектері мен адсорбциялық қасиеттеріне ұнтақтаудың әсері бар екендігін көрсетті. Сонымен қатар электр разрядының әсері негізінен шикізаттың минералогиялық құрамына әсер етеді. Көмір күлін электрофизикалық өңдеуді қолдану ғылыми және практикалық қызығушылық тудырады, өйткені бұл құнды өнімдерді (кремний, глинозем, сирек кездесетін металдар және т.б.) толықтай алу үшін және/немесе технологиялық режимдерді «жұмсарту» мақсатында күлді одан әрі өңдеуге сапалы дайындауға мүмкіндік береді.

Түйін сөздер: көмір, күл, электромагниттік өңдеу, электр зарядты өңдеу, химиялық құрамы, физикалық-химиялық сипаттамалары.

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ВЛИЯНИЕ ЭЛЕКТРОФИЗИЧЕСКОГО ВОЗДЕЙСТВИЯ НА ФИЗИКО-ХИМИЧЕСКИЕ ХАРАКТЕРИСТИКИ ЗОЛЫ УГЛЯ МАЙКУБЕНСКОГО МЕСТОРОЖДЕНИЯ

Аннотация. В работе исследовано влияние электрофизической обработки золы угля месторождения «Шоптыколь» (Майкубенский бассейн, Казахстан) на ее физико-химические характеристики. Предварительно угольную золу обрабатывали на электромагнитном аппарате (для тонкого измельчения частиц золы), в котором золу предварительно перемешивали с магнитными гранулами (диаметром 2-3 мм) и выгружали в рабочую камеру (установленную внутри индуктора), и процесс измельчения проводили 3 раза по 8 минут. Затем золу, смешанную с водой (в массовом соотношении 1/2 соответственно), подвергали воздействию на высоковольтной электроразрядной установке с напряжением до 30 кВ в течение 3 минут для ослабления и/или разрыва химических связей в частицах золы. Физико-химические характеристики золы угля до и после электрофизической обработки исследовали методами многоэлементного инструментального нейтронно-активационного анализа на многоканальном амплитудном анализаторе импульсов (компания «Канбегга») (для элементного анализа на содержание микроэлементов), энергодисперсионной рентгеновской спектроскопии на сканирующем растровом электронном микроскопе SEM (Quanta 3D 200i) с приставкой для энергодисперсионного анализа (для изучения структуры и размерности золы и анализа на содержание макроэлементов), рентгеновской дифракции на дифрактометре Rigaku MiniFlex 600 (для анализа на минеральный состав), лазерной дифракции на приборе Malvern Mastersizer 3000 (для анализа объемного распределения частиц золы по размерам), Брунауэра-Эммета-Теллера (БЭТ) на анализаторе Sorbtometer M (компания «Катакон») (для определения удельной поверхности и удельного объема пор). Результаты микроэлементного анализа исследуемого угля показали наличие в наибольшем количестве (от 0,08 до 3,54 %) таких металлов, как кальций, барий, стронций, натрий, а остальные элементы присутствуют в очень малых количествах (от 0,01 % и менее), особенно серебро, тантал, золото, бром, лютеций. Результаты анализа на содержание макроэлементов в

золе угля показали, что основными макроэлементами являются кислые и амфотерные оксиды кремния, алюминия и железа, общая концентрация которых составляет 85 %. Рассчитанный модуль основности (M_0) для исследуемой зола составил 0,112, что позволяет ее отнести к классу кислых зол ($M_0 < 1$), что обуславливает отсутствие вяжущих свойств. Электронно-микроскопический анализ зола показал, что рельеф поверхности частиц имеет высокую степень шероховатости и поры различной геометрической формы размером примерно до 500 нм, что соответствует макропорам с размерами >50 нм. Кроме того, после электромагнитной обработки зола приобретает более развитую поверхностную и пористую структуру. Результаты рентгеновской дифракции показали, что общим для всех исследуемых образцов зола является наличие двух кристаллических фаз основных золообразующих элементов – α -кварц и муллит ($3Al_2O_3 \cdot 2SiO_2$). Установлено, что в результате электроразрядной обработки зола удаляются каолинит и ангидрит и дополнительно образуются минеральные фазы с содержанием редких металлов Ga, Ge, Li, что, по-видимому, обусловлено одновременным влиянием и сложным механизмом всех действующих факторов электрогидравлического эффекта, приводящих к разрыву сорбционных и периферических химических связей и к образованию новых соединений. Результаты анализа насыпной плотности и адсорбционной активности по метилоранжу образцов зола угля показали, что значения данных параметров после электромагнитной и электроразрядной обработок заметно больше по сравнению с исходной золой, что совпадает с данными, полученными методом электронной микроскопии, где электромагнитная обработка приводит к более развитой поверхностной и пористой структуре. Результаты измерений удельной площади поверхности и удельного объема пор (по предельному заполнению) исследуемых образцов зола угля показали, что зола угля представляет собой пористый материал. Электромагнитная обработка образцов зола способствует заметному увеличению удельной поверхности (в 1,6 раз) и удельного объема пор (в 1,5 раза). Вместе с тем, дальнейшая электроразрядная обработка зола (после электромагнитной обработки) почти не приводит к заметному изменению значений удельного объема пор и удельной поверхности. Анализ объемного распределения частиц по размерам при различных значениях объемной плотности $D_V(10)$, $D_V(50)$, $D_V(90)$ (соответственно 10%, 50%, 90% частиц от их общего количества) показал, что после обработки электрическим разрядом происходит незначительное уменьшение размеров частиц (в 1,1-1,3 раза) зола для всех объемных распределений. Вместе с тем, электромагнитная обработка зола угля приводит к более существенному уменьшению размеров частиц зола по сравнению с электроразрядной обработкой, особенно для среднего распределения $D_V(50)$, где размер частиц уменьшается в 18,2 раза (от 129 до 7 мкм). Таким образом, исследование влияния электрофизического воздействия на зола угля показало, что на измельчение частиц зола и адсорбционные свойства эффективнее оказывает электромагнитная обработка. Вместе с тем, электроразрядное воздействие преимущественно оказывает воздействие на минералогический состав сырья. Использование электрофизической обработки зола угля представляет определенный научный и практический интерес, так как позволяет осуществить качественную подготовку зола для ее дальнейшей переработки с целью более полного извлечения ценных продуктов (кремнезема, глинозема, редкоземельных металлов и др.) и/или «смягчения» технологических режимов проведения данного процесса.

Ключевые слова: уголь, зола, электромагнитная обработка, электроразрядная обработка, химический состав, физико-химические характеристики.

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TESTING OF THE PROTOTYPE OF MINI-HYDRO POWER PLANTS OF HYDROCYCLONE TYPE IN PRODUCTION CONDITIONS

Abstract. The aim of the project is to develop and test a new technical solution to improve the technological scheme of mini hydroelectric power plants using the hydrocyclone effect of water treatment.

Method of research. Computer simulation of the process was carried out by SolidWorks (flow simulation). Additional software "Autodesk Simulation CFD" was used to verify the calculations. Initial industrial experiments were carried out with the water flow in the hydrocyclone through the pipe with diameter of 100mm., and then the pipe was disconnected and supplied with water through a quadrangular inlet size 240 x 167 mm. The Third variant of the experiments was conducted in the combined form, i.e. in the presence of a quadrangular pipe and the inlet pipe.

Research result. It is established that the manufactured sample is quite workable in production conditions. The range of tested and confirmed parameters is within the following limits: head $H= 1.5-2.5$ m, water flow- $Q = 45-120$ L/c. at the same time, power generation is provided within $N = 0.5-2.0$ kW. The obtained parameters on a specific test object require approbation in a wider range and testing them in order to establish a rational mode of operation of the mini HPP of the proposed design.

Key words: mini hydroelectric power station, hydro turbine, generator, computer simulation, experimental sample, production test.

Introduction. To calculate the expected energy parameters and computer modeling of the process in the manufactured experimental sample, according to the prepared technical documentation, their tasks and methods were adopted based on the size of the installation, possible technological parameters of the test and taking into account the experience of development and operation of small and mini HPPs [1-17].

At the same time, the entry of water with mechanical impurities into the hydrocyclone body (figure 1) was carried out in two versions: through a pipe with a diameter of 124mm (mm) and through a quadrangular hole with a size of 240mm x 167mm. In the cone part, sediment removal through a sand hole with a diameter varying within 50-200mm (mm) by means of a valve was provided. The cleaned part of the flow is carried out through the drain pipe (diameter 200mm (mm), located at the end of the hydrocyclone. The total length of the hydrocyclone body to the gate of the sand hole is 1480mm. The diameter of the cylindrical part is 700mm [5].

In the calculations, two options were considered for the operation of the hydraulic turbine at pressures $H=1$, $H=1.5$ m, which can be provided at the selected site (range) of the branched part of the Turgen river.

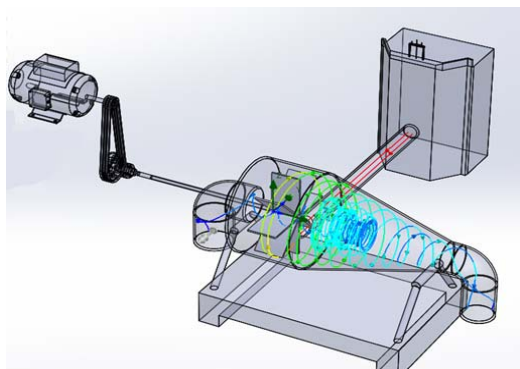


Figure 1 –
General design scheme of mini hydroelectric power station of hydrocyclone type

Computer computational modeling [18,19] implemented by SolidWorks (flow simulation). Additional software "Autodesk Simulation CFD" was used to verify the calculations. When comparing these programs, errors were made in the range of 10-12%.

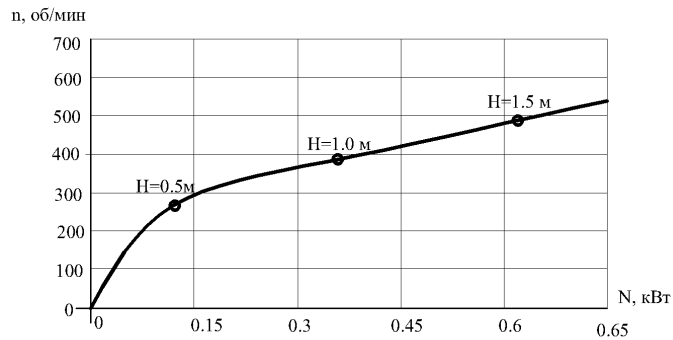
Result of calculation. In computer simulation according to the first variant, i.e. at a head $H=1.0$ m, the speed of the generator rotor was within $n=395$ rpm. And in the next variant, i.e. at $H=1.5$ m, the speed was equal to $n=490$ rpm.

Calculations show that when the heads are opened, the torque generated by the water flow on the blades is $M1=8.2$ N*m and $M2=12$ N*m.

Then, the generator power according to the variant - 1

$M1=0,339$ kW = 339w, and according to the variant -2 $M2 = 0.616$ kW = 616w. Figure 2 shows a graph of the power dependence on the rotation of the hydraulic unit $N=f(n)$

Figure 2 – Graph of power dependence on hydraulic unit speed $N=f(n)$



There is some increase in unit power with increasing shaft speed of the turbine corresponding to the pressure of the incoming water.

Verification of the obtained data of the calculation program was carried out in an analytical way using well-known formulas.

Then, the power of the hydraulic unit

$$N=Q*g*H*h, \text{ вт} \tag{1}$$

where Q – water consumption at the inlet of the unit, m^3/s .

$$Q=V*F=3,13*0,012=0,037 \text{ m}^3/\text{s}; \tag{2}$$

where V – water speed, m / s

$$V=\sqrt{2*g*H}=\sqrt{2*9.81*0.5}=3.13 \text{ m/s} \tag{3}$$

F – area cross-section of the inlet, m^2 .

When the diameter of the inlet pipe $D=0.124$ m then $F=0.012\text{m}^2$

g – acceleration of free fall, 9.81 m/s.

$h=0.65$ -efficiency for two multiples (Crossfair) and simple active hydroturbines'.

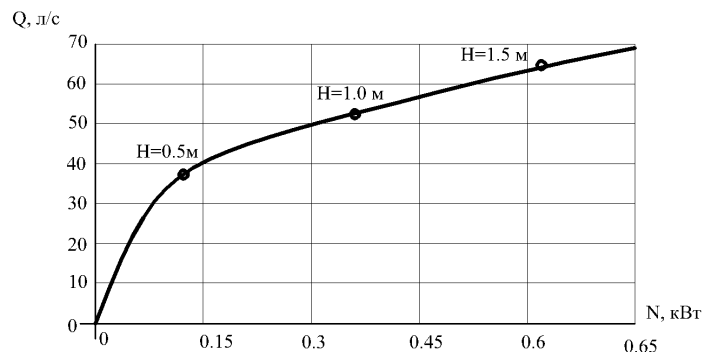
Then, under the first option

$$N=0,037*9,81*0,5*0.65=0.118 \text{ kW}=118 \text{ W} \tag{4}$$

Computational modeling and verification calculation showed minor errors of the results (121 W and 118 W). In other cases, the test calculations almost coincided with the original data.

Figure 3 shows a graph of the dependence of the flow rate on the power, which changes similarly to the previous case.

Figure 3 – A graph of flow rate from power



To check the maximum possible capacity of the unit under consideration, the inlet section of the pipeline was increased to 240 x 167 mm, and the cross-section area $F=0.04 \text{ m}^2$. Water pressure $H=1.5 \text{ m}$.

Then, the speed and flow rate at the inlet of the pipeline

$$V = \sqrt{2 * g * H} = \sqrt{2 * 9.81 * 1.5} = 5.42 \text{ m / s} \quad (5)$$

$$Q = 5.42 * 0.04 = 0.217 \text{ m}^3 / \text{s}$$

The generated power

$$N = 0,217 * 9,81 * 1,5 * 0,65 = 2,076 \text{ kW} = 2076 \text{ W};$$

If we take into account that for household and economic needs of a separate residential building, the required power on average is within 1200 W-1500 W, then we can consider the obtained power value to be quite sufficient for normal provision. If necessary, you can increase the power by increasing the initial pressure of the incoming water. For example, at a head of 3 m, the power of the hydraulic unit will increase to 5.87 kW.

For general clarity of the process under consideration, below are the isometries of velocities and pressure in a hydrocyclone with a hydraulic turbine at different pressures.

1) at the pressure (head) of the inlet flow $H = 1.0 \text{ m}$.

In this case, there is a slight increase in the water velocity at the inlet to $VVC = 4.5-5.5 \text{ m / s}$, and the pressure $r_{vx} = 8000-8500 \text{ PA}$ (figure 4).

2) at the pressure (head) of the inlet flow $H = 1.5 \text{ m}$.

As can be seen from the following figure, the required (working) speed and pressure to ensure normal operation of the hydraulic turbine and removal of impurities through the sand hole is achieved at $H = 1.5 \text{ m}$.

In this case, the speed is equal to $VVC = 5.5 - 6.5 \text{ m/s}$, and the inlet pressure rises to $r_{vx} = 10000-11000 \text{ PA}$.

Methods and results of production tests. The prototype of the hydrocyclone hull for processing the technological process was designed by the executors of project No. 7 and manufactured by the forces of IP "Originative" (Esik) [3-5].

The purpose of the test was to check the performance of the manufactured new sample of mini HPP in real conditions and to establish the expected technological parameters.

The tests were carried out on a branched section (fast current) of the Turgen river with a corresponding pressure-flow characteristic.

According to the results of R&D for 2019, the test considered the issues of establishing changes in the pressure-flow characteristics and the effect of these changes on the generated power is mainly when working on water without taking into account the degree of its purification in the hydrocyclone [1,2].

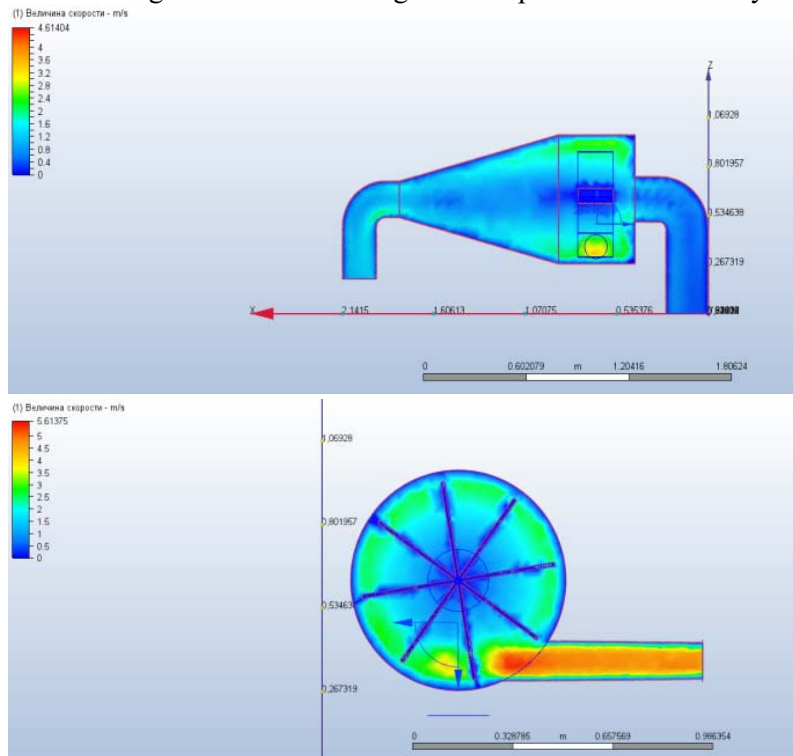


Figure 4 – Isometry of velocities in a hydrocyclone at $H= 1.0 \text{ m}$

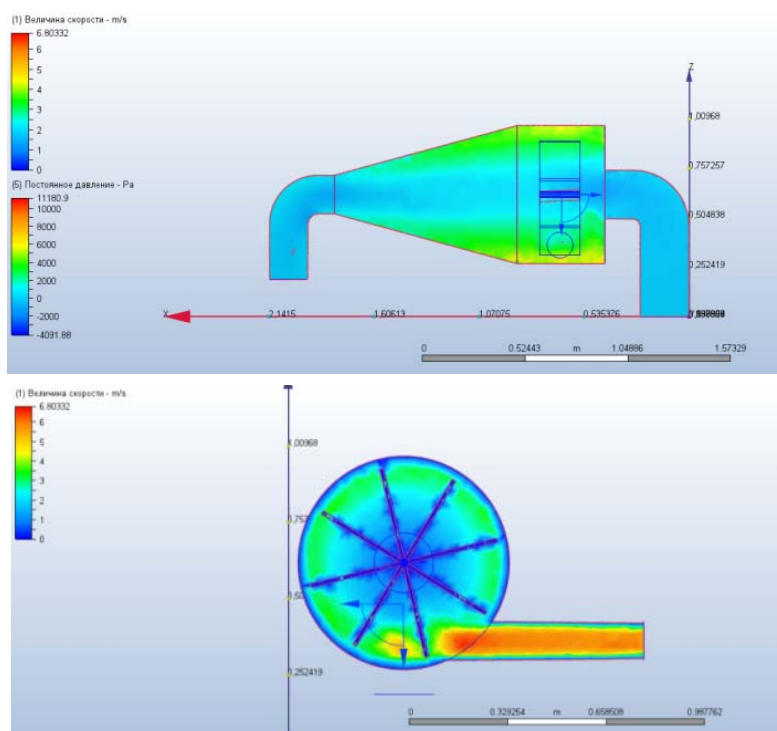


Figure 5 – Isometry of velocities (a) and pressure (b) in hydrocyclone at $H= 1.5$ m

The mode of operation on the alluvial mode, i.e. at different concentrations of sand in the water used, will be considered in 2020.

In order to study the changes in the main technological parameters of the mini hydroelectric power station (head, speed and flow rate, shaft speed, power) under different operating conditions of the installation, a water supply regulator in the form of a gate installed at the outlet of the camera was used. And the pressure of the supplied and used water in the three discharge holes (inlet, drain and sand hole) were determined by pressure gauges (accuracy class-2.5).

On the basis of the manometer reading, the speed was calculated by the formula, and then the flow rate of the supplied water-KV, m^3/s . The frequency of rotation of the shafts of the hydraulic turbine and generator was measured using a tachometer.

With the use of these experimental data, the power generated by the generator of the mini HPP was established.

If necessary, the water flow through the drain pipe Q_{SL} and the sand hole Q_{pes} were measured by volume method using a metal container with a volume of 20L, to establish the reliability of the measurement reading, they were compared with preliminary calculated data.

The first experiments were carried out when water was supplied to the hydrocyclone through a pipe with a diameter of 100 mm., and then the pipe was disconnected and water was supplied through a quadrangular inlet pipe with a size of 240 x 167 mm. The third version of the experiments was carried out with a combined version, i.e. in the presence of a pipe and a quadrangular inlet pipe.

In case of impossibility of direct measurement of the flow-pressure characteristic the pre-prepared curves of calibration of these indicators were used.

In General, the results of the test show that the developed design is quite workable and it allows to achieve the realization of the goal.

Confirming this conclusion, the operating mode of mini hydroelectric power station (figure 6) is achieved by using the combined version of the experiments, when the water supply to the hydrocyclone housing ($DC = 700mm$) is carried out through the pipe and partially through the inlet pipe (figure 6). In this case, the flow rate of the supplied water through the pipe from the camera was regulated by a paddle gate.

Based on this, the following is only the data obtained in the combined version, i.e. in the presence of a pipe and a quadrangular inlet pipe (table 2).

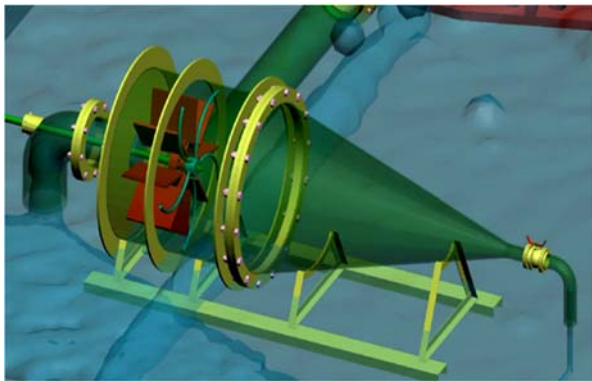


Figure 6 – Types of mini HPP when water is supplied to the hydrocyclone housing through the pipe and partially through the inlet pipe

Table 2 – Technological parameters of the prototype mini hydroelectric power station of hydrocyclone type obtained during the production test

Total area inlet, F, m ²	Pressure water on input, H _B , m	Speed water on input, V _B , m	Expenditure water on input, Q, m ³ /s	Frequency rotations, n, turn/min	Torsional moment, M, H*m	Power hydraulic unit, N _a , kW _r
0,05	1,5	0,90	0,045	80	59,6	0,500
0,05	1,6	1,24	0,062	100	66,8	0,700
0,05	1,7	1,68	0,084	120	79,5	1,000
0,05	1,8	1,90	0,095	150	76,4	1,200
0,05	2,0	2,14	0,107	200	71,6	1,500
0,05	2,5	2,30	0,114	300	63,7	2,000

As can be seen from the table, with an increase in the water pressure at the inlet-HB increases the flow rate of the supplied water-QB. The maximum flow rate of the hydrocyclone is provided at a head of HB = 2.5 m. In this case, the shutter of the camera is open to the full cross-section.

It should be noted that the change in torque is not proportional to the straight line, but to the parabola, although in modeling its dependence on the speed was inversely proportional.

The achieved capacity of the hydraulic unit within the range of N = 0.5-2.0 kW is quite sufficient parameter for the selected test object, which is characterized by a low head of water flow due to the small difference in the river bed. This means that the considered mini hydroelectric power plant has additional opportunities to increase the power characteristics when using it in areas with a significant slope.

On the basis of the results of the tests and analysis of the data obtained, an act and a test report were drawn up, which indicated the proposals and conclusions of the Commission. In them, in particular, it is noted that the presence of a pulley of a significant diameter (d=0.4 m) contributes to steady rotation and its frequency increases to a certain extent due to the inertia force up to 300 rpm or more.

The act specifies the efficiency of directed water supply to the surface of the blades of the hydraulic turbine with the help of a pipe (nozzles) than the use for this purpose of 4 coal nozzles located relative to the outer surface of the hydrocyclone.

It was noted that in the future it is necessary to make the following improvements of a constructive nature:

- the conical part of the hydrocyclone body should be performed in a shortened form and provide for the removal of trapped solids from the side with a significant diameter (about 200-250mm).

This is due to the fact that the delay of the swirling liquid in the hydrocyclone creates resistance in the body and thereby slows down the rotation of the hydro turbine.

Conclusion. 1. The manufactured sample is quite workable and can be used in production conditions. The range of tested and confirmed parameters is within the following limits: head $H = 1.5-2.5$ m, water flow- $Q = 45-120$ L/c. At the same time, power generation is provided within $N = 0.5-2.0$ kW.

2. The achieved capacity of the hydraulic unit within the range of $N = 0.5-2.0$ kW is quite sufficient parameter for the selected test object, which is characterized by a low head of water flow due to the small difference in the river bed. This means that the mini HPP under consideration has an additional technological opportunity to increase the power characteristics when used in areas with a significant slope.

3. The obtained parameters on a specific test object require approbation in a wider range and testing them in order to establish a rational mode of operation of the mini HPP of the proposed design and protection of the hydraulic unit from abrasive wear, based on our experience [20-22].

The specified design of mini hydroelectric power station of hydrocyclone type is developed under the target program "Creation of bases of serial production of the Kazakhstan sources of renewable energy of the world level" (BR05236263, NAS RK, 2018-2020).

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ГИДРОЦИКЛОНДЫҚ ТИПТЕГІ МИНИ ГЭС-тің ТӘЖІРИБЕЛІК ҮЛГІСІН ӨНДІРІСТІК ЖАҒДАЙДА СЫНАҚТАН ӨТКІЗУ

Аннотация. Гидроэлектрстанцияларда электр энергиясын өндіруге байланысты шығындардың аса төмен болуы мен оның бәсекеге қабілетті бағасына сай атқарылуы инвесторлар үшін тартымды бизнес екендігі белгілі.

Сонымен қатар, шағын немесе мини ГЭС-терді салған аймақты аса су баспайды және жылу электростанцияларымен салыстырғанда ауаға CO₂ тарауы мүлдем орын алмайды.

Тиісті ақпараттық және патенттік іздеулер нәтижесінде, оның техникалық-экономикалық негіздемесін ескере отырып, ҚР Ұлттық ғылым академиясында цилиндрлі-конусты гидроциклонмен жабдықталған гидроэлектрстанциясының шағын (микро) нұсқасы жасалды. Бұл техникалық шешім жеке ғимарат пен тұрғын үй-жайларды өз алдына дербес түрде электр энергиясымен жабдықтауға және көптеп зауыттан шығаруға мүмкіндік туғызады.

Сынақтан өткерудің мақсаты – жасалған жаңа мини ГЭС моделінің өндіріс жағдайындағы жұмыс қабілеттілігін тексеру және күтілетін технологиялық параметрлерді анықтау.

Сынақ барысында ағын тегеурінінің сипаттамаларында болатын өзгерістерді анықтау жағдайлары қарастырылды және гидроциклондағы су айналымы барысында бұл өзгерістердің өндірілетін қуатқа әсері қарастырылды.

Зерттеу әдістері. Процессордың компьютерлік модельдеуі SolidWorks (ағымды модельдеу) бағдарламасына сәйкес жүргізілді. Есептеулерді тексеру үшін «Autodesk Simulation CFD» қосымша бағдарламалық жасақтамасы пайдаланылған.

Бастапқы өндірістік сынақ гидроциклонға су диаметрі 100 мм болатын құбыр арқылы жеткізілген, ал содан кейін құбыр бекітіліп, қажетті су мөлшері 240x167 мм төртбұрышты құбыр арқылы берілген. Эксперименттің үшінші нұсқасы екі құбырдың бірге істеген жағдайында атқарылған.

Зерттеу нәтижелері. Сынақтан өткерілген ГЭС-тің тәжірибелік нұсқасының өндірістік жағдайда толықтай жұмыс істейтіні анықталған. Сынақ кезінде қарастырылған параметрлер диапазоны келесі өлшемдермен анықталады: тегеурін $H = 1,5-2,5$ м берілген су өтімі – $Q = 45-120$ л/с. Осы параметрлер жағдайында алынатын гидротурбина қуатының шамасы $N = 0,5-2,0$ кВт арасында қамтамасыз етілген.

Осы сынақтар кезінде анықталған параметрлер алдағы уақытта неғұрлым кең диапазонда сыналатын болады және су ағындары тегеурінді өзендерде мини ГЭС-тің ұтымды режимі қалыптастырылады.

Түйін сөздер: мини ГЭС, гидротурбина, генератор, компьютерлік моделдеу, тәжірибелік үлгі, өндірістік сынақ.

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ИСПЫТАНИЕ ОПЫТНОГО ОБРАЗЦА МИНИ ГЭС ГИДРОЦИКЛОННОГО ТИПА В ПРОИЗВОДСТВЕННЫХ УСЛОВИЯХ

Аннотация. Общеизвестно, что, благодаря относительно низким эксплуатационным затратам и конкурентоспособной цене за электроэнергию, выработанной на ГЭС, они представляют собой очень привлекательный бизнес для инвесторов. Кроме того, при строительстве малых и мини ГЭС не происходит затопления прилегающих территорий, сокращаются выбросы CO₂ за счет замещения теплоэлектроцентралей, работающих на ископаемом топливе.

На основе информационного и патентного поиска в мировом масштабе и с учетом целесообразности, в АН РК разработан мини (микро) вариант ГЭС, снабженная цилиндрикоконическим гидроциклоном. Это позволяет обеспечить локальное энергообеспечение отдельных зданий и жилых помещений, а также облегчает организацию их серийного производства.

Целью испытания являлась проверка работоспособности изготовленного нового образца мини ГЭС в реальных условиях и установление предполагаемых технологических параметров.

При испытании рассматривались вопросы по установлению изменения напорно-расходной характеристики и влияние этих изменений на вырабатываемую мощность преимущественно при работе на воде без учета степени ее очистки в гидроциклоне.

Методы исследования. Компьютерное расчетное моделирование процесса осуществилось по программе SolidWorks (flow simulation). Для проверки произведенных расчетов было использовано дополнительное программное обеспечение «Autodesk Simulation CFD».

Первоначальные производственные опыты проводились при подаче воды в гидроциклон по трубе с диаметром 100 мм, а затем труба была отключена и обеспечена подача воды через четырехугольный входной патрубок размером 240x167 мм. Третий вариант опытов проводился при совмещенном варианте, т.е. при наличии трубы и четырехугольного входного патрубка.

Результаты исследований. Установлено, что изготовленный образец мини ГЭС вполне работоспособен для выработки электроэнергии в производственных условиях.

Диапазон апробированных и подтвержденных параметров составляют в следующих пределах: напор $H = 1,5-2,5$ м, расход воды – $Q = 45-120$ л/с. При этом обеспечивается выработка мощности в пределах $N = 0,5-2,0$ кВт. Полученные параметры в ходе этих испытаний будут апробированы в более широком диапазоне и отработаны рациональные режимы работы мини ГЭС предлагаемой конструкции в условиях эксплуатации в реках со значительным перепадом течение воды.

Ключевые слова: мини ГЭС, гидротурбина, генератор, компьютерное моделирование, опытный образец, производственное испытание.

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WAVE SPREADING IN RESILIENT VISCOUS-PLASTIC LAYER WITH CAVITY ON THE RIGID BASE

Abstract. Explosion energy effective management at cavities creation in the rocks and soil massif in seismic investigation and dynamic pressure action from explosion and an earthquake on constructions demand more strict calculations for defining wave fields tensed-deforming condition. Therefore big attention is paid for development and improvement of drilling-and-blasting works processes by production workers and scientists. Nowadays scientific and practical works are conducted on studying explosive, rocks crushing processes under the external forces influence, in particular, as well as the blown-up mass consequence influence on the environment.

This scientific work considers research on waves spreading in resilient viscous-plastic layer with cavity based resilient basis under the dynamic pressure from day surface over the cavity.

This task is solved by “discontinuity disintegration” method of S. K. Godunov. This method advantage is all possible gaps in calculations according to this method are represented closer to real, ones than calculations obtained by artificial viscosity.

During the task of this research the hyperbolic type of the first order differential equations system has been obtained describing dynamic pressure influence on resilient viscous-plastic layer around the cavity on layer border and elastic basis.

Obtained numerical solution results can be applied for wave fields assessment, various nature of tension with boundary conditions, designing of various underground constructions.

Key words: resilience, layer, resilient viscous-plastic, cavity, wave, tensed-deforming condition, pressure.

Problem definition and main equations deducing conclusion on resilient and viscous-plastic waves spreading in a layer with cavity based on the elastic basis. Wave source is a dynamic pressure effecting on a layer from a day surface under entry conditions:

$$u = v = \sigma_x = \sigma_y = \tau = 0; \quad \begin{cases} -\infty \leq x \leq \infty \\ 0 \leq y \end{cases} \quad \text{at } t = 0;$$

and the boundary conditions [1,2]:

$$\begin{cases} v = tBe^{-At} \\ u = 0; \end{cases} \quad \text{at } \begin{cases} n_{11} \leq x \leq n_{22}; \\ y = 0; \\ t \geq 0, \end{cases}$$

where $A, B = const$; v, u – responding create medium particle speed on the axis x and y ;
 $\sigma_x, \sigma_y, \sigma_z, \tau$ – responding create tension.

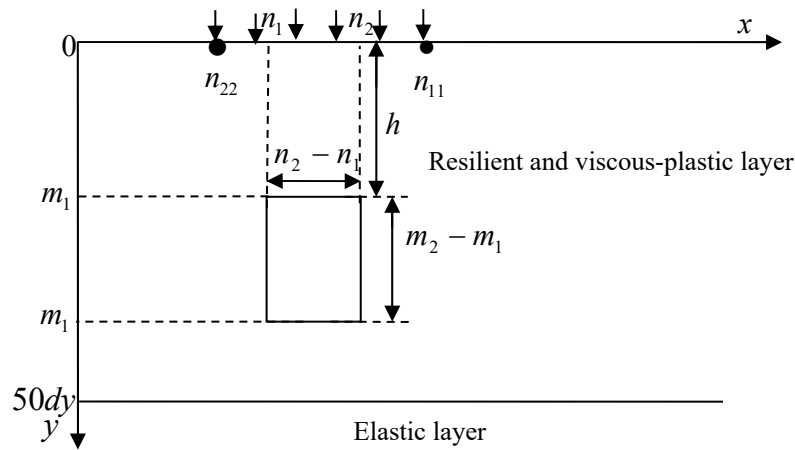


Figure 1 – Cavity in resilient and viscous-plastic layer based on elastic basis

Resilient and viscous-plastic medium equations have the type [3,4,5]:

$$\dot{\varepsilon}_{ij} = \frac{1}{2\mu} \dot{s}_{ij} + \frac{1}{2K} \dot{s} \delta_{ij} + \eta [\Phi(F)] \left(\alpha \delta_{ij} + \frac{s_{ij}}{2\sqrt{J_2}} \right), \tag{1}$$

where α - parameter of soil widening speed.

Function $[\Phi(F)] = \begin{cases} 0 & \text{at } F \leq 0; \\ F & \text{at } F > 0. \end{cases}$ is defined basing on the results of experimental research according to material dynamic features. Function $\Phi(F)$ choice allows to reflect deformation speed influence on fluidity limit [6,7,8,9].

Plane deformation is considered:

$$\begin{aligned} \varepsilon_{11} = \varepsilon_{xx} &= \frac{\partial u_x}{\partial x}; & \varepsilon_{22} = \varepsilon_{yy} &= \frac{\partial u_y}{\partial y}; & \varepsilon_{33} = \varepsilon_{zz} &= 0; \\ \varepsilon_{12} = \varepsilon_{xy} &= \frac{1}{2} \left(\frac{\partial u_x}{\partial y} + \frac{\partial u_y}{\partial x} \right); & \varepsilon_{13} = \varepsilon_{xz} = \varepsilon_{23} = \varepsilon_{yz} &= 0, \end{aligned}$$

where u_x, u_y - displacement on axis x and y , $u = \frac{du_x}{dt}$, $v = \frac{du_y}{dt}$ - speed on axis x and y .

Volume deformation [10,11] has the type:

$$\dot{\varepsilon}_{ii} = \frac{1}{3k} \dot{\delta}_{ii} + 3\alpha\eta \langle \Phi(F) \rangle, \tag{2}$$

The resilient and viscous-plastic medium equations system set to a dimensionless size relatively to elasticity parameters [10,11,12] have the type:

$$\left\{ \begin{array}{l} r_{12} \frac{\partial u}{\partial t} = \frac{\partial \sigma_x}{\partial x} + \frac{\partial \tau}{\partial y}; \\ r_{12} \frac{\partial v}{\partial t} = \frac{\partial \sigma_y}{\partial y} + \frac{\partial \tau}{\partial x}; \\ \frac{\partial \sigma_x}{\partial t} = a_{12} \left\{ \frac{\partial u}{\partial x} + \left(1 - \frac{2}{\gamma_1^2}\right) \frac{\partial v}{\partial y} + \Phi_1 \right\}; \\ \frac{\partial \sigma_y}{\partial t} = a_{12} \left\{ \frac{\partial v}{\partial y} + \left(1 - \frac{2}{\gamma_1^2}\right) \frac{\partial u}{\partial x} + \Phi_2 \right\}; \\ \frac{\partial \sigma_z}{\partial t} = a_{12} \left\{ \left(1 - \frac{2}{\gamma_1^2}\right) \frac{\partial u}{\partial x} + \left(1 - \frac{2}{\gamma_1^2}\right) \frac{\partial v}{\partial y} + \Phi_3 \right\}; \\ \frac{\partial \tau}{\partial t} = a_{12} \left\{ \frac{1}{\gamma_1^2} \frac{\partial u}{\partial y} + \frac{1}{\gamma_1^2} \frac{\partial v}{\partial x} + \Phi_4 \right\}. \end{array} \right. \quad (3)$$

where $r_{12} = \rho_1 / \rho_2$, ρ_1 - resilient and viscous-plastic medium density, ρ_2 - elastic medium density, $a_{12} = \frac{\rho_1 a_1^2}{\rho_2 a_2^2}$, a_1 - longitudinal sound speed in resilient and viscous-plastic medium, a_2 - longitudinal sound speed in elastic medium, $\gamma_1 = a_1 / b_1$, b_1 - transverse sound speed in resilient and viscous-plastic medium [13,14,15].

$$\left\{ \begin{array}{l} \Phi_1 = -(1/\gamma_1^2) \eta \langle \Phi(F) \rangle \left[(3\gamma_1^2 - 4)\alpha + \frac{1}{3}(2\sigma_x - \sigma_y - \sigma_z) / \sqrt{J_2} \right]; \\ \Phi_2 = -(1/\gamma_1^2) \eta \langle \Phi(F) \rangle \left[(3\gamma_1^2 - 4)\alpha + \frac{1}{3}(2\sigma_y - \sigma_x - \sigma_z) / \sqrt{J_2} \right]; \\ \Phi_3 = -(1/\gamma_1^2) \eta \langle \Phi(F) \rangle \left[(3\gamma_1^2 - 4)\alpha + \frac{1}{3}(2\sigma_z - \sigma_x - \sigma_y) / \sqrt{J_2} \right]; \\ \Phi_4 = -(1/\gamma_1^2) \eta \langle \Phi(F) \rangle (\tau / \sqrt{J_2}). \end{array} \right.$$

According to definitive-difference (3) equations systems [16,17,18] have the type:

$$\left\{ \begin{array}{l} r_{12} \frac{u^{n,m} - u_{n,m}}{\Delta t} = \frac{(\sigma_x)_{n_2} - (\sigma_x)_{n_1}}{\Delta x} + \frac{\tau_{m_2} - \tau_{m_1}}{\Delta y}; \\ r_{12} \frac{v^{n,m} - v_{n,m}}{\Delta t} = \frac{(\sigma_y)_{m_2} - (\sigma_y)_{m_1}}{\Delta y} + \frac{\tau_{n_2} - \tau_{n_1}}{\Delta x}; \\ \frac{(\sigma_x)^{n,m} - (\sigma_x)_{nm}}{\Delta t} = a_{12} \left\{ \frac{u_{n_2} - u_{n_1}}{\Delta x} + \left(1 - \frac{2}{\gamma_1^2}\right) \frac{v_{m_2} - v_{m_1}}{\Delta y} + \Phi_{1n,m} \right\}; \\ \frac{(\sigma_y)^{n,m} - (\sigma_y)_{nm}}{\Delta t} = a_{12} \left\{ \frac{v_{m_2} - v_{m_1}}{\Delta y} + \left(1 - \frac{2}{\gamma_1^2}\right) \frac{u_{n_2} - u_{n_1}}{\Delta x} + \Phi_{2n,m} \right\}; \\ \frac{(\sigma_z)^{n,m} - (\sigma_z)_{nm}}{\Delta t} = a_{12} \left\{ \left(1 - \frac{2}{\gamma_1^2}\right) \frac{u_{n_2} - u_{n_1}}{\Delta x} + \left(1 - \frac{2}{\gamma_1^2}\right) \frac{v_{m_2} - v_{m_1}}{\Delta y} + \Phi_{3n,m} \right\}; \\ \frac{\tau^{n,m} - \tau_{n,m}}{\Delta t} = a_{12} \left\{ \frac{1}{\gamma_1^2} \frac{u_{m_2} - u_{m_1}}{\Delta y} + \frac{1}{\gamma_1^2} \frac{v_{n_2} - v_{n_1}}{\Delta x} + \Phi_{4n,m} \right\}. \end{array} \right. \quad (4)$$

For elastic base the definitive-difference type of differential equations system [19,20]:

$$\left\{ \begin{aligned} \frac{u^{n,m} - u_{n,m}}{\Delta t} &= \frac{\sigma_{xn2} - \sigma_{xn1}}{\Delta x} - \frac{\tau_{m2} - \tau_{m1}}{\Delta y}; \\ \frac{v^{n,m} - v_{n,m}}{\Delta t} &= \frac{\tau_{n2} - \tau_{n1}}{\Delta x} + \frac{\sigma_{ym2} - \sigma_{ym1}}{\Delta y}; \\ \frac{\sigma_x^{n,m} - \sigma_{x,n,m}}{\Delta t} &= \frac{u_{n2} - u_{n1}}{\Delta x} + \left(1 - \frac{2}{\gamma^2}\right) \frac{v_{m2} - v_{m1}}{\Delta x}; \\ \frac{\sigma_y^{n,m} - \sigma_{y,n,m}}{\Delta t} &= \left(1 - \frac{2}{\gamma^2}\right) \frac{u_{n2} - u_{n1}}{\Delta x} + \frac{v_{m2} - v_{m1}}{\Delta x}; \\ \frac{\tau^{n,m} - \tau_{n,m}}{\Delta t} &= \frac{1}{\gamma^2} \frac{u_{m2} - u_{m1}}{\Delta y} + \frac{1}{\gamma^2} \frac{v_{n2} - v_{n1}}{\Delta x}, \end{aligned} \right. \quad (5)$$

There are some results of definitive-difference equations system numerical solution which have been showed in figures 3, 4, 5, 6 and 7.

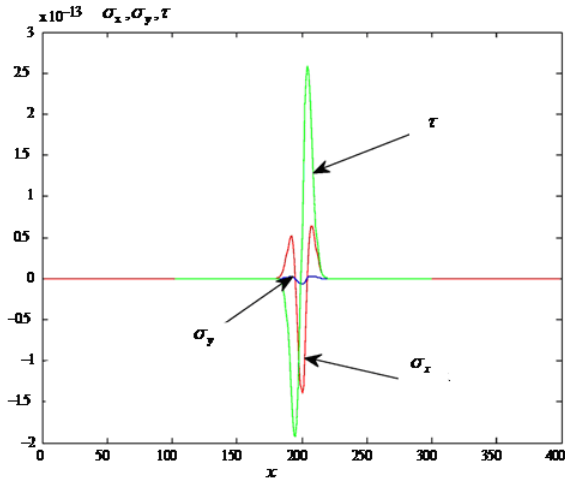


Figure 2 – Normal and tangent tension on axis $x, x = 1dx - 400dx$, at depth under the cavity $y = 21dy$ at a moment of time $t = 395dt$

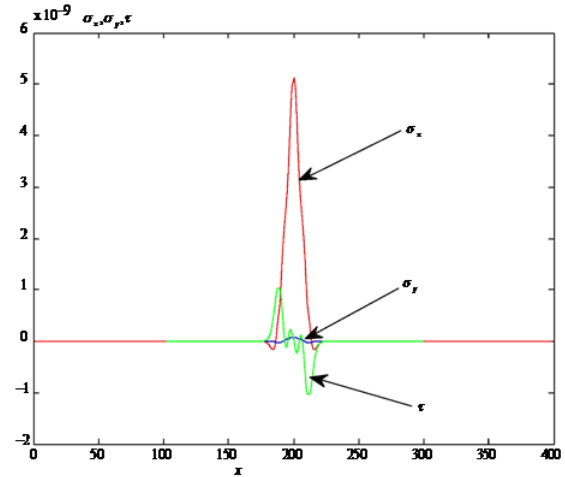


Figure 3 – Normal and tangent tension on axis $x, x = 1dx - 400dx$, at depth under the cavity $y = 5dy$ at a moment of time $t = 395dt$

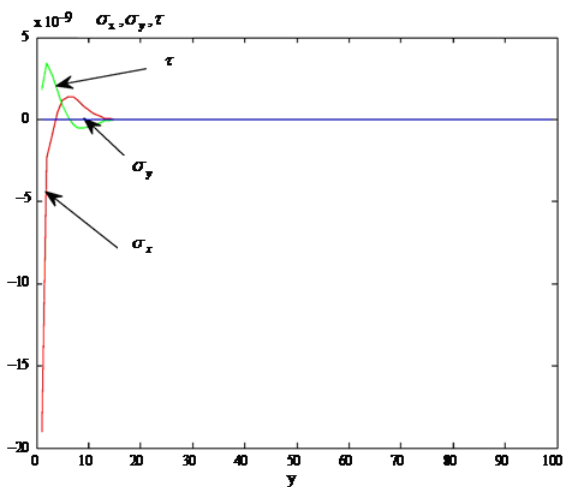


Figure 4 – Normal and tangent tension on axis $y, x = 1dx - 190dx$, at depth along the left vertical side $y = 1dy - 100dy$ at a moment of time $t = 395dt$

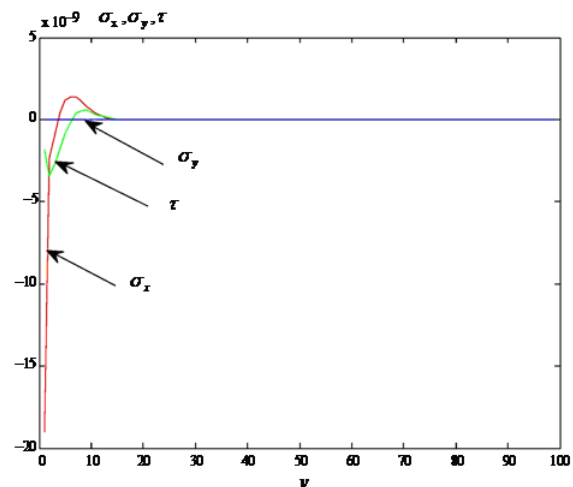


Figure 5 – Normal and tangent tension on axis $y, x = 210dx$, at depth along the right vertical side $y = 1dy - 100dy$ at a moment of time $t = 395dt$

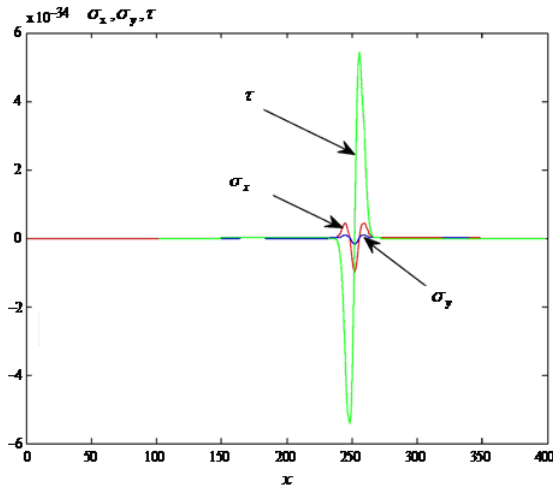


Figure 6 – Normal and tangent tension on axis x , on the border of resilient and viscous-plastic layer and elastic base $x = 1dx - 400dx, y = 50dy$ at a moment of time $t = 395dt$

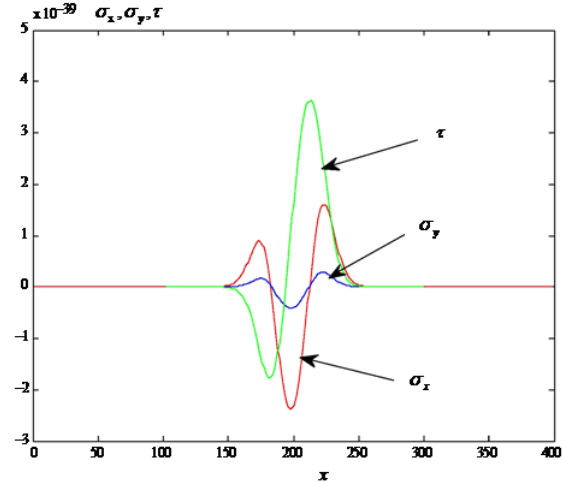


Figure 7 – Normal and tangent tension on axis $x, x=1dx - 400dx$, at depth in elastic base $y = 70dy$ at a moment of time $t = 395dt$

If to compare graphs 2 and 3 where the tension changes along the bottom and top are given and consider these schedules ordinates difference that equals to $2 \cdot 10^3$, i.e. the tension magnitude over the cavity surpass in several orders than under the cavity. The conclusion follows: the cavity top (ceiling) should be strengthened and made stronger, than cavity bottom (floor).

If to compare graphs 4 and 5 where tension changes on depth along the left and right vertical sides, are given it is visible that tension magnitude along the specified sides of one order.

If to consider graphs in figures 6 and 7, then figure 6 shows tension changes along border of two mediums of resilient and viscous-plastic layer and the elastic basis, and figure 7 shows tension in the elastic basis in the horizontal direction. From these schedules it is visible that tension values on two mediums border are higher on two points, than tension magnitudes in the elastic basis.

Conclusion. The hyperbolic equations initial system in first order private derivatives relating to tension components has been researched, characteristic surfaces and characteristic ratios on them are found. The wave field analysis depending on the set pressure form is conducted. Comparison of resilient and viscous-plastic layer free surface fluctuations and its border with the elastic basis are shown on the schedules constructed as the tension dependence from coordinates and time.

The calculation results of analysis received at layer physical parameters and, on free surface in a particular, confirm that medium viscous and plastic properties weaken the set signal characteristics, at the same time the arising plastic areas weaken structural connections in the medium, i.e. led to considerable loss of durability. The results of analysis shows what parts of a cavity are committed to stronger pressure and where strengthenings are necessary. The received results correspond to physics process that confirm the correctly chosen research technique, the constructed model and its realization.

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СЕРПІМДІ НЕГІЗДЕ ЖАТҚАН ҚҰЫСЫ БАР СЕРПІМДІ-ТҮТҚЫРЛЫПЛАСТИКАЛЫҚ ҚАБАТТА ТОЛҚЫННЫҢ ТАРАЛУЫ

Аннотация. Тау жыныстары массивінде қуыс жасағанда және жерқыртысында сейсмикалық барлауда жарылысты тиімді басқару және жарылыстың әсерінен пайда болатын динамикалық жүктемеден немесе жер сілкінісінен құрылыстарға әсер ететін толқын өрісінің кернеулі-деформацияланған күйін анықтау кезінде дәлдігі жоғары есептеу сұлбасын жасау талап етіледі. Сондықтан бұрғылапжару жұмыстарын өркендетуге

және жетілдіруге ғалымдар мен өндірісшілер жағынан үлкен көңіл бөлініп келеді. Қазіргі кезде жарылыс жұмыстарын зерттеуге, оның ішінде сыртқы күштердің көмегімен тау жыныстарын ұсақтау үрдісін қарастыруға және жарылыстан пайда болған заттардың қоршаған ортаға әсерін ғылыми-практикалық зерттеу жұмыстарын жүргізуде.

Бұл ғылыми жұмыста серпімді негізде жатқан қуысы бар серпімді-тұтқырлыпластикалық қабаттың жоғарғы жағында жатқан жазық беттен әсер ететін динамикалық жүктемеден таралатын толқыны зерттеледі.

Берілген мәселені шешуде С. К. Годуновтың «үзіліс ыдырау» әдісі қолданылған. Қолданылған әдістің артықшылығы сонда, бұл әдіспен алынған барлық мүмкін болатын үзілістердің есебі жасалған және алынған жасанды тұтқырлық есебімен салыстырғанда, бұл әдіс шындыққа өте жақын жанасады. Қарастырылған есепті зерттеу жолында серпімді-тұтқырлыпластикалық қабаттағы қуыстың айналасына, қабаттың шекарасына және серпімді негізге динамикалық жүктеменің әсерін сипаттайтын гиперболалық түрдегі бірінші ретті дифференциалдық теңдеулер жүйесі алынған.

Қуыс айналасындағы серпімді-тұтқырлыпластикалық ортаның және екі орта шекарасының кернеулі-дифференциалдық күйін сипаттайтын дифференциалдық теңдеулерді сандық түрде шешу үшін алгоритм жазылып, программа кешені құрылған. Сандық шешімдерінің нәтижелілік графигі ортаның геометриялық параметрлерінің уақытқа тәуелді түрінде берілген.

Алынған нәтижелер төменгі және жоғарғы қабырғаларының бойындағы кернеулердің өзгерістері және графиктердің ординаталарының айырмашылығы – 10^6 -ға тең, яғни серпімді-тұтқырлыпластикалық қабатта қуыстың жоғары қабырғасының кернеулік шамасы қуыстың төменгі қабырғасының кернеулік шамасынан бірнеше есе жоғары екенін көрсетеді. Ол кернеудің таралуы бірқалыпсыз, яғни уақыттың өзгеруіне және тереңдіктің артуына байланысты толқынның өшуін білдіреді. Бұдан шығатын тұжырым: негізгі күш жазық беттің үстіңгі қабатына түседі, яғни жазық беттің астыңғы қабырғасына қарағанда, үстіңгі қабырғасын күшейту қажет және берік жасау керек.

Ғылыми мақалада негізгі мәселенің жекеше жағдайлары да қарастырылған, яғни жазық беттің көлденең қабырғасына түсетін динамикалық күштің әсері. Алынған нәтижелерден мынадай тұжырымдамалар шығады: вертикаль оң жақ және сол жақ қабырғалардың бойындағы кернеу шамаларының тереңдікке байланысты әсерлерінің өзгерісінде көп айырмашылық жоқ. Осыған байланысты, вертикаль қабырғаларға түскен динамикалық күштің таралуы бірқалыпты деп есептеуге болады.

Жұмыста екі ортаның шекарасындағы кернеулердің өзгерісі мұқият зерттелген. Жасалған жұмыстан $t = 395dt$ уақыт моментіндегі $x = 1dx - 400dx$, $y = 50dy$ координаталары бойынша нормаль және жанама кернеулердің серпімді негіздегі шамасы – 10^{-34} және серпімді-тұтқырлыпластикалық қабаттағы кернеудің шамасы – 10^{-13} екендігі анықталған. Сондықтан серпімді-тұтқырлыпластикалық ортадан серпімді негізге жылжыған толқын – 10^{21} дәрежесіне дейін кемітінін көруге болады.

Серпімді қабаттағы кернеулердің шамасы $t = 395dt$ уақытында x осі бойынша $x = 1dx - 400dx$, $y = 70dy$ тереңлікте – 10^{-39} шамасына тең болады. Кернеудің қабылдаған шамасынан толқын серпімді-тұтқырлыпластикалық қабаттан және екі ортаны бөліп тұрған шекарадан өткеннен соң, қатты әлсірейтінін байқауға болады, яғни ортаның тұтқырлығы мен пластикалығы берілген күшті әлсіретеді.

Зерттеулер нәтижесі серпімді-тұтқырлыпластикалық қабаттағы төртбұрышты қуыстың айналасындағы шамаларды бағалауға қолданылады. Қарастырылған зерттеу әдісін қабаттардың кернеулік деформациясын анықтауға және сол арқылы жерасты құрылымдарының беріктігі мен орнықтылығын бағалауда және сияқты геодинамикалық мәселелерді шешу барысында қолдануға болады.

Зерттеу барысында алынған нәтижелерді әртүрлі сипаттағы кернеулік күйлердің толқындық өрістерін бағалау мақсатында қолдануға, осыған ұқсас есептерде шектік шарттармен шектелген есептерді шешуге және әртүрлі жерасты құрылымдар мен құрылыстардың проектировании кернеулік күйлерін анықтауда қолдануға болады.

Түйін сөздер: серпімділік, қабат, серпімді-тұтқырлыпластикалық (қабат), қуыс, жүктеме, толқын, кернеулі-деформациялық күй.

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РАСПРОСТРАНЕНИЯ ВОЛНЫ НА УПРУГО-ВЯЗКОПЛАСТИЧЕСКОМ СЛОЕ С ПОЛОСТЬЮ НА УПРУГОМ ОСНОВАНИИ

Аннотация. Эффективное управление энергией взрыва при создании полостей в массиве горных пород и грунтов в сейсмической разведке и действие динамических нагрузок от взрыва и землетрясения на

сооружения требуют более строгих расчетных схем для определения напряженно-деформированного состояния волновых полей. Поэтому вопросам развития и совершенствования процессов буровзрывных работ уделяется большое внимание со стороны производителей и ученых. В настоящее время ведутся научно-практические работы по изучению взрывных, в частности изучаются процессы дробления горных пород под воздействием внешних сил, также влияние на окружающую среду последствия от взорванной массы.

В данной научной работе рассматриваются исследования распространения волн в упруго-вязкопластическом слое с полостью, лежащем на упругом основании при воздействии динамической нагрузки со стороны дневной поверхности над полостью. Для решения поставленной задачи применяется метод «распада разрыва» С.К. Годунова. Преимущество данного метода заключается в том, что все возможные разрывы в расчетах по этому методу представляются более близкими к реальным, чем расчеты, полученные при использовании искусственной вязкости. При исследовании данной задачи получена система дифференциальных уравнений первого порядка гиперболического типа, которая описывает влияние динамической нагрузки на упруго-вязкопластический слой вокруг полости, на границе слоя и на упругом основании.

Для численных решений дифференциальных уравнений разработан программный комплекс с алгоритмом, для определения напряженно-деформируемого состояния вокруг полости в упруго-вязкопластическом слое и на границе двух сред.

Результаты численного решения представлены в виде графиков зависимости геометрических параметров среды от времени.

Из полученных результатов видно, что изменения напряжений вдоль нижней и верхней стенки, а также разность ординат этих графиков равна -10^6 , то есть в упруго-вязкопластическом слое величины напряжений над полостью превосходят в несколько порядков, чем величины напряжений под полостью. Что означает неравномерное распределение напряжений, то есть с течением времени и увеличением глубины волна угасает. Отсюда следует, что основная нагрузка приходится на верхнюю стенку полости, то есть верхнюю стенку полости надо укреплять и сделать более прочным, чем нижнюю стенку полости.

В научной статье также рассмотрен частный случай основной задачи – влияние динамической нагрузки на вертикальные стенки полости. По полученным результатам можно сделать следующие выводы: изменения напряжений по глубине вдоль левой и правой вертикальных стенок имеют незначительные отклонения, то есть величины напряжений вдоль указанных стенок одного порядка. Это означает, что динамическая нагрузка на вертикальные стенки полости распределена равномерно.

В работе подробно изучено изменение напряжения на границе двух сред. Из этого следует, из работы напряжения на границе упруго-вязкопластического слоя и упругого основания при координатах $x = 1dx - 400dx$, $y = 50dy$ в момент времени $t = 395dt$ имеем нормальные и касательные напряжения порядок -10^{-34} , эти же напряжения в упруго-вязкопластическом слое имеют порядок -10^{-13} , что означает: волна при движении к границе с упругим основанием убывает на порядок -10^{21} .

Результаты параметров напряжений в упругом слое по оси x , $x = 1dx - 400dx$, на глубине $y = 70dy$ в момент времени $t = 395dt$ имеет порядок -10^{-39} . Мы видим из расчетов параметров напряжений, что после прохождения волны упруго-вязкопластического слоя и границы двух сред – волны сильно гасятся, то есть вязкие и пластические свойства среды ослабляют характеристики задаваемого сигнала.

Результаты исследований позволят дать оценку параметрам волновых процессов вокруг прямоугольной полости в упруго-вязкопластическом слое. Предложенная методика исследования может быть использована для определения напряженно-деформированного состояния слоя, которые могут быть использованы при оценке прочности и устойчивости подземных сооружений, а также при решении задачи геодинамики.

А также полученные результаты могут быть применены для оценки волновых полей, для установления характера напряженного состояния, при решении аналогичных задач с граничными условиями и при проектировании различных подземных сооружений и конструкций.

Ключевые слова: упругость, слой, упруго-вязкопластичность, полость, нагрузка, волна, напряженно-деформируемое состояние.

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**DEVELOPMENT OF A MULTIFUNCTIONAL
CORROSION INHIBITOR, POSSESSING THE PROPERTIES
OF A MICROEMULSION**

Abstract: To protect the oilfield equipment from corrosion, a multifunctional bactericide inhibitor with microemulsion properties was developed that promotes oil displacement. Laboratory researches have shown that the reagent has high inhibiting and bactericidal properties at concentration of 500 mg/l. At the same time the protective effect of the general corrosion constitutes 94-96% and suppression extent of SRB - 99%. While conducting experimental studies on linear models of layer it has been established that at the reagent concentration of 10% the coefficient of oil replacement relatively to the layer water increases by 16%.

Field tests showed that, during the application of this reagent, the protective effect of corrosion was 90%, and the degree of SRB suppression constituted 97%.

As a result of reagent influence on productive layer in oil production of the wells has increased in average by 11%.

Key words: corrosion, bactericide inhibitor, degree of protection, suppression extent, increase of oil production, maintenance of layer pressure.

Introduction. Various technological methods such as: heat treatment of layer, pumping of the chemical reagents and injection of gas or sea water were applied on oil layers to strengthen the oil production. The application scales of influence methods on oil deposits are enormous.

One of the dominating influence methods on layer that applied on the Azerbaijan fields is the maintenance of layer pressure (MLP) by downloading water into the layer through the system of injection wells.

The MLP in its turn is very metal - and power-intensive system that is related to the arrangement of the parting and bringing conduits (pipelines), construction of sectional pump stations, power supply objects and their protection for the purpose to increase in service life.

The acquired practice of long-term exploitation in Azerbaijani oil fields has shown that, the main reason of MLP system damages is the corrosion destruction of pipelines in consequence of sea water injection without the preliminary sterilization. At the same time the corrosion aggression of layer water amplifies because of the existence of corrosion aggressive bacteria in the environment as well as the increase in concentration of such ions as Cl^- , SO_4^{2-} , H_2S and CO_2 gases [1].

A sharp increase in the corrosion rate of steel with an increase in sulfide ion concentration in alkaline and neutral media was noted. The second after hydrogen sulfide on aggressiveness component of oilfield environments is oxygen [2,3].

Microbiologically influenced corrosion is a big concern in oil and gas industry [4-6]. Pits and other damage arising from microbiological corrosion damage downhole equipment, manifolds, and pipelines. The most aggressive among bacteria stimulating bio-corrosion are sulfate reducing bacteria (SRB) [7-10].

During operation of oil deposits, asphalt-tar-paraffin (ATP) compounds in heavy and high viscosity oils precipitate in well bottom zone (WBZ) and thus, weaken the filtration ability of layer fluids and cause a sharp decrease in production. In order to eliminate such difficulties, the physical and chemical methods were developed to affect WBZ depending on physical, chemical and filtration properties of fluids.

However, due to the use of expensive techniques and chemical reagents, the economic benefits of these operations are not considered as satisfactory.

Methods developed for intensifying oil production need to be improved. For this reason, it is expedient to develop effective methods to prevent complications that occur during well operation.

Chemical method, especially microemulsion flooding, plays an important role in enhanced oil recovery technique due to its ability to reduce interfacial tension between oil and water to a large extent as well as alter wettability of reservoir rocks [11].

Microemulsion is used to increase permeability of well bottom zone and to rise oil recovery factor of injection wells. The efficiency of microemulsion depends on the dissolution of ATP compounds contained in oil, intensification of oil flow to the well bottom, recovery and increase of well bottom zone conductivity. Compared to the ordinary emulsions, microemulsions mix well with layer water and hydrocarbons and have small dimensions and suspended particles. Dilution of microemulsion with water (over 40%) leads to its transformation. This transformed microemulsion is used for wider application areas by mixing with oil and water [12-17].

Researches show clearly that mixing cationic and non-ionic surfactants is useful in testing and supporting microemulsion conductivity models [18].

However, in chemical enhanced oil recovery (EOR), the microscopic sweep efficiency depends primarily on achievement of a low interfacial tension [19].

Aims and Objectives. Considering the urgency of the existing problem, a new combined bactericide-inhibitor was developed based on naphthenic acid salts, isopropyl alcohol, light gas oil fraction and technical hydrated phosphatide, which has emulsifier properties that influence various processes in the formations.

Laboratory research. The study of inhibitory and bactericidal properties of the reagent under the laboratory conditions is carried in accordance with standards. For testing, steel samples 1020 (USA standard) were prepared and installed into the U-shaped cell with a stirring device. Fluid velocity relatively to the samples is 0.3 m/sec. Duration of the experiments is 6 hours at the 25°C degree. Testing of reagent at various concentrations (100-600 mg/l) was carried out in acidic and alkaline environments. The results of laboratory researches are presented in the figure 1.

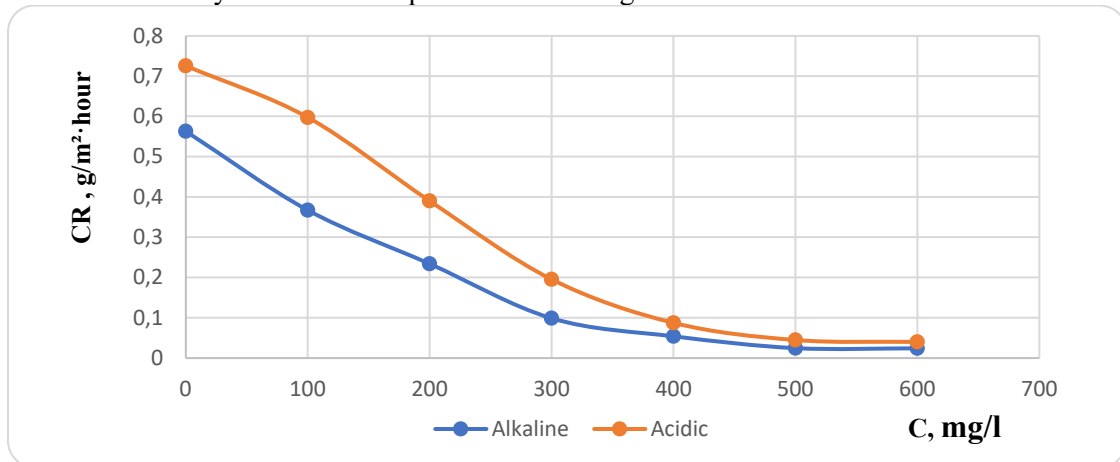


Figure 1 – The dependence of the corrosion rate (CR) in various environments on the concentration of the reagent (C)

Determination of the inhibitor efficiency was conducted by gravimetric method. The essence of the method constitutes determining the rate of corrosion by mass loss of witness specimens in the control and test environment.

The corrosion rate is computed by the expression given below:

$$CR = \frac{m - m_1}{St} \quad (1)$$

where CR - corrosion rate, g/m²·hour; m - mass of the test specimen before the test, g; m₁ - mass of the test specimen after the test, g; S - the surface area of the witness specimen, m²; t - test time, hour.

The effectiveness of the protective action of the inhibitor was characterized by the degree of protection IE, %.

$$IE = \frac{CR - CR_1}{CR} 100\% \quad (2)$$

where CR и CR₁ - corrosion rates of the sample without inhibitor and with inhibitor

As shown in figure 1, the speed of corrosion without inhibitor in various environments was 0.5631 - 0.7257 g/m²·hour. Depending on the reagent concentration, corrosion speed in the corresponding environment has reached 0.0236-0.5974 g/m²·hour and at the same time the protective effect constituted 18-96%.

Laboratory researches have shown that the reagent has high inhibiting properties at optimum concentration of 500 mg/l. At the same time the protective effect of general corrosion was 94-96% (0.0240-0.0447 g/m²·hour).

To study the mechanism of the protective action of the reagent, a potentiostatic method of obtaining polarization curves of 1020 steel was also used. The research results are shown in figure 2.

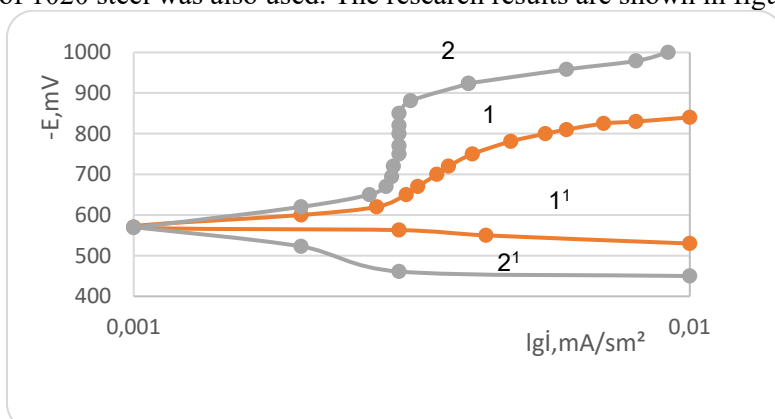


Figure 2 – Cathode (1-2) and anodic (1'-2') potentiostatic polarization curves:
1, 1' - cathode and anode curves without reagent; 2, 2' - cathode and anode curves with a reagent (500 mg/l)

As can be seen from figure 2, a mixed-type reagent is capable of equally effectively inhibiting both electrochemical reactions on an electrode at a concentration of 500 mg/l, which is consistent with gravimetric tests.

Determination of bactericidal properties of reagent with concentrations of 100-600 mg/l was carried out on the culture of SRB with the load equal to 10³ bacteria/ml, at the temperature of 30-32⁰C within 15 days. The culture of SRB for these researches has been marked out from layer waters of the “Bibieybat” field.

The effectiveness of the bactericide is characterized by the degree of suppression of sulfate reducing bacteria, which is determined by the formula:

$$IE_{bak.} = \frac{C - C_1}{C} 100\%$$

where IE_{bak.} - degree of suppression; C and C₁ - the presence of H₂S in test of the studied water without reagent and with reagent respectively.

Researches have shown that at concentration of 500 mg/l suppression extent of SRB becomes 99% (figure 3).

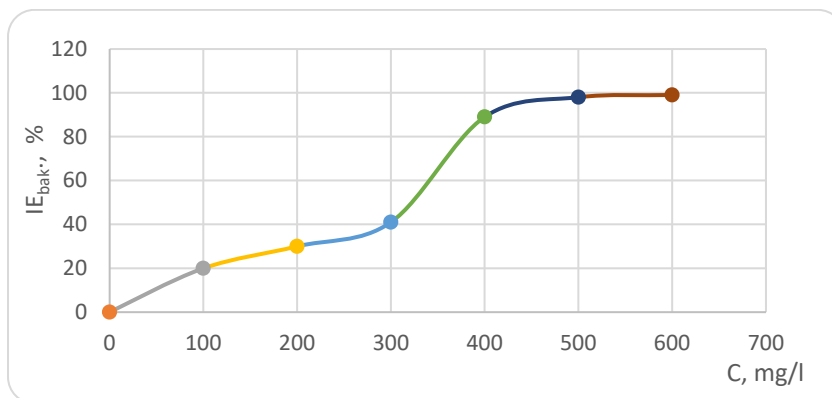


Figure 3 – Bactericidal properties of reagent in various concentrations

Under laboratory conditions effect of reagent in different concentrations on the viscosity of the oil also have been studied. Dynamic viscosity (mPa·s) was carried out at the viscometer "Reotest-2" at the temperature of 25° C and a strain rate equal to 0.33sec⁻¹. For this purpose, was used oil from well № 43 of "Muradkhanli" filed (table 1).

Table 1 – Physico-chemical properties of the studied oil

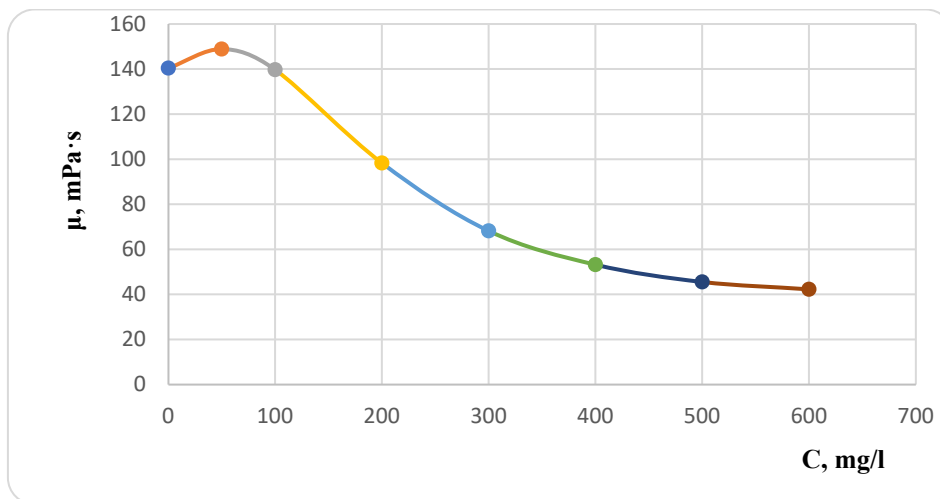
Options	Meanings
Dynamic viscosity of oil, mPa · s	140,4
Density of oil, kg /m ³ at 20°C	915
The content of asphaltenes, %	0,72
Sulfur content in oil,%	0,3
The paraffin content in oil, %	7,2
The content of silica gel resin, %	16
Water content, %	28
Freezing point, °C	16
Mechanical impurities, %	0,62

To assess effectiveness of the reagent regulating oil viscosity, the efficiency index (E_{eff}) is estimated by the formula:

$$E_{\text{eff}} = \frac{\mu_o - \mu_k}{\mu_o} \quad (4)$$

where E_{eff} - the efficiency index of the reagent; μ_o - the dynamic viscosity of the initial oil, Pa·s; μ_k - the dynamic viscosity of the oil with the reagent, Pa·s.

The reagent efficiency index (E) shows how many percent the dynamic viscosity of the oil with the reagent has decreased relative to the dynamic viscosity of the original oil. The results are depicted in figure 4.

Figure 4 – Dependence of dynamic viscosity (μ) of high viscosity oil on reagent concentration (C)

The data in figure 4 indicates that, as the concentration of the reagent increases, shear stress and the dynamic viscosity decreases. For optimum concentration of the reagent 500 mg/l dynamic viscosity are equal to 45.72 Poise correspondingly, herewith the dynamic viscosity is decreased in 3 times, what is 67%.

The improvement in the fluidity of high-viscosity oils can be explained by the fact that the test reagent possesses surface-active properties and is capable of changing the phase and energy interactions at the interfaces between the polar and nonpolar phases.

Technical phosphatide in turn consists of residues of glycerol, fatty acids, phosphoric acid and nitrogen-containing compounds - serine, ethanolamine and choline, and in some cases other substances. Hydration of technical phosphatide leads to the formation of a phosphatide emulsion containing 45-70% water [20]. Taking into account the fact that phosphatides, which are emulsifiers, as well as alcohol and hydrocarbons, which form a microemulsion, are present in the developed reagent. 10% mixture of reagent with water can be used as a rim injected into the formation. Therefore, in laboratory conditions, the effect of the reagent on oil displacement was also studied.

Moreover, to study the reagent effects on oil extrusion process some researches were conducted under the laboratory conditions. Results of the laboratory researches are presented in figure 5.

Experimental studies (at 25° C) on linear model of layer with the initial oil saturation of 76% loaded by quartz sand with permeability 1.2 mkm². At the first stage of experiment at the room temperature and constant pressure difference of 0.025 MPas oil was forced out by layer water. At the same time the displacement coefficient after passing through the layer model of 1.9 steam volumes of water, and in the final period is 0.49 (figure 5 (a)). Thus, layer water has forced out only 49% available oil and this indicates the low oil washout ability of layer water.

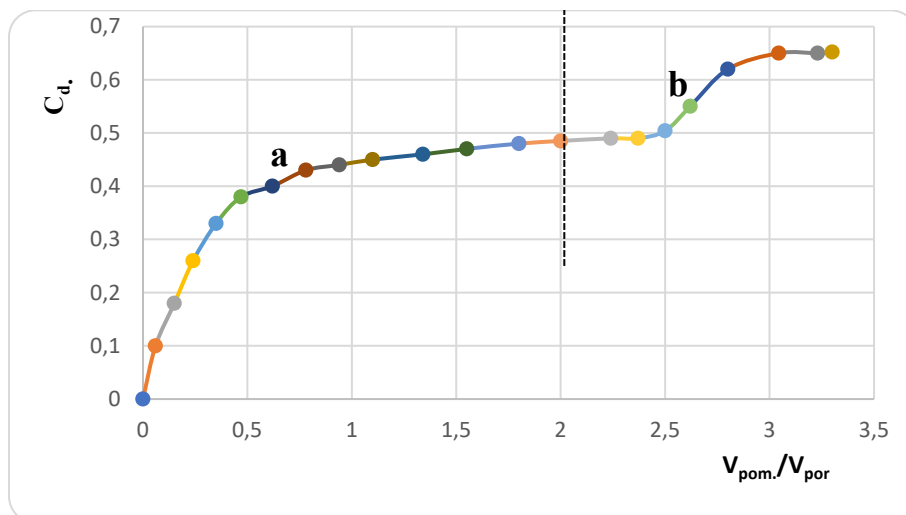


Figure 5 – Dependence of oil displacement coefficient from the porous environment with layer water (a) and 10% solution of reagent (b).
 $V_{pom.}/V_{por.}$ - Volume of pumped agents from pore volume, C_d - Displacement coefficient

At the second stage of experiment reagent solution in concentration of 10% was applied to the layer water before full replacement of residual oil. At this stage 1.4 volumes of solution were injected into the model of layer that has forced out another 16% of residual oil (figure 5 (b)).

It should be noted that the developed microemulsion, which displaces oil from heterogeneous layers, has some features:

- improves the rheological properties of highly viscous oil;
- helps to improve the movement of oil in the reservoir and reduce the breakthrough of the injected water to the production wells, thereby improving its oil-bearing capacity;
- due to the wetting of the surface of the rock with a 10% solution of the reagent, the relationship of the oil with the rock is reduced.

Thus, laboratory studies have shown that the reagent, due to the diphylic properties owing to the presence of polar (hydrophilic) and non-polar (hydrophobic) groups, can be used in small concentrations as a corrosion inhibitor, and at high concentrations, being a microemulsion, stimulates oil displacement by increasing the permeability of rocks.

Field tests. Due to injection of raw layer water to maintain layer pressure, field tests of the reagent on the results of laboratory tests were carried out at injection wells of OGEU (Oil Gas Extraction Unit) “Bibiebatneft”.

Batcher pump delivery rate can be determined by calculation using the amount of injected liquid to the well and concentration of inhibitor working solution.

Firstly, 25 pore volume of reagent solution with concentration of 10% was pumped by impact dose to increase the rate of oil extrusion and carrying out bactericidal treatment. Further, the reagent was pumped with the working concentration of 500 mg/l.

For corrosion speed determination samples of steel 1020 were installed in cartridges from inert materials located in water conduits supplying pumped water into the well. Tests were carried out within 2 months: the first month without the inhibitor, the second month - with reagent supply. Endurance duration of samples was 30 days and then they were selected for further assessment of protective effect. Determination of protective action of bactericide inhibitor was carried out in the laboratory by a gravimetric method on mass loss of steel samples. In parallel, for the chemical and microbiological analyses, the layer water was taken to study the bactericidal properties of reagent.

Field tests have shown that while using reagent the speed of corrosion has on average decreased from 0.1129 to 0.0112 g/m²·hour, the protective effect at the same time constituted 90%. The amount of hydrogen sulfide decreased from 36.3 to 1.2 mg/l. Moreover, the amount of sulfate-reducing bacteria has decreased from 10⁶ to 10¹ bacteria/ml, at the same time suppression extent of SRB constituted 97%.

It is also necessary to note that as a result of the reagent influence on productive layer, oil production in the corresponding oil-extracting wells has increased on average by 11%.

Protection of equipment against corrosion allow to reduce the number of damages and, respectively, to cut down expenses on their elimination, to increase reliability and to prolong service life of pipelines, and finally to increase ecological safety of objects.

Multifunctional reagent was developed for the protection of underground and above ground oil-field equipment of the MLP system from the general and microbiological corrosion. In this case, the reagent can be used in drilling, operating of steel tanks, receiving and pumping oil, as well as to improve oil displacement in reservoirs.

Conclusion.

1. Based on salts of naphthenic acids, isopropyl alcohol, light gas oil fraction and technical hydrated phosphatide, a new combined bactericide-inhibitor has been developed that has microemulsion properties and influences various processes occurring in reservoirs. At the same time the protective effect in laboratory conditions of the general corrosion constitutes 94-96%, and SRB suppression extent is 99%.

2. The results of filtration studies performed on bulk reservoir models showed that the developed reagent has a complex effect. At the reagent concentration of 10% displacement coefficient relatively to layer water increases by 16%.

3. In trade conditions the protective effect constitutes 90%, SRB suppression extent - 97%. At the same time as a result of reagent influence on productive layer oil production has increased in average by 11%.

4. The alternation of various concentrations during the periodic injection of this reagent solves the corrosion protection problems of oilfield equipment of the MLP system and the displacement of residual oil from the oil-bearing layers without additional costs.

5. Application of this reagent possessing oil extrusion ability, bactericidal and inhibiting properties, is represented economically expedient as the technology of its obtaining is quite simple. Moreover, the prime cost is low because of the usage of available local raw materials.

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МИКРОЭМУЛЬСИЯНЫҢ ҚАСИЕТТЕРІНЕ ИЕ КӨПФУНКЦИОНАЛДЫ КОРРОЗИЯ ИНГИБИТОРЫН ӘЗІРЛЕУ

Аннотация. Әзірбайжан кен орындарында қабатқа әсер етудің басым түрде қолданылып келе жатқан әдістерінің бірі – қабаттық қысымды сүйемелдеуді (ҚҚС) қысымдарға айдау ұңғымаларының жүйесі арқылы су айдаумен ұстап тұру. ҚҚ жүйесіндегі микробиологиялық коррозияны тудыратын зақымданудың негізгі

себебі – алдын ала стерилизациялаусыз теңіз суын айдау, және соның салдарынан құбырлардың коррозиялық бұзылуы көрініс табады. Биокоррозды қоздыратын бактериялардың ішіндегі ең агрессивтісі – сульфатты қалпына келтіруші бактериялар (СҚҚБ).

Пайдалану ұңғымаларының кенжар маңы аймағының өткізгіштігін арттыру және айдау ұңғымаларының қабылдағыштығын жақсарту үшін қабатқа әсер ету әдістерінің бірі – микроэмульсияны пайдалану, ал ол, әдетте қабатқа қайту түрінде айдалады.

Қазіргі проблеманың өзектілігін ескере отырып, нафтен қышқылы тұздары, изопропил спирті, жеңіл газойл фракциясы және техникалық гидратталған фосфатид негізінде микроэмульсия қасиеттеріне ие және қабаттарда өтетін түрлі процестерге әсер ететін жаңа біріктірілген бактерицид-ингибитор әзірленді.

Зертханалық жағдайларда реагенттің ингибициялаушы және бактерицидтік қасиеттерін зерттеу стандарттарға сәйкес жүзеге асырылды.

Зертханалық жағдайларда ингибитордің тиімділігін анықтау гравиметриялық әдіспен жүзеге асырылды. Реагентті әртүрлі концентрацияларда (100-600 мг/л) сынау қышқыл және сілтілі ортада жүргізілді. 100-600 мг/л концентрациясындағы реагенттің бактерицидтік қасиеттерін анықтау СҚҚБ дақылында жүргізілді. Зерттеулер 500 мг/л оңтайлы концентрациясы кезінде реагенттің қорғаныш әсері – 94-96 %-ды, ал СҚҚБ басу дәрежесі 99 %-ды құрағанын көрсетті.

Зертханалық жағдайларда реагенттің түрлі концентрациялардағы мұнайдың тұтқырлығына және мұнайға әсері зерттелді. Реагенттің оңтайлы концентрациясы 500 мг/л болғанда, мұнайдың динамикалық тұтқырлығы 3 есе төмендейді, бұл 67 %-ды құрайды. Қабаттың желілік моделінде жүргізілген зерттеулер әзірленген микроэмульсияның 10 %-дық концентрация кезінде қабаттық суды салыстырмалы ығыстыру коэффициентін 16 %-ға арттыратынын көрсетті. Бұл жағдайда өте тұтқыр мұнайдың реологиялық қасиеттері жақсарып, жыныстың бетін суландыруға байланысты, мұнайдың жыныспен байланысы азаяды, сондай-ақ қабатта мұнайдың жылжуы жақсарып және пайдалану ұңғымаларына айдалатын судың ағуы азаяды.

Сонымен, зертханалық зерттеулер реагенттің аз концентрациялардағы коррозия ингибиторы ретінде қолданылуы мүмкін екендігін көрсетті, ал жоғары концентрациялар кезінде жыныстардың өткізгіштігін арттыру есебінен мұнайдың қысылуын ынталандырады.

Әзірленген реагенттің кәсіптік сынағы «Бибиэйбат-нефть» МГӨБ-да ҚҚС жүйесінде жүргізілді. Алдымен, мұнайдың қысылуын арттыру және қабатқа соққы дозасымен бактерицидті өңдеу жүргізу үшін реагенттің 10 %-дық ерітіндісінің (микроэмульсияның) 25 кеуектік көлемі айдалды, содан кейін реагентті 500 мг/л жұмыс концентрациясында айдау жалғастырылды.

Коррозия жылдамдығын анықтау үшін 1020 болаттан жасалған болат үлгілер ұңғымаға айдалатын суды беретін су өткізгіштерде орналасқан инертті материалдардан жасалған кассеталарға орнатылды.

Бактерицид-ингибитордың қорғаныш әсерін анықтау зертханада болат үлгілердің массасының жоғалуы бойынша гравиметриялық әдіспен жүргізілді.

Реагенттің бактерицидтік қасиеттерін зерттеуде химиялық және микробиологиялық талдау үшін қабаттық су қатар алынды.

Кәсіпшілік сынақтар 500 мг/л концентрациясы кезінде, реагенттің қорғаныш әсері 90 %-ды, ал СҚҚБ басу дәрежесі – 97 %-ды құрағанын көрсетті.

Сондай-ақ реагенттің өнімді қабатқа әсері нәтижесінде тиісті мұнай өндіру ұңғымаларында мұнай өндіру орташа есеппен 11 % - ға артқанын атап өту қажет.

Осылайша, әзірленген көпфункционалды реагент жалпы және микробиологиялық коррозиядан ҚҚС жүйесінің жер асты және жер үсті мұнай кәсіпшілігі жабдығын қорғау үшін ұсынылған. Бұл ретте реагент бұрғылау, мұнайды жинау, қабылдау және айдау үшін болат резервуарларды пайдалану кезінде, сондай-ақ қабаттардағы мұнайдың қысылуын жақсарту үшін қолданылуы мүмкін.

Түйін сөздер: коррозия, бактерицидті ингибитор, қорғаныс деңгейі, басу дәрежесі, мұнай өндіруді арттыру, қабатты қысымын сүйемелдеу.

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РАЗРАБОТКА МНОГОФУНКЦИОНАЛЬНОГО ИНГИБИТОРА КОРРОЗИИ, ОБЛАДАЮЩЕГО СВОЙСТВАМИ МИКРОЭМУЛЬСИИ

Аннотация. Одним из доминирующих методов воздействия на пласт, применяемых на месторождениях Азербайджана, остается поддержание пластового давления (ППД) закачкой в пласт воды через систему нагнетательных скважин. Основной причиной повреждений в системе ППД является коррозионное разрушение трубопроводов вследствие нагнетания морской воды без предварительной стерилизации, которое вызывает

микробиологическую коррозию. Наиболее агрессивными среди бактерий, стимулирующих биокоррозию, являются сульфатвосстанавливающие бактерии (СВБ).

Одним из методов воздействия на пласт для повышения проницаемости призабойной зоны эксплуатационных скважин и улучшения приемистости нагнетательных скважин является использование микроэмульсии, которая обычно закачивается в пласт в виде оторочки.

Учитывая актуальность существующей проблемы, на основе солей нафтеновых кислот, изопропилового спирта, легкой газойлевой фракции и технического гидратированного фосфатида разработан новый комбинированный бактерицид-ингибитор, обладающий свойствами микроэмульсии и оказывающий влияние на различные процессы, протекающие в пластах.

Изучение ингибирующих и бактерицидных свойств реагента в лабораторных условиях осуществлялось согласно стандартам.

Определение эффективности ингибитора в лабораторных условиях осуществлялось гравиметрическим методом. Испытания реагента в различных концентрациях (100-600 мг/л) проводили в кислых и щелочных средах. Определение бактерицидных свойств реагента в концентрации 100-600 мг/л проводилось на культуре СВБ. Исследования показали, что при оптимальной концентрации 500 мг/л защитный эффект реагента составил 94-96%, а степень подавления СВБ -99%.

В лабораторных условиях изучалось также влияние реагента в различных концентрациях на вязкость нефти и нефтевытеснение. При оптимальной концентрации реагента 500 мг/л динамическая вязкость нефти снижается в 3 раза, что составляет 67%. Исследования, проведенные на линейной модели пласта показали, что разработанная микроэмульсия при 10% концентрации увеличивает коэффициент вытеснения относительно пластовой воды на 16%. Это происходит за счет того, что улучшаются реологические свойства высоковязкой нефти, уменьшается связь нефти с породой в связи со смачиванием поверхности породы, а также улучшается продвижение нефти в пласте и уменьшение прорыва закачиваемой воды к эксплуатационным скважинам.

Итак, лабораторные исследования показали, что реагент в малых концентрациях может использоваться как ингибитор коррозии, а при высоких концентрациях стимулирует нефтевытеснение за счет увеличения проницаемости пород.

Промысловые испытания разработанного реагента проводились в системе ППД в НГДУ "Бибиэйбат-нефть". Сначала для повышения нефтевытеснения и проведения бактерицидной обработки пласта ударной дозой было закачено 25 поровых объемов 10% раствора реагента (микроэмульсии), а затем продолжена закачка реагента уже в рабочей концентрации 500 мг/л

Для определения скорости коррозии стальные образцы-свидетели из стали 1020 устанавливались в кассетах из инертных материалов, расположенных в водоводах, подающих нагнетаемую воду в скважину.

Определение защитного действия бактерицид-ингибитора проводилось в лаборатории гравиметрическим методом по потере массы стальных образцов.

Для изучения бактерицидных свойств реагента параллельно была взята пластовая вода для химического и микробиологического анализов.

Промысловые испытания показали, что защитный эффект реагента при концентрации 500 мг/л составил 90%, а степень подавления СВБ - 97%.

Необходимо также отметить, что в результате воздействия реагента на продуктивный пласт добыча нефти в соответствующих нефтедобывающих скважинах увеличилась в среднем на 11% .

Таким образом, разработанный многофункциональный реагент рекомендован для защиты подземного и наземного нефтепромыслового оборудования системы ППД от общей и микробиологической коррозии. При этом реагент может найти применение при бурении, эксплуатации стальных резервуаров для сбора, приема и откачки нефти, а также для улучшения нефтевытеснения в пластах.

Ключевые слова: коррозии, бактерицидный ингибитор, степень защиты, степень подавления, увеличение добычи нефти, поддержание пластового давления.

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INVESTIGATION OF POWER AND FORCE PARAMETERS OF PRESSING OF PRECISIONS AT THE CONTINUOUS PRESSING MILL OF NEW CONSTRUCTION

Abstract. In the article, by using the direct method in the calculus of variations, the mechanism of deformation force development in the matrix, when pressing rods in a new device with is considered, in addition the kinematics of the process is analytically analyzed and the forces acting on the screw-like rolls of this device are calculated. On the basis of the calculated data, it is established that the pressing stress decreases with increasing torques applied to the screw-like rolls of the proposed device. It is proved that with increasing the value of the input angle of the matrix, the forces and the pressing torque are increased. It is shown that the direction of friction forces exerts a significant influence on the pressing stress. The smallest force and the pressing torque are obtained with an angle of friction forces of 45°. The conducted researches made it possible to obtain new scientific data on the force parameters of rod pressing on a new device, and the practical application of the results of the study will ensure an increase in the efficiency of the manufacturing processes of bar products.

Key words: force, torque, contact pressure, screw-like rolls, matrix, kinematics process, rod, workpiece.

Introduction. Non-ferrous metals are used to produce a wide range of products, in which an important place is occupied by solid and hollow profiles of various configurations. The technology of their production at most factories in the CIS countries differs by the discreteness of the operations of melting, casting, cutting ingots, heat treatment, pressing, and the equipment used is of great energy and metal consumption, it requires considerable production areas, which ultimately raises production costs [1,2,3]. In this regard, the task of increasing the production efficiency of non-ferrous metal profiles is one of the most important and urgent.

The specialists of the countries of the near and far abroad have developed and introduced into the industry aggregates of continuous casting and pressing [4,5,6]. Continuous casting and pressing of non-ferrous metals, allow to increase technical and economic indicators of manufacturing small-scale products in comparison with traditional pressing on horizontal hydraulic presses. Work on the solution of this problem is stimulated by the creation and widespread use in recent years of methods for the continuous pressing of non-ferrous metals, Conform, Extralling, Linex, combined rolling-pressing (CRP).

Based on the above technical solution, the Springfield laboratory and the Advanced Metal Forming Group under the UKAEA UK Nuclear Power Authority developed a continuous pressing line [6,7]. The advantages of the line are the following: high quality of press products, relatively low production costs; low specific capital costs; a small amount of technological waste (3-7% instead of 25-45% of traditional waste); great technological flexibility. Currently, installations using the Konfo method of pressed products are manufactured by the British firms «HoltonMachinery» and «BabcockWireEquipment».

The advantages of these methods include the possibility of welding the metal in the deformation zone, the simplicity of the kinematic scheme, high technological flexibility due to the rapid tool change, deformation does not require heating to high temperatures, since during the forming process, heat is generated that ensures high plasticity of the metal [8,9]. Continuous pressing according to the «Conform» method allows obtaining high quality and accuracy of geometric dimensions of finished products without additional processing, almost full use of the material of the workpiece due to the absence of a press residue, a significant reduction in capital investments during construction and energy consumption during operation.

Analysis of known device [10,11,12] for implementing the «Conform», «Extrolling», «Linex» method made it possible to identify their shortcomings, imposing limitations and creating difficulties in practical implementation: the cross-section of the workpiece must correspond exactly to the cross section of the channel (otherwise the active friction forces will not be sufficient for pressing); the amount of active frictional forces can not be adjusted and, as a rule, considerably exceeds the required value, which leads to an unjustifiably large expenditure of energy; using the Conform method leads to a strong heating of the deforming tool and, as a consequence, to a decrease in its durability; properties of press products are characterized by heterogeneity due to uneven deformation due to the creation of reactive frictional forces at the metal-press junction (shoe), which is not entirely acceptable, for example, for electrical products.

It should be noted that most of the above methods have not been properly applied in industry, since the proposed technical solutions did not ensure a steady flow of the process and create pressures necessary for metal extrusion. At the same time, powerful shear deformations of the metal are not developed along the workpiece cross-section, which does not create the conditions for a good study of the structure of the metal and an increase its properties.

On the basis of the foregoing, it can be concluded that the development of a radial-shear mill (RSM) for pressing rods and tubes is currently very acute, which makes it possible to produce high-quality non-ferrous metal products.

The main task of this work is to study the energy-force parameters of the rod deformation process in a continuous-pressing mill of a new design.

Materials and method of the experiment. In this paper, we propose a new combined method for pressing rods and tubes [13].

The device for continuous pressing of rods and pipes comprises a main drive, a work stand, rolls rotating in different directions and a die. The rolls have smooth and undulating cone-shaped gripping and crimping portions, respectively, and calibrating cylindrical portions. In this case, the protrusions or valleys of the rolls, having the same width and correspondingly the same height or depth, are made along a helix with an angle between the tangent to the helical line and a line passing through the point of tangency along the generatrix perpendicular to the base of the roll equal to 45 to 60°.

Analysis of the literature review [14] and practical experience of enterprises producing bar products showed, that the study of the power parameters in the «roll-harvesting» system will allow to reveal the most loaded local surfaces of the tool and to develop measures to reduce the force and increase the tool's durability. The results of the research will allow developing new technical measures to reduce the effort and increase the durability of the roll and determine the time of its replacement.

In the proposed method of continuous pressing, the extrusion of metal through the die aperture is effected by contact friction of the rotating screw-like rolls formed on the contact surface and by the deformable bar stock. In this regard, the value of the contact area of the workpiece with the tool is largely determined by the pressing pressure, the torque in the screw-like rolls and the power of the electric drive of the installation, etc. When a bar stock is grasped by two (three) rotating rolls, it is crimped and moved along the rolls due to rotational and translational motion. After this, the protrusions and hollows of the helical rolls is completely filled with a metal, and the contact area between them grows until the active friction force reaches a value sufficient to extrude the metal into the channel of the matrix.

Therefore, in the initial stage of deformation the gripping zones should provide the pressure necessary to completely fill the protrusions and hollows of the helical rolls and create pressure for metal extrusion.

As noted above, when pressing the bars, due to the creation of insufficient pressure to extrude the metal and the poor quality of the products due to surface defects and the appearance of cracks on the surface of the workpiece, problems may arise. One of the reasons of the reduction in pressure and surface defects is the slippage of the working surface of the rolls relative to the compressible workpiece.

To describe the mechanism of deformation force development during pressing by screw-like rolls, moved rotationally, we consider the theoretical solution of such a problem by the method of direct calculus of variations [15]. Due to the rotation of the helical rolls, to the pressed workpiece, a torque M is applied and it is counterbalanced by the moment of tangential frictional forces on the contact surface of the matrix (figure 1).

In a new device for the continuous deformation of metal bars, flow is obtained during the pressing process with a rotationally moving screw-like roller. In this case, the metal of the billet gives a rotational-translational motion due to protrusions and depressions located along the helical lines on the working surface of rotationally moving rolls. Therefore, we divide the pressing stress into two components. The first component creates a torque, promotes the flow of metal along the helix, and the second - acts along the axis of pressing.

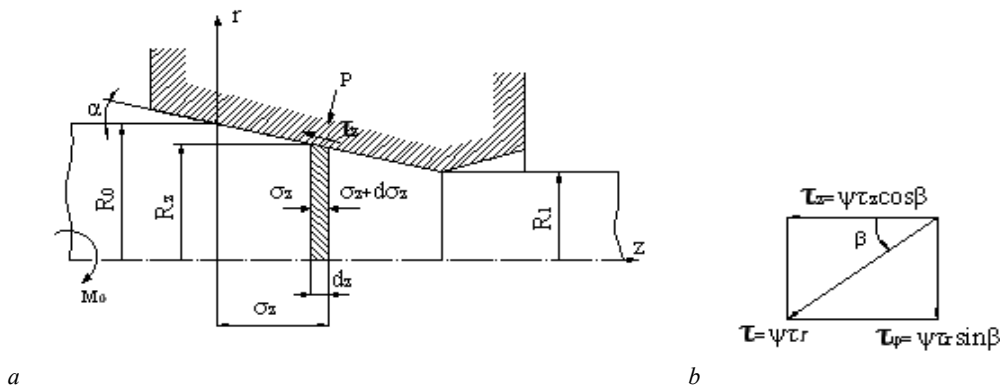


Figure 1 – Scheme to determine the pressing pressure of a workpiece with torsion:
 a – scheme of the pressing process; b – scheme of friction stress vector decomposition

Bring in a cylindrical coordinate system with the z -axis along the pressing axis. Suppose that the frictional law is given on the contact surface in the form $\tau_i = \psi \tau_T e_i$, where e_i is the directing cosine of the unit vector, determining the directions of the frictional stress; ψ is some function that depends on the ratio of the dimensions of the deformation center and the state of rubbing surfaces ($1 \leq \psi \leq 0$).

In an arbitrary section of the deformation center, the torque acts (figure 1 a, b)

$$M = M_o - \int_0^{2\pi} \int_0^z \tau_\varphi R_z^2 d\varphi dz = M_o - \frac{2\pi}{3\sqrt{3}} \cdot \frac{\psi \sigma_T \sin \beta}{a} \left[1 - \left(\frac{R_o - za}{R_o} \right)^3 \right]. \tag{1}$$

The notation: $tg\alpha = a$, $R_z = R_0 - za$. The angle β determines the direction of friction forces acting on the contact surface.

The equation of equilibrium of the elementary layer, shaded in figure 1, has the following form:

$$(R_0 - z\alpha) \frac{d\sigma_z}{dz} + 2\sigma_z a - 2ap - \frac{2}{\sqrt{3}} \psi \sigma_T \cos \beta = 0. \tag{2}$$

Under the assumptions $\sigma_\varphi = \sigma_r$, $\tau_{rz} = 0$, $\tau_{\varphi r} = 0$. The plasticity condition can be written in the form:

$$(\sigma_z - \sigma_r)^2 + 3\tau_{\varphi z}^2 = \sigma_T^2$$

or after expansion in a power series with respect to $\tau_{\varphi z}^2 / \sigma_T^2$

$$\sigma_r = \sigma_z - \sigma_T \left(1 - \frac{3}{2} \frac{\tau_{\varphi z}^2}{\sigma_T^2} \right). \tag{3}$$

As in [15], in expression (3), it was restricted to two terms of the expansion. Assume that:

$$\tau_{\varphi z} = \frac{3}{2\pi} \left\{ \frac{M_0}{(R_0 - za)^3} - \frac{2\pi \psi \sigma_T \sin \beta}{\sqrt{3} a} \left[\frac{1}{(R_0 - za)^3} - \frac{1}{R_0^3} \right] \right\} \quad (4)$$

Taking $\sigma_r = p$, then the equation (2), taking into account expression (3), can be rewritten in the form:

$$(R_0 - za) \frac{d\sigma_z}{dz} + 2a\sigma_T \left(1 - \frac{3 \tau_{\varphi z}^2}{2 \sigma_T^2} \right) - \frac{2}{\sqrt{3}} \psi \sigma_T \cos \beta = 0. \quad (5)$$

Substituting equations (4) into expressions (5), after integration the stresses σ_z were obtained. Then, for the pressing stress the following equation was established:

$$\begin{aligned} p_{\text{BK}} = \sigma_z \Big|_{z=\frac{R_0-R_1}{a}} = \sigma_T \left[\frac{\varepsilon}{2} \left(\frac{27}{4\pi^2} K^2 \sin^2 \beta + \frac{3}{\pi} K \cos \beta - 2 \right) + (e^{3\varepsilon} - 1) \right] \times \\ \times \left(\frac{3}{32} m^2 - \frac{9}{2\sqrt{3}\pi} mK \sin \beta + \frac{9}{8\pi^2} K^2 \sin^2 \beta \right) + (e^{1.5\varepsilon} - 1) \times \\ \times \left(\frac{mK}{2\sqrt{3}\pi} \sin \beta - \frac{K^2}{\pi^2} \sin^2 \beta \right) \frac{9}{4} \Big], \end{aligned} \quad (6)$$

where $K = \frac{2\pi \psi}{3\sqrt{3} a}$; $\varepsilon = 2 \ln \frac{R_0}{R}$ – the draft for one pass; $m = \frac{M_0}{W_p \tau_r}$ – polar resistance of the initial section of the rod.

The value of β in the real state can be found by using the stationarity properties of the functional $I = \int_V \tau_T H^o dV - \int_S F_i v_i^o dS$ [6], where V is the deformable volume bounded by the surface S ; v_i^o – kinetic possible flow velocities; F_i – components of surface stresses; H^o – intensity of shear strain rates. In the case under analysis, the above functional reduces only to the surface integral (the deformed state does not vary). As a result, it is obtained:

$$\sin \beta = \frac{m e^{1.5\varepsilon} (e^{1.5\varepsilon} - 1)}{4 \frac{\psi}{a} \left[\varepsilon + \frac{(e^{1.5\varepsilon} - 1)^2}{3} \right]}.$$

On the basis of the calculated data, it was established that:

- the pressing stress decreases with the increase of the torque moments applied to the screw-like rolls of the proposed device;
 - with increasing angle α (figure 2) and coefficient k , the forces and the pressing torque are increased;
 - forces direction of the friction β has a significant influence on the pressing frictional forces stress.
- The smallest force and the pressing torque are obtained at an angle of friction forces of 45° .

According to our calculated data and the opinion of the authors of [16], the strength conditions of the process of continuous metal pressing are significantly influenced by the magnitude of the input angle of the matrix

The value of the input angle of the matrix α (figure 1) is determined from the expression (without taking energy costs into the calibrating belt) [16]:

$$N_o = N_f + N_\tau \quad (7)$$

At this value during pressing N_f the minimum specific energy for metal shaping is achieved, as well as the friction is overcome along the lateral surface of the matrix cone N_τ , if the first derivative of the functional energy at the input angle is equal to zero.

$$\frac{\partial N_o}{\partial \alpha} = 0. \quad (8)$$

As a result of the solution of expression (8), a formula of total power in the deformation center was obtained for continuous metal pressing [16]:

$$N_o = 2S_o v_o \tau_s \ln \left(\frac{R}{r} \left(\frac{2f_2}{\sin 2\alpha} + \frac{1}{27tg^2\alpha} \times \left((12 + 9tg^2\alpha)^{\frac{3}{2}} - 12^{\frac{3}{2}} \right) \right) \right), \quad (9)$$

where S_o – base area of the input cone of the matrix, $S_o = \pi R^2$, mm²; v_{np} – pressing velocity; v_o – longitudinal velocity component at the entrance to the deformation zone, $v_o = v_{np} / \pi R^2$, m/s; τ_s – average shear stress, $\tau_s = \sigma_s / \sqrt{3}$, MPa; σ_s – the yield strength of the metal in the deformation zone, MPa; f_2 – coefficient of friction along the lateral surfaces of the input cone of the matrix; R – radius of the base of the entrance cone of the matrix, mm; r – radius of the calibration hole of the matrix, mm.

Because of the transcendence of expression (9), the problem of finding the optimal value of the input angle α can be solved numerically. In [16], the software application MathCad was used to calculate the optimal value of the input angle α . The results of calculations of the optimal value of α at $r = 1.5$ mm; $R = 3$ mm; $v_{pr} = 0.15$ m/s; $\sigma_s = 70$ MPa and various friction coefficients are given in table 1. These values correspond to the minimum value of the power N_o . It can be seen from Table 1 that when $f_2 = 0.5$; $\alpha = 1.268$ rad; $\alpha = 72.7^\circ$.

Table 1 – Results of calculation [16]

	f_2									
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
N_o , kw	1.304	1.655	2.044	2.467	2.937	3.448	3.997	4.582	5.219	5.89
α , rad	0.923	1.079	1.167	1.225	1.268	1.301	1.327	1.348	1.366	1.381

When designing a device for continuous pressing of rods, it is important to determine the force parameters that arise when rolling in helical rolls to create the pressure necessary to extrude the metal through the matrix.

To determine the forces, acting on the rolls, it is necessary to know the area of the contact surface and the pressure of the rolled material. The width of the projection of the contact surface in an arbitrary section of the deformation center is [17]

$$b_i = \omega \sqrt{\frac{2rR_i \cdot \Delta r_i}{R_i + r_i}}, \quad (10)$$

where ω – coefficient of ovalization; r_i – billet radius in an arbitrary cross-section; R_i – radius of the roll in an arbitrary cross-section; Δr – compression of the workpiece in an arbitrary cross-section.

The reduction of the workpiece in an arbitrary cross-section can be determined from formula [17]:

$$\Delta r_i = \pi \left(\frac{D_H}{D_i} \right) \left(\frac{F_H}{F_i} \right) \left(\frac{\eta_o}{\eta_T} \right) r tg \beta_1 tg \alpha_1, \quad (11)$$

where r_i , D_i , F_i – radius of the workpiece, roll diameter, cross-sectional area of the workpiece in an arbitrary cross-section of the deformation zone; D_H , F_H – the diameter of the roll and the cross-sectional area of the workpiece at the input of the matrix; η_o , η_T – coefficient of axial and tangential billet speed, taking into account its slip along the surface of the rolls; β_1 , α_1 – the feed angle and the angle of inclination of the generator of the input cone to the rolling axis.

By dividing the total length of the deformation center (along the workpiece axis) by a number of segments ΔL_i , it is possible to calculate the area of the projection of the contact surface [17]:

$$F_K = \sum 0,5(b_i + b_{i+1}) \Delta L_i. \quad (12)$$

The average pressure of the helical rolling of a continuous billet can be determined by the formula A.I. Tselikov [17]:

$$p = 2\sigma_T [1,25 \ln(2r/b) + 0,62(b/L) - 0,25] \quad (13)$$

if $1 \leq 2r/b \leq 8.5$.

The torque that must be applied to each work roll to carry out pressing in the proposed device can be calculated by the formula [17]:

$$M = 0.5P(2r \sin \varphi_1 \cos \beta_1 + b_{av} \cos \varphi_1 \cos \gamma_1) \quad (14)$$

where $b_{av} = F_c/L$, F_c – contact area; L – the length of the contact surface; $\varphi_1 = \arctg(0.5b/r)$ – angle of deflection of the resultant roll; γ_1 – angle of rolling.

According to the calculated data, the contact pressure acting on the roll, when pressing a billet of carbon steel at a temperature of 1100 °C, is 80 - 130 MPa, and when pressing titanium alloys, is equal to 130 - 190 MPa.

Conclusion. The conducted research made it possible to obtain new scientific data on the force parameters of the rod pressing process on the new device, and the practical application of the results of the research will ensure an increase in the efficiency of the manufacturing processes of bar products.

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ҚҰРЫЛЫМЫ ЖАҢА ҮЗДІКСІЗ БАСПАҚТАУ ҚОНДЫРҒЫСЫНДА ШЫБЫҚТЫ ДЕФОРМАЦИЯЛАУДЫҢ ЭНЕРГИЯКҮШТІК ПАРАМЕТРІН ЗЕРТТЕУ

Аннотация. Жұмыста, әртүрлі елдердің мамандарымен біріге отырып, үздіксіз құю және баспақтау агрегаттарын өнеркәсіпке енгізілгені және жасап шығарылғаны көрсетілген. Түсті металдарды үздіксіз құю және баспақтау, көлденең гидравликалық пресстерде дәстүрлі баспақтаумен салыстырғанда, ұсақтұржынды өнімдерді дайындаудың техникo-экономикалық көрсеткіштерін жоғарылатуға мүмкіндік беретіні атап өтілген. Үздіксіз әдістерді қолдану, қосымша өңдеусіз жоғары сапалы және дәл геометриялық өлшемді өнім алуға мүмкіндік беретіні көрсетілген. Сонымен қатар, дайындаманың материалы толықтай пайдаланылады, пресс-қалдықтардың болмауынан, құрылыс кезінде күрделі салымдар және пайдалану кезінде энергияны тұтынуы айтарлықтай төмендейді. Мақалада, практикалық іске асыру кезінде қиындықтар мен кемшіліктер туындататын үздіксіз құю және баспақтаудың кемшіліктері де көрсетілген. Үздіксіз баспақтаудың кемшіліктеріне жататындар: құралдың канал қимасына, дайындама қимасының сәйкес келу дәлдігіне қойылатын талаптар; белсенді үйкеліс күштерінің мөлшерін түзету қиындықтары. Аталған кемшіліктер, үлкен энергия шығындарына, деформацияланатын құралдың қатты қызуына және нәтижесінде оның қызмет ету мерзімін төмендетуге әкелетіні көрсетілген. Баспа өнімдерінің қасиеттері, деформацияның біркелкі таралмауынан біртеқ-сізпен сипатталатыны анықталды. Осы кемшіліктерді жою үшін, жұмыста шыбықтар мен құбырларды үздіксіз баспақтауға арналған құрылғы ұсынылады. Бұл құрылғы, басты жетектен, жұмыс қапастарынан, әртүрлі бағытта айналатын біліктерден және пресс-ұяқалыптан тұрады. Біліктер, тегіс және толқынды-конус тәрізді қарпу және жаншу учаскелерінен, сәйкесінше калибрлеуші цилиндрлік учаскелерден тұрады. Мұнда біліктің бетінде, бұрандалы сызықпен орындалған, ойық пен шығыңқы жерлер, бірдей енге, осыған сәйкесті бірдей биіктікке иемденген. Осы кезде, бұрандалы сызыққа жанасатын сызық пен білік бетінің құрастырушысына перпендикулярлы жанасу нүктесі арқылы өтетін сызық арасындағы бұрыш 45-60°-қа тең. Шыбықтарды баспақтау келесідей. Дайындама, біліктер арасындағы саңылауға беріледі және біліктердің бір бағытқа айналуы кезінде, біліктердің толқынды-конус тәрізді шығыңқы бөліктері және ойықтарымен деформацияланады. Біліктер өздерінің айналмалы қозғалысымен, деформацияланатын металды қозғалтып, пресс-ұяқалыптың тесігі арқылы сығып шығарады. Мақалада тура вариациялық есептеу әдістемесімен айналып қозғалатын бұрандалы пішінбілігі бар жаңа қондырғыда шыбықтарды баспақтағанда ұяқалыпта пайда болатын деформациялау күшінің даму механизмі қаралған, ал тағы да аналитикалық тәсілмен осы қондырғының бұрандалы пішінбілігіне әсер ететін күш есептелген және процестің кинематикасы қаралған. Есептеліп алынған мәліметтер негізінде, ұсынылған қондырғының бұрандалы пішінбілігіне түсірілген айналдыру моментінің өсуімен баспақтау кернеуі азайатындығы анықталған. Осымен бірге, ұяқалыптың кіру бұрышының мәні үлкейген сайын баспақтаудың күші мен айналдыру моменті үлкейетіндігі дәлелденген. Баспақтау кернеуіне елеулі әсерді, үйкеліс күшінің әсер ету бағыты көрсететіндігі жұмыста көрсетілген. Баспақтаудың ең аз күші мен айналдыру моменті, үйкеліс күшінің әсер ету бағытының бұрышы 45°-тең болғанда пайда болатындығы анықталған. Жүргізілген зерттеулер жаңа қондырғыда шыбықтарды баспақтау процесінің күштік параметрлері туралы жаңа мәліметтерді алуға мүмкіндік берді, ал алынған зерттеу мәліметтерін

практикада қолдану, шыбық тәрізді бұйымдарлы жасау процестерінің нәтежелігін жоғарлатуды қамтамасыз етеді.

Түйін сөздер: күш, айналдыру моменті, жанау кысымы, бұрандалы пішінбілік, ұяқалып, процестің кинематикасы, шыбық, дайындама.

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ИССЛЕДОВАНИЕ ЭНЕРГОСИЛОВЫХ ПАРАМЕТРОВ ПРЕССОВАНИЯ ПРУТКОВ НА УСТАНОВКЕ НЕПРЕРЫВНОГО ПРЕССОВАНИЯ НОВОЙ КОНСТРУКЦИИ

Аннотация. В работе показано, что специалистами различных стран разработаны и внедрены в промышленность, агрегаты непрерывного литья и прессования. Отмечено, что непрерывное литье и прессование цветных металлов, позволяют повысить технико-экономические показатели изготовления мелкосортной продукции, по сравнению с традиционным прессованием на горизонтальных гидравлических прессах. Показано, что применение непрерывных способов позволяют получить изделие высокого качества и точными геометрическими размерами без дополнительной обработки. При этом практически полностью используется материал заготовки, благодаря отсутствию пресс-остатка, значительно снижается капитальное вложение при строительстве и энергозатраты в процессе эксплуатации. В работе выявлены и недостатки агрегатов непрерывного литья и прессования, накладывающие ограничения и создающие сложности при практической реализации. К недостаткам непрерывного прессования отнесены: требования к точности совпадения сечения заготовки к сечению канала инструмента; трудность регулировки величины активных сил трения. Показано, что данные недостатки приводят к большим энергозатратам, к сильному разогреву деформирующего инструмента и, как следствие, к снижению его стойкости. Установлено, что свойства пресс-изделий характеризуются неоднородностью из-за неравномерности распределение деформации. Для преодоления этих недостатков в работе предлагается устройство для непрерывного прессования прутков и труб. Данное устройство содержит: главный привод, рабочую клетку, вращающиеся в разные стороны валки и пресс-матрицу. Валки имеют гладкие и волнисто-конусообразные участки захвата и обжатия, соответственно, и калибрующие цилиндрические участки. При этом выступы или впадины валков, имеющие одинаковую ширину и соответственно высоту или глубину, выполнены по винтовой линии с углом между касательной к винтовой линии и линией, проходящей через точку касания по образующей перпендикулярно основанием валка равным от 45° до 60°. Прессование прутков осуществляют следующим образом. Заготовка подается в зазор между валками и деформируется с выступами и впадинами волнисто-конусообразных участков валков при вращении валков в одном направлении. Валки своим вращательным движением поступательно двигают деформируемый металл и выдавливают их через отверстие пресс-матрицы. В статье методом прямого вариационного исчисления рассмотрен механизм развития усилия деформирования в матрице при прессовании прутков в новом устройстве с вращательно двигающимся винтообразным валком, а также аналитическим способом исследована кинематика процесса и рассчитаны усилия, действующие на винтообразные валки данного устройства. На основе полученных расчетных данных установлено, что напряжение прессования уменьшается с ростом крутящих моментов, приложенных к винтообразным валкам предлагаемого устройства. При этом доказано, что с увеличением значения входного угла матрицы увеличиваются усилия и крутящий момент прессования. Показано, что существенное влияние на напряжение прессования оказывает направление действия сил трения. Наименьшее усилие и крутящий момент прессования получены при угле направления действия сил трения, равном 45°. Проведенные исследования позволили получить новые научные данные о силовых параметрах прессования прутков на новом устройстве, а практическое применение результатов исследований обеспечит повышение эффективности процессов изготовления прутковых изделий.

Ключевые слова: усилие, крутящий момент, контактное давление, винтообразные валки, матрица, кинематика процесса, пруток, заготовка.

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DECISION SUPPORT SYSTEM FOR OPTIMIZATION OF RES GENERATORS PLACEMENT BASED ON GEOSPATIAL DATA

Abstract. The Republic of Kazakhstan has significant deposits of fossil fuels and Kazakhstan is one of the largest energy producers among the countries of Central Asia. At the same time, Kazakhstan has one of the highest renewable energy potential in the world, evaluated as 300 to 1000 billion kWh/year. Application of renewable energy sources both at industrial and household levels, provide the transformation of the energy system to a "green state". However, these initiatives should be substantiated by appropriate information maintenance in order to support the transformation of the country's economy to a higher quality environmental condition. The paper covers existing methods and software for processing of resource-invariant heterogeneous data which could be applied to evaluation of renewable energy. This work describes the multi-criteria decision support making system MIGIS (multi-criteria intellectual geoinformation system) which is aimed to provide evaluation of territory suitability for RES generators installation based on spatial data. The MIGIS architecture is based on the concept of independent data processors. We considered some technical issues addressed in the process of development. Examples the task of identifying locations favorable for the installation of energy generators executed by the system are presented.

Key words: decision making support methods, geo information systems, intelligent information technologies, renewable energy, spatially distributed resources.

Introduction. In Kazakhstan, over the past 15 years, there has been a large increase in the urban population, especially in Almaty, Astana, and Shymkent. The complex of problems of the city of Almaty, arising due to its intensive growth, is about the same as that of other major cities with some special features: air pollution, due to the location of the city in the center of a mountain area, and increased seismic activity. The air basin of the city is one of the most polluted.

According to https://www.numbeo.com/pollution/rankings_current.jsp. Almaty is on the 228th place in terms of pollution index among 273 registered cities. The city is ranked 173 in terms of cumulative quality of life.

Changes in the environmental indicators of the city and improving the quality of life in general require a change in the attitude of the population to environmental problems. Ecological culture and environmental protection are a necessary element of the systems Smart City and at the same time one of the important elements to be assessed in the system of social development of a person. Environmental initiatives related such as the usage of renewable energy in large energy systems, as well as at the level of a separate household, ensure the transformation of the energy system to a "green state". However, in the information society, these initiatives must be supported by appropriate informational support and systems that support the transformation of the country's economy to a much better ecological state and convenient for both industrial clients and individuals with "green thinking".

The largest settlements of the Republic of Kazakhstan are connected to the centralized energy supply. However, there are significant areas that do not have access to a unified energy system. For example, the entire territory of the Aktobe region, as well as remote villages in other areas are not connected to high-voltage magistral power lines. As a result, there is a need for the construction of additional distribution networks in these areas, as well as for autonomous power generation, including those on the basis of renewable energy sources (RES) for agricultural settlements and industrial enterprises, recreation facilities, distant pasture farms, and for areas with difficult environmental conditions [1].

These disproportions, as well as developed agricultural production, implying the presence of seasonal or year-round autonomous consumers of heat and electricity, makes the use of renewable energy systems in the republic relevant [2]. Note that Kazakhstan is one of the richest countries in the world in terms of renewable energy. The size of the gross potential of different types of renewable energy on the territory of Kazakhstan is estimated varying from 300 billion to 1 trillion kWh/year, including 0.929-1.820 billion kWh/year from wind energy, 2.5 billion kWh/year from solar energy, 170 billion kWh/year from hydro energy, and 150.6 billion kWh/year from biomass energy [3]. Of course, realization of the entire energy potential is impossible. Moreover, due to the high cost of energy generators based on renewable energy sources, it is necessary to optimize criteria when choosing a location for the installation of energy generators.

This paper discusses methods for developing solutions based on expert assessments (clustering approach) and briefly describes the system developed on its basis. Unlike the existing examples described in the literature, the proposed system is a generalization of the cluster approach, applicable to calculate the suitability of the location for installation of generators of different types even in case of lack of data.

The work consists of the following parts:

The first part is a brief review of the literature, which describes the current practice of assessing the potential of renewable energy sources, including, probably the only project implementing a classification for assessing of wind energy potential.

The second part describes the multi-criteria decision support system (MCDM) for assessing the potential of renewable energy sources.

The third part describes some of the results obtained by the MCDM geo information system MIGIS.

The conclusion describes the possible ways of developing of the system for evaluating various spatially distributed resources.

Practice of assessing the potential of renewable energy. For economically sound use of renewable energy, it is necessary to assess the potential and select the most optimal locations and methods for collecting and processing energy, including the choice of types of generators. Such an assessment usually includes three stages.

First, the potential of renewable sources is estimated. The assessment is multi-level and includes [4]: the calculation of the theoretical (gross) potential, the evaluation of the technical potential, depending on environmental parameters, efficiency of the generator, infrastructure, etc. At the last stage, the economic potential is estimated, taking into account as many factors as possible. Since RES is mostly dependent on geographic factors, an additional step was proposed in [5] – the assessment of the geographic potential of RES. Geographic potential is defined as part of the technical potential that is geographically available and necessary in a particular region (figure 1).

Secondly, an analysis of the factors associated with the use of renewable energy is performed. Such factors include geographical (natural, geomorphological, location factors [6]), environmental, technical, economic and social. In particular, recent studies show that the problem of utilization of generators [7], landscape and aesthetic limitations manifested in areas of mass recreation [8], etc. should be taken into account. Some factors may prohibit the use of renewable energy sources, for example, territories of national parks, geographically or geophysically unsuitable territories, etc. Other factors such as the availability of cheap renewable energy sources or high energy demand may contribute to the suitability of the territory for installation of generators (figure 2). Thirdly, since the majority of RES are geographically distributed, dependent on natural and anthropogenic factors, these resources are visualized usually using geoinformation systems (GIS) [9]. There are also examples of systems that support the interactive mode of calculating the available technical potential of renewable energy sources, for example, solar energy [10].

Gross potential of renewable energy is estimated in a number of works. For example, the atlas [11] describes the methods and results of calculations of natural resources and energy potentials of the sun, wind, small water flows, peat, biomass of agricultural waste, waste of timber and wood industries of Russia.

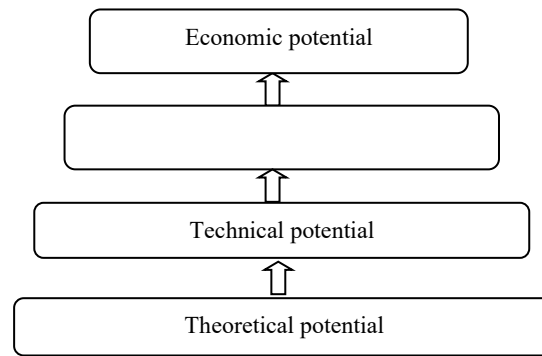


Figure 1 – Stages of the RES potential assessment

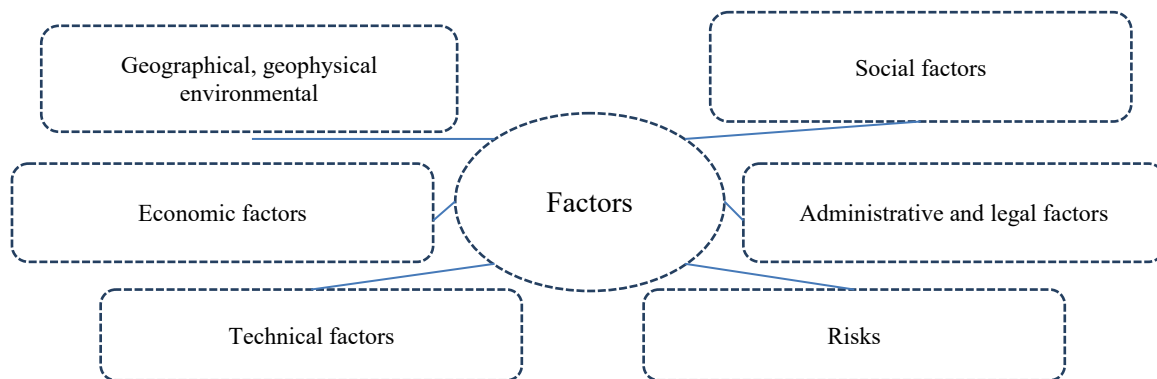


Figure 2 – Groups of factors affecting the installation of energy generators

Detailed calculation of the potential of renewable energy sources, including economic, on one of the regions of Spain is described in [12]. The potential of the forest biomass of Italy was studied in detail in [13], where all possible functions and scenarios of forest use are considered. The work [14] is an example of solving the problem of assessing the potential of renewable energy (solar and wind energy) for rural areas.

There are a number of examples of a detailed analysis of a territory that take into account, among other things, economic factors of the use of renewable energy sources [15,16].

A methodically close approach was applied in the dissertation work [17], where a combination of factors influencing the placement of energy generators was classified according to the degree of influence on decision making. A somewhat extended taxonomy of the factors mentioned is shown in figure 2.

Currently, a number of large scientific schools have been created that assess the potential of renewable energy sources and visualize them using web technologies in the USA (National Renewable Energy Laboratory - NREL) [18], Europe (European Commission for Renewable Energy [19]), Russia (GIS “Renewable energy sources in Russia” [20]), international level (International Renewable Energy Agency [21]). The preliminary work done in the Republic of Kazakhstan allowed us to offer a methodology for assessing the potential of renewable energy sources based on open data sources and specific methods of aggregating factors [22,23].

However, in order to successfully apply existing cartographic data, its additional analysis is required in order to assess the economic potential of renewable energy, and the systems described above implement only a part of the analysis related to a particular type of energy and to a specific territory. Combining the above-mentioned methods within a single system is necessary and useful for analyzing a territory from the point of view of different factors.

Multi-criteria decision support system for assessing the potential of renewable energy. The developed system (multi-criteria intellectual geographical information system - MIGIS) provides functions for storing, processing, visualizing and analyzing data. The system based on MCDM method BaFAHP [24]. The proposed software architecture is scalable in terms of functional and technical capabilities by adding new computing power and storage.

In the process of research and development of the system the following problems were taken into account:

1) The heterogeneity of data. This problem is related to both the data format and data sources. As for data formats, two fundamentally different forms of spatial data must be taken into account: vector and raster data, each of which has a number of different technical implementations. Data sources, in turn, provide data in different formats with different temporal and spatial resolutions.

2) Scalability. Since the system takes into account a large number of factors (up to 70) presented as high-resolution data, which need to be processed and analyzed separately, as well as aggregated together, significant computational power is necessary.

3) User base. The system should be developed for different users including researchers and enthusiasts, developers and business/industry.

These requirements must be met, while preserving the integrity of the security of the system, taking into account the various roles of access and permissions, as well as the ability to manage spatial data in different regions.

The main functionality of MIGIS is implemented using data processors (DP), the number of which is highly scalable. Although DP can perform any tasks, three categories of data processors can be distinguished:

Import data processors (IDP). Used to analyze data from any external sources, including files, external databases, API, etc.

Data Normalization Processors (NDP) Due to the heterogeneity of the data, it is difficult to suggest universal DP for normalization. Therefore, an extensible set of NDP is a feasible solution.

Data Aggregation Processors (ADP). The data obtained as a result of the work of IDP and NDP must be consolidated to obtain an assessment of the territory. Aggregation of data and factors can be performed on the basis of different mathematical models. Therefore, the extensible list of ADP will allow to expand the functionality of the system. The outcome of the MIGIS system is a set of maps linked to a geographic region (country, region, etc.).

Data and results. The developed system was used for a number of computational experiments for checking and analyzing the developed model of aggregation. Since aggregation requires normalized data, and the problem of normalizing heterogeneous data relies on expert judgment, the system was also used to visualize and analyze the proposed methods for normalizing and adjusting their parameters based on experimental results.

Figure 4 shows an example of several displayed layers, including vector layers (a map of railways and buildings) and raster (two layers with statistics of different daily wind speeds). Figure 3 also shows part of the system interface – a navigation panel on the left, which also to navigate through other system menus and panels, and also contains a list of regions, factor groups and layers.

Layers in figure 3:

Blue lines (vector) – railways.

Black dots (vectors) are polygons showing the locations of buildings.

The green and purple scale raster layer is a map showing the average number of days per year with wind speeds of less than 2 m/s and more than 10 m/s.

The ability to overlay different data allows you to simultaneously analyze several different factors.

In the current implementation, several sets of layers are loaded into the system, which are necessary for making decisions when deploying RES generators. The data includes:

– Layers of vector data from open source OpenStreetMap project. This data includes: the location of roads and railways, waterways, reservoirs, glaciers, buildings, and information from the land-use registry;

– NASA SSE (Solar Meteorology and Solar Energy) data layers — raster data, including average, maximum, minimum, and consistency statistics for solar radiation, air temperature, atmospheric pressure, humidity, and wind speed;

– Layers obtained by processing the source data.

Data loaded by IDP is normalized. Implemented NDP providing the following types of normalization: linear, threshold and threshold with linear interpolation (figure 4).

Aggregation. The aim of the system is to support decision-making in the area of installation of renewable energy generators in the form of aggregated layers (maps) indicating areas favorable for the installation of a specific energy collection system.

For data aggregation, two ADPs are currently implemented on the basis of a multiplicative model and a Bayesian algorithm using subjective probabilities estimated in the course of knowledge extraction from

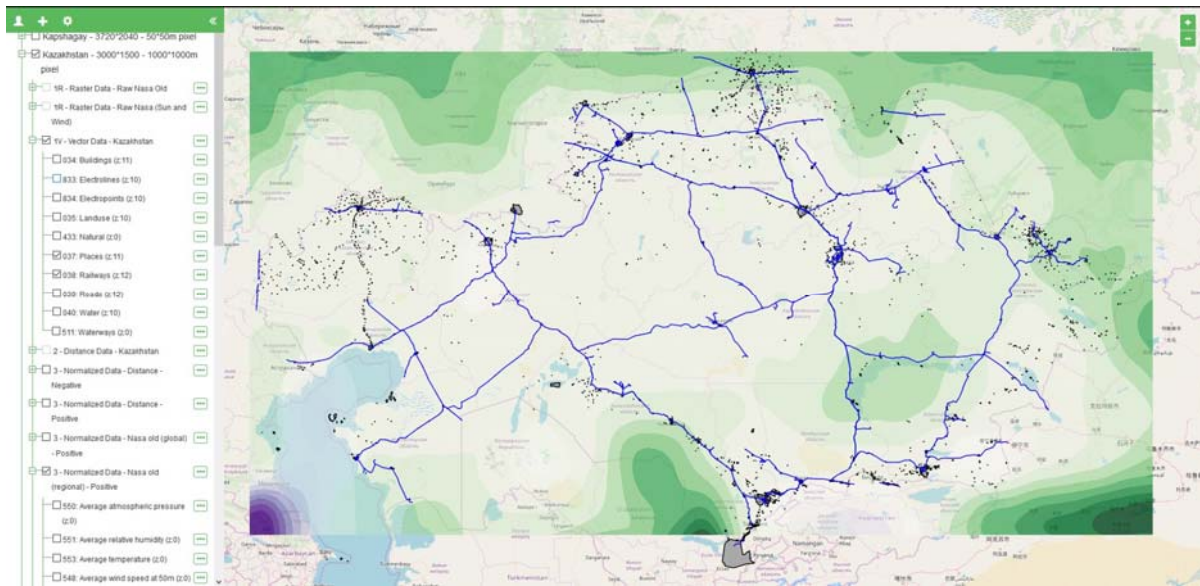


Figure 3 – Example of displaying multiple layers

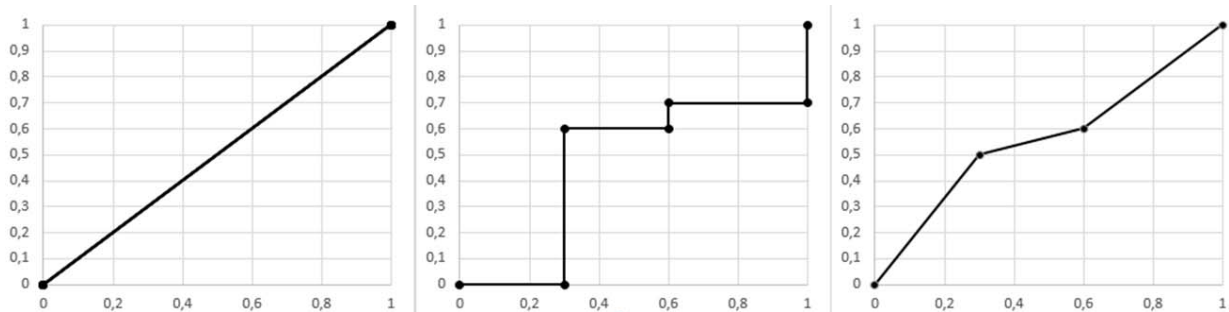


Figure 4 – Examples of the response function of the implemented normalization algorithms (linear, threshold and threshold with linear interpolation)

experts. The peculiarity of the Bayesian inference model is that it allows one to obtain not only a single value, but two subjective probabilities corresponding to the positive and negative hypotheses about the feasibility of installation of RES generator. In addition, the model works in the case when estimates of some factors are absent.

Figure 5 shows an example of the result of aggregation of factors using the developed algorithm based on the Bayesian model (Bayesian ADP) for the territory of Kazakhstan in the area between the cities of Almaty and Kapshagay. The factors affecting the theoretical feasibility of installing wind generators, in particular, the distance to buildings, power lines, electrical infrastructure, roads, water objects, data from the land use registry, the registry of national parks, reserves, data on the average wind speed at an altitude of 50m are considered. Green zones correspond to high values of the positive hypothesis (generator deployment is feasible), and red zones - negative (wind turbine deployment is not feasible or impossible).

Currently, with a given set of factors, the results of the algorithms can be used as a preliminary basis for decision making. For example, it is clear in which areas it is forbidden to deploy the generators. At the same time, the map shows some aggregated indicators of the total infrastructure and residential/commercial presence, taking into account roads, energy infrastructure and settlements. Figure 5 (right) shows a map of two hypotheses overlaid - positive (green) and negative (red), which is one of the features of the developed aggregation algorithm. At the same time, the values of these two hypotheses are not reduced to a simple inversion of the first to the second, and can be used independently in a detailed analysis of the territory.

The simplest way to verify the proposed model and the system implemented on its basis is to compare the locations of existing generators and the forecast that the model made. Figure 9 shows the locations of the wind - (left) and solar (right) power generators in the area of the Kapshagay reservoir (Kapshagay city). It can be seen that the existing power complexes are located in the green zones predicted by the system.

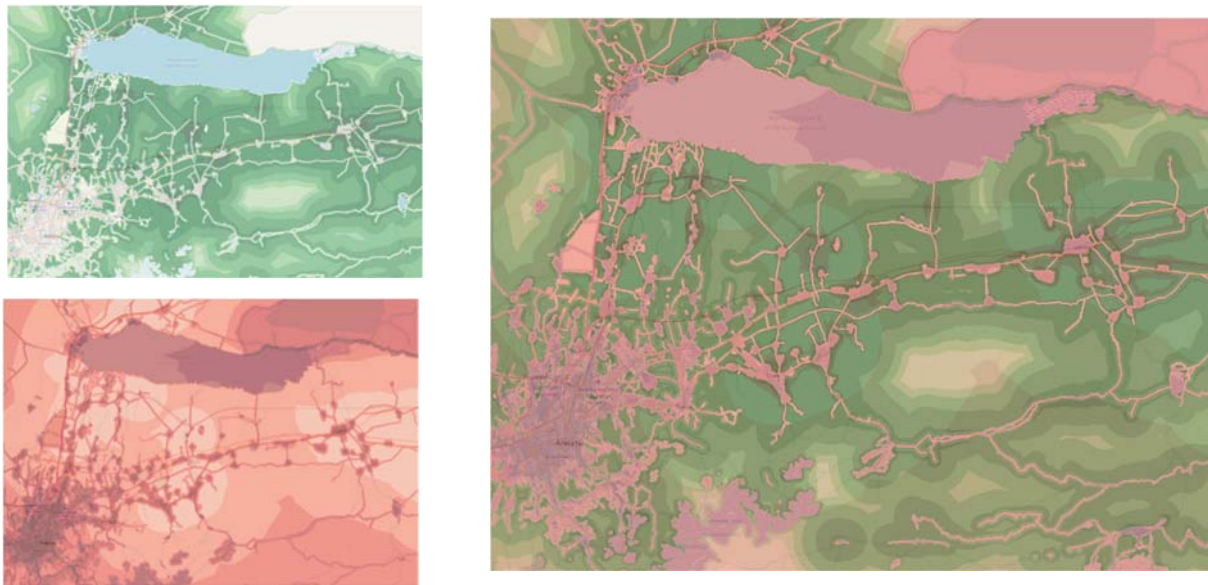


Figure 5 – Example of aggregation of criteria using the Bayesian model. Left: above - the result of the calculation for the "positive" hypothesis, below for the "negative". Right map is combining both hypotheses

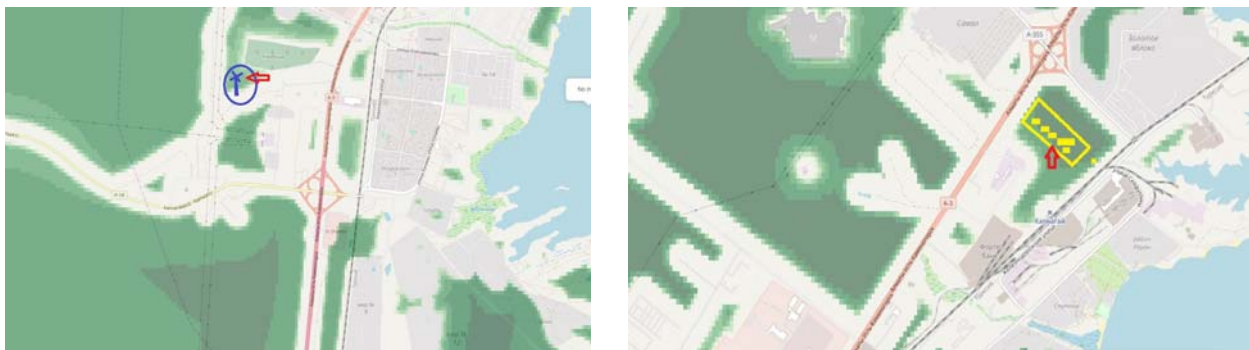


Figure 6 – Placement of wind and solar power generators in the area of Kapshagai (placement areas are marked by arrows) More detailed information about the operation of the system can be found at <http://migis.kz> (username "observer", password "migispassword").

Conclusion. Despite the great potential of renewable energy sources in Kazakhstan, it is a complex task to utilize it optimally. Therefore, it is necessary to choose places in the Republic where the use of RES would be most useful. Pure technical considerations are not enough for a detailed analysis of these areas, since the choice of location for the construction of energy generators is influenced by many different factors that must be evaluated and consolidated in a generalized assessment.

The paper presents a prototype of the multi-criteria decision support system MIGIS. The system allows assessing the suitability of the sites for the installation of RES generators using several methods of consolidating expert estimates and the gross energy potential (currently, two types of aggregation are used: the multiplicative method and the hybrid method using Bayesian output). The MIGIS architecture is based on a system of unified modules, which will make it relatively easy to increase functionality by adding data processors and aggregators.

Since the problem of decision-making, including the automatic allocation of resources and management, is becoming increasingly important, we can expect growth in scientific and industrial demand for systems like the MIGIS described above, designed to support decision-making in the analysis and assessment of spatially distributed resources.

The system architecture, based on the concept of independent data processors, allows the system to be expanded in terms of data sources, solving problems of calculating the energy potential on the basis of more accurate mathematical models and algorithms for consolidating estimates of various factors.

From the point of view of software and hardware implementation, the system is distributed (cloud) and modular. These features make it relatively universal both in terms of the data being processed and in terms of the functions implemented.

The system provides the ability to store-process heterogeneous data, extend processing power, parse data from external sources. The ability to build Data Processor cascades is supported.

The Bayesian model of inference, used to aggregate heterogeneous data, provides subjective probabilities of two hypotheses (pro and con). The model remains operable in case of incomplete data, when it is impossible to obtain estimates of some criteria. The accuracy of the forecast deteriorates, however, the model makes it possible to estimate this deterioration.

In our opinion, the implemented methods and models can be used to support decision making not only in the area of application of the RES, but also other types of spatially distributed resources [25].

The main problem in using the developed system in practice is low accuracy and general lack of the data. Some data obtained from open sources, for example, the values of incident solar radiation and wind speed from the NASA SSE database, are presented in a degree grid and averaged to monthly mean, which does not give a detailed idea of the spatial and temporal distribution of these characteristics. The data of the Open Street Map on Kazakhstan's infrastructure is not complete, and in case of water resources the data are erroneous. Therefore, one of the tasks of further research may be the task of creating more reliable arrays of initial data. The second task, the solution of which can improve the accuracy of recommendations, is the development of a system that combines decision support methods based on expert assessments and machine learning methods. In this context, a good example is the windcat.ch. project, in which, using deep learning on the data of currently installed wind generators, the suitability of territories for wind generators installation is predicted.

Despite the noted shortcomings, a comparison of the results obtained with the actual installation of the generators shows that the proposed model and the system developed on its basis are able to predict areas favorable for the placement of power generators based on RES. Evaluation of the accuracy of the forecast and its improvement is the task of further research.

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ҚОРШАҒАН ОРТА БОЙЫНША ЭНЕРГЕТИКАЛЫҚ ЖЕЛІЛЕРДІ ОРНАТУ ЖӨНІНДЕГІ ОПТИМАЛДЫ ПАЙДАЛАНУШЫЛАРДЫ ТАҢДАУ ТУРАЛЫ ШЕШІМ-ҚОЛДАНУ МҮЛІК-КРИТЕРИЯЛЫҚ ҚОЛДАУ ЖҮЙЕСІ

Аннотация. Қазақстан Республикасында қазба отынының елеулі кен орындары, сондай-ақ Орталық Азиядағы ең ірі энергия өндірушілердің бірі бар. Сонымен бірге, Қазақстан жылына 300-1000 млрд. кВт.сағ. деп бағаланатын жаңартылатын энергия көздері (ЭКЖ) бойынша әлемдегі ең бай елдердің бірі болып табылады. Жаңартылатын энергия көздерін кең ауқымда да, жеке үй шаруашылығында да қолдану энергия жүйесінің «жасыл» мемлекетке айналуын қамтамасыз етеді. Дегенмен, бұл бастамаларды еліміздің экономикасын сапалы экологиялық жағдайға айналдыруға қолдау көрсететін тиісті ақпараттық қолдау арқылы қолдау қажет. Жаңартылатын энергияны пайдалану мүмкіндігін бағалау үшін пайдаланылуы мүмкін ресурстық-инвариантты гетерогенді деректерді өңдеудің қолданыстағы әдістері және бағдарламалық қамтамасыз ету қарастырылған. ЭКЖ қолдану есебі жалпы, техникалық, географиялық және экономикалық потенциалдарды бағалау жолымен орындалатыны көрсетілген. Көптеген жағдайларда әзірлемелердің авторлары басқа елдердегі (Испания, Греция, АҚШ) жаңартылатын энергия генераторларын орналастыруға ықпал ететін және кедергі келтіретін факторлардың жиынтығын ескеретін шешімдер қабылдауды қолдаудың жергілікті жүйелерін қалыптастырады. Сонымен бірге, қалыптасқан практика мақала авторлары әзірлеген (ВаАНРФ) шешім қабылдауды көпкритериалды қолдаудың түпнұсқалық моделіне негізделі алатын ЭКЖ генераторларын орналастыру бойынша шешім қабылдауды қолдаудың әмбебап жүйесін ұсынуға мүмкіндік береді, біріншіден, екі баламалы гипотезаны қарауға және екіншіден, ақпараттың жетіспеушілігі жағдайында

жұмыс істеуге мүмкіндік береді. Бұл ретте, осыған басқа елдерден айырмашылығы Қазақстан үшін ЭЖЖ-нің үлкен жалпы потенциалымен қатар, халықтың тығыздығы төмен және жергілікті географиялық және геофизикалық жағдайлар туралы ақпараттың жетіспеушілігі бар орасан зор аумақтар тән. Ұсынылған модель айтыла өткен кемшіліктерді біршама дәрежеде жеңуге мүмкіндік береді. Осы негізде жасалған көп критерийлік зияткерлік геоақпараттық жүйе көп критерийлерді шешуге қолдау көрсету жүйесі сипатталған. Тәуелсіз дербес деректер процессорларының тұжырымдамасына негізделген MIGIS архитектурасы қарастырылып, даму үдерісінде шешілген кейбір техникалық мәселелер қарастырылады және жүйе жұмысының мысалдары энергия генераторларын орнату үшін қолайлы жерлерді анықтау міндеттерінде беріледі. Леспелі географиялық, геофизикалық және экономикалық ақпараттың жетіспеушілігіне байланысты осындай жүйелерге тән шектеулер айтылған. Алдағы зерттеулерде аймақты жіктеуді орындауға мүмкіндік беретін Машиналық оқыту әдістерін қосымша қолдану ұсынылды.

Түйін сөздер: шешімдерді қолдау әдістері, геоақпараттық жүйелер, зияткерлік ақпарат технологиялары, жанартылатын энергия, кең таралған ресурстар.

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СИСТЕМА ПОДДЕРЖКИ ПРИНЯТИЯ РЕШЕНИЙ ДЛЯ ВЫБОРА ОПТИМАЛЬНЫХ МЕСТ УСТАНОВКИ ГЕНЕРАТОРОВ ЭНЕРГИИ НА БАЗЕ ВИЭ

Аннотация. Республика Казахстан имеет значительные месторождения ископаемых видов топлива, а также является одним из крупнейших производителей энергии в странах Центральной Азии. В то же время Казахстан является одной из самых богатых стран мира с точки зрения ресурсов, возобновляемых источников энергии (ВИЭ), оцениваемых в 300-1000 млрд кВтч в год. Применение ВИЭ как в крупном масштабе, так и на уровне отдельного домовладения обеспечивают трансформацию энергетической системы к "зеленому состоянию". Однако эти инициативы должны подкрепляться соответствующим информационным обеспечением, обеспечивающим поддержку трансформации хозяйства страны к высокому экологическому состоянию. Рассматриваются существующие методы и программные средства для обработки ресурсоинвариантных гетерогенных данных, которые могут быть применены для оценки возможностей использования возобновляемой энергии. Показано, что расчет применимости ВИЭ выполняется путем оценки валового, технического, географического и экономического потенциалов. В большинстве случаев авторы разработок в других странах (Испания, Греция, США) формируют локальные системы поддержки принятия решений, учитывающих совокупность факторов, способствующих и препятствующих размещению генераторов возобновляемой энергии. Вместе с тем, сложившаяся практика позволяет предложить универсальную систему поддержки принятия решений по размещению генераторов ВИЭ, которая может базироваться на оригинальной модели многокритериальной поддержки принятия решений, разработанной авторами статьи (ВаАНРФ), позволяющей, во-первых, рассматривать две альтернативные гипотезы и, во-вторых, работать в условиях недостатка информации. При этом, в отличие от других стран для Казахстана, наряду с большим валовым потенциалом ВИЭ, характерны огромные территории с низкой плотностью населения и недостаток информации о местных географических и геофизических условиях. Предложенная модель позволяет в некоторой мере преодолеть указанные недостатки. Описывается разработанная на этой основе многокритериальная система поддержки принятия решений MIGIS (multi-criteria intellectual geoinformation system), обеспечивающая оценку территории с точки зрения установки генераторов энергии использующих ВИЭ. Рассмотрена архитектура MIGIS, основанная на концепции независимых процессоров данных, освещены некоторые технические вопросы, решенные в процессе разработки, приведены примеры работы системы в задаче выявления мест благоприятных для установки генераторов энергии. Упомянуты ограничения, присущие такого рода системам, которые связаны с недостатком сопутствующей географической, геофизической и экономической информации. В дальнейших исследованиях предложено дополнительно использовать методы машинного обучения, которые позволяют выполнить классификацию территории.

Ключевые слова: методы поддержки принятия решений, геоинформационные системы, интеллектуально-информационные технологии, возобновляемая энергия, пространственно распределенные ресурсы.

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COMPLEX EVALUATION OF GEODYNAMIC SAFETY IN THE DEVELOPMENT OF HYDROCARBON RESERVES DEPOSITS

Abstract. The article is devoted to the study of geodynamic processes occurring during the development of hydrocarbon deposits in the western region of Kazakhstan.

To perform the work, an integrated research method was used, including: conducting repeated geodetic observations of the deformations of the undermined areas with the help of modern geodetic instruments; assessment of the influence of various factors on the process of subsidence of the earth's surface by theoretical calculation of the subsidence of the roof of the reservoir; taking into account the influence of the intensity of development of deposits on the displacement of the earth's surface; conclusions on the nature of geodynamic processes in the territory under consideration.

Innovative methods of conducting geodynamic monitoring using modern geodetic instruments have been substantiated and proposed, which makes it possible to increase the reliability of determining the parameters of the earth's subsidence in order to ensure maximum safety of developing oil and gas fields.

Keywords: hydrocarbon deposits, the earth's surface, subsidence, roof of stratum, geostatic pressure, geodynamic polygon, geodesic monitoring.

Introduction. Large-scale development of oil and gas resources leads to intensive movements of the earth's surface, which leads to bending of wells, rupture of oil and gas and water pipelines, destruction of railways and roads. All this is a consequence of changes in the geodynamic regime of the geological environment due to large-scale development of the subsoil, which is confirmed by the results of experimental studies of the movement of the earth's surface in the Caspian zone.

Geodynamic processes in the development of hydrocarbon deposits are quite widely represented in numerous publications in the world's leading scientific journals. A significant part of the work is devoted to such issues as the forecast and monitoring of deformations of the earth's surface and of man-made seismic phenomena [1].

Various methods are used to calculate subsidence of the earth's surface in oil and gas fields. Some of these methods are similar to those used in coal and ore deposits and use functions of single influence of elementary volume taken on the earth's surface [2,3].

Research methods. Integrated research method was used in the work, including: conducting and analyzing the results of instrumental observations of earth surface displacement, theoretical calculation of roof subsidence, methods of numerical experiment and evaluation of stressed state of massif.

The content of the work. Integrated geodynamic monitoring was performed at the Tengiz deposit located in Atyrau region of Republic of Kazakhstan. Tengiz oil and gas deposit was discovered in 1979, and the first oil refining and production complex was opened in 1991. Massive deposits of this field are located at a depth of 3.8 to 5.4 km. The forecasted reserves of the field amount to 3 billion 133 million tons of oil and 1.8 trillion. M³ of gas.

During movement of the earth's surface monitoring in the area of oil and gas production, following specific requirements arise: 1) raising public awareness of results; 2) raising efficiency of observations; 3) economic efficiency of researches. From this position goal has been set, idea has been justified, and tasks of researches of the Department of Surveying and Geodesy of the Satbayev University at the Tengiz fields have been formulated.

Geodetic observations. At «Tengiz» GDP, the leveling of the II class was carried out with a digital laser gradiometer of LEICA WILD NA 3003. The principle of leveling is based on the processing of the encoded signal. Advantages of such a system are the simplicity of measurement, the absence of read and write errors, the automatic calculation of heights during measurement and data recording [4].

High-precision releveling was carried out in two cycles, sometimes according to the forecast of seismologists additional measurements were made, the results of which are shown in figure 1.

The figure shows the results of the leveling definitions for 2015, which indicate:

1) Continuity of the processes of deformation of the earth's surface, and along with this the deformation is unevenly in time;

2) Maximum rates of deformation observed in 2008-2016 and confined to fault zones.

Repeated geodetic measurements were also carried out by electronic total stations of Leica TS110, TS120 and the results of determining the subsidence of the frames were compared with the results of leveling.

The processing of satellite observations was carried out according to the LGO program (Leica, Switzerland), included in the set of GPS receivers, and the adjusted coordinates and heights of all network points in a given local coordinate system were obtained. To assess GDP deformations of the earth's surface, the horizontal and vertical displacements of 9 workstations on the pipeline profile line are analyzed.

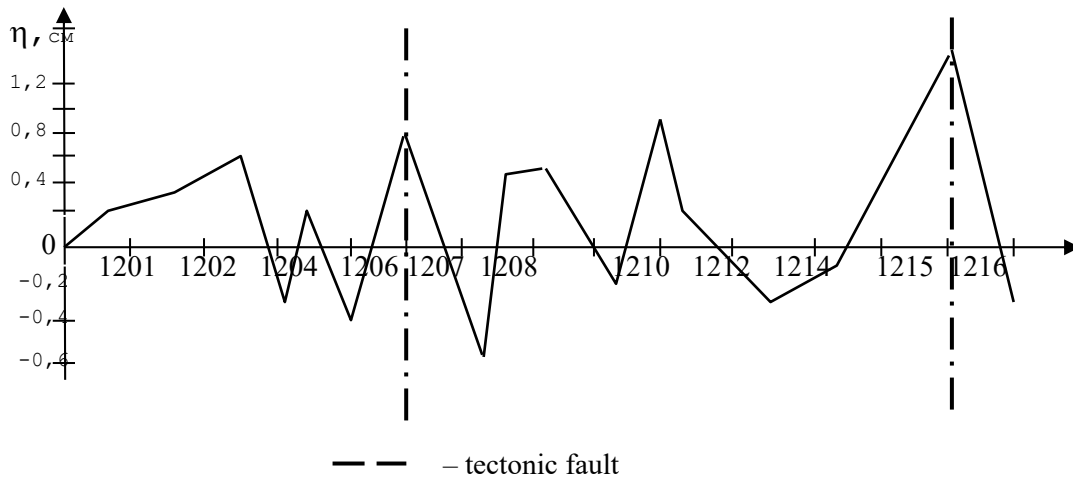


Figure 1 – Graphs of the benchmark displacement of «Tengiz» GDP

Analyzing the satellite measurements from November, 2008 to June, 2016 there were no horizontal displacements of the points.

To analyze the accuracy of measurements made by GPS receivers, the main satellite network was measured by an electronic total station TS 1201 (Leica). A comparative analysis of the measurements performed (table 1) shows that the accuracy of GPS measurements practically coincides with the accuracy of measurements by total station.

Thus, repeated leveling measurements were carried out with the help of laser levels, total stations and GPS equipment at the Tengiz.

Figure 2 shows the graph of the benchmark movements of «Tengiz» GDP levelling net for the period 2008-2016 and 1992-2016 on the profile 1–3, consisting of 25 benchmark.

Profile 1-3 runs across the polygon from north to south, crossing the central part of the polygon. In the period 2008-2016 benchmark displacements were from 2 mm to 8 mm., and for the period 1992-2016. $\eta_{max} = 2.9$ cm.

Table 1 – Comparative analysis of satellite and linear measurements

From the point	To the point	S-GPS (network scheme)	NS 1201	dS	Relative error
1	2	2359.266	2359.265	0.001	1/1947000
2	4	2606.720	2606.714	0.006	1/429000
2	3	1220.430	1220.428	0.002	1/663000
1	4	2276.461	2276.465	-0.004	1/625000
1	3	2840.789	2840.796	-0.007	1/386000
4	3	1962.898	1962.896	0.002	1/1002000
Standard error				0.005	

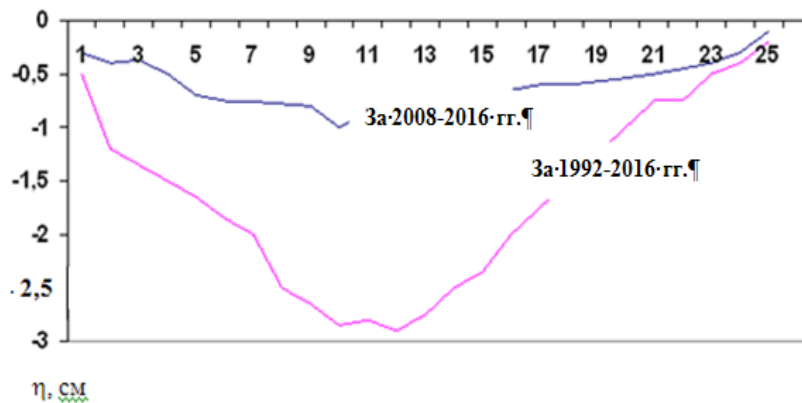


Figure 2 – Graph of dislocation of frames by profile 1-3

Theoretical researches. To correctly predict the subsidence of the earth’s surface (SES), it is necessary to know the technogenic component of the total vertical SES.

According to the types of reservoirs being developed, changes in its elastic properties and vertical compression of the oil reservoir framework, the fields under consideration are divided into two groups: granular and fractured cavernous reservoirs. According to the hypothesis of the hydrostatic stressed state advanced by A.Heim, stress state of the earth's crust at any of its points is a function of the depth of occurrence of rocks. Heim believed that the stresses in the earth's crust should be distributed according to the hydrostatic law, i.e.

$$\sigma_x = \sigma_y = \sigma_z = \rho H \tag{1}$$

where σ_x, σ_y – normal horizontal stresses; σ_z – vertical normal stress; ρ – the volume weight of rocks; H – the depth of the surface.

Taking the hypothesis of hydrostatic stress state, the magnitude of the vertical compression of the reservoir can be determined by the following formula

$$\partial \eta = \frac{1}{3} h [\beta_{ck} d(\sigma - P) + \beta_{TB} dP] \tag{2}$$

where β_{ck} – index of volume compression of reservoir skeleton; σ – the average normal stress, MPa; h – the height of the reservoir, m; P – reservoir pressure, MPa; β_{TB} – compressibility factor collectors solid phase; dP – drop in reservoir pressure, MPa.

As can be seen from the formula (2) the basic parameters characterizing the volume compression of collectors are the value of volumetric strain and the magnitude of the reservoir pore volume strain of solid phase collectors.

For the calculation of subsidence earth's surface features different formulas. S.Avershin derived equation for SES calculation [5]:

$$\frac{\partial \eta}{\partial z} = a(z) \frac{\partial^2 \eta}{\partial x^2}, \tag{3}$$

In equation of R. Muller [6] factor adopted by Z are linearly dependent:

$$\frac{\partial \eta}{\partial z} = a(z) \left[\frac{\partial^2 \eta}{\partial x^2} + \frac{\partial^2 \eta}{\partial y^2} \right], \tag{4}$$

All equations η – JPG quantity; $a(z)$ – coefficient characterizing the change in the properties of rocks in the vertical; x, y, z – rectangular coordinates.

Most accurately reflects the actual occurrence of reservoir conditions is considered to be the equation (4), but here it is necessary to determine three values (x, y, z).

For the SES calculation in terms of oil and gas deposits, we introduce a cylindrical coordinate system (figure 3). Center field roof we accept as the origin of the system.

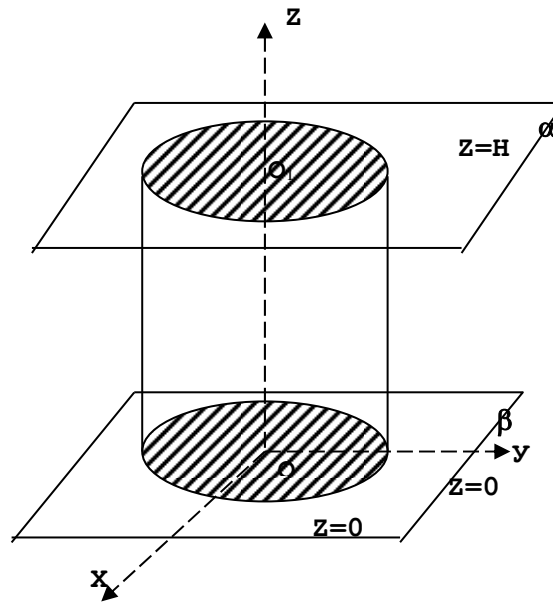


Figure 3 – Cylindrical coordinate system:

α - plane of the earth's surface; β - flat seam roof; H- the depth of the reservoir; r - the radius of the formation.

Plats lies at a depth H and its radius is r. Subsidence of seam roof (SSR) does not extend beyond the circle of radius r c centered at the origin. In this coordinate system, the equation (4) becomes a parabolic form:

$$\frac{\partial \eta}{\partial z} = \left[\frac{\partial^2 \eta}{\partial r^2} + \frac{1}{r} \cdot \frac{\partial \eta}{\partial r} \right] \cdot a(z), \tag{5}$$

After deciding the type of equation (5) was obtained by calculating formula:

$$\theta_{i,K+1} = \frac{1}{2} \theta_{i,K} + \frac{1}{4} (\theta_{i-1,K} - \theta_{i+1,K}) + \frac{1}{8i} (\theta_{i-1,K} - \theta_{i+1,K}), \tag{6}$$

where $\theta_{i,K}$ – approximate value of subsidence; i – step number (range) horizontally; K – step number vertically.

Calculations were carried out both in fissured-cavernous and granular reservoir for a period of time beginning development to 2010 on the fields of Kazakhstan. Note that on the deposits of granular reservoirs shear roof subsidence rate were equal to zero. Maximum roof subsidence on fissured-cavernous (pore) collectors was observed by the deposit Makat (64 mm) from 1974 to 1976. The reason for high rate of roof subsidence on this deposit is a significant reservoir pressure decline and large capacity of developed reservoir.

If we compare the fields by the roof subsidence indicators for the period of operation, we should single out the Tengiz field, where the maximum value of SSR is $q = 58$ mm or $V = 12$ mm/year for 5 years. Despite the fact that the depth the reservoir of the Tengiz field is huge ($m = 1500$ m) compared to other deposits, the value of the average subsidence of the roof subsidence in 5 years is only 12 mm. This small value is due to the maintenance of reservoir pressure at the initial level (insignificant drop of 2.6 MPa), as well as by the elastic properties of the reservoir.

Since the extraction of fluids is carried out from great depths, and the maximum roof subsidence is only 60 mm in five years, it is first necessary to theoretically test whether there is any place of land subsidence at all. For this purpose, the minimum depth of occurrence of the deposit of the considered deposits is taken to be $H = 3500$ m and the maximum value of SSR is ≈ 60 mm.

The problem reduces to determining the subsidence of the point 0_1 , located at a distance of 3500 m from the point 0 (figure 6). To solve such a problem it is necessary to calculate successively the subsidence of points along the 00_1 axis, which are from point 0 at distances of 500.0; 1000.0; 1500.0 and 3500.0 m.

Carrying out calculations using formula (6) is a very complex and time-consuming task. Therefore, express calculation methodology of has been created with the aim of operational forecasting of the SSR and SES. Based on the results of theoretical calculations, the graph-analytical dependence of the SSR on the depth of the developed reservoir is obtained (figure 4).

$$\theta_{exp} = 0,015 \ln(0,01 \cdot H) \quad (7)$$

Figure 4 shows that with increasing depth of fluids production reservoir pressure increases, hence, the value of SSR are greater than in shallowness. When impact of mining development on SES is considered with increasing depth of development the magnitude of the deformations alternately decreases [7].

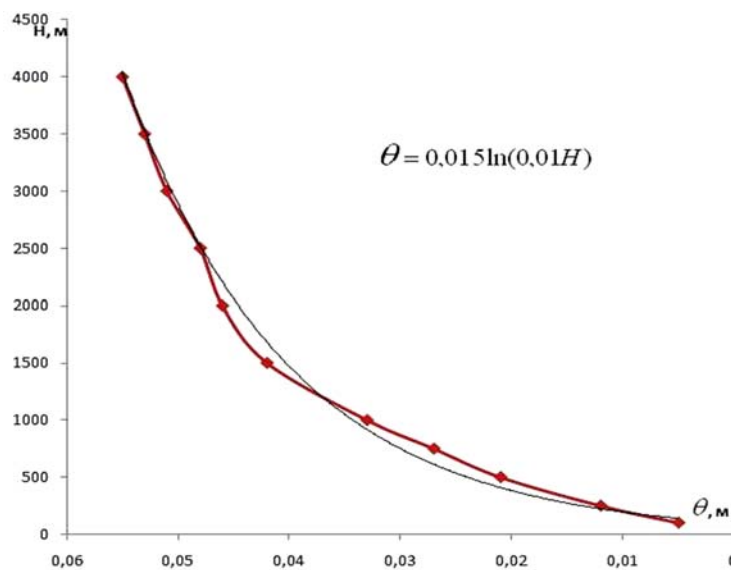


Figure 4 – Dependency graph of SSR on the depth H

According to this truth for SES prediction based SSR and depth of development and received graphoanalytical dependence (figure 5), where the horizontal axis represents the SES.

Thus, to predict SES depending on the SSR and the depth of development, a graph-analytic dependence of two types is recommended: exponential (logarithmic) and linear.

$$\eta_{SES exp} = -14,5 * \ln * (0,0002H) \quad (8)$$

with error of 6.8% and a linear

$$\eta_{SES lin} = 45,5 - 0,0127H \quad (9)$$

with error of 29.8%, i.e., logarithmic dependence accurately predicts subsidence of the earth's surface and is easier to make calculations.

As seen from the graph, on the earth's surface at a depth $H = 4$ km of 6 mm is passed magnitude roof subsidence is 60 mm.

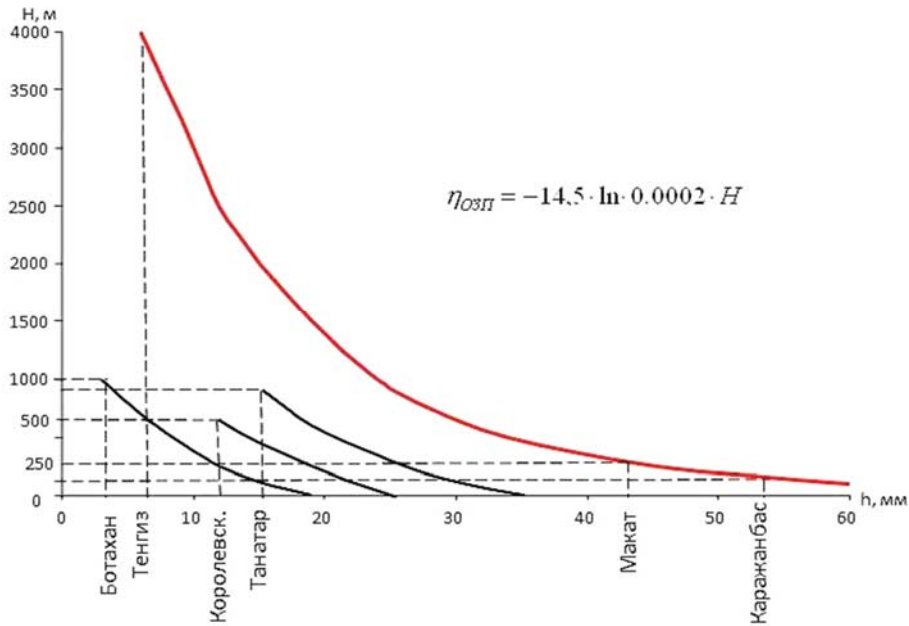


Figure 5 – Graph predict of SES depending on SSR and the depth of the development of the H

On the Kenkiyak, Kulsary, Oryskazgan and other deposits, where the development depth is more than 1000 m, and the SSR on the day surface is not transmitted at all, i.e. SES will be zero. In contrast to these, in the Makat, Tanatar, Korolevskoye, Tengiz and Botakhan deposits, the technogenic SES are 43, 18, 12, 6, 4 mm, respectively.

Numerical experiment of the field displacement process. There are various methods for calculating the subsidence of the earth's surface, but in our opinion, a more universal approach to the modeling of dynamic processes is a method based on the use of cellular automata [8].

We made forecast of the strain – stress state of mountain massif. The reservoir lies at considerable depth and is represented by fairly strong limestone, deposit is characterized by abnormally high reservoir pressure. The complex salt-dome tectonics, as well as the asymmetrical nature of the area of lowering the initial reservoir pressure, necessitated the development of a volumetric finite element model (figure 6) Productive carbonate rocks were the main “base” layer.

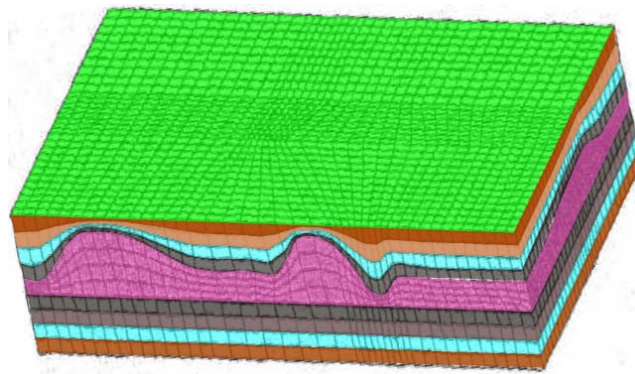


Figure 6 – Volumetric model of an oil field site

Results discussion. Technique of conducting repeated observations of the points of GDP has been improved, including complex geodesic observations: (high-precision digital leveling electronic tachometers and GPS-technology) which will improve the accuracy and efficiency of determining of earth's surface subsidence and the effectiveness of monitoring due to the computerization of field and office of surveying and geodetic works.

Currently, instrumental geodynamic studies conducted in a number of regions have shown that in many cases localized seismic manifestations and accidents are directly or indirectly associated with

anomalous changes in the current strain - stress state of the earth's surface. The technogenic geodynamic phenomena are necessarily confined to the areas of the influence of technogenic loads created in the production areas.

Conclusions.

1. Method for calculating the subsidence of the roof of stratum has been developed to predict the earth's surface subsidence from the subsidence of the roof of the formation, novelty of which is the theoretical provision of interaction between the deformations of the formation's roof and the earth's surface with technological parameters.

2. A numerical model was developed and implemented to assess the intensity of anthropogenic seismic phenomena during oil and gas production based on the use of a special rock model taking into account the complete deformation diagram along the section planes. In the future, all information on the laws of the process of displacement of the earth's surface is used to ensure industrial safety of subsoil use.

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КӨМІРСУТЕК ШИКІЗАТ КЕН ОРЫНДАРЫН ИГЕРУДІҢ ГЕОДИНАМИКАЛЫҚ ҚАУІПСІЗДІГІН КЕШЕНДІ БАҒАЛАУ

Аннотация. Мақала батыс Қазақстан аймақтарында көмірсутегі шикізат кенорнын игеру кезінде болатын геодинамикалық үдерістерді зерттеуге арналған. Сейсмоактивті аумақтарда пайдалы қазбалардың кен орындарын көлемді және белсенді игеруді мысал ете отырып, жер бетінің қозғалысын кешенді мониторинг жасау нәтижелері көрсетілген.

Жұмысты орындау үшін, зерттеудің кешенді әдісі қолданылған және оған: заманауи геодезиялық аспаптар көмегімен игеріліп жатқан аумақтың деформациясына геодезиялық бақылаулар жүргізу; шатыр жабындарының шөгуін теориялық есептеу жолымен жер бетінің шөгу үдерісіне әртүрлі факторлардың әсерін бағалау; жер бетінің жылжуына кен орындарын игеру қарқындылығының әсерін есептеу; қарастырылған аумақта геодинамикалық үдерістің сипаттамасы туралы қорытынды жасау кіреді.

Орындалған жұмыстың құрамы. Кешенді геодинамикалық бақылау Қазақстан Республикасының Атырау облысында орналасқан Теңіз кен орнында жүргізілді. II классты нивелирлеу LEICA WILD NA 3003 сандық лазерлік аспаптың көмегімен кен орнында орындалды. Нивелирлеу принципі кодталған сигналды өңдеуге негізделген.

2015 жылғы нивелирлеу нәтижелері мыналарды көрсетеді:

1) жер бетіндегі деформация процестерінің үздіксіздігін, сонымен бірге уақыт өте деформация біркелкі болмайтындығын;

2) 2008-2016 ж. ығысулардың ең жоғары мөлшері байқалғандығын және жер жарылымдары аймақтарымен шектелген.

Leica TS110, TS120 жалпы станцияларымен бірнеше рет геодезиялық өлшеулер жүргізілді және шатырдың шөгуін анықтау нәтижелері нивелирлеу нәтижелерімен салыстырылды. Серіктік бақылауларды өңдеу GPS қабылдағыштарының жиынтығына кіретін LGO бағдарламасына сәйкес жүзеге асырылды (Лейка, Швейцария) және осы жергілікті координаттар жүйесіндегі барлық желілік нүктелердің түзетілген координаттары мен биіктіктері алынды. Жердің жалпы ішкі өнімінің деформациясын бағалау үшін 9 жұмыс станциясының көлденең және вертикалды ығысулары талданды.

2008 жылғы қарашадан 2016 жылғы маусымға дейін серіктік өлшеулерді талдағанда нүктелердің көлденең ығысуы болған жоқ. GPS қабылдағыштарымен жүргізілген өлшеулердің дәлдігін талдау үшін негізгі серіктік желі TS 1201 тахеометрімен өлшенді (Leica). Өлшеулердің салыстырмалы талдауы көрсеткендей GPS өлшеу дәлдігі тахеометрдің дәлдігімен бірдей.

Жер бетінің ығысуын есептеу Қазақстанның кен орындарында игеру басталған уақыттан 2010 жылға дейін кезеңде жарықты-кавернозды және түйіршіктелген коллекторда да жүргізілді. Түйіршіктелген коллекторлар кен орындарында шатырдың жылжу жылдамдығы нөлге тең болды. Жарықты-кавернозды (кеуекті) коллекторлардағы шатырдың барынша шөгуі Мақат кен орнында (64 мм) 1974 жылдан 1976 жылға дейін байқалды. Бұл кен орнында шатырдың шөгуінің жоғары жылдамдығының себебі қабаттық қысымның едәуір төмендеуі және игерілген қабаттың үлкен сыйымдылығы болып табылады.

Егер кен орындарын пайдалану кезеңінде шатырдың шөгу көрсеткіші бойынша салыстырсақ, біз Теңіз кен орнын бөліп алуымыз керек, мұнда шатырдың шөгуінің максималды мәні $q = 58$ мм немесе $V = 12$ мм/жыл

5 жыл ішінде құрайды. Теңіз кен орны шоғырының тереңдігі басқа кен орындарымен салыстырғанда ($m = 1500$ м) үлкен екеніне қарамастан, 5 жыл ішінде шатырдың орташа шөгуінің шамасы небәрі 12 мм-ді құрайды.

Тау массивінің кернеулі жағдайына болжам жасалды. Коллектор едәуір тереңдікте орналасқан және өте күшті әктас болып табылады, кен орны жоғары қабаттық қысыммен сипатталады. Күрделі тұзды-күмбезді тектоника, сондай-ақ бастапқы қабаттық қысымның төмендеуі аймағының асимметриялық сипаты соңғы элементтердің көлемді моделін әзірлеу қажеттігіне себепші болды. Негізгі "базалық" қабаттар өнімді карбонатты жыныстар болды.

Қорытынды. Мұнай және газ кенорындарын игеру қауіпсіздігін және экономикалық тиімділігін қамтамасыз ету мақсатында, жер бетінің шөгу параметрлерін анықтауды тездетіп және сенімділігін жоғарылатуды, заманауи геодезиялық аспаптарды пайдаланып, геодинамикалық мониторинг жүргізудің инновациялық әдістері ұсынылған және негізделген.

Түйін сөздер: көмірсутек өнімдері, жер беті, шөгу, қабат шатыр, қабаттық қысым, геодинамикалық полигон, геодезиялық мониторинг.

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КОМПЛЕКСНАЯ ОЦЕНКА ГЕОДИНАМИЧЕСКОЙ БЕЗОПАСНОСТИ ПРИ РАЗРАБОТКЕ МЕСТОРОЖДЕНИЙ УГЛЕВОДОРОДНОГО СЫРЬЯ

Аннотация. Статья посвящена изучению геодинамических процессов, происходящих при разработке месторождений углеводородов в западном регионе Казахстана. Представлены результаты комплексного мониторинга деформации земной поверхности на примере участков интенсивного и масштабного освоения недр в сейсмоактивных районах.

Для выполнения работ использован комплексный метод исследований, включающий: выполнение повторных геодезических наблюдений за деформациями подрабатываемых территорий с помощью современных геодезических приборов; оценку влияния различных факторов на процесс оседания земной поверхности путем теоретического расчета оседаний кровли пласта; учет влияния интенсивности разработки месторождений на смещения земной поверхности; выводы о характере геодинамических процессов на рассматриваемой территории.

Состав выполненных работ. Комплексный геодинамический мониторинг проводился на месторождении Тенгиз, расположенный в Атырауской области Республики Казахстан. На территории месторождения было выполнено нивелирование II класса с помощью цифрового лазерного нивелира LEICA WILD NA 3003. Принцип нивелирования основан на обработке кодированного сигнала.

Результаты определения нивелирования за 2015 год указывают:

1) непрерывность процессов деформации земной поверхности, причем наряду с этим деформация происходит неравномерно во времени;

2) максимальные скорости деформации наблюдаются в 2008-2016 гг. и ограничены зонами разломов.

Повторные геодезические измерения также проводились электронными тахеометрами Leica TS110, TS120, и результаты определения оседания кровли сравнивались с результатами нивелирования.

Обработка спутниковых наблюдений проводилась в соответствии с программой LGO (Leica, Швейцария), включенной в набор приемников GPS, и были получены скорректированные координаты и высоты всех точек сети в данной локальной системе координат. Для оценки деформаций земной поверхности проанализированы горизонтальные и вертикальные смещения 9 рабочих станций на линии профиля трубопровода.

При анализе спутниковых измерений с ноября 2008 года по июнь 2016 года горизонтальных смещений точек не было. Для анализа точности измерений, выполненных приемниками GPS, основная спутниковая сеть измерялась электронным тахеометром TS 1201 (Leica). Сравнительный анализ выполненных измерений показывает, что точность измерений GPS практически совпадает с точностью измерений тахеометром.

Расчеты смещений земной поверхности проводились как в трещинно-кавернозном, так и в гранулированном коллекторе за период времени начала разработки до 2010 года на месторождениях Казахстана. На месторождениях гранулированных коллекторов скорость оседания кровли сдвига была равна нулю. Максимальное оседание кровли на трещинно-кавернозных (пористых) коллекторах наблюдалось на месторождении

Магат (64 мм) с 1974 по 1976 год. Причиной высокой скорости оседания кровли на этом месторождении является значительное снижение пластового давления и большая емкость развитого пласта.

Если сравнить месторождения по показателям оседания кровли за период эксплуатации, мы должны выделить месторождение Тенгиз, где максимальное значение оседания кровли составляет $q = 58$ мм или $V = 12$ мм/год в течение 5 лет. Несмотря на то, что глубина залежи месторождения Тенгиз огромна ($m = 1500$ м) по сравнению с другими месторождениями, величина среднего оседания кровли за 5 лет составляет всего 12 мм. Это небольшое значение обусловлено поддержанием пластового давления на начальном уровне (незначительное падение 2,6 МПа), а также упругими свойствами пласта.

Сделан прогноз напряженно-напряженного состояния горного массива. Коллектор находится на значительной глубине и представлен довольно сильным известняком, месторождение характеризуется аномально высоким пластовым давлением. Сложная соляно-купольная тектоника, а также асимметричный характер области понижения начального пластового давления обусловили необходимость разработки объемной модели конечных элементов. Основными «базовыми» слоями были продуктивные карбонатные породы.

Заключение. Обоснованы и предложены инновационные методы выполнения геодинамического мониторинга с использованием современных геодезических приборов, что позволяет повысить достоверность и оперативность определения параметров оседания земной поверхности, с целью обеспечения максимальной безопасности и экономической эффективности освоения нефтегазовых месторождений.

Ключевые слова: месторождения углеводородов, земная поверхность, оседание, кровля пласта, пластовое давление, геодинамический полигон, геодезический мониторинг.

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STUDYING THE PROCESS OF LITHIUM CHLORIDE EXTRACTION FROM THE BRINE

Abstract. The purpose of the research is to create a technology for processing the hydromineralic raw materials of Kazakhstan for the production of lithium salts and rare earth elements, the development of a highly efficient technology for obtaining lithium, lithium compounds and rare earth elements of the Aral region.

The study of Chemical and mineralogical compositions of hydromineral raw materials of lakes of the Aral region are studied by the method of deposition. Conditions of receiving lithium concentrates are studied. Conditions concoction of lithium minerals and receiving concentrates for extraction chloride of lithium are studied. Cleaning of lithium concentrates from ions of calcium and magnesium and chemical composition of the hydromineral raw materials, the effective methods of precipitating lithium in the form of lithium carbonate, its purification from the impurities of Ca^{2+} , Mg^{2+} by the precipitation method are studied. Extraction methods for processing lithium-containing precipitates and sorption methods for extracting lithium from brines are studied. Water-salt systems have been studied for the directed search for effective methods for obtaining lithium salts from brine and saline lake precipitation.

Key words: hydromineralic raw materials, salt solution, sludge, lithium chloride, rare earth elements.

The lightest alkali metal - lithium, which is considered to be "future and strategic metal" is widely used in the fields of porcelain and the production of glass, refrigeration, metallurgy, medicine, aerospace, military industry, atomic energy, electronics, alloys and batteries, etc. Lithium resources exist in nature either in solid ores or in liquid brines. However, the limited reserves of solid lithium ores and high costs associated with its extraction indicate that the extraction of lithium from salt salts will be a future trend.

In the world from rare metals treat widely used lithium and its connections. Annual requirement of lithium makes 65-70 thousand tons. The most part of lithium about 80% in natural waters are concentrated. Therefore foreign countries: the USA, Chile, Italy, Japan, etc. constantly conduct researches on extraction of lithium from concrete natural waters since the raw source underground waters is cheap full-fledged raw materials [1].

The most large-scale deposits of lithium are known in granite pegmatites of natro-lithium type since lithium in the nature intimately associates with sodium (owing to similarity of power characteristics of ions of lithium and sodium), especially in fields of a residual crystallization. However, in recent years the increasing value is gained by fields of sedimentary type and underground salt waters and waters of salty lakes [2,3].

Now the leaders of the world market are FMC Lithium Division from the USA and SQM from Chile, each of which controls 30% of the world market for lithium. In South America, this metal is mined in the bottom of a dried-up salt lakes. The extraction of REE from brine and solid deposition in the focus of numerous works [4,6].

Currently, the sorption methods are widely used in applied radiochemistry: in the processes of reprocessing of irradiated nuclear fuel (SNF), the allocation and separation of rare earth (REE) and transuranic elements (TUE) and in the processing of liquid radioactive waste (LRW). The synthesized ion exchange materials AXION series (Am, Pu) represent the gel of the phosphorus-nitrogen-containing ion-exchange polymers that have high selectivity in relation to ions of REE and TUE in strongly acidic environments. The high potential of the AXION ion-exchange materials for the extraction of uranium, REE and TUE from nitric acid media, and also for extracting indium from waste zinc production is shown.

Famous scientists extract tantalum and niobium from concentrates by extraction method. Depending on the selected scheme on the enrichment redistribution it is possible to obtain concentrates with a content of 20-45% Nb₂O₅ and 2-4.5% Ta₂O₅. For isolation and separation of niobium and tantalum the method of extraction from fluoride - sulfate solutions was used. The influence of consumption of HF and H₂SO₄ and other terms of the decomposition of the concentrate in the enumeration Ta, Nb and accompanying elements in solution, the effect of the ratio of volumes of organic and water phases V_v:V_w, HF and H₂SO₄ concentrations on the distribution of Ta, Nb and impurities on the operations of extraction, washing and stripping. By results of researches the schematic diagram is offered [5]. As the extractant used the octanol - 1. According to this scheme, the planned extraction of Ta and Nb in solution during the decomposition of the concentrate of at least 95 and 98%, respectively, in the finished products of 92 and 94%.

Extraction of lithium from hydromineral raw materials is a necessary and relevant task in view of limitation of ore stocks (the main reserves of lithium are revealed as accompanying fields of tantalum, niobium, tungsten and tin). For release of lithium from solutions use extraction, reagent or adsorptive methods. For its receiving from thermal waters of oil fields the electrothermic coagulation method with soluble iron-aluminum anodes [6], extent of extraction of lithium of 70,5% is tested. The received results showed high efficiency and insignificant power consumption of process. However, it demands further completion. In particularly, the issues of thickening, filtration and disposal allocated to the lithium-containing precipitate. Continue work on the isolation of lithium from multicomponent solutions by chemisorption on the aluminium hydroxide [7]. Deposition of lithium is carried out using a variety of aluminum-containing reagents: hydroaluminate sodium (HAUS), active forms of aluminium hydroxide (AGO), soluble salts aluminum, various composite mixes [8].

There are known methods for extracting lithium from solutions of magnesium chloride by extraction using an extractant with iron-containing tributyl phosphate, with the addition of water-insoluble carboxylic acid and re-extraction of lithium, with a solution of hydrochloric acid to obtain the desired product with a low concentration of lithium [9].

A large deposit with proven reserves of lithium is in the East Kazakhstan – Kalba ridge, where the mountains of the Altai pass into the coaching staff. However, theoretically a larger lithium deposit must be in the Aral region – at the bottom of the dried sea. The information that there are lithium reserves in the salt marshes of the Aral Sea region is mentioned in the old Soviet reference books.

The considerable proportion of lithium are in lakes and lake oozes, underground waters, in ocean water (1,5-10-5mass. %). In the course of receiving lithium salts from hydromineral raw materials inorganic and organic sorbents depending on the content of lithium in various form connection were applied earlier. Extraction of lithium from complex mineral compounds not always decided successfully because of low extent of extraction of lithium in marketable products.

The volume of brine in the southern and Northern basin of the lake Zhaksykylysh lithium 40-60mg/l (Mg₂⁺ not more than 0.2%, Ca₂⁺ is not more than 0.4%, SO₄²⁻ - not more than 1.2%), silt content significantly exceeds and is 60-120mg/kg. in addition, the required enrichment of the brine to the required quality lithium concentrate is needed. Available reserves of hydromineral raw materials (lakes and lacustrine silts, brine and saline deposits) in the Aral sea region provide annual demand for lithium.

The technological basis for use of mineral resources available in the Aral region will be developed taking into account features of this hydromineral raw materials, scheduled chemical upgrading of equipment to ensure the integrated use of raw materials waste-free technology.

Thus, a detailed study of all of the above processes of the proposed technology, of course, is relevant, and obtain new results on the solubility in the system LiCl - NaCl – Na₂SO₄ – H₂O and REE (La, Pr, Nd, Er, Hf, Ta) with regard to the influence of impurities in hydromineral raw materials and determine the optimal conditions, the flow rate of the extractant, temperature and time of sorption process lithium and REE determines the scientific novelty of the research.

For the experiment, a brine of salt lakes of the Aral region is used, the composition of which is presented in table 1.

Table 1 – Composition of the brine of the Zhaksykylysh deposit*

Sample number	30-1.	30-2.	30-3.	30-4.
Li7 mg/kg	263.50279	311.94302	128.38595	142.01970
B11 mg/kg	102.93350	750.75133	95.18996	225.84787
Na23 mg/kg	70639.89147	89061.56736	75962.03229	83489.99644
Mg24 mg/kg	23513.35944	43707.03329	17750.59646	19025.78142
Al27 mg/kg	24.84001	237.44130	16.68423	9.90388
La139 mg/kg	0.00512	0.02087	0.00479	0.00237
Ce140 mg/kg	0.00768	0.02087	0.00479	0.00949
Pr141 mg/kg	0.00256	0.00522	0	0
*Brine selected from various trajectories of the deposit.				

From the data in table 1, it is clear that the lithium content in the sample varies within the range 128.38-263.50 mg/kg, and the rare earth elements are almost insignificant.

To conduct the experiment, the brine sample is pre-averaged, an aliquot is taken (table 2) is placed in a 100 ml flask mounted on a magnetic stirrer with a speed controller (set at 600 rpm) after butyl alcohol of 30 ml is added. The sample is stirred for a given time consisting of a layer of alcohol and water. During the mixing process, when using anhydrous butanol at the alcohol-water phase boundary, a white precipitate consisting of sodium chloride precipitates.

After a given time (table 2), the sample is transferred to a separating funnel, where after separation of butanol and water, the lower water layer is drained. The alcohol layer is evaporated to a dry state in a vacuum (water-jet pump). The residue is "dried" from traces of butanol in a drying oven at a temperature of 130°C.

The resulting precipitate was investigated on the ISP device for the lithium content and the degree of lithium extraction was calculated from the results obtained. The sediment was studied with the SEM instrument. The results of the experiment are given in table 2 and 3 and are shown in figure 1, 2 and 3.

Table 2 – Change of sediment yield depending on the volume of brine

V of sample, ml	m, gr.	Extraction time, min	Extraction degree of LiCl, %
10	0,3498	15	86,9
20	0,3032	15	84,4
30	0,3097	15	84,2
50	0,3031	15	83,9

From the data in table 2, it is seen that with the increase in the volume of brine at a constant flow rate of butyl alcohol extractant and time, the degree of lithium extraction gradually decreases. At the rate of brine 10 ml. the degree of extraction of lithium is 96,9%, with the increase of brine flow up to 50 ml., the degree of extraction of lithium is reduced to 83.9%. Figure 1 shows the mass output from the volume of the extracted brine.

Figure 1 shows that under the same conditions, the weight of the precipitate changes with the change in the volume of extracted brine. The higher the consumption of brine, the less the mass of the sediment. When extracting 10 ml of brine, the yield of the precipitate is 0.3498 g, and when extracted 50 ml of brine – the precipitate yield is 0.3031 g.

Subsequently, brine extraction was performed in the time interval 10-30 min. The results of the experiment are given in table 3.

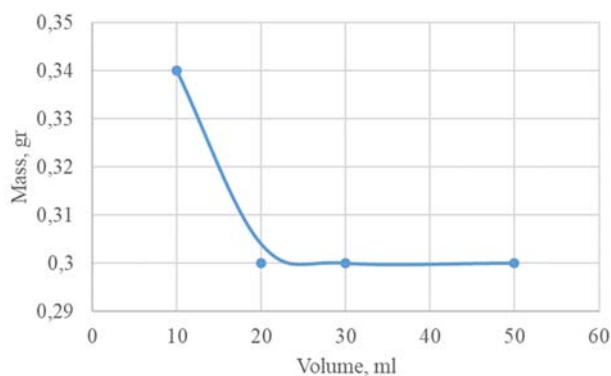


Figure1 – The mass output from the volume of the extracted brine

Table 3 – Dependence of the extraction degree of lithium chloride on the process time

№	V of sample, ml	Vof extractant, ml	Extraction time, min	m, g.	Extraction degree of LiCl,%
23-1	10	30	10	0,32183	86,9
23-2	10	30	15	0,47845	96,7
23-3	10	30	20	0,47080	95,9
23-4	10	30	25	0,42264	92,6
23-5	10	30	30	0,36393	88,7

From the data in table 3 it follows that at a constant flow rate of 10 ml of brine and 30 ml of extractant, and with an increase in the duration of extraction, the degree of lithium extraction gradually increases. With a runtime of 10 min the degree of extraction of lithium is 86,95, when the runtime 15 min the degree of extraction of lithium is 96,7%, and in further time of 30 min. the degree of extraction of lithium is reduced and is 88.7%. The greatest degree of lithium extraction is achieved by a time of 15 min. At the same time, the mass of the precipitate from the brine increases from the beginning, then with an increase in the extraction time, the mass of the precipitate decreases. Figure 2 shows the precipitation output from time.

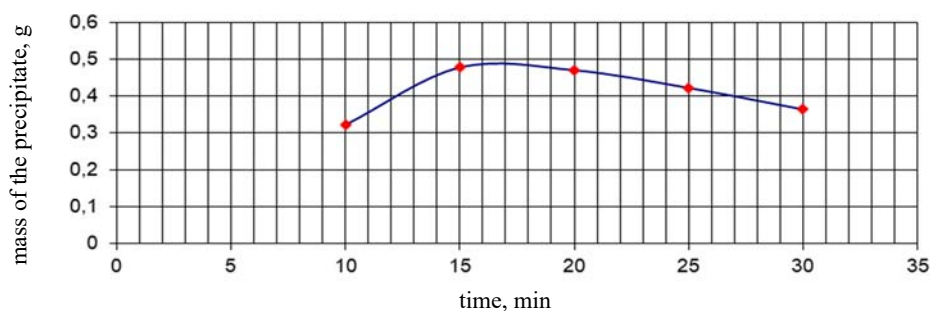


Figure 2 – The mass output from the volume of the extracted brine

Element	Weight, %	Atomic, %
O	4.64	8.25
Na	34.45	42.62
Mg	0.62	0.73
S	0.39	0.34
Cl	59.90	48.05

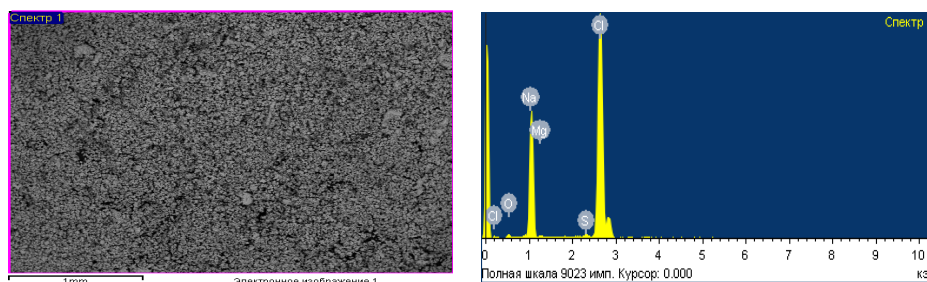


Figure 3 – Elemental analysis of the precipitate obtained from the brine of salt lakes in the Aral region

From figure 2 it is seen that at a time 10 min, the mass of the precipitate is 0,32183 g, and at 15 min. the mass of the precipitate is 0,47845, then the time from 20 min. up to 30 min. the mass of the precipitate is reduced and is equal to 0,36393 g. i.e. the output mass and the degree of extraction of lithium are reduced at the same time. The precipitate may consist of lithium chloride salt and sodium. To determine the composition of the precipitate after the separation of lithium chloride, the separated mass was investigated with SEM. Figure 3 shows the elemental analysis of the precipitate.

It is seen from figure 3 that the precipitate consists mainly of sodium and chlorine and a small amount of magnesium and sulfur.

Conclusion. Thus, the data obtained allow to receive valuable products of lithium chloride and table salt from the brine of the salt lakes of the Aral sea region. At the same time, with the increase in the volume of brine at a constant flow rate of butyl alcohol extractant and time, the degree of lithium extraction gradually decreases from 96.9% to 83.9%. With a constant consumption of brine 10 ml. and extractant volume of 30 ml. and with increasing the duration of extraction, the degree of lithium extraction gradually increases. If the duration from 10 min. to 15 min. is 96,7%, and in the future with the increase of time up to 30 min. the degree of lithium extraction is reduced and is 88.7%.

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ТҰЗДЫ ЕРТІНДІДЕН ЛИТИЙ ХЛОРИДІН БӨЛІП АЛУ ПРОЦЕССИН ЗЕРТТЕУ

Аннотация. Зерттеу мақсаты – тұзды көлдердің тұзды ертінділерінен литий хлоридін алу процесін зерттеу және Қазақстанда литий тұздары мен сирек кездесетін элементтерді өндіру үшін гидроминералды шикізатты өңдеу технологиясын жасау. Литий концентраттарын кальций мен магний иондарынан тазарту процесі және гидроминералды шикізаттың химиялық құрамы зерттелді. Литийді литий карбонаты түрінде тұндыру ең тиімді әдіс. Құрамында литийі бар тұнбаларды өңдеудің экстракциялық әдістері және литийді ертінділерден алудың сорбциялық әдістері зерттелген. Тұзды және тұзды көл шөгінділерінен литий тұзын алудың тиімді әдістерін іздестіру үшін су-тұз жүйелері зерттелді. Арал маңындағы көлдердің гидроминералды шикізатының химиялық және минералогиялық құрамы тұндыру әдісімен зерттелді.

Литийдің дәлелденген қорлары бар ірі кен орны Қазақстанның шығысында - Қалба жотасында және Арал теңізі аймағында - құрғатылған теңіз түбінде орналасқан. Литийдің едәуір бөлігі көлдер мен көлдердің шөгінділерінде жер асты сулары мен теңіз суында (1,5–10,5%) болатындығы анықталды. Жақсықылыш көлінің оңтүстік және солтүстік бассейндерінің тұздықтарының көлеміндегі литийдің құрамы 40-60 мг/л (Mg^{2+} - 0,2% артық емес, Ca^{2+} - 0,4% артық емес, SO_4^{2-} - 1,2% артық емес), ал оның шөгінділердегі құрамы әлдеқайда жоғары және 60-120 мг/кг құрайды. Литий тұздарын гидроминералды шикізаттан алу кезінде, қосылыстың әртүрлі формаларындағы литийдің құрамына байланысты бұрын бейорганикалық және органикалық сорбенттер қолданылған. Күрделі минералды қосылыстардан литийді алу әрдайым сәтті шешілмеді, өйткені литийді товарлы өнім түрінде алу деңгейі төмен болды. Тұз ертіндісін литий концентратының қажетті сапасына дейін байыту керек. Арал аймағындағы гидроминералды шикізаттың (көлдер мен көл сулары, тұздар мен тұзды батпақтар) қоры литийге деген жылдық қажеттілікті қамтамасыз етеді.

Литий минералдарын концентрациялау және литий хлоридін экстракциялау үшін концентраттар дайындау шарттары зерттелді. Бутил спиртінің экстрагенті мен уақытты тұрақты тұтыну кезінде, тұзды мөлшердің жоғарылауымен литий экстракциясының деңгейі біртіндеп төмендейтіні анықталды. 10 мл. тұздықты тұтынған кезде, литийді экстракциялау дәрежесі 96,9% құрайды, тұздықты тұтыну мөлшері 50 мл. дейін артқанда, литийді экстракциялау дәрежесі 83,9% дейін төмендеді. Тұздықты үнемі тұтыну және экстракция көлемінің жоғарылауы кезінде, экстракцияның ұзақтығының артуымен литийдің экстракция дәрежесі біртіндеп артады. Ұзақтығы 10 минут ішінде литийдің шығарылу деңгейі 86,95, ал 15 минутта - 96,7% құрайды, одан әрі 30 минутқа дейін жоғарылағанда, литийдің шығарылу деңгейі төмендейді және 88,7% құрайды. Литий экстракциясының ең жоғары дәрежесіне 15 минут ішінде қол жеткізіледі. Сонымен қатар бір мезетте, алдымен тұзды ертіндіден алынған тұнба массасының шығымы артады, содан кейін өндіру уақыты ұлғаюымен тұнба массасының шығымдылығы төмендейді.

Түйін сөздер: гидроминералды шикізат, тұз, тұнба, литий хлориді, сирек кездесетін элементтер.

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ИЗУЧЕНИЕ ПРОЦЕССА ЭКСТРАКЦИИ ХЛОРИДА ЛИТИЯ ИЗ РАССОЛА

Аннотация. Цель исследования заключается в изучение процесса экстракции хлорида лития из рассола соленых озер и создании технологии переработки гидроминерального сырья Казахстана на продукцию солей лития и редкоземельных элементов. Исследован процесс очистки литиевых концентратов от ионов кальция и магния и химического состава гидроминерального сырья. Эффективными методами осаждения лития в виде карбоната лития является метод осаждения. Исследованы экстракционные методы переработки литийсодержащих осадков и сорбционные методы извлечения лития из рассолов. Изучены водно-солевые системы для направленного поиска эффективных способов получения литиевых солей из рапы и осадков соленых озер. Изучены химические и минералогические составы гидроминерального сырья озер Аральского региона методом осаждения.

Крупное месторождение с доказанными запасами лития находится в восточном Казахстане – в Калбинском хребте и в Приаралье – на дне высохшего моря. Установлено, что значительная часть лития находится в озерах и озерных илах, подземных водах, в морской воде (1,5-10,5масс.%). Рассол Южного и Северного бассейна озера Жаксыкылыш содержат 40-60мг/л лития (Mg^{2+} - не более 0,2%, Ca^{2+} - не более 0,4%, SO_4^{2-} - не более 1,2%), в илах содержание составляет 60-120мг/кг.

В процессе получения литиевых солей из гидроминерального сырья ранее применялись неорганические и органические сорбенты в зависимости от содержания лития в различной форме соединения. Извлечение лития из комплексных минеральных соединений не всегда решалось успешно из-за низкой степени извлечения лития в товарный продукт.

Необходимо обогащение рассола до требуемого качества литиевого концентрата. Имеющиеся запасы гидроминерального сырья (озерах и озерных илах, рапах и солончаковых отложениях) в Аральском регионе обеспечивают годовую потребность в литии.

Для проведения эксперимента пробу рапы предварительно усредняют, отбирают аликвоту помещают в колбу на 100 мл установленную на магнитную мешалку с регулятором оборотов (установить на 600 об/мин) после добавляют экстрагент-бутиловый спирт в количестве 30 мл. Пробу, состоящую из слоя спирта и воды, перемешивают в течение заданного времени. В процессе перемешивания при использовании безводного бутанола на границе фаз спирт-вода выпадает белый осадок, состоящий из хлорида натрия.

После заданного времени пробу переносят в делительную воронку, где после разделения бутанола и воды нижний водный слой сливают. Спиртовой слой упаривают до сухого состояния в вакууме (водоструйный насос). Остаток «досушивают» от следов бутанола в сушильном шкафу при температуре 130 °С.

Результаты исследования показали, что чем больше расход рапы, тем меньше масса осадка. Полученный осадок исследовали на приборе ИСП на содержание лития и по полученным результатам считали степень экстракции лития. Осадок исследовали на приборе РЭМ. При экстракции 10 мл рапы выход осадка составляет 0,3498 г., а при экстракции 50 мл рапы - выход осадка составляет 0,3031 г. Процесс экстракции хлорида лития проведен в интервале времени 10-30 мин. Полученные данные показали, что при постоянном расходе рапы 10 мл. и объеме экстрагента 30 мл с увеличением продолжительности экстракции степень экстракции лития постепенно возрастает. При продолжительности 10 мин степень экстракции лития составляет 86,95, при 15 мин. составляет 96,7%, а в дальнейшем времени 30 мин. степень экстракции лития уменьшается и составляет 88,7%. Наибольшая степень экстракции лития достигается при времени 15 мин. Одновременно выход массы осадка из рапы сначала возрастает, затем с увеличением времени экстракции выход массы осадка уменьшается.

Изучены условия концентрирования литиевых минералов и получение концентратов для экстракции хлорида лития. Установлено, что с увеличением объема рапы при постоянном расходе экстрагента бутилового спирта и времени степень экстракции лития постепенно уменьшается. При расходе рассола 10 мл степень экстракции лития составляет 96,9%, с увеличением расхода рассола до 50 мл степень экстракции лития снижается до 83,9%. При постоянном расходе рассолов и объема экстрагента, с увеличением продолжительности экстракции, степень экстракции лития постепенно возрастает.

Установлено, что увеличение продолжительности экстракции от 10 мин до 15 мин приводит к увеличению степени экстракции хлорида лития и составляет 96,7%, в дальнейшем при повышении времени до 30 минут степень экстракции хлорида лития уменьшается до 88,7%. Наибольшая степень экстракции лития достигается за время 15 минут. Одновременно выход массы осадка из рассола сначала возрастает, затем с увеличением времени экстракции выход массы осадка уменьшается.

Ключевые слова: гидроминеральное сырье, рассол, ил, хлорид лития, редкоземельные элементы.

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**RATIONAL SELECTION OF THE FORM OF SUPPORT
FOR THE FORMATION OF GENETIC COMPOSITION OF ROCKS
IN THE CONDITIONS OF THE BESKEMPIR FIELD**

Abstract. One of the main strategic tasks of independent Kazakhstan is increase in a gold and foreign exchange reserve, especially, when the world financial market from time to time faces and endures financial and credit shocks, crises and cataclysms. In these conditions internal monetary and credit investments into economy, reliability and stability of tenge are of particular importance. In this regard the role of a gold and foreign exchange reserve of the country sharply increases. Having great potential opportunities for significant increase in production of precious metals at the expense of industrial reserves of gold in a subsoil and also at the expense of gold in technogenic and mineral educations, in tails of enrichment and products of metallurgical conversion, Kazakhstan far not fully uses these opportunities. In this regard our researches are devoted to studying of a geomechanical condition of the Beskempir field relating to ore the field of the Akbakaysky field. The article considers the research results with regard to the determination of the strain-stress state of rock masses (displacements, stresses, fracture zones etc.) depending on the mining geological and mining technical factors in the conditions of Beskempir field. Based on the detected regularities of the change of the strain-stress state of rock masses, rational forms and parameters of support were selected using the software products, which enhance the stability of development headings. This ensures the development of new and improvement of existing technologies for efficient and safe driveage.

Key words: lining, rock mass, stress-strain state, uncontrolled caving, mass, mine technical and mining geological conditions.

Relevance. In the present time, Kazakhstan ranks tenth with the world rating of gold reserves and 25th with the mining of the precious metal, and 3rd and 4th among the CIS countries correspondingly. The precious metal mining is an important constituent because Kazakhstan aims at getting into the thirty developed countries in the world. Over thousands of years, gold has been a permanent companion of people. The functions of this dense, soft and noble metal have always expanded: from the tool of making savings and symbol of luxury and power to the important details of electronic devices. During the history, humanity has mined over 150 thousand tons of pure gold. The mining methods of the metal have always been improved: from primitive search for nuggets and washing sand to highly efficient mines, open pits, concentration plants and refineries [1,2,3,16].

Analysis of existing research. Currently, one of the most perspective gold field is the Akbakay field, within which there is the Beskempir field is located. The Beskempir field is situated in the northern part of South Kazakhstan in the Zhambyl Region 300 km to the south-west of the city of Balkhash [4].

The gold mining in the world practice employs two major methods of gold production: open-pit mining at primary deposits of poor oxidized ores with subsequent extraction of metal using the method of heap leaching and mining of rich ores [5].

The gold field Beskempir is situated right in the intensive tectonically distorted crossing of faults. The maximum distortion is in the western part of the field.

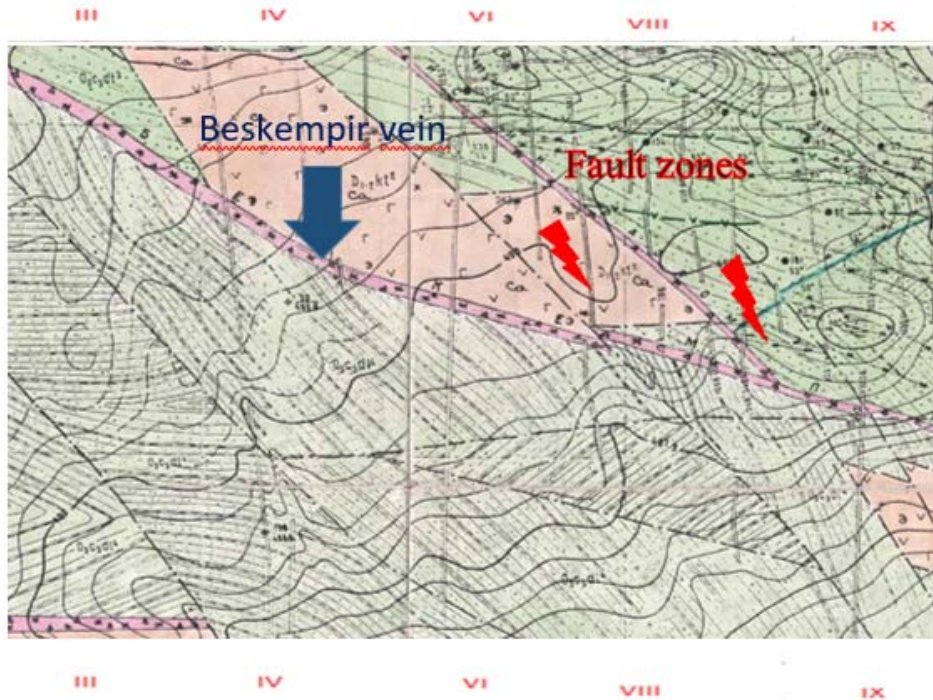


Figure 1 – Geological map of the Beskempir field (western flank)

For detailed research of engineering geological structure of the rock mass at the place of the drift at the level of +230m (260) at the Beskempir field, the geological maps and sections of the 308-322 block were examined. To examine the rock mass, the +230m (260) horizontal working was selected (western flank of the Beskempir field) and the geological map (M:2000) of the area as well as geological sections in the IV-IV, VI-VI, VIII-VIII (M:10000) profiles was constructed. As a result of the research it was established that the genetic classification of rocks sharply changes due to the tectonic faults (figure 1).

Main objective of research. The research of the genetic composition of the rock mass of the Beskempir field used the classifications of the rocks proposed by the scientists M.V. Lomonosov, F.R. Levinson, A.P. Karpinskiy and others. The genetic classification of rocks was examined accounting for the conditions of their formation, structure of the mass and properties of the rocks [6]. In compliance with this classification, the following types of rocks were identified (figure 2).

During the examination of the rock composition at the place of location of the +230m (260) drift at the Beskempir field, the core samples were collected for the 308-322 block. In harmony with the geological map and geological sections of the IV-IV, VI-VI, VIII-VIII (M:10000) profile which are based

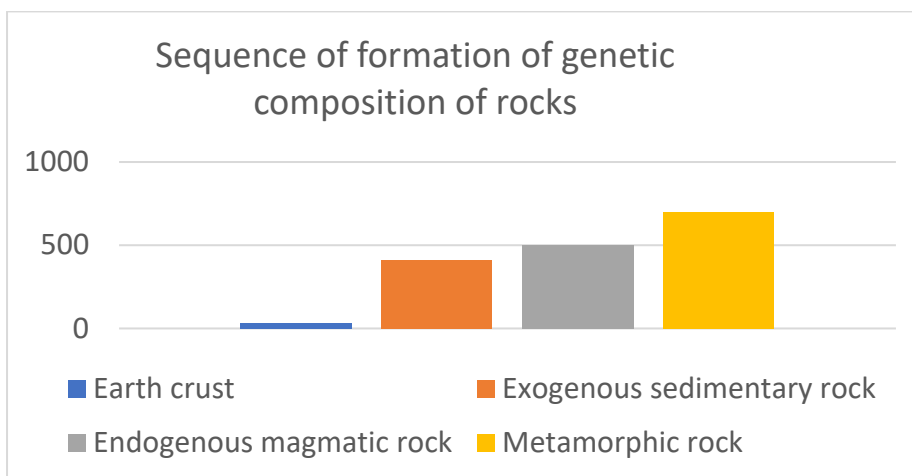


Figure 2 – Sequence of formation of genetic composition of rocks

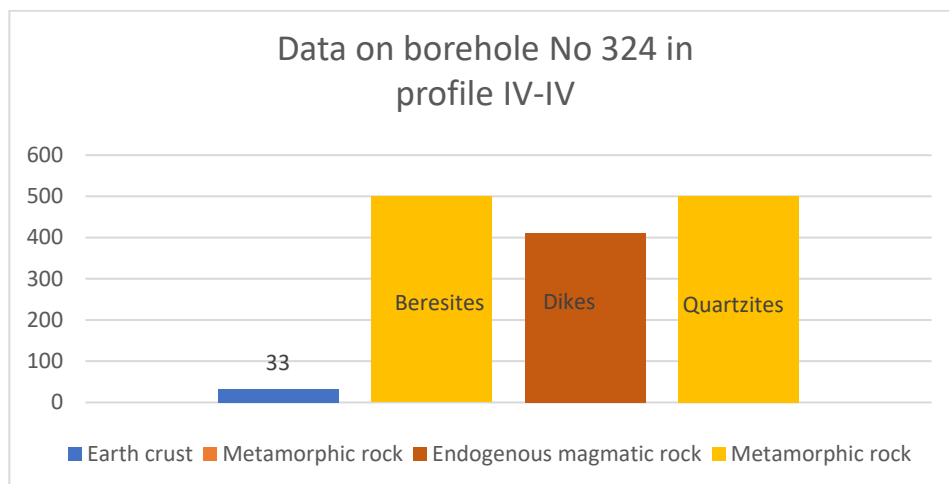
on the drilling data of borehole No57 at the depth of 350 m, No324 at the depth of 590m, No316 at the depth of 450m, No268 at the depth of 700m, No245 at the depth of 520m, No313 at the depth of 480m, No104 at the depth of 170m, No288 at the depth of 510m, No843 at the depth of 410m, No82 at the depth of 350m, No68 at the depth of 100m.

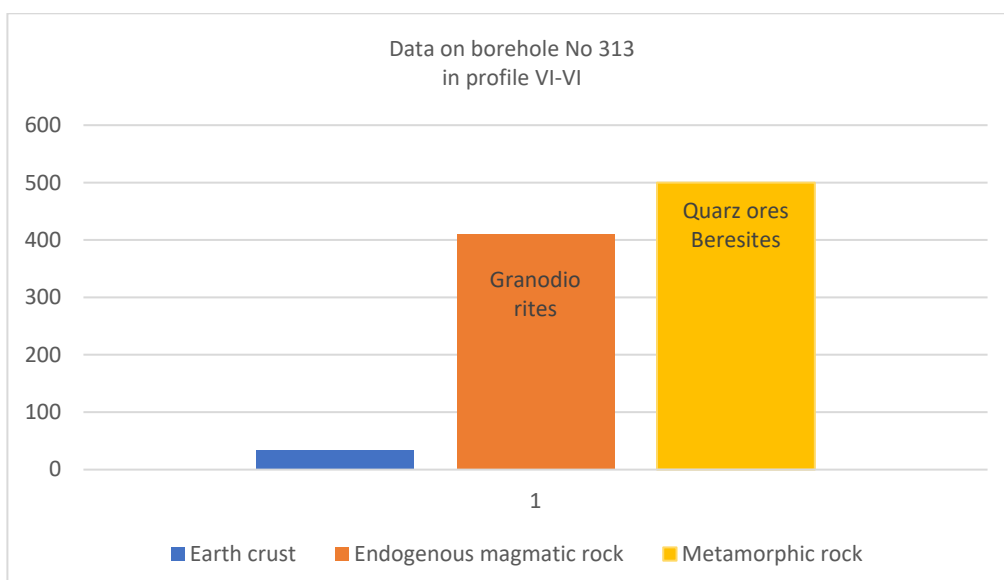
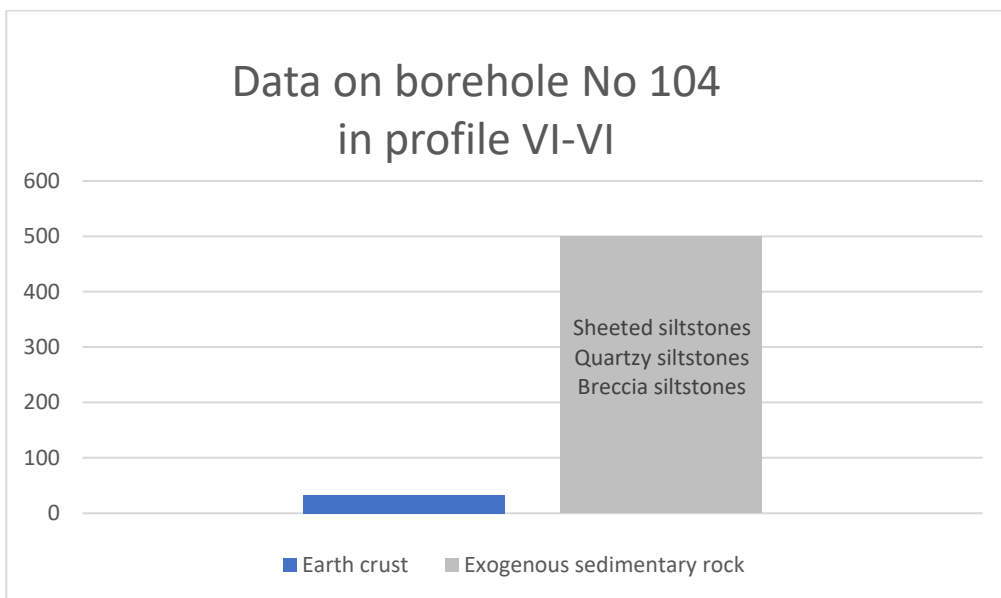
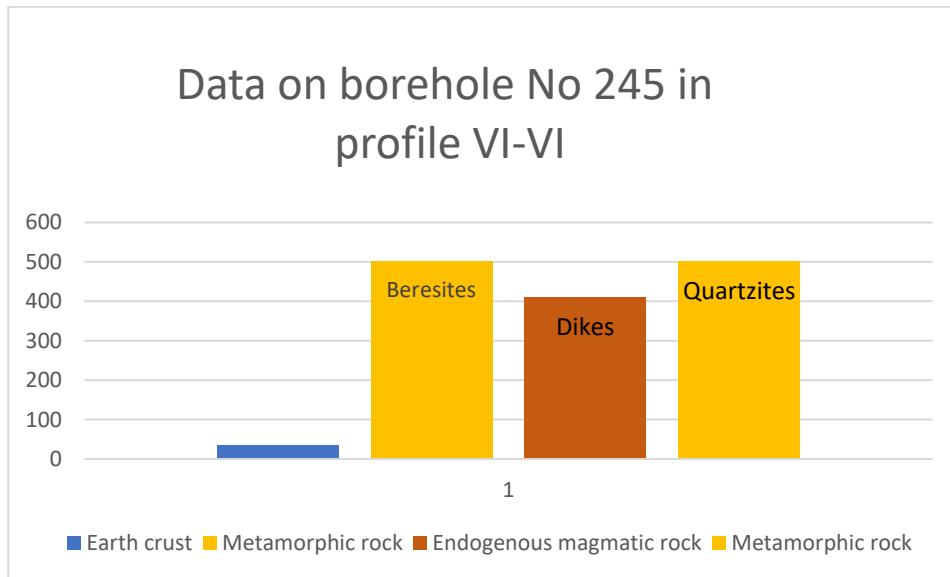
The strength test of samples (core samples) was done in the geological laboratory on a special press by crushing the lumps of selected samples. The staff of the Mining Department of the Kazakh National Research University named after K.I. Satpayev took part in the test [7]. The research results with regard to the determination of strength characteristics of the rocks from the Beskempir field are supported by the certificate of laboratory testing (figure 3).

The results of laboratory research revealed that in the future at the driving of a heading at the strike continuation level of +230m the genetic composition of the rock mass sharply changes, which testifies about the tectonic fault (figure 4).



Figure 3 – Testing of the core samples in the laboratory conditions





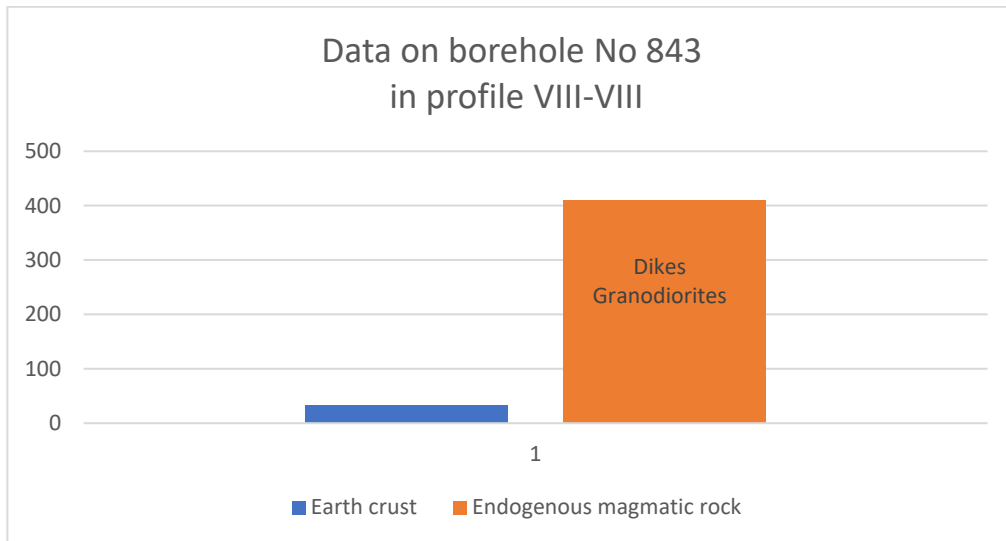


Figure 4 – Sequence of formation of genetic composition of the rock mass in line with the geological composition of core samples selected from boreholes

The results of the conducted research allowed the selection of the rational form of support for concrete mining geological conditions at the development of a drift at the level of +230m (260) at Beskempir field. As a result of the research of the rock mass condition and physical and mechanical properties of rocks in line with SNiP II-94-80 depending on the stability category it is recommended to apply various forms of support in sections [8].

Main part of research. The total design length of the drift is 1,200m, out of which the most unstable and stable-fractured rocks in various categories constitute 500m (figure 5). Based on the results of the test of core samples, the ultimate uniaxial compression strength is 40-70 MPa. The rest of the sections are stable from category I (700m).

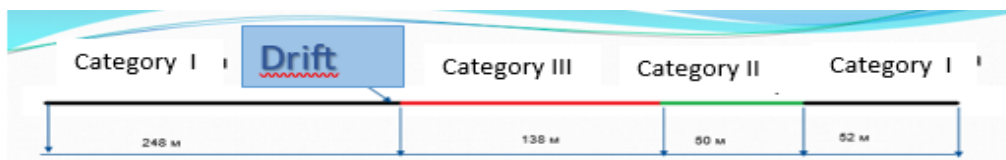


Figure 5 – Recommended design of the support for the researched object in the conditions of Beskempir field at the level of +230m (260)

Recommended forms of support according to the rock stability categories

Rock stability category	Permitted distance of the support from the face	Form of support
Very stable (I)	Up to 100 m	Shotcrete not less than 30mm thick At junctions – Anchors + shotcrete
	At junctions not more than 1m	Support is not needed (at the operation life of developments not more than 5 years). At junctions – roof bolting
Stable (II)	Up to 10 m	Combined (Anchors + shotcrete). At junctions - combined (Anchors + shotcrete reinforced with screen or fiber not less than 50mm thick)
	Anchors not more than 0.8-1m, shotcrete up to 10 m.	Shotcrete not less than 50mm thick. At junctions – combined support (Anchors + shotcrete)
Medium stability (III)	The first layer of shotcrete is applied without delay, then anchors and screen are installed and the second layer of shotcrete is applied on the screen with a lag of not more than 0.8m-1m	Combined (Anchors + screen + shotcrete not less than 50mm thick). It is permitted to use shotcrete with 50-90mm thick fiber instead of the screen.
		Combined (Anchors + shotcrete not less than 50mm thick) At junctions - combined (Anchors + screen + shotcrete not less than 50mm thick). It is permitted to use shotcrete with 50-90mm thick fiber instead of the screen.

The unstable zones were identified using the special software Examine2D. The software Examine2D allowed the identification of the area of unstable section [9-17]. The results of this research allowed recommending various rational supports according to the stability categories (table).

Conclusions. Support of workings and their maintenance in working order is one of the major and most important production processes at underground mining of useful resources. Safe and productive operation of underground miners and operation of the whole mine is impossible without it. Costs for support and repair of workings are high and considerably increase as the mining operations go deeper.

The forms of support recommended herein reduce material consumption and cost, increase operational reliability of working and labor productivity at the development heading.

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«БЕСКЕМПІР» КЕНОРНЫНЫҢ ШАРТТАРЫ БОЙЫНША ТАУ-ЖЫНЫСТАРЫНЫҢ ГЕНЕТИКАЛЫҚ ҚҰРЫЛЫМЫНА БАЙЛАНЫСТЫ РАЦИОНАЛДЫ БЕКІПЕ ТҮРІН ТАҢДАУ

Аннотация. Қазіргі таңдағы қаржы нарығының негізгі мәселелерінің бірі қаржы-дағдарыстары мен катаклизмге байланысты Тәуелсіз Қазақстанның басты стратегиялық міндеттерінің бірі алтын-валюта резервін ұлғайту, нығайту болып отыр. Бұл жағдайда экономикаға ішкі ақша-кредит инвестициялаудағы теңгенің сенімді әрі тұрақты болуы өте өзекті мәселе. Осы мәселеге байланысты еліміздің алтын-валюта резервін күрт өсуіне алып келіп отыр. Жер қойнауындағы өнеркәсіптік алтын қорының есебі, сондай-ақ техногендік-минералдық түзілімдердегі, байыту қалдықтары мен металлургиялық бөлініс өнімдеріндегі алтын есебінен асыл металдар өндірісін Елеулі ұлғайту үшін үлкен әлеуетті мүмкіндіктерге ие. Қазақстан осы мүмкіндіктерді толық көлемде пайдалана алмай отыр. Өнеркәсіптік қорлар бойынша Қазақстан бүгінгі күні сегізінші (2,12%) орында, ал кендегі алтынның орташа мөлшері бойынша әлемде екінші орында. Бүгінгі күні қорларды өңдеу қарқыны өте төмен және өнеркәсіптік қорлар көлемінің шамамен 0,5-0,6% құрайды. Пайдалы қазбаларды барлау барысында ескерілмей қалған қорларды қайта барлау арқылы өндіру. Сонымен қатар алға қойылған міндетке қол жету үшін бар шикізатты өндіру және қайта өңдеу процестерін де тиімді пайдаланып олардан жоғары сапалы тауарды өндіруге дайындау қажет. Осыған байланысты біздің зерттеулеріміз Ақбақай кен орнының кен алаңына жататын «Бескемпір» кен орнының геомеханикалық жағдайын зерттеуге арналған. «Бескемпір» кен орнының кен алқабы көне салынған (Кеңгір) өңірлік сынықтардан және екінші ретті ұзақ сақталатын сынықтардан (Кеңгірсіз, Долинный және т.б.) операциялық жарықтарға, жарықшақтар, жарықшақтар мен жарықшақты құрылымдарға дейінгі күрделі, әртүрлі бағытталған көптеген бұзушылықтар болып табылады. Сондықтан көлденең және көлбеу тау-кен қазбаларына, әсіресе күрделі тау-кен геологиялық және тау-кен техникалық жағдайларда жүргізілетін бекітпенің түрі мен құрылымын зерттеу және таңдауды оңтайландыру маңызды ғылыми-техникалық міндет болып табылады. Мақалада «Бескемпір» кен орнының жерасты тау-кен жұмыстарының қазіргі жағдайымен болашақта дамыту мәселесі қарастырылған. Жерасты тау-кен жұмыстарын өту барысында тектоникалық жарылыстың әсерінен кернеулі жағдай күрделене түседі, әсіресе +230м (260) деңгейдегі болашақ штрек қазбаларын жүргізуде, туындаған мәселелерді шешу мақсатында қазбалардың орнықтылығын арттыруды қамтамасыз ететін іс-шараларды ойластыру қажеттілігі туындайды. Ең алдымен осы қауіпті аймақтың тау-кен геологиялық шарттарын зерттеп, мәселелерді шешу жағдайлары қарастырылды. Зерттеліп отырған штрек қазбасының маңайын алынған сынамалардың нәтижесіндегі деректерге сүйене отырып генетикалық құрылымдары зерттелді. Негізгі талдау барысында (М:10000) IV-IV, VI-VI, VIII-VIII қималарға сүйене отырып, генетикалық құрылымдардың өзгерістері байқалды. Құрылымдардың күрт өзгеруі мен олардың тау-кен кернеулі жағдайын тұрақтардыру үшін рационалды бекітпе (әр қашықтыққа бірнеше) түрі ұсынылады. Ұсынылған бекітпе түрі тектоникалық жарылыстан ұсақталған тау-жыныстарының өздігінен құлап, кен шығару мен жеткізу деңгей жиегіндегі қазу жүйесіне артық салмақ түспеуін қамтамасыз етеді.

Түйін сөздер: бекітпелер, тау-кен сілемі, тау-кен кернеулі жағдайы, өздігінен құлау, сілем, тау-кен техникасы, тау-кен геологиялық жағдайы.

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**РАЦИОНАЛЬНЫЙ ВЫБОР ТИПА КРЕПИ ПО ФОРМИРОВАНИЮ
ГЕНЕТИЧЕСКОГО СТРОЕНИЯ ГОРНЫХ ПОРОД В УСЛОВИЯХ
«БЕСКЕМПИРСКОГО» МЕСТОРОЖДЕНИЯ**

Аннотация. Одной из главных стратегических задач независимого Казахстана является увеличение золото-валютного резерва, особенно, когда мировой финансовый рынок временами сталкивается и переживает финансово-кредитные потрясения, кризисы и катаклизмы. В этих условиях особое значение приобретают внутренние денежно-кредитные инвестиции в экономику, надежность и стабильность тенге. В этой связи резко возрастает роль золото-валютного резерва страны. Имея большие потенциальные возможности для существенного увеличения производства благородных металлов за счет промышленных запасов золота в недрах, а также за счет золота в техногенно-минеральных образованиях, в хвостах обогащения и продуктах металлургического передела, Казахстан далеко не в полной мере использует эти возможности. По промышленным запасам Казахстан сегодня занимает восьмое (2,12%) место, а по среднему содержанию золота в рудах – второе место в мире. Сегодня темпы отработки запасов очень низкие и составляют примерно 0,5-0,6% от объема промышленных запасов. При возобновлении разведочных работ геологические запасы могут расти быстрее, чем выбывающие. Для достижения поставленной задачи увеличения производства золота необходимо исключить потери, возникающие в процессе добычи и переработки золотосодержащего сырья, до производства товара высокой готовности. В связи с этим наши исследования посвящены изучению геомеханического состояния месторождения «Бескемпир», относящегося к рудным полям Акбакайского месторождения. Рудное поля месторождения «Бескемпир» являются осложненными многочисленными, разно ориентированными нарушениями от региональных разломов древнего заложения (Кенгирский) и долгоживущих разломов второго порядка (Бескемпирский, Долинный и др.) до опережающих разрывов, трещин отрыва, скола и трещинных структур. Поэтому исследование и оптимизация выбора типа и конструкции крепи для горизонтальных и наклонных горных выработок, особенно, проводимой в сложных горно-геологических и горнотехнических условиях, является важной научно-технической задачей. Рассмотрены результаты исследований по определению напряженно-деформированного состояния породных массивов в зависимости от горно-геологических и горнотехнических факторов в условиях Бескемпирского месторождения. Для изучения породного массива был выбран горизонтальный выработка на горизонте +230м (260) (западного фланга месторождений Бескемпир) и получена геологическая карта (М:2000) района, а также геологические разрезы по профилю IV-IV, VI-VI, VIII-VIII (М:10000). В результате исследований установлено, что генетическая классификация горных пород резко меняется в связи с тектоническими разломами. На основе выявленных закономерностей изменения напряженно-деформированного состояния породных массивов с использованием программных продуктов определены рациональные типы и параметры крепи, повышающие устойчивость подготовительных горных выработок. Это позволит разрабатывать новые и совершенствовать существующие технологии для эффективного и безопасного проведения горных выработок.

Ключевые слова: крепь, породный массив, напряженно-деформированное состояние, самообрушение, массив, горнорудная техника, горно-геологические условия.

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INFLUENCE OF THE GEOMETRIC SHAPE OF THE MOLD ON THE CAST BILLET STRUCTURE FOR FORMING PROCESSES

Abstract. The article shows the effectiveness of system analysis based on Shubnikov-Curie symmetry principle, in solving problems of thermal effect on the molten liquid metal when it is solidified in a mold. It has been suggested that a binary axis, relative to the lateral surface, appears in the ingot structure. In accordance with the generalized structure of the billet, geometric structure of crystallites and crystallographic texture are determined by the influence of the thermal field during the crystallization of the melt. The thermal field is determined by the geometry of the mold and the structural features of its sprue and bottom parts.

Analysis of the generalized structure of the field of physical activity allows us to optimize the properties of the cast billet for subsequent forming processes of semi-finished products for mechanical engineering. This is important for the performance characteristics of the finished products.

It has been experimentally proved that the structure of the cast billet (distribution of grains in the material) undergoes changes in accordance with Shubnikov-Curie principles of symmetry, during the crystallization process in the molds of various sections. It affects the physico-mechanical properties of the cast billet, including the plastic deformation during further forming processes.

Key words: forming processes, crystallization, symmetry, heat flux, texture, Shubnikov-Curie principle, mold.

Introduction. The production of metallurgical billets consists of two main technological processes: 1) obtaining a cast ingot by pouring the molten metal into the casting mold; 2) pressure treatment of the ingot, mainly rolling. As a result, the billet acquires certain mechanical and crystallographic texture – the predominant orientation of its internal components. The crystallographic texture determines the anisotropy of the polycrystalline materials properties.

Formation of properties in the cast billet (i.e. casting) depends on heat removal from the melt into the mold during its solidification. The crystallographic texture is responsible for the formation of the physico-mechanical properties.

In the known technological metal forming processes, the results of transcrystallization have a significant impact on the macro- and microstructure of semi-finished products, as well as their quality. This is primarily due to the presence of both globular and axial textures in the ingot [1-3]. Consequently, one of the promising ways to improve the physico-mechanical properties of polycrystalline materials is a comprehensive consideration of the natural anisotropy of the polycrystalline grains properties (crystallographic texture) and their geometric shape texture at all stages of technological processing.

Researches considering texture in wrought alloys are non-systematic and are aimed at solving particular problems. For example, in 1994, an application was filed and a patent for an invention to improve the ingot technology for the production of multilayer rolling was obtained [4]. The results did not attract wide scientific attention, apparently due to the lack of a systematic approach.

Possible ways to control the crystallization process in order to obtain a given crystal structure of ingots and castings are usually limited to the analysis of the methods of grinding crystalline grains in conventional casting molds [5,6,7].

Methods for obtaining shaped castings with a directional crystal structure (texture) are based on controlling the relation of macrostructural zones in the system: peripheral fine-grained zone – columnar crystals – equiaxed crystals.

The question concerning the microstructure of ingots of wrought alloys (texture) is not considered properly. Here, the ingot texture will be understood as features of the structure due to crystallographic directions and planes, related by symmetry characteristics to the structure of the thermal field (created by the mold during the process of crystallization), as well as the structure of the melt before it is cast into the mold.

The formulation of the research objective and the physical essence of the process. This research is carried out with the help of the system analysis, which is based on the generalized Shubnikov-Curie symmetry principle [8,9]. The work investigates how the thermal field structure of a casting mold influences on the macrostructure of the cast billet.

The formation of the crystallographic texture of the castings can be studied at thermal and heat-kinetic levels simultaneously. The study at thermal level is based on the heat-transfer process between the boundary surface of the melt and the relatively cold wall of the mold. The basis of heat-kinetic research is analysis of crystallization processes.

Heat-transfer processes will be determined by the generalized structure of the thermal field, which can be identified on the basis of the Curie symmetry principle for heterogeneous systems. In this case, the heterogeneous system is represented, on the one hand, by the symmetry characteristic of the crystallographic texture of the anisotropic metal sheet from which the wall of the mold is made. On the other hand, it is represented by the symmetry characteristic of the thermal field structure of the melt (due to the cross-sectional shape and geometric relations of the limiting surfaces of the mold), as well as the influence of the pouring conditions and the difference in the heat removal conditions between the bottom and the sprue parts of the mold.

Symmetry of the crystallographic texture of the metal sheet (which is obtained by the method of lengthwise rolling and is used for manufacturing of the walls and bottom of the mold) can be represented by the following formula. It includes the generating elements of symmetry of the generalized structure of the physical field of rolling, characterized by the relation of kinematic and geometric parameters of the dynamic system. This system determines the set of generating elements of symmetry and their relative position:

$$G_{\text{np}} = m m 2, \quad (1)$$

where G is a symmetry group; m – plane of symmetry; 2 – binary axis.

The structure of the thermal field of the melt relative to the normal of the side surface can be represented by an expression that includes the plane of symmetry m relative to the side surface of the melt, passing through the axis of the mold, aligned with the Z axis in an orthogonal coordinate system. It coincides with one of the symmetry planes (which belong to the symmetry group, describing the structure of the thermal field relative to the axis of the mold). In this case, the generalized structure of thermal field for the side surface of the ‘melt-mold’ system can be represented in the following way:

$$G_{\text{сис}} = G_{\text{np}} \subseteq G_{\text{расп.}} = m. \quad (2)$$

According to the Curie principle, the symmetry group of a system is the highest subgroup of intersection groups of a system. Thus, the generalized structure of the side surface of the thermal field can be described by a single symmetry plane, which is common to the structure of the thermal field and the structure describing crystallographic texture of the anisotropic sheet.

The generalized structure of the thermal field relative to the normal, combined with the axis of the mold, is determined by the cross-sectional shape and geometric relationships of the bounding surfaces of the mold, as well as the influence of the pouring conditions and the difference in the heat removal conditions between the bottom and the sprue parts of the mold. However, in this case, the structure of the thermal field must be considered for three-dimensional space. It is necessary to take into account the structure of the heat removal of the total lateral surface in the volume of the entire melt. The geometrically connected lateral surfaces are the system-forming elements of the generalized structure of the thermal field.

Thermal field isotherms will be determined by the anisotropy of the mold wall. They can be described based on the symmetry characteristics of the geometric and crystalline textures, as a response of previous methods of processing the materials from which the wall of the mold is made.

For thin-walled molds, the temperature field can be considered like for two-dimensional space, neglecting the direction perpendicular to the plane, which coincides with the plane of the mold wall. In this case, the distribution pattern of the thermal field isotherms in the system “side wall of the mold – external environment” will be determined by the temperature field of the side surface of the melt in the system “side wall of the mold – melt”.

The physical nature of the isotherms distribution on the wall of the mold is determined by the thermal conductivity k [$V \cdot m^{-1} \cdot K^{-1}$], linking the heat flux h [V/m^2] with the temperature gradient dT/dZ via a well-known formula:

$$h = -k \frac{dT}{dZ}. \quad (3)$$

In case of real anisotropic materials, the heat flux is not parallel to the temperature gradient; therefore, the thermal conductivity is described by the polar tensor of the second rank (which is considered to be symmetric for this process). In this case, the symmetry of the polar tensor of the second rank is expressed by Neumann’s principle (the main postulate in crystallography) and thermodynamic relations, which describe the irreversibility of these processes for heat transfer. So, for the symmetric polar tensor of the second rank, the following equality can be created:

$$k_{ij} = k_{ji}. \quad (4)$$

The polar tensor of the second rank, which describes the thermal conductivity, is symmetric relative to the main diagonal. Only six independent coefficients have to be determined for the further calculations.

The value k_{ij} is considered in two directions: the direction in which we measure the temperature gradient, and the direction in which we measure the heat flux. In general, these directions do not coincide, and the analytical form of the relation is:

$$h_i = -k_{ij} \frac{dT}{dZ_j}. \quad (5)$$

The minus sign shows that the heat is always directed opposite to the direction of the temperature gradient.

Based on (1), the components of the thermal conductivity of the symmetric tensor of the second rank are calculated as follows:

$$k_{ij} = \frac{h_i}{\frac{dT}{dZ_j}}. \quad (6)$$

They can be presented in the following matrix form:

$$k_{ij} = \begin{bmatrix} k_{11} & k_{12} & k_{13} \\ k_{21} & k_{22} & k_{23} \\ k_{31} & k_{32} & k_{33} \end{bmatrix}. \quad (7)$$

Considering the influence of anisotropy on the distribution of properties, it is important to accurately determine the measured values at the stage of designing the shape and volume of the mold.

Since metallic materials are mainly used in polycrystalline state, the mechanism of their texture formation depends on the structure of the original billet. The distribution of the texture intensity is determined by the initial crystallographic texture, as a response of the last technological process. In the known technological metal forming processes, during the first hot rolling of ingots, the results of crystallization have a significant impact on the macro- and microstructure of the billet, as well as its quality. This is primarily due to the presence of both the globular and axial texture in the ingot [1].

In determining the effect of symmetry on the physico-mechanical properties of semi-finished and finished products, four types of symmetry are studied: the symmetry of the original billet, the symmetry of the external field effects, the symmetry of the resulting change and the symmetry of the physical properties of the product [4].

The definition of the symmetry of physical properties is based on the Neumann's principle: the symmetry group of any physical property G_{CB} should include all the elements of a point group (crystallographic class) of a crystal G_K . In other words, the group G_K either coincides with the group G_{CB} , or is its subgroup. This statement can be presented, using the elements of the theory of groups:

$$G_K \subseteq G_{CB}. \quad (8)$$

Mathematically, this condition is expressed by the equality of the tensors T :

$$T'_{ijk\dots} = T_{ijk\dots} \quad (9)$$

Nowadays the idea that the final physico-mechanical properties of semi-finished products and operating characteristics of finished products are formed at the process stage has become widely accepted [15]. Thus, it is important not only to consider the initial structure of the cast billet, but also to set it when designing the specified operational properties of the finished product.

Based on Shubnikov-Curie principle of symmetry, a technology of directional crystallization in ingots was developed, in order to consider their physico-mechanical properties. This is possible due to the specified temperature gradient in the considered directions of the heat flux during the ingot crystallization [16-23].

Experimental research and discussion of the results. The current paper presents the results of an experiment to obtain a casting in a mold of a pentagonal cross section, a physical system for creating a controlled heat flux (figure 1 *a, b*).



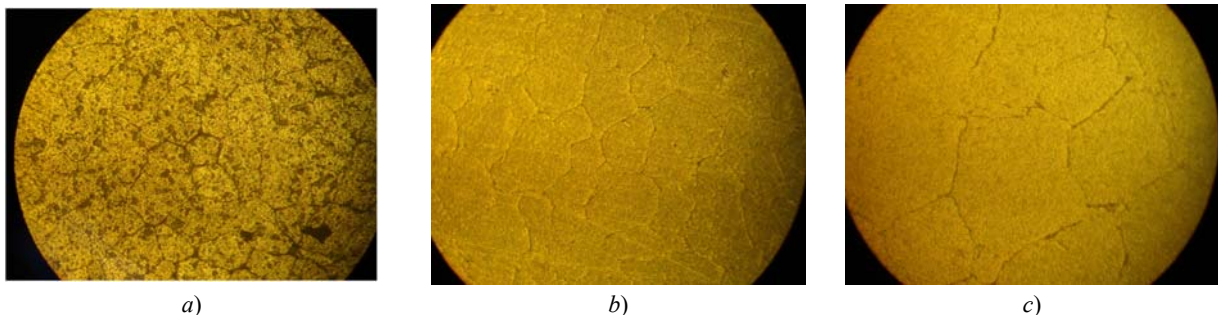
Figure 1 – Pentagonal casting (*a*) and mold (*b*)

The source material is an aluminum bar AD 1 (1.5 kg) and an aluminum ingot (1.5 kg). The metal was heated in the furnace up to 820°C.

A steel plate (5 mm thick) was used as the substrate for the metal mold, in order to create directional solidification. The lower part of the mold was filled with sandy-clay mixture and placed on a plate (figure 1, *b*).

Before being poured, the melt was cooled to the temperature $T_{fill.} = 700^\circ\text{C}$ (controlled by the thermocouple). After that, the metal was poured into the prepared mold (unheated, at room temperature). The cooling of the casting (60 min) was carried out in the open air.

The results of the metallographic study of the obtained samples are shown in figure 2.



Magnification: *a*) 100x; *b*) 200x; *c*) 500x

Figure 2 – Microstructure of aluminum-copper alloy, pentagon casting, pouring at 700 °C, unheated mold, cooling outdoors, etching with hydrofluoric acid solution

Figure 2 shows that the grain boundaries are viewed weakly, due to the short duration of etching. The shape of grains is also very remarkable. They are identical with the geometry of the casting mold. However, as it has been mentioned, the heat transfer in different directions is not the same for each point, and therefore the grains grow in the shape of irregular pentagons. Nevertheless, extraordinary polycrystallites can also be observed. Their shape coincides almost perfectly with the geometric shape of the mold. This fact can be explained by the Curie dyssymmetrization principle.



Figure 3 – Macrostructure of an aluminum alloy ingot with the response of the generalized structure of the thermal field

Figure 3 shows the macrostructure of the aluminum alloy ingot, with the response of the generalized structure of the thermal field. Geometric texture is clearly expressed there, due to the geometric parameters of the heat removal.

Conclusion.

1. In order to study the crystallographic texture of the ingot, it is necessary to consider the generalized structure of the thermal field as a heterogeneous system. This system is formed by different relations of geometrically connected lateral surfaces of the mold and the symmetry characteristics of the melt at heat kinetic level.

2. The effectiveness of system analysis (based on the Shubnikov-Curie principle of symmetrization-dissymmetrization) in solving problems of thermal effect on the molten liquid metal, is experimentally proved.

3. Based on the system analysis, it can be argued that the billet, obtained by casting into a mold with a pentagonal cross-sectional shape according to the presented technology, has reduced ductility and elasticity properties and cannot be recommended for further forming processes.

4. Based on theoretical studies and experimental data, it can be argued that the management of crystallographic texture in casting processes and its consideration in the design of metal forming technologies will optimize the properties of semi-finished and finished products for mechanical engineering.

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ИЗЛОЖНИЦАНЫҢ ГЕОМЕТРИЯЛЫҚ ПІШІНІНІҢ ҚЫСЫММЕН ӨНДЕУГЕ АРНАЛҒАН ҚҰЙЫЛҒАН ДАЙЫНДАМА ҚҰРЫЛЫМЫНА ӘСЕРІ

Аннотация. Металлургиялық дайындама құйып алып кейін қысыммен өңдеу процесінде белгілі механикалық және кристаллографиялық текстураға, яғни оның ішкі элементтерінің (кристаллиттерінің) айрықша бағытына ие болады. Біртекті металдың кристаллиттері бір кристалдық құрылысына ие болып кристаллографиялық текстурасымен басқаша айтқанда, кристаллографиялық остерінің өзара бағыттарымен айыры-

лады. Дәл осы кристаллографиялық текстурасы физика-механикалық қасиеттерінің пайда болуына жауапты және көпкристалдық материалдың қасиеттері анизотропиясын анықтайды.

Текстура және, демек, қасиеттердің пайда болу процесі балқыма қатаю кезінде жылуды балқымадан қалыпқа (изложницаға) беру құбылысына байланысты. Жылу беру процестері жылу өрісінің Кюридің гетерогенді жүйелер үшін симметрия принципі негізінде айқындалатын жалпыланған құрылымымен анықталады. Бұл сәтте гетерогенді жүйе бір жағынан қалып қабырғасы жасалған анизотропты металл парағының кристаллографиялық текстурасының симметриялық сипаттамасымен білінеді. Екінші жақтан балқыманың жылу өрісі құрылымының симметриялық сипаттамасымен көрсетіледі. Ал сол құрылым қалыптың көлденең қимасы пішінімен және беттерін шектейтін геометриялық қатынастармен, сонымен бірге балқыма құю жағдайларының әсерімен және қалыптың (изложницаның) түбі мен құю жақтарындағы жылуды әкету жағдайларының айырмашылығымен анықталады.

Мақалада изложницада қатайғанда сұйық металл балқымасына жылу әсері есептерін шешу үшін Шубников-Кюри симметризация-диссимметризация принципі негізінде жүйелің талдау қолданудың тиімділігі көрсетіледі. Сығымдама құрылымында бүйірлік жағы бойынша екінші реттік симметрия осі пайда болу туралы болжам ұсынады. Дайындаманың жалпыланған құрылымына тиісті, кристаллиттердің геометриялық құрылымы және кристаллографиялық текстурасы балқыма кристалданған кезіндегі жылу өрісінің әсерімен анықталады. Жылу өрісі изложницаның геометриясымен және оның құю мен түп бөліктері құрылысының ерекшеліктерімен анықталады.

Сығымдаманың кристаллографиялық құрылымын зерттеу үшін жылу өрісінің жалпыланған құрылымын қалыптың (изложницаның) геометриялық байланған бүйір беттерінің және балқыманың жылу-кинетикалық деңгейіндегі симметриялы сипаттамаларының әртүрлі қатынастарымен түзілген гетерогенді жүйе ретінде қарастыру қажет.

Физикалық әсер ететін өрісінің жалпыланған құрылымын талдау машина жасауда пайдаланатын жартылай өнімдерді қысыммен өңдеу процестерімен алу үшін құйылған дайындаманың қасиеттерін тиімді етуге мүмкіндік туғызады. Осыны дайын бұйымның пайдаланушылық қасиеттерін есепке алу үшін білу қажет.

Қимасы әртүрлі изложницаларда кристалдану процесінде құйылған дайындаманың құрылымы (материал көлемінде дәндер таралуы) Шубников-Кюри симметризация-диссимметризация принципіне сәйкес өзгертіндігі эксперименталды көрсетілген. Құрылым өзгеруі өз ретінде құйылған дайындаманың физика-механикалық қасиеттеріне әсер етеді.

Түйін сөздер: қысыммен өңдеу, кристалдану, симметрия, жылу ағыны, текстура, Шубников-Кюри принципі, изложница.

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ВЛИЯНИЕ ГЕОМЕТРИЧЕСКОЙ ФОРМЫ ИЗЛОЖНИЦЫ НА СТРУКТУРУ ЛИТОЙ ЗАГОТОВКИ ДЛЯ ОБРАБОТКИ ДАВЛЕНИЕМ

Аннотация. Металлургическая заготовка в процессе литья и последующей обработки ее давлением приобретает определенную механическую и кристаллографическую текстуру – преимущественную ориентацию составляющих ее внутренних элементов (кристаллитов). В однородных металлах кристаллиты обладают одинаковым кристаллическим строением, но отличаются взаимной ориентацией кристаллографических осей – кристаллографической текстурой. Именно кристаллографическая текстура ответственна за формирование физико-механических свойств и определяет анизотропию свойств поликристаллических материалов.

Процесс формирования текстуры и, соответственно, свойств зависит от отвода теплоты от расплава в форму (изложницу) при затвердевании расплава. Процессы теплопередачи будут определяться обобщенной структурой теплового поля, которая может быть выявлена на основе принципа симметрии Кюри для гетерогенных систем. В данном случае гетерогенная система представлена, с одной стороны, симметричной характеристикой кристаллографической текстуры анизотропного металлического листа, из которого изготовлена стенка изложницы. С другой стороны – симметричной характеристикой структуры теплового поля расплава, обусловленной формой поперечного сечения и геометрическими соотношениями ограничивающих

поверхностей изложницы, а также влиянием условий заливки и различием условий теплоотвода между донной и литниковой частью изложницы.

Показана эффективность применения системного анализа на основе принципа симметризации-диссимметризации Шубникова-Кюри при решении задач теплового воздействия на расплав жидкого металла при его затвердевании в изложнице. Выдвинуто предположение о появлении в структуре слитка оси симметрии второго порядка относительно боковой поверхности. В соответствии с обобщенной структурой заготовки, геометрическая структура кристаллитов и кристаллографическая текстура определяются воздействием теплового поля при кристаллизации расплава. Тепловое поле определяется геометрией изложницы и особенностями строения ее литниковой и донной частей.

Для исследования кристаллографической текстуры слитка необходимо рассматривать обобщенную структуру теплового поля как гетерогенную систему, образованную различными соотношениями геометрически связанных боковых поверхностей изложницы и симметричными характеристиками расплава на теплокинетическом уровне.

Анализ обобщенной структуры поля физического воздействия позволяет оптимизировать свойства литой заготовки для последующих процессов обработки давлением полуфабрикатов для машиностроения. Это необходимо для учета эксплуатационных свойств готового изделия.

Экспериментально показано, что структура литой заготовки (распределение зерен в объеме материала) в процессе кристаллизации в изложницах различного сечения претерпевает изменения в соответствии с принципами симметрии Шубникова-Кюри, что, в свою очередь, оказывает влияние на физико-механические свойства литой заготовки, в том числе и на характер пластической деформации в процессе дальнейшей ее обработки давлением.

Ключевые слова: обработка давлением, кристаллизация, симметрия, тепловой поток, текстура, принцип Шубникова-Кюри, изложница.

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THE RESEARCH OF THE STEEL CUTTING BLADE RELIABILITY FOR THERMO-FRICTIONAL PROCESSING

Abstract. The scientific and theoretical research of the steel cutting blade working for thermo-frictional cutting. An option of rod approximation when a solid of a circular blade is considered as a hingeless circular arch on given to the middle of the surface of blade flat from multiplicity approaches to the modeling of calculation scheme of working rotating blade is offered. A classical work method was applied to study stress-strain state; taking into account an arch symmetry a number of unknown forces equal 3. To exclude incidental coefficient, feature of an elastic center for weightless infinitely rigid console was used. To clarify results of calculation of reliability of the cutting blade was used by software package Lira. The contour plots of stresses and displacements were presented. Comparison of the calculations results of the saw blade based on two computational models: rod and bar changes indicate similarity laws of stress, but there is a definite difference in the values of stress, which is explained by the difference approximating expressions.

Key words: thermo-frictional cutting, a cutting blade, a hingeless circular arch, contour plots of stress, bending moments, cross forces, longitudinal forces.

Introduction. The process of thermo-frictional cutting metal blank of rapidly rotating steel disc found widespread at the metallurgical enterprises in the Commonwealth of Independent States (CIS) and abroad. The main advantage of this method is the technological simplicity, low cost and high performance cutting.

One of the advantages of thermo-frictional cutting is making discs from conventional structural steels (steel 50, 50G, 65G, etc.) than the saving of scarce tool steels and alloys. Disks geometrically distinguished: with smooth cylindrical outer surfaces, a knurled or serrated, toothed [1]. The latter have increased productivity, as a friction metalworking chip formation is added to the process, as well as delivered to the cutting zone additional oxygen [2]. But such drives require constant re-sharpening the teeth. In order to reduce the side friction disc on the metal blank to be cut from the end of the disc ends undercut at $0.5 \div 1$ mm. Usually discs are cooled with the air, but in the case of cutting an extended cooling water is recommended. Friction discs cut metal blank of steel and cast iron of different profiles and hardness. The special effect is achieved when cutting hard materials: hardened alloyed, corrosion-resistant and high-temperature alloys [3]. Applications thermo-frictional cutting is cold and hot cutting rolled section steel of small, medium and large sizes. In [4] the process of thermo-frictional cutting of metal blank is characterized as a high-performance method for the separation of hot and cold metal blanks of various materials, with major disadvantage inherent in this process - the formation of large burrs at the ends of metal blank to be cut. The entire surface of metal blank friction and a small part of the continuously updated disc friction surface are constantly involved while friction cutting. Figure 1 shows a diagram of the thermo-frictional cutting of the metal blank.

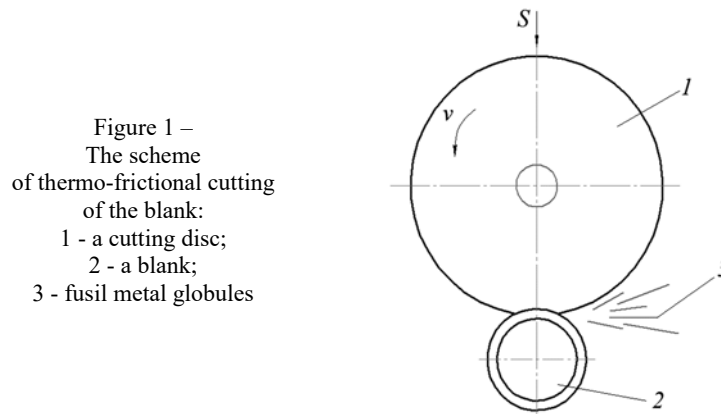


Figure 1 –
The scheme
of thermo-frictional cutting
of the blank:
1 - a cutting disc;
2 - a blank;
3 - fusil metal globules

Figure 1 shows a diagram of thermo-frictional cutting of metal blank, where cutting disc rotates with velocity v , it has a vertical feed S . Upon contact with the pipe, the rotary disc heats the contact layer of the metal blank. As a result, the heat released by friction is accumulated mainly in a small volume of metal blank, while continuously cooled disk is heated slightly [5,6]. Heating metal blank in the cutting zone occurs so rapidly that a few hundreds of a second contact plate temperature approaches the melting temperature of metal, the blank surface layer softens, microroughnesses of rotating disk is embedded in the surface of the metal blank and conduct microcutting [7]. The largest globules of fusil metal by centrifugal force and break away from the disc are ejected from the cutting zone in the form of sparks beam (see figure 1). Small globules are welded to the disc, forming microroughness like the abrasive grains. In the process of cutting the microprojections are worn because of the metal blank and by the time of exit from the cutting zone are cooled down in the air and crumbled from the disc. But with each new revolution of the disk on its friction, surface forms a fresh layer of micro-roughness. Thus, cutting process is connected with the process microcutting, so exceptionally high performance is achieved during the thermo-frictional cutting [8,9]. Thus, the main disadvantages of the thermo-frictional processing are the noise generated by the disc during operation, the formation of large burrs at the ends, the complexity of cutting a thin-walled products [10,11,12].

The authors patented the resource saving methods of thermal frictional manufacture into small velocity [13,14,15], constructions of cutting blades [16,17] and systems [18]. Comparison with traditional methods of manufacture shows that using this method reduces costs of equipment by 3-5 times by the feasibility selling at simplified machines ($n_{sp} < 4000$ rpm) and increases tool durability in 10-30 times [19,20,21,22,23]. However, there is the problem of providing a cutting surface perpendicularity, which is directly dependent on the stiffness and dimensional stability of the cutting disc. In this regard, work to study the reliability of steel cutting discs is relevant.

The research methods. A cutting blade is modeled as a hingeless arch to study its reliability, it is possible to perform calculations, using a rod model in the form of a hingeless circular arch, for half a cutting blade.

The photographs of steel cutting blades made of the different materials are shown (figure 2).



Figure 2 – The photographs of the cutting blades:
(a) a cutting blade of steel 65D; (b) a cutting blade of steel 50; (c) a cutting blade of steel 45;
(d) a cutting blade of steel Hardox (e) a cutting blade of steel 20

Calculating theory of hingeless archs. A cutting blade can be considered as a rod system in the form of a hingeless circular arch with a rectangular cross section. A hingeless arch is curve-linear rod with two tough ends. Figure 3 shows geometric arch scheme. In this arch number of unknowns equal to six (there are 6 reactions in its supports: 2 vertical, 2 horizontal and 2 moments, equations for arch balance can be made up only 3), therefore this system is thrice statically indeterminable ($n=3$).

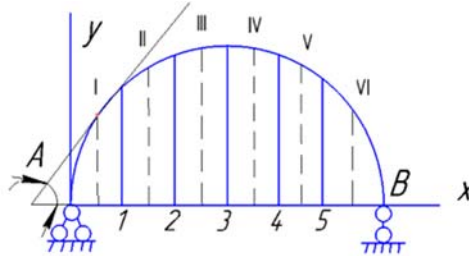


Figure 3 – The geometrical scheme of an arch

Main unknowns (figure 4a) - Z_1 inversely symmetrical force, - Z_2, Z_3 symmetrical forces. The canonical equations of flexibility method

$$\begin{cases} \delta_{11}Z_1 + \delta_{12}Z_2 + \delta_{13}Z_3 + \Delta_{1p} = 0, \\ \delta_{21}Z_1 + \delta_{22}Z_2 + \delta_{23}Z_3 + \Delta_{2p} = 0, \\ \delta_{31}Z_1 + \delta_{32}Z_2 + \delta_{33}Z_3 + \Delta_{3p} = 0. \end{cases} \quad (1)$$

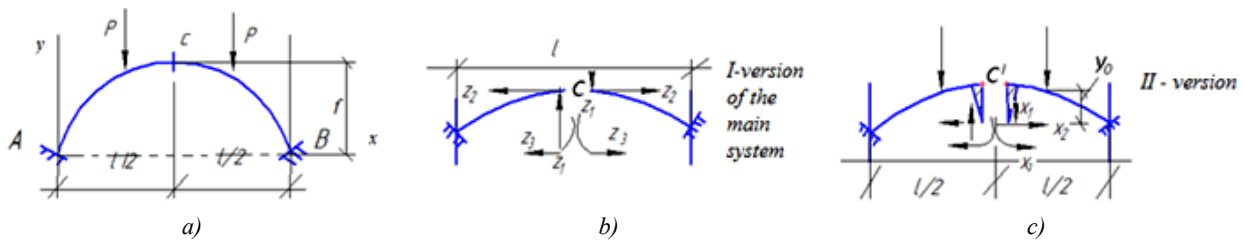


Figure 4 – The calculated scheme of the arch and options of the main systems

Multiplication symmetrical and inversely symmetrical of diagrams moments results in $\delta_{12} = \delta_{21} = \delta_{13} = \delta_{31} = 0$, inasmuch as $\delta_{32} \neq \delta_{23} = 0$ instead of first option of main system (figure 4b) we choose second option at the main system (figure 4c). To do this we attach weightless and tough 2 symmetrical consoles with length « Y_0 » sections making in cut lock. We attach new principal unknown forces X_1, X_2, X_3 (X_1, X_2 forces X_3 bending moments to the consoles ends («C») point).

Matching 2 options of main systems (figure 4 b, c) we get the ratio between 2 kinds of main unknowns:

$$z_1 = X_1; z_2 = X_2; z_3 = X_3 - X_2 \cdot y_0. \quad (2)$$

The system of the canonical equations for symmetrical unknowns (X_2) and (X_3) will be the next (for figure 4b).

$$\begin{cases} X_2 \delta_{22} + X_3 \delta_{23} + \Delta_{2p} = 0, \\ X_2 \delta_{32} + X_3 \delta_{33} + \Delta_{3p} = 0. \end{cases} \quad (3)$$

Where in it is necessary to choose length console (y_0) such way that incidental displacement (δ_{23}) in system (3) turn to zero naturally. Figure 5 shows the calculated scheme of an arch and the main system.

Figure 6 shows the bending moments, cross and longitudinal forces.

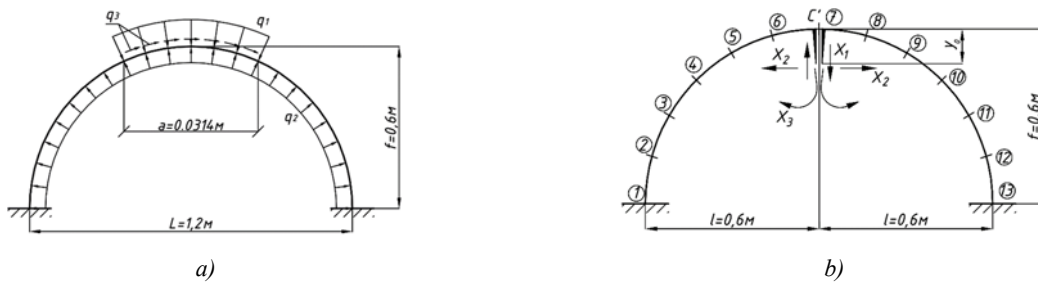


Figure 5 – The calculated scheme of the arch and the main system:
 (a) the calculated scheme; (b) the main system

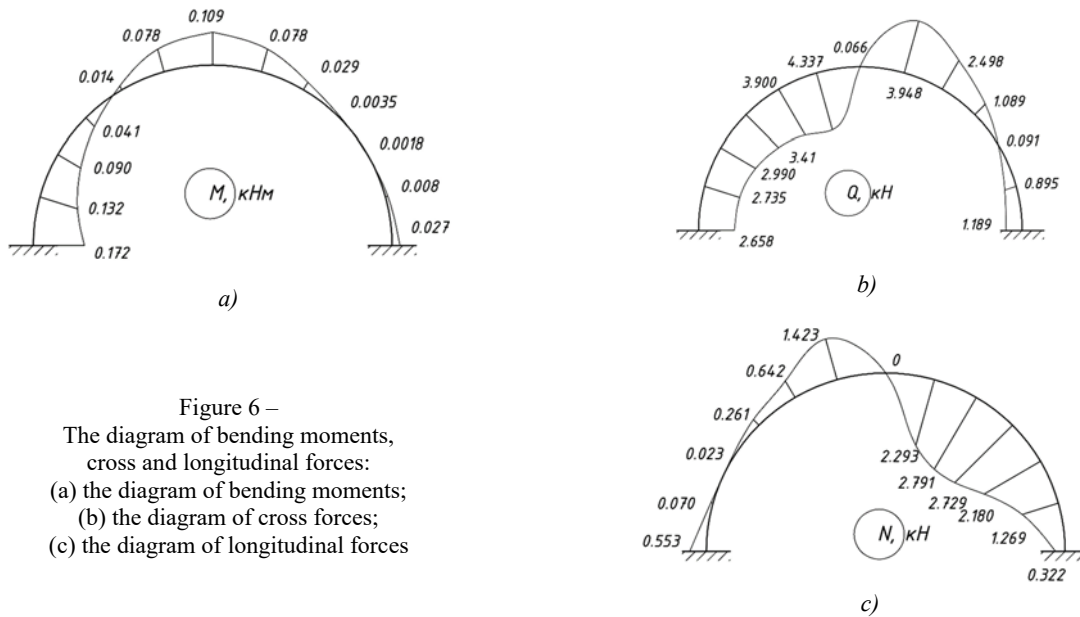


Figure 6 –
 The diagram of bending moments,
 cross and longitudinal forces:
 (a) the diagram of bending moments;
 (b) the diagram of cross forces;
 (c) the diagram of longitudinal forces

By the values inner forces, the stresses into arches can be calculated by the following equations:

$$\sigma_K = -\frac{N}{A} \left(1 + \frac{y_F \cdot y_K}{i_x^2} \right) \tag{4}$$

where $A = bh$ - cross sectional area; y_F - the most distant point from neutral line; y_k - point of application; i_x^2 - square radius of inertia.

$$\tau = \frac{Q \cdot S_x}{J_x \cdot b} \tag{5}$$

where $J_x = bh^3 / 12$ - moment of inertia; $S_x = bh^2 / 8$ - static moment; b - thickness of a blade; h - width (radius) of a blade.

We can do test of strength of a blade by the following theory of strength.

$$\sigma_{red} = \sqrt{\sigma_K^2 + 3 \cdot \tau^2} \leq R \cdot \gamma_c \tag{6}$$

where $\sigma = \pm\sigma_M \pm \sigma_N$ - full normal stress; R - calculated resistance; γ_c - coefficient of working conditions.

The calculated results are presented in table 1.

Table 1 – The calculating stress in the arch

№	σ_K	τ	σ_{red}	№	σ_K	τ	σ_{red}
1	-16,76	8,31	22,09	8	3,34	12,34	21,63
2	-13,6	8,55	20,11	9	- 2,79	7,81	13,81
3	-9,33	9,34	18,68	10	-5,32	3,4	7,94
4	-3,72	10,66	18,83	11	-4,35	0,28	4,38
5	2,8	12,19	21,30	12	-1,81	2,8	5,18
6	11,09	13,55	25,96	13	2,14	3,72	6,79
7	11,35	13,21	25,54				

Calculation of reliability of a cutting blade on lira software package Calculation was fulfilled on Lira software package 9.6. The calculated scheme (figure 7) is taken in the form half an arch with 4 nodes bars loaded by the linear loadings which considered a cutting process.

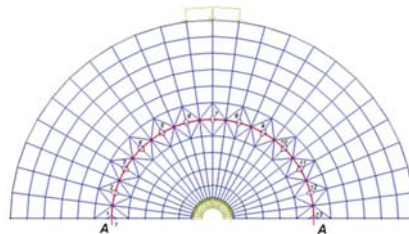


Figure 7 – The calculated scheme of the half-disc

Calculating results are showed below (figure 13). Data of stress component by appropriate sectors are showed in a table 2.

Resulting stressed for half - disc are determined by the following equation:

$$\sigma_{red} = \sqrt{\sigma_x^2 + \sigma_z^2 + 3 \cdot \tau_{xz}^2} \leq R \cdot \gamma_c \quad (7)$$

Table 2 – Calculation of stress (two-dimensional problem) in bars (by section A-A)

№	σ_x	σ_z	τ_{xz}	σ_{red}	№	σ_x	σ_z	τ_{xz}	σ_{red}
1	-3.19	-3.7	-1.86	5.85	8	-0.27	-20.4	-11.1	28.03
2	-3.95	-3.26	2.13	6.31	9	3.57	-21.58	-1.14	21.96
3	-6.25	-2.28	2.14	7.62	10	0.86	-16.74	6.09	19.80
4	-9.96	-0.84	1.35	10.27	11	-4	-10.54	9.07	19.34
5	-14.9	0.78	-1.94	15.29	12	-9.07	-4.38	8.73	18.17
6	-17.4	-1.06	-9.44	23.90	13	13.32	-1	5.86	16.78
7	-11	-10.5	-15.5	30.85					

Figure 8 shows the contour plots of stress and displacement by the axis.

The discussion of the received results. The received theoretical results after the researches testify to the following issues:

Work modeling of cutting metal blade was fulfilled in two options (as a rod system – in the form a hingeless circular arch and as a two-dimensional system – in the form thin circular isotropic bar with holes) gives results (as stresses and displacements) are sufficiently close to each other which indicates the reliability initial theoretical assumptions. The contour plots of stresses and displacements along the axis (figure 8 a,b,c) resulting in software package Lira, adequately reflects the work of cutting blade. Thus, for example, N_x , τ_{xz} , N_z increasingly concentrated in the zone of maximum loading blade (closer to the outer contour of the blade) with the blade concentrating stresses in feed zone a treated material body. The

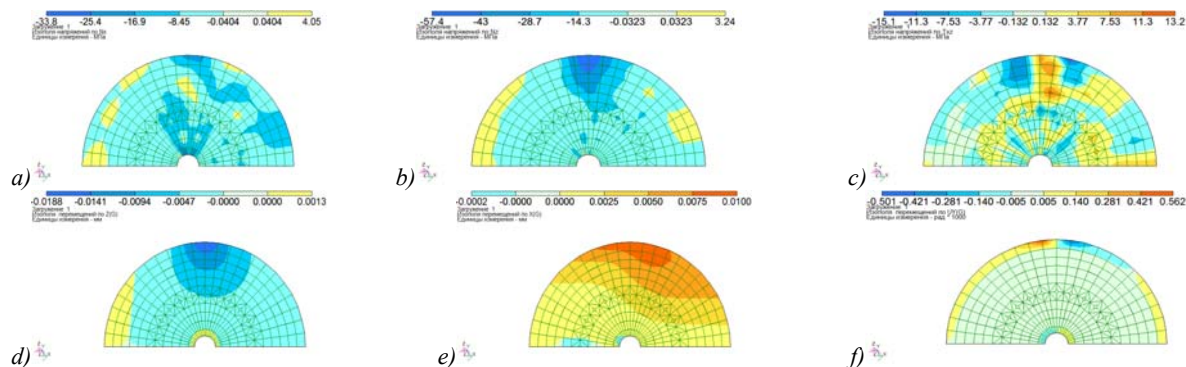


Figure 8 – Contour of the plots and displacement by the axis:
 a) stress contour of plots (σ_x) by the axis X; b) stress contour of plots (σ_z) by the axis Z;
 c) stress contour of plots (τ_{xz}); d) displacement contour of plots by the axis Z;
 e) displacement contour of plots by the axis X; f) contour of plots of angle of rotation relative to the axis Y

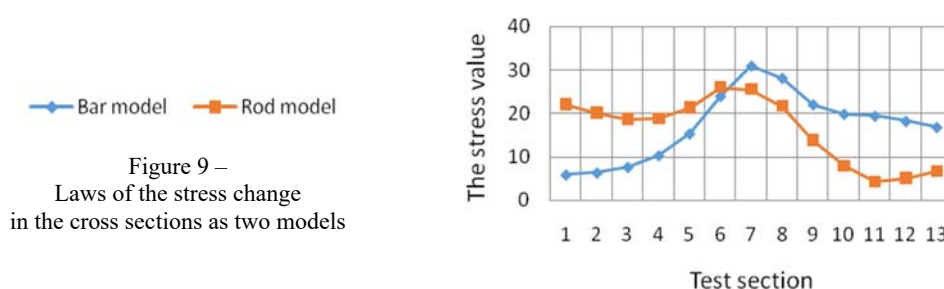


Figure 9 –
 Laws of the stress change
 in the cross sections as two models

received results of calculation are in the form of two models (a rod and bar) showed that under given conditions is provided strength a condition blade saw wherein received value of stress in two calculations don't diverge much (figure 9).

Thus, the given two options of modeling provide reliable protection work.

Conclusions. 1. The methods of a stressed state calculation of a cutting blade was developed for thermal frictional cutting the bars in the cutting process, which is a rotating circular blade in diameter 240 mm, and constant thick $t = 4$ mm.

2. Cutting blade process was modeled by 2 options; as a rod system (in the middle «half-blade» axis) in the hingeless arch form (three times statically indeterminate system) as a two-dimensional system (a circular half-blade) as a thin isotropic bar.

3. The calculations are made with using the following methods: the analytical forces, methods are for hingeless arch (manual count), the numerical methods of finite elements for the bar in the form of «semi-circle» (a machine calculation) based on software package Lira 9.6).

4. Comparison of the calculations results of the saw blade based on two computational models: rod and bar changes indicate similarity laws of stress (figure 9), but there is a definite difference in the values of stress, which is explained by the difference approximating expressions.

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ТЕРМОФРИКЦИЯЛЫҚ ӨНДЕУГЕ АРНАЛҒАН БОЛАТТАН ЖАСАЛҒАН ДИСКІЛІ КЕСКІШТІҢ СЕНІМДІЛІГІН ЗЕРТТЕУ

Аннотация. Авторлар кескіш дискілер мен қондырғыларды аз жылдамдықпен термофрикциялық өндеудің ресурс үнемдеу әдістерін патенттеді. Өндеудің дәстүрлі әдістерімен салыстыру көрсеткендей, пайдаланылатын бұл әдіс жабдықтауға кететін шығынды қарапайым станоктарда қолдану мүмкіндігі арқылы 3-5 есе

азайтады (пшп<4000 айн/мин), аспаптардың беріктігін 10-30 есе арттырады. Алайда, кескіш дискінің қаттылығы мен формасының тұрақтылығына тікелей байланысты болып келетін кесу орнының жоғарғы қабатының перпендикулярлығын қамтамасыз ету проблемасы орын алуы мүмкін. Соған байланысты, болаттан құйылған кескіш дискілердің сенімділігін зерттеуге бағытталған жұмыстар маңызды болып табылады. Берілген жұмыста термофрикциялық кесу үшін арналған болат кескіш дискінің ғылыми-теориялық зерттеулері жүргізілген. Жұмыс істеп тұрған айналмалы дискінің есептік сұлбасын үлгілеуге көптеген тәсілдерден, дөңгелек дискінің қатты денесі диск жазықтығының орта бетіне келтірілген шарсыз айналмалы арка ретінде қарастырылатын стерженьді аппроксимация нұсқасы ұсынылған. Кернеулі-деформацияланған күйді зерттеу үшін классикалық тәсіл қолданылған; арканың симметриясы ескереіле отырып, белгісіз күштер саны үш деп алынды. Кескіш дискінің сенімділігін зерттеу нәтижелерін нақтылау үшін Liga комплекстік бағдарламасында есептеулер жүргізілді. Кернеулер мен орын ауыстырулардың изополясы келтірілген. Дискі араның екі есептеу модулі бойынша есептеу нәтижелерін салыстыру: стерженьді және пластикалық кернеулердің өзгеру заңдылықтарының ұқсастығын көрсетеді, дагенмен кернеулер шамасында белгілі бір өзгешеліктер бар, ол аппроксимация өрнектерінің әртүрлілігімен түсіндіріледі.

Зерттеулер жүргізу нәтижесінде алынған теориялық қорытындылар кескіш дискінің жұмысын моделдеуді екі нұсқада орындау (стерженді жүйе ретінде – шарнирсіз доғалы арка түрінде және қос шамалы жүйе ретінде – саңылаулы жіңішке доғалы изотропты пластина түрінде) бір-біріне өте ұқсас нәтижелер беретінін көрсетеді (кернеулі және ауыстырмалы түрде), ал бұл түпкілікті теориялық болжамдардың дұрыстығын айқындап береді. Liga 9.6 бағдарламалық кешенінде алынған осьтер бойынша жүретін кернеулер мен ауысымдар изоәрісі кескіш дискінің жұмысын баламалы түрде көрсетеді. Екі модель түрінде (стерженді және пластиналы) алынған есептеулер нәтижелері көрсеткендей, берілген күштің жағдайында дискідегі араның беріктілігі жағдайын қамтамасыз етеді, сонымен бірге алынған кернеулердің мәндері екі есептеуде де аса алшақ болмайды. Жүргізілген зерттеулер нәтижесінде диаметрі 240 мм, тұрақты қалыңдығы $t=4$ мм доғалы айналмалы дискі болып келетін, кесу процесінде термофрикциялық түрде кесуге арналған кескіш дискінің кернеулі күйін есептеп шығару әдістемесі әзірленді.

Кескіш дискінің атқаратын жұмысы екі нұсқада: стерженді жүйе ретінде (ортадағы ось бойынша (жартылай дискі) – шарнирсіз дискі түрінде (үш реттік статистикалық анықталмаған жүйе); қос шамалы жүйе ретінде (доғалы жартылай дискі) – жіңішке изотропты пластина түрінде моделденеді. Есептеулер келесідей әдістермен: күштердің аналитикалық әдістерімен – шарнирсіз арка үшін (қолмен атқарылатын есептер); түпкі элементтерді санау әдістерімен – «жартылай доға» түріндегі пластиналар үшін (машиналы есептер – Liga 9.6 бағдарламалық кешен негізінде) жүргізіледі. Осы стерженді және пластиналы екі есептеу модельдері бойынша дискілі араны есептеу нәтижелерін салыстыру көрсеткендей, кернеудегі өзгерістер заңдылықтары ұқсас болып шыққан, алайда, аппроксимирлі болып келетін айырмашылықтарымен түсіндірілетін кернеулердің шамалары бойынша белгілі бір айырмашылықтары да болады.

Түйін сөздер: термофрикциялық кесу, кескіш диск, шарнирсіз айналмалы арка, кернеулер изополясі, иілгіш моменттер, бойлық күш, көлденең күш.

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ИССЛЕДОВАНИЕ НАДЕЖНОСТИ СТАЛЬНОГО РЕЖУЩЕГО ДИСКА ДЛЯ ТЕРМОФРИКЦИОННОЙ ОБРАБОТКИ

Аннотация. Авторами запатентованы ресурсосберегающие способы термофрикционной обработки малых скоростях, конструкции режущих дисков и устройств. Сравнения с традиционными способами обработки показывают, что использование рассматриваемого снижает расходы на оборудование в 3-5 раз за счет возможности реализации на упрощенных станках (пшп<4000 об/мин), увеличивает стойкость инструмента в 10-30 раз. Однако существует проблема обеспечения перпендикулярности поверхности резания, которая непосредственно зависит от формоустойчивости и жесткости режущего диска. В этой связи работа, направленная на исследование надежности стальных режущих дисков, является актуальной. Выполнено научно-теоретическое исследование работы стального режущего диска для термофрикционной резки. Из множества подходов к моделированию расчетной схемы работающего вращающегося диска предложен

вариант стержневой аппроксимации, когда твердое тело кругового диска рассматривается как бесшарнирная круговая арка, по приведенной к срединной поверхности плоскости диска. Для исследования напряженно-деформированного состояния применен классический метод сил; с учетом симметрии арки число неизвестных сил равно трем. Для исключения побочных коэффициентов использовано свойство упругого центра для невесомой бесконечно жесткой консоли. Для уточнения результатов исследования надежности режущего диска произведен расчет на программном комплексе Lira. Приведены изополя напряжений и перемещений. Сравнение результатов расчетов дисковой пилы по двум расчетным моделям – стержневая и пластинчатая – показывают схожесть закономерностей изменения напряжений, однако существует определенное различие по величинам напряжений, что объясняется различием аппроксимирующих выражений. Полученные в результате исследований теоретические результаты свидетельствуют о том, что моделирование работы режущего диска выполнены в двух вариантах (как стержневая система – в виде бесшарнирной круговой арки и как двумерная система – в виде тонкой круговой изотропной пластины с отверстиями) дает результаты (в виде напряжений и перемещений), достаточно близкие между собой, что свидетельствует о достоверности исходных теоретических предположений. Изополя напряжений и перемещений по осям, полученные на программном комплексе Lira, адекватно отражают работу режущего диска. Полученные результаты расчетов в виде двух моделей (стержневой и пластинчатой) показали, что в условиях заданных усилий обеспечиваются условия прочности дисковой пилы, при этом полученные значения напряжений в обоих расчетах сильно не расходятся. В результате выполненных исследований была разработана методика расчета напряженного состояния режущего диска для термофрикционной резки заготовок в процессе резания, представляющего собой круглый вращающийся диск диаметром 240 мм, постоянной толщиной $t=4$ мм. Работа режущего диска была смоделирована двумя вариантами: как стержневая система (по срединной оси «полудиска») – в виде бесшарнирной арки (трижды статически неопределимая система); как двумерная система (круговой полудиск) – в виде тонкой изотропной пластины. Расчеты произведены следующими методами: аналитическими методами сил – для бесшарнирной арки (ручной счет); численными методами конечных элементов – для пластины в виде «полукруга» (машинный счет – на основе программного комплекса Lira 9.6). Сравнение результатов расчетов дисковой пилы по двум расчетным моделям: стержневая и пластинчатая показывают схожесть закономерностей изменения напряжений, однако есть определенное различие по величинам напряжений, что объясняется различием аппроксимирующих выражений.

Ключевые слова: термофрикционная резка, режущий диск, бесшарнирная круговая арка, изополя напряжения, изгибающие моменты, поперечные усилия, продольные усилия.

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**SOCIO-ECONOMIC ASPECTS OF NATURE MANAGEMENT
IN THE KAZAKHSTAN'S CASPIAN SEA REGION BASED
ON FUNCTIONAL ZONING OF THE TERRITORY**

Abstract. The article considers the socio-economic conditions of the Atyrau and Mangystau regions with the areas of the adjacent Caspian Sea shelf with an emphasis on the natural-resource potential, the ecological state and the peculiarities of economic use. Based on the assessment of the mapping of the types of economic use of lands, the functional zoning of the region under study was fulfilled and recommendations for sustainable nature management were given. The main target functions of the sectors of economic activity that determine the need for the use of territories and water areas were clarified to fulfill the functional zoning. Particular attention was paid to the industrial and transport use of territories and water areas with the detailed study of the current state of the most important regional industries: petrochemical and fisheries sector. Also, an assessment was given to the residential, agricultural and nature protection types of use of the territories of the regions and the adjacent water area of the Caspian Sea. On the basis of the results of the researches, a map of functional zoning was compiled, on which special zones of the main sectors of activity (industrial, transport, agricultural, nature protection, tourist-recreational, etc.) were allocated. A complex of possible interventions in existing nature management was defined for each of the functional zones in order to reduce or prevent the formation of conflict zones in nature management and to stimulate the most profitable industries from the socio-economic and environmental points of view.

Key words: functional zoning, socio-economic conditions, resources, economic use, nature management, land use, GIS-mapping.

Introduction. At the present stage of development of Kazakhstan, state policy is becoming poly-centric and much attention is paid to the regions: mechanisms are being introduced for stimulating competitive industries and economic development of promising districts to form a common economic space that is harmoniously integrated into the global economic system.

The Atyrau and Mangystau regions of Kazakhstan, with a total area of 284,2 thousand square meters and a population of 1312 thousand people, are transboundary relative to the Caspian Sea for 4 states of the area. Over the period of independence, the share of these regions in the total GRP of the country has increased almost 13 times – from 3,4% (1993) to 18,8% (2019) [1]. Currently in the Caspian Sea region of Kazakhstan, about 70 hydrocarbon deposits are being developed, 65,3 million tons of oil and 26,7 billion cubic meters of gas are being produced [1].

Research methods. Functional zoning is the most important component of sustainable regulation of the use of the territory, which determines those types of environmental management that can prevent or reduce the level of conflicts, promote the industry most beneficial from the socio-economic and environmental point of view for each of the zones on the basis of modern socio-economic development of the natural environment and the ecological state of resources.

First of all, functional zoning involves conducting an analysis of environmental management and includes component-based characteristics of the natural environment, analysis of the socio-economic and environmental situation of the territory. The types of environmental management are studied and mapped, and a classification is created from the point of view of impact on the natural environment [2,3].

The main stages of functional zoning are:

- collection and assessment of data on the components of the natural environment of the research area with the compilation of a set of thematic maps;
- assessment of the ecological state of the components of the natural environment;
- assessment of the socio-economic development of the territory and types of land use;
- assessment and mapping of land use types;
- analysis of land use, identification of ecological conflicts, analysis of causes, search for acceptable solutions;
- determination of the optimal option for the use of the territory by sectors of activity with the identification of zones requiring changes in the nature of use.

Almost all lands are used in natural or economic terms, a change in environmental management leads to the redistribution of lands between sectors. For example, territories allocated for residential or industrial facilities are withdrawn from agricultural land use, reserve lands or other categories of lands. Over time, due to their degradation, they will no longer have the natural value that they had before the redistribution. On the maps of actual environmental management, the territories used by the main types of land use are distinguished.

Analysis and results. Functional types of use of the territory are formed on the basis of revealing the mutual influence of existing natural conditions and the nature of the population's activity, including the analysis of natural, socio-economic, eco-economic and regulatory factors. The result of the study is displayed in a cartographic manner with the revealed actual data of the current land use. It is known that the lands used by man for industrial, agricultural and residential functions, which in the region under study occupy an area of 10710,3 thousand ha or 37,8%, are exposed to main anthropogenic impact.

Residential type of land use. Historically, the settlements of the Caspian Sea region are distributed extremely unevenly [4]. Narrow stripes on the coasts of the delta channels of the Volga, along the banks of the Zhaiyk (Ural), ZhEM (Emba), Oil (Uil), Sagiza rivers, lakes, northern and eastern coasts of the Caspian Sea, along highways, near sand massifs of peninsulas are most densely populated.

There were changes in the location of settlements with the development of industry and transport, they began to develop near deposits and transport hubs, and in recent decades, urbanization processes have intensified. The necessary condition for the emergence and sustainable development of residential territories is the availability of resources in quantity, quality and diversity sufficient to meet the basic vital requirements of the population, at least to maintain a minimum acceptable standard of living [5,6]. So, as a result of industrial expansion, development of the richest reserves of natural resources, new settlements in the Caspian Sea region - Tengiz, Prorva, Ozen, Zhetybai, Tenge, Munaishy and others, on the new railway lines - Akkol, Akkystau, Borankul, Beineu, Mangyshlak, Sayotes, as well as new administrative and industrial centers of Aktau, Zhanaozen, Kulsary and others appeared.

Industrial and transport type of land use. The Caspian Sea region is one of the largest industrial centers of the country. The basis of the economic growth of the Caspian Sea region is the mining industry, namely the extraction of hydrocarbons and its partial processing [7]. Thus, out of 90 million tons of crude oil produced in the country in 2018, 72% fall on the Atyrau (47 million tons) and Mangystau (18 million tons) regions [1].

Over twelve years, industrial lands increased by 84,5 thousand ha in the Atyrau region alone, and by almost 100 thousand ha in the Mangystau region. Almost 50% of the country's oil is being currently produced on 6% of the coastal zone. In general, the lands of industry, transport, communications, defense and other non-agricultural purposes occupy 3,4% of the region's territory.

Agricultural type of land use. Against the background of the active development of the oil and gas industry, agriculture of the region, especially the agricultural industry, is experiencing one of the most difficult periods.

The location of the Caspian Sea region in the depths of the continent of Eurasia determined the continentality of its climate. In addition, it is located in semi-desert and desert zones. This was the basis for the formation of an extremely arid climate, low fertility and salinity of desert soils and a lack of fresh water. Moreover, severe natural and climatic conditions are becoming more complicated against the background of worsening of ecological state. Processes of desertification are actively developing in the region.

Agricultural lands (99,3%) are used mainly as pastures. And these pastures are more attractive for grazing small cattle.

Environmental land use. In the territories of the Atyrau and Mangystau regions there are a number of specially protected natural areas (SPNAs).

On the lands of SPNAs, areas of non-coincidence of interests of nature users appear. One of the main conflict areas exists on the territory of the conservation zone of the Northern Caspian region, where, despite the special status of the object, decisions were made on the development of hydrocarbon deposits. On the lands of the Karakiya-Karakol Nature Sanctuary, a part of the uranium quarry enters, which is currently on standby, but nevertheless continues to have a negative impact on the environment. Almost all the SPNAs of the region are negatively affected due to overgrazing of livestock.

The lands of the *forest fund* include land areas covered by forest, as well as not covered by forest, but provided for the needs of forestry [8]. It is important to note that over a decade and a half the land area of the forest fund in the region has been almost unchanged. Forest areas are distributed extremely unevenly, especially in the Mangystau region, 93% of these lands are located in the Beineu district.

The *water fund* in the context of areas and districts of the Atyrau and Mangystau regions, taking into account water conservation zones, is only 1,8 thousand hectares, but it is of great importance both for the population and its household needs, and for the stable functioning of natural systems.

The *reserve lands* include all lands not provided for ownership or land use, which are under the jurisdiction of the district executive bodies.

Low-productive pastures located in the desert and semi-desert zones, as well as other lands, were transferred to the reserve lands. In recent years, there has been a tendency towards the development of reserve lands for agricultural and other purposes.

Functional zoning. Based on the assessment and mapping of the socio-economic development of the territory and the types of existing environmental management, functional zoning was performed within the Kazakhstan's Caspian Sea region (figure 1). The conducted analysis of the socio-economic situation of the territory made it possible to assess the current situation and identify opportunities for development. The results of the research reflecting the geographical characteristics of the district, the socio-demographic situation and the economic condition of the territory are interpreted to represent them in the GIS in the form of integrated assessments reflecting the state and tendency of the studied component to change.

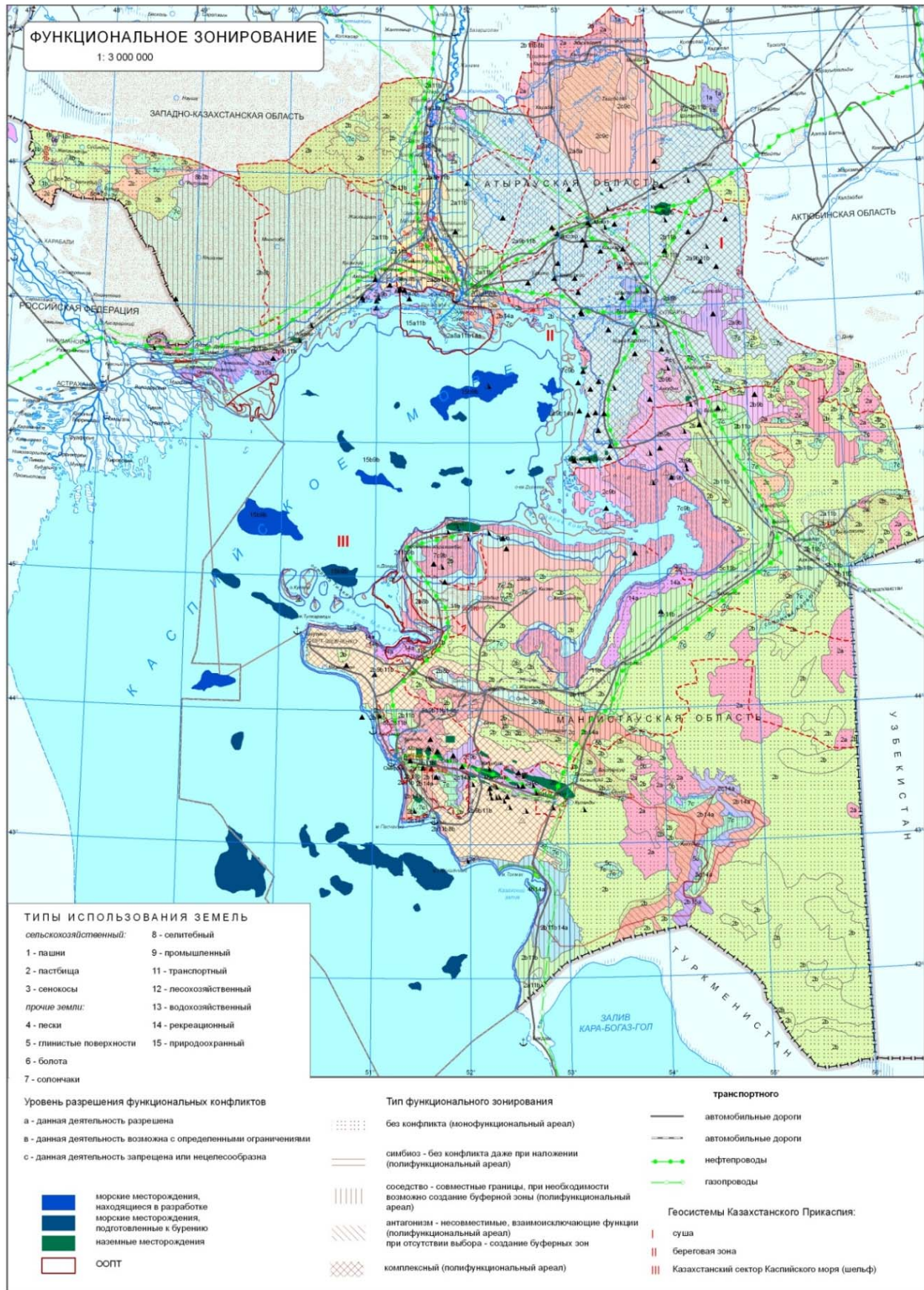
The implementation of functional zoning is necessary for the purposes of regulation and territorial organization of areas, identification of special zones of the main sectors of activity (agriculture, industry, transport, tourism, recreation, etc.). In addition, functional zoning serves for environmental purposes in SPNAs - in order to differentiate them into exclusive zones (for walking, diving, fishing, water sports, etc.). Moreover, the functional zoning establishes a set of possible interventions in the existing environmental management for each of the zones in order to prevent or reduce the level of conflicts, as well as stimulate the industries that are most beneficial from the socio-economic and environmental point of view.

Certain types of use are allowed in the designated areas, the rest are either prohibited or allowed under the agreed conditions.

Some of the limitations are set due to their impact on natural resources. These factors are taken into account when planning the multi-purpose economic development of the Kazakhstan's Caspian Sea region. The areas, where it is necessary to carry out measures on restoring natural resources, are identified in order to restore and conserve natural resources. These are lands subject to reclamation, reforestation, as well as wetlands, etc. A cartographic analysis of the types of land use shows that most of the study area occupied by the accumulative and denudation plains is monofunctional and is used for pasture. The degree of anthropogenic degradation of these lands is associated with an increase in pasture loads near settlements, and there is a threat of withdrawal of these lands from economic circulation due to the created conflict situation. Local areas of land suitable for pastures are occupied by industrial and transport facilities, i.e. conflict areas are formed due to the simultaneous use of lands for these two functions. Multifunctional (occupying about 18% of the territory) conflict areas on these lands are associated with negative changes in environmental quality in the area of higher-intensity functions of facilities of oil and gas sector, which limits the possibility of using the territory as a pasture or for other function.

The determination of the spatial combination of functions in this conflict situation is possible only according to antagonistic form with the creation of buffer zones around the deposits.

The symbiotic type of conflict-free or slightly conflict (occupy about 39% of the territory) situation includes local areas of joint use of pasture lands and water fund. The conflict-free situation in the study area is created by the imposition of lands of forest and water funds according to the type of neighbor



Map of functional zoning

functions (occupy about 35% of the territory). They have common boundaries and their mutual interaction is very insignificant, which makes it possible to preserve the parameters of development of both functions.

The greatest attention in the study area should be paid to territories with the simultaneous use of activities that are incompatible with each other (antagonistic type - occupy about 7% of the territory). Such antagonistic functions include residential – conservational (for example, the villages of Peshnoye, Damba, Taskala and others in the Atyrau region located in the SPNAs), residential - industrial (the villages of Sarykamys, Karaton and the Tengiz Gas Processing Plant), recreational - industrial (conservation zone in the northern part of the Caspian Sea and exploration and preparation for the development of oil and gas deposits of the shelf of the North Caspian region), conservational - transport and industrial (conservation zone in the northern part of the Caspian Sea - the development of marine corridors) and others. The interests of antagonistic functions can be taken into account by creating buffer zones that absorb the effects of antagonists on each other. The possibility of rational and sustainable nature management of the territory of the Kazakhstan's Caspian Sea region depends on the optimization of activities and the development of mechanisms for resolving conflicts that have arisen or possible in conflict areas.

Conclusion. Functional zoning is one of the advanced methods for the integrated assessment of the territory, which was first used for the Kazakhstan's Caspian Sea region in the framework of the scientific and applied project on "Ecological zoning of the Caspian Sea region of the Republic of Kazakhstan", implemented by the Institute of Geography of the Ministry of Education and Science of the Republic of Kazakhstan at the request of the Ministry of Environmental Protection of the Republic of Kazakhstan in 2008.

The methodological approaches used made it possible to identify conflict areas in territories with different types of functional use.

The socio-economic conditions of the Atyrau and Mangystau regions were studied with an emphasis on resources and features of economic land use. The analysis of economic activity contributed to the identification of environmental problems in the state of the lands:

- the main adverse and limiting factors in the areas of oil fields are chemical pollution of soils and groundwater with oil products, heavy metals, leakage of hydrogen sulfide from wells;
- human-induced disturbances are linear (alignments of field roads) or locally-pattern (construction and drilling sites, industrial waste landfills, oil wells, etc.);
- disturbances of the soil and vegetation cover in settlements and their surrounding zone within the range from 3-5 to 10 km are strong, often irreversible and are connected with construction, laying of communications and the road network around cities. Degradation of vegetation around the settlements is often caused by overgrazing and a network of roads diverging radially from the center in almost all directions. Landfills of household waste, construction waste, scrap metal are often connected with settlements;
- agricultural lands are almost completely used as pastures, which are unequal in quality, productivity and season of use. As a result of poorly regulated grazing, a transformation of vegetation took place in part of the territory.

The analysis of environmental problems and geo-information mapping of the functional use of lands made it possible to identify conflict areas and define functional zones:

- conflict-free (monofunctional area);
- symbiotic - without conflict even when superimposing functions (multifunctional area);
- neighborhood - joint borders, if necessary, the creation of a buffer zone is possible (multifunctional area);
- antagonism - incompatible, mutually exclusive functions (multifunctional area), complex (multifunctional area).

The conducted functional zoning of the economic systems of the Kazakhstan's Caspian Sea region made it possible to justify the system of measures for further sustainable social and economic development of the region, which is:

- restoration of degraded lands within the buffer zone of 3-5 km through the regulation of livestock grazing, the organization of seeded pastures, planting trees and shrubs. In the settlements – activities on planting trees and shrubs with the creation of park zones, protective forest strips, etc.;
- land reclamation through the creation of artificial plant groupings from phytomeliorant species of local flora in the areas of oil fields, where the main negative and limiting factor is the chemical pollution of soils and groundwater with oil products, heavy metals and leakage of hydrogen sulfide from wells;
- strict regulation of the recreational load in the desert zone;

– regulation of the use of wormwood pastures; it is important to preserve cereals (feather grass, wheatgrass) and spring ephemeroïds in their composition, which can be used in the spring-summer-autumn period. Pastures with a predominance of perennial saltwort (*Anabasis salsa*, *Nanophyton erinaceum*) are less productive and can be used mainly in autumn;

– the introduction of pasture rotation, the establishment of a normal load on the pastures, compliance with the start and end dates of grazing, as well as conducting phytomelioration.

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АУМАҚТЫ ФУНКЦИОНАЛДЫ ЗОНАЛАУ НЕГІЗІНДЕ ҚАЗАҚСТАНЫҢ КАСПИЙ МАҢЫ АЙМАҒЫНДАҒЫ ТАБИҒАТТЫ ПАЙДАЛАНУДЫҢ ӘЛЕУМЕТТІК-ЭКОНОМИКАЛЫҚ АСПЕКТІЛЕРІ

Аннотация. Мақалада табиғи-ресурстық әлеуеті, экологиялық жағдайы және шаруашылықтық пайдалану ерекшеліктеріне ерекше көңіл бөле отырып, Каспий теңізінің қайраңына жақын жатқан участкелермен бірге Атырау және Маңғыстау облыстарының әлеуметтік-экономикалық жағдайлары зерттелді. Жерлерді шаруашылықтық пайдалану типтерін бағалау мен картографиялау негізінде, зерттеліп отырған аймақты функционалдық зоналау жүргізілді және табиғатты тиімді пайдалануға ұсыныстар берілді. Функционалдық зоналауды жүргізу үшін, аумақты немесе су айдынын пайдалану қажеттілігін анықтайтын шаруашылықтық қызмет ету секторларының негізгі мақсаттық қызметтері анықталды. Аумақты және су айдынын өнеркәсіпке және көлікке пайдалануға ерекше көңіл бөле отырып, аймақтың өнеркәсіптік маңызды салаларының қазіргі жағдайына талдау жасалды. Сондай-ақ, Каспий теңізінің су айдынына жақын жатқан аумақтар мен облыс аумағын пайдаланудың селитебті, ауылшаруашылық және табиғатты қорғау типтері бойынша баға берілді. Зерттеу нәтижесі бойынша, қызметтің негізгі салаларының (өнеркәсіптік, көлік, ауылшаруашылық, табиғатты қорғау, туристік-рекреациялық және т.б.) арнайы зоналары бөлінген, функционалдық зоналау картасы құрастырылды.

Жерді пайдаланудың типтеріне картографиялық талдау жасау зерттеу аумағының көп бөлігін аккумуляциялық және денудациялық жазықтар алып жатқандығын және оларды шаруашылықтың көптеген салаларында, оның ішінде жайылымдар ретінде пайдаланылатынын көрсетеді. Бұл жерлердің антропогендік дағдарысқа ұшырау дәрежесі елді мекендердің айналасындағы жайылымдық жүктеменің өсуімен байланысты, осы шиеленіс жағдайына байланысты бұл жерлер шаруашылықтық айналымнан шығып қалуы мүмкін. Осы жерлердегі көп салаларда пайдаланылатын (аумақтың 18 %-ын алып жатыр) шиеленісті ареалдар мұнай және газ секторы нысандарының өте қарқынды даму зонасындағы қоршаған орта сапасының кері өзгерістерімен байланысты, сондықтан бұл аумақтарды жайылым немесе басқа мақсатта пайдалану мүмкіндігі шектеледі. Осындай шиеленіс жағдайындағы жерді пайдалану мақсаттарының кеңістіктік үйлесімділігін анықтау тек кен орындарындағы айналасындағы буферлік зоналардың антагонизм түрі бойынша ғана анықталады. Шиеленіссіз немесе шиеленіс әлсіз (аумақтың 39 %-ын алып жатыр) жағдайлардың симбиоздық түрлеріне жайылымдық жерлер мен су қорын бірге қолданатын кішігірім ареалдар жатады. Зерттеу аумағының шиеленіссіз жағдайларын орман және су қорлары жерлерінің көршілес түр бойынша қабаттасуы құрайды (аумақтың 35 %-ын алып жатыр). Олардың шекаралары ортақ және бір-біріне әсері аз, сондықтан екеуінің де даму көрсеткіштері сақталады. Зерттеу аумағында баса назар аударатын нәрсе – ол бір уақытта бір-біріне сәйкес келмейтін шаруашылық іс-әрекеттерге пайдаланылатын жерлер (антагонизмдік түр – аумақтың 7 %-ын алып жатыр). Осындай антагонизмдік түрлерге селитебті-табиғатты қорғау (мысалыға ерекше қорғалатын табиғи аумақтарда орналасқан Пешное, Дамба, Тасқала және т.б. сияқты Атырау облысының ауылдары), селитебті-өнеркәсіптік (Сарықамыс және Қаратон ауылдары және Теңіз газ өңдеу зауыты), рекреациялық-өнеркәсіптік (Каспий теңізінің солтүстік бөлігіндегі қорықтық аймақ және Солтүстік Каспий шельфінде орналасқан мұнай және газ кен орындарын игеруге дайындық), табиғатты қорғау көліктік-өнеркәсіптік (Каспий теңізінің солтүстік бөлігіндегі қорықтық аймақ – теңізде көлік дәліздерін дамыту), және т.б. Антагонизмдік түрді дамытуды антагонистердің бір-біріне деген әсерін азайтатын буферлік зоналарды құру арқылы жүргізу керек.

Табиғатты пайдаланудағы шиеленіскен зоналардың қалыптасуын төмендету немесе алдын алу және өнеркәсіп салаларының әлеуметтік-экономикалық және экологиялық тұрғыдан алғанда айтарлықтай тиімділігін арттыру үшін, әрбір функционалдық зонаға қазіргі табиғатты пайдалануда болуы мүмкін әсер ету кешендері анықталды.

Түйін сөздер: функционалдық зоналау, әлеуметтік-экономикалық жағдайлар, ресурстар, шаруашылықта пайдалану, табиғатты пайдалану, жерді пайдалану, ГАЖ-картографиялау.

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СОЦИАЛЬНО-ЭКОНОМИЧЕСКИЕ АСПЕКТЫ ПРИРОДОПОЛЬЗОВАНИЯ В ПРИКАСПИЙСКОМ РЕГИОНЕ КАЗАХСТАНА НА ОСНОВЕ ФУНКЦИОНАЛЬНОГО ЗОНИРОВАНИЯ ТЕРРИТОРИИ

Аннотация. Изучены социально-экономические условия Атырауской и Мангистауской областей с участками прилегающего шельфа Каспийского моря с акцентом на природно-ресурсный потенциал, экологическое состояние и особенности хозяйственного использования. На основе оценки и картографирования типов хозяйственного использования земель выполнено функциональное зонирование исследуемого региона и даны рекомендации рационального природопользования. Для выполнения функционального зонирования уточнены основные целевые функции секторов хозяйственной деятельности, определяющие необходимость использования территорий и акваторий. Особое внимание уделено промышленному и транспортному использованию территорий и акваторий с детализацией современного состояния наиболее важных региональных отраслей промышленности: нефтехимической и рыбной. Также дана оценка селидебному, сельскохозяйственному и природоохранному типам использования территорий областей и прилегающей акватории Каспийского моря. По результатам исследований составлена карта функционального зонирования, на которой выделены специальные зоны основных секторов деятельности (промышленной, транспортной, сельскохозяйственной, природоохранной, туристско-рекреационной и др.). Для снижения либо предотвращения формирования конфликтных зон в природопользовании и стимулирования наиболее выгодных с социально-экономической и экологической точки зрения отраслей промышленности, для каждой из функциональных зон определен комплекс возможных вмешательств в существующее природопользование.

Ключевые слова: функциональное зонирование, социально-экономические условия, ресурсы, хозяйственное использование, природопользование, землепользование, ГИС-картографирование.

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**RESEARCH OF SOLAR-LITHOSPHERIC RELATIONSHIPS
IN NORTH TIAN SHAN ATTRACTING PALOSEISMIC DATA**

Abstract. The purpose of the work is to systematize data on strong earthquakes in the Northern Tien Shan, taking into account the results of paleoseismic studies, and to establish patterns in the concomitant variations in solar activity, both during the instrumental period of observations and reconstructed by the radiocarbon ¹⁴C method to a depth of ~ 1000 years. It is shown that the dates of the occurrence of strong earthquakes in the study area gravitated to the dates of the extreme state of solar activity - solar grand minimums or grand maximums. So, during the solar grand maximum in 1960 ± 40yrs, such earthquakes occurred: Kemino-Chuisk M6.9 in 1938, Chatkal M7.5 in 1946, Kokshaal M6.6 in 1969, Sary-Kamysh M6.8 in 1970, Zhalanash-Tyup M7.0 in 1978, Baysorun M6.4 in 1990, and Suusamyр M7.5 in 1992. During the solar grand minimum of Dalton (1790-1820), the Almaty M6.7 earthquake occurred in 1807, and during the solar grand minimum of Gleisberg (1880-1915) earthquakes occurred: Belovodsk M6.9 in 1885, Vernensk M7.3 in 1887, Chilik M8.3 in 1889, and Kemin M8.2 in 2011. The strong earthquakes that occurred in the area of Alakol lake at ~ 910 ± 300yrs [1], in the tectonic zone of the Issyk-Ata fault at ~ 1385 ± 100 [2], in the Chon-Aksu river valley in (1480–1660) [3], in the vicinity of the Balkhash lake at the Lepsinsk Fault in 1715 [4] were accompanied by the solar grand minima of Oort (~ 1040 ± 30), Wolf (~ 1305 ± 35), Sporer (~ 1470 ± 80) and Maunder (~ 1680 ± 40), respectively. It is assumed that with the beginning of the 21st century a new solar grand minimum began to develop [5, 6], and quite strong earthquakes have already occurred in the study area namely: Sarydzha, 2013, M6.8 and Kadzhisay, 2014, M6.2. Clustering of strong earthquakes in the Northern Tien Shan during periods of extreme solar activity is in line with a similar clustering of strong earthquakes throughout the whole planet [7].

Key words: solar activity, paleoseismicity, clustering of strong earthquakes.

Introduction. The problem of forecasting strong earthquakes is relevant for the entire planet, including the adjacent territories of Kazakhstan and the Kyrgyz Republic, located in seismically active regions of the Northern Tien Shan. To date, it has been established that strong earthquakes tend to temporarily cluster. To date, it has been established that strong earthquakes tend to temporarily cluster. So, at the beginning of the 20th century, the strongest seismic events occurred on the Tien Shan in 1911, M8.2; Alaska in 1899, M 8.0; in Western Turkmenistan in 1895, M 8.0; Kashgariya in 1902, M8.2; Northern Mongolia in 1905, M8.2; California in 1906, M8.3; China in 1906, M8.3; Colombia in 1906, M8.6 [3,8]. After that for about 25 years on the planet there were no earthquakes with a magnitude of 8.5 or more, and only in the middle of the XX century there was a strong earthquake in South Kamchatka - Northern Kuriles in 1952, M9.0; Aleut in 1957, M 8.6; in Chile in 1960, M9.5; in Alaska in 1964, M 9.2 [9-11].

In the first decade of the 21st century, a number of extremely strong earthquakes again appeared in different regions of the Earth: three of them were in Indonesia near the island of Sumatra 12/26/2004. M9.1, March 28, 2005. M8.5, and 04/11/2012, M8.5; three in Chile 02/27/2010. M8.8; 04/01/2014, M8.2, and 09/16/2015. M8.3; two on the Kuril Islands on 11/15/2006, M8.3, and 01/13/2007, M 8.1; in Japan on 03/11/2011, M9.0; Sea of Okhotsk on May 24, 2013, M8.3; Mexico City 09/08/2017, M8.2 [3,7,8,10-12]. The probability of the effect of clustering strong earthquakes in the middle of the 20th century

(1950-1965) and the beginning of the 21st century (2004-2011) was evaluated in [9,10,13] where it was concluded that the probability of its accident is very small – is no more than 0.5%.

After five strongest earthquakes with magnitudes $M_w \geq 8.5$ that occurred at the beginning of the 21st century, and especially after the M9.0 earthquake in Japan, at the meeting of the Seismological Society of America in 2011, a heated debate about whether the observed temporary clusterization of strong earthquakes has some physical cause, as well as the possibility of a strong earthquake in the near future [10,11,14]. The question was posed in [7]: “If global clustering of earthquakes is so important that it should be taken into account when assessing seismic hazard, then seismological data should reject the “null hypothesis” that the temporal distribution of earthquakes on the planet is described by the distribution Poisson (uniform distribution of random independent events that occur at a constant speed).

However, immediately the question arose about the reliability of the results of such testing conducted on a time-limited sample of very rare events (which are the strongest earthquakes). The work [15] evaluated the effectiveness of traditional statistical tests to unambiguously answer the question of the existence or absence of clustering of earthquakes in catalogs with a small number of events. He concluded that when analyzing a fairly short sample with rare events, as in the case of a sample of ~ 110 years for earthquakes with $M \geq 8.0$ (95 events), the test results cannot be considered absolutely reliable. The conclusion [15] is consistent with the opinion [7], who noted: “... even if there is a global process leading to the generation and clustering of earthquakes, the length of the instrumental seismological series is currently too small to reliably to discover. This situation may change either with the accumulation of seismological data in the future, or with the advent of the physically justified hypothesis of earthquake generation, which will positively affect the test results.” This article develops both of the issues voiced by [7]. Firstly, the clustering of strong earthquakes is analyzed from the perspective of a new hypothesis of their generation associated with variations in solar activity, and secondly, the length of a series of strong earthquakes increases due to the use of paleoseismic data to a depth of ~ 1000 years (for example, the Northern Tien Shan).

Strong earthquakes and solar activity. Figure 1 shows the temporal distribution of earthquakes with magnitudes $M \geq 8.0$ that occurred on the planet since 1900 from the work [7], where by ovals 1-3 we designated the periods of their clustering – at the beginning of the XX century, its middle and at the beginning of the XXI century. Figure 2 shows the variations in the annual average sunspot numbers.

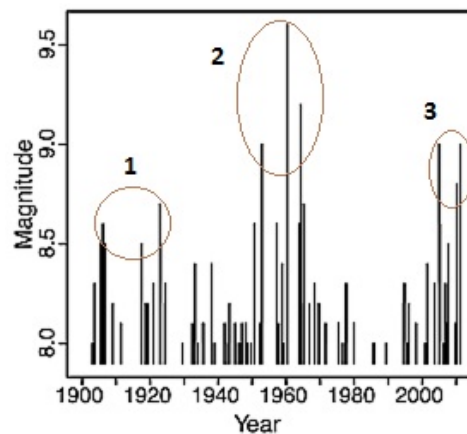


Figure 1 – Time distribution of earthquakes with magnitudes $M \geq 8.0$, which occurred on the planet since 1900 from the work [7]; ovals 1-3 mark three time periods for the clustering of strong earthquakes

Figure 2 shows that the intensity of 11 summer solar cycles varies over time. The state of solar activity, in which the intensity of several consecutive 11 year cycles is significantly less than the average value, is characterized as a solar grand minimum, and when it is significantly greater than the average value, it is described as a solar grand maximum. In the 19th – 20th centuries, there was a solar grand minimum in the period 1880–1915, named after the astronomer Gleisberg, and a solar grand maximum in the period 1960 ± 40 years [16], and since the beginning of the 21st century, as suggest [5, 6], a new solar grand minimum began to develop.

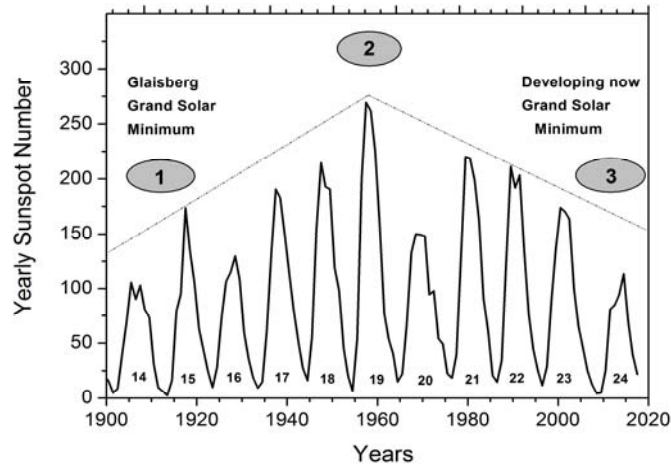


Figure 2 – Yearly mean number of sunspots from 1900 to 2017. The digits indicate sequential numbers of the solar cycles; dark ovals mark the periods of clustering of the strongest earthquakes on the planet in accordance with figure 1

Comparing figures 1 and 2, it is not difficult to see that the global clustering of earthquakes in the early XX and XXI centuries (ovals 1, 3) coincides with periods of Grand minima of solar activity: Gleisberg - at the beginning of the 20th century, and the current one, which began in the 21st century [5,6]. Global clustering of earthquakes in the middle of XX century (oval 2) coincides with the Grand maximum of solar activity centered around 1960 with a range of ± 40 years [16]. It was in 1960 that the planet's greatest earthquake occurred in Chile with M9.5 (figure 1). The previous global solar maximum took place approximately 2500 years earlier and accounted for ~ 445 BC [16]. The tendency of the confinement of strong earthquakes, either to minima or to maxima of solar activity, is also traced in the analysis of seismicity in specific regions of the planet. For example, [17] studied the relationship between solar activity, volcanic eruptions and seismicity in Japan, it was shown that of the 12 major earthquakes ($M \geq 7.5$) that occurred in 1700-2010, nine events (75%) occurred in the solar activity minima, and the dates of the three earthquakes were timed to the time of solar maxima.

Figure 3 shows the strongest earthquakes (magnitude over 7) of the Northern Tien Shan that occurred during the period of the solar grand minimum of Gleisberg (Verny 1887, M7.3; Chilik 1889, M8.3; and Kemin 1911, M8.). Also, we show a strong earthquake in Almaty in 1807, M6.7 [18].

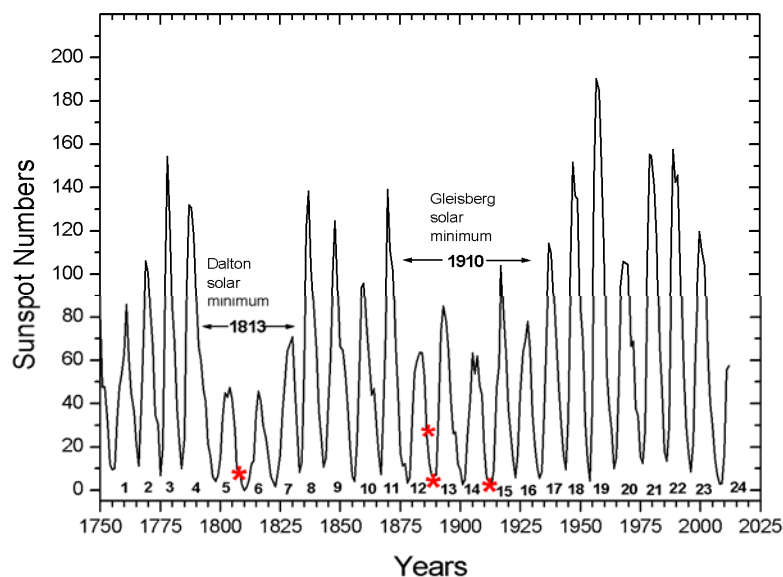


Figure 3 – Yearly mean number of sunspots in 1750-2011 (1-24 solar cycles) <http://www.sidc.be/silso/datafiles>; red circles - dates of the strongest historical earthquakes in the Northern Tien Shan occurred at solar grand-minima, namely: Almaty 1807, Verny, 1887, Chilik, 1889, and Kemin 1911, as adapted from [19]

Figure 3 shows that the Almaty earthquake of 1807 occurred during the Dalton solar grand minimum at the completion phase of the low-amplitude 11-year solar cycle at number 5, and the following three events (Vernensk, Chilik and Kemin) occurred during the Gleisberg solar grand minimum at the completion phase of the low-amplitude solar cycles numbered as 12 and 14.

At the middle of the 20th century, the peak of the solar grand maximum occurred in 1960±40 years [16]. According to seismological catalogs, clustering of strong earthquakes also occurred in the Northern Tien Shan during this period of time - such seismic events occurred as: Kemino-Chuisk 1938, M6.9; Chatkal 1946, M7.5; Kokshaal 1969, M6.6; Sary-Kamysh 1970, M6.8; Zhalanash-Tyup 1978 1978, M7.0; Baysorun 1990, M6.4; Suusamyр 1992, M7.5. After the Suusamyр earthquake, for about 15 years there were no strong earthquakes in the region, and only in 2007, with the development of the new solar grand minimum, as suppose [5,6], strong earthquakes Sarydzhas, 2013, M6.8 and Kadzhisay, 2014, M6.2 occurred.

Solar activity and paleo-earthquakes in the Northern Tien Shan. As shown above, the problem of solar-lithospheric relations in the Northern Tien Shan was studied earlier [19,20 and references in herein] on the basis of instrumental series of seismological data, however, their duration in accordance with the conclusions of [7,15] cannot be considered sufficient for reliable conclusions about the nature of long-term variations in seismic activity. To increase the length of seismological series, which is necessary to increase the reliability of conclusions about long-term patterns in the frequency of occurrence of strong earthquakes, as noted in [7], we used for our analysis the data on strong paleo-earthquakes detected in the Northern Tien Shan to a depth of ~ 1000 years.

Thus, in [3], paleoseismological studies were carried out in the Chon-Aksu river valley (42°50'N, 77°21'E). A trench up to 6 m deep with a length of 18-20 m was studied and it was shown that here seismically calm periods alternate for several thousand years with periods when several strong seismic events occur during a period of several hundred years (figure 4). This pattern of alternating calm and disturbed seismic periods is typical for regions of intracontinental seismicity, where the process of stress accumulation is very slow [21]. Figure 4 shows that in the studied region, the last of the discovered earthquakes was the event dated 1480-1660 years, that is, that occurred before the Almaty earthquake in 1807.

Figure 5 shows the variations in solar activity from 900 to 2000 AD, reconstructed by radiocarbon ¹⁴C as presented at the web-site https://en.wikipedia.org/wiki/Solar_cycle method. One of the horizontal

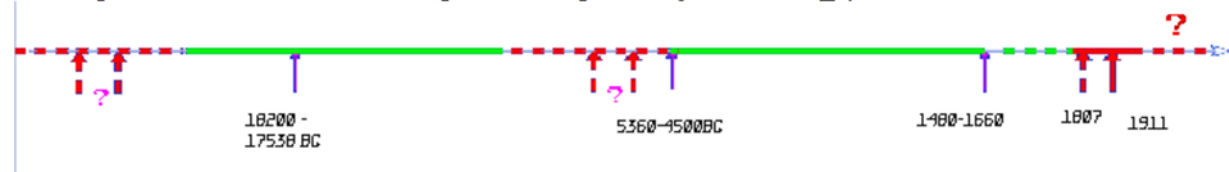


Figure 4 – Periods of seismic activation and calm according to data obtained in the trench in the Chon-Aksu River valley (42°50'N, 77°21'E). Blue arrows - dated events, red arrows are solid - confident data, dotted lines - the alleged events [3]

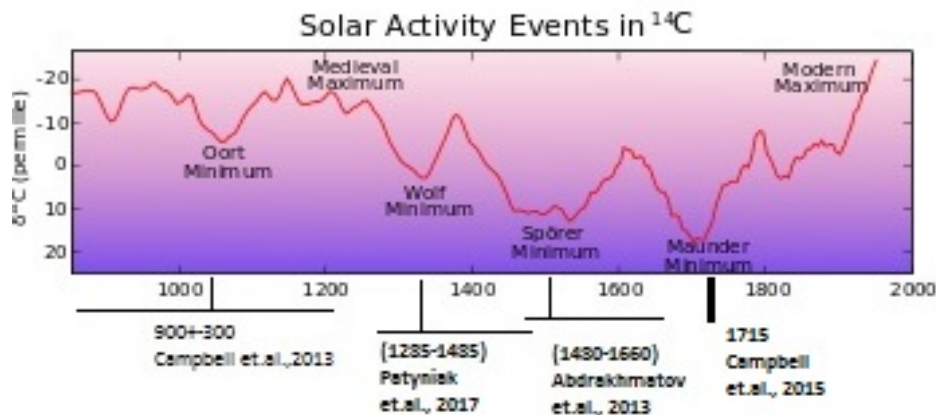


Figure 5 – Variations in solar activity in 900 - 2000 AD reconstructed by the radiocarbon method ¹⁴C, with periods of solar grand minima highlighted: Oort; Wolf, Spörer and Maunder (https://en.wikipedia.org/wiki/Solar_cycle); the horizontal and vertical lines at the bottom of the figure show the degree of confinement of the paleo-earthquakes established in the Northern Tien Shan to the solar grand minima (see text)

lines at the bottom of the figure marks the time period (1480-1660yrs) when a paleo-earthquake occurred in the Chon-Aksu river valley. A vertical line drawn perpendicular to this segment marks the extremum in the solar grand minimum of Sперer, which occurred in 1470 ± 80 AD [16]. It is seen, the period of paleo-earthquake established in [3] in the Chon-Aksu river valley can be attributed to the Sперer solar grand minimum, of course, with taking into account errors in the paleo data, both for seismic and solar activity.

In [1], paleoseismological studies of the Dzungar fault in the region of Alakol lake. The age of five periods of seismic activation in the region was estimated and it was established that the last of them occurred $\sim 1100 \pm 300$ years ago, i.e., in $\sim 910 \pm 300$ AD. One of the horizontal lines at the bottom of Figure 5 marks the interval 910 ± 300 AD, and the line perpendicular to the segment marks the date of the extremum in the solar Oort grand minimum, which took place at 1040 ± 30 AD [16]. It can be seen that the period of paleo-earthquake established in [1] in the region of Alakol lake can be attributed to the solar grand minimum of Oort.

In [2], paleoseismological studies were carried out in the river valley Dzhelamysh in the tectonic zone of the Issyk-Ata Fault, near Bishkek. The results of the study revealed the consequences of three strong paleo quakes - two in BC and the last one in a new era in $\sim 1385 \pm 100$ AD. One of the horizontal lines in Fig. 5 marks the time period (1285-1485yrs), when a paleo-earthquake occurred in the tectonic Issyk-Ata fault zone, and the line perpendicular to the segment marks the extremum in Wolf's solar grand minimum, which occurred at 1305 ± 35 AD [16]. It is seen that the paleo-earthquake period established in [2] in the zone of the tectonic Issyk-Ata fault can be attributed (with taking into account dating errors) to the solar grand Wolf minimum.

The seismological catalog [18] provides a historical record of an ancient seismic event that occurred on the Northern Tien Shan in the vicinity of Lake Balkhash in 1715. The paper [4] presents the results of detailed field and satellite studies of this region (the Lepsinsky fault extending 120 km east-west from the high-mountain Dzhungar Ala-Too to the Kazakh platform), where about 10 meter vertical shift along the entire length of the fault was discovered. The results of geomorphological analysis, radiocarbon and luminescent dating methods showed that the fault was formed in Holocene as a result of at least two seismic events, the last of which occurred about 400 years ago with a magnitude of M_w 7.5–8.2. The thick vertical line in Figure 5 marks the date of the earthquake in 1715 that occurred in the vicinity of Lake Balkhash at the Lepsinsky Fault. It can be seen that this seismic event occurred during the period of the deepest solar grand minimum of Maunder, which took place in 1680 ± 40 AD [16].

Conclusion. Clustering periods of the planet's strongest earthquakes (magnitude M8 or more) at the beginning of the 20th century, its middle and the beginning of the 21st century [3,7-11,13,14] fell on periods of the extreme state of solar activity – solar grand minimums at the beginning of the 20th and beginning of the 21st centuries, and the solar grand maximum at the middle of the 20th century.

On the territory of the Northern Tien Shan, strong earthquakes also demonstrate the effect of temporary clustering, similar to what is happening for the planet as a whole. The strongest earthquakes of the recent past: Verny 1887 M7.3; Chilik 1889 M8.3; Kemin 1911 M8.2 were confined to the solar grand minimum Gleisberg, which took place in 1880-1915 yrs.

Analysis of paleoseismic data in the Northern Tien Shan to a depth of ~ 1000 years showed that strong earthquakes that occurred during this period in the area of Alakol lake at $\sim 910 \pm 300$, in the tectonic zone of the Issyk-Ata fault at $\sim 1385 \pm 100$, in the valley of the Chon-Aksu River in the period 1480-1660, in the vicinity of Balkhash lake on the Lepsinsky Fault in 1715, also gravitated to the periods of solar grand minimums: Oort, Wolf, Sперer and Maunder, respectively.

The results obtained, firstly, support the idea of the existence of geospace relationships, which is currently being actively developed, including in Kazakhstan [19,20,22], and confirm the existence of solar-lithospheric relationships, which was first drew the attention of the world known astronomer Wolf almost two centuries ago. Secondly, the results speak in favor of the fact that the paleoseismic data currently accumulated for different regions of the planet can increase the length of the series of strong earthquakes, which will reveal more reliable long-term (secular) variations of the Earth's seismic activity.

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**ПАЛЕСЕЙЗМИКАЛЫҚ МӘЛІМЕТТЕРДІ ҚАТЫСУЫМЕН
СОЛТҮСТІКПЕН ТЯНЬ-ШАНЬДАҒЫ КҮН-ЛИФОФЕРИКАЛЫҚ
БАЙЛАНЫСТЫ ЗЕРТТЕУ**

Аннотация. Жұмыстың мақсаты – Солтүстік Тянь-Шаньдағы күшті жер сілкінісі туралы мәліметтерді жүйеге келтіру, палеозеологиялық зерттеулердің нәтижелерін ескере отырып, бақылаудың инструменталды кезеңінде және радиокарбон ¹⁴C әдісімен ~ 1000 жыл тереңдікке дейін қайта құру арқылы күн белсенділігінің қатар жүретін өзгерулерінің заңдылықтарын анықтау. Зерттеу аймағында күшті жер сілкіністерінің пайда болу күндері күн белсенділігінің төтенше жағдайына – күн гранд-минимумдары немесе grim-максимумдарға сәйкес келетіні көрсетілген. Күннің максималды мөлшері 1960 жылы - 40 гт. жер сілкіністері орын алды: 1938 жылы Кемино-Чуй М6.9, 1946 жылы Чаткал М7.5, 1969 жылы Көкшаал М6.6, 1970 жылы Сары-Камыш М6.8, 1978 жылы Жалаңаш-Түпск М7.0, 1990 жылы Байсорун М6.4. және Суусамыр М7.5 1992 ж. Дальтонның ең үлкен күндік минимумы кезінде (1790-1820 жж.), Алматыда М7.8 жер сілкінісі 1807 жылы болды, ал Глейсбергтің (1880-1915) күндік минималды жер сілкінісі кезінде: 1885 жылы Беловодское М6.9, Верненское М7.3 1887 ж., 1889 жылы Чилик М8.3, 1911 жылы Кемин М8.2. Бұл аймақта қатты жер сілкінісі болды. Алакөл ~ 910 ± 300 г [1], Ыстық-Ата жарылысының тектоникалық аймағында ~ 1385 ± 100 г [2], Чон-Ақсу өзенінің алқабында (1480-1660 жж.) [3], шамамен. 1715 жылы Лепсі бұзылуындағы Балқаш [4] Оорт (~ 1040 ± 30), Қасқыр (~ 1305 ± 35), Сперера (~ 1470 ± 80) және Майдер (~ 1680 ± 40) күндік минимумымен бірге жүрді. сәйкесінше. ХХІ ғасырдың басынан бастап күннің жаңа минимумы дами бастады деп болжануда [5, 6] және зерттеу аймағында қатты күшті жер сілкіністер болды: Сарыжа, 2013 ж., М6.8 және Каджисай, 2014, М6.2. Күннің төтенше белсенділігі кезеңінде Солтүстік Тянь-Шаньдағы қатты жер сілкіністерінің кластары бүкіл планетаның осы кезеңдерінде күшті жер сілкіністерінің кластеріне сәйкес келеді [7]. Сонымен, ХХ ғасырдың басында күн гранд-минимумында күшті жер сілкінісі тек Тянь-шанада ғана емес, 1895 ж. М 8.0 Батыс Түрік-менияда да болды; 1902 ж. М 8.2 Кашгарияда; 1905 ж. М 8.2 Солтүстік Моңғолияда; 1906 ж. М 8.3 Калифорнияда; 1906 ж. М 8.3 Қытайда; 1906 ж. М 8.3 Колумбияда; 1906 ж. М 8.6 Колумбияда болды [3, 8]. Осыдан кейін шамамен 25 жыл бойы планетада магнитудасы 8.5 және одан да көп жер сілкінісі болған жоқ, тек ХХ ғасырдың ортасында күн гранд-максимум кезеңінде Оңтүстік Камчаткада – Солтүстік Курил аралында 1952 ж. М 9.0; Алеутта 1957 ж. М 8.6; Чилиде 1960 ж. М 9.5; Аляскада 1964 ж. М 9.2 қатты жер сілкінісі болды [9-11]. ХХІ ғасырдың басында күн гранд-минимумы қайта дами бастады және жердің әр түрлі аймақтарында тағы да бірқатар экстремалды күшті жер сілкіністері пайда болды деп болжайды [5,6], олардың үшеуі Индонезияда маңында болған. Суматрада 26.12.2004 ж. М 9.1, 28.03.2005 ж. М 8.5, және 11.04.2012, 8.5; үшеуі Чилиде 27.02.2010 ж. М 8.8, 01.04.2014 ж. М 8.2, және 16.09.2015 ж. М 8.3; екеуі Курил аралында 15.11.2006 ж. М 8.3, және 13.01.2007 ж. М 8.1; Жапонияда 11.03.2011 ж.М. 9.0; Охот теңізінде 24.05.2013 ж. М.8.3; Мехикода 08.09.2017 ж. М 8.2 [3, 7, 8, 10-12]. ХХІ ғасырдың басында, m≥8.5 магнитудасы бар бес күшті жер сілкінісі әсіресе Жапонияда М 9.0 жер сілкінісінен кейін, 2011 жылы Америка Сейсмологиялық қоғамының отырысында қатты жер сілкінісінің байқалып отырған Уақытша кластеризациялануы кездейсоқ немесе кейбір физикалық себептерге ие екендігі, сондай-ақ жақын болашақта күшті жер сілкінісінің пайда болу мүмкіндігі туралы қызу пікірталас болды [10, 11, 14]. ХХ ғасырдың ортасында (1950-1965 жж.) және ХХІ ғасырдың басында (2004-2011 жж.) күшті жер сілкіністерін кластеризациялау әсерінің ықтималдығын бағалау [9, 10, 13] жұмыстарында орындалды және оның кездейсоқ ықтималдығы өте аз - 0.5%-дан аспайды деген қорытынды жасалды. Жұмыста келтірілген нәтижелер күн-литосфералық байланыстардың болуы идеясын қолдайды [17, 19, 20, 22] және қазіргі уақытта планетаның әр түрлі аймақтары үшін жинақталған палеосейсмикалық деректер күшті жер сілкіністері қатарының ұзындығын ұлғайтуы мүмкін, бұл жердің сейсмикалық белсенділігінің ұзақ мерзімді (ғасырлық) вариацияларын анықтауға мүмкіндік береді.

Түйін сөздер: күн белсенділігі, палеозеизм, күшті жер сілкіністерінің кластары.

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ИССЛЕДОВАНИЕ СОЛНЕЧНО-ЛИТОСФЕРНЫХ СВЯЗЕЙ НА СЕВЕРНОМ ТЯНЬ-ШАНЕ С ПРИВЛЕЧЕНИЕМ ПАЛЕОСЕЙСМИЧЕСКИХ ДАННЫХ

Аннотация. Цель работы – систематизировать данные о сильных землетрясениях на территории Северного Тянь-Шаня с учетом результатов палеосейсмических исследований и установить закономерности в сопутствующих вариациях солнечной активности как за инструментальный период наблюдений, так и восстановленных радиоуглеродным ¹⁴C методом на глубину ~1000 лет. Показано, что даты возникновения сильных землетрясений на исследуемой территории тяготеют к датам экстремального состояния солнечной активности – солнечным гранд-минимумам или гранд-максимумам. Так во время *солнечного гранд-максимума в 1960±40 гг.* произошли землетрясения: *Кемино-Чуйское М6.9 в 1938 г., Чаткальское М7.5 в 1946 г., Кокшаальское М6.6 в 1969 г., Сары-Камышское М6.8 в 1970 г., Жаланаши-Тюпское М7.0 в 1978 г., Байсорунское М6.4 в 1990 г. и Суусамырское М7.5 в 1992 г.* Во время солнечного гранд-минимума Дальтона (1790-1820 гг.) произошло Алматинское М6.8 землетрясение в 1807 г., а во время солнечного гранд-минимума Гляйсберга (1880-1915 гг.) произошли землетрясения: Беловодское М6.9 в 1885 г., Верненское М7.3 в 1887 г., Чиликское М8.3 в 1889 г., и Кеминское М8.2 в 1911 г. Сильным палеоземлетрясением, произошедшим в районе о. Алаколь в ~910±300 г [1], в зоне тектонического Исык-Атинского разлома в ~1385±100 г [2], в долине реки Чон-Аксу в (1480-1660 гг.) [3], в окрестности о. Балхаш на *Лепсинском разломе* в 1715г [4], сопутствовали солнечные гранд-минимумы Оорта (~1040±30), Вольфа (~1305±35), Шперера (~1470±80) и Маундера (~1680±40), соответственно. Предполагается, что с началом XXI века начал развиваться новый солнечный гранд-минимум [5,6], и на исследуемой территории в наши дни уже произошли достаточно сильные землетрясения: Сарыджаское, 2013 г., М6.8 и Каджисайское, 2014 г., М6.2. Кластеризация сильных землетрясений на Северном Тянь-Шане в периоды экстремальных состояний солнечной активности находится в соответствии с аналогичной кластеризацией сильных землетрясений на всей планете [7].

Так, в начале XX века при солнечном гранд-минимуме сильные землетрясения произошли не только на Тянь-Шане, но и в Западной Туркмении в 1895 г. М 8.0; Кашгарии в 1902 г. М8.2; Северной Монголии в 1905 г. М8.2; Калифорнии в 1906 г. М8.3; Китае в 1906 г. М8.3; Колумбии в 1906 г. М8.6 [3, 8]. После этого в течение примерно 25 лет на планете не происходило землетрясений с магнитудой 8.5 и более, и только в середине XX века в период солнечного гранд-максимума произошли сильные землетрясения на Южной Камчатке – Северных Курилах в 1952 г., М9.0; Алеутах в 1957 г. М 8.6; в Чили в 1960 г. М9.5; на Аляске в 1964 г. М 9.2 [9-11]. Предполагают [5,6], что с началом XXI века вновь начал развиваться солнечный гранд-минимум, и в разных регионах Земли вновь возник целый ряд экстремально сильных землетрясений: три из них были в Индонезии вблизи о. Суматра 26.12.2004 г. М9.1, 28.03.2005 г. М8.5, и 11.04.2012, М8.5; три в Чили 27.02.2010 г. М8.8, 01.04.2014 г. М8.2, и 16.09.2015 г. М8.3; два на Курилах 15.11.2006 г. М8.3, и 13.01.2007 г. М 8.1; в Японии 11.03.2011 г. М9.0; Охотском море 24.05.2013 г. М8.3; Мехико 08.09.2017 г. М8.2 [3, 7, 8, 10-12]. После пяти сильнейших землетрясений с магнитудами $M \geq 8.5$, произошедших в начале XXI века, и особенно после М9.0 землетрясения в Японии, на заседании Сейсмологического Общества Америки в 2011 году разгорелись жаркие дебаты о том, случайна ли наблюдаемая временная кластеризация сильных землетрясений или имеет некоторую физическую причину, а также о возможности возникновения сильного землетрясения в ближайшем будущем [10, 11, 14]. В работах [9, 10, 13] была выполнена оценка вероятности эффекта кластеризации сильных землетрясений в середине XX века (1950-1965 гг.) и начале XXI века (2004-2011 гг.) и сделан вывод, что вероятность его случайности очень мала – составляет не более 0.5%. Приведенные в работе результаты поддерживают идею существования солнечно-литосферных связей [17, 19, 20, 22] и говорят в пользу того, что палеосейсмические данные, накопленные в настоящее время для различных регионов планеты, могут увеличить длину рядов сильных землетрясений, что позволит выявить более надежно долговременные (вековые) вариации сейсмической активности Земли.

Ключевые слова: солнечная активность, палеосейсмичность, кластеризация сильных землетрясений.

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DIGITALIZATION AND THE POTENTIAL FOR IMPROVING THE DESIGN AND PLANNING OF MINING OPERATIONS IN OPEN CAST MINING

Abstract. Modern traditional and most widely used technologies for the development of mineral deposits by the open method using cyclical technologies have significant potential for improving efficiency and reducing the cost of mining and transport operations. This article focuses on how and by what means this potential can be realized.

The potential and directions of improving the efficiency of mining and transport operations on open cast mining are revealed by the example of scientific and practical research using the methodology of automated corporate management of geotechnological complexes.

Today, in the field of open-pit mining, most widely automated accounting and control systems, and also, automated dispatching systems for mining and transport operations managing are used. However, they make it possible to realize only a third of the existing potential for improving the efficiency of the mining process.

In conclusion the article concludes that in the context of the transition to Industry-4.0, improving the efficiency of mining and transport operations on open cast mining is possible only on the basis of a unified methodology of design, planning and management of geotechnological complexes, developed on the basis of in-depth analysis in the framework of an automated corporate approach using the economy of process management.

Keywords: mining-transport work, management, organization, efficiency, digitalization, automation.

Introduction.

To increase the efficiency of mining and transport works in open pits with auto, rail and combined auto-rail transport, accounting and control systems, automated dispatching systems of mining and transport works are traditionally used. At this level of organization of production management, only a small part of the potential for improving efficiency is realized. Analogical directions are developed in geology [1]. It's possible mainly due to the increasing the discipline of production and faster and more efficient distribution of trucks on loading and unloading points. For a more complete realization of existing potential at the enterprise, a more complete and in-depth digitalization of the main production processes is required.

The modern stage of development of automation of mining technological processes, characterized by flexible and non-standard production, corresponds to the concept of "Industry 4.0", which is based on two fundamental principles [2]:

1. Automated intellectual interaction between the operator and the equipment involved in the production process.

2. Relationship of logistics operations throughout the value chain of cost forming of the product to increase the efficiency of technological processes.

The necessary approach can be implemented in the framework of the automated corporate management system of the geotechnological complex (the AKSU GC) "CEBADAN-Mining", the structure and content of which are presented in figure 1.

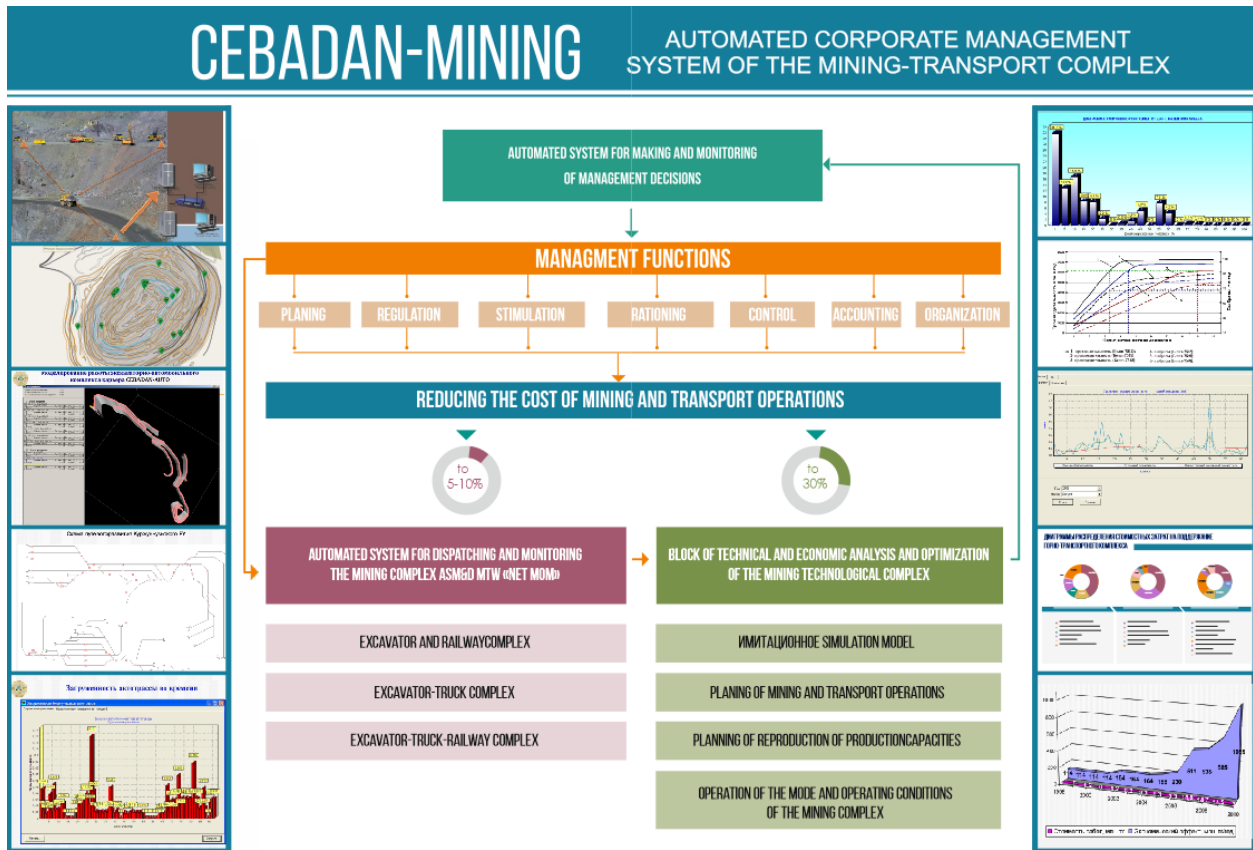


Figure 1 – Structure and content of the automated corporate management system of the geotechnological complex “CEBADAN-Mining”

The system includes the automated monitoring and dispatching system for mining and transport operations – ASM&D MTW “Net-MOM”, based on the information and technical platform of the positioning and communication system – ASP&C. The second important module of the System is the analytical block, which is based on the methodological support of technical and economic analysis of the functioning of geotechnological complex utilizing specialized method of simulation modeling of analyzed mining and transport processes. The third module is an automated system for the adoption and monitoring of management decisions.

The main task resolved within the System is the intellectual interpretation of information about the dynamics of factors of external and internal environment of the enterprise. Accordingly, intellectual analytic data processing plays a key role: a methodological base, implemented in the form of software, that not only records and transmits the data received from sensors, but also forms operational solutions based on a holistic view of the content of the process in a particular context. Thus, within the framework of the AKSU GK system, a completed cycle of analytics 3.0 has been implemented, which ensures continuous production of the necessary information, search for optimal management decisions and a feasibility study of their implementation.

One of the main functions of the AKSU GK is a quality, reliable and operational information support of the management system of the geotechnological complex, based on its adequate and deep digitalization. In order to implement this, the task of organizing the collection, processing and production of derivative information about the work and the state of the geotechnological complex of the enterprise is being solved. At open-cast mining, notion of a “geotechnological complex” is a single complex of the mine workings and the mining and transport system of a quarry, as it is assumed by the notion of “Geotechnology” [3]. Accepted, within the framework of the adopted approach, as a single object of automated management, the geotechnological complex is characterized by its specific mining and technical, mining and geometric, mining and geological, organizational and economic parameters, which should be

adequately taken into account. The first task related to the digitization of production processes is solved at four principal levels.

The first level is related to the formation of initial database, which includes existing standards, technical characteristics, principles of production organization, indicated in the relevant instructions, accepted methods, restrictions, equipment certificates, design solutions, work plans, etc.

At the second level, the collection of the necessary objective, reliable and operational data is provided by the generated automated positioning and communication system. The first to be resolved are, issues of operational accounting of the state of all elements, subsystems and the geo-technological system as a whole. Information is recorded with a certain step. At the same time, the data on the operating time and downtime of the equipment is generated. Working time, as well as in idle times, can be recorded by separate operations (excavation, preparation of the face, stages of the excavation cycle, technological and unplanned downtime, reservation time of transport sections, etc.) and in general per shift. At the same stage, according to the approved methods, the primary data from metering and control devices on the state of the fuel tank, tire pressure, useful mass, energy consumption, current and average speeds, and the amount of emissions are accumulate.

An important condition for collecting and processing information at the second stage is operational economic assessment of the forming cost of mining and transport works by the end of each shift. An economic-mathematical model, built into the monitoring and communication system, allows to evaluate and summarize all integrable costs by operation and, depending on the actual performance of the mining and transport complex, calculate their unit cost per ton/m³.

At the third level, in the automated mode, all derivative information on work of the mining-transport complex is formed. This information further is analyzed by specialist.

At the fourth level the formation of information data on the work of the mining and transport complex, at analytic stage, as part of technical and economic analysis of the actual it's work on the data formed at the second stage, using a reliable model of the mining and transport complex operations, develops more effective and predictable options for its functioning.

The architecture of the «EcoStruxure» software and information complex of «Schneider Electric», one of the largest players in the field of industrial automation, was built in a very similar way [4]. The system is based on a three-tier architecture, which combining all the equipment at the object, and is capable of collecting, analyzing and using the information obtained. At the bottom level – connected "iron", for example, shields, flow meters, sensors, and so on. Products and solutions for the collection and processing of primary data – this is already the second level. The third one occurs when various applications and services that evaluate all the processes at the object and give recommendations for optimizing its work.

The distinctive feature and effectiveness of the application of automated control systems for Geotechnological complexes, in comparison with the traditionally used automated accounting and control systems in the world, as well as automated dispatching systems for mining and transport works, are shown in table 1.

Firstly, automated accounting and control systems, as well as automated dispatching systems for mining and transport works, due to the limited realizable accounting and control functions, operational regulation and partly organization of the production process, are clearly limited in realizing the existing potential for improving the efficiency of mining-transport quarry systems. In this case, the potential to reduce the cost of mining and transport works is 5-10% by eliminating unauthorized fuel discharges, increasing production discipline and eliminating some downtime of the main mining and transport equipment, which depends on the quality of operational distribution of transport on loading and unloading points. Unlike them, unified management of the geotechnological complex, implemented with the help of AKSU GK, provides an opportunity to reduce the cost of mining and transport works by 20-30% or more.

Secondly, automated dispatching systems for mining and transport works, as calculations show and confirms the practice of their use, have a limitation on their profitability. On quarries with the number of transport units less than 10-12 pieces they do not pay back themselves. Therefore, as a rule, in small and medium open-pit mines, especially those not related to the extraction of precious minerals, they are used much less frequently and do not provide a possible economic effect.

At the same time, in-depth automated analytics, based on in-depth automated digitalization of the process of functioning of a geotechnological complex, allows to realize a significantly greater potential for

Table 1 – The effectiveness of implementation of the main functions of mining and transport operations management in the framework of the AKSU GK

FUNCTIONS	EFFECT AND CONDITIONS OF ITS GAINING	LEVELS OF EFFECTS GAINING	POSSIBILITIES
Recording	Once only for 5-10%	Dispatch system	Improvement of production discipline, monitoring of major TEI
Control			
Regulation			
Organization			
Norm setting	In case of permanent performance up to 30%	Analytical unit of the ACMS GC	Optimization of modes and conditions of operation of the major technological equipment
Stimulation			
Planning	Within the frames of short-, medium- and long-term periods		
Regulation			
Organization			

competitiveness in comparison with an approach focused on the use of high-level production capacities, main mining and transport equipment, as follows from table 2 [5].

As follows from the data presented in the table, factors of automation, integration and perfect organization of mining and transport operations play a significant role in mining. Practically similar conclusion can be drawn from the diagrams shown in figure 2. It follows from the diagrams that a complete renovation of the main technological equipment with the former system of management of mining and transport operations allows for a temporary cost reduction of 10-15%, but with each subsequent year of its operation, this effect decreases and disappears. At the same time, only replacement of the organization of the mining and transport complex management to ones with a corporate and process ensures a reduction in the cost of mining and transport operations by 30-35% and more, and over the years this effect remains unchanged. Ideal case incurs the automated corporate management of the mining and transport complex combined with the optimal level of its profitability.

Table 2 – Factors of competitiveness of a mining enterprise

П/П	ЭЛЕМЕНТЫ И ИХ ГРУППЫ	ОЦЕНКА ВЛИЯНИЯ, %*	
		В СТРАНАХ ЛИДЕРАХ	В СТРАНЕ
1	ЭЛЕМЕНТЫ ТЕХНИЧЕСКОЙ ГРУППЫ		
1.1	Уровень производственных технологий	12	16
1.2	Уровень основного и вспомогательного оборудования	10	14
1.3	Уровень информационных систем и их технических средств	1	0,5
1.4	Уровень локальных систем автоматизированного управления и робототехники	2	1
1.5	Уровень комплексной автоматизированной системы управления технологическими процессами	18	6
1.6	Уровень интегрированной организационно-технической АСУ предприятием	10 (6+4)	3
1.7	Уровень управления производственно-технологическими и ремонтно-профилактическими процессами в плане соблюдения технологических нормативов и требования техники безопасности труда	1	0,5
1.8	Степень оптимизации технологических процессов и эксплуатационных режимов работы оборудования (материало- и энергоэффективность, качество продукции и минимизация её себестоимости)	12	4
1.9	Степень комплексного использования сырьевых ресурсов	2	1,5
1.10	Степень оптимальности ремонтно-профилактических работ по основному и вспом-му оборудованию	3	1,5
1.11	Соответствие организационно-технологической структуры производства требованиям теории надежности и резервирования	1	0,8
1.12	Рациональность компоновочного размещения в пространстве и на площадках элементов производственно-технологического комплекса предприятия	1	0,7
2	ЭЛЕМЕНТЫ ЭКОНОМИЧЕСКОЙ ГРУППЫ		
2.1	Эффективность менеджмента предприятия (все аспекты)	6	4
2.2	Эффективность маркетинговой деятельности с учетом достижений логистики по оптимизации потоковых процессов различных видов (грузовых, информационных, энергетических и финансовых)	11	1,5
2.3	Финансовые элементы	4	1,5
2.4	Инвестиционные элементы	6	0,2
	ВСЕГО	100	63,2

At times of lack of investment resources, the most significant direction of intensifying the reduction of mining production costs without significant capital investments is the introduction of process management of the mining and transport complex [6,7]. The process approach in production management allows more fully and efficiently to realize its basic functions of planning, organizing, rationing, regulating, controlling and accounting for the operation of the mining and transport complex, which greatly increases its efficiency and, therefore, the competitiveness of the enterprise itself.

The process management of the mining and transportation complex in a quarry is carried out by taking into account a combination of factors of the external and internal environment of an enterprise based on economic and mathematical modeling of production processes [8]. The basis for managing production processes is automated monitoring and dispatching of mining and transport operations within the corporate management system, which ensures the rapid collection and analytical processing of reliable information on the operation of the mining and transport complex in specific mining and technical, mining and geological, economic and organizational conditions for its functioning [9,10].

The basis of intellectual automation of production processes is an economic-mathematical model that provides formalized economic representation of economic objects, processes, phenomena and their interconnections [11,12].

As practice shows, overwhelming majority of modern mining enterprises use an economic analysis system that corresponds to the functional management of the mining transport divisions and is based on local criteria: an excavator park - the cost of the rock mass mining, a park of trucks and locomotives - the cost per ton-kilometer, etc. [13-16].

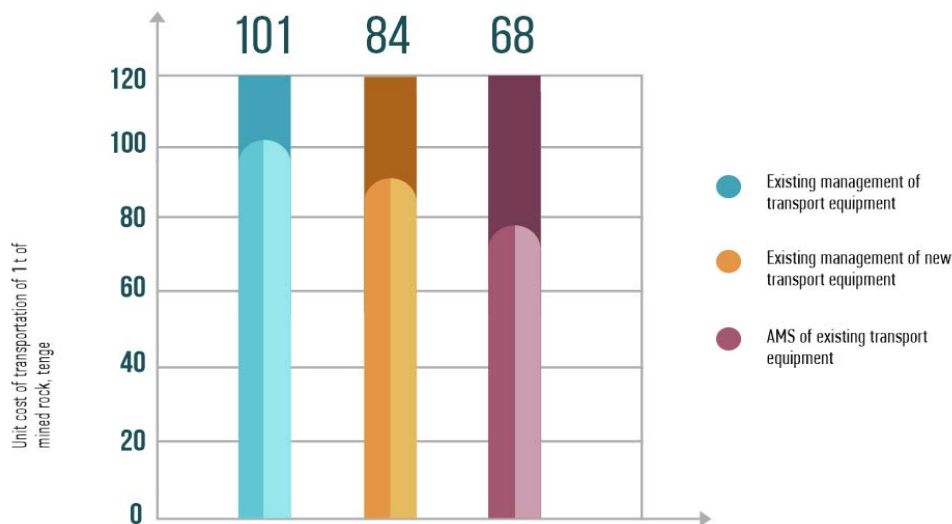


Figure 4 – Efficiency of organizational and technical factors of mining production

In general, according to the technological scheme of enterprise, the main economic indicator of its work is the cost of 1 ton (or 1 m³) of extracted mineral raw materials. For example, the indicator of the cost of extracting rock mass, which is considered as a complex and widely used in the T. Kemm model [17-18] of the formation of costs for open work, is calculated by

$$c = c_d + k_v c_v, \quad (1)$$

where C_d is the cost of mining without stripping operations, USD/t; C_v is the cost of stripping, in US dollars/m³; K_v - stripping coefficient, m³/t.

As can be seen, this approach suggests calculating the cost of production by simply summing up the values of two albeit key, but separate indicators: the cost of extracting the useful mineral and the cost of overburden excavation.

In the proposed approach, the main criterion of economic efficiency of the results of mining-transport complex work is the specific current costs of extracting one cubic meter of rock mass, calculated by the formula:

$$C_{RM} = \frac{C_E + A}{V_{RM}}, \quad (2)$$

where C_E - operating costs; A - depreciation deductions; V_{RM} - the volume of extracted rock mass per shift, m^3 .

The optimization of the parameters of the mining and transport complex in a quarry with a combined transport (for example truck - rail way) is made according to the criterion of minimum unit operating costs with an objective function of the following form:

$$C_{RM} = f(C_e, C_a, C_{rw}, C_{ol}) \rightarrow \min, \quad (3)$$

where C_e , C_a , C_{rw} and C_{ol} – respectively specific operating costs for excavation, auto transport, rail way transport and overloading warehouses. At the same time, indicators on the volumes of mined ore, overburden, as well as the average content of the useful component in the ore serve as limitations.

The scientific and methodological base of the analytical unit of the AKSU GK allows not only to analyze and purposefully correct the current state of the geotechnological complex, but also to conduct a technical and technological audit of new design, investment, innovative and organizational solutions. At the stage of implementation of the AKSU GK with the help of an analytical unit, a preliminary technical and economic assessment is carried out, which makes it possible to determine with a high degree of accuracy existing potential of a real increase in efficiency and a decrease in the cost of mining and transport works. For large and medium-sized quarries, it is usually about 15-30%, which provides savings of about \$1-3 million/year. In contrast to automated dispatching systems, due to a more complete realization of the existing potential, the use of this system is economically feasible in small pits too.

Conclusion. In condition of the transition to the Industry-4.0, the main drivers of which are digitalization and automation, for the successful implementation of the existing potential to improve the efficiency of open cast mining operations, it is obvious the expediency of developing a unified methodology for the design, planning and management of geotechnological complexes on the basis of in-depth analytics (operational level) within the automated corporate (integrated) approach using the economy of process management.

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АШЫҚ ТАУ-КЕН ЖҰМЫСТАРЫ КЕЗІНДЕГІ ТАУ-КЕН ТРАНСПОРТЫНЫҢ ЖҰМЫСТАРЫН ӘЛЕУЕТТІК ЖОҒАРЛАУ ТИІМДІЛІГІ ЖӘНЕ САНДЫҚ ЖҮЙЕСІН ЖОБАЛАУ ЖӘНЕ ЖОСПАРЛАУ

Аннотация. Циклдік технологияларды пайдалана отырып, ашық әдіспен пайдалы қазбалар кен орындарын игерудің қазіргі заманғы дәстүрлі және кеңінен қолданылатын технологиялары пайдалы қазбаларды өндіру және тасымалдау жұмыстарының тиімділігін жоғарылату және құнын төмендету үшін елеулі әлеуетке ие. Мақалада осы әлеуетті қалай іске асыруға болатынын қарастырады. Карьердегі тау-кен және көлік жұмыстарының тиімділігін арттырудың әлеуеті мен бағыттары геотехнологиялық кешендерді автоматтандырылған корпоративтік басқару әдіснамасын қолдана отырып, ғылыми-практикалық зерттеулер мысалында анықталды.

Бүгінгі таңда ашық карьерді өндіру саласында ең көп бухгалтерлік және бақылаудың автоматтандырылған жүйелері, тау-кен және тасымалдау операцияларын автоматтандырылған диспетчерлеу жүйесі қолда-

нылатын. Алайда, олар тау-кен жұмыстарының тиімділігін арттыру үшін бар әлеуеттің үшінші бөлігін ғана іске асыруға мүмкіндік береді. Мақалада әлеуетті барынша толық іске асыру механизм мен мүмкіндіктері ашылады. Автоматтандыру және санды жүйесі тиісті ғылыми-инновациялық әлеуетті дамыту жағдайында ғана қажетті нәтиже беретінін атап өткен жөн.

Инвестициялық ресурстардың жетіспеушілігі жағдайында күрделі капиталды салымдарсыз тау-кен шығындарының төмендеуін жеделдетудің маңызды бағыты тау-кен-көлік кешенін технологиялық басқаруды енгізу болып табылады. Процесс тәсіл - бұл кәсіпорынның қызметін өзара байланысты өндірістік процестер жиынтығы ретінде қарастыратын басқарудың қазіргі заманғы тұжырымдамасы. Өндірісті басқарудағы технологиялық тәсіл бізге тау-кен-көлік кешенін жоспарлау, ұйымдастыру, реттеу, бақылау және есепке алудың негізгі функцияларын неғұрлым толық және тиімді жүзеге асыруға мүмкіндік береді, бұл оның тиімділігін, демек кәсіпорынның бәсекеге қабілеттілігін айтарлықтай арттырады.

Карьердегі тау-кен-көлік кешенін технологиялық басқару өндірістік процестерді экономикалық және математикалық модельдеу негізінде кәсіпорынның сыртқы және ішкі ортасы факторларының үйлесімін ескере отырып жүзеге асырылады. Өндірістік процестерді басқарудың негізі корпоративті басқару жүйесі аясында тау-кен жұмыстарының автоматтандырылған мониторингі және кестесі болып табылады, ол нақты тау-кен, геологиялық, экономикалық және ұйымдастырушылық жағдайларында тау-кен тасымалдау кешенінің жұмысы туралы шынайы ақпаратты жедел жинау және аналитикалық өңдеуді қамтамасыз етеді.

Мақалада ашылған тағы бір маңызды сала - карьерлердің геотехнологиялық кешендерін тұрақты және бағдарланған технологиялық жаңғырту үшін цифрландырудың іргелі маңыздылығы. Цифрландыру, оның мазмұны бойынша, үнемі дамып келе жатқан ғылыми-әдістемелік әлеуетке сәйкес келуі керек, бұл геотехнологиялық кешендердің жұмысын сапалы жедел талдауға мүмкіндік береді. Бұл әртүрлі инновациялардың техникалық және ұйымдастырушылық тиімділігін бағалауға мүмкіндік береді. Цифрландыру – бұл кәсіпорынды жаңарту процесінің негізгі кезеңдерінің бірі және оны технологиялық саясат аясында жүйелі түрде жүргізу керек. Ол кәсіпорынның менеджерлері мен талдаушылары үшін оның даму стратегиясын анықтайтын тиімді құралға айналуы керек.

Геотехнологиялық кешендерді корпоративті басқарудың автоматтандырылған жүйелерінің бағдарламалық-аналитикалық потенциалы пайдалы қазбалар кен орнын игеруді жобалау аясында іске асырылған геотехнологиялық кешенді жобалау сатысында, сондай-ақ оларды пайдалану кезеңінде, жиі кездесетін қайта құру кезінде басқару шешімдерін әзірлеу кезінде де бірдей қолданылуы керек. Тау-кен өндірісіндегі орны. Бірыңғай әдістеме кен орындарын пайдалану кезеңінде жүзеге асырылатын әртүрлі шараларды жобалаудың тиімділігін салыстырмалы бағалауды жүргізуге практикалық мүмкіндік береді.

Қорытындылай келе, мақалада Индустриалды-4.0-ге көшу кезінде, автоматтандырылған корпоративтік тәсілдің шеңберінде терең талдау негізінде әзірленген геотехнологиялық кешендерді жобалау, процестерді басқарудың экономикасын пайдалана отырып жоспарлау және басқарудың жалпы әдіснамасы негізінде ашық тау-кен өндірісінде тау-кен жұмыстарының тиімділігін арттыруға болады деп қорытынды жасалады.

Түйін сөздер: тау-кен жұмыстарын жүрізу, басқару, ұйымдастыру, тиімділік, сандық жүйе, автоматтандыру.

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ЦИФРОВИЗАЦИЯ И ПОТЕНЦИАЛ ПОВЫШЕНИЯ ЭФФЕКТИВНОСТИ ПРОЕКТИРОВАНИЯ И ПЛАНИРОВАНИЯ ГОРНОТРАНСПОРТНЫХ РАБОТ НА ОТКРЫТЫХ РАЗРАБОТКАХ

Аннотация. Современные традиционные и наиболее широко применяемые технологии освоения месторождений полезных ископаемых открытым способом с применением циклических технологий имеют существенный потенциал повышения эффективности и снижения себестоимости горнотранспортных работ. Статья посвящена тому, каким образом и за счет чего можно реализовывать этот имеющийся потенциал. Потенциал и направления повышения эффективности горнотранспортных работ в карьере раскрываются на примере научно-практических исследований с использованием методологии автоматизированного корпоративного управления геотехнологическими комплексами.

На сегодня в области открытых горных работ наибольшее распространение получили системы автоматизированного учета и контроля, автоматизированные системы диспетчеризации горнотранспортных

работ. Однако они позволяют реализовать только третью часть имеющегося потенциала повышения эффективности добычного процесса. В статье раскрывается механизм и возможности в существенной степени более полной реализации имеющегося потенциала. Отмечается, что автоматизация и цифровизация могут дать нужный эффект лишь в условиях развития соответствующего научно-инновационного потенциала.

В условиях дефицита инвестиционных ресурсов наиболее существенным направлением интенсификации снижения затрат горного производства без значительных капитальных вложений является внедрение процессного управления горнотранспортным комплексом. Процессный подход – современная концепция управления, которая рассматривает деятельность предприятия как совокупность взаимосвязанных производственных процессов. Процессный подход в управлении производством позволяет более полно и качественно реализовывать его основные функции планирования, организации, нормирования, регулирования, контроля и учета работы горнотранспортного комплекса, что в значительной мере повышает его эффективность, а значит и конкурентоспособность самого предприятия.

Процессное управление горнотранспортным комплексом в карьере осуществляется с учетом совокупности факторов внешней и внутренней среды предприятия на основе экономико-математического моделирования производственных процессов. Основой управления производственными процессами являются автоматизированный мониторинг и диспетчеризация горнотранспортных работ в рамках системы корпоративного управления, которые обеспечивают оперативный сбор и аналитическую обработку достоверной информации о работе горнотранспортного комплекса в конкретных горнотехнических, геологических, экономических и организационных условиях его функционирования.

Другим, важным направлением, раскрываемым в статье, является принципиальная значимость цифровизации для устойчивого и целенаправленного процесса технологической модернизации геотехнологических комплексов карьеров. Отмечается, что цифровизация, по своему содержанию, должна соответствовать постоянно развивающемуся научно-методическому потенциалу, позволяющему осуществлять качественный пооперационный анализ функционирования геотехнологических комплексов. Это создаёт возможность оценки эффективности различного рода инноваций, как в техническом плане, так и в организационном. Цифровизация является одним из базовых этапов процесса модернизации предприятия и должна осуществляться системно в рамках реализуемой им технологической политики. Она должна стать эффективным инструментом менеджеров-аналитиков на предприятии, определяющих стратегию его развития.

Программно-аналитический потенциал автоматизированных систем корпоративного управления геотехнологическим комплексам должен быть в одинаковой степени применим как при выработке управленческих решений на стадии проектирования геотехнологического комплекса, реализуемого в рамках проектирования освоения месторождения полезных ископаемых, так и на стадиях их эксплуатации, а также реконструкции, которые часто имеют место в горном производстве. Единая методология обеспечивает практическую возможность проведения сравнительной оценки эффективности проектирования различного рода мер, реализуемых на стадии эксплуатации месторождения.

В заключении статьи приводится вывод о том, что в условиях перехода к Индустрии-4.0, обеспечение повышения эффективности горнотранспортных работ на открытых разработках возможно лишь на базе единой методологии проектирования, планирования и управления геотехнологическими комплексами, развиваемой на основе углубленной аналитики в рамках автоматизированного корпоративного подхода с применением экономики процессного управления.

Ключевые слова: горнотранспортные работы, управление, организация, эффективность, цифровизация, автоматизация.

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**MIGRATORY ACTIVITY AT THE LANDFILL SITE
OF MICROELEMENTS OF THE CASPIAN DEPRESSION**

Abstract. The article analyzes the migration activity of microelements in the territories of the Azgir and Taysoygan polygons located in the Caspian Depression. At landfills, soils are characterized by strong salinity, and the concentration of salts in the dry residue is 0.28-0.71%. According to the type of salinization according to the composition of the anions, they belong to the sulfate-soda-chloride type, and according to the composition of the cations to the magnesium-sodium type of salinization. The content of a number of chemical elements in the soil of the landfill is several times higher than the background ones, for example, vanadium, zirconium, aluminum, magnesium, calcium, potassium. The content of a number of chemical elements exceeds the threshold of phytotoxicity, for example, vanadium, zinc, cobalt exceeds 1.5 times. Bioindication studies have revealed the concentration of toxic trace elements in food chains that exist in biota in the study area. A noticeable increase in the content of lead, silver, titanium and zinc in plant tissues was recorded. The results on the correlation of the content of chemical elements in the soil and plants showed very low values, despite the fact that they differed in terms of different species. The results obtained with sufficient certainty indicate that additional enrichment of the soil with metals leads to their accumulation in plants.

Key words: Azgir landfill, Taysoygan landfill, salinization type, microelements, phytotoxicity, correlation coefficient.

Introduction. In the Caspian Depression on the territory of the Republic of Kazakhstan, there were two training ranges, one of which Azgir was a nuclear training ground and Taisoigan, which was used as a military training ground.

At the Azgir landfill, located in the Kurmangazy district of Atyrau region from 1966 to 1979, 17 nuclear explosions were carried out in the thickness of rock salt strata at a depth of 165 to 1,500 m using nuclear explosive techniques at the Galit facility.

The Taysoygan landfill located in the Kyzylkuginsk district of the Atyrau region began operating in 1952. This landfill was divided into three sections: the Makat site, the Taysoygan landfill and the landfill site near the village of Ushtoba.

Wastes generated as a result of the activity of these landfills are dangerous in that mobile radioelement can migrate and become involved in the biological cycle, that is, there is a big threat to the agricultural fields of pastures and therefore to rural residents who consume water and use agricultural products.

The composition of water-soluble salts migrating in the soil and weathering crust is limited by a relatively small number of chemical compounds. These are sodium, calcium, magnesium and potassium salts of hydrochloric, sulfuric, carbonic, silica and much less often nitric acid. Water soluble salts have a great effect on plants and soil properties. The presence of salts has a great effect on plants and soil properties. The presence of salts causes an increase in the osmotic pressure of the soil solution. Salts have toxic effects on plants, disrupt metabolism, make it difficult for plants to absorb nutrients from the soil, and cause a decrease in yield and deterioration in the quality of agricultural products [1]. Under the

influence of sodium and magnesium chlorides, the absorption of calcium and iron by plants decreases 3 times, phosphorus and manganese 2 times, SO₄, SiO₂ 1.5 times.

Methods. A comprehensive research method was used in the work, including experimental and laboratory methods and the method of correlation and regression analysis. Spectral emission analysis made it possible to estimate the content of 42 chemical elements in the samples taken.

Results. The studied soils from the Azgir and Taysoygan landfills are represented by saline and highly saline soils. The degree of salinity is determined by the dry residue [2]. The concentration of salts of about 0.3-0.5% of the dry residue in the water extract inhibits the development of most cultivated plants and belongs to saline soils. Chemical studies have shown that the solids content is 0.28-0.71%, that is, the soil is saline (table 1).

Table 1 – The results of the analysis of water extracts of soils

No.	Place of selection	Dry residue	Cl ⁻ meq / 100g	SO ₄ ²⁻ meq / 100g	HCO ₃ ⁻ meq / 100g	Ca ²⁺ meq / 100g	Mg ²⁺ meq / 100g	Na ⁺ meq / 100g
1	Taysoygan	0,28-0,52	1,5-5	0,2-0,4	0,6-1,0	0,08-1,2	0,8-1,4	0,9-3,8
2	Azgir	0,22-0,71	0,3-2,5	1,03-7,41	0,2-1,2	0,4-2,3	0,5-7,8	0,08-5,9

Along with determining the degree of salinity, the type of salinity was also established (table 2). According to the composition of the anions of the soil, they belong to the sulfate-soda-chloride type.

Table 2 – Sulphate-soda-chloride composition of water extract of soils

Place of selection	$\frac{Cl^-}{SO_4^-} > 1$	$\frac{HCO_3^-}{Cl^- + SO_4^-} - (0.1 - 0.6)$	$\frac{HCO_3^-}{Cl^-} < 1$	$\frac{HCO_3^-}{SO_4^-} < 1$
Taysoygan	7,5-20,0	0,15-0,47	0,13-0,4	1,25-5,0
Azgir	0,25-0,33	0,12-0,15	0,48-0,66	0,16-0,19

It should be noted a very high content of toxic chlorides from 0.3 to 5.2 meq / 100g. According to the composition of cations, the studied soil belongs to the magnesium-sodium type of salinization (table 3).

The average content of HCO₃⁻ is in the range of 0.6-1.0 meq/100 g; SO₄²⁻ 0.2-0.4 meq/100g; Ca²⁺ - 0.6-1.2 meq / 100 g; Mg²⁺ - 0.8-1.6 meq/100 g; Na⁺ - 0.9-3.8 meq/100 g [3].

Table 3 – Magnesium-sodium type of salinization according to the composition of cations

Place of selection	$\frac{Na^+}{Ca^{++} + Mg^{++}}$	$\frac{Ca^{++}}{Mg^{++}} < 1$	$\frac{Na^+}{Ca^{++}} > 1$	$\frac{Na^+}{Mg^{++}} > 1$	$\frac{Mg^{++}}{Ca^{++}} > 1$
Taysoygan	0,5-1,67	0,5-1,0	1,1-3,1	1,1-3,9	1,0-2,0
Azgir	0,08-0,58	0,29-0,8	0,2-2,56	0,146-0,75	1,25-3,4

From an environmental point of view, not the average, and often even more important, values may be not the average values of the content of toxic elements in plants, but their maxim observed at individual points or sections of the territory. Animals that feed on vegetation in such areas for even a short time may receive an excessive amount of toxic elements and in turn, accumulate them in their tissues and organs.

The data from tables 4 and 5 show that the content of a number of chemical elements in the plants of landfills in many cases exceeds the thresholds of toxic effects on animals [4].

The content of vanadium, zirconium, aluminum, magnesium, calcium, potassium in the soil of the landfill is higher than in the background areas by about 8 times. Soil contamination with these elements is recorded in a two-kilometer strip adjacent to the border of the Azgir landfill. Thus, the maximum contents of titanium, manganese, magnesium, lead, nickel, copper, cobalt, strontium, silver, phosphorus and molybdenum recorded in the landfill significantly exceed the toxicity threshold [5].

Table 4 – Comparison of elements of the composition of vegetation at the Azgir landfill and in the background areas (in mg/kg of dry weight)

No.	Element	At the test site (n = 65)				In the background territories (n = 27)				$\frac{x_n}{x_\phi}$	Student criterion
		Cp (X _n)	σ	Min	Max	Cp (X _n)	σ	Min	Max		
1	Silicon	9604,2	91094	1120	5220	7135,2	4938,5	200	20850	1,4	1,7
2	Aluminum	846,49	1220	40	8352	416,6	251,9	10	1165	2,1	2,7
3	Magnesium	2017,8	1339,5	244,5	5444	2138,9	1350,5	100	5526	0,9	0,4
4	Calcium	4590,1	4123,9	405,5	2049	5064,1	3595	200	14440	0,9	0,4
5	Iron	662,94	1014,6	26	6264	396,9	315,6	25	1312	1,7	1,9
6	Manganese	41,91	50,26	4	239,1	44,7	31,9	1	100	0,9	0,3
7	Nickel	2,328	3,983	0,2	23,9	1,41	1,22	0,01	5,82	1,7	1,7
8	Cobalt	0,7923	1,4236	0,01	8,352	0,424	0,456	0,01	1,87	1,9	1,9
9	Vanadium	2,889	5,327	0,1	41,76	1,72	1,71	0,02	7,5	1,7	1,6
10	Chromium	5,995	11,63	0,2	68,32	3,1	2,16	0,05	9,37	1,9	1,9
11	Molybdenum	0,846	0,984	0,14	5,045	0,54	0,854	0,964	2,77	1,1	0,4
12	Zirconium	13,025	8,825	1	51,24	11,48	6,62	0,5	29,52	1,1	0,9
13	Copper	14,087	13,449	0,83	68,32	13,76	10,55	0,25	41,9	1,0	0,3
14	Lead	1,9447	2,8593	0,01	1708	1,6	1,64	0,015	7,5	1,2	0,7
15	Silver	0,0735	0,0851	0,007	0,451	0,0401	0,053	0,003	0,28	1,5	2,0
16	Zinc	9,2060	7,9692	1	36,14	6,53	5,15	0,2	20,58	1,4	1,9
17	Tin	0,2157	0,3535	0,01	2088	0,185	0,21	0,01	0,75	1,2	0,5
18	Lithium	2097,3	1,9330	0,662	10,44	2,59	2,06	0,35	5622	1,1	0,8
19	Strontium	45,987	83,313	0,01	5202	67	73,07	0,01	320,6	0,7	1,2

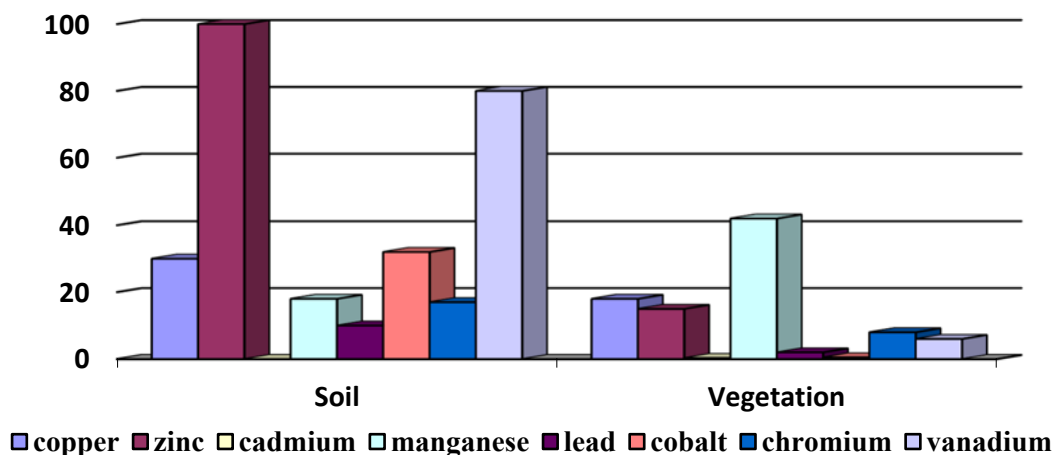
Table 5 – Comparison of vegetation composition elements at Taysoygan landfill and in the background areas (in mg/kg of dry weight)

No.	Element	At the test site (n = 65)			In the background territories (n = 27)			$\frac{x_n}{x_\phi}$	Student criterion
		Cp (X _n)	σ	Min	Max	Cp (X _n)	σ		
1	Iron	365	10	600	390	50	1500	0,93	1,9
2	Manganese	29,9	0	120	38,2	25	60	0,78	0,3
3	Cobalt	0,125	0,05	0,38	0,17	0,05	0,23	0,74	1,9
4	Molybdenum	1,56	0,3	4,2	1,35	0,3	2,7	0,29	0,3
5	Copper	1,5	0	6,0	5,1	0,9	27	0,29	0,3
6	Lead	1,05	0,3	3,65	0,16	0,02	0,4	6,56	0,7
7	Zinc	13,8	4,0	57	15,68	6,0	31,0	0,88	1,9
8	Tin	0,39	0	0,8	0,22	0	0,5	1,8	0,5
9	Cadmium	0,42	0,08	1,66	0,12	0,02	0,29	3,5	2,1

Bioindication studies revealed a significant infection of the territory of the Azgir landfill with a number of toxic chemical elements and found their migration from soil to plants and further to herbivores, in which the concentration of pollutants was noted, which could cause disease in the population. An increase in the content of lead, titanium, zinc and other heavy metals in the tissues of farm animals was recorded [6].

In order to assess the degree of environmental hazard and pollution detected, the concentrations of elements taking place were compared with average norms, as well as threshold ones with respect to toxic

effects on living organisms. The maximum concentrations of cobalt, vanadium, chromium, molybdenum, zinc and strontium, and even average concentrations exceed the phytotoxicity thresholds “in accordance with figure”. Thus, the average vanadium content in the soils of the landfill (79 mg / kg) is more than 1.5 times higher than the phytotoxicity threshold (50 mg / kg), and the maximum values of its content (100-150 mg / kg) were noted in some samples, as taken at the places where rockets fall, and background [7].



The content of heavy metals in soil and vegetation

The average zinc content in the soil of the landfill (102 mg/kg) significantly exceeds the phytotoxicity threshold (70 mg/kg), and its maximum concentration reaches 100-150 mg/kg for samples taken at the places where the winged rivers fall. With such a concentration of zinc, anemia, inhibition of oxidative processes, and plant chlorosis are possible. With respect to cobalt, it should be noted that its maximum concentrations exceed the phytotoxicity threshold at sites 1 and 4, where they reach 30 mg/kg. The content of molybdenum and zirconium did not statistically significantly differ in the samples taken at the places where different types of missiles fell, and in the background samples, not reaching the phytotoxic limit in the case of molybdenum [8].

Particular attention should be paid to strontium. In terms of average content (109 mg/kg), it does not exceed either the normal concentration in soils or the phytotoxicity threshold (600 mg/kg). However, this element is completely absent (or rather, its content is below the detection threshold of 10 mg/kg in soils in the background areas. Therefore, its increased content at the landfill is quite obviously due to technogenic factors. In addition, the strontium content in the soil significantly exceeds the phytotoxicity threshold (600 mg/kg) reaching 1000, 1500 and even 2000 mg/kg. It should be noted that strontium content in soils in an amount of more than 600 mg / kg can lead to human disease, and concentrations above 1000 mg/kg cause rickets and bone fragility at home [9].

Aluminum, magnesium, calcium and silver turned out to be on average more than in the background samples. Moreover, the greatest excess of aluminum and calcium over the background was observed at the places where air-to-ground missiles fell. The layers that are richest in calcium turn out to be carried out to the surface in funnels at the places where rockets fall. Moreover, the minimum value of silver concentration in soil samples, both taken at the places where rockets fell and background ones, is critical with respect to phytotoxicity (2 mg/kg). The iron content turns out to be approximately the same in soil samples taken at the places where the rockets fell, and in the background and on average it agrees well with the passport standard (34300 mg/kg). The content of manganese, copper and titanium at the places where rockets fall is higher than the background in cases of cruise missiles. At ethos, the average copper concentration in the samples of the triz groups turned out to be close to the passport standard (30 mg/kg), but a number of samples taken at the rocket fall sites exceeded the toxicity threshold (60 mg/kg).

Nickel, lead, tin, thallium, lithium, barium and chromium turned out to be on average more in samples taken at the places of impact of all types of missiles in general. This increase was primarily determined by cruise missiles and tactical air-to-ground missiles. The chromium content in some samples

reached the phytotoxicity threshold (75-100 mg/kg). Note that the passport standard (110 mg/kg) also exceeds the toxicity threshold. The average values of thallium content in soil samples turned out to be close to the passport data of the State Standard (13 mg/kg).

Discussion. The results of the analyzes allow us to unequivocally state that at the places of impact of various types of rockets there is a change in the chemical composition of the soil. The content of aluminum, magnesium, calcium, manganese, nickel, cobalt, titanium, chromium, copper, lead, silver, zinc, tin, lithium, and barium in soils at the places where different types of rockets fall. The places where cruise missiles fall are especially prominent, where there was an increase in the concentration of all these elements [10].

It must be emphasized that the concentration of vanadium in some samples exceeded the toxicity threshold, the same was characteristic of the concentration of chromium; a number of samples taken at the places of impact of different types of missiles are already the minimum silver concentration for soil samples are critical in terms of toxicity, and are very distinguished by the silver content of the soil in the places of the fall of tactical missiles: both in the places of the fall of the missiles and background, the toxic level for zinc.

Plant samples were also analyzed. The minimum, maximum and average values and standard deviation of the concentration of each of the elements in the composition of plant samples from the polygons were obtained. The element content in samples of each group was averaged for all collected plant species [11].

The concentrations of silicon, aluminum, magnesium, calcium, manganese in the vegetation of the Azgir range do not exceed the norm, however, a number of background samples and samples taken at the places where cruise missiles fell, exceeded the threshold toxicity (70 mg/kg dry matter). The same was characteristic of nickel: the average values were within the range of norm, but some background samples taken at the places where cruise missiles fell exceeded the toxicity threshold (6.7 mg/kg of dry weight). A similar result was obtained for cobalt, where some samples exceeded the toxicity threshold (2 mg/kg of dry weight). The titanium content was within normal limits (up to 380 mg/kg of dry weight). For vanadium and chromium, as well as zirconium and molybdenum, the average concentration values were within normal limits, but a number of background samples and samples from rocket fall sites exceeded the threshold concentration toxicity. The copper content, on average, corresponded to the norm, however, some background samples and samples from the rocket fall sites exceeded the threshold toxic concentration (25 mg/kg of dry weight). The threshold concentration toxicity for lead (5 mg/kg of dry weight) was likewise exceeded. The average silver concentration in the dry matter of the landfill plants exceeded the threshold toxic concentration (0.2 mg/kg). Zinc concentrations in some background samples exceeded the upper threshold level (100 mg/kg). The concentration of tin remained within normal limits (up to 5 mg/kg). The concentration of strontium in the vegetation of the landfill did not reach a toxic level (100 mg/kg).

The data presented make it possible to assume that the increased content of the majority of identified micro- and microelements in the soil accumulation horizon of the landfill can lead to further migration of these elements into plants and further into animals that feed on them and their accumulation in these organisms. From plants and domestic animals, toxic elements can enter human food and lead to the appearance of diseases and other negative consequences [12].

An analysis of the relationship between the content of chemical elements in soil and plants showed, firstly, very low, practically irreplaceable, in general, correlation values; secondly, differences in species for this indicator. In other words, the amount of metal in the soil does not yet indicate its mandatory accumulation in the plant, and vice versa. Two random variables can be interconnected and not being in a functional relationship. This relationship is called correlation. Using extremely reliable (at the level of 0.95) values of the correlation coefficient, although not high, we are convinced that only a few elements have such a relationship: soil-wormwood ($n = 40$) - Cr ($r = \text{plus } 0.34$); ebel-soil ($n = 50$) - Mn ($r > 0.30$); Fe ($r = \text{plus } 0.28$) Zn ($r = \text{plus } 0.28$); Pb ($r = \text{plus } 0.25$); quinoa soil ($n = 35$) - correlation coefficients are close to reliable in Mn and Cr ($r = \text{plus } 0.25$).

A calculation at 20 points at which samples of all three plant species were taken confirmed the validity of the correlation for chromium in soil and plants ($r = \text{plus } 0.44$) for wormwood, for Pb ($r = \text{plus } 0.55$) for ebelek and found a new relationship - according to Sr ($r = \text{plus } 0.45$) for the quinoa [13].

Conclusion. The results obtained with sufficient certainty indicate that the additional enrichment of the soil with metals leads to their accumulation in plants. Indication of the allochthonous origin of the metal in the plant is associated with a level of $KO > 20$. The coefficient calculated for all elements made it possible to rank these elements by the degree of contamination of wormwood by them: Ag - 103, Mo - 24, Sn - 24, Zn - 20, Cu - 16.

The studied soils from the Azgir and Taysoygan landfills are represented by saline and highly saline soils with a solids content of 0.28-0.71%. The content of a number of chemical elements in plants and soil in many cases exceeds the thresholds of toxic effects on animals. The content of vanadium, zirconium, aluminum, magnesium, calcium, potassium in the soil of the landfill is higher than in the background areas by about 8 times.

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ПРИКАСПИЙ ОЙПАТЫНДАҒЫ ПОЛИГОНДАР АЙМАҒЫНДА МИКРОЭЛЕМЕНТТЕРДІҢ КӨШІ-ҚОН БЕЛСЕНДІЛІГІ

Аннотация. Мақалада Каспий маңындағы ойпатында орналасқан Азғыр және Тайсойған полигондарының аумағында микроэлементтердің көші-қон белсенділігі талданады. Атырау облысының Құрманғазы ауданында орналасқан «Азғыр» полигонында 1966-1979 жылдар аралығында «Галит» қондырғысында 165-тен 1500 м тереңдіктегі тау тұздарының қалыңдығында ядролық жарылғыш техниканы қолдану арқылы 17 ядролық жарылыс жүргізілген. Атырау облысының Қызылқұға ауданында 1952 жылдан бастап Тайсойған полигоны жұмыс істей бастады. Бұл полигон үш бөлімге бөлінді: Мақат учаскесі, Тайсойған полигоны және Үштоба ауылының жанындағы полигон.

Полигондарда топырақ қатты тұзданумен сипатталады, ал құрғақ қалдықтағы тұздың мөлшері 0,28-0,71% құрайды. Аниондардың құрамы бойынша тұздану түріне қарай олар сульфат-сода-хлорид түріне жатады, ал катиондардың құрамы бойынша тұзданудың магний-натрий түріне жатады. Бұл жағдайда 0,3-тен 5,2 мэкв/100 г-ға дейін улы хлоридтердің өте жоғары мөлшерін атап өту керек. HCO_3^- - орташа мөлшері 0,6-1,0 мэкв/100 г аралығында; SO_4^{2-} 0,2-0,4 мэкв/100г; Ca^{2+} - 0,6-1,2 мэкв/100 г; Mg^{2+} 0,8-1,6 мэкв/100 г; Na^+ - 0,9-3,8 мэкв/100 г.

Экологиялық тұрғыдан алғанда, орташа емес, тіпті одан да маңызды мәні өсімдіктердегі улы элементтердің орташа мәндері емес, олардың жеке нүктелерінде немесе аумақтың учаскелерінде байқалатын максимумы болуы мүмкін. Полигон топырағындағы бірқатар химиялық элементтердің құрамы фондық элементтерге қарағанда бірнеше есе жоғары, мысалы, ванадий, цирконий, алюминий, магний, кальций, калий. Бірқатар химиялық элементтердің құрамы фитоулылық шегінен асады, мысалы, ванадий, мырыш, кобальт 1,5 еседен асады. Полигонның топырағындағы ванадийдің орташа мөлшері (79 мг/кг) фитоулылық шегінен (50 мг/кг) 1,5 есе жоғары, ал кейбір үлгілерде оның құрамының максималды мәні (100-150 мг/кг) жергілікті алынғандықтан байқалады. Ерекше назар стронцийге аудару керек. Орташа құрамы бойынша (109 мг/кг) ол топырақтағы қалыпты мөлшерден де, фитоулылық шегінен (600 мг/кг) аспайды. Алюминий, магний, кальций және күміс фондағы үлгілерге қарағанда орта есеппен көп болды. Зымыран құлаған жерлерде алынған топырақ сынамаларында темір мөлшері шамамен бірдей, ал фондында және орташа есеппен ол төлқұжат стандартына сәйкес келеді (34300 мг/кг). Зымыран құлаған жерлерде марганец, мыс және титанның құрамы зымырандар жағдайында өндік деңгейден жоғары. Сонымен бірге, әртүрлі тобының үлгілеріндегі мыс мөлшерінің орташа мәні паспорт стандартына жақын болды (30 мг/кг), бірақ зымыран құлаған жерлерде алынған бірқатар сынамалар уыттылық шегінен асып кетті (60 мг/кг). Никель, қорғасын, қалайы, таллий, литий, барий және хром зымырандардың барлық түрлерінің әсерінен алынған үлгілерде орташа есеппен көп болды. Бұл өсу ең алдымен зымырандармен және әуе-жердегі тактикалық ракеталармен анықталды. Кейбір үлгілердегі хром мөлшері фитоулылық шегіне жетті (75-100 мг/кг).

Биоиндикациялық зерттеулер зерттеу аймағында биотада болатын тамақ тізбектеріндегі улы микроэлементтердің мөлшерін анықтады. Өсімдік тіндерінде қорғасын, күміс, титан және мырыштың айтарлықтай өсуі тіркелді. Азғыр диапазоны өсімдіктеріндегі кремний, алюминий, магний, кальций, марганец мөлшері нормадан аспайды, алайда ракеталар құлаған жерлерде алынған бірқатар үлгілер мен сынамалар шекті

уыттылықтан асып кетті (құрғақ зат 70 мг/кг). Бұл никельге де тән болды: орташа мәндер мөлшерде болды, бірақ ракеталар құлаған жерлерде алынған кейбір үлгілер уыттылық шегінен асып кетті (құрғақ салмағы 6,7 мг/кг). Кобальтқа ұқсас нәтиже алынды, онда кейбір үлгілер уыттылық шегінен асып кетті (2 мг/кг құрғақ зат). Титанның мөлшері қалыпты шектерде болды (380 мг/кг құрғақ зат). Ванадий мен хром, сондай-ақ цирконий және молибден үшін мөлшерінің орташа мәні қалыпты шектерде болды, бірақ зымыран құлаған орындардағы фондық үлгілер мен үлгілер шекті мөлшерінің уыттылығынан асып түсті. Мыс құрамы орта есеппен мөлшерге сәйкес болды, алайда зымыран құлаған жерлердегі кейбір фондық үлгілер мен сынамаалар шекті уытты мөлшерден асып түсті (25 мг/кг құрғақ зат). Қорғасын үшін шекті мөлшеріндегі уыттылық (5 мг/кг құрғақ зат) асып кетті. Полигон өсімдіктерінің құрғақ затындағы орташа күміс шекті уытты мөлшерден асып кетті (0,2 мг/кг). Кейбір фондық үлгілердегі мырыш мөлшері жоғарғы шекті деңгейден асып кетті (100 мг/кг). Қалайы мөлшері қалыпты шектерде қалды (5 мг/кг дейін). Полигон өсімдіктеріндегі стронций мөлшері уытты деңгейге жетпеді (100 мг/кг).

Топырақтағы және өсімдіктердегі химиялық элементтердің арақатынасы туралы нәтижелер, әртүрлі түрлер бойынша ерекшеленетіндігіне қарамастан, өте төмен мәндерді көрсетті. Жеткілікті сенімділікпен алынған нәтижелер топырақты металдармен қосымша байыту олардың өсімдіктерде жиналуына әкелетіндігін көрсетеді.

Түйін сөздер: Азғыр полигоны, Тайсойған полигоны, тұздану түрі, микроэлементтер, фитоулылық, корреляция коэффициенті.

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МИГРАЦИОННАЯ АКТИВНОСТЬ МИКРОЭЛЕМЕНТОВ НА ТЕРРИТОРИЯХ ПОЛИГОНОВ ПРИКАСПИЙСКОЙ НИЗМЕННОСТИ

Аннотация. Проведен анализ миграционной активности микроэлементов на территориях полигонов Азгир и Тайсойған, расположенных в Прикаспийской низменности. На Азгирском полигоне, расположенного в Курмангазинском районе Атырауской области в период с 1966 по 1979 годы на объекте «Галит», методами ядерно-взрывной техники было проведено 17 ядерных взрывов в толще пластов каменной соли на глубине от 165 до 1500 м. Ракетный полигон Тайсойған, расположенный в Кызылкугинском районе Атырауской области начал действовать с 1952 года. Данный полигон подразделялся на три участка: площадка «Мака́т», полигон «Тайсойған» и участок полигона недалеко от поселка Уштоба.

На полигонах почвы характеризуются сильной засоленностью, концентрации солей в сухом остатке составляют 0,28-0,71%. По типу засоления согласно состава анионов они относятся к сульфатно-содово-хлоридному типу, а по составу катионов к магниевно-натриевому типу засоления. При этом необходимо отметить очень большое содержание токсичных хлоридов от 0,3 до 5,2 мэкв/100г. Среднее содержание HCO_3^- - находится в пределах 0,6-1,0 мэкв/100 г; SO_4^{2-} 0.2-0.4 мэкв/100г; Ca^{2+} - 0,6-1,2 мэкв/100 г; Mg^{2+} - 0,8-1,6 мэкв/100 г; Na^+ - 0,9-3,8 мэкв/100 г.

С точки зрения экологии, не меньшее, а нередко даже большее значение могут иметь не средние величины содержания токсических элементов в растениях, а их максимумы, отмечаемые в отдельных точках или участках территории. Содержание ряда химических элементов в почве полигона в сравнении с фоновыми выше в несколько раз, например, ванадия, циркония, алюминия, магния, кальция, калия. Содержание ряда химических элементов превышают порог фитотоксичности, например, ванадия, цинка, кобальта превышает до 1,5 раза. Среднее содержание ванадия в почвах полигона (79 мг/кг) более в 1,5 раза выше порога фитотоксичности (50 мг/кг), а максимальные значения его содержания (100-150 мг/кг) отмечены в некоторых пробах как взятых на местах падения ракет, так и фоновых. Особое внимание следует обратить на стронций. По среднему содержанию (109 мг/кг) он не превышает ни нормальной концентрации в почвах, ни порога фитотоксичности (600 мг/кг). Алюминия, магния, кальция и серебра оказалось в среднем больше, чем в фоновых пробах. Содержание железа оказывается примерно одинаковыми в пробах почв, взятых на местах падения ракет, и в фоне и в среднем хорошо согласуется с паспортным стандартом (34300 мг/кг). Содержание марганца, меди и титана на местах падения ракет превышает фоновое в случаях крылатых ракет. При этом средние значения концентрации меди в пробах разных групп оказались близкими к паспортному стандарту (30 мг/кг), но ряд проб, взятых на местах падения ракет дал превышение порога токсичности

(60 мг/кг). Никеля, свинца, олова, таллия, лития, бария и хрома оказалось в среднем больше в пробах, взятых на местах падения всех типов ракет в целом. Это увеличение определялось в первую очередь крылатыми ракетами и тактическими ракетами «воздух-земля». Содержание хрома в некоторых пробах достигало порога фитотоксичности (75-100 мг/кг).

Биоиндикационные исследования выявили концентрирование токсичных микроэлементов в цепях питания, существующих в биоте в районе исследований. Зарегистрировано заметное увеличение содержания свинца, серебра, титана и цинка в тканях растений. Концентрации кремния, алюминия, магния, кальция, марганца в растительности полигона Азгир не превышают нормы, однако ряд фоновых проб и проб, взятых в местах падения крылатых ракет, дал превышение пороговой токсичности (70 мг/кг сухого вещества). То же было характерно и для никеля: средние значения находились в пределах нормы, но некоторые фоновые пробы, взятые на местах падения крылатых ракет дали превышение порога токсичности (6,7 мг/кг сухого вещества). Аналогичный результат был получен и для кобальта, где некоторые пробы дали превышение порога токсичности (2 мг/кг сухого вещества). Содержание титана было в пределах нормы (до 380 мг/кг сухого вещества). Для ванадия и хрома, а также циркония и молибдена средние значения концентрации лежали в пределах нормы, но ряд фоновых проб и проб с мест падения ракет дал превышение пороговой токсичности концентрации. Содержание меди, в среднем соответствовало норме, однако некоторые фоновые пробы и пробы с мест падения ракет дали превышение пороговой токсической концентрации (25 мг/кг сухого вещества). Аналогично превышалась пороговая токсичность концентрации для свинца (5 мг/кг сухого вещества). Средние значения концентрации серебра в сухом веществе растений полигона дали превышение пороговой токсической концентрации (0,2 мг/кг). Концентрации цинка в некоторых фоновых пробах превысили верхний пороговый уровень (100 мг/кг). Концентрация олова оставались в пределах нормы (до 5 мг/кг). Концентрация стронция в растительности полигона не достигала токсического уровня (100 мг/кг).

Результаты по корреляции содержания химических элементов в почве и растениях показали очень низкие значения, при том, что они различались по показателям у разных видов. Полученные результаты с достаточной определенностью говорят о том, что дополнительное обогащение почвы металлами приводит к их накоплению в растениях.

Ключевые слова: полигон Азгир, полигон Тайсойган, тип засоления, микроэлементы, фитотоксичность, коэффициент корреляции.

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**ECOLOGY AS A BASIC PRINCIPLE
OF SUSTAINABLE DEVELOPMENT**

Abstract: The article sets out environmental friendliness. The concept of sustainable development is disclosed. Certain basic measures of sustainability: environmental, social and institutional, economical. The proposed methodology for assessing environmental sustainability and land consolidation, which is a prerequisite for territorial planning and development of the territory, helps to improve the environment, protect and fertility of the soil, increase the efficiency of environmental protection and improve the quality of life in rural areas.

Key words: sustainable development, environmental friendliness, water, land, environmentally sustainable areas, principles of sustainability, cadastre.

Introduction. In 1987, the United Nations World Commission on Environment and Development issued a report entitled “Our Common Future,” which suggested that environmental problems were addressed through a so-called new type of economic development. Sustainable development would guarantee the preservation of life on Earth, the preservation of the functions of nature and would not reduce biological diversity and would not jeopardize the interests of another nation or future generations. An organized and coordinated process aimed at sustainable development and compliance with the principles of environmental management is called environmental management (Hejda, 2004).

Sustainable development of society is a development that preserves the ability of present and future generations to satisfy their basic necessities of life. (Maier et al., 2012).

The principle of sustainability has the following main dimensions: environmental, social and institutional, economical further for example: moral and ethical

Methods. Assessment of the overall environmental sustainability of the area is carried out using the KES method. KES has already been created for municipalities in the area and is available at the Czech Statistical Office and the Ministry of Regional Development. However, KES cannot reflect all aspects of the area’s environmental sustainability, such as the quality of life in the area. Therefore, this is an indicative figure that does not have enough information. For this reason, the practical use of the landscape will be taken into account only.

We are engaged in land consolidation in cadastral territories located in the area of interest, which are available on the eAGRI web portal. This is the portal of the Ministry of Agriculture, where you can enter the relevant data: region, district, cadastral territory on the map to determine whether the selected site processed land consolidation and at what stage.

An important aspect of assessing the sustainability of an area is the risk of erosion. Given the theme and content of this work, it will be mainly water and soil erosion. An erosion map will be provided from

the state land registry published by the Ministry of Agriculture on the eAGRI portal in electronic form, so that remote and continuous access to the main data from the public part of the land use registry is possible. The term pLPIS is used for the public part of the LPIS Internet application. To determine the level of erosion threat for a selected cadaster in a controlled area, you can also use the “Soil Erosion Monitoring” web portal, which is presented as a separate web application on the SOWAC geospatial GIS managed by the Research Institute of Soil Reclamation and Protection.

On the National Geoportal INSPIRE (Infrastructure for Spatial Information in Europe) map portal, we will enter the relevant research area and find the elements of the TSES territorial environmental sustainability system.

The study is conducted in the form of e-mail, telephone or personal contacts in order to find out information, access and the decision of municipal representatives on the issue of land consolidation in connection with the conditions of runoff, in the form of questionnaires. We are interested to know whether and to what extent the representatives of the municipalities are aware of the possibilities and necessity of land consolidation, including due to the fact that there is minimal land consolidation in this area. We will find out whether the municipalities with expanded competencies in the Vir River Basin influence the negative effects of climate change, and whether they are fighting for the conservation of water in the landscape and how.

The research plan sets the following main objectives:

- Goal 1: to investigate the problem and solution of runoff conditions from the point of view of the Vi dam;
 - Task 2: compile a map of cadastral zones from the Svratka source to the Vir reservoir, including problems of the drainage basin;
 - Goal 3: to study the attitude of municipalities with expanded competence in solving flow conditions;
 - Goal 4: to evaluate communication with representatives of municipalities with expanded powers;
 - Goal 5: Examine whether AFP records a link between the adverse effects of climate change, runoff conditions, and complex land consolidation;
 - Task 6: examine whether AFPs recognize the importance of land consolidation;
 - Goal 7: to examine whether there is enough land consolidation information in the RIPs;
 - Goal 8: to find out if AFP is aware of the possibility of applying for a CPA in the land department “from below”;
 - Task 9: find out if RIP is taking any initiatives to solve the flow problem;
 - Task 10: check if the RIP is familiar with the grant program: ongoing call 9 to apply for support from the Integrated Regional Operational Program (hereinafter referred to as IROP), specific objective 3.3
- Support the development and application of spatial research documents published by the Ministry of Regional Development of the Czech Republic.

Telephone representatives and a written contact will be established with ORP representatives, within the framework of which a questionnaire survey will be conducted.

Results. Kender (2004) states that water fulfills a number of functions and is one of the most migratory components in the landscape. According to him, it is important to address the improvement of water quality especially in small, small watercourses, because these are the basis of the system of ecological stability. Water quality is particularly important in a given locality, in a given landscape area, because it is interconnected with the locality and it is connected with interconnection of other environmental phenomena and relations to habitats, to ecosystems (Kender, 2004). Soukup is looking for a solution of the water regime in the landscape, more precisely an improvement of the runoff conditions in the basin. The measures identified do not work in themselves, as the effect of the individual measures is composite and complementary and acts as a whole (Soukup, 2008).

According to Syrovatka in the past improperly performed amelioration, the problem of deforestation, soil drainage, plowing and subsequent decomposition of organic matter in the soil (Syrovátka, 2008).

Transplant cooling disorder, where plants actively cool their organs and the surrounding air and limit the passage of heat to the soil (see, eg, Syrovatka, et al., 1999). The conversion of water into steam produces a huge amount of energy that heats the air during condensation. Plants are not only a cooler, but

also a regulator of the local climate. Water for transpiration is taken from the soil; however, if the soil water supply is not transpired, cooling does not occur, air and soil are heated. Even a small disturbance in landscape cooling tends to deepen and widen. In disrupted soil, water runoff from soil to subsoil increases to the detriment of water supply, surface runoff and evaporation from the soil increase, for example due to non-integrated plant cover, soil compaction by agricultural technology or soil build-up, to the detriment of water infiltration into soil. The lack of water in the soil increases, plants do not transpire, air and soil overheat. The superheated air, containing a large amount of water, rises to high altitudes, where it cools, condenses and storms from heat and local rainfall. However, the dried soil surface is water-repellent, water does not seep and a local flood occurs. Loss of the cooling function of the vegetation cover in large areas leads to changes in the energy flow, influencing the movement of air masses, which can result in disastrous floods (Syróvátka, 2008).

Prevention should not be underestimated. The problem of preventing river basin protection against the impact of climate change in the landscape and restoring the basic functions of the landscape of individual river basins must be addressed at the same time at local, regional and supra-regional level. Thus, the matter takes on a serious political and economic dimension, while it is clear that addressing the issue of restoration and maintaining ecological stability in river basins will be a very long process. This process must be started as soon as possible, as any minor change in the landscape and in the behavior of those who manage and decide on the landscape will be beneficial (see, eg, Syrovátka, 1995; Syrovátka et al., 2002). A new approach to the landscape supporting the restoration of 'forest' conditions, applied across the trans-regional scale, can contribute to stabilizing the continent's climate and limiting the warming process (Syróvátka, 2008).

Addressing mitigation of the effects of climate change (drought) from above. The Ministry of Agriculture (MZE) has been given 25 major tasks from the government concerning defense against long-term drought and water scarcity, mitigating their negative impacts and supporting the enhancement of the landscape's function in water retention. MZE cooperates in this field with other ministries and organizations. The processes must be complementary. Based on the government's assignment, the Ministry launched new subsidy programs in 2016 with the aim of increasing the landscape's water retention capacity, modified the legislative framework and some procedures in this area, and adopted further measures.

Water management issues are fundamental within the landscape and therefore land consolidation. As a result, a functioning and well-organized landscape means reducing water runoff on the soil surface, reducing erosion and quality water in wells, streams and springs. It is necessary to link the results of the solution of precipitation-runoff conditions, erosion processes and water quality issues with the concept of land consolidation. Even the solution of water management problems should precede the proposals of land consolidation (Váchal, 2011).

The parties to the land consolidation proceedings are the owners of the land affected by the land consolidation proceedings, natural and legal persons whose ownership or other rights in rem may be affected by land consolidation, the builder in the event that the land consolidation is triggered as a result of construction activities, municipalities in whose territorial area the land is included in the area of land consolidation. The land consolidation procedure is considered to be initiated at the initiative of the Land Office and the Land Office shall commence it whenever the owners of the land agree with more than half the area of agricultural land in the cadastral area concerned (Czech Republic).

Complex land consolidation is one of the most important steps supporting the reduction of impacts of floods and droughts in the landscape. The aim is to improve the hydrological situation in the landscape by naturally retaining water in the landscape, achieving good ecological and chemical status of surface waters and good chemical and quantitative status of groundwater. KoPÚ solves land consolidation in a complex way usually in the whole cadastral area. The comprehensive solution then includes access to land, erosion control, water management measures. CoPÚ places higher demands on processing and financing (Vlasák, 2007). Simple land consolidation is partial and therefore concerns usually only part of one cadastral area or a problem selected in it (Ministry, 2010).

Conceptual revitalization of the landscape means corrections leading to the process of restoration and balancing of the water regime of the river basin and soil, establishing a consensus between bio and socioecological relations in the landscape and interests of landscape protection and its functions with the

interests of the local community. The aim of the revitalization of the landscape and the CPA is also to strengthen the diversity of activities in agriculture, to increase the attractiveness of small firms using new local resources (eg orchards, fast-growing trees, neglected traditional crops, local energy, etc.). Syrovatka attaches importance mainly to the CoPU process "from below", which takes into account the economic aspects of the consequences of inappropriate landscape management, where erosion and lack of organic component causes a decline in soil creditworthiness. The use of the CoPU principle is essential especially in the sphere of ownership relations to land; without this instrument, the much-needed revitalization of the spring areas is unrealistic. Syrovatka is of the opinion that the created model will be applicable in agricultural catchments throughout the Czech Republic.

The current one-sided farming management in most river basins reduces the ecological stability of the landscape and thus reduces its resistance to various climate changes, resulting in floods, erosion, droughts, torrential rainfall, windstorms etc. water in Pilsen. The solution of this problem in the form of a complex revitalization of the river basin landscape (restoration of landscape features, revitalization of small streams and springs, changes of cultures, etc.) will increase the ecological stability of the landscape and its resilience to most manifestations of climate change.

The main objective of the project was sufficient information and enlightenment to ensure support, approval and decision of preparation and implementation of complex land consolidation with the intention to stabilize runoff conditions for the cadastral area of Dolce and Kucín by management of municipalities and landowners. It was necessary to cooperate and support the management of municipalities, owners, project solvers, relevant land office and design office and cooperation with the local community and volunteers (Slunečko, 2012).

Representatives of municipalities are aware of the needs of the river basin and the necessity of solving the runoff conditions of the area. An example is the municipality with extended competence (ORP) Přeštice, which flows through the river Úhlava. The municipality of Přeštice used the announced subsidy program of the Ministry for Regional Development for the preparation of the Territorial Landscape Study for the entire administrative district of the municipality with extended competence. According to the latest available information, the municipality carried out a public contract for the selection of the contractor of this study, which was selected in March 2017, and it can be assumed that work on the study has begun (Přeštice, 2017).

The European Union (EU) Funds include financial instruments primarily designed to support the economic growth of the Member States, improve the education of the population and reduce social inequalities. Regional Policy of the European Union also called cohesion policy (cohesion policy) means the application of the principle of solidarity within the European Union, which aims to improve the quality of life of citizens of the European Union with the assistance of richer countries to poorer developing countries and regions (Ministry).

One of the European Union's cohesion policy funds is the Integrated Regional Operational Program (IROP), approved by the European Commission on 4 June 2015. IROP is a broad-based program that aims to improve the quality of life in various areas. On 31 July 2015, the Ministry for Regional Development launched the first two calls for proposals under the Integrated Regional Operational Program. One of them concerns the acquisition of land-use plans for municipalities with extended powers. Concentrating EU funds in certain types of territories will support the development of these areas and contribute to redressing territorial disparities. Specifically, it is community-led local development that focuses on rural space and aims to support the local needs of the rural area and develop cooperation at the local level (Ministry).

Discussion. Hejda notes that in 1987 the World Commission on Environment and Development at the United Nations released a report entitled *Our Common Future*, which was expressed the idea that environmental problems were solved with a new type of economic development, so-called. Permanently sustainable development (SD). Sustainable development would guarantee the preservation of life on Earth, preserve the functions of nature and not reduce biodiversity, nor jeopardize the interests of another nation or future generations. An organized and coordinated process towards sustainable development and respecting the principles of sound management of the environment is referred to as environmental management (Hejda, 2004).

Sustainable development of society is a development that keeps the ability of current and future generations to satisfy their basic life needs. (Maier et al., 2012).

The principle of sustainability has the following basic dimensions:

- ecological;
- social and institutional;
- economical further for example: morally- ethical.

The basic principle of sustainable development is the need (interest) to balance these three main elements. Currently, in our opinion, economic interest prevails, which is not good (Maier et al., 2012).

In terms of sustainability, the river basin should be considered taking into account environmental, social and institutional and economic foundations.

The theory and practice of sustainable development have not yet found a balance between the economic, social and environmental needs of mankind, and the quality of life has not yet been sufficiently defined. He considers the quality of life and, therefore, the theoretical foundations of sustainable development as a broadly philosophical problem, and believes that this approach is more practical and logical than the search for separate and unrelated solutions to individual problem areas (Syrovátka, 2004).

Spatial planning documentation may include, inter alia:

- Landscape mapping of cadastral areas of individual municipalities, determination of endangered areas (including aspects of water supply to municipalities);
- Study of development documents and zoning plans with respect to relations to the surrounding landscape;
- Determination of risks for individual municipalities resulting from detected instability in the surrounding landscape;
- Evaluation of landscape character in terms of tourism development potential;
- Study of municipalities' cards in the Strategy for the Development of Water Supply and Sewerage, followed by the control of the above-mentioned sources of drinking and technical water in municipalities. If there are water mains, the state of sustainability of the source will be assessed, including control of drinking water analysis, if only wells, sampling and quality analyzes will be carried out at selected sources;
- Determining the state of wastewater management in municipalities;
- Synthetic processing of results for individual municipalities will also take into account the possibilities of recommendations for the implementation of CPA, where CPA are already implemented, suitable solutions will be recommended.

Research and its proper implementation presuppose the need to define a research plan. The research plan is a generally conceived goal that determines the main lines of the research direction. The project is then subdivided into more specific sub-objectives representing the different areas under investigation. For the research it is necessary to satisfy the determination of the research sample. If the sample is small and accessible and is researched entirely for research purposes, it is called a research file, then it is exhaustive research. During the research it is important to take care of the validity and reliability of the collected data (Novotná, 2014).

When using the method of data collection in the form of an interview, the interaction between the interviewer and the respondent (interviewee) occurs. With this method, the data may be distorted by the interviewer, which affects the interviewee by his/her appearance, behavior and behavior. Therefore, the interviewer must be inconspicuous and bland. The disadvantage of this method is that the interviewee responds in an interaction with the interviewer differently than in writing the questionnaire. The advantage of this method of data collection is the lower risk of misunderstanding of the question and the possibility of submitting additional information to the interviewer. According to Novotná, interviews are divided according to the standardization criterion into:

- standardized (structured) interview - a fixed structure of questions with an offer of answers;
- semi-standardized (semi-structured) interview - it has a syllabus and a goal. It often develops them according to the situation;
- non-standardized (unstructured) interview - it does not have a set curriculum, it may be a free narrative (Novotná, 2014).

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ЭКОЛОГИЯЛАНДЫРУ ТҰРАҚТЫ ДАМУ НЕГІЗГІ ПРИНЦИПІ

Аннотация. Мақалада экологиялық тазалық туралы айтылған. Тұрақты даму тұжырымдамасы ашылды. Тұрақтылықтың белгілі бір негізгі шаралары: экологиялық, әлеуметтік және институционалдық, экономикалық. Территориялық жоспарлау мен аумақты дамытудың міндетті шарты болып табылатын экологиялық тұрақтылықты және жердің шоғырлануын бағалаудың ұсынылған әдістемесі қоршаған ортаны жақсартуға, топырақтың қорғалуы мен құнарлылығына, қоршаған ортаны қорғаудың тиімділігін арттыруға және ауылдық жерлерде өмір сүру сапасын жақсартуға көмектеседі.

Зерттеуде ландшафтты концептуалды жандандыру өзен бассейні мен топырақтың су режимін қалпына келтіруге және теңдестіруге, ландшафттағы био және әлеуметтік-экологиялық қатынастар мен ландшафтты және оның функцияларын жергілікті қоғамдастықтың мүдделерімен қорғау мүдделері арасында консенсус орнатуға әкелетін түзетулерді білдіреді. Пейзажды және ПБЗ-ны жандандырудың мақсаты ауылшаруашылық қызметінің әр түрлілігін арттыру, жаңа жергілікті ресурстарды (мысалы, бақтар, тез өсетін ағаштар, ұмытылған дәстүрлі мәдениеттер, жергілікті энергия және т.б.) пайдалана отырып, шағын фирмалардың тартымдылығын арттыру болып табылады. Ірімшік жасаушы негізінен КОП процесіне үлкен мән береді, бұл эрозия мен органикалық компоненттің жетіспеушілігі топырақтың төлем қабілеттілігінің төмендеуіне әкелетін ландшафттық басқарудың тиімсіз салдарының экономикалық аспектілерін ескереді. СоРУ қағидатын пайдалану жерді меншік қатынастары саласында әсіресе маңызды; бұл құралсыз көктемгі алаңдарды белсенді түрде іске қосу мүмкін емес. Сыроватка бұл модель Чехияның барлық ауылшаруашылық жерлерінде қолданылатын болады деп санайды.

Көптеген өзендер бассейндеріндегі егіншілікті біржақты басқару ландшафттың экологиялық тұрақтылығын төмендететіні және, демек, су тасқынына, эрозияға, құрғақшылыққа, нөсер жаңбырға, дауылға және т.б. әкелетін әртүрлі климаттық өзгерістерге тұрақтылығын төмендететіні анықталды. Пилсендегі су. Бұл проблеманы өзен бассейнінің ландшафтын жан-жақты жандандыру түрінде шешу (ландшафт ерекшеліктерін қалпына келтіру, кішігірім ағындар мен бұлақтарды қалпына келтіру, дақылдардың өзгеруі және т.б.) ландшафттың экологиялық тұрақтылығын және оның климаттың өзгеруінің көптеген көріністеріне тұрақтылығын арттырады.

Зерттеулер және олардың дұрыс орындалуы зерттеу жоспарын анықтау қажеттілігін көрсетеді. Зерттеу жоспары - бұл зерттеудің негізгі бағыттарын айқындайтын жалпыға ортақ мақсат. Содан кейін жоба әртүрлі зерттеу бағыттарын білдіретін нақты мақсаттарға бөлінеді. Зерттеу үшін зерттелетін үлгінің анықтамасын қанағаттандыру қажет. Егер үлгі кішкентай болса және қол жетімді және тек зерттеу мақсаттары үшін зерттелетін болса, онда бұл зерттеу файлы деп аталады, онда бұл жан-жақты зерттеу. Зерттеу барысында жиналған деректердің шынайылығы мен шынайылығына қамқорлық жасау керек (Новотна, 2014).

Осылайша, сұхбат түрінде мәліметтер жинау әдісін қолдану кезінде сұхбат беруші мен жауап беруші (сұхбат алушы) өзара әрекеттесетіні анықталды. Осы әдісті қолдана отырып, сұхбаттасушы сыртқы түріне, мінез-құлқына байланысты сұхбаттасушыға әсер ететін мәліметтерді бұрмалай алады. Сондықтан сұхбат беруші көрінбейтін және жұмсақ болуы керек. Бұл әдістің кемшілігі – сұхбат алушының сауалнаманы жазғаннан гөрі интервьюермен әрекеттесуіне басқаша жауап беруі. Мәліметтерді жинаудың бұл әдісінің артықшылығы - мәселені түсінбеу қаупінің төмендігі және сұхбат алушыға қосымша ақпарат беру мүмкіндігі.

Түйін сөздер: тұрақты даму, экологиялық таза, су, жер, экологиялық тұрақты аймақтар, тұрақтылық қағидалары, кадастр.

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ЭКОЛОГИЧНОСТЬ КАК ОСНОВНОЙ ПРИНЦИП УСТОЙЧИВОГО РАЗВИТИЯ

Аннотация. Рассматривается экологичность как основной принцип устойчивого развития. Раскрыто понятие «устойчивое развитие». Определены основные измерители устойчивости: экологический, социальные и институциональные, экономический. Предложена методика оценка экологической устойчивости района и консолидация земель, которая является основой для территориального планирования и развития территории, способствует улучшению состояния окружающей среды, защите и плодородию почвы, эффективному управлению водными ресурсами, улучшению экологической устойчивости ландшафта и улучшению качества жизни в сельской местности.

В ходе исследования установлено, что концептуальная ревитализация ландшафта означает коррекции, ведущие к восстановлению и уравниванию водного режима речного бассейна и почвы, установлению консенсуса между био и социоэкологическими отношениями в ландшафте и интересами охраны ландшафта и его функций с интересами местная общественность. Целью возрождения ландшафта и ЦПУ также является усиление разнообразия видов деятельности в сельском хозяйстве, повышение привлекательности небольших фирм, использующих новые местные ресурсы (например, сады, быстрорастущие деревья, забытые традиционные культуры, местная энергия и т.д.). Сыrovатка придает большое значение в основном процессе CoPU «снизу», который учитывает экономические аспекты последствий ненадлежащего управления ландшафтом, когда эрозия и недостаток органического компонента приводят к снижению кредитоспособности почвы. Использование принципа CoPU особенно важно в сфере отношений собственности на землю; без этого инструмента столь необходимая активизация весенних площадей нереальна. Сыrovатка считает, что созданная модель будет применима в сельскохозяйственных водосборах по всей Чешской Республике.

Обнаружено, что нынешнее одностороннее управление земледелием в большинстве речных бассейнов снижает экологическую стабильность ландшафта и, таким образом, снижает его устойчивость к различным изменениям климата, что приводит к наводнениям, эрозии, засухам, проливным дождям, ураганам и т.д. воды в Пльзене. Решение этой проблемы в виде комплексной ревитализации ландшафта речного бассейна (восстановление ландшафтных особенностей, ревитализация небольших ручьев и родников, изменение культур и т.д.) Повысит экологическую устойчивость ландшафта и его устойчивость к большинству проявления изменения климата.

Исследования и их правильная реализация предполагают необходимость определения плана исследований. План исследования является общепризнанной целью, определяющей основные направления исследования. Затем проект подразделяется на более конкретные подцели, представляющие различные исследуемые области. Для исследования необходимо удовлетворить определение исследуемой выборки. Если выборка мала и доступна и исследуется исключительно для исследовательских целей, это называется исследовательским файлом, то это исчерпывающее исследование. Во время исследования важно позаботиться о достоверности и достоверности собранных данных (Novotná, 2014).

Таким образом, выявлено, что при использовании метода сбора данных в форме интервью происходит взаимодействие интервьюера и респондента (интервьюируемого). При использовании этого метода интервьюер может исказить данные, что влияет на собеседника из-за его внешнего вида, поведения и поведения. Поэтому интервьюер должен быть незаметным и мягким. Недостатком этого метода является то, что интервьюируемый реагирует на взаимодействие с интервьюером иначе, чем при написании анкеты. Преимущество этого метода сбора данных заключается в более низком риске недопонимания вопроса и возможности предоставления дополнительной информации интервьюеру.

Ключевые слова: устойчивое развитие, экологичность, вода, земля, экологически устойчивые районы, принципы устойчивости, кадастр.

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OPTIMAL SYNTHESIS OF PLANAR LINKAGES

Abstract. This paper investigates the optimal synthesis of planar linkages. The main idea of this paper is to find the initial approximations based on the use of Burmester points for function generator linkages, path generator linkages, motion generator linkages. The results of the numerical synthesis of the linkages depend on the choice of the initial approximations. A more flexible method to the search for initial approximations is the method based on the use of Burmester points. This method allows the determination of the initial approximations analytically for three, four or five by established initial data of synthesis. In this case, the problem is reduced to determining the solutions of polynomials, respectively the second, third and fourth degree. The method consists in that the synthesized linkage is conditionally divided into initial kinematic chains and closing kinematic chains, and Burmester points are determined for each chain. After the choice of initial approximations, an objective function is formed according to the output criteria, depending on the synthesis parameters, using the Chebyshevsky (best) or quadratic approximation problems. The synthesis parameters of planar linkages are determined from objective function minimum. According to this method, a program for the synthesis of planar linkages has been developed. An example is included to demonstrate the method.

Keywords: synthesis, optimal, planar linkages, initial approximations, Burmester points.

Introduction. Synthesis of planar multiple bar linkages has been extensively studied in the last ten years. Dimensional synthesis is one of the most important stages in the design of the linkages, since at this stage the basic kinematic properties necessary for the mechanism are formed to perform the functions assigned to it. The dimensional synthesis of linkages is divided into three types [1]:

- 1) It is required to realize the given function of the position of the output link of the mechanism - synthesis of transmission mechanisms ("function generation");
- 2) It is required to reproduce the trajectory of the working point in the plane - the synthesis of the guide mechanisms ("path generation");
- 3) It is necessary to reproduce the given motion of the solid body in the plane - the synthesis of the motion mechanisms ("motion generation").

When exact realization of the given motion is required, the problem arises of exact synthesis. However, the number of output object positions that can be reproduced accurately is generally limited. On the other hand, any movement in practice cannot be reproduced with perfect accuracy due to inaccuracies in the manufacture of elements (links, kinematic pairs, etc.) of the mechanism.

Therefore, the methods of approximate synthesis of the linkages have developed greatly. The problems of the kinematic synthesis of linkages reduce to the problem of approximation of a function. This formulation of the problem of linkages synthesis was proposed in the work of P.L. Chebyshev [2]. By way of compiling synthesis equations which follow from the constraint equations can be divided into geometric and algebraic methods [3-6]. The geometric synthesis methods are compiled on the basis of the equation of the projected closed kinematic chain. The algebraic constraint equations used methods that are imposed on the output link of moving mechanism. By the method of solving the synthesis equations, the existing methods for the synthesis of linkages can be divided into two groups: 1) analytical methods; 2) optimization methods.

In analytical synthesis, part of the constant parameters of the mechanism is calculated directly by analytical formulas. These formulas are obtained as a result of solving the synthesis equations in an explicit form [7, 8]. Upon optimal synthesis of linkages, additional synthesis conditions, such as the optimal transmission angle, the minimum value of the generalized force at the input, etc. can be taken into account. In connection with the advent of modern high-speed computers, optimal synthesis of linkages have been created, which were considered in [9-16]. The advantages of optimization methods for the synthesis of linkages are particularly evident in cases where the "classical" methods of kinematic synthesis based on kinematic geometry or various methods of approximation, are inapplicable or ineffective.

Initial approximations for plane linkages. The success of the search for the optimal linkage largely depends on the choice of the initial approximation, determined by classical methods, while the linkage designed by classical methods often requires optimization taking into account additional synthesis conditions. The results of the numerical synthesis of linkages depend on the choice of the initial approximations. The choice of initial approximations can be made using the metric parameters of the mechanism analog. In this case, it is possible to obtain only one mechanism, which reproduces an approximately desired trajectory. The initial approximations can be found using random search methods, for example the LP_τ sequence generator. In this case, the initial approximations are distributed in a given multidimensional space using the LP_τ sequence [17, 18]. The method makes it possible to obtain the most complete picture of optima distribution of considered functional; however, large dimension parameters of the synthesis can greatly increase the computational volumes. A more flexible method to the search for initial approximations is the method based on the use of Burmester points. This method allows determining the initial approximations analytically for three, four or five by established initial data of synthesis. In this case, the problem is reduced to finding solutions of polynomials, respectively the second, third and fourth degree. The principle of method lies in the fact that the synthesized mechanism is conditionally divided into initial kinematic chains (IKC) and closing kinematic chains (CKC), and for each chain Burmester points are determined [19, 20]. For example, to synthesize a path-generator four-bar linkage, this mechanism is divided into the IKC, which is a dyad O_1AC , and CKC, which is a bar O_2B (figure 1). Consider the method of finding initial approximations, based on the use of Burmester points for function generator linkages, path generator linkages, motion generator linkages.

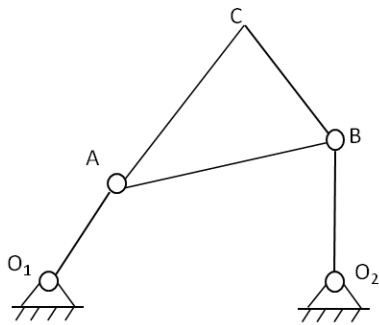


Figure 1 – Path generator four-bar linkage

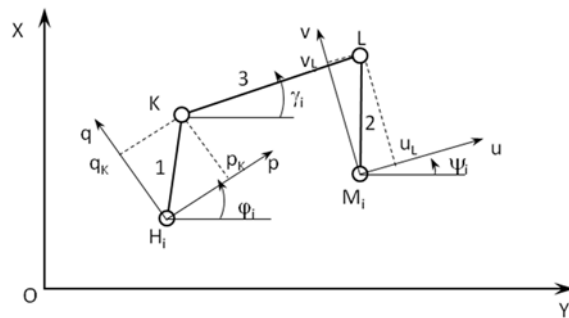


Figure 2 – Initial kinematic chain

For function generator linkages. Suppose that N positions of the two movable planes 1 and 2 are given, for the initial kinematic chain. Movable planes are determined by the coordinates $x_{H_i}, y_{H_i}, x_{M_i}, y_{M_i}$ of the points H and M , and the rotation angles ϕ_i, ψ_i around these points ($i = 1, 2, \dots, N$), (figure 2). It is necessary to determine the Burmester points K and L in the corresponding movable planes, lying on arcs of circles with centers at the points H and M .

We will compose the algebraic equation of closure of vector contours, relative to the coordinate system

$$\left. \begin{aligned} x_{L_i} &= x_{H_i} + p_K \cos \phi_i - q_K \sin \phi_i + l_3 \cos \gamma_i = x_{M_i} + u_L \cos \psi_i - v_L \sin \psi_i, \\ y_{L_i} &= y_{H_i} + p_K \sin \phi_i + q_K \cos \phi_i + l_3 \sin \gamma_i = y_{M_i} + u_L \sin \psi_i + v_L \cos \psi_i, \\ i &= 1, 2, \dots, N \end{aligned} \right\} \quad (1)$$

Excluding an unknown angle γ_i , the system of Eq. (1) reduced to the form

$$A_j + B_j p_K + C_j q_K + D_j u_L + E_j v_L + F_j (p_K u_L + q_K v_L) + G_j (p_K v_L - q_K u_L) = 0 \quad (2)$$

where (3)

$$\left. \begin{aligned} A_j &= \left[(x_{M_i} - x_{H_i})^2 + (y_{M_i} - y_{H_i})^2 - (x_{M_{i+1}} - x_{H_{i+1}})^2 - (y_{M_{i+1}} - y_{H_{i+1}})^2 \right] / 2 \\ B_j &= -(x_{M_i} - x_{H_i}) \cos \phi_i - (y_{M_i} - y_{H_i}) \sin \phi_i + \\ &\quad + (x_{M_{i+1}} - x_{H_{i+1}}) \cos \phi_{i+1} + (y_{M_{i+1}} - y_{H_{i+1}}) \sin \phi_{i+1} \\ C_j &= (x_{M_i} - x_{H_i}) \sin \phi_i - (y_{M_i} - y_{H_i}) \cos \phi_i - \\ &\quad - (x_{M_{i+1}} - x_{H_{i+1}}) \sin \phi_{i+1} + (y_{M_{i+1}} - y_{H_{i+1}}) \cos \phi_{i+1} \\ D_j &= (x_{M_i} - x_{H_i}) \cos \psi_i + (y_{M_i} - y_{H_i}) \sin \psi_i - \\ &\quad - (x_{M_{i+1}} - x_{H_{i+1}}) \cos \psi_{i+1} - (y_{M_{i+1}} - y_{H_{i+1}}) \sin \psi_{i+1} \\ E_j &= -(x_{M_i} - x_{H_i}) \sin \psi_i + (y_{M_i} - y_{H_i}) \cos \psi_i + \\ &\quad + (x_{M_{i+1}} - x_{H_{i+1}}) \sin \psi_{i+1} - (y_{M_{i+1}} - y_{H_{i+1}}) \cos \psi_{i+1} \\ F_j &= -\cos(\phi_i - \psi_i) + \cos(\phi_{i+1} - \psi_{i+1}) \\ G_j &= -\sin(\phi_i - \psi_i) + \sin(\phi_{i+1} - \psi_{i+1}), j = 1, 2, \dots, N-1 \end{aligned} \right\} \quad (3)$$

If the hinges H and M are taken as the frames, we get a function generator four-bar linkage (figure 3) and coefficients of the system Eq. (2) take the following form:

$$\left. \begin{aligned} A_j &= 0 \\ B_j &= -(x_{M_0} - x_{H_0})(\cos \phi_i - \cos \phi_{i+1}) - (y_{M_0} - y_{H_0})(\sin \phi_i - \sin \phi_{i+1}) \\ C_j &= (x_{M_0} - x_{H_0})(\sin \phi_i - \sin \phi_{i+1}) - (y_{M_0} - y_{H_0})(\cos \phi_i - \cos \phi_{i+1}) \\ D_j &= (x_{M_0} - x_{H_0})(\cos \psi_i - \cos \psi_{i+1}) + (y_{M_0} - y_{H_0})(\sin \psi_i - \sin \psi_{i+1}) \\ E_j &= (x_{M_0} - x_{H_0})(\sin \psi_i - \sin \psi_{i+1}) + (y_{M_0} - y_{H_0})(\cos \psi_i - \cos \psi_{i+1}) \\ F_j &= -\cos(\phi_i - \psi_i) + \cos(\phi_{i+1} - \psi_{i+1}) \\ G_j &= -\sin(\phi_i - \psi_i) + \sin(\phi_{i+1} - \psi_{i+1}), j = 1, 2, \dots, N-1 \end{aligned} \right\} \quad (4)$$

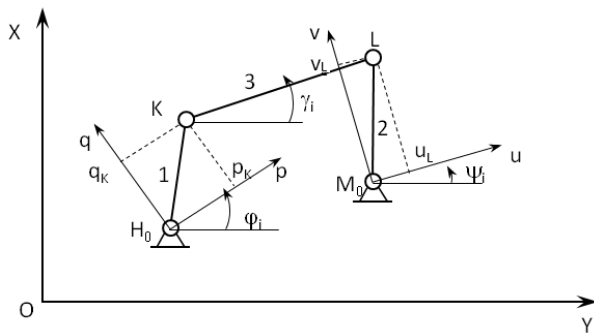


Figure 3 – Transfer four-bar

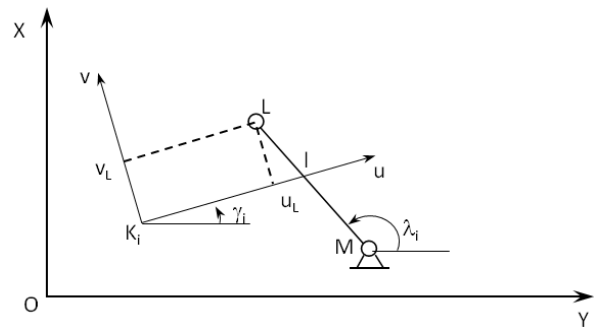


Figure 4 – The binary link

$$A_j + B_j x_{H_0} + C_j y_{H_0} + D_j p_K + E_j q_K + F_j (x_{H_0} p_K + y_{H_0} q_K) + G_j (x_{H_0} q_K - y_{H_0} p_K) = 0 \quad (9)$$

where

$$\left. \begin{aligned} A_j &= [x_{L_i}^2 + y_{L_i}^2 - x_{L_{i+1}}^2 - y_{L_{i+1}}^2] / 2 \\ B_j &= -x_{L_i} + x_{L_{i+1}}, C_j = -y_{L_i} + y_{L_{i+1}} \\ B_j &= -x_{L_i} \cos \phi_i - y_{L_i} \sin \phi_i + x_{L_{i+1}} \cos \phi_{i+1} + y_{L_{i+1}} \sin \phi_{i+1} \\ E_j &= x_{L_i} \sin \phi_i - y_{L_i} \cos \phi_i - x_{L_{i+1}} \sin \phi_{i+1} + y_{L_{i+1}} \cos \phi_{i+1} \\ F_j &= -\cos \phi_i + \cos \phi_{i+1}, G_j = -\sin \phi_i + \sin \phi_{i+1}, j = 1, 2, \dots, N-1 \end{aligned} \right\} \quad (10)$$

We obtained a system of equations of the form for all the three cases

$$A_j + B_j x_1 + C_j x_2 + D_j x_3 + E_j x_4 + F_j (x_1 x_3 + x_2 x_4) + G_j (x_1 x_4 - x_2 x_3) = 0, \quad (11)$$

$$j = 1, 2, \dots, N-1$$

If three positions of moving planes ($N = 3$) are given from Eq. (11) we obtain a system of two equations with four unknowns. In this case, two parameters of the mechanism, for example x_1, x_2 are given arbitrarily and the system Eq. (11) is solved with respect to the remaining two unknowns. The solution has the form

$$\left. \begin{aligned} x_3 &= d_1 / d_0, \\ x_4 &= d_2 / d_0, \end{aligned} \right\} \quad (12)$$

where

$$\begin{aligned} d_0 &= |(D_j + F_j x_1 - G_j x_2) \quad (E_j + G_j x_1 + F_j x_2) |, \\ d_1 &= |(-A_j - B_j x_1 - C_j x_2) \quad (E_j + G_j x_1 + F_j x_2) |, \\ d_2 &= |(D_j + F_j x_1 - G_j x_2) \quad (-A_j - B_j x_1 - C_j x_2) |, \\ j &= 1, 2 \end{aligned}$$

If four positions of moving planes ($N = 4$) are given from Eq. (11) we obtain a system of three equations with four unknowns.

In this case, one parameter of the mechanism, for example x_1 , is given arbitrarily and system Eq. (11) is solved with respect to the remaining three unknowns.

Alternately, excluding the two unknowns (for example, x_3 and x_4), we obtain a cubic equation that is solved by analytically known methods [21].

$$k_3 x_2^3 + k_2 x_2^2 + k_1 x_2 + k_0 = 0, \quad (13)$$

where

$$\begin{aligned} k_0 &= h_1 + h_2 x_1 + h_4 x_1^2 + h_6 x_1^3, k_1 = h_3 + h_8 x_1 + h_7 x_1^2, k_2 = h_5 + h_6 x_1, k_3 = h_7, \\ h_1 &= d_{24} d_{31} - d_{21} d_{34}, h_2 = d_{14} d_{21} - d_{11} d_{24} + d_{24} d_{32} - d_{22} d_{34} - d_0 d_{31}, \\ h_3 &= d_{11} d_{34} - d_{14} d_{31} + d_{24} d_{33} - d_{23} d_{34} - d_0 d_{21}, \\ h_4 &= d_{14} d_{22} - d_{12} d_{34} + d_0 d_{11} - d_0 d_{32}, \\ h_5 &= d_{13} d_{34} - d_{14} d_{33} + d_0 d_{11} - d_0 d_{23}, \\ h_6 &= d_0 d_{12}, h_7 = d_0 d_{13}, \\ h_8 &= d_{14} d_{23} - d_{14} d_{32} + d_{12} d_{34} - d_{13} d_{24} - d_0 d_{22} - d_0 d_{33}, \end{aligned}$$

$$\begin{aligned}
d_0 &= |E_j \ F_j \ G_j|, d_{11} = |-A_j \ F_j \ G_j|, \\
d_{12} &= |-B_j \ F_j \ G_j|, d_{13} = |-C_j \ F_j \ G_j|, d_{14} = |-D_j \ F_j \ G_j|, \\
d_{21} &= |E_j \ -A_j \ G_j|, d_{22} = |E_j \ -B_j \ G_j|, d_{23} = |E_j \ -C_j \ G_j|, d_{24} = |E_j \ -D_j \ G_j|, \\
d_{31} &= |E_j \ F_j \ -A_j|, d_{32} = |E_j \ F_j \ -B_j|, d_{33} = |E_j \ F_j \ -C_j|, d_{34} = |E_j \ F_j \ -D_j|, \\
j &= 1, 2, 3
\end{aligned}$$

The cubic equation Eq. (13) can be solved analytically and have one or three real roots [21] that substituting into Eq. (11) we obtain two equations in two unknowns x_3, x_4 , are defined analogously to Eq. (12).

If five positions of moving planes ($N = 5$) are given, from Eq. (11) one by one excluding the three unknowns (for example, x_2, x_3, x_4), we obtain a fourth-order equation of the form

$$k_4 x_1^4 + k_3 x_1^3 + k_2 x_1^2 + k_1 x_1 + k_0 = 0, \quad (14)$$

where

$$\begin{aligned}
k_0 &= h_3 h_3 + h_1 h_3, k_1 = h_1 h_{10} + (h_2 + h_4) h_8 + 2h_3 h_6, k_2 = h_6 h_5 + (h_7 + h_5) h_8 + 2h_3 h_{11} + (h_2 + h_4) h_{11}, \\
k_3 &= h_8 h_7 + (h_7 + h_5) h_{10} + 2h_6 h_{11}, k_4 = h_{11} h_{11} + h_9 h_{10}, \\
h_1 &= d_{41}(d_{33} - d_{21}) - d_{31}(d_{43} + d_{11}), h_2 = -d_{41}(d_{22} - d_{13}) + d_{31}(d_{23} + d_{12}), \\
h_3 &= -d_{41} d_{23} - d_{31} d_{13}, \\
h_4 &= -(d_{32} - d_{11})(d_{43} + d_{11}) + (d_{42} - d_{21})(d_{33} + d_{21}), \\
h_5 &= -(d_{32} - d_{11})(d_{23} + d_{12}) + (d_{42} - d_{21})(d_{13} + d_{22}), \\
h_6 &= -d_{13}(d_{32} - d_{11}) - d_{23}(d_{42} + d_{21}), \\
h_7 &= -d_{22}(d_{33} - d_{21}) + d_{12}(d_{43} + d_{11}), h_9 = d_{22}(d_{13} - d_{22}) - d_{12}(d_{23} + d_{12}), \\
h_{10} &= -d_{13}(d_{13} - d_{22}) - d_{23}(d_{23} + d_{12}), h_{11} = d_{12} d_{13} + d_{22} d_{23} \\
d_0 &= |D_j \ E_j \ F_j \ G_j| \\
d_{11} &= |-A_j \ E_j \ F_j \ G_j|, d_{12} = |-B_j \ E_j \ F_j \ G_j|, d_{13} = |-C_j \ E_j \ F_j \ G_j|, \\
d_{21} &= |D_j \ -A_j \ F_j \ G_j|, d_{22} = |D_j \ -B_j \ F_j \ G_j|, d_{23} = |D_j \ -C_j \ F_j \ G_j|, \\
d_{31} &= |E_j \ F_j \ -A_j \ G_j|, d_{32} = |E_j \ F_j \ -B_j \ G_j|, d_{33} = |E_j \ F_j \ -C_j \ G_j|, \\
d_{41} &= |D_j \ E_j \ F_j \ -A_j|, d_{42} = |D_j \ E_j \ F_j \ -B_j|, d_{43} = |D_j \ E_j \ F_j \ -C_j|, \\
j &= 1, 2, 3, 4.
\end{aligned}$$

The fourth-order equation Eq. (14) can also be solved analytically [21], it can have two or four real roots or have none. If there are two real roots and one of them was determined analytically, then the second root can be determined from the following equation

$$x_2 = (h_3 + h_6 x_1 + h_{11} x_1^2) / (h_8 + h_{10} x_1)$$

If there are four real roots, then x_3 and x_4 are determined from

$$\begin{aligned}
x_3 &= (d_{11} + d_{12} x_1 + d_{13} x_2) / d_0, \\
x_4 &= (d_{21} + d_{22} x_1 + d_{23} x_2) / d_0
\end{aligned}$$

After the choice of initial approximations, an objective function is formed according to the output criteria depending on the synthesis parameters \vec{P} , using the Chebyshevsky (best) or quadratic approximation problems. For the Chebyshev approximation problem, the synthesis parameters are determined as a minimum of the functional [22-25]

$$S(\vec{P}) = \max_{i=1,N} |\Delta q_i(\vec{P})| \Rightarrow \min_{\vec{P}} S(\vec{P}), \quad (15)$$

where $\Delta q_i(\vec{P})$ is the weighted difference function for the selected mechanism [22-25].

According to this method, a program for the synthesis of planar linkages has been developed.

Conclusion. The optimal synthesis of planar linkages was developed. The method of searching for initial approximations based on the use of Burmester points for function generator linkages, path generator linkages, motion generator linkages was considered. The objective function was formed according to the output criteria, depending on the synthesis parameters of linkages, using the Chebyshevsky or quadratic approximation problems. The synthesis parameters of linkages are determined from functional minimum. The program for the synthesis of planar linkages has been developed. The program used the following optimization methods: the Nelder-Mead method (the deformable polyhedron), the kinematic inversion method, the coordinate descent method, the spiral coordinate descent method, the quadratic interpolation-extrapolation method and the sliding tolerance method. We synthesized path generator four-bar linkage at 19 preset positions of the coupler point and planar linkages of Assur of the third and fourth classes. Using the method of optimal synthesis, the gripper with desired law of motion of the bucket edges was designed. A prototype of the gripper was manufactured and tested.

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ЖАЗЫҚ ИІНТІРЕКТІ МЕХАНИЗМДЕРДІҢ ОҢТАЙЛАНДЫРЫЛҒАН СИНТЕЗІ

Аннотация. Берілген жұмыста жазық иінтіректі механизмдердің оңтайлы синтезі зерттеледі. Бұл мақаланың негізгі мақсаты бағытталған иінтіректі механизмдер, орынауыстырғыш иінтіректі механизмдер, берілісті иінтіректі механизмдер үшін Бурместер нүктелерін пайдалануға негізделген бастапқы жуықтауын анықтау. Жазық көп буынды иінтіректі механизмдерінің синтезі соңғы он жылда қарқынды дамып келеді. Геометриялық синтез – иінтіректі механизмдерін жобалаудағы ең маңызды кезеңдердің бірі, себебі дәл осы кезеңде механизм өзіне жүктелген функцияларды орындау үшін қажетті негізгі кинематикалық қасиеттер қалыптасады. Иінтіректі механизмдердің геометриялық синтезі үш түрге бөлінеді: берілісті механизмдердің синтезі («функция генераторы»); бағыттаушы механизмдердің синтезі («траектория генераторы»); қозғалмалы механизмдердің синтезі («жазықтық-параллель қозғалыс генераторы»). Берілген қозғалыстың нақты орындалуы қажет болған кезде, дәл синтездеу мәселесі туындайды. Дегенмен дәл шығаруға болатын шығыс объектісінің орналасу саны шектеулі. Екінші жағынан, іс-әрекеттегі кез келген қозғалысты механизм элементтерінің (буындар, кинематикалық жұптар және т.б.) кателіктеріне байланысты дәлдікпен көбейту мүмкін емес. Сондықтан механизмдерді синтездеу теориясында соңғы жылдары, негізінен, механизмдерді жуық синтездеу әдістері жасалды. Осылайша, кинематикалық синтездің жоғарыда аталған барлық мақсаттары функцияны жақындату мәселесіне дейін азаяды. Мұндай синтездеу мәселелерін тұжырымдау П.Л. Чебышевтің классикалық жұмыстарынан бастау алады. Байланыс теңдеулерінен шығатын синтездік теңдеулерді құрастыру әдісі мен қолданыстағы синтез әдістерін алгебралық және геометриялық деп бөлуге болады. Геометриялық синтез әдістері құрастырылған кинематикалық тізбектің тұйықтық теңдеулері негізінде құрастырылады. Алгебралық синтез әдістері механизмнің шығыс буынының қозғалысына қойылған байланыс теңдеулерін қолданады. Синтез теңдеулерін шешу тәсілдерімен байланыстыра отырып, қолданыстағы иінтіректі механизмдерді синтездеу әдістерін екі топқа бөлуге болады: 1) аналитикалық әдістер; 2) сандық-оңтайландыру әдістері. Аналитикалық синтездеу механизмнің тұрақты параметрлерінің бөлігі тікелей аналитикалық формулалар арқылы есептеледі. Бұл формулалар синтез теңдеулерін нақты түрде шешу нәтижесінде алынған. Иінтіректі механизмдерінің синтезін оңтайландыру кезінде қосымша синтез жағдайларын ескеруге болады, мысалы, қозғалыс берудің оңтайлы бұрышы, жалпыланған кіріс күшінің минималды мәні және т.б. Механизмдерді синтездеудің оңтайландыру әдістерінің артықшылығы, әсіресе, кинематикалық геометрияға немесе әртүрлі жуықтау әдістеріне негізделген кинематикалық синтездің «классикалық» әдістері қолданылмайтын немесе тиімсіз болған жағдайда көрінеді. Иінтіректі механизмдердің сандық синтезінің нәтижесі бастапқы жақындаудың таңдауына байланысты. Бастапқы жақындауды іздеудің ең тиімді әдісі – Бурместер нүктелерін пайдалануға негізделген әдіс. Бұл әдіс синтездің үш, төрт және бес берілген бастапқы деректердің

аналитикалық бастапқы жақындауын анықтауға көмегі тиеді. Бұндай жағдайда екінші, үшінші және төртінші дәрежедегі полиномдардың шешімдерін анықтау қажет болады. Әдісте, синтезделген иінтіректі механизм бастапқы және тұйықталған кинематикалық тізбекке бөлінеді, сонымен бірге әрбір тізбектің Бурместер нүктесі анықталады. Бастапқы жақындауды таңдағаннан соң, квадратты жақындау немесе Чебышев есептерінің көмегімен синтез параметрлеріне байланысты шығыс өлшемдері бойынша мақсатты функция құрылады. Жазық иінтіректі механизмдер синтезінің параметрлері мақсатты функцияның минимумына байланысты анықталады. Осы әдіске сәйкес, жазық иінтіректі механизмдер синтезінің бағдарламасы жасалды. Берілген әдісті демонстрациялау үшін үлгі келтірілді.

Түйін сөздер: оңтайлы, жазық иінтіректі механизмдер, бастапқы жақындау, Бурместер нүктесі.

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ОПТИМИЗАЦИОННЫЙ СИНТЕЗ ПЛОСКИХ РЫЧАЖНЫХ МЕХАНИЗМОВ

Аннотация. В настоящей работе исследуется оптимальный синтез плоских рычажных механизмов. Основная идея этой статьи – в нахождении начальных приближений, основанной на использовании точек Бурместера для передаточных рычажных механизмов, направляющих рычажных механизмов, перемещающихся рычажных механизмов. Синтез плоских многозвенных рычажных механизмов интенсивно развивается в последние десять лет. Геометрический синтез является одним из наиболее ответственных этапов проектирования рычажных механизмов, поскольку именно на этом этапе формируются основные кинематические свойства, необходимые механизму для выполнения возложенных на него функций. Геометрический синтез рычажных механизмов, подразделяется на три вида: синтез передаточных механизмов («генератор функции»); синтез направляющих механизмов («генератор траектории»); синтез перемещающих механизмов («генератор плоско-параллельного движения»). При требовании точной реализации заданного движения возникает задача точного синтеза. Однако количество положений выходного объекта, которые можно воспроизвести точно, как правило, ограничено. С другой стороны, любое движение на практике невозможно воспроизвести с идеальной точностью из-за погрешностей изготовления элементов (звеньев, кинематических пар и т.д.) механизма. Поэтому в теории синтеза механизмов за последние годы развивались главным образом методы приближенного синтеза механизмов. Таким образом, все указанные выше задачи кинематического синтеза сводятся к задаче приближения функции. Такая формулировка задач синтеза восходит к классическим работам П.Л. Чебышева. По способу составления уравнений синтеза, которые вытекают из уравнений связей, существующие методы синтеза можно разделить на алгебраические и геометрические. Геометрические методы синтеза составляются на базе уравнений замкнутости проектируемой кинематической цепи. Алгебраические методы синтеза используют уравнения связей, которые налагаются на движение выходного звена механизма. По способу решения уравнений синтеза, существующие методы синтеза рычажных механизмов можно разделить на две группы: 1) аналитические методы; 2) численно-оптимизационные методы. При аналитическом синтезе часть постоянных параметров механизма вычисляется непосредственно по аналитическим формулам. Эти формулы получаются как результат решения уравнений синтеза в явном виде. При оптимизационном синтезе рычажных механизмов можно учитывать дополнительные условия синтеза, такие как оптимальный угол передачи движения, минимальное значение обобщенной силы на входе и т.д. Преимущества оптимизационных методов синтеза механизмов проявляются особенно в тех случаях, когда "классические" методы кинематического синтеза, основанные на кинематической геометрии или различных способах аппроксимации, неприменимы или малоэффективны.

Результаты численного синтеза рычажных механизмов зависят от выбора начальных приближений. Более гибким методом поиска начальных приближений является метод, основанный на использовании точек Бурместера. Этот метод позволяет определить аналитически начальные приближения по трем, четырем или пяти заданным исходным данным синтеза. В этом случае задача сводится к определению решений полиномов соответственно второй, третьей и четвертой степени. Метод заключается в том, что синтезируемый рычажный механизм условно разбивается на исходные и замыкающие кинематические цепи, и для каждой цепи определяются точки Бурместера.

После выбора начальных приближений формируется целевая функция по выходным критериям, зависящая от параметров синтеза, при помощи задач Чебышевского (наилучшего) или квадратического приближений. Параметры синтеза плоских рычажных механизмов определяются из минимума целевой функции. В соответствии с этим методом была разработана программа синтеза плоских рычажных механизмов. Приведен пример для демонстрации данного метода.

Ключевые слова: синтез, оптимальный, плоские рычажные механизмы, начальные приближения, точки Бурместера.

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ANALYSIS OF THE STRESS-STRAIN STATE OF TRAVEL PIPES WITH THE USE OF HARDWARE AND SOFTWARE COMPLEX

Abstract. In the work, the stress-strain state in the structural elements of reinforced concrete span structures of railway overpasses under its own weight and temporary load based on experimental and numerical methods was studied. Based on the analysis of the numerical results of the stress-strain state of the span structures of the railroad overpass, it was proved that for comparison assessment with the normalized stress range, the use of 2 loading options is sufficient as a static load: hitch and raft.

The results of the stress-strain state in the girder reinforced concrete span structures of the overpass can be used in the calculations of seismic stability and stability of similar structures with an increase in the operational load on railway bridges.

Proved the need for periodic monitoring of the stress-strain state of artificial structures under operational loads in order to determine the actual technical condition of structures, effective assessment of the reliability of bridge structures and to establish the correspondence between the design scheme and the actual working structures on the main lines of Kazakhstan.

Keywords: railroad overpass, beam span structures, stress-strain state, temporary load, own weight, stability, seismic resistance.

The article presents multivariate numerical and experimental data on the stress-strain state of the railroad overpass under the influence of loads from the operating rolling stock. These studies can then be used in the design of artificial structures and for comparison with the data obtained during the field tests to identify defects in the structural elements of railway bridges.

Description of the calculated model. The design model of the structure is constructed according to the data of the working documentation for the analysis of stress-strain state. A general view of the design model of the structure under consideration is presented in figure 1.

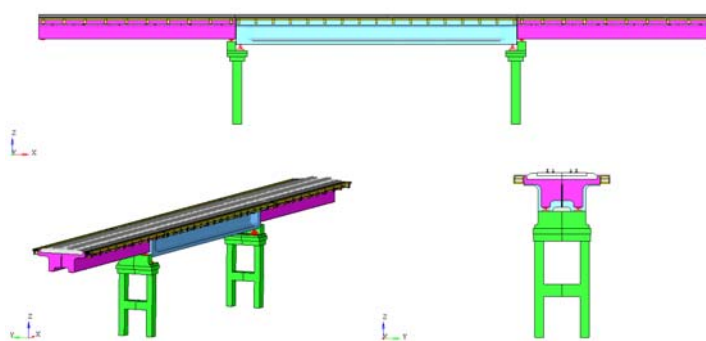


Figure 1 – A deformable finite element model of the overpass. General form

Models of reinforced concrete elements of supporting structures of the overpass take into account the joint work of reinforcing elements and concrete filling. The concrete filling of the structures of reinforced concrete blocks of the span structures of 16.5 m and 23.6 m, as well as the frames and pedestals of the intermediate supports of the overpass are given by volume elements. Reinforcing elements of structures (frames, grids, bundles of wires for prestressing concrete) of span structures and intermediate support structures are specified by core elements and take into account their spatial arrangement in concrete filling.

Accepted loads. All values of loads are taken without taking into account the various coefficients of the joint venture [1] and SNiP [2] (working conditions, reliability for loads, reliability for liability, etc.). The own weight of the structures of the structure is taken into account by the task of inertial load - gravity. Temporary loads are set according to the following types of effects: static load on the weight of the coupling according to the "locomotive-car" scheme; static load on the weight of a raft of three locomotives. The impact of the weight of the locomotive (TEM-18 diesel locomotive, 2 carts, 3 axles per carriage) is specified in the form of concentrated forces of 202.7 kN/axis in the nodes of the rail track model in accordance with the distances: 16,900 mm between axles of automatic couplings; 8800mm between the pins of carts; 1850 mm between bogie axles.

The impact of the weight of the car (hopper-metering model 55-76, 2 carts, 2 axles per carriage) is set in the form of concentrated forces of 228.7 kN/axis into the nodes of the rail track model in accordance with distances: 11 520 mm between the axles of the couplings; 7200 mm between the pins of carts (car base); 1850 mm between bogie axles. The considered schemes of temporary loads are presented in figure 2 - six schemes for coupling "one locomotive + one car" and in figure 3 – five schemes for raft "three locomotives".

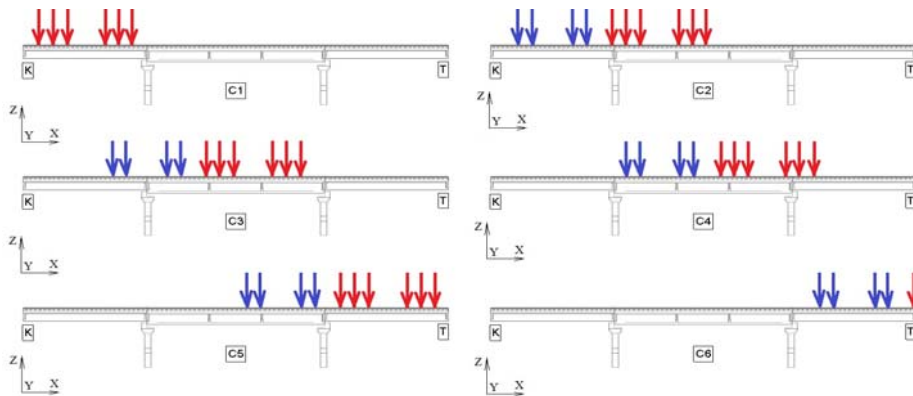


Figure 2 – Schemes of temporary loads from the coupling "locomotive-car" (C1-C6) "K" – Kulsary, "T" – Tengiz

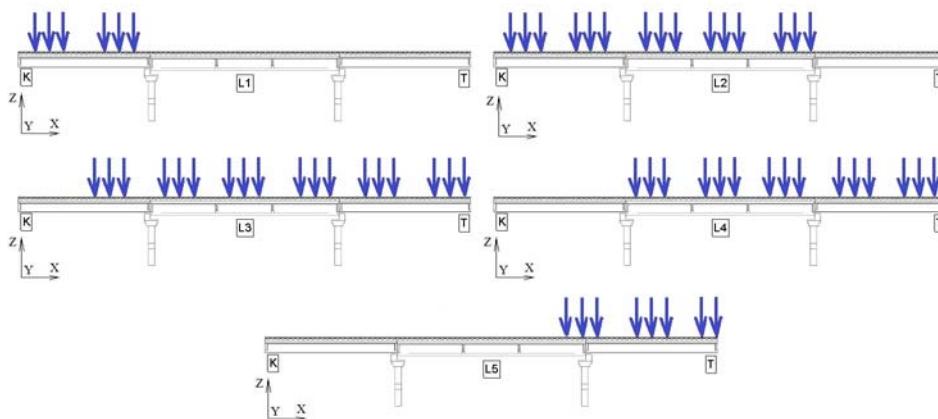


Figure 3 – Schemes of temporary loads from the raft "3 locomotive" (L1-L5) "K" - Kulsary, "T" – Tengiz

The results of the calculated static analysis. Calculations of the stress-strain state of the elements of the structure are performed for the given combinations of loads (design cases) [3, 4].

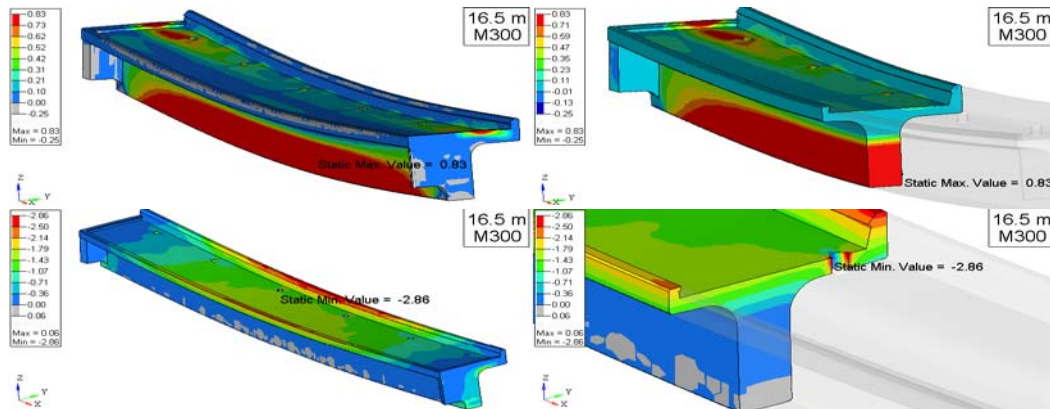
The following settlement cases are considered (12 cases in total), where they are indicated: C – Kulsary; T - Tengiz; PS0-1 - superstructure from the Kulsar; PS1-2 - span of 23.6 m; PS2-3 - superstructure from Tengiz:

- P0. "The tension of the reinforcement blocks 23.6 m + Own weight";
- C1. "P0 + coupling (middle of locomotive over middle of PS0-1)";
- C2. "P0 + coupling (middle of the car over the middle of PS0-1)";
- C3. "P0 + coupling (middle of the car above the support K)";
- C4. "P0 + coupling (middle of coupling over the middle of PS1-2)";
- C5. "P0 + coupling (middle of the coupling over support T)";
- C6. "P0 + coupling (middle of the car over the middle of PS2-3)";
- L1. "P0 + raft (middle of locomotive No. 1 over the middle of PS0-1)";
- L2. "P0 + raft (middle of locomotive No. 2 above bearing K)";
- L3. "P0 + raft (5th axis of the 2nd locomotive over the middle of PS1-2)";
- L4. "P0 + raft (2nd axis of the 3rd locomotive over the middle of PS1-2)";
- L5. "P0 + raft (2nd axis of the 3rd locomotive over the middle of PS2-3)".

The results of the calculations are presented as deformation values at the control points obtained using virtual sensors (compliant core elements with an initial length of 60 mm with linearly elastic properties of steel) installed on the concrete spans of the overpass. Control points are selected on the lower belt in the middle sections of the superstructure of the structure:

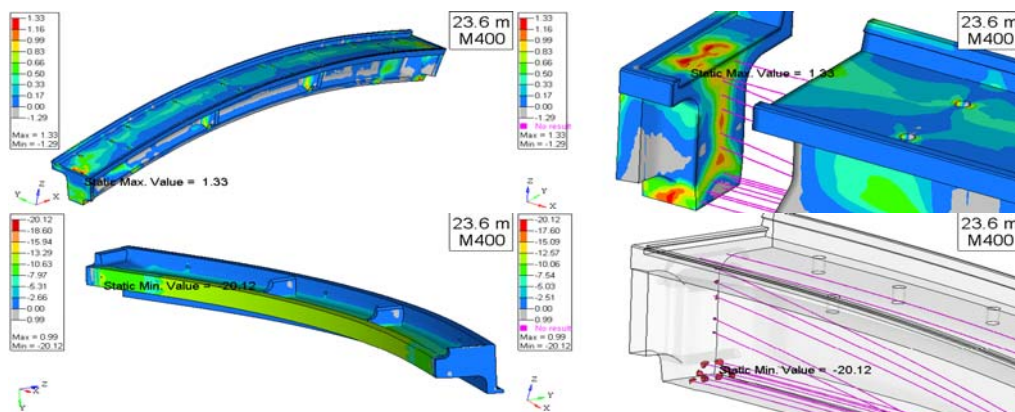
- "dat12" - a sensor in the middle of the superstructure PS0-1;
- "dat34" - a sensor in the middle of the span of the PS1-2;
- "dat56" - a sensor in the middle of the PS2-3 span.

Calculations of structural elements for given loads are presented in the form of stress distributions of concrete blocks of span structures of the overpass for the design case P0 (figures 4, 5) and as the stress values at test points and virtual sensors for all considered design cases (table 1).



main maximum stresses - top, main minimum stresses – bottom

Figure 4 – Calculated case P0. Deformed state and distribution of main stresses (MPa) in concrete of span structures 16.5m



main maximum stresses - top, main minimum stresses - bottom

Figure 5 – Calculated case P0. Deformed state and distribution of main stresses (MPa) in concrete of superstructures 23.6m

Table 1 – The calculated values of the virtual stresses on the concrete spans of the overpass

Settlement case	Stress, MPa			Stresses increment from temporary load, MPa		
	dat 1, 2	dat 3, 4	dat 5, 6	dat 1, 2	dat 3, 4	dat 5, 6
Rebar tension	0,00	-22,87	0,00	–	–	–
Π0	4,50	-17,97	4,50	–	–	–
C1	9,26	-17,97	4,50	4,76	0,00	0,00
C2	8,98	-15,20	4,50	4,48	2,77	0,00
C3	6,29	-14,01	4,50	1,79	3,96	0,00
C4	4,50	-14,08	5,23	0,00	3,89	0,73
C5	4,50	-16,00	9,24	0,00	1,97	4,74
C6	4,50	-17,97	8,96	0,00	0,00	4,46
L1	9,24	-17,97	4,50	4,74	0,00	0,00
L2	9,77	-14,08	4,50	5,27	3,89	0,00
L3	8,02	14,10	9,30	3,52	3,87	4,80
L4	4,50	14,08	9,80	0,00	3,89	5,30
L5	4,50	17,81	9,68	0,00	0,16	5,18

The results of experimentally obtained data. Field tests of a single-track railroad overpass through a highway in the production area were carried out in the spring of 2018 using a tensor metric software and hardware complex (TPAK) [5]. The overpass was built in 188, according to the following scheme: 16.5+23.6+16.5m for 56km of PK 9+50 railway line Kulsary-Tengiz, from prefabricated reinforced concrete structures.

Strain gages (dat 1,2,3,4,5,6) are installed, on each block of flying structures in the middle part (odd on the right blocks, even on the left blocks), the glued strain gauges are also protected from external influences environment for the purpose of further monitoring for 8-10 years.

As an example in figures 6, 7, diagrams of measured fibrous stresses in the stretched zone (lower part of the rib) in the middle of blocks of reinforced concrete span structures of a railroad overpass are given when exposed to temporary loads from the TEM-18 diesel locomotive and the Hopper - Dozator car (static tests table 2).

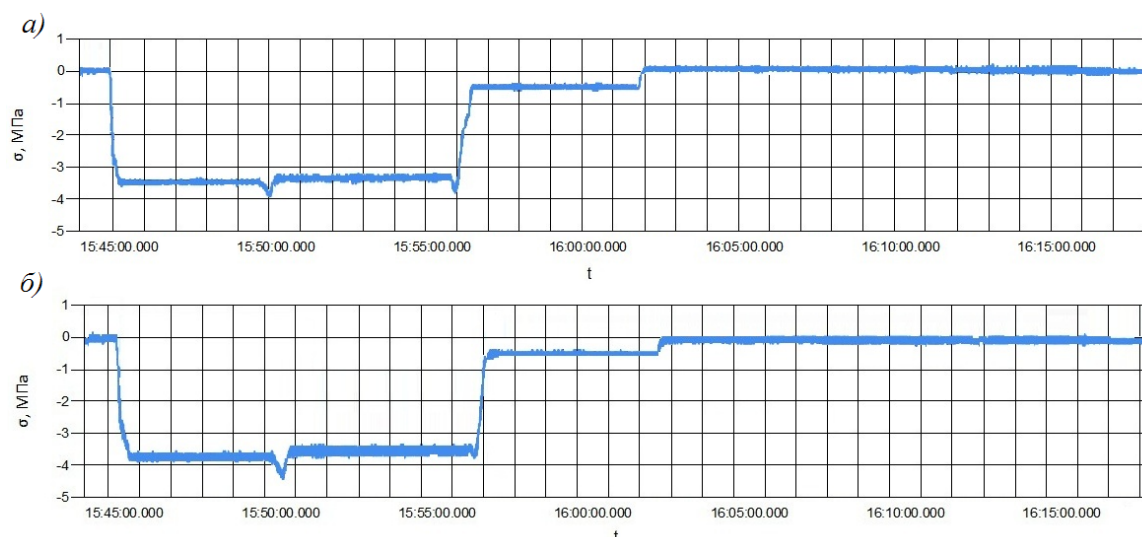


Figure 6 – Fiber stress diagrams of the tension zone PS 0-1 (dat 5, 6, load C1):
a – in the right block; b – in the left block

In [6], a detailed description of the technical part (primary and secondary converters) and software of the used TENZ hardware and software complex is presented. The data obtained by calculation are consistent with the experimental data obtained in [7–14].

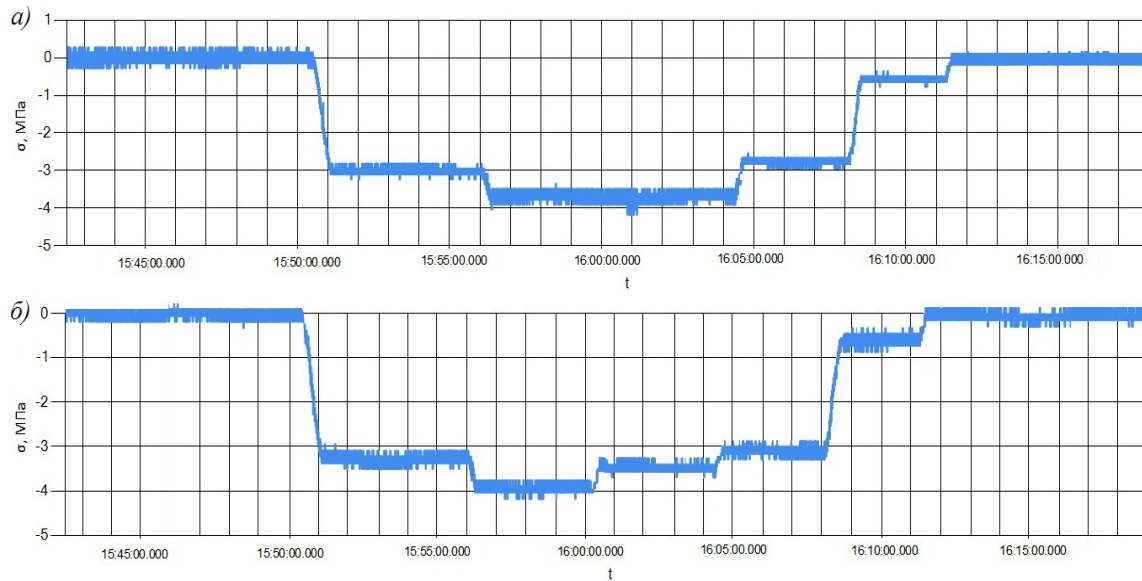


Figure 7 – Fiber stress diagrams of the tension zone PS 1-2 (dat 3, 4, load C4):
a – in the right block; b – in the left block

Table 2 – Fiber stresses from temporary loads of the coupler and raft (static tests)

Railway overpass 16.5 + 23.6 + 16.5 m for 56 km PK9 + 50						
Layout Scheme temporary load	PS 0-1		PS 1-2		PS 2-3	
	Right block 1+1	Left block 1+2	Right block 1+3	Left block 1+4	Right block 1+5	Left block 1+6
	σ , MPa	σ , MPa	σ , MPa	σ , MPa	σ , MPa	σ , MPa
C1	3,78	3,55	0	0	0	0
C2	2,95	3,02	2,96	3,23	0	0
C3	2,67	2,57	3,65	3,89	0,89	0,82
C4	0	0	3,67	3,53	3,46	3,41
C5	0	0	2,87	3,09	4,20	4,10
C6	0	0	0,67	0,75	2,87	2,71
L1	4,02	3,75	0,02	0,03	0	0
L2	4,97	5,08	3,42	3,71	0,02	0,06
L3	3,15	3,03	3,28	3,48	4,14	4,10
L4	0,12	0,15	3,56	3,49	4,99	4,96
L5	0	0	0,48	0,41	4,86	4,82

Conclusions. From the analysis of the stresses obtained by calculation in the beam-concrete concrete spans of the overpass it follows that to determine the stress-strain state of the spans of the railroad overpass in order to compare with the normalized range, 2 loading options are quite enough as a static load: (locomotive + wagon) and raft (3 locomotives).

The obtained results of stresses in girder reinforced concrete span structures of the overpass can be used in calculations of similar structures for seismic resistance, as well as in dynamic calculations of stability with increasing operational load on railway bridges.

To determine the actual technical condition of structures and the most effective assessment of the reliability of bridge structures and to establish consistency between the design scheme and the actual work of the structures on the trunk lines of Kazakhstan, it is necessary to periodically monitor the stress-strain state of artificial structures under operational loads.

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ЖОЛ ӨТПЕСІНІҢ КЕРНЕУЛІ ДЕФОРМАЦИЯЛЫҚ КҮЙІН АППАРАТ БАҒДАРЛАМАЛЫҚ КЕШЕНІН ҚОЛДАНА ОТЫРЫП ТАЛДАУ

Аннотация. Жұмыста эксперименталдық және сандық әдістер негізінде темір жол өткелдерінің темір-бетон аралық құрылыстары конструкцияларының элементтерінің нақты салмағы мен уақытша жүктеменің әсері, кернеулі-деформацияланған жай-күйі (КДЖ) зерттелді. КДЖ сандық нәтижелерін талдау негізінде темір жол өткелінің аралық құрылыстары нормаланатын кернеу диапазонымен салыстыру үшін статикалық жүктеме ретінде тиеудің тіркеу және жинақтау 2 нұсқаларын қолдану жеткілікті екендігі дәлелденді.

Конструкциялардың нақты техникалық жай-күйін анықтау мақсатында, көпірлер конструкцияларының сенімділігін тиімді бағалау және Қазақстан магистральды желілеріндегі құрылыстың есептік схемасы мен нақты жұмысының арасындағы сәйкестікті белгілеу мақсатында, пайдалану жүктемелерімен жасанды құрылыстардың КДЖ мерзімді мониторингін жүргізу қажеттігі дәлелденген.

Жұмыста қолданыстағы жылжымалы құрамның жүктемелерінің әсер етуі кезінде темір жол өткелінің кернеулі-деформацияланған күйі туралы көп нұсқалы сандық және эксперименталдық деректер берілген. Осы зерттеулер бұдан ары жасанды құрылыстарды жобалау кезінде және темір жол көпірлері конструкцияларының элементтеріндегі ақауларды анықтау мақсатында, нақты сынақтар жүргізу кезінде алынған деректермен салыстыру үшін пайдаланылуы мүмкін.

Жол өткелінің көтергіш конструкцияларының темір-бетон элементтерінің модельдерінде армирлеуші элементтер мен бетон толтырылуындағы бірлескен жұмысы ескеріледі. Темір бетон блоктарының 16,5 м және 23,6 м аралық құрылымдардағы конструкциясының, сондай-ақ жол өткелінің аралық тіректерінің рамалары мен тумбаларын бетонмен толтырылуы көлемді элементтермен берілген. Аралық тіректердің аралық құрылыстары мен құрылыстарының конструкцияларының арматураланған элементтері (қаңқалар, торлар, бетонның алдын ала кернеуіне арналған сымдар шоғыры) өзекті элементтермен берілуі және олардың бетонды толтырудағы кеңістікте орналасуы ескерілген.

Жол өткелінің темір-бетон аралық құрылыстарындағы есептік жолмен алынған кернеулерді талдаудан, нормаланатын диапазонмен салыстыру мақсатында, темір жол өтпелерінің аралық құрылыстарының КДЖ анықтау үшін статикалық жүктеме ретінде тиеудің 2 нұсқасын қолдану жеткілікті: тіркеу (локомотив + вагон) және жинақтау (3 локомотив).

Жол өткелінің темір-бетон аралық құрылыстарындағы кернеулердің алынған нәтижелерін сейсмикалық төзімділікке ұқсас құрылыстардың есептерінде, сондай-ақ темір жол көпірлеріне пайдалану жүктемесін арттыру кезінде орнықтылықтың динамикалық есептерінде пайдалануға болады.

Конструкциялардың нақты техникалық жай-күйін анықтау және көпірлер конструкцияларының сенімділігін неғұрлым тиімді бағалау және құрылыстың есептік схемасы мен нақты жұмысының арасындағы сәйкестікті белгілеу үшін Қазақстанның магистральдык желілерінде пайдалану жүктемелерімен жасанды құрылыстардың КДЖ-ның мерзімді мониторингін жүзеге асыру қажет.

Түйін сөздер: темір жол өтпесі, арқалықты аралық құрылым, кернеулі-деформациялық күй, уақытша жүктеме, меншікті салмақ, орнықтылық, сейсмикалық тұрақтылық.

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АНАЛИЗ НАПРЯЖЕННО-ДЕФОРМИРОВАННОГО СОСТОЯНИЯ ПУТЕПРОВОДОВ С ИСПОЛЬЗОВАНИЕМ АППАРАТНО-ПРОГРАММНЫХ КОМПЛЕКСОВ

Аннотация. В работе изучено напряженно-деформированное состояние (НДС) в элементах конструкций железобетонных пролетных строений железнодорожных путепроводов под действием собственного веса и временной нагрузки на основе экспериментальных и численных методов. На основе анализа численных

результатов НДС пролетных строений железнодорожного путепровода доказано, что для сравнительной оценки с нормируемым диапазоном напряжений в качестве статической нагрузки достаточно применение 2-х вариантов загрузки: сцепка и сплотка.

Доказана необходимость проведения периодического мониторинга НДС искусственных сооружений под эксплуатационными нагрузками в целях определения фактического технического состояния конструкций, эффективной оценки надежности конструкций мостов и установления соответствия между расчетной схемой и действительной работой сооружений, на магистральных линиях Казахстана.

В работе представлены многовариантные численные и экспериментальные данные о напряженно-деформированном состоянии железнодорожного путепровода при воздействии нагрузок от эксплуатируемого подвижного состава. *Данные исследования в дальнейшем могут быть использованы при проектировании искусственных сооружений и для сравнения с данными, полученными при проведении натурных испытаний с целью выявления дефектов в элементах конструкций железнодорожных мостов.*

Модели железобетонных элементов несущих конструкций путепровода учитывают совместную работу армирующих элементов и бетонного заполнения. Бетонное заполнение конструкций железобетонных блоков пролетных строений 16,5 м и 23,6 м, а также рам и тумб промежуточных опор путепровода заданы объемными элементами. Армирующие элементы конструкций (каркасы, сетки, пучки проволок для предварительного напряжения бетона) пролетных строений и строений промежуточных опор заданы стержневыми элементами и учитывают их пространственное расположение в бетонном заполнении.

Из анализа полученных расчетным путем напряжений в балочных железобетонных пролетных строениях путепровода следует, что для определения НДС пролетных строений железнодорожного путепровода с целью сравнения с нормируемым диапазоном, в качестве статической нагрузки вполне достаточно применение 2-х вариантов загрузки: сцепка (локомотив + вагон) и сплотка (3 локомотива).

Полученные результаты напряжений в балочных железобетонных пролетных строениях путепровода, можно использовать в расчетах подобных сооружений на сейсмостойкость, а также в динамических расчетах устойчивости при увеличении эксплуатационной нагрузки на железнодорожные мосты.

Для определения фактического технического состояния конструкций и наиболее эффективной оценки надежности конструкций мостов и установления соответствия между расчетной схемой и действительной работой сооружений на магистральных линиях Казахстана необходимо осуществлять периодический мониторинг НДС искусственных сооружений под эксплуатационными нагрузками.

Ключевые слова: путепровод железнодорожный, балочные пролетные строения, напряженно-деформированное состояние, временная нагрузка, собственный вес, устойчивость, сейсмостойкость.

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**WAYS TO IMPROVE THE EFFICIENCY IN PERFORMANCE
OF CORONA DISCHARGE OZONATORS**

Abstract. This article analyzes several ways to increase the corona discharge current in ozonators, which can further improve the ozone efficiency and reduce the specific energy consumption of the ozonating element at low air pressures in the discharge zone. Their capabilities, advantages and disadvantages when used in ozonating elements are described. The dependences of the voltages on the air pressure for different constant values of the discharge current measured at pressures starting from 100 mm Hg up to a pressure of 680 mm Hg at normal air temperature of 20°C are shown. The obtained data show that when the current values are constant and the pressure decreases, it turns out that the voltage decreases as much as the energy consumption increases. A table has been compiled that records the ozone efficiency and specific energy costs, as well as the corresponding values of voltages and currents for the three pressures, where it can be established that at low air pressures, it is possible to obtain fairly high values of specific energy consumption (166 g/kWh), which is the main advantage of the described method of obtaining ozone. In order to use the existing dependence of the discharge current value on the ambient air pressure, the effect of a natural pressure drop in the discharge zone due to the electric wind was tested when the ion-convection pump mode is observed. A method has been developed for air exhausting out of the working volume of the ozonizing element, which in turn involves the passage of ozonized air through the exhaust device, which ultimately significantly reduces the efficiency of obtaining ozone. This problem is solved with the help of an electric wind that occurs in the corona discharge zone; and a pressure drop around the corona element is observed.

Keywords: corona discharge, ozone, ozonator, the corona needle, productivity, energy consumption.

A method of producing ozone in electric discharges is the safest and most effective of all known, which is characterized by an optimal ratio of energy consumption to the concentration of ozone produced.

Corona discharge (one of the types of electrical discharge) occurs in a gas in a strongly inhomogeneous electric field between two electrodes – a high voltage and grounded separated by a gap (discharge gap) and a dielectric. Ozone is produced by the dissociation of oxygen molecules into the corona layer caused by electron impact.

The results of theoretical and experimental research of recent years have shown that a negative corona discharge with microelectrodes (microwires, the needle (the tip), sharp edges and a thin spiral with radii of curvature of not more than 25-50 microns) compared with other types of corona discharge provides a higher specific discharge current and a large current density on the corona electrode [1,2].

The ozone performance of any ozonized element primarily depends on the magnitude of the discharge current, and thus in order to reduce the specific energy consumption it is necessary to reduce the voltage values in the same discharge current. There are several ways to strengthen the corona discharge current, which leads to the increase of ozonized element productivity. Consider their possibilities, advantages and disadvantages when they are used in ozonized elements.

One of the ways to strengthen the corona discharge current, which is equivalent to increasing productivity of ozonized element, is to reduce the distance between electrodes of the discharge gap. In this case, at the same supply voltages it is possible to obtain higher values of the discharge current, if the breakdown between the electrodes does not occur.

Another way of strengthening the discharge current is to heat the corona electrode or to heat the air surrounding the discharge gap. In this case, with the increase of temperature the ionization rate in the discharge layer increases due to the increase of the length of free path of electrons, thus the current density in the outer area of the corona increases considerably. It was found that when air is heated up to 140°C and at the same voltage values the discharge current increases in five times, but the application of this method to strengthen the discharge current is caused by a number of technical difficulties: the need for an additional device to heat the air and then to blow it through ozonized element, and the thermal insulation of ozonized element from the environment is required as well. Furthermore, at such air temperature (140°C) one can only decompose ozone produced in ozonized element.

Another way to improve performance of ozonized element is to use pure oxygen instead of air. Indeed, in this case, the ozone output increases almost in two times. The reason hindering the use of this method is its high cost. Furthermore, under production conditions the use of oxygen does not meet the safety requirements.

One of the most effective ways to reduce specific energy consumption in obtaining ozone is the performance of ozonized element at lower air pressures. In this case, the only way to apply this method is to suck off the air from working volume of ozonized element, which provides passing the ozonized air through the aspirator and ultimately the effectiveness of obtaining ozone considerably reduces. This problem was solved by [4] using the electrical wind which occurred in the corona discharge zone, and it was found that the pressure around the discharge element decreased.

The results of the research showed that in the whole range of temperature and air pressure the characteristics of corona discharge are the functions of air density. The impact of temperature on the corona discharge is described by the same laws as the dependence of the air density on the temperature. Air pressure or its density has an influence on the amount of the discharge current through the initial field strength of corona discharge, which determines the firing voltage at a given interval [5].

Based on the numerous measurements of the initial voltage of corona discharge Peak managed to give the empirical formula for the initial field strength of corona occurring on the surface of the corona wire with a radius r_0 [6]. The comparison of the calculated and experimental data shows [7,8] that in general the best convergence (for coaxial cylinders) can be obtained for the following Peak formula:

$$E_0 = 30,3\delta\left(1 + \frac{0,298}{\sqrt{r_0\delta}}\right) \quad (1)$$

where δ - relative air density, which is defined by the formula:

$$\delta = \frac{0,386p}{273 + T} \quad (2)$$

where p - barometric pressure, $mmHg$, T - air temperature, °C; $\delta = 1$ under atmospheric conditions adopted for the normal ($p = 760$ mm Hg, $T = 20^\circ C$).

The impact of E_0 on the value of corona discharge current can be determined by the initial voltage U_0 (1) onvolt-ampere characteristic of corona discharge, Townsend formula is given as an example [8].

$$I = \frac{8\pi\varepsilon_0\kappa(U - U_0)U}{R^2 \ln \frac{R}{r_0}} \quad (3)$$

where ε_0 - dielectric constant, and κ - mobility of ions, U - voltage between electrodes, U_0 - initial voltage of corona discharge.

It is advisable to check the conformity of the experimental values of corona discharge ignition voltage with the calculated ones by Peak formula (1). Table 1 shows the experimental results of measurements and the calculated values of initial voltage U_0 , U_C and field intensities of corona E_0 , E_C depending on pressure and air temperature. All measurements and calculations are referred to negative corona discharge.

The values δ , given in the table were calculated by the formula (2). Using the formula (1) the tension on the surface of the corona wire can be calculated using the experimental values U_0 . While the values U_0

are measured by the sufficient accuracy (0.1%), a large error may be introduced due to the unevenness of the diameter along the length of the corona wire in the determination of E_0 by the formula (1).

The table of data analysis shows that in most cases the values E_C are greater than values E_0 . The difference between E_0 and E_C does not depend on ρ and T and makes 3% on average, whereas values E_0 may be changed with respect to E_C with increasing temperature sometimes up to 7%.

It was found out [9] that primarily the decrease of air density tended to reduce the value of the initial voltage of corona discharge, thus, the volt-ampere characteristics significantly increased.

Now consider the output parameters of ozonized element at low air pressures, which include the performance of ozone (g/h) and specific energy consumption (g/kWatt·h). To do this, we use the characteristics of ozonized element, obtained in work [9, p. 169, figure 57], and approximating it we find a formula for the dependence of the ozone on corona discharge current:

Table 1 – Initial voltage and tension of corona field (atm.air $R = 0,5$ cm, $r_0 = 0,0025$ cm)

p, mmHg	T, °C	Δ	U_0 , V	E_0 , kV/cm	E_C , kV/cm formula (3)	U_C , V formula (1)
100	24,5	0,133	1000	75,5	72,5	955
80	24,5	0,266	1400	105	107	1420
300	24,5	0,399	1750	132	132,3	1755
400	24,5	0,532	2050	155	156	2065
500	24,5	0,665	2300	173	176	2330
680	24,5	0,903	2700	204	209	2770
680	40,0	0,852	2520	190	203	2690
680	60,0	0,801	2460	185	196	2600
680	80,0	0,755	2400	181	189	2510
680	100	0,715	2350	177	183	2423
680	120	0,678	2260	170	178	2360
680	140	0,648	2200	166	173	2290

$$P_p = KI \quad (4)$$

Where P_p – ozone productivity (g/h), K - coefficient of proportionality (g/h·mA), I - discharge current (mA). Using the magnitude of the inclination angle characteristics we can calculate the value of the proportionality coefficient $K = 0.2$ g/h·mA.

Specific energy consumption (P_s) is determined by the ratio of ozone productivity (P_p) to the energy consumption $W = U \cdot I$ kW per hour, that is:

$$P_s = \frac{P_p}{W} = \frac{KI}{UI}, \text{ g/kWatt/h} \quad (5)$$

where U - voltage between the electrodes, kV, I - discharge current, A.

In fact, at a certain current P_s depends only on the value U , the smaller its value, the higher P_s . The comparison of the experimental values P_{PE} with the calculated P_{PC} by the formula (4) is of great interest. To illustrate this comparison we make a table which also includes the experimental values P_{SE} .

Table 2 – Ozone productivity and energy output of ozonated element

U, kV	5	5,6	6,1	6,4	6,6
I, mA	0,5	1,0	1,5	2,0	2,5
P_{PE} , g/h	0,09	0,25	0,36	0,45	0,5
P_{PC} , g/h	0,13	0,24	0,33	0,44	0,53
P_{SE} , g/kWatt/h	45	40	35	32	29

As can be seen from the data in table 2, the maximum difference between $P_{II\Omega}$ and $P_{II\Lambda}$ does not exceed 8%, and therefore the determination of P_{II} for the other values of the discharge current according to the formula (4) leads to a small measurement error. The calculation formula (5) can be used to determine P_y .

Figure 1 shows the dependence of voltage (U) on the air pressure (p) for various values of the constant values of current discharge (I), measured at pressures ranging from 100 mm Hg. up to pressure of 680 mm Hg. under the air temperature 20°C as normal. From these data we can conclude that when the value I is constant and p is reduced it turns out that the less the value U is, the more P_S is.

In accordance with the law of states of ideal gas, the decrease of air pressure also reduces the concentration of oxygen molecules in the air that can lead to reduction of ozone formation in the discharge gap. Meanwhile, the decrease in p also leads to the opposite effect: strengthening the ionization processes due to the lengthening of the mean free path of electrons, and therefore, to the increase of their energy. Thus, the reduction of p cannot significantly influence on the degree of ozone output as when p is reduced the permanence of discharge current values is provided by the required density of charge stream which mainly consists of oxygen ions and ozone.

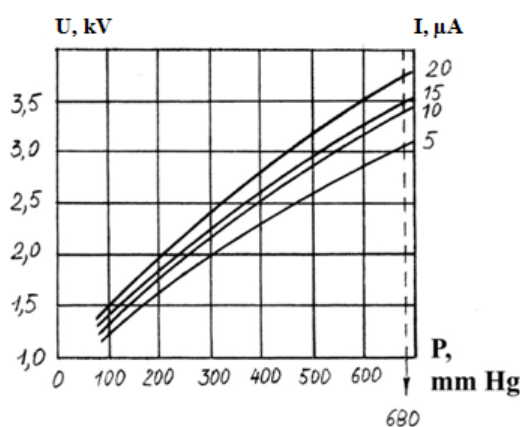


Figure 1 – Dependence of voltage on air pressure

Table 3 shows the productivity of the ozone (P_{PS}) and specific energy consumption (P_S), as well as the corresponding values of U and I for the three air pressure.

Table 3 – Output parameters of ozonated element at low air pressures

P, mm Hg.	100				400				680			
I, μ A	5	10	15	20	5	10	15	20	5	10	15	20
U, kV	1,2	1,3	1,4	1,5	2,3	2,5	2,6	2,8	3,1	3,4	3,5	3,8
P_{PC} , g/h	10^{-3}	$2 \cdot 10^{-3}$	$3 \cdot 10^{-3}$	$4 \cdot 10^{-3}$	10^{-3}	$2 \cdot 10^{-3}$	$3 \cdot 10^{-3}$	$4 \cdot 10^{-3}$	10^{-3}	$2 \cdot 10^{-3}$	$3 \cdot 10^{-3}$	$4 \cdot 10^{-3}$
P_S , g/kW/h	166	153	142	133	87	80	77	71	64	58	57	52

The main discharge processes under the corona needle and corona wires are not different fundamentally and they vary according to the electric field configuration and discharge power. In this regard, in order to study the impact of air pressure on characteristics of corona discharge there has been used the coaxial electrode system which is characterized by experimental simplicity and convenience, and it is also ozonized element for obtaining ozone in corona discharge.

As can be seen from the data in Table 3, at low air pressure it is possible to get quite high values of specific energy consumption (166 g/kW·h), which is the main advantage of this method of producing ozone.

In order to use the existing dependence of discharge current value on the air pressure, there has been tested the effect of natural pressure reduction in the discharge area due to the electric wind when there is an ion-convection pump mode.

A device was developed for producing ozone in a corona discharge zone, comprising a corona electrode in the form of needles and the outer electrode as a grid located in the tube with a plug made of ozone resistant insulating material (Teflon, Vinyl and etc.) [10].

The most advantageous modification is ozonator containing successive ozonized elements made in the form of "the corona needle - flat metal mesh", which are placed in the half-closed chamber and are arranged symmetrically in the direction of the electric wind, which occurs in the direction of the open side of the camera, the ozonator contains ozonized elements located near the closed part of the chamber and additional ozonator discharge electrodes located near the open end of the chamber for the narrow part circle section nozzle.

As it was noted, the principle of convection ion pump based on the known parameters of the electric corona wind that generally reduces the pressure in the discharge interval was used in the proposed design of the ozonator [11]. It was found that the decrease in pressure in the discharge zone allows you to raise the efficiency of the ozonator. Furthermore, it is expected that the effect of reducing the pressure in the interelectrode space to be more noticeable if a discharge system is placed in a half-closed chamber in such a manner that caused an electric wind is directed towards the open portion of the chamber. In the case of series, connection of several elements in the ozonized discharge chamber disposed symmetrically, the effect of reducing the pressure in the chamber to be more significant than a single corona needle. The total sum of the determined pressure differential $\Delta p = \Delta p_1 + \Delta p_2 + \dots$ etc, and so the magnitudes of discharge currents of ozonated elements at the same potential differences tend to the increase.

A new design that allows to divide the processes of formation of ozone and the creation of an electric wind, which leads to the provision of a low specific energy consumption with a simple design [12].

Figure 2 represents a functional diagram of ozonator which operates in a semi-closed mode and consists of separate elements arranged ozonated and discharge electrodes to generate an electric wind. Ozonated elements 4 units in the form of electrode system as "needle-net" contain the discharge electrodes 1 and 2 to the external electrode grid disposed in a sealed portion of the tube 3 made of ozone resistant insulating material (Teflon, Vinyl and etc.). Corona electrode K is supplied from the power supply unit (PSU) of negative polarity high voltage, and the grid electrode 2 is grounded. The additionally corona electrodes 4 attached to the grid electrode 2 and located near the open part of the edge portion of the circle narrow nozzle chamber section 5 (section AA) is used to create electric wind in ozonator chamber. The second electrode is a grid 6, which is attached to the open part of the tube and is connected to the positive pole of the power source.

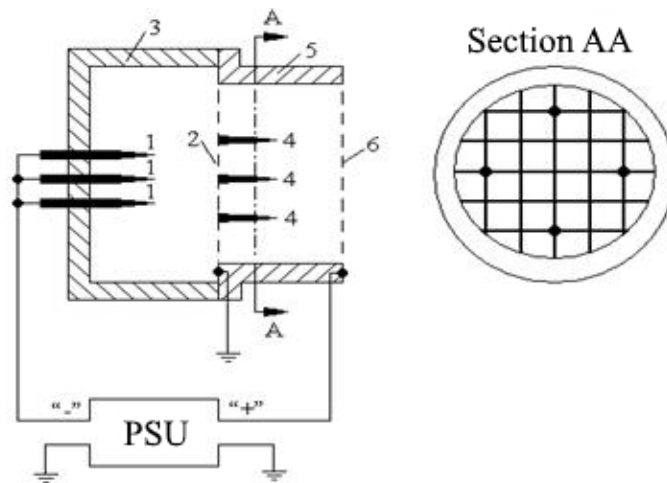


Figure 2 – Functional diagram of the ozonator

After the voltage (-U) of sufficient magnitude to the discharge electrodes, there is corona discharge between them and a grid electrode 2, and formed with a negative space charge, consisting essentially of oxygen ions and ozone tends to grid electrode 2 at a zero potential, wherein the partially neutralized, forming a molecule of oxygen and ozone, and most of the ions are accelerated towards the electrode 6 with positive potential.

Within the certain time (less than 5 seconds) there is set stable electric wind directed into the open part of the discharge chamber and the ozonator starts operate in the ion pump convection mode. At the same time, there is a gradual decrease in the air pressure within the discharge chamber and, as might be expected, it increases the force of the discharge current. This situation cannot last long as at some point begins the process of suction air through the outer wall region of the discharge chamber. To prevent wall surface in the air suction chamber, discharge electrodes are additionally installed on the edge of the circle fitting section narrowest part five (section AA). After some time, a stable set of low air pressure conditions inside the discharge chamber, which means that the prevalence of process air suction of external air into the process in the chamber.

Ozonated elements, 4 units have the following parameters: the radius of curvature of the needles $r_0 = 0.2$ mm, the diameter of the insulating tube 16 mm, the distance from the tips of the needles to the grid equal to $r_1 = 6$ mm, and supply voltage U of the discharge chamber was changed in the range of 4 to 14 kV. When you turn on the power supply voltage of 10 kV initially, the average current of the discharge chamber was equal to 30 mA. Afterwards, when establishing steady mode of electric wind in the open part of the discharge chamber, the current increases gradually reaching 38 mA. To determine the specific energy consumption of the device (g/kV/h) in one or the other case, the use of the calibration curve removed ozonometer type LEK designed by St. Petersburg technical university for ozonated element in the corona discharge. On average, the specific productivity of ozonated element makes 0.8 grams of ozone per hour with the power of 4 mA discharge current. On this basis, we calculate the specific power outputs of the device in different operational modes. In this specific energy output of the device at atmospheric air pressure of 680 mm Hg (Almaty) and at the initial time is 20 g/kV/h, while at steady mode of electric wind it was 23,5g/ kV/h. In the second mode, in order to maintain the initial discharge current 8 mA, it is necessary to reduce the power supply voltage to 8, 5kV, which ultimately leads to a reduction in specific energy consumption for the production of ozone in the corona discharge.

The comparison of value of the power supply reduction at a constant discharge current of known voltage dependence of corona discharge off air pressure [13] allows approximately determine the air pressure in the discharge area, for example, in our case, air pressure reduction relatively to atmospheric (680 mm Hg) was about 100 mm Hg.

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ТӘЖДІ РАЗРЯД НЕГІЗІНДЕГІ ОЗОНАТОРЛАР ЖҰМЫСЫНЫҢ ТИІМДІЛІГІН АРТТЫРУ ЖОЛДАРЫ

Аннотация. Берілген мақалада озонаторлардағы тәждік разряд тоғын күшейтудің бірнеше жолдары қарастырылған, олар озон өнімділігін одан әрі арттыруға және разряд маңайындағы ауа қысымы төмен болған кезде озондаушы элементтің нақты энергия шығынын азайтуға мүмкіндік береді. Озондаушы элементтерде қолданылған кездегі олардың мүмкіндіктері, артықшылықтары мен кемшіліктері сипатталады.

Ауа температурасын 20 °С қалыпты деп алып, 100 мм.с.б. бастап 680 мм.с.б. дейінгі аралықтағы қысыммен өлшенген разрядтық токтың (I) әртүрлі тұрақты мәндері үшін кернеудің (U) ауа қысымына (P) тәуелділігі келтірілген. Алынған мәліметтер бойынша токтың мәндері тұрақты және қысым төмендеген жағдайда кернеудің қаншалықты төмендегенімен энергия шығыны соншалықты өсетіні көрінеді.

Тәждеуші инедегі және тәждеуші сымдарда өтетін негізгі разрядтық процестер түбегейлі ерекшеленбейді және олар электр өрісінің конфигурациясында және разрядтан болатын қуатпен ерекшеленеді. Осыған байланысты ауа қысымының тәждік разряд сипаттамаларына әсерін зерттеу үшін эксперименталды қарапайымдылыққа ие болатын және ыңғайлы болып келетін электродтардың коаксиалды жүйесі қолданылды, сонымен қатар ол тәжді разрядта озон алуға арналған озондаушы элемент болып табылады.

Озонның өнімділігі мен энергияның меншікті шығындарын, сондай-ақ қысымның үш түрлі мәндері үшін кернеулер мен токтардың тиісті мәндерін анықтайтын кесте жасалды, мұнда ауа қысымы төмен болған кезде энергияның меншікті шығындарының айтарлықтай жоғары шамасын (166 г/кВт·сағ.) алуға болатындығы анықталды, мұның өзі сипатталған озон алу әдісінің басты артықшылығы болып табылады. Ауа тығыз-

дығының төмендеуі, ең алдымен, тәжді разрядтың бастапқы кернеуінің төмендеуіне әкелетіні анықталды және бұл жағдайда вольтамперлік сипаттамалардың тұрақтылығы айтарлықтай артады.

Разряд тогының қоршаған ортаның қысымына тәуелділігін қолдану мақсатында разряд маңайындағы қысымның электрлік жел әсерінен табиғи түрде төмендеу құбылысы зерттелді, осы кезеңде иондық-конвекциялық сорғы режимі байқалды.

Ауаның температурасы мен қысымының барлық диапазонында тәждік разрядтың сипаттамалары тек ауа қысымының функциялары болып табылатынын көрсететін зерттеулер нәтижелері келтірілген. Ауа температурасының тәждік разрядқа әсері ауа тығыздығының оның температурасына тәуелділігімен бірдей сипатталады.

Тәждік разрядтың тоқ күшіне түсетін ауаның қысымы немесе оның тығыздығы тәждік разряд өрісінің бастапқы кернеулігі арқылы әсер етеді, өз кезегінде ол берілген аралықта разряд пайда болуының кернеуін анықтайды. U_0 тәжірибелік мәндерін тиісті формулаларға қойып, тәждеуші сымның бетіндегі кернеулік есептелген. U_0 мәндерін жоғары дәлдікпен (0,1%) өлшеген кезде, кернеулікті анықтау барысында тәждеуші сымның ұзындығы бойынша біркелкі еместігіне үлкен қателік енуі мүмкін болатындығы байқалды. $U_0 E_0$ формуласы бойынша анықтаған кезде (1), ұзындық бойынша корона сымның біркелкі болмауына байланысты үлкен қате пайда болуы мүмкін. Төмендетілген ауа қысымындағы озондаушы элементтің шығу параметрлері, яғни озонның өнімділігі (г / сағ.) және энергияның меншіктік шығыны (г / кВт.сағ) анықталды.

Авторлар озондаушы элементінің жұмыс көлемінен ауаны сорып алу әдісін жасады, бұл өз кезегінде озондалған ауаның сору қондырғысы арқылы өтетінін, нәтижесінде озон алудың тиімділігінің айтарлықтай төмендейтінін болжайды. Бұл мәселе тәжді разряд маңайында пайда болатын электрлік жел көмегімен шешіледі және тәждеуші элементтің айналасындағы қысымның төмендеуі анықталды.

Түйін сөздер: тәжді разряд, озон, озонатор, тәждеуші ине, өнімділік, энергия шығыны.

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ПУТИ ПОВЫШЕНИЯ ЭФФЕКТИВНОСТИ РАБОТЫ ОЗОНАТОРОВ НА КОРОННОМ РАЗРЯДЕ

Аннотация. Рассмотрены несколько путей для усиления тока коронного разряда в озонаторах, которые могут позволить дополнительно повысить производительность по озону и снизить удельные энергозатраты озонирующего элемента при пониженных давлениях воздуха в зоне разряда. Описаны их возможности, достоинства и недостатки при применении их в озонирующих элементах.

Построены зависимости напряжений от давления воздуха для различных постоянных значений тока разряда, измеренных при давлениях, начиная от 100 мм рт. ст. вплоть до давления 680 мм рт. ст., считая температуру воздуха нормальной 20 °С. Полученные данные показывают, что при постоянстве значений тока и в случае снижения давления оказывается, что на сколько снижается величина напряжения, на столько повышается энергетические затраты.

Основные разрядные процессы при коронирующей игле и при коронирующей проволоке принципиально не отличаются и разнятся они по конфигурации электрического поля и по мощности разряда. В связи с этим для исследования влияния давления воздуха на характеристики коронного разряда была использована коаксиальная система электродов которая обладает экспериментальной простотой и удобством и также является озонирующим элементом для получения озона в коронном разряде.

Составлена таблица, фиксирующая производительность по озону и удельные энергетические затраты, а также соответствующие значения напряжений и токов для трех давлений, где можно установить, что при пониженных давлениях воздуха можно получить довольно высокие значения удельных энергозатрат (166 г/кВт·ч), что является основным преимуществом описанного способа получения озона. Установлено, что уменьшение плотности воздуха, в первую очередь, ведет к снижению значения начального напряжения коронного разряда, причем крутизна вольтамперных характеристик при этом заметно увеличивается.

С целью использования существующей зависимости значения тока разряда от давления окружающего воздуха был опробован эффект естественного понижения давления в зоне разряда из-за электрического ветра, когда наблюдается режим ионно-конвекционного насоса.

Приведены результаты исследования, показывающие, что во всем диапазоне температур и давлений воздуха характеристики коронного разряда являются функциями только плотности воздуха. Влияние температуры воздуха на коронный разряд описывается той же закономерностью, что и зависимость плотности воздуха от его температуры. Давление воздуха или плотность его на величину силы тока разряда влияет

через начальную напряженность поля коронного разряда, которая в свою очередь, определяет напряжение возникновения разряда в данном промежутке.

Используя экспериментальные значения U_0 , по формуле (1) вычислена напряженность на поверхности коронирующего провода. Обнаружено, что тогда как значения U_0 измеряются достаточно с высокой точностью (0,1%), при определении E_0 по формуле (1) может вноситься большая погрешность из-за неравномерности диаметра коронирующего провода по длине. Определены выходные параметры озонирующего элемента при пониженных давлениях воздуха, к которым относятся производительность по озону (г/ч) и удельные энергетические затраты (г/кВт.ч).

Авторами разработан способ отсасывания воздуха из рабочего объема озонирующего элемента, что в свою очередь предполагает прохождение озонированного воздуха через отсасывающее устройство, при котором в конечном итоге, в значительной степени снижается эффективность получения озона.

Данная задача решена с помощью электрического ветра, возникающего в зоне коронного разряда, и установлено понижение давления вокруг коронирующего элемента.

Ключевые слова: коронный разряд, озон, озонатор, коронирующая игла, производительность, энергозатраты.

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**СИНТЕЗ НАНОПОРОШКОВ ДИОКСИДА ТИТАНА
АНАТАЗНОЙ МОДИФИКАЦИИ**

Как известно, соединения титана широко применяются в области химии и металлургии, а также в народном хозяйстве. Например, соли трехвалентного титана – в качестве восстановителей в химических процессах и как переносчики заряда при восстановлении трудновосстанавливаемых анионов селена (VI), теллура (VI) и мышьяка (V), а также при получении ультрадисперсных нанопорошков меди. Титанилсульфат аммония широко применяется при обработке кожи. Гидроксид титана (IV) – в качестве сорбента, диоксид титана – как пигмент для красителей, кроме этого его используют для покрытия солнечных панелей, которые относятся к третьему поколению солнечных батарей, теоретическое значение КПД для таких панелей составляет более 30 % [1-4].

Сложность синтеза соединений титана обусловлена его исключительной стойкостью во многих агрессивных средах. Это объясняется тем, что на поверхности металла в атмосферных условиях образуется защитная пленка, обеспечивающая его коррозионную стойкость [1-3]. Природа защитной пленки может быть различна. При воздействии на титан раствора соляной кислоты на его поверхности образуется защитный слой из гидрида титана TiH_2 , при воздействии на титан азотной кислоты на его поверхности также образуется защитный слой из гидратированной двуокиси титана содержащий одну молекулу воды H_2TiO_3 , в серной кислоте образуются нерастворимые соединения TiO_3 , также обладающие защитными свойствами. Попытки электрохимического растворения титана при анодной поляризации постоянным током также не приводят к его растворению, поскольку защитные слои обладают высокими сопротивлениями и протекание тока в цепи становится невозможным.

Тем не менее процесс электрохимического растворения титана стал возможен при наложении различных видов нестационарных импульсных токов, в том числе промышленного переменного тока. Было обнаружено, что титан способен терять свой оксидный слой и подвергаться электрохимическому растворению с образованием преимущественно соединений трехвалентного титана [4].

Дальнейшие исследования показали, что после предварительной поляризации титановых электродов катодным импульсным током или промышленным переменным током с частотой 50 Гц, титан остается активным и после выключения электрического тока, т.е. металл продолжает химически растворяться с постоянной скоростью [5-8].

Нами была рассмотрена возможность электрохимического растворения титана в неводных средах. В частности, в качестве электролитов испытаны растворы серной и щавелевой кислот в метиловом спирте. Все реагенты перед использованием обезвоживались под вакуумом, метанол абсолютировался прокаленным сульфатом меди с последующей обработкой магнием и перегонкой. Для предотвращения потерь метанола при электролизе процесс проводился при постоянной температуре 20°C, при этом в горло колбы был вставлен дефлегматор с обратным холодильником, так, чтобы конденсирующийся метанол обратно стекал в колбу. Электролиз в щавелевокислом

растворе возможен при ее концентрациях выше 100 г/л, электропроводность раствора – 600 $\mu\text{S}/\text{cm}$. При этом плотность тока составляет около 2000 A/m^2 . В растворе серной кислоты в метаноле процесс окисления титана идет лучше с образованием органических соединений титана. Таким образом, показана принципиальная возможность электрохимического растворения титана в неводных средах при поляризации импульсным наложением переменного тока.

Также рассмотрено химическое растворение титана без предварительной поляризации с последующим синтезом наноразмерного диоксида титана. Испытаны следующие реагенты: плавиковая кислота, бифторид аммония, соляная кислота, серная кислота. После растворения проводилось химическое или электрохимическое окисление в анодном полупространстве, разделенном анионитовой мембраной с последующим гидролизом с получением гидроокиси титана золь-гель методом [9]. Гидроокись титана отмывалась от побочных солей, сушилась и прокаливалась для кристаллизации титана в форме анатаза. Установлено, что если прокалывание вести при температурах ниже 350 $^{\circ}\text{C}$, то кристаллизации не происходит, и диоксид титана остается в аморфном состоянии.

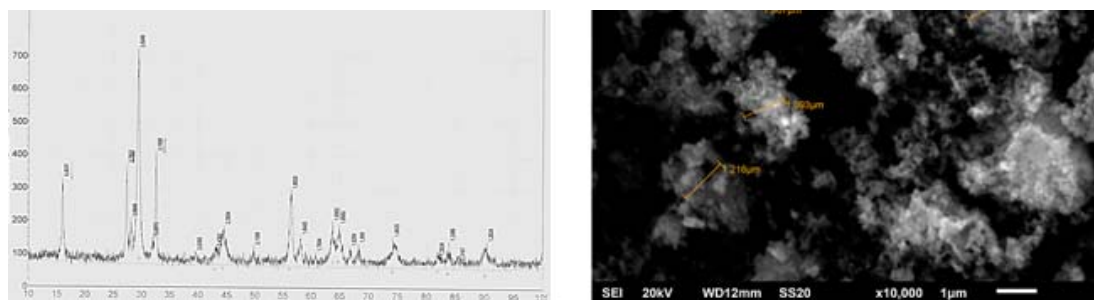
В растворе плавиковой кислоты с концентрацией 46% процесс протекает наиболее интенсивно. Титановая пластина массой 2,7867 грамм на 95% растворилась в течение 30 минут. В результате образовался осадок фиолетово-розового цвета. При продувке воздухом происходит доокисление низковалентных соединений титана до Ti (IV).

Растворение титана в бифториде аммония также идет с заметной скоростью, однако не так интенсивно, как в плавиковой кислоте. Элементный анализ продуктов, полученных из фторидных растворов, приведенный в таблице, показал большое содержание фтора.

Элементный состав

Спектр	O	F	Na	Al	Si	Ca	Ti	Итого
Спектр 1	28,85	16,58	0,67	0,64	0,10	0,22	52,94	100,00
Спектр 2	29,10	16,25	0,68	0,32	0,07	0,26	53,32	100,00
Спектр 3	29,29	15,62	0,63	0,93	0,09	0,23	53,21	100,00
Среднее	29,08	16,15	0,66	0,63	0,09	0,24	53,15	100,00

При рентгенографическом анализе было обнаружено две фазы – диоксид титана в модификации анатаз и оксифторид титана – TiOF_2 . Такой композитный материал является перспективным анодным материалом в литий ионных батареях [10]. На рисунке приведена рентгенограмма полученного образца и его микрофотография.



Рентгенограмма композитного материала и микрофотография

В растворах серной кислоты заметное растворение наблюдается при концентрации кислоты 10 моль/л и выше. При температуре 40 $^{\circ}\text{C}$ растворение прекращалось в течение получаса. При температуре 70 $^{\circ}\text{C}$ и выше растворение титана происходит интенсивно с образованием сульфата трехвалентного титана.

Дальнейшее растворение титана проводилось в концентрированной соляной кислоте 34%, 11М при нагревании от 60 $^{\circ}\text{C}$ и выше. В отличие от серной кислоты растворение протекало без образования осадка и более интенсивно. Элементные составы образцов, полученных из сернокислого и солянокислого растворов, практически идентичны. На рентгенограмме диоксида титана, получен-

ного после прокалки и измельчения, обнаруживается одна фаза диоксида титана в модификации анатаз. Средний размер частиц составил 1-5 мкм, однако видно, что они состоят из более мелких агрегатов. Размер частиц, рассчитанный по формуле Шеррера для полученных образцов, составил 10-30 нм.

По интенсивности (скорости) растворения можно составить следующий ряд: плавиковая кислота – концентрированная соляная кислота при нагревании – растворы серной кислоты при нагревании – бифторид аммония. Наиболее перспективно выглядит применение соляной кислоты, которая обеспечивает высокую скорость процесса и при этом не образуются побочные продукты восстановления. Таким образом, разработаны методы получения нанопорошков диоксида титана анатазной модификации, которые нашли применение для создания эффективных преобразователей солнечной энергии в электрическую.

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SYNTHESIS OF ANATASE MODIFICATION TITANIUM DIOXIDE NANOPOWDERS

The brief report presents the results of the electrochemical dissolution of titanium in non-aqueous media and its chemical dissolution in various electrolytes. Particularly, solutions of sulfuric and oxalic acids in methyl alcohol were tested as electrolytes. All reagents were dehydrated in vacuo before use, methanol was absolutized by calcined copper sulfate, followed by treatment with magnesium and distillation.

Electrolysis in an oxalate acid solution is possible at its concentrations above 100 g/l. So a solution containing 10 g/l of oxalic acid has a specific conductivity of only 87 $\mu\text{S}/\text{cm}$, which is less than that of tap water, electric conductivity of solution with 100 g/l of oxalic acid is 600 $\mu\text{S}/\text{cm}$. At current density of 2000 A/m^2 , electrode voltage was 160 V; during electrolysis for an hour, the current efficiency was 0.73%. Higher values were achieved in a solution of sulfuric acid in methanol. the same current density, voltage on electrolysis cell was 25 V, and the current efficiency was 7.5% in terms of trivalent titanium. Consequently the fundamental possibility of titanium electrochemical dissolution in non-aqueous media during polarization by industrial alternating current is shown.

The chemical dissolution of titanium without prepolarization with the subsequent synthesis of nanosized titanium dioxide is also considered. The following reagents were tested: fluorhydric acid, ammonium bifluoride, hydrochloric acid, sulfuric acid. After dissolution, chemical or electrochemical oxidation was carried out in the anode half-space separated by an anion exchange membrane followed by hydrolysis to obtain titanium hydroxide by the sol-gel method. Titanium hydroxide was washed off from side salts, dried and calcined to crystallize titanium in anatase form. It was found that if calcination is carried out at temperatures below 350°C, crystallization does not occur and titanium dioxide remains in an amorphous state.

In a solution of fluorhydric acid with a concentration of 46%, the process proceeds most intensively. The result was a violet-red precipitate and a green solution with colloidal particles. Titanium dissolution in ammonium bifluoride also proceeds at a noticeable rate, but not as intensively as in fluorhydric acid. Over time, the intensity of dissolution decreases. Elemental analysis of products obtained from fluoride solutions showed a high fluorine content. An X-ray analysis revealed two phases - titanium dioxide in the anatase modification and titanium oxyfluoride - TiOF_2 .

In sulfuric acid solutions, a noticeable dissolution is observed at an acid concentration of 10 mol/l. At a temperature of 40°C, dissolution ceased within half an hour, at the same time, the smell of hydrogen sulfide was felt, and the leaf was uniformly covered with a dense layer of sediment. Further titanium dissolution was carried out in concentrated hydrochloric acid with heating from 60°C and above. In contradistinction to sulfuric acid, dissolution proceeded without formation of precipitation and was more intense. The elemental compositions of obtained samples from sulfate and hydrochloric acid solutions are almost identical. X-ray diffraction pattern shows one phase of titanium dioxide in anatase modification. The average particle size was 1-5 microns; however, it can be seen that they are composed of smaller aggregates. The particle size calculated according to the Scherrer formula for the obtained samples was 10-30 nm.

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