ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫ
Satbayev University

ХАБАРЛАРЫ

ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН
Satbayev University

N E W S

OF THE ACADEMY OF SCIENCES
OF THE REPUBLIC OF KAZAKHSTAN
Satbayev University

SERIES
OF GEOLOGY AND TECHNICAL SCIENCES

3 (447)

MAY – JUNE 2021

THE JOURNAL WAS FOUNDED IN 1940

PUBLISHED 6 TIMES A YEAR

ALMATY, NAS RK

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. Webof 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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«ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы».
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)
Меншіктенуші: «Қазақстан Республикасының Ұлттық ғылым академиясы» РҚБ (Алматы қ.).
Қазақстан Республикасының Ақпарат және қоғамдық даму министрлігінің Ақпарат комитетінде 29.07.2020 ж. берілген **№ KZ39VPY00025420** мерзімдік басылым тіркеуіне қойылу туралы куәлік.
Тақырыптық бағыты: *геология және техникалық ғылымдар бойынша мақалалар жариялау.*
Мерзімділігі: жылына 6 рет.
Тиражы: 211 дана.
Редакцияның мекен-жайы: 050010, Алматы қ., Шевченко көш., 28, 219 бөл., тел.: 272-13-19, 272-13-18
http://www.geolog-technical.kz/index.php/en/

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Типографияның мекен-жайы: «Аруна» ЖК, Алматы қ., Муратбаева көш., 75.

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«Известия НАН РК. Серия геологии и технических наук».
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)
Собственник: Республиканское общественное объединение «Национальная академия наук Республики Казахстан» (г. Алматы).
Свидетельство о постановке на учет периодического печатного издания в Комитете информации Министерства информации и общественного развития Республики Казахстан **№ KZ39VPY00025420,** выданное 29.07.2020 г.
Тематическая направленность: *публикация статей по геологии и техническим наукам.*
Периодичность: 6 раз в год.
Тираж: 211 экземпляров.
Адрес редакции: 050010, г. Алматы, ул. Шевченко, 28, оф. 219, тел.: 272-13-19, 272-13-18
http://www.geolog-technical.kz/index.php/en/

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Адрес типографии: ИП «Аруна», г. Алматы, ул. Муратбаева, 75.

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News of the National Academy of Sciences of the Republic of Kazakhstan. Series of geology and technology sciences.
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)
Owner: RPA «National Academy of Sciences of the Republic of Kazakhstan» (Almaty).
The certificate of registration of a periodical printed publication in the Committee of information of the Ministry of Information and Social Development of the Republic of Kazakhstan **No. KZ39VPY00025420,** issued 29.07.2020.
Thematic scope: *publication of papers on geology and technical sciences.*
Periodicity: 6 times a year.
Circulation: 211 copies.
Editorial address: 28, Shevchenko str., of. 219, Almaty, 050010, tel. 272-13-19, 272-13-18, http://www.geolog-technical.kz/index.php/en/

© National Academy of Sciences of the Republic of Kazakhstan, 2021

Address of printing house: ST «Aruna», 75, Muratbayev str, Almaty.

NEWS
OF THE NATONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5227
Volume 3, Number 447 (2021), 6-11 **https://doi.org/10.32014/2021.2518-170X.54**

ISSN 2224-5227.
UDC 537.523.3:541.13

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DEVELOPMENT OF OPTIMAL CONDITIONS FOR OBTAINING OZONE FOR DECONTAMINATION OF WAREHOUSE AIR

Abstract. The object of the research is the development of optimal conditions for the creation of the ozone elements. He provides decontamination of warehouse air. The aim of the work is the safety of food and non-food products when treated with ozone. This article presents the calculations and development of a mathematical model of the optimal characteristics of innovative technical means for producing ozone. Ozone is designed to neutralize mold fungi, harmful and toxic waste in various industries of the Republic of Kazakhstan. All over the world, both in the near and far abroad, aconsumeruse of the ozone elements for cleaning and decontamination air, water and food products. Ozone has an oxide ability, a powerful bactericidal effect, neutralizes various types of mold fungi and yeast, toxic components, etc. This article discusses the optimal conditions for the production of ozone in ozone devices. The authors develop small-sized ozone devices that will reduce energy and capital costs for the technological lain by 5-10 times compared to foreign analogues. The creation of small-sized ozone devices is achieved due to the production of ozone as a result of a corona discharge from a micro wire whose diameter does not exceed 100 microns. The material for the article on the use of ozone in the agricultural sector, light industry and other industries that ensure the safety of food and non-food products was the research of scientists from near and far abroad, as the work of the authors. The article includes the results of calculations for obtaining the optimal dimensions of corona wires. Depending on the demand for ozone, not only the size, but also the number of ozone cells devices calculated. To vary the size and other parameters of the ozone cells, a mathematical modeling technique was used, which allowed us to obtain the current-voltage characteristics of the ozone cell. To control the mode of the ozonator, a circuit with a control unit is developed.

Key words: ozone, corona discharge, air, room, characteristics, model.

Introduction. All over the world, people are concerned about the microbiological purity of the air in industrial and warehouse premises, such as the textile, woodworking, agricultural sector, etc. In concentrations exceeding the recommended norms, bacteria and mold fungi contribute to the development of many infectious diseases, various mycoses, and provoke allergic reactions [1-3].

The volume of production and consumption of food products by the world's population is growing every year. The Republic of Kazakhstan is one of the countries with a developed system of agro-industrial complex, where there is an annual increase in the number of farm animals and the volume of seed produced [3-5].

As for the production and storage facilities of textile, woodworking and other industries, their processing is of great importance for human health. Issues of labor protection at modern enterprises, including textile ones, are one of the most important problems today, where the main direction is to clean the air from dust and toxic components. Dust is formed during sorting, machining and transportation of various fibrous materials: cotton, flax, hemp, wool, synthetic fibers, etc. [6-9].

Food safety is a public health issue that continues to grow in importance. Governments around the world are stepping up efforts to improve food safety [6]. Therefore, the issues of microbiological cleanliness of the air at various enterprises, processing of products are very relevant.

Novelty. In Kazakhstan, a group of scientists has been engaged in the use of ozone for a long time, which together with colleagues from Uzbekistan conducts research in four areas: air purification of premises of various industries, purification of drinking and waste water, treatment and disinfection of textile materials and food products, as well as storage facilities manufactured goods.

To determine the effect of ozone on the improving safety of industrial premises and warehouses of finished products, the study was carried out using the OAC-1 air ozone device developed by the authors.

Studies have found that a decrease in air pressure in the discharge gap does not affect the process of come out ozone format, on the contrary, it leads to an increase in ozone output at low energy consumption [3-6].

The small dimensions of the corona electrodes, the diameter of which does not exceed 100 microns, will significantly reduce the metal consumption of the device, the capital costs of the plant for processing agricultural products, the costs of the technological line will be 5-10 times lower compared to analogues [7].

One of the important advantages of the ozone device is the absence of air treatment, which significantly reduces the cost of processing products [10]. One of the types of the developed model is an ozone device element for the treatment of atmospheric air and can be used for disinfection and sanitation of air in industrial and office premises, as well as for disinfection of drinking and wastewater. Figure 1 shows a diagram of the model. Ozone device element contains the frame of fluoric, (fluorine) plastic 1 with windows 2 for free access of air, the rod of fluoric plastic 3 coaxially disposed in the housing, the coil of copper wire 4 is wound on the rod, corona wire of tungsten or molybdenum in the form of helix 5, located on top of the first winding 4 and terminals K1, K2, K3 to connect ozone device item with a power source [11-16].

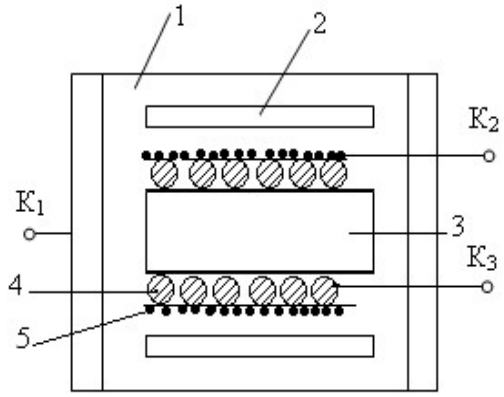

Figure 1-Ozonating element

An alternating voltage of sufficient magnitude is applied to the terminals K2, K3 of the ozone element, after which a corona-barrier discharge occurs in the gaps between the turns of the first winding, leading to the formation of ozone in the atmospheric air [16-18].

Methods. To select the optimal operating conditions of the ozone element, a mathematical model was developed for selecting the diameter of the corona wire, step and inter-turn distance.

The description of the model [14-16]:

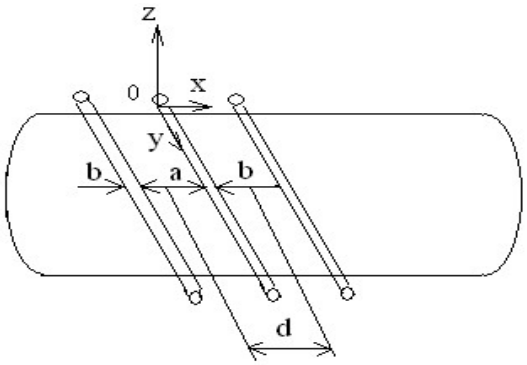

Figure 2 – Section of the ozone cell

1. Analysis of the results of theoretical calculations of the functions Ex = f(z, x, τ, a, b, d); Ez = f (z, x, τ, a, b, d) of the corona-barrier discharge fields, here Ex, Ez, z, x, τ, a, b, d – respectively x and z components of the field strength; components of the radius of the equipotent line, where the potential is sought; the charge per unit length of the charged wire τ; the inter-turn distance a; the diameter of the corona electrode b; the step of the spiral d (figure 2) [14].

2. Planning of a multi-factor element for a preliminary assessment of the mechanical and electrical values of the design of the proposed ozone element on the corona and corona-barrier discharge.

3. Identification and restriction as a result of a multivariate experiment of the range of changes in variables and constants that characterize the working version of the model.

4. Determination of the calculated analytical dependencies taking into account the multivariate experiment and the identified limitations in order to eliminate a number of parameters appearing in the theoretical formula.

5. Finding the analytical dependences of the calculated values through the main varying parameters.

6. Introduction of the found analytical dependences and constants into the theoretical formula, its transformation into an engineering formula, and comparison of the calculation results, error estimation.

$$E_x = 2\tau C + \tau B\left\{e^{-S}\frac{2\pi sinG}{dsinG} + e^{-2S}\frac{4\pi sin2G}{dsin2G}\right\},$$

$$E_z = 2\tau F + \tau B(e^{-S}2\pi ctgG + e^{-2S}4\pi ctg2G), \quad (1)$$

where: $B = \frac{4\pi a\left(1-2ln\frac{a}{b}\right)}{d} C = \frac{X}{Z^2+X^2}; G = \frac{2\pi X}{d}; F = \frac{Z}{Z^2+X^2}; S = \frac{2\pi|Z|}{d}; x = r_0; z = r.$

where: $\tau = \frac{2\pi\varepsilon U_0}{ln\frac{d}{r_0}} = 27.3$ –the charge per unit length of the wire.

Substituting the values E_X, E_Z of the field strength:

$$E_{xz} = \sqrt{E_x^2 + E_z^2} = 163.75 \text{ V}.$$

$$E_x = 2 \cdot 0.071 \cdot \tau + (-17.8)\left(0.04 \cdot \frac{2\pi}{a} + 0.0025 \cdot \frac{4\pi}{a}\right),$$

$$E_z = 2 \cdot 0.37 \cdot \tau + \tau(-17.8)\left\{0.04 \cdot \frac{2\pi}{a} ctg\frac{\pi a}{a} + 0.0025 \cdot \frac{4\pi}{a} ctg\frac{2\pi a}{a}\right\} \quad (2)$$

where: $\tau = \frac{2\pi\varepsilon U_0}{ln\frac{d}{r_0}} = 27.3$ the charge per unit length of the wire.

Substituting the values EX ,EZof the field strength: $E_{xz} = \sqrt{E_x^2 + E_z^2} = 163.75$ V.

Conclusions. As a result of the simulation, the block diagram shown in Figure 3 was compiled [14].

The above theoretical studies of the function E for the design of the OKR type us to establish the intervals of change in the main electrical parameters of the field: for U_0 = -1 kV; x = 0.005 cm; z = 0.026 cm; Ex = -88.57 kV/cm; Ez= -137.7 kV/cm; E = 163.75 kV / cm[14-23].

The digital values of the fixed and calculated values are entered into an intermediate formula for determining the components of the electric field strength, the main varying factors in which are the initial values of the diameter, the inter-turn distance, the spiral step, the radius of the equipotent line, where the potential is sought, the radius of the wire, the potential on the surface of the wire, the charge per unit length of the charged wire(Figure 3) [14].

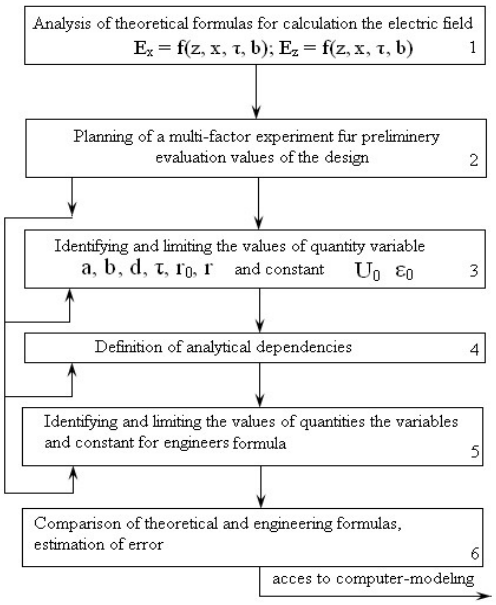

Figure 3 - Structure of the mathematical model

Result. Based on the simulation results, an algorithm and a program for calculating the operating parameters and modes (table).

Current-voltage characteristics of the corona-discharge system depending on the number of tubes

$U_{датр.}$ В		0	20	40	60	80	100	120	150
1 tube	U_1, В	0	1	2,2	3,8	5	5,2	5,80	6,4
	$I_{1к}$, мкА	0	9	20	34	45	47,27	52,72	58,18
2 Tubes	U_2, В	0	0,8	3	4,8	6,40	8	10	12
	$I_{2к}$, мкА	0	7,27	27	43	58	72	90	109
3 Tubes	U_3, В	0	1	3,2	5	7	8,2	10,3	12,5
	$I_{3к}$, мкА	0	9	29	45	63	75	93,6	113
4 Tubes	U_4, В	0	1,3	3,7	5,2	7,7	8,2	10,3	12,6
	$I_{4к}$, мкА	0	11,82	33,64	47,27	70	74,54	93,64	114,54

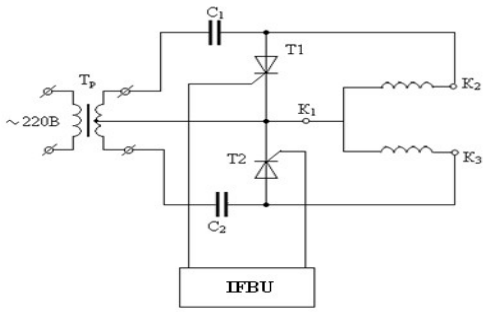

Figure 4 – The scheme of automatic control of the ozone device

The current-voltage characteristics of the ozone device depending on the external conditions and the parameters of the discharge gap are obtained experimentally (figure 5) [16-23].

The scheme of automatic control of the ozonator is shown in Figure 4, where the data obtained as a result of modeling and calculation are set in the pulse-phase control unit of the IFBU, controlled thyristors T1 and T2 are used for voltage conversion. The pulse to the control electrodes of the thyristors is supplied from the control unit and the IFBU.

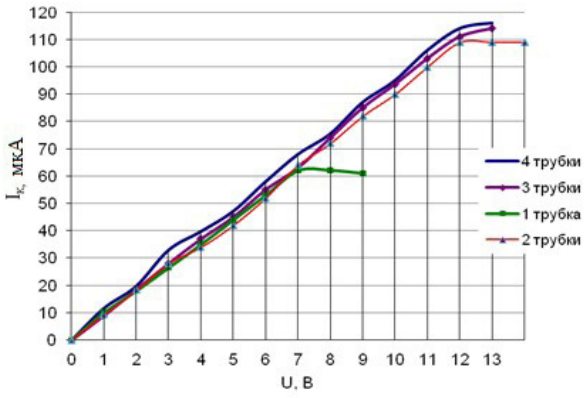

Figure 5- Current-voltage characteristics of corona-discharge devices

Tests of the prototype OAC-1 were performed in the laboratory conditions of the Kazakh Republican Sanitary and Epidemiological Station (KRSES).

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ҚОЙМАЛАРДЫҢ АУАСЫН ЗАЛАЛСЫЗДАНДЫРУ ҮШІН ОЗОН АЛУДЫҢ ОҢТАЙЛЫ ШАРТТАРЫН ӘЗІРЛЕУ

Аннотация. Зерттеу нысаны-сақтау бөлмелерінің ауасын зарарсыздандыруды қамтамасыз ететін озон элементін құру үшін оңтайлы жағдайларды жасау. Жұмыстың мақсаты-озонмен өңдеу кезінде азық-түлік және азық-түлік емес өнімдердің қауіпсіздігі. Бұл мақалада озон алуға арналған инновациялық техникалық құралдардың оңтайлы сипаттамаларының математикалық моделін есептеу және дамыту келтірілген. Озон Қазақстан Республикасының әр түрлі өнеркәсіп салаларындағы зең саңырауқұлақтарын, зиянды және уытты қалдықтарды бейтараптандыруға арналған. Бүкіл әлемде, жақын және алыс шетелде, озонаторлар ауаны, суды және тамақ өнімдерін тазарту және зарарсыздандыру үшін қолданылады. Озон күшті тотығу қабілетіне ие, күшті бактерицидтік әсерге ие, зең мен ашытқының әртүрлі түрлерін, улы компоненттерді және т. б. бейтараптандырады. Авторлар шетелдік аналогтармен салыстырғанда технологиялық желінің энергетикалық және күрделі шығындарын 5-10 есе азайтуға мүмкіндік беретін шағын озонаторларды жасайды. Шағын өлшемді озонатор құрылғыларын құру диаметрі 100 микроннан аспайтын микро сымнан тәждік разряд нәтижесінде озонды алу нәтижесінде қол жеткізіледі. Озонды аграрлық секторда, жеңіл өнеркәсіпте және азық-түлік және азық-түлік емес өнімдердің қауіпсіздігін қамтамасыз ететін басқа салаларда қолдану туралы мақаланың материалы жақын және алыс шетел ғалымдарының зерттеулері, сондай-ақ авторлардың жұмыстары болды. Мақалада тәж сымдарының оңтайлы мөлшерін алу үшін есептеу нәтижелері келтірілген. Озонның қажеттілігіне байланысты тек мөлшері ғана емес, сонымен қатар озонатор жасушаларының саны да есептеледі. Озон жасушаларының өлшемдері мен басқа параметрлерін өзгерту үшін математикалық модельдеу әдісі қолданылды, бұл озон жасушасының вольт-ампер сипаттамаларын алуға мүмкіндік берді. Озонатор режимін басқару үшін басқару блогы бар схема жасалды.

Түйін сөздер: озон, тәжді разряд, ауа, бөлме, сипаттамалары, моделі.

УДК 537.523.3:541.13

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РАЗРАБОТКА ОПТИМАЛЬНЫХ УСЛОВИЙ ПОЛУЧЕНИЯ ОЗОНА ДЛЯ ОБЕЗЗАРАЖИВАНИЯ ВОЗДУХА СКЛАДОВ

Аннотация. Объектом исследования является разработка оптимальных условий для создания озонирующего элемента, обеспечивающего обеззараживание воздуха складских помещений. Целью работы является безопасность продовольственных и непродовольственных продуктов при обработке озоном. В данной статье приведены расчеты и разработка математической моделиоптимальных характеристик инновационных технических средств для получения озона. Озон предназначен для нейтрализации плесневых грибков, вредных и токсичных отходов в различных отраслях промышленности Республики Казахстан. Во всем мире, как в ближнем, так и дальнем зарубежье, для очистки и обеззараживания воздуха, воды и пищевых продуктов используют озонаторы. Озон обладает сильной окислительной способностью, мощным бактерицидным действием, нейтрализует различные

виды плесневых грибков и дрожжей, токсичные компоненты и т.п. В данной статье рассматриваются оптимальные условия для выработки озона в озонирующих устройствах. Авторы разрабатывают малогабаритные озонаторы, которые позволят снизить энергетические и капитальные затраты на технологическую линию в 5-10 раз по сравнению с зарубежными аналогами. Создание озонаторных устройств малых габаритов достигается вследствие получения озона в результате коронного разряда с микропроволоки, диаметр которой не превышает 100 микрон. Материалом для статьи о применении озона в аграрном секторе, легкой промышленности и др. отраслях, обеспечивающего безопасность продовольственных и непродовольственных продуктов явились исследования ученых ближнего и дальнего зарубежья, а также работы авторов. В статью вошли результаты расчетов для получения оптимальных размеров коронирующих проволок. В зависимости от потребности в озоне рассчитаны не только размеры, а также количество озонаторных ячеек. Для вариации размеров и других параметров озонирующих ячеек была применена методика математического моделирования, что позволило получить вольт-амперные характеристики озонирующей ячейки. Для управления режимом озонатора разработана схема с блоком управления.

Ключевые слова: озон, коронный разряд, воздух, помещение, характеристики, модель.

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NEWS
OF THE NATONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5227
Volume 3, Number 447 (2021), 12-16 **https://doi.org/10.32014/2021.2518-170X.55**

УДК 125 875 5

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МЕТОДЫ РАСЧЕТА НАДЕЖНОСТИ КОНСТРУКЦИИ ОГРАЖДЕНИИ ПОЛОС ВСТРЕЧНЫХ ДВИЖЕНИЙ ТРАНСПОРТА

Аннотация. В статье рассматриваются вероятностные методы расчёта защитных ограждений автодорог на основе теории предельных состояний конструкций. При этом расчетные схемы представлены в виде многопролетной неразрезной балки и рамы. Рамная расчетная схема рассмотрена в различных вариантах: жесткое соединение профильного листа со стойками с жесткими опорами, шарнирные соединения профильного настила с защищенными стойками, жесткое соединение со стойками с шарнирными опорами. Все задачи, доведенные до определения предельного состояния. Ограждающие конструкции в основном предназначены для обочины дорог, но их можно использовать и как разделительные полосы движения. Выполнен динамический расчет стойки с профильным листом, при этом расчетная схема определена как цепь с двумя стяжками свободы.

Ключевые слова: дорожные защитные ограждения теория надежности профилированный лист и динамические расчеты обочины дороги разделительная полоса.

Ежегодно на автомобильных дорогах СНГ в результате дорожно-транспортных происшествий (ДТП) погибает до 100 000 человек [1]. Например, за 9 месяцев 2020г. в Казахстане из-за дорожных происшествий погибло 1265 человек, пострадало 11780 человек. Поэтому проблемам разработки мероприятий, снижающих аварийность на дорогах во всём мире, уделяется огромное внимание.

Следствием этого является изменение характера взаимодействия автомобиля с ограждением: боковой скользящий удар преобразуется в косой фронтальный, при котором энергия соударения увеличивается в несколько раз. В результате происходит последовательное разрушение нескольких стоек, опускание балки на поверхность дороги и выезд автомобиля за ограждение (рисунок 1).

Рисунок 1 - Характер повреждения профильных ограждений автомобильных дорог.

На дорогах Республики Казахстан получили большое распространение барьеры безопасности, собранные из гнутого листа с размерами поперечного сечения 312х84х4мм

Использование такой балки в сочетании с упруго-хрупкими стойками, расположенными через 4м, каждая из которых воспринимает реакцию около 30-35кН, приводит к возникновению отдельного значительного поперечного прогиба балки в нагруженном пролете.

Ограждающий разделитель полос автомобильных дорог состоит из парных профилированных стальных листов, расположенных параллельно-горизонтально в

середине вдоль дороги и закрепленных к стойкам на расчетной высоте. Соединение листов со стойками осуществляется при помощи коротких пластинок и косорасположенных вертикальных арматурных каркасов. Стойки в плане установлены в шахматном порядке на расчетном расстоянии (рисунок. 2).

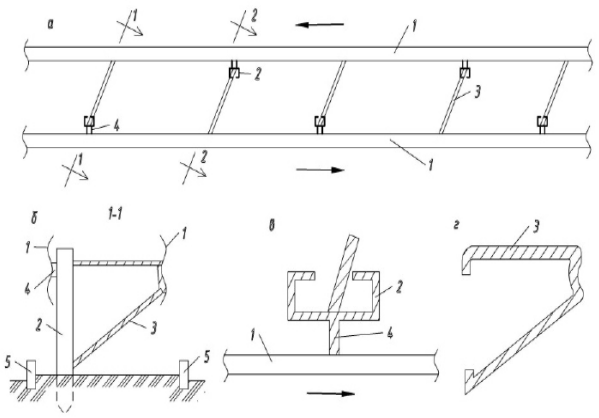

Рисунок 2 - Разделитель полос автомобильных дорог.
а - разделитель полос в плане; б - сечение 1-1 - схемы расположения разделителя в разрезе; в - схемы соединения элементов; г - арматурный каркас: 1 -профилированный лист; 2 -стойка; 3 - арматурный каркас; 4 - соединительная пластина-кронштейн; 5 - бордюр дороги.

Поперечное расстояние между осями стоек устанавливается по нормативным требованиям. Профилированные листы расположены с двух сторон стоек и закреплены к ним двумя способами: к одной стойке через вертикальные пластинки – в виде кронштейна, а к другой смежной стойке – через косоустановленный арматурный каркас. Причём один свободный конец арматурного каркаса закрепляется непосредственно к верхней части стойки, а второй свободный конец – к заделке стойки, а фигурная средняя часть косорасположенного арматурного каркаса закрепляется непосредственно к противоположным профнастилам.

В последние десятилетия в теорию расчёта строительных конструкций стали внедряться вероятностные методы. Одновременно с корректировкой существующих методов они предлагают новое содержание критерия качества - вероятность безотказной работы или надёжность конструкций [4]. В связи с постоянно уменьшающейся материалоёмкостью конструкций их надёжность снижается; определить, насколько она снизилась и каково её численное значение - это первая задача теории надёжности, отражающая аспект безопасности.

В условиях технического прогресса очень быстро происходит моральное старение сооружений – значительно быстрее, чем раньше. Сделать сооружение таким, чтобы оно исчерпало свою надежность точно к моменту его морального устаревания - это вторая задача теории надежности, отражающая экономические аспекты.

Таким образом, безопасность и экономичность являются важнейшими аспектами практики строительства, а количественное их определение - задача актуальная и необходимая.

Вероятность разрушения при нормальном законе распределения ζ может быть вычислена по формуле проф. А.Р. Ржанинына [2].

$$V=0{,}5-\phi(\gamma), \quad (1)$$

где $\gamma=(\bar{R}-\bar{\zeta})/(\sqrt{(R^{\wedge}+\zeta^{\wedge})}$ – характеристика безопасности (табл.1).

Таблица 1

V	0.1	0.01	0.001	0.0001	$3.2*10^{-5}$	$3.2*10^{-6}$	$3.2*10^{-7}$
γ	1.28	2.32	3.15	3.77	4	4.5	5

Значение $\gamma>5$ можно считать очень большими и соответствующими крайне малой вероятности разрушения. Определение V по формуле (1) при больших γ затруднительно, и в этом случае рекомендуется применять асимптотическую формулу.

$$V=\frac{1}{\sqrt{2\pi}}\frac{\gamma^2-1}{\gamma^3}exp\frac{-\gamma^2}{2}. \quad (2)$$

А.Р. Ржаницын предложил вероятность безотказной работы конструкции P (t) за заданный срок службы n лет определять как вероятность неравенства.

$$R-\zeta_n>0, \quad (3)$$

где ζ_n- нагрузка, которая может возникнуть в течение расчетного срока службы; R - характеристика прочности конструкции, выраженная в тех же единицах и отвечающая предельному состоянию конструкции по прочности.

Разность $Z=R-\zeta_n$ определяет резерв прочности конструкции.

При Z=0 означает, что достигнуто предельное состояние, при Z<0 наступает отказ. а Z≥0 безотказная работа.

В статье задачи надежности решается в стадии наступления предельного состояния конструкции. Метод предельных состояний базировался на исследование русских учёных Н.С. Стрелецкого, Ж.Гуле [3], В.Л.Бидерман [9], А.В. Перельмутер, В.М. Келдыша [8], Демьянушко И.В. [5] и др. В дальнейшем расчет по предельным состояниям завоевал широкое признание во всём мире и в настоящее время он положен в основу из стандарта ISO-2394 и системы Еврокодов, где получил название

«метод частных коэффициентов надежности». Для раскрытия несущей способности системы использован кинематический метод, который основан на исследовании энергии, рассеиваемой при образовании различных кинематический допустимых механизмов разрушения.

Решение получается путем приравнивания работы внутренних ($M_F \cdot \varphi$) и внешних сил ($P \cdot \delta$).

В общем виде уравнение имеет вид

$$\sum P_{t,пр}\ \delta\_i - \sum M_{k,пр}\ \varphi_k = 0 \ \text{ или } \sum M_{k,пр}\ \varphi\_k = \sum P_{t,пр}\ \delta_i, \qquad (4)$$

где φ_k - углы поворота стержнейb пластических шарнирах; δ_i - линейные перемещения точек приложения соответствующих нагрузок (перемещение считаются малыми); i и k— порядковые номера нагрузок и предельных моментов соответственно.

Из полученной системы уравнений выбирается тот, который дает наименьшую величину нагрузки. При упругом пластическом расчёте вместо действительный диаграммы растяжения сжатия принимается диаграмма Прандтля.

Зарубежные ученые А. Рыжиньски [2] экспериментально, и Т. Нокака теоретически доказали, что с точки зрения практики влияние нормальных сил на несущую способность конструкции несущественно и, следовательно, в обычном расчёте его можно не учитывать.

Упрощения расчета обуславливается тем, что в отдельных элементах системы внутренние усилия задолго до разрушения принимают постоянные значения, не зависящие от деформаций этих элементов. Рассмотрим расчет стоек на динамические воздействия, при этом выполняем расчёт как для системы с одной и с двумя степенями свободы (рисунок. 3).

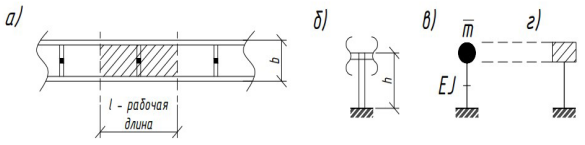

Рисунок 3 - К разработке динамических расчетных схем опорных стен.

а - фрагмент общего вида разделителя полос в плане; б - поперечный разрез; в - расчетная схема с одной степенью свободы; г - тоже, с двумя степенями свободы.

Система с одной степенью свободы (рисунок 3в).

Круговая частота ω линейных колебаний системы с одной степенью свободы определяется при наличии одной массы по следующим формулам:

$$\boldsymbol{\omega} = \sqrt{\frac{r_{11}}{m}} = \sqrt{\frac{r_{11}g}{P}} = \sqrt{\frac{g}{\delta_{ст}}} = \sqrt{\frac{1}{m\delta_{11}}}, \qquad (5)$$

Период колебаний (продолжительность одного цикла колебаний) - по формуле: $\boldsymbol{T=2\pi/\omega}$,

где $\boldsymbol{m}$-сосредоточенная масса; $\boldsymbol{r_{11}}$ - жёсткость упругой связи, на которой закреплена масса m, т.е. её реакция при статически единичном перемещение массы; $\boldsymbol{g}$-ускорение силы тяжести, $\boldsymbol{g=9,81}$ м/сек^2; $\boldsymbol{P=mg}$ - величина груза, имеющего массу m;δ_0- статическое перемещение под грузом $\boldsymbol{P}$;$\boldsymbol{\delta_{11}}=1/\boldsymbol{r_{11}}$ - статическая массы от единичной силы приближённой к ней.

Для систем, работающих на изгиб на растяжение и сжатие:

$$\boldsymbol{\delta_{11}} = \sum \int \frac{M_1^2 dS}{EJ}; \boldsymbol{\delta_{11}} = \sum \frac{N_1^2 S}{EF} \qquad (6)$$

Единичный прогиб под массой m по условию задачи:

$$\boldsymbol{\delta_{11}} = \frac{h^2}{3EJ}; \text{ круговая частота } \boldsymbol{\omega} = \sqrt{\frac{3EJ}{mh^3}} \qquad (7)$$

Теперь рассмотрим расчет стойки с двумя степенями. Допустим на стойки высотой h закреплен собранный груз с массой m, центр тяжести которого расположен в точке $\boldsymbol{C}$ (рисунок 4а). Момент инерции груза относительно перпендикулярной плоскости чертежа оси, проходящей через точку $\boldsymbol{C}$, равен $\boldsymbol{I}$ (для определенности примем $\boldsymbol{I=ml^2/8}$). Определить частоты и формы собственных колебаний [6].

Система имеет две степени свободы, соответствующие вертикальному перемещению точки С и поворота груза. Обозначим $\mathbf{u_1}$ и $\mathbf{u_2}$- амплитудные значения перемещений (рисунок 4б).

Инерционная сила и момент сил инерции составляют:

$$\boldsymbol{F = \omega^2 m u_1}, \quad \boldsymbol{M = \omega^2 I u_2}. \qquad (8)$$

Уравнения динамического равновесия (в обратной форме) имеют такой вид:

$$\boldsymbol{u_1 = F\delta_{11} + M\delta_{12}}, \ \boldsymbol{u_2 = F\delta_{21} + M\delta_{22}}. \qquad (9)$$

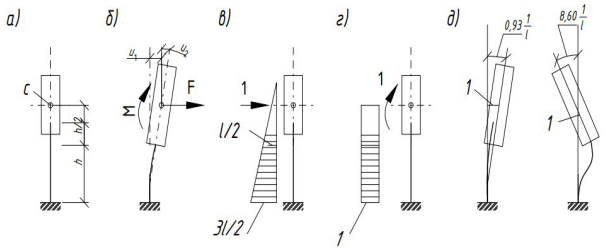

Рисунок 4 - К расчету стойки с профлистом.
а - расчетная схема; б - формы деформации (степень свободы); в, г - единичные эпюры моментов; д - формы колебаний (соответственно первая и вторая).

Коэффициенты влияния находим, перемножая эпюры, соответствующие единичным нагрузкам (рисунок 4 в, г):

$$\boldsymbol{\delta_{11}} = \frac{13l^3}{12EJ}, \boldsymbol{\delta_{12}} = \boldsymbol{\delta_{21}} = \frac{l^2}{EJ}, \boldsymbol{\delta_{22}} = \frac{l}{EJ}. \qquad (10)$$

Подстановка этих значений в равенства (40) приводят к уравнениям

$$\boldsymbol{zu_1} = \mathbf{13}\boldsymbol{u_1} + \mathbf{12}\boldsymbol{\vartheta l u_2},\ \boldsymbol{zu_2} = \frac{\mathbf{12}\boldsymbol{u_1}}{\boldsymbol{l}} + \mathbf{12}\boldsymbol{\vartheta u_2}, \qquad (11)$$

где для сокращения обозначены

$$\boldsymbol{z} = \frac{\mathbf{12}\boldsymbol{EJ}}{(\boldsymbol{ml^3\omega^2})};\ \boldsymbol{\vartheta} = \boldsymbol{I}/(\boldsymbol{ml^2})$$

Формы колебаний показаны на рисунке 4 д.

Условие ортогональности в данном случае имеет вид

$$\boldsymbol{mu_{11}u_{12}} + \boldsymbol{Iu_{21}u_{22}} = \boldsymbol{m}\cdot\mathbf{1}\cdot\mathbf{1} + \left(\frac{\boldsymbol{ml^2}}{\mathbf{8}}\right)\left(\frac{\mathbf{0,93}}{\boldsymbol{l}}\right)\left(-\frac{\mathbf{8,60}}{\boldsymbol{l}}\right) = \mathbf{0}.$$

Статистические методы расчёта на безопасность, по нашему мнению, наряду с уточнением формул и методов, определяющих разрушающие состояния, должны лечь в основу новых усовершенствованных методов расчета сооружений [7]. Статистические методы дадут возможность полностью и эффективно использовать экономию, получающуюся в результате повышения качественных показателей автодорожного строительства.

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КӨЛІКТІҢ ҚАРАМА-ҚАРСЫ ҚОЗҒАЛЫСЫ ЖОЛАҚТАРЫНЫҢ ҚОРШАУ ҚҰРЫЛЫСЫНЫҢ СЕНІМДІЛІГІН ЕСЕПТЕУ ӘДІСТЕРІ

Аннотация. Мақалада автокөлік тежегісіне қойылатын қоршау құрастырғыштардың сенімділігін ықтыймал теория арқылы есептеудің тәсілдері берілген. Есептеу сұлбасын көп аралықты үздіксіз сәуле және рама түрінде ұсынылған. Рама сұлбасының бірнеше түрлері қарастырылған:
профиль кесіндісі арқалы қысқа арқалық қатты бекітілген, арқалық жер негізіне қатты қондырылған және профильді арқалық қатты бекітілген тірегі бар арқалыққа топса арқылы жалгастырылған, профильді арқалық тірегі топсалы арқалыққа қатты бекітілген. Әр арқалыққа кинематикалық тәсілмен қиратын күштердің мәндері анықтаған. Осылардың сенімділік сипаттамалары ықтымал тәсілі арқылы есептелініп қасиеттері салыстырылған және тиімділігіне кесте арқылы көрсетілген. Қоршау конструкциялары негізінен жол жиегіне арналған, бірақ оларды бөлу жолақтары ретінде де қолдануға болады. Профильді арқалығы бар устаның тербелісін табу үшін динамика саласының "еркімдік теориясы" қолданылды.

Түйін сөздер: жол жғасының қоршауы, сенімділік теориясы, профильді тактайша қалқан, тербеліске есептеу, жол айыршасы, ықтыймал теориясы.

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METHODS FOR CALCULATING THE RELIABILITY OF THE CONSTRUCTION OF ONCOMING TRAFFIC LANES

Abstract: The article discusses probabilistic methods for calculating road safety barriers based on the theory of limit states of structures.In this case, the design schemes are presented in the form of a multi-span continuous beam and frame.The frame design scheme is considered in various variants: rigid connection of the profile sheet with posts with rigid supports, hinged connections of the profile flooring with protected posts, rigid connection with posts with hinged supports. All tasks brought to the determination of the limit state. Fencing structures are mainly designed for roadsides, but they can also be used as dividing lanes. A dynamic calculation of a rack with a profile sheet is performed, and the design scheme is defined as a chain with two freedom ties.

Key words: road safety barriers reliability theory profiled sheet and dynamic calculations of the with two freedom ties.

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NEWS
OF THE NATONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5227
Volume 3, Number 447 (2021), 17-21 **https://doi.org/10.32014/2021.2518-170X.56**

УДК 629.73"313"

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DESIGN FEATURES OF MODERN FLIGHT SIMULATION DEVICES, MOBILITY SYSTEMS AND VISUALIZATION SYSTEMS

Abstract. The aviation system is a complex and dynamic structure, the parts of which interact with each other, affect each other, and their interaction should be as safe as possible. The safe functioning of this system ultimately depends on the lives of people, both in the air and on the ground. Training and retraining of pilots, as you know, goes in several stages, and simulator training takes a significant and unconditional place in the ground training of future pilots. During the simulator training, the pilot acquires, maintains and improves practical skills and abilities with the help of devices that simulate the cockpit and flight of the aircraft.

Keywords: aviation technology, simulator, flight simulation, mobility systems, visualization systems, safety.

The use of so-called simulation dynamic stands-simulators or dynamic simulators for training pilots, dispatchers and other specialists associated with the safe operation of aircraft in real conditions makes it possible to be at the helm of the aircraft. To feel in real time, without threat to life, its virtuality and its probable abilities, and the admissibility of sensations in piloting and control. The simulators are capable of simulating certain situations, various meteorological conditions and special cases when moving on the ground, in flight, as well as simulating the operation of aircraft systems using special models implemented in the software of the simulator's computer complex. They are economical, reliable, and most importantly, safe, since a real flight is always associated with a certain risk, and especially when the pilot who controls it is not experienced. With the help of simulators, you can work out many emergency situations, even those that are not provided for by legislative acts and flight manuals. In accordance with the Order of the Minister for Investments and Development of the Republic of Kazakhstan dated June 5, 2018 No. 431 "On Amending the Order of the Minister of Transport and Communications of the Republic of Kazakhstan dated September 28, 2013 No. 764" flight safety ”simulator training on an integrated flight simulator is performed at least once every 6 months, in the amount of 12 hours and at least once every 3 months in the amount of 6 hours [1].

Today, simulators are used to train and maintain a professional level, both in civil and military aviation, and the demand for simulator training is increasingly important, since the human factor still continues to be the main cause of aviation accidents and incidents. It should also be noted that the development of aviation technology and software made it possible to bring the technical capabilities of simulators to such a level of perfection that training on simulators becomes more effective than training on a real aircraft. Of great importance in the modern process of training and retraining of pilots and maintaining their professional skills is the fact that an aviation simulator allows you to save significant financial resources in view of the fact that the cost of operating a real aircraft significantly exceeds the cost of operating a simulator (despite the high cost of modern simulators, approaching the cost of the aircraft themselves).

In addition to training purposes, modern simulators can also be used for scientific purposes, for example, to determine the procedure algorithm in case of violation of the flight parameters specified in the aircraft flight manual. In military aviation, simulators are capable of simulating a combat situation, the use of any aircraft weapons of destruction of the enemy, which are difficult to implement in the course of military exercises.

There are three types of simulators: tactical simulators called Full Mission Simulator, complex simulators - Full flight simulator, and procedural simulators - Flight Procedures Training Device. Most often, complex and procedural simulators are used in civil aviation. On procedural simulators, pilots acquire the skills to perform procedures for preparing and performing a flight, procedural simulators do not provide an opportunity to acquire piloting skills, while integrated simulators are able to provide training for a student in functional duties in aircraft control.

Complex simulators are very complex systems. They are able to simulate the movement of an aircraft, both along the take-off field and in flight. They have mobility systems or so-called acceleration simulators that set the cab in motion, which allows you to feel the created vertical, longitudinal and lateral overload

and angular accelerations along all three axes, in addition, it is possible to simulate movement.

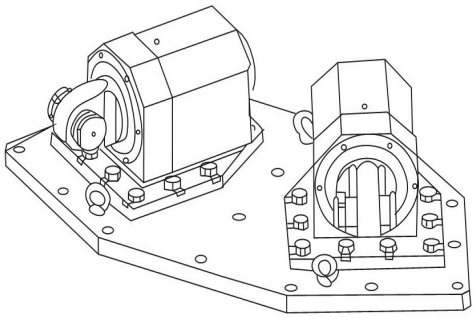

Figure 1. Paired gimbal of the mobility system.

The control of the mobility system comes from the control stand, which includes: a control computer with drive links of the mobility system for settings and adjustments; drive link control crate; uninterruptible power supply; software.

Since the simulator platform is limited in its stroke, the overload can only be reproduced for a limited amount of time, but even this time is sufficient for the pilot to be informed of the change in overload caused by a control error.

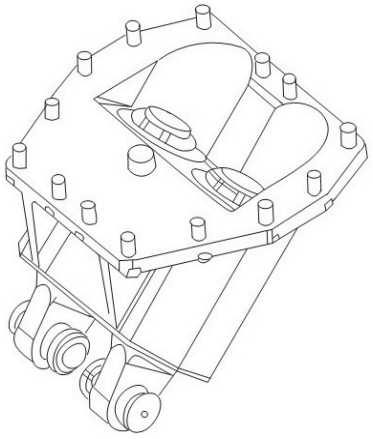

Figure 2. Lower gimbal.

	Name of characteristic	Units of measurement	Value of characteristic	Note
1	Maximum consumed electric power	kw	90	
2	Carrying capacity	Kg	9000	
3	Maximum linear displacements of PDS (operational)	m		The characteristic value must be at least as specified in the table.
	longitudinal X			
	vertical Y		+1,38..1,07	
	transverse Z		+0,88...-1,01±1,12	
4	Maximum angular displacements of PDS (operational)	degree		
	longitudinal X		±24,9	
	vertical Y		±27,9	
	transverse Z		+25…-29	
5	Maximum travel speeds along each of the three axes of rotation of the PDS	m/s	0,6	The maximum movement speed of the PDS is created by a harmonic signal with an amplitude of 0.2 m and a frequency at which the PDS movement speed of 0.6 m / s will be achieved
6	Maximum rotational speeds for each of the three axes of rotation	°/c	20,0	The maximum rotation speed of the PDS is created by a harmonic signal with an amplitude of 5 grams and a frequency at which a rotation speed of 20°/s will be reached.
	Name of characteristic	Units of measurement	Value of characteristic	Note

7	Maximum acceleration of movement along each of the three axes of rotation	m/s^2	6,0	The maximum acceleration of the displacement of the PDS is created by a harmonic signal with an amplitude of 0.03 m and the frequency at which the acceleration of displacement of the PDS is 6 m / s²
8	Maximum acceleration of rotation on each of the three axes of rotation	°/s	60,0	The maximum acceleration of the PDS rotation is created by a harmonic signal with an amplitude of 0.03 m and a frequency at which an acceleration of rotation of 60 deg / s² will be achieved
9	The characteristic of the quality (smoothness) of movement when controlling movement along the yaw axis Y			Ускорение перемещения ПДС создается гармоническим сигналом с амплитудой 0,3 м и частотой при которой будет достигнуто ускорение перемещения ПДС 0,6 м/с²
	Deviation of the acceleration of movement along the yaw axis (Y) from the specified, no more	m/s^2	0,04	
	Parasitic acceleration of rotation about the roll axis (X), no more	$°/s^2$	1,0	
	Parasitic acceleration of rotation relative to the pitch axis (Z), no more	$°/s^2$	1,0	
	Frequency response for each of the 6 degrees of freedom			The amplitude of displacement at the initial frequency of 0Hz is 0.25 m, and the amplitude of rotation is 6 degrees, the final frequency is 10 Hz.
	Attenuation of the amplitude of displacement at the following frequencies <0,5 0,5…1,0 1,0…2,5 2,5…10	dB	0…-1,0 -1,0…-2,5 -2,5…-4,0 No increase in amplitude	

Visualization systems are of great importance in flight simulators. They reproduce images that reflect reality as much as possible. These systems change the off-cockpit environment depending on the pilot's procedures. The images have to be perceived correctly by the pilot and this is a very big problem. There are two systems for visualizing the outside of the cockpit environment, projection and collimation. Each of them has its own advantages and disadvantages. A projection system for visualizing the outside of the cockpit environment. A screen is located at a distance of about 3-5 meters from the trained pilot. The projector projected onto the screen an image corresponding to the manipulations made by the pilot, generated by the software. The advantage of such a system is its simplicity and low cost. The projection system does not require the pilot to "get used" to the image and, consequently, the pilot's visual organs are not fatigued. Among the new training technologies, promising projection laser technologies are currently leading [3]. The disadvantages of such a system include the underestimated realism of the image. Collimation system for visualization of the out-of-cab environment. This system uses mirrors, beamsplitter and spherical concave, and also uses a projector. The beam of light rays from the projector propagates radially and refracts in such a way that the specified light rays in the beam become parallel to each other. The best performance is possessed by an imaging system based on optical collimation devices (spherical mirror + beam-splitting plate) and several projection monitors (from 3 to 5). A rational optical design, a special power structure and an almost ideal sphericity of a glass mirror make it possible to easily

assemble multi-window visualization systems from such OCDs, which ensure the fusion and continuity of a panoramic image [4].

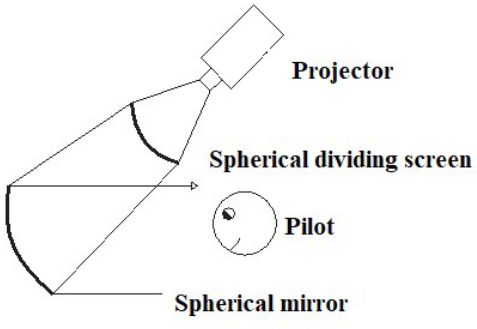

Figure 3- Layout of the functional parts of the visualization system

The disadvantages of this system are its complexity, high cost, as well as a negative effect on the organs of vision, which is expressed in the rapid fatigue of the pilot's eyes.

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ҰШУ ҮШІН ҚҰРЫЛҒЫЛАРДЫҢ ЖАСАУ ЕРЕКШЕЛІКТЕРІ, ҰТЫМДЫҚ ЖҮЙЕЛЕРІ ЖӘНЕ ВИЗУАЛИЗАЦИЯ ЖҮЙЕЛЕРІ

Аннотация. Авиациялық жүйе – бұл күрделі және динамикалық құрылым, оның бөліктері бір-бірімен әсерлеседі, бір-біріне әсер етеді және олардың өзара әрекеттесуі мүмкіндігінше қауіпсіз болуы керек. Бұл жүйенің қауіпсіз жұмыс істеуі, сайып келгенде, адамдардың әуеде де, жерде де өміріне байланысты. Ұшқыштарды даярлау және қайта даярлау, өздеріңіз білетіндей, бірнеше кезеңнен өтеді және дайындық жаттығулары болашақ ұшқыштардың жер үстінде даярлауында маңызды және сөзсіз орын алады. Дайындық оқудан өткен кезде тыңдаушы кабинаның және әуе кемесінің ұшуын имитациялайтын құрылғылардың көмегімен практикалық дағдылар мен іскерліктерді алады, ұстайды және жетілдіреді.

Түйін сөздер: авияциялық техника, тренажер, ұшуды имитациялау, ұтқырлық жүйелері, қауіпсіздік.

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КОНСТРУКТИВНЫЕ ОСОБЕННОСТИ СОВРЕМЕННЫХ УСТРОЙСТВ ИМИТАЦИИ ПОЛЕТА, СИСТЕМЫ ПОДВИЖНОСТИ И СИСТЕМЫ ВИЗУАЛИЗАЦИИ

Аннотация. Авиационная система представляет собой сложную и динамичную структуру, части которой взаимодействуют между собой, влияют друг на друга и их взаимодействие должно быть максимально безопасным. От безопасного функционирования этой системы в конечном итоге зависят жизни людей как в воздухе, так и на земле. Подготовка и переподготовка пилотов, как известно, идет в несколько этапов, и тренажерная подготовка занимает значительное и безусловное место в наземной подготовке будущих пилотов. При прохождении тренажерной подготовки пилот приобретает, поддерживает и совершенствует практические навыки и умения с помощью устройств, имитирующих кабину и полет воздушного судна.

Ключевые слова: авиационная техника, тренажер,имитация полета, системы подвижности, системы визуализации, безопасность.

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NEWS
OF THE NATONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5227
Volume 3, Number 447 (2021), 22-28 **https://doi.org/10.32014/2021.2518-170X.57**

UDC 621. 09.1

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USING ANSYS WB FOR OPTIMIZING PARAMETERS OF A TOOL FOR ROTARY FRICTION BORING

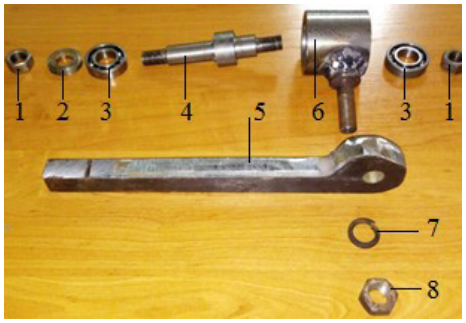
Abstract. The authors developed a special design of a rotary friction tool with a self-rotating cup cutter for rotary friction boring of large holes. This paper presents the results of parametric optimization of stressed components of the rotary friction tool by virtual experiments in ANSYS WB. The authors predicted the cutting force components at the worst position of the cup cutter, which was 20 degrees as contact forces in the process of boring a large diameter hole, and built a design model. Using the Johnson-Cook model as the failure criterion for the elements of the mesh, projections of the cutting forces resulting from the hole processing were obtained. The relation between input and output parameters (stresses) is established, optimization criteria are specified, and optimal parameters of the tool stresses components are chosen. It was also found that the averaged values of the force at the initial moment (cutting into the workpiece) change linearly, then becoming practically constant. The idea of parametric optimization consisted in carrying out several virtual experiments, in which the possible range of variation of the basic dimensions was indicated and the optimization criteria were set, the optimal parameters of the tool design were selected from the presented candidates. The optimization method bypasses the design cycle, which is costly and time-consuming due to prototype testing and subsequent refinement.

Key words. Rotary friction tool, large hole machining, cup cutter, parameter optimization, cutting force, bearing fit, design model, stress.

Introduction. In modern mechanical engineering, one of the pressing problems is the processing of large holes. Engineering practice sets high requirements to the accuracy of size, shape and location. Most often, large holes are processed with boring tools. The processing of these tools involves a number of difficulties, primarily due to the low rigidity of the tool and difficulty of supplying cutting fluid and removing pulp (a mixture of chips and cutting fluid) to the cutting zone. This leads to a decrease in the accuracy and performance of the machining and durability of the tool. As part of the government-funded research, the authors studied and developed resource-saving combined methods of thermal frictional processing [1,2,3,4], in particular the rotary friction boring of large holes [5,6]. For rotary friction boring of large holes, the authors developed a special design of a rotary friction tool with a self-rotating cup cutter. Figure 1 shows the general view of the rotary friction tool and its parts.

The performed experimental research has shown that correct choice of the tool parameters and dimensions has a direct impact on the quality and accuracy of processing. In this regard, finding optimal parameters and dimensions of the

a)



b)

1 - nut; 2 - sealing washer; 3 - bearing; 4 - shaft; 5 - holder; 6 - head body; 7 - engraved washer; 8 - clamping nut

Figure 1 - The rotary friction tool and its parts

proposed special rotary friction tool with a self-rotating cup cutter is a relevant task.

Techniques to optimize parameters. Designing a tool structure is a long process in which design parameters are constantly changing until they meet the performance criteria, while the mass must be minimal at a low cost [7,8,9]. An initial design undergoes many changes and improvements before reliable geometric parameters are found (Figure 2)

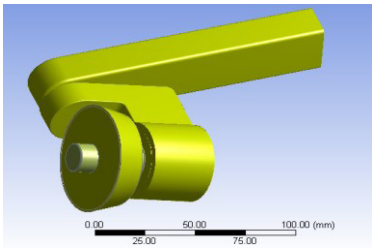


Figure 2 - Initial scheme of the tool design

The designing stages are expensive and time-consuming. Due to time and cost limitations, the decision is made on the basis of the most satisfactory option and experience of designing [10,11,12]. For today's problems, it is proposed to use optimization techniques to save time and consider the largest number of options, taking into account the spread of parameters, thereby ensuring stability of the solution to external factors. The idea of parametric optimization consists in carrying out several virtual experiments which take into account the spread of the input parameters (geometric parameters of the tool), i.e. the possible range of change in basic dimensions. We established the relation between input and output parameters (stress). Then, having set the optimization criteria and based on calculated data, we chose optimal parameters of the tool design from the candidates (variants). The optimization procedure consists of the following steps [8,12,13,14]: building a design model, determining the parameters, planning the experiment, building the response surfaces, building an optimization model, launching an optimization, viewing the results.

At each stage, additional settings may be required that can significantly affect the calculation results.

Building a design model. To build a design model, at first, we determined the predicted components of the cutting force (figure 3) at the worst position of the cup cutter, which was 20 degrees as contact forces in the process of boring a larger diameter hole of 30CrMnSiA. We made the calculation by the finite element method. As the failure criterion for the elements of the mesh, we chose the most widely used Johnson-Cook model. The cutting force projection data were obtained for the following cutting mode: spindle speed - n = 660 rpm, feed - s = 0.42 mm/rev, cutting depth t = 1.0 mm.

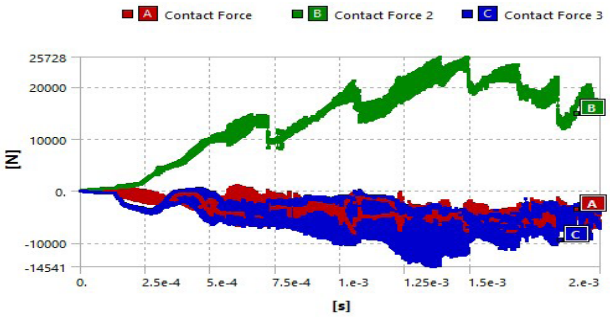


Figure 3 - The predicted change in the projection of the cutting force during rotary frictional boring

It should be noted that actually due to the discrete model the predicted cutting force is not definite, but experiences some fluctuations in the process of rotary friction boring (Figure 3). Therefore, we will determine the value of the cutting force projection by an average value. The average values of the cutting force are presented in the graph (Figure 4).

Figure 4 - Average values of cutting force

Reliability of the model is confirmed by the sensitivity of the cutting force and temperature to the change in the cutting speed in accordance with modern concepts: with increasing cutting speed, the cutting force decreases and the temperature rises.

Determining the parameters. planning the experiment. To perform the optimization calculation, the computer applications are used. The main parameters of the shaft geometry are (Figure 5): V10 - projection height (default 4 mm); H11 - projection width (default 10 mm); V13 = V8 - radius of the bearing fit (default 8 mm). The output parameter of the shaft (a parameter obtained after the solution) will be von Mises stress (461.6 MPa). Choose a plan for planning a virtual experiment. In the planning of the experiment, we must specify the range of change for each parameter and select the scheme. In our task, the main composite project is chosen (Figure 6). When choosing design points with a set of parameters, we use this scheme of experiment design which allows improving the efficiency of calculations.

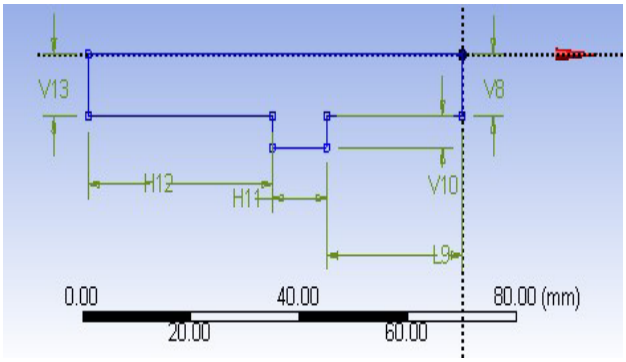


Figure 5 - Basic parameters of the shaft geometry

Properties of Outline A2: Design of Experiment

	A	B
1	Property	Value
2	Design Points	
3	Preserve Design Points After DX Run	
4	Failed Design Points Management	
5	Number of Retries	
6	Design of Experiments	
7	Design of Experiments Type	Central Composite Design
8	Design Type	Rotatable
9	Template Type	Standard

Central Composite Design
Optimal Space-Filling Design
Box-Behnken Design
Custom
Custom + Sampling
Sparse Grid Initialization
Latin Hypercube Sampling Design

Figure 6 - Virtual experiment design Plan

In this task, the following spreads of parameters were set: radius of the bearing fit from 15 to 25, projection width from 5 to 20, projection height, also discrete, from 3 to 8.

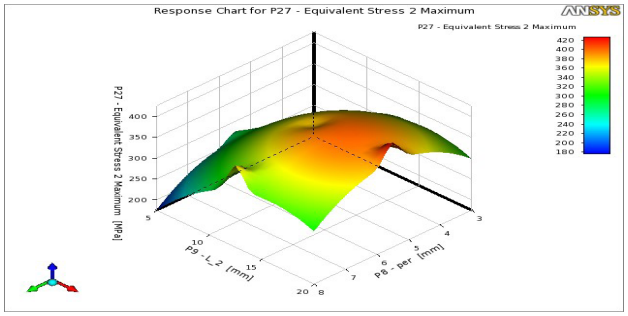
For calculation, using the main composite project, we have got 75 design points which will be determined by the finite element method. This point is very important and should be considered when optimizing. The experiment with the design points is presented in Figure 7.

Table of Schematic C2: Design of Experiments (Central Composite Design : Rotatable : Standard)

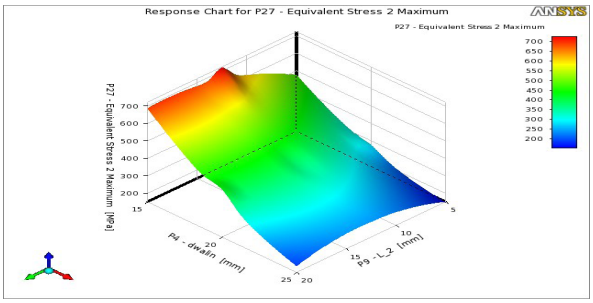
	A	B	C	D	E	F
1	Name	Update Order	P4 - dwalin (mm)	P8 - per (mm)	P9 - L_2 (mm)	P27 - Equivalent Stress 2 Maximum (MPa)
2	1	8	20	5.5	12.5	376.52
3	2	1	15	5.5	12.5	723.28
4	3	15	25	5.5	12.5	238.25
5	4	6	20	3	12.5	315.07
6	5	10	20	8	12.5	371.48
7	6	7	20	5.5	5	276.3
8	7	9	20	5.5	20	426.01
9	8	2	17.027	4.0135	8.0405	416.22
10	9	11	22.973	4.0135	8.0405	209.96
11	10	4	17.027	6.9865	8.0405	369.46
12	11	13	22.973	6.9865	8.0405	207.52
13	12	3	17.027	4.0135	16.96	510.1
14	13	12	22.973	4.0135	16.96	238.92
15	14	5	17.027	6.9865	16.96	463.26
16	15	14	22.973	6.9865	16.96	240.72

Figure 7 - Plan of the experiment with the design points

Building the response surfaces. Response surfaces are functions of a different nature which describe output parameters as a function of the input parameters. The response surfaces represent the approximated values of the output parameters in the entire analyzed space without the need for a complete calculation at all points. There are several types of response surfaces: a second-order polynomial, Kriging, nonparametric regression, a neuron network, a sparse grid [15,16,17,18,19]. Figure 8 shows the response surfaces.



a - the width and height of the projection;



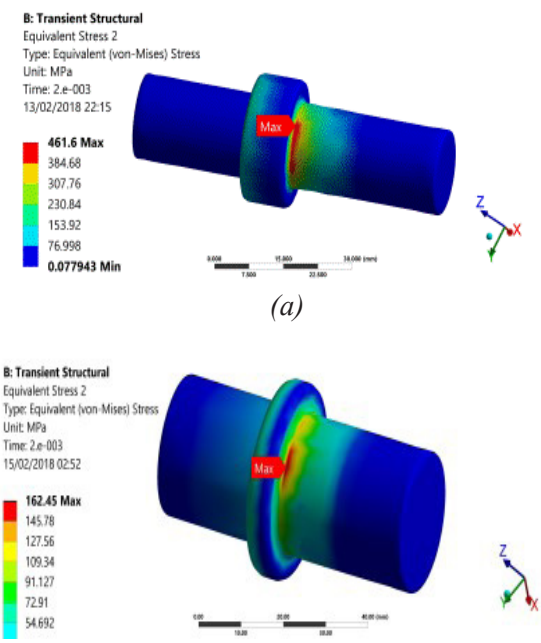
b - radius of the bearing fit and the projection width

Figure 8 - Surface response:

Different approximation for the same set of data is given below. In order to make sure the choice of approximating the design data is correct, we use the method of estimating the distribution of design points on the response surface, as well as the coefficients: the determination coefficient (R-squared, it shows how well the response surface reflects the variability of the output parameter), the root-mean-square error, relative root-mean-square error, relative error of the absolute maximum. In our case, the Kriging approximation was the most suitable technique [20,21,22].

Building an optimization model. Viewing results. The optimization approach is an approach in which the search for the "best" possible design takes into account limitations on a set of parameters. We establish a series of target design conditions that will be used to form the optimal version: desired values of input values and response parameters are set, parameters are given the ranks of importance, a set of design options is generated, the most promising candidates are selected [23,24,25]. There are four methods for optimizing the response surface in DX: Shifted Hammersley, MOGA (Multi-objective Genetic Algorithm), NLPQL (Nonlinear Programming by Quadratic Lagrangian), MISQP (Mixed-Integer Sequential Quadratic Programming). In our case, the stresses should be in the range from 152 to 160 MPa. As a result of the calculation, 5 variants were obtained among which we choose the appropriate one. Similarly, the remaining tool components are optimized, becoming robust and effective. As a result, for the selected shaft parameters

and taking into account the bearing dimensions, we perform a dynamic strength analysis and hence obtain the following picture of the change in the maximum stress (Figure 9).

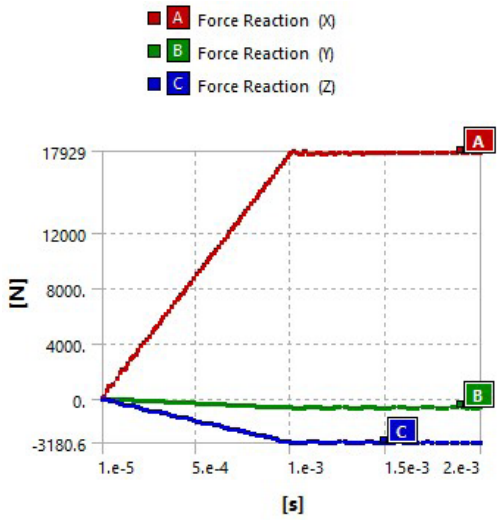


(a)

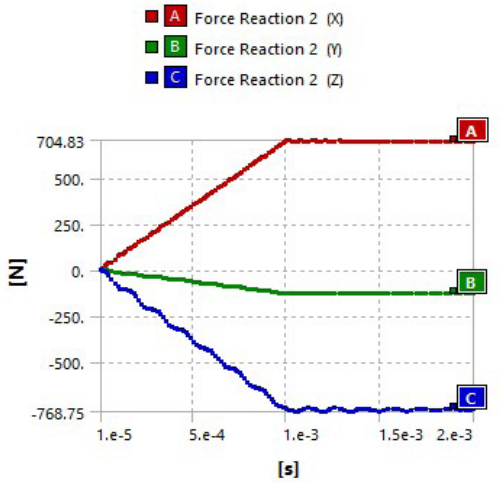
(b)

Figure 9 - Stress state of the shaft before (a) and after (b) optimization

This completes the shaft optimization and then we proceed to build a design model of the tool body (bearing), changing the parameters obtained after optimizing the shaft design. Using the components of the reference reactions from the strength calculation, we obtain the design scheme of the bearing assembly (Figure 10).



(a)

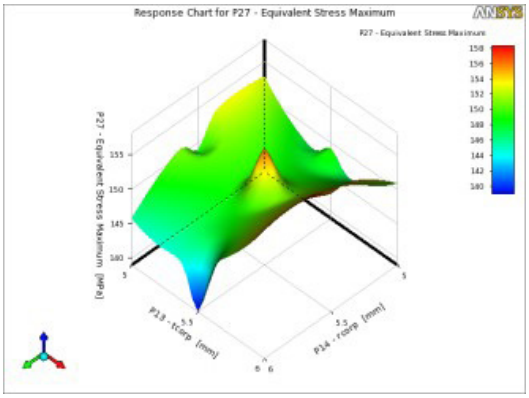


(b)

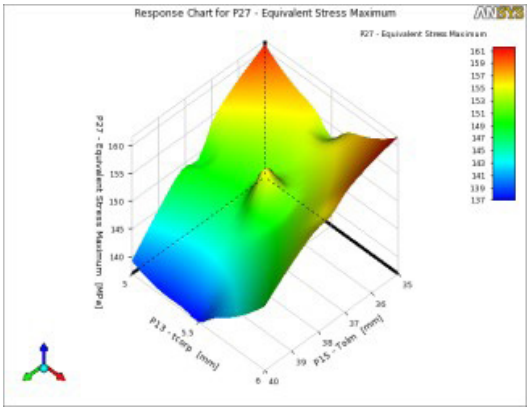
a) the first bearing; b) the second bearing

Figure 10 - Diagram of reaction forces

By the same algorithm, we determine the response surfaces (the maximum Mises stresses) from the main parameters (Figure 11).



(a)



(b)

a - from the bottom thickness and neck thickness;
b - from the bottom thickness and wall thickness

Figure 11 - Response surfaces

On the figure below, the first option is the most optimal from the presented candidate points since the input parameters in it, namely the dimensions of the tool body, are minimized and the resultant stress is in the specified limit of allowed values (Figure 12).

Table of Schematic D4: Optimization , Candidate Points

	A	B	C	D	E	F	G	H
1					P15 - Tolm (mm)		P27 - Equivalent Stress Maximum (MPa)	
2	Reference	Name	P13 - tcorp (mm)	P14 - rcorp (mm)	Parameter Value	Variation from Reference	Parameter Value	Variation from Reference
3		Candidate Point 1	6	5.8618	35	-0.01%	163	1.49%
4		Candidate Point 2	5.0005	5.0005	35.003	0.00%	160.61	0.00%
5		Candidate Point 3	5.2435	5.8091	35.009	0.02%	155.19	-3.37%
6		Candidate Point 4	5.9725	5.2026	35.012	0.03%	157.57	-1.89%
7		Candidate Point 5	5.4865	5.4048	35.016	0.04%	154.81	-3.61%

Figure 12 - Candidate points of the body parameters

Figure 13 shows the Mises stress in the body after optimization.

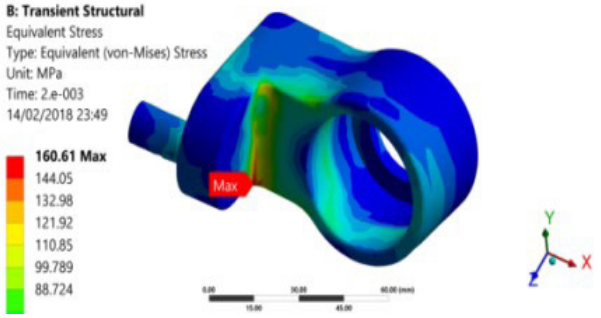


Figure 13 - The Mises stress in the body after optimization

In this regard, a part of the tool parameters for hole boring (which significantly affects the stress state) has been optimized, meeting the strength requirement.

Conclusions

1. Using the Johnson-Cook model as the failure criterion for the elements of the mesh, projections of the cutting forces resulting from hole processing were obtained.

2. The predicted changes in the projection of the cutting force and the cutting temperature are sensitive to changes in the cutting speed in accordance with modern concepts: with increasing cutting speed, the cutting force decreases and the temperature rises.

3. It is found that the averaged values of the force at the initial moment (penetration into a workpiece) vary linearly, then becoming practically constant.

4. The idea of parametric optimization consisted in carrying out several virtual experiments in which the possible range of variation of the basic dimensions and optimization criteria are specified, and optimal parameters of the tool design from the candidates are chosen.

5. The optimization method outstrips the design cycle, which is costly and time-consuming due to prototype tests and subsequent adjustments.

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РОТАЦИЯЛЫҚ-ФРИКЦИЯЛЫҚ БҰРҒЫЛАУҒА АРНАЛҒАН ҚҰРАЛ КОНСТРУКЦИЯСЫН ANSYS WB КӨМЕГІМЕН ПАРАМЕТРЛІК ОҢТАЙЛАНДЫРУ

Аннотация. Авторлар үлкен тесіктерді айналмалы үйкеліс үшін өздігінен айналатын шыныаяқ кескіші бар айналмалы үйкеліс құралының арнайы дизайнын жасады. Мақалада ANSYS WB-де виртуалды эксперименттер арқылы айналмалы үйкеліс құралының кернеулі компоненттерін параметрлік оңтайландыру нәтижелері келтірілген.

Авторлар кесу күшінің құрамдас бөліктерін үлкен диаметрлі тесікті бұрғылау процесінде байланыс күші ретінде 20 градус болатын шыныаяқ кескіштің ең нашар күйінде болжап, есептелген модель жасады. Джонсон-Кук моделін тор элементтерін бұзу критерийі ретінде қолдана отырып, тесікті өңдеу нәтижесінде пайда болатын кесу күштерінің проекциясы алынды. Кіріс және шығыс параметрлері (кернеулер) арасындағы қатынас орнатылады, оңтайландыру критерийлері белгіленеді және құралдың кернеуінің оңтайлы параметрлері таңдалады. Сондай-ақ, бастапқы сәтте күштің орташа мәні (дайындамаға кесу) сызықтық түрде өзгеріп, содан кейін тұрақты болып қалатыны анықталды.

Параметрлік оңтайландыру идеясы бірнеше виртуалды зерттеулер жүргізу болды, онда негізгі өлшемдердің өзгеруінің мүмкін диапазоны көрсетілген және оңтайландыру өлшемдері берілген,

кандидаттардан құрал дизайнының оңтайлы параметрлері таңдалған.

Оңтайландыру әдісі прототиптерді сынақтан өткізуге және оларды кейіннен жетілдіруге байланысты қымбат және ұзақ болатын жобалау циклын айналып өтеді.

Түйін сөздер: айналушы үйкеліс құрал, үлкен тесіктерді өңдеу, табақшалы кескіш, параметрлерді оңтайландыру, кесу күші, мойынтірек қондырғысы, есептеу үлгісі, кернеу.

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ПАРАМЕТРИЧЕСКАЯ ОПТИМИЗАЦИЯ СРЕДСТВАМИ ANSYS WB КОНСТРУКЦИИ-ИНСТРУМЕНТА ДЛЯ РОТАЦИОННО-ФРИКЦИОННОГО РАСТАЧИВАНИЯ

Аннотация. В современном машиностроении одной из актуальных проблем является обработка больших отверстий, к которым предъявляются высокие требования по точности размера, формы и расположения. Чаще всего на производстве обработка больших отверстий осуществляется расточными инструментами. Обработка этими инструментами сопряжена с рядом трудностей, обусловленных, прежде всего, низкой жесткостью инструмента, сложностью подвода в зону резания смазочно-охлаждающей жидкости (СОЖ) и отвода пульпы (смеси стружки и СОЖ). Это приводит к снижению точности и производительности обработки, а также стойкости инструмента.

Авторы спрогнозировали составляющие силы резания в наихудшем положении чашечной фрезы, которая составляла 20 градусов как контактные силы в процессе расточки отверстия большого диаметра и построили расчетную модель. Используя модель Джонсона-Кука в качестве критерия разрушения элементов сетки, были получены проекции сил резания, возникающих в результате обработки отверстия. Устанавливается соотношение между входными и выходными параметрами (напряжениями), задаются критерии оптимизации и выбираются оптимальные параметры составляющих напряжений инструмента. Так же установлено, что усредненные значения силы в начальный момент (врезания в заготовку) меняются линейно, затем становясь практически постоянными.

Достоверность модели подтверждает чувствительность силы и температуры резания к изменению скорости резания в соответствии с современными представлениями: с увеличением скорости резания сила резания уменьшается, а температура повышается. Метод оптимизации обходит цикл проектирования, который является дорогостоящим и длительным из-за проведения испытаний прототипов и последующей их доработки.

Ключевые слова: вращающийся фрикционный инструмент, обработка больших отверстий, чашечный резец, оптимизация параметров, сила резания, посадка подшипника, расчетная модель, напряжение.

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NEWS
OF THE NATONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5227
Volume 3, Number 447 (2021), 29-33 **https://doi.org/10.32014/2021.2518-170X.58**

UDC 622.248.75

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FLUID INFLUX TO A BATTERY OFINCOMPLETE HORIZONTALLY BRANCHED WELLS IN DEFORMED FORMATION

Abstract. Using numerousexperimentalandfield researches, it was established that there are rock deformations duringoil and gas fields development, occurred due to thereservoir response. It has been established that formationvolume of pore space is decreased due to elastic expansion of rock grains and increase of compression strength transferred to matrix from mass of overlying rocks due to formation pressure depletion. As the result, there are deformation processes in porous medium accompanied by degradation of its porosity and permeability, and suffered greater change compared to the formation porosity, sufferedpermeability at the samepressure variation.

Demonstration of mentioned anomalies under formation conditions leading to non-linear effect can strongly influence the whole process of the reservoir development and lead to various qualitative and quantitative differences between the observed facts and the indicators which were calculated using standard methods.

Formulas for determination of debits of incomplete horizontally branched wells (HBW) in deformed formation for various number of horizontal shafts in a battery were obtained in this work using image method of drains (sources) and superposition. Obtainedestimate indicatorscan be used inengineering works during development of the deposits indeformed environment.

Key words: yield, rock deformation, external boundary, steady state, pressure, bore length, permeability.

Nowadays there are a lot of publications devoted tostudy of variousproduction characteristics of horizontal wells. Currently, a higher performance of horizontal wells is observed compared to vertical wells and under otherwise equal conditions this is the fact proved theoretically and confirmed in practice.

Based on the performed researches and accumulated practical experience, according to the current opinion, the maximum effect on the use of the horizontal wells can be useful at the production facilities with the following characteristics [1, 2,3]:

- facilitiesbelow the gas capandfacilities withbottom waters;
- collectors with verticaljointing;
- deposits anddifficult to accessproduction zones;
- shelf anddifficult to access production zones;
- during operation ofgas deposits;
- usingenhanced oil recovery, particularlythermal methods;
- with oil viscosity (μ>10 mPas);
- low-efficiencymode ofreservoir production;
- net productive zone– at least 3 m;
- low permeability of collectors (k<0,1μm2);
- largeremaining recoverable reserves.

In terms of modernscientific-technological progress, when there was a technical ability to drill deep and ultradeep wells, there is a real opportunity of involvement into development of deeply buried wells.

Nowadays development of deep-seated deposits is one of the principal tasks of gas and oil producing industry. This leads tointensive need of comprehensive study of flows of formation fluidsandconstruction ofcomputational models of development ofdeep oil collectors (characterized byhighreservoir pressure and temperature) subject tochanges ofporopermproperties of porous medium and fluids.

Deep-seated deposits, which are characterized by high reservoir pressure, are in state of thermodynamic equilibrium before development.

Development of these deposits will lead to distortion of thisequilibrium of bedded system. As noted above, rock matrix of collector is subject to heavy loads in case of decrease of reservoir pressure, asformation pressure isunaltered, and effectivepressure is increasing. As the result, deformation processes are changed in porous medium, accompanied by decrease of its porosity and permeability.

This affects filtration of formation fluids and basic development parameters of the deposit. Literature in this area of researches isvarious andnumerous. The list of works related to this problem can be found in the publications [1, 3, etc.].

Of course, it should be expected that nature of fluid influx to horizontal wells in these terms will be distinguished from thenature of fluid influx in collectors at shallow depth.

In view of this let's consider a problem of fluid influxto a battery of incomplete horizontally branched wells during formation deformation.

Problem statement. Let's formulate the problem as follows: if filtration mode is steady, let's determine afluid influx toshaft ofround battery, incomplete according to nature, level ofproduction wells, located relative to impenetrable roof and bottom of final formation with deformed collector during reservoir development (Fig.1).

Fluid is low compressible, withconstant viscosity. Fluid filtration is under theDarcy's law.

Taking into account the indicated conditions, the task on determination of function of pressure field is restricted to solution ofLaplace equation.

One ofspecific solutions of this problem was found in the work [4-6] usingimage ofdrains (sources) relative to roof and bottom of formationandsuperpositionnot including deformation ofdeposit collector during development.

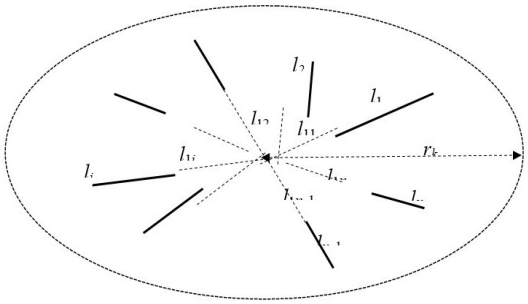

Fig.1. Projection scheme of shafts ofbattery of horizontally branched wells onbottom plane of round formation with round external boundary

Using the mentioned approach when battery of horizontally branched wells is used in deformed formation with random number n and various lengths l1, l2,…lnof shafts, a formula of cumulative mass yield of well is obtained as follows:

$$Q = \frac{2\pi K_o h\rho}{\mu B} \cdot \frac{\varphi_k - \varphi_c}{\left[\frac{1}{Ln}\left(\sum_{i=0}^{n} l_i l_n \frac{a_n R_k}{l_i} + \omega_1 h\right) + \omega_2\right]}, \quad (1)$$

where h – net oil thickness, μ – oil viscosityinformation conditions; B – formation volume factor; ρ – oil density;

$$\varphi(x,y,z) = \int_{p_k}^{p} \overline{K}(p)dp;\ \overline{K}(p) = \frac{K(p)}{K_o}; \quad (2)$$

K(p) – permeability value on current pressure is determinedby experiment; Ko – permeability value of rockwithpressure at formation depth;

$$\omega_1 = \left[ln(\frac{h}{2\pi R_c}) - ln(\sin\frac{\pi Z_o}{h})\right];$$

$$\omega_2 = \pi h(\frac{1}{md} - \frac{1}{mD})\frac{1}{n}\sum_{i=0}^{n}\frac{1}{l_i};$$

Pk – pressure value at external boundary of reservoir; Pc – average value of pressure at shafts of battery of horizontal wells; Rk– radius ofexternal boundary of reservoir; Rc– value of radiuses which is equal for all horizontal wells;

Ln = l1+ l2+…+ln, n ≤ 24; D = 2Rc; d=2δ;

δ - value of radiuses which is equal for allround perforations; m –number of perforations per 1 m of filter; Zo –distance frombottom formation toa plane where all horizontal shafts n are located.

In this case, when length of well shafts is considered as equal, i.e.l1= l2=…=ln=l, Ln= nlthe formula (1) will be as follows:

$$Q = \frac{2\pi K_o h\rho}{\mu B} \frac{\varphi_k - \varphi_c}{\left[ln\frac{a_n R_k}{l} + \frac{h}{nl}(\omega_1^* + \pi\omega_2^*)\right]}, \quad (3)$$

where $\omega *_1 = \left[ln(\frac{h}{2\pi R_c}) - ln(\sin\frac{\pi Z_o}{h})\right]$; $\omega *_2 = (\frac{1}{md} - \frac{1}{mD})$;

Values of quantitiesan, included in formulas (1) and (3), were obtained in the work [4] and given in the Table 1.

Table 1 –Values of quantitiesan depending on number (n) of shafts ofmulti-hole horizontal well

n	a_n	n	a_n	n	a_n
1	3,1422	9	1,6777	17	1,6574
2	2,0828	10	1,6725	18	1,6565
3	1,8621	11	1,6686	19	1,6557
4	1,7768	12	1,6656	20	1,6550
5	1,7344	13	1,6632	21	1,6545
6	1,7102	14	1,6613	22	1,6540
7	1,6950	15	1,6593	23	1,6535
8	1,6844	16	1,6584	24	1,6530

Using knownanalytical dependence K (p) oneffective pressure [3]:

$$\overline{K}(p) = a[1 - \alpha(P_k - P_c)], \quad (4)$$

Subject to (4),formulas (2) and (3) will be as follows:

$$Q = \frac{2\pi K_o h\rho}{\mu B} \cdot \frac{a(P_k - P_c)[1 - {}^{\alpha}/_{2}(P_k - P_c]}{\left[\frac{1}{ln}\left(\sum_{i=0}^{n} l_i ln\frac{a_n R_k}{l_i} + \omega_1 h\right) + \omega_2\right]}, \quad (5)$$

$$Q = \frac{2\pi K_o h\rho}{\mu B} \cdot \frac{a(P_k - P_c)[1 - {}^{\alpha}/_{2}(P_k - P_c]}{\left[ln\frac{a_n R_k}{l} + \frac{h}{nl}(\omega_1^* + \pi\omega_2^*)\right]}, \quad (6)$$

wherea =A+B°Pk – CP_r; α=B°/a; A, B°, C – known coefficients determined byleast square procedure using standard subprogram with data of experimental investigations for three classes of rocks distinguished byelastic characteristics of components ofsolid phase; Pr – formation pressure [3-9].

Impact indicator oflateral permeability changeonpressure on operation ofincomplete wells of round battery on the basis of ratios (5) and (6) and determined by theequation:

$$\Omega = \frac{Q(subject\ to\ deformation)}{Q(without\ deformation)} = \left[1 - \frac{\alpha}{2}(P_k - P_c)\right], \quad (7)$$

To assess impact of perforations and changes of permeability on pressure on yield using formulas (6) and (7),numerical calculations were performed at following initial data:

h=20 m, k=0,1 μm2; Rk=1000 m, Rc=0,1 m, α=0.0126 1/MPa, δ=0,01 m, d=2δ=0,02 m, μ=3mPas, B=1,2, Pc=5 MPa, Pk=10 MPa, L=(100, 300, 700) m, m=(12, 18, 24, 30, 36) 1/mand foropen hole well m=∞.

The results of calculations are provided at Fig.2-4 and in Table 2.

Table 2–Yield of the battery ofhorizontally branched wells, m3/day

	Number of wells n	Length of well shaftl, m			
		100	300	500	700
12	1	144	249	384	485
	2	153	317	460	615
	3	156	329	487	663
	4	157	335	499	686
	5	158	338	506	698
24	1	175	315	424	531
	2	190	366	520	691
	3	194	382	555	752
	4	196	389	570	781
	5	197	391	579	797
36	1	189	329	440	548
	2	206	385	544	720
	3	211	403	581	787
	4	214	411	599	819
	5	215	415	608	836
50	1	223	362	475	586
	2	249	418	598	788
	3	256	454	644	868
	4	259	465	665	908
	5	261	470	676	929

It is apparent on the tables and graphs that yields of the battery of horizontally branched wells are increased at fixed values of n andl with the increase of density of perforations per onelinear meter.

The formula (7) leads to the fact that yield in the deformed formation is smaller than yield of the battery ofhorizontally branched wells, draining porous nondeforming formation (α=0) with the same pressure differences and other equal characteristics of formation[7-11].

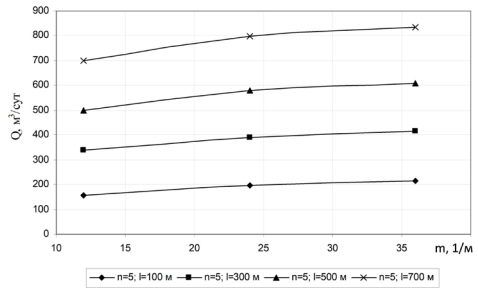

Fig 2. Dependence of battery yield of horizontally branched wells on number of perforations

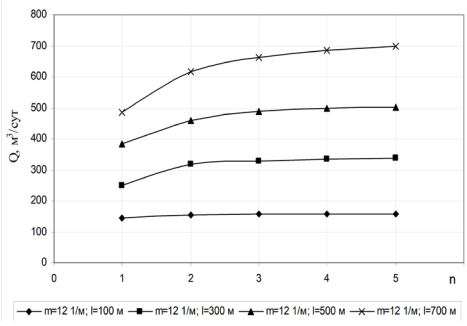

Fig 3. Dependence of battery yield of horizontally branched wells on number of shafts

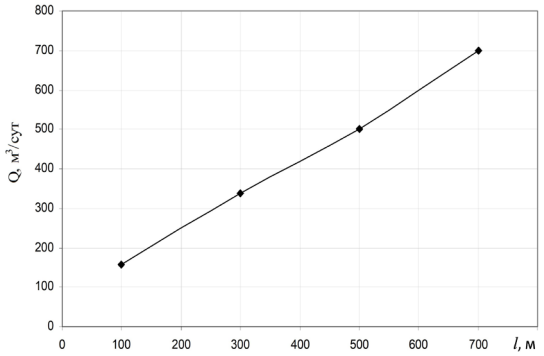

Fig 4. Dependence of battery yield ofhorizontally branched wells onlength of shaft (m=12 1/m; n=5)

Conclusions:

- a mathematical model was proposed, scientifically defined and implemented and its solution for steady filtration of fluid to horizontally branched wellsin deformed porous medium. The analysis of derived dependence demonstrated thatwell yield in deformed formation is smaller thanwell yield draining non de forming formation (α=0) with the samepressure difference and other equal formation characteristics.

- slowdown of rate of growth of well yield is observed for multi hole horizontal wells with an increase of number of shafts.

- it was established that in deformed deposits under otherwise equal conditions, density of perforations shall be notably higher than in nondeforming deposits.

УДК 622.248.75

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ДЕФОРМАЦИЯЛАНАТЫН ҚАБАТТА ЖЕТІЛМЕГЕН ТАРМАҚТАЛҒАН-КӨЛДЕНЕҢ ҰҢҒЫМАЛАРДАҒЫ СҰЙЫҚТАРДЫҢ АҒЫНЫ

Аннотация. Көптеген эксперименттік және кәсіптік зерттеулер барысында мұнай және газ кен орындарын игеру кезінде қабат қысымының өзгеруіне байланысты, тау жыныстарының деформациясы бар екенін анықталды. Қабат қысымның төмендеуімен қабаттың кеуек кеңістігінің көлемі жыныс түйірлерінің серпімді кеңеюі және қаңқаға жоғары жатқан жыныстардың массасынан берілетін қысым күштерінің артуының салдарынан азаятыны анықталды. Нәтижесінде кеуекті ортадағы деформациялық процестердің өзгеруі оның кеуектілігі мен өткізгіштігінің төмендеуімен бірге жүреді, ал қабаттың кеуектілігімен салыстырғанда едәуір өзгеріс қысымның бірдей өзгеруімен өткізгіштікке ұшырайды. Сызықтық емес әсерлерді тудыратын осы ауытқулардың резервуарлық жағдайдағы көрінісі кен орнын игерудің бүкіл процесіне айтарлықтай әсер етуі мүмкін және бақыланатын фактілер мен әдеттегі әдістерге сәйкес есептелген көрсеткіштер арасындағы әртүрлі сапалық және сандық айырмашылықтарға әкелуі мүмкін. Бұл жұмыста ағындарды (көздерді) айналы бейнелеу әдісін және суперпозицияны қолдана отырып, батареядағы көлденең оқпандардың әртүрлі саны үшін деформацияланатын қабаттағы жетілмеген тармақталған-көлденең ұңғымалардың (ТКҰ) дебиттерін анықтауға арналған формулалар алынды. Алынған есептік көрсеткіштер деформацияланатын ортадағы кен орындарын игеру кезінде инженерлік жұмыстарда пайдаланылуы мүмкін.

Түйін сөздер: дебит, тау жынысының деформациясы, қуат тізбегі, стационарлық режим, қысым, оқпан ұзындығы, өткізгіштік.

УДК 622.248.75

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ПРИТОК ЖИДКОСТИ К БАТАРЕЕ НЕСОВЕРШЕННЫХ РАЗВЕТВЛЕННО-ГОРИЗОНТАЛЬНЫХ СКВАЖИН В ДЕФОРМИРУЕМОМ ПЛАСТЕ

Аннотация. Многочисленными экспериментальными и промысловыми исследованиями установлено, что в процессе разработки нефтяных и газовых месторождений имеются деформации пород, происходящие вследствие изменения пластового давления. Установлено, что с падением пластового давления объём порового пространства пласта уменьшается вследствие упругого расширения зерен породы и возрастания сжимающих усилий, передающихся на скелет от масс вышележащих пород. В результате происходит изменение деформационных процессов в пористой среде, сопровождаемое снижением её пористости и проницаемости, причём более значительное

изменение, по сравнению с пористостью пласта, претерпевает проницаемость при одном и том же изменении давления.

Проявление в пластовых условиях указанных аномалий, вызывающие нелинейные эффекты, может значительно влиять на весь процесс разработки залежи и приводить к различным качественным и количественным расхождениям между наблюдаемыми фактами и теми показателями, которые рассчитывались по обычным методикам.

В данной работе с применением метода зеркального отображения стоков (источников) и суперпозиции получены формулы для определения дебитов несовершенных разветвленно-горизонтальных скважин (РГС) в деформируемом пласте для разного числа горизонтальных стволов в батарее. Полученные расчетные показатели могут быть использованы в инженерных работах при разработке месторождений в деформируемой среде.

Ключевые слова: дебит, деформация породы, контур питания, стационарный режим, давление, длина ствола, проницаемость.

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NEWS
OF THE NATONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5227
Volume 3, Number 447 (2021), 34-39 **https://doi.org/10.32014/2021.2518-170X.59**

UDS:621.643.03

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IMPROVING THE EFFICIENCY OF THE FUNCTIONING OF GAS PIPELINES, TAKING INTO ACCOUNT THE STRUCTURAL FEATURES OF GAS FLOWS

Abstract. The multi-phase and different composition of gas flows during the development of offshore oil and gas-condensate fields leads to high costs of energy in the system of in-field storage and transportation of well products.

The analysis of the existing storage and transportation systems of gas-condensate mixtures shows that the geophysical nature and complexity of the internal structure of the transported fluids must be taken into account when choosing the mode parameters and calculation schemes of the pipelines. High-speed gas lines can be operated in a so-called "dry" mode, in which the liquid is carried along with the gas, the pipeline profile is relatively straight, without ups and downs. In this case, the formation of so-called "stagnant zones" in the pipeline is excluded.

However, if the processing depth of the gas does not allow it to be transported in a single-phase state, then the condensing gas factor manifests itself. The hydraulic characteristics of vertical ups and downs on offshore pipelines are complicated, and pipelines are often filled with water and condensate. As a result, the pressure in the pipeline increases and the location of the collection point for condensing gases away from the production site can cause major problems.

If we characterize oil and gas-condensate flows as a dynamic system in which alternating structural changes take place, the question of whether these systems are fractal is of great scientific interest.

Based on the change in the fractal value, it is possible to diagnose structural changes during the transportation of various systems, including condensing gases in the pipelines.

In this article the modes of change of basic parameters of a gas flow (pressure, flow rate and temperature) on various lines of a gas pipeline for the purpose of the producing of diagnostic criterion for revealing of liquid inclusions as a part of transported gas are investigated in this article. It is established, that in the presence of liquid inclusions at movement of gas flows there are the structural changes peculiar to fluid systems, systems which can be identified by variations of fractal dimensions of flowcharacteristics.

Studies have shown that the study of the dynamics of structural changes in gas flows can play a role in diagnosing the formation of liquid phase embryos in gas pipelines. For this purpose, diagnostics for the movement of gas streams accompanied by liquid deposits in the pipelines has been proposed.

Key words: gas pipeline, gas flow, diagnosing, flow characteristic, structure form, fractal prices,multiphase, condensation.

Introduction. Transportation of production from with gas or gas condensate fields or associated gases from oil fields is interfaced to increase of the energy expenditure, caused by multiphaseflows. The analysis of existing systems of gathering and transportation of gas condensate mixes shows, that increase of efficiency demands the knowing of the rheological nature and complexity of internal structure of transported fluids at a choice of modes and calculations of pipelines. High flow rates in gas pipelines can provide a so-called dry mode of operation, i.e. carrying out of liquid inclusions with gas if the pipeline has rather equal profile. Thereby formation possibility in it of so-called stagnant zones is excluded. When depth of processing of gas does not provide its transportation to a single-phase condition, we deal with condensing gas. Presence up and down streams in the marine pipelines complicates their hydraulic characteristic, horizontal and elevating sites of gas pipelines are often filled in with a condensate and water. As a result, pressure in the pipelineraises. The investigation shows, that unlike a single-phase stream, range of gathering of condensing gas cannot increase is boundless with increase in diameter of the pipeline. As shows long-term experience of arrangement of sea deposits on Caspian Sea, transportation of such streams to coastal terminals and points of gathering of production is interfaced to considerable difficulties. So, on a movement course on trade pipelines in these systems there are the phase transitions accompanied by branch of a liquid and a condensate. Accumulation in the lowered sites of a line of the pipeline of the separated liquid and a condensate leads to formation of clogging in the

pipeline and considerably complicates transportation of production [1,2].

Methods. Considering gathering in view of range of points of gathering from an extraction place, the above-stated problems arise on a course of movement of production, not reaching to them. One of ways of the decision of this problem is the choice of an optimum mode of the swapping excluding the beginning of formation of a liquid phase on all length of the pipeline to point of gathering and preparation of production. This problem is reduced to a choice of optimum diameter of thepipeline.

Let's present a gas stream as the system having the characteristic ordered structural form of a current at a certain combination of values of gas dynamics parameters, describing its current condition. Change of a mode of transportation leads to transfer to other structural form and the system is as though reconstructed on other structure form with other measure of orderliness. Differently alternation of various structural forms of a current is accompanied by consecutive change of the ordered structures with the measure of orderliness. Thus, on change of a measure of orderliness of system as a whole it is obviously possible to identify the beginning of formation or transition to other structuralform.

For an evaluation of a measure of disorder of various structural systems the estimation technique fractal measures [3,4,5] which has been used at carrying out of researches of the presented work is effectively used. According to this technique, dynamics of gas dynamics parameters on the basis of operating data on various sites of main gas pipeline Azadkend-Bilesuvar (the Azerbaijan Republic) first of all has been investigated. Metering have been made on the various sites differing not only the extent, but also character of a profile of a line, that also makes changes to character of a current of gas streams in the presence of liquidinclusions.

Results anddiscussion. The results of measurement (table. 1) have been constructed curves in dimensionless sizes for change of pressure, temperature and flow rate on various sites of a gas pipeline and these curves have been processed by a method of a covering for an estimation Hausdorf's fractal dimensions [4-5].

Table 1. Measurement data for Bilesuvar

№	Pressure	Temperature	Flow	№	Pressure	Temperature	Flow
	kPa	°C	m3/hour		kPa	°C	m3/hour
1	251.809	20.004	0.656	26	252.567	18.352	0.620
2	251.904	19.132	0.620	27	252.775	19.308	0.581
3	251.981	18.506	0.597	28	252.697	19.347	0.596
4	251.917	18.307	0.589	29	252.786	18.934	0.590
5	251.820	17.808	0.592	30	252.808	19.027	0.599
6	251.806	17.773	0.596	31	252.389	18.599	0.657
7	251.694	18.871	0.625	32	251.150	18.142	0.876
8	250.374	18.087	0.862	33	251.036	19.556	1.028
9	250.079	19.475	1.031	34	251.860	24.337	0.951
10	250.907	23.533	0.965	35	251.971	29.409	0.946
11	251.106	28.738	0.965	36	251.459	32.922	1.039
12	250.600	33.885	1.037	37	250.513	35.447	1.103
13	249.644	37.847	1.061	38	249.963	37.471	1.061
14	248.972	40.847	1.015	39	250.285	38.818	0.915
15	249.137	42.790	0.880	40	250.170	37.153	0.885
16	249.061	43.462	0.827	41	250.637	36.166	0.839
17	248.962	42.592	0.833	42	249.443	34.823	1.014
18	248.806	39.853	0.890	43	249.216	30.458	1.099
19	248.758	34.786	1.000	44	249.258	27.485	1.141
20	248.825	30.301	1.082	45	249.033	23.833	1.219
21	248.327	25.194	1.249	46	250.118	21.698	1.081
22	249.717	22.374	1.063	47	251.379	21.092	0.876
23	251.090	21.690	0.853	-	-	-	-
24	251.807	20.221	0.762	-	-	-	-
25	252.334	18.860	0.675	-	-	-	-

Results of processing of curves on various sites of a gas pipeline are presented on figure 1. As have shown results of the analysis of data curves of dynamics for these parameters, carry strongly pronounced fractal character. This conclusion proves to be true good enough flattening of the curves received by a method of a covering for an estimation of Hausdorf's dimension on all samples taken for the analysis.

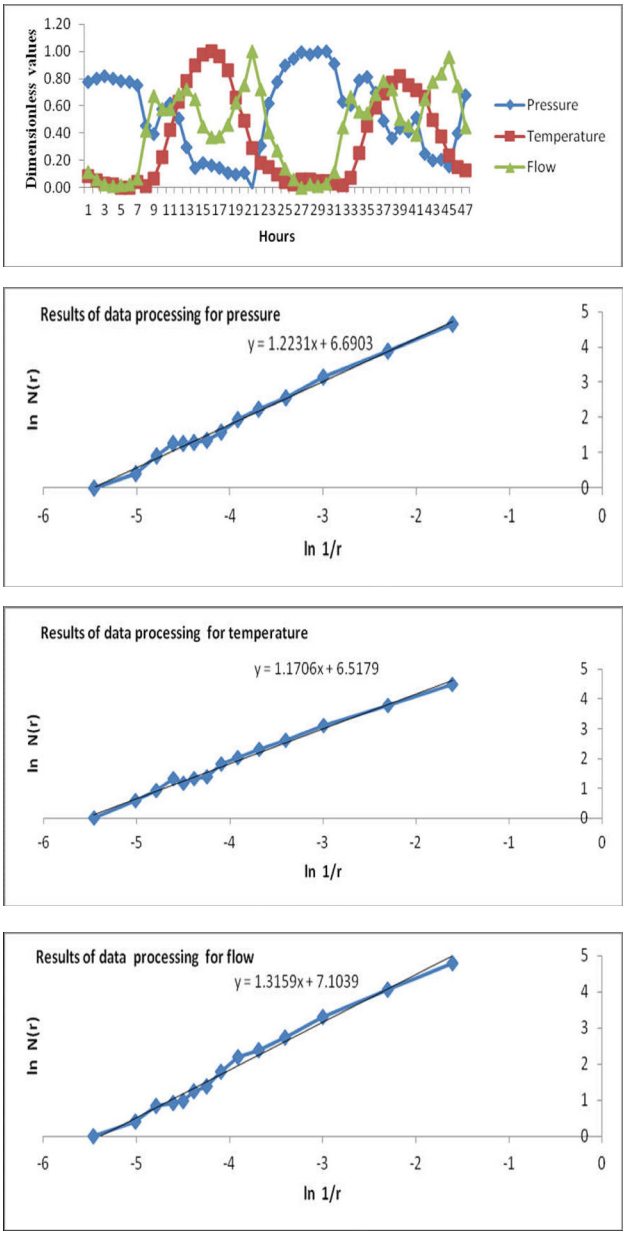

Figure 1. Results of data processing for Bilesuvar line

The fractal properties for dynamics characteristics of gas pipelines allows us to identify structural modes of a current on change fractal measures. Moreover, data on gas structure, presence of liquid inclusions is possible to connect with character of change fractal dimensions of the gas dynamics characteristics and to find corresponding diagnosticcriterion.

That is, differently presence of liquid inclusions leads to change of the structural form of a current of a stream on the pipeline which degree of orderliness is defined by fractal measure. Hence, in a gas stream without liquid inclusions and with liquid inclusions fractal measure of structure of a stream will be various.

For the purpose of revealing of possibility of early diagnosing of formation of a liquid phase in a gas pipeline on change of component composition of gas, gas samples in operating conditions have been taken. Gas sampling points are presented in figure 2. In a point 3 on an exit of compressor station selection of test of associated gas was made, and in a point 1 after installations on preparation of gas selection of test of natural gas was made. Further these two gas streams after mixture are transported to delivery measuring station on which input in a point 3 samples already for a mix of natural and associated gases were taken. From each point have been taken two samples of gas (Test 1 and Test 2).

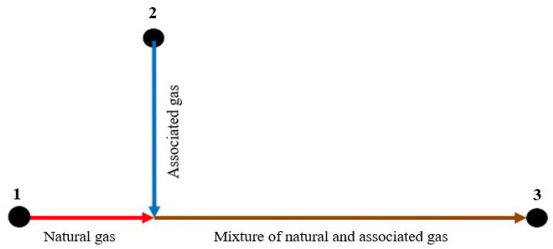

Figure 2. Points of gas samples

Results of the analysis of the taken tests, and also corresponding values of defined parameters for a mix of the natural and associated gas, calculated by the additively rule are shown in the table 2. Apparently from the table, actual values of parameters of a mix of natural both associated gases and the corresponding values calculated by additivity rule, most strongly differ on following positions: content of heavyfractions (C_5+); content of contamination and moisture content; dryness of gas (C_1/C_2+) and a dew-point (T_{dp}). For more evident picture on figure 3 the picture of change of parameters C_5+ and C_1/C_2+ depending on parities of associated and natural gases as a part of a mix is presented. Here by arrows, it is shown, to what content of associated gas in a mix there correspond actual values of parameters of a mix of gas and so differs from a mix of natural and associated gases in the ratio 85:15%.

Thus, by results of the spent researches it is established, that diagnosing of a structural condition of a gas stream expediently in frameworks, the analysis which can serve as the tool for studying of the latent order in dynamics of disorder systems what gas mixes with liquid inclusions are. The effective mathematical apparatus for diagnosing of movement of gas streams with liquid inclusions in pipeline systems is offered enough simple,but.

Table 2. Results of analysis of component composition

Parameters	Natural gas (point 1)		Associated gas (point 2)		Mixture of gases (point 3)		Parameters calculated by rule of addivity		Error,%	
	Test 1	Test 2	Test 1	Test 2	Test 1	Test 2	Test 1	Test 2	Test 1	Test 2
O_2, mol. %	0.02	0.015	0.011	0.015	0.014	0.02	0.019	0.015	24.93	33.33
CO_2	0.071	0.071	0.53	0.539	0.157	0.163	0.140	0.141	12.26	15.44
N_2	3.452	3.449	1.562	1.572	2.994	3.048	3.169	3.167	5.51	3.77
C_1	95.484	95.648	91.64	91.5	94.634	94.617	94.907	95.026	0.29	0.43
C_2	0.352	0.35	3.482	3.459	1.009	1.041	0.822	0.816	22.82	27.52
C_3	0.583	0.447	1.176	1.197	0.618	0.597	0.672	0.560	8.03	6.70
C_4	0.007	0.004	0.912	0.953	0.211	0.206	0.143	0.146	47.81	40.76
C_{5+}	0.027	0.013	0.673	0.743	0.357	0.303	0.124	0.123	188.14	147.35
C_1/C_{2+}	98.539	117.504	14.679	14.405	43.113	44.0694	85.960	102.039	49.84	56.81
ρ^{20}, kg/m^3	0.696	0.6941	0.7518	0.755	0.713	0.712	0.705	0.703	1.18	1.20
Δ, relative density	0.578	0.5763	0.6242	0.627	0.592	0.591	0.585	0.584	1.18	1.20
Moisture content (V),g/ l	0,248	0.223	4.7265	4.799	0.354	0.359	0.919	0.909	61.51	60.54
Dew-point, °C	-9	-10	34	35	-12	-12	-2.55	-3.25	370.59	269.23
Contamination, mg/ l	0.4115	0.5733	0.080	0.079	0.645	0.621	0.362	0.499	78.39	24.38
Burning temperature (above) (20°C), MC/m^3	36.24	36.16	39.690	39.83	37.27	37.16	36.7575	36.711	1.39	1.22
Burning temperature (under) (20°C), MC/m^3	32.65	32.58	35.850	35.98	33.61	33.5	33.13	33.090	1.45	1.24
Vobbe number (above)	47.66	47.64	50.190	50.26	48.44	48.34	48.0395	48.033	0.83	0.64
Vobbe number (under)	42.94	42.92	45.340	45.4	43.67	43.58	43.3	43.292	0.85	0.67

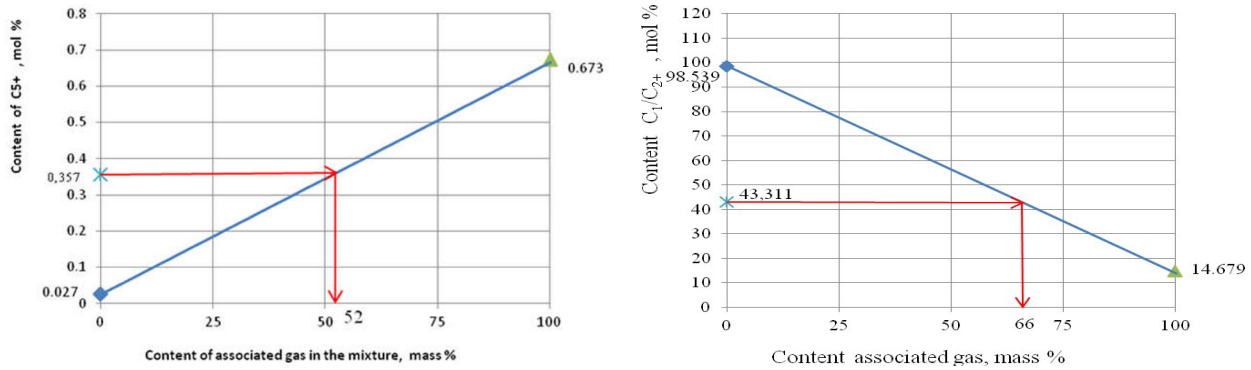

Figure 3. Variations of parameters C_5+ and C_1/C_2+ from ratios of associated and natural gases

УДС: 621.643.03

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ГАЗ АҒЫНДАРЫНЫҢ ҚҰРЫЛЫМДЫҚ ЕРЕКШЕЛІКТЕРІН ЕСКЕРЕ ОТЫРЫП, ГАЗ ҚҰБЫРЛАРЫ ЖҰМЫСЫНЫҢ ТИІМДІЛІГІН АРТТЫРУ

Аннотация. Мұнай және газ-конденсат кенорындарын игеру кезінде газ ағындарының көп фазалы және әр түрлі құрамы кеніште сақтау және тасымалдау жүйесінде энергияның жоғары шығындарына әкеледі.

Газ-конденсатты қоспалардың қолданыстағы сақтау және тасымалдау жүйелерін талдау құбыр режимінің параметрлері мен есептеу схемаларын таңдау кезінде тасымалданатын сұйықтықтардың геофизикалық табиғаты мен ішкі құрылымының күрделілігін ескеру керектігін көрсетеді. Жоғары жылдамдықты газ желілері «құрғақ» деп аталатын режимде жұмыс істей алады, онда сұйықтық газбен бірге тасымалданады, құбыр профилі салыстырмалы түрде түзу, құлдыраусыз болады. Бұл жағдайда құбырдағы «тоқырау аймақтарының» қалыптасуы алынып тасталады.

Алайда, егер газды өңдеу тереңдігі оны бір фазалы күйде тасымалдауға мүмкіндік бермесе, онда конденсацияланатын газ факторы көрінеді. Теңіз құбырларындағы тік көтерілулер мен құлдыраулардың гидравликалық сипаттамалары күрделі, ал құбырлар көбінесе сумен және конденсатпен толтырылады. Нәтижесінде құбырдағы қысым күшейіп, конденсацияланатын газдарды жинайтын орынның өндіріс орнынан алыста орналасуы үлкен мәселелерді тудыруы мүмкін.

Егер біз мұнай мен газ-конденсат ағындарын ауыспалы құрылымдық өзгерістер болатын динамикалық жүйе ретінде сипаттайтын болсақ, онда бұл жүйелер фракталды ма деген сұрақ үлкен ғылыми қызығушылық тудырады.

Фракталдық шаманың өзгеруіне сүйене отырып, әр түрлі жүйелерді, оның ішінде құбырлардағы конденсатты газдарды тасымалдау кезінде құрылымдық өзгерістерді диагностикалауға болады.

Бұл мақалада тасымалданатын газдың құрамына сұйық қосындыларын анықтаудың диагностикалық критерийін құру мақсатында газ құбырының әр түрлі желілеріндегі газ ағынының негізгі қысымының (қысым, шығын және температура) өзгеру режимдері келтірілген. Газ ағындарының қозғалысы кезінде сұйықтық қосындылары болған кезде сұйықтық жүйелеріне тән құрылымдық өзгерістер болатындығы анықталды, оларды ағын сипаттамаларының фракталдық өлшемдерінің өзгеруімен анықтауға болады.

Зерттеулер көрсеткендей, газ ағындарының құрылымдық өзгеру динамикасын зерттеу газ құбырларындағы сұйық фазалық эмбриондардың түзілуін диагностикалауда маңызды рөл атқара алады. Осы мақсатта құбырлардағы сұйық шөгінділермен жүретін газ ағындарының қозғалысын диагностикалау ұсынылды.

Түйін сөздер: газ құбыры, газ ағыны, диагностика, ағын сипаттамасы, құрылым формасы, фракталдық бағалар, көп фазалы, конденсация.

УДК:621.643.03

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УЛУЧШЕНИЕ ЭФФЕКТИВНОСТИ ФУНКЦИОНИРОВАНИЯ ГАЗОПРОВОДОВ С УЧЕТОМ СТРУКТУРНЫХ ОСОБЕННОСТЕЙ ТЕЧЕНИЯ ГАЗА

Аннотация. При разработке морских нефтяных и газоконденсатных месторождений многофазность и различный состав газовых потоков приводит к высоким затратам энергии в системе внутрипромыслового сбора и транспортировки скважинной продукции.

Анализ существующих систем сбора и транспортировки газоконденсатных смесей показывает, что при выборе режимных параметров и расчетных схем трубопроводов необходимо учитывать геофизический характер и сложность внутреннего строения транспортируемых флюидов. Высокую скорость газа можно достичь в так называемом «сухом» режиме, при котором жидкость уносится вместе с газом, когда профиль трубопровода относительно прямой, без подъемов и спусков. В этом случае исключается образование так называемых «застойных зон» в трубопроводе.

Однако, если глубина переработки газа не позволяет транспортировать его в однофазном состоянии, то проявляется фактор конденсации газа. Если морские трубопроводы имеют участки вертикальных подъемов и спусков, то гидравлические характеристики становятся сложными, и трубопроводы часто заполняются водой и конденсатом. В результате давление в трубопроводе увеличивается, и расположение точки сбора конденсируемых газов вдали от производственной площадки может вызвать серьезные проблемы.

Если охарактеризовать потоки нефти и газового конденсата как динамическую систему, в которой происходят чередующиеся структурные изменения, вопрос о фрактальности этих систем представляет большой научный интерес.

По изменению фрактальной величины можно диагностировать структурные изменения при транспортировке различных систем, в том числе конденсирующихся газов в трубопроводах.

В статье представлены режимы изменения основных параметров газового потока (давления, расхода и температуры) на различных участках газопровода с целью выработки диагностического критерия для выявления жидких включений в составе транспортируемого газа. Установлено, что при наличии жидких включений при движении газовых потоков происходят структурные изменения, свойственные жидкостным системам, которые можно идентифицировать по вариациям фрактальных размерностей характеристик потока.

Исследования показали, что изучение динамики структурных изменений газовых потоков может сыграть роль в диагностике образования зародышей жидкой фазы в газопроводах. Для этого предложена диагностика движения газовых потоков, сопровождаемых отложениями жидкости в трубопроводах.

Ключевые слова: газопровод, поток газа, диагностирование, характеристика потока, структурная форма, фрактальная величина, многофазность, конденсация.

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OF THE NATONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5227
Volume 3, Number 447 (2021), 40-45 **https://doi.org/10.32014/2021.2518-170X.60**

UDC 550.83

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GEOMECHANICAL MODELING OF STRUCTURES OIL AND GAS FIELDS

Abstract. The presence of areas of accumulation of hydrocarbons in the sedimentary strata is genetically related both to the conditions of sedimentation and to secondary changes in the properties of the geological environment, caused along with other and geodynamic processes. At the same time, it is the stress-strain state that is the key characteristic of the environment, the analysis of which makes it possible to predict the influence of geodynamic factors that cause deformation processes in the sedimentary stratum, on the formation of zones of decompaction and increased fracturing, areas of increased filtration-capacity properties of reservoir rocks, the direction of natural migration of hydrocarbons.

Using the example of 3D seismic data obtained at the Akshabulak area, the possibility of integrating geomechanical modeling and additional express analysis of seismic data in solving problems related to determining the probable places of accumulations and directions of natural migration of hydrocarbons is shown.

Key words: math modeling, decompaction zones, seals.

Introduction. The geological environment is exposed to mechanical force fields of various nature and, as a result, is in a certain stress-strain state (SSS). In the general case, at any point in the geological environment, a number of independent force fields act, primarily lithostatic and tectonic fields. There is a wide range of reasons for the occurrence of tectonic stresses. In the conditions of the sedimentary strata, one of the main reasons is the deformation of sedimentary rock layers in the course of their geodynamic evolution.

Today, seismic exploration is the only geophysical method that allows, on the one hand, to perform detailed structural constructions of the studied stratum, which reflects the total deformation that the geological environment experienced during its evolution from the accumulation of sediment strata to the manifestation of modern neotectonics, and on the other based on the analysis of the velocities of propagation of elastic waves and density to give very accurate information about the elastic properties of the medium. Such information, in turn, allows building a geomechanical model, which is a structural model with specified elastic properties. In recent years, researchers have repeatedly noted in their works the possibility of studying the stress-strain state on the basis of structural-velocity models of the medium according to seismic data when solving problems of oil and gas geology [1-7].

Research methodology. The following stages can be distinguished in the development of models:

Stage 1. Creation of spatial models of the distribution of decompaction zones.

The construction of such models can be used at the prospecting stage, since they make it possible to identify, in the section of the studied structure, areas of decompaction, which can be associated with the real spatial position and morphology of possible reservoirs, as well as those elements of the deep structure that can serve as supply channels, migration channels or areas of possible accumulation of hydrocarbons.

To solve this problem, we used data on the distribution of values of travel time of longitudinal seismic waves to the corresponding reflecting boundaries. Spatial representation of the distribution of travel time values, as a carrier of information about the inhomogeneities of the geological environment, makes it possible to identify and establish the position of decompaction zones, which manifest themselves as areas of relatively increased travel time values distributed in the investigated volume of the earth's crust [8].

Stage 2. Construction of a spatial model of a geological section in the parameters of the stress-strain state.

Mechanical and mathematical modeling of the geological environment involves the calculation of a set of parameters of the stress-strain state with a spatial reference of the calculated values. The distribution of the latter in the geological space can be used to solve a wide range of applied problems. Including when performing geodynamic zoning of territories and determining areas of potential

energy concentration, identifying zones of increased permeability and assessing the directions of possible movement of fluids, etc.

To calculate the parameters of the stress-strain state, the well-known relations of the theory of elasticity and plasticity are used under the condition of the continuity of the medium, which is expressed in the continuity of stresses and displacements, as functions of the coordinates of the point.

Let us give in general form the basic equations of the theory of elasticity in invariant form, which are used to determine the stress-strain state of rocks.

Equation of motion in invariant form:

$$\rho \frac{\partial^2 \vec{u}}{\partial t^2} = \mathrm{div}(\sigma) + \rho \vec{F}; \qquad (1)$$

Cauchy equations:

$$\varepsilon = \mathrm{sym}(\nabla \vec{u}) \equiv \frac{1}{2}(\nabla \vec{u} + (\nabla \vec{u})^{\mathrm{T}});$$

The equation of state for elastic media (Hooke's law), expressed through the Lamé coefficients:

$$\sigma = \lambda \mathrm{trace}(\varepsilon)\mathrm{I} + 2\mu\varepsilon; \qquad (3)$$

where

$$\lambda = \frac{E\nu}{(1+\nu)(1-2\nu)},\ \mu = \frac{E}{2(1+\nu)},\ K = \frac{E}{3(1-2\nu)}; \qquad (4)$$

E – is the modulus of elasticity; ν – is Poisson's ratio; K – volumetric expansion module.

To get an idea of the possible directions of fluid migration, calculations of the spatial distribution of lithostatic pressure (5) were performed with the subtraction of vertical pressure or pressure under the action of gravity:

$$P_{hydro} = (\sigma_{xx} + \sigma_{yy} + \sigma_{zz})/3 \qquad (5)$$

$$P_{ostat} = P_{hydro} - \rho g h \qquad (6)$$

Stage 3. Development of complex parametric models.

The construction of complex models is aimed at analyzing the correspondence of the distribution of decompaction with the distributions of the parameters of the stress-strain state in the investigated block of the earth's crust. In particular, the identification of areas of low pressure is one of the main conditions for the movement of fluids in the geological environment. Therefore, it seems important to establish their spatial position and link them with the distribution of decompaction zones, which, by definition, can be reservoirs, as well as serve as channels for their migration. The applied methodology was previously tested on the data of regional seismic observations and showed good convergence of the established decompaction zones with the known hydrocarbon deposits of the Caspian region. The main provisions of the proposed method of statistical analysis are given in the works.

Results and discussion. The object of this study was the Akshabulak structure, confined to the Aryskum depression, the thickness of the sedimentary cover is ~ 3 km, including the known hydrocarbon-producing horizons, localized in the depth interval 1.5-2 km from the earth's surface.

To develop density models, isochron and iso-depth maps were used for the next horizons, which made it possible to form the basis of future models (Figure 1):

- roofs of the Aryskum horizon of the Lower Neocomian deposits (II).
- roofs of Upper Jurassic deposits (III);
- intermediate horizon in the Middle Jurassic (IV);
- the surface of the Paleozoic basement (Pz).

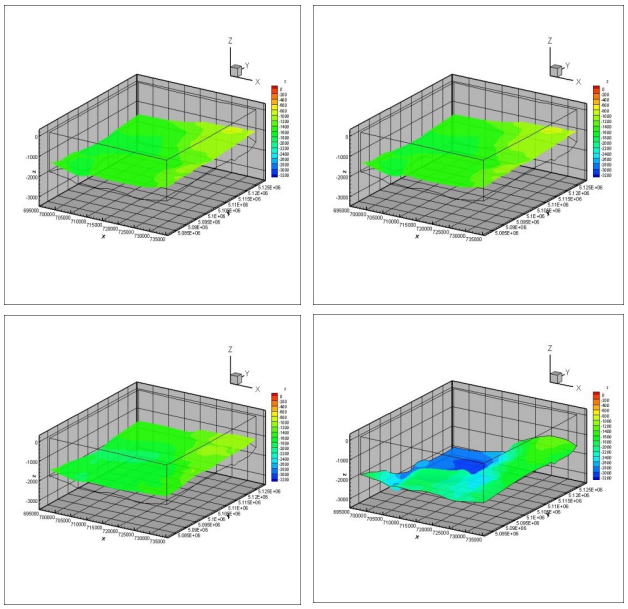


Figure 1. 3D images of iso-depth maps of the Akshabulak structure
(Y axis points North)

Features of the spatial distribution of density inhomogeneities.

The analysis of the results of the obtained distribution of travel times was carried out taking into account the known materials [19] about the position in the section of productive strata and tectonic faults.

The model shown in Figure 2 (A) indicates that the Akshabulak structure is a geological object that includes two clearly visible uplifts, to which the Akshabulak and Ashisay deposits are confined. Its section contains relatively decompacted layers, localized at the same depths as the productive horizons.

From the results illustrated in Figures 2 (B) and 4, it follows that the relatively decompressed sections of the section, shown by shades of yellow, stand out in the form of columnar segregations and can function as migration channels that ensure the movement of fluids from the lower horizons to the earth's surface.

A feature of the created models is a very low threshold of the time interval, which is on the order of (- 0.02 +0.03) s at a smoothing depth of 50, which, apparently, can be correlated with the composition of the rocks of the geological section. It is possible that the entire lower half-space is a fluid-saturated stratum separated by natural barriers - fluid seals.

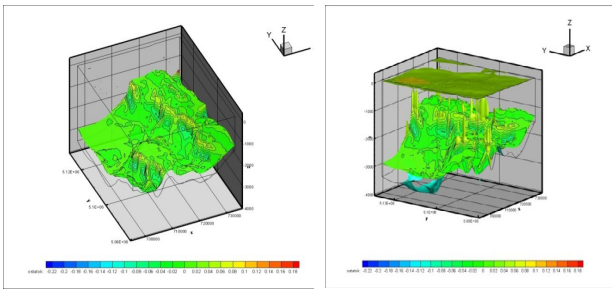


Figure 2. Spatial model of the site – A. The model of the distribution of zones of decompression in the geological cross-section of the Akshabulak – B.

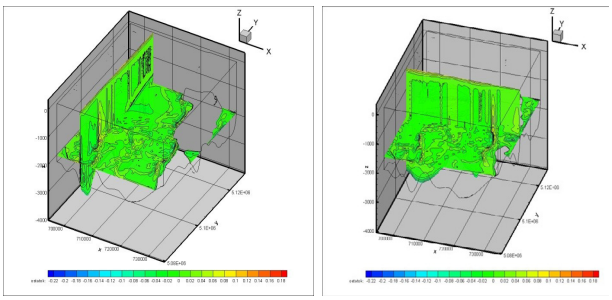


Figure 3. Spatial projection of vertical sections of the distribution of areas with reduced density in the geological section of the Akshabulak structure

Features of the possible direction of fluid flows in the geological half-space.

In order to differentiate the section from the point of view of the geometry of weakened zones and the associated possible directions of migration paths of fluids, including hydrocarbons, it is necessary to get an idea of the spatial distribution of the values of the horizontal component of the lithostatic pressure.

Figure 4 illustrates the distribution of the values of the horizontal component of the lithostatic pressure in the section of the Akshabulak structure, and they indicate that the lower half-space of the geological section is heterogeneous in its permeability. In accordance with the legend on the drawing, the distribution of colors should be interpreted as a decrease in pressure when changing from light blue to blue.

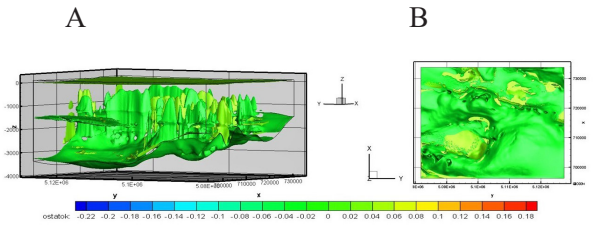
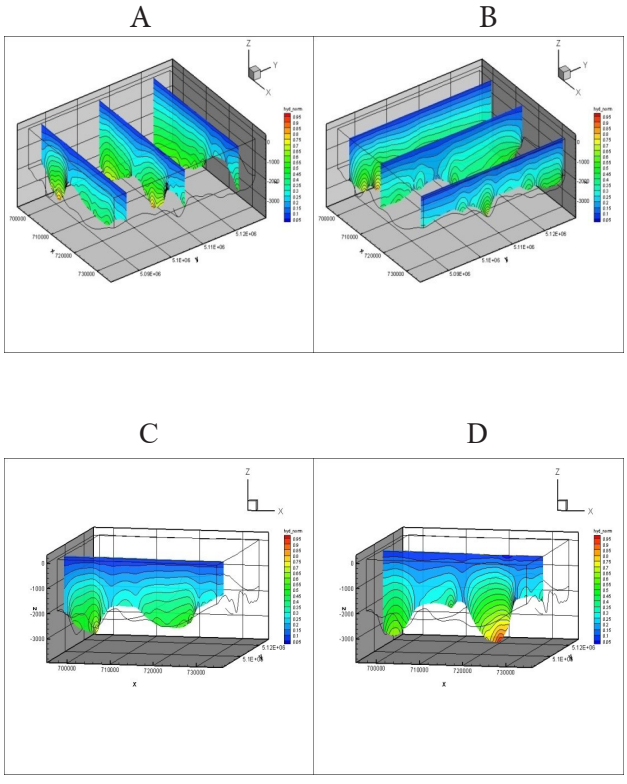


Рисунок 4. An example of the distribution of density inhomogeneities in the context of the Akshabulak structure. A -3D; B – bottom view.

The frontal distribution of reduced pressure (Figure 5) indicates that there are at least two low pressure channels in the investigated half-space, separated by a large area of relatively high pressure. The identified channels spatially coincide with the location of the Akshabulak fields.

In the presence of conditions for the accumulation of hydrocarbons, due solely to the geostructural features of the site, conclusions can be drawn about the possible ways of fluids entering natural traps.

Attention is drawn to the morphology of the identified areas of reduced pressure. If at the base the section is differentiated laterally with clearly pronounced elements of vertical zoning according to the values of the pressure distribution, then as it rises to the day surface this pattern degenerates with the formation of extensive lateral areas - potential zones of increased permeability. The latter can be interpreted as areas of possible lateral migration of fluids. Provided there is a seal, there is a potential for the formation of a structural trap.



E (h= -1100 m) F (h= -1400 m) G (h= -1800 m)

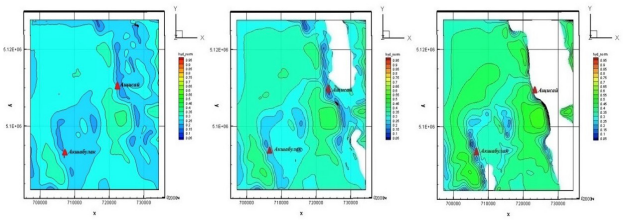


Figure 5. Spatial projections of vertical (A, B, C, D) and horizontal (E, F, G) sections of the distribution of mean pressure values in the section of the structure of the Akshabulak field.

The validity of this assumption is confirmed by the distribution of density inhomogeneities in the above figure 3, 4.

A B

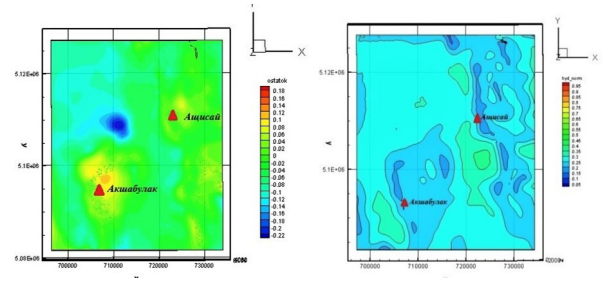


Figure 6. Distributions of mean pressure values (A) and distributions of areas with low density in the section of the structure of the Akshabulak field.

As shown in Figure 6, the distribution of decompaction zones and SSS parameters are correlated with each other, being complementary and mutually confirming data, which make it possible to increase the efficiency of geophysical studies, both at the stage of prospecting and at the stage of exploitation of hydrocarbon deposits.

The main conclusions are as follows.

1. The proposed method for analyzing seismic data allows you to get a visual spatial representation of the properties of the geological environment. In particular, the position of the reservoirs, the supply channels for the migration of hydrocarbons, the identification of new zones of increased permeability. The data on the distribution of the parameters of the stress-strain state also reflect the physical state of the considered volume of the geological environment and can be used to identify and localize possible tectonic faults or weakened zones.
2. A visual representation of the morphology of productive horizons provides a basis for the design of well placement and allows conclusions to be drawn regarding the possible location of new deposits.
3. The proposed methodology can be used as one of the stages of the search and exploration of hydrocarbon deposits in the predicted areas in order to identify productive horizons in the section.

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МҰНАЙГАЗ КЕН ОРНЫ ҚҰРЫЛЫМДАРЫНЫҢ ГЕОМЕХАНИКАЛЫҚ МОДЕЛЬДЕУ

Аннотация. Шөгінді қабаттарда көмірсутектердің жинақталу аймақтарының болуы генетикалық тұрғыдан тұнба жағдайымен де, геологиялық ортаның басқа да геодинамикалық процестермен қатар туындаған қасиеттерінің екінші реттік өзгеруімен байланысты. Сонымен қатар, қоршаған ортаның негізгі сипаттамасы болып табылатын стресс-деформация күйі болып табылады, оны талдау шөгінді қабатта деформация процестерін тудыратын геодинамикалық факторлардың әсерін, ыдырау мен сынудың жоғарылау аймақтарының пайда болуына, су қоймасының жыныстарының сүзілу-сыйымдылық қасиеттерінің жоғарылауына, көмірсутектердің табиғи миграциясының бағытына әсерін болжауға мүмкіндік береді.

Ақшабұлақ учаскесінде алынған 3 өлшемді сейсмикалық мәліметтер мысалын қолдана отырып, көмірсутектердің жинақталған орындары мен табиғи көші-қон бағыттарын анықтауға байланысты мәселелерді шешу кезінде геомеханикалық модельдеуді және сейсмикалық деректерге қосымша экспресс-талдауды енгізу мүмкіндігі көрсетілген.

Түйін сөздер: математикалық модельдеу, декомпрессия аймақтары, сұйық тығыздағыштар.

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ГЕОМЕХАНИЧЕСКОЕ МОДЕЛИРОВАНИЕ СТРОЕНИЙ НЕФТЕГАЗОВЫХ МЕСТОРОЖДЕНИЙ

Аннотация. Наличие областей аккумуляции углеводородов в осадочной толще генетически связано как с условиями седиментации, так и с вторичными изменениями свойств геологической среды,

обусловленными наряду с иными и геодинамическими процессами. При этом именно напряженно-деформированное состояние является той ключевой характеристикой среды, анализ которой позволяет прогнозировать влияние геодинамических факторов, обуславливающих деформационные процессы в осадочной толще, на формирование зон разуплотнения и повышенной трещиноватости, областей увеличения фильтрационно-емкостных свойств пород-коллекторов, направление естественной миграции углеводородов.

На примере 3D сейсмических данных, полученных на участке Акшабулак, показана возможность комплексирования геомеханического моделирования и дополнительного экспресс-анализа сейсмических данных при решении задач, связанных с определением вероятных мест скоплений и направлений естественной миграции углеводородов.

Ключевые слова: математическое моделирование, зоны разуплотнения, флюидоупоры.

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NEWS
OF THE NATONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5227
Volume 3, Number 447 (2021), 46-52 **https://doi.org/10.32014/2021.2518-170X.61**

UDC 502(470.67)

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LOCAL MONITORING OF THE ENVIRONMENTAL SITUATION IN RESIDENTIAL AREAS WITH HIGH LEVELS OF ELECTROMAGNETIC RADIATION

Abstract. The growing energy demand of the city of Shymkent has led to the construction and introduction of new energy hubs, high-voltage power lines, which are being built and conducted around residential areas exposed to environmental and carcinogenic risks. In turn, when constructing new energy facilities, energy companies and designers should present a cartography of residential areas in the project, in addition to the features of the selected territories and the population, which becomes a multi-factor object and subject of research when taking into account environmental and sanitary-epidemiological requirements, as well as when choosing optimal solutions in terms of routing high-voltage power lines. In our case, the residential district of Nursat, Nazarbayev Avenue and Kazygurt were chosen as such objects, which are polluted residential areas from the point of view of the spread of electromagnetic radiation generated by high-voltage power lines with a voltage of 110 and 220 kV.

The introduction of modern information technologies of a new generation made it possible to pinpoint and determine the main zones of electromagnetic radiation contamination, to establish the gradients of the electric and magnetic fields according to the degree of its impact, as well as to determine the number of residential objects that are partly exposed to carcinogenic and environmental risk by using the functional features of the geoinformation program.

Key words: mapping software, satellite monitoring, open access streets maps, coordinates of reference points, geolocal data, polygonal grid

Introduction. In the article [1], the main purpose of the study was to determine the safe distance of residential buildings from the source of electromagnetic fields generated by high-voltage power lines. The article [2] shows the importance of using Arc GIS geoinformation technologies in processing certain results and analyses on the impact of low-frequency energy objects on the environment. ICNIRP standards were used to evaluate this result. The results showed that the electric field strength is below the standard limit. Regulatory bodies such as the Energy Holding Company of Nigeria (PHCN), the Occupational Health and Safety Code (OHSC), and the Lagos State Urban and Regional Planning Regulations (LSURP) have legislated a minimum failure rate for every infrastructure located near power lines. These rules were used to evaluate the infrastructure that violates the rules. 12.5% of the assessed infrastructures complied with the PHCN regulation, 56.85% with the LSURP regulation and 78.12% with the OHSC regulation.

In the studies [3], during the experimental work, the main emphasis was placed on the establishment of their own national standards for the effects of electromagnetic radiation, followed by the presentation of the obtained standards on a regional database.

In turn, the processed database will be publicly available to energy companies and designers in order to ensure the safety of workers and residents of nearby residential areas who are exposed to a carcinogenic risk during the construction and during the implementation of high-voltage power lines.

In [4], a study was conducted in which the reaction of people to new routes of high-voltage power lines was clearly shown experimentally.

The research [5] developed a new open-source approach based on information platforms, which allows for transparent and reproducible route determination, tracking and evaluation, covering the whole of Europe. Each layer represents a criterion that affects the routing of the power line.

Together with the start and end points of the construction project, this allows you to create rasters of accumulated costs for various ratios between the perspective weights that are relevant in the routing process of the linear infrastructure.

The paper [6] presents a new method of automated route selection for the construction of new power lines, based on geographic information systems (GIS). It uses a dynamic programming model to optimize the route. Environmental constraints are taken into account along with all operating,

maintenance and installation costs, including a new approach to the costs associated with the slope of the terrain crossed by power lines. The computational and visual capabilities of GIS are used to select economic corridors, with total costs not exceeding the threshold set by the user. Examples of intensive modeling illustrate the power and flexibility of the proposed methodology.

Materials and methods of research. During the environmental monitoring, objects that are under the influence of electromagnetic radiation generated by high-voltage lines were visually shown on the example of data cartographies. When creating data cartographies, the coordinates of reference points of high-voltage power lines were obtained, which were obtained using Google maps satellite monitoring [7-9]. The coordinates of the location of low-frequency energy facilities in the Kazygurt and Nursat microdistrict are shown in the following table 1.

Table 1 – Coordinates of reference points of high-voltage high-voltage power transmission lines that were carried out in the Kazygrut, Nursat microdistrict and along Nazarbayev Avenue.

OBJECTID	x, м	y, м	z, м	name
1	69,56505792	42,29352498	25	Kazugurt
2	69,56671752	42,29604867	25	Kazugurt
3	69,5635874	42,29121334	25	Kazugurt
4	69,55852767	42,2918258	25	Kazugurt
5	69,5534706	42,2923942	25	Kazugurt
6	69,5494745	42,29284474	25	Kazugurt
7	69,54513641	42,29406788	25	Kazugurt
8	69,54062849	42,29531494	25	Kazugurt
9	69,53608063	42,29658172	25	Kazugurt
10	69,53194278	42,2977167	25	Kazugurt
11	69,52682585	42,29920416	25	Kazugurt
12	69,52120685	42,30071241	25	Kazugurt
13	69,5674	42,29711387	25	Kazugurt
14	69,517873	42,30164907	25	Kazugurt
15	69,66111903	42,35435369	20	Nursat
16	69,65849679	42,35520754	20	Nursat
17	69,65630018	42,35590878	20	Nursat
18	69,65389224	42,35668267	20	Nursat
19	69,65166657	42,35737922	20	Nursat
20	69,64943143	42,35809723	20	Nursat
21	69,64718974	42,35880808	20	Nursat
22	69,64661969	42,35898763	20	Nursat
23	69,63772058	42,36182363	20	Nazarbayev avenue
24	69,63609364	42,36234736	20	Nazarbayev avenue
25	69,63354906	42,36332174	20	Nazarbayev avenue
26	69,63105546	42,36426242	20	Nazarbayev avenue
27	69,62903561	42,36502889	20	Nazarbayev avenue
28	69,62708935	42,3657687	20	Nazarbayev avenue
29	69,62594653	42,36620148	20	Nazarbayev avenue

After establishing the reference points of high-voltage power lines, which were carried out in the Kazygurt, Nursat microdistrict and along Nazarbayev Avenue, data on high-voltage power lines were entered in the Open Street Maps application.

The cartographic data for the Kazygurt and Nurset microdistricts are shown in Figures 1 and 2.

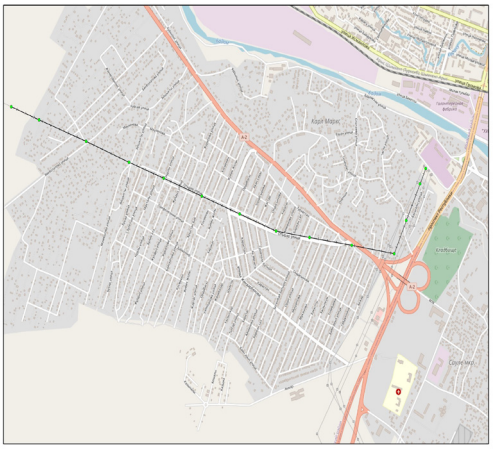


Figure 1. GIS Map of Kazygurt microdistrict based on Open Street Maps applications

Рисунок 2. GIS Map data of the Nursat microdistrict based on Open Street Maps applications

Figure 1 and 2 show the main parts of the neighborhood (streets) that are exposed to electromagnetic radiation.

The geographic information application program Arc GIS allows you to obtain the necessary information about geolocal data, process, and analyze the environmental situation at selected sites. In turn, by introducing the necessary information into the program, you can get specific results and conclusions when conducting environmental monitoring. First, the task is set by introducing the main gradients in the degree of danger of electric and magnetic fields, to determine the quantity of residential objects that are in the danger zone of the electromagnetic field generated by a high-voltage power line, 110 kV and 220 kV voltages [10-11].

Figure 3 shows a sample of geolocal data based on the ESRI ArcGIS program. As a necessary parameter, the distance ranges from the initial wire of the power lines to the point of interest were entered. This range was taken by the hazard gradient of the electric and magnetic fields.

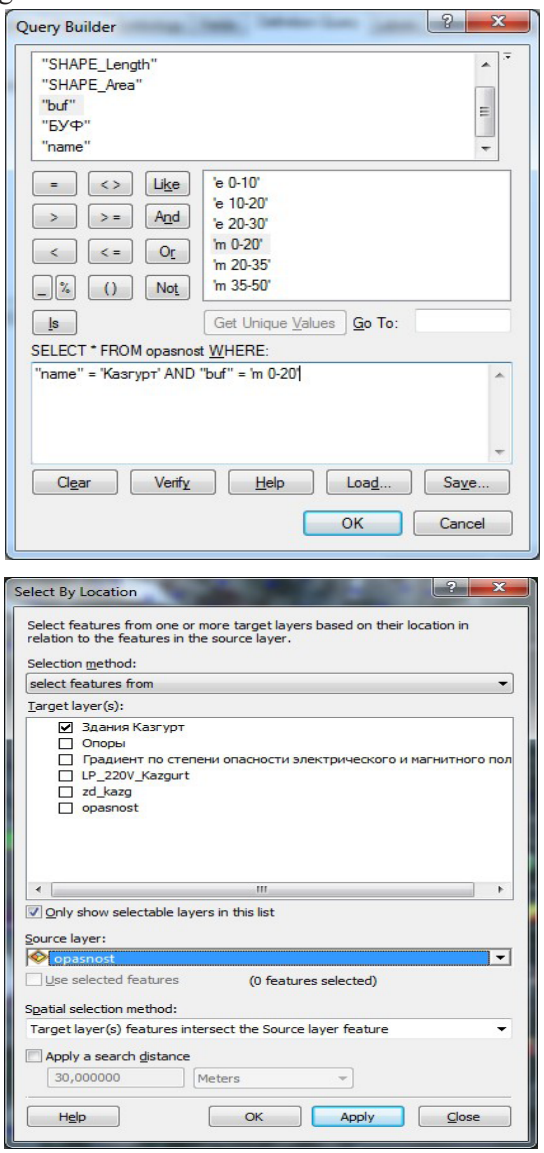


Figure 3. A selection of geolocal data based on the ESRI ArcGIS geoinformation program.

Figure 4 shows a selection of point features that were determined based on the construction of a polygon grid. In the polygonal grid, residential buildings of the Kazygrut microdistrict were calculated, which are located in the danger zone of the electric field in high-voltage power lines with a voltage of 220 kV.

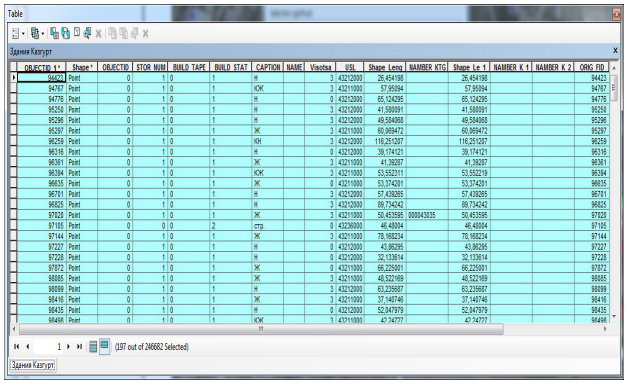


Figure 4. Selection of point objects based on a polygonal grid that are located in the zone of high danger of the electric field in the Kazygurt microdistrict.

Figure 5 shows a selection of point features that were determined based on the construction of a polygon grid. In the polygonal grid, residential buildings of the Kazygrut microdistrict were calculated, which are located in the danger zone of the magnetic field in high-voltage power lines with a voltage of 220 kV.

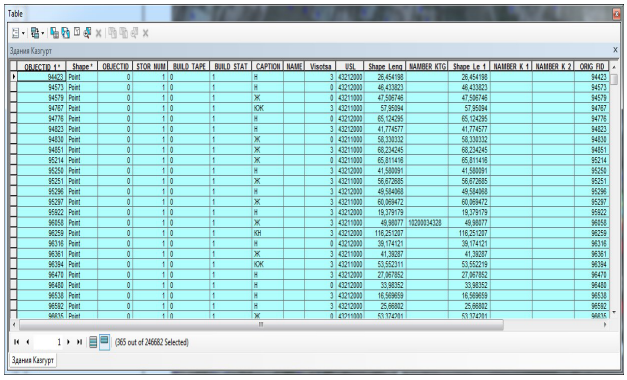


Figure 5. Selection of point objects based on a polygonal grid on the example of residential objects of the Kazygurt microdistrict located in the zone of high magnetic field activity.

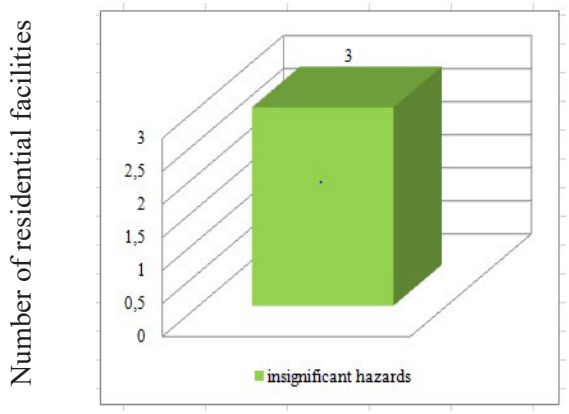
Similarly, for the residential districts of Nursat and for N. Nazarbayev Avenue, residential objects located in the zone of high, medium and insignificant danger of electric and magnetic fields were identified.

When ranking the electric and magnetic fields according to the degree of their impact on the environment, the maximum permissible levels of the electromagnetic field intensity were used.

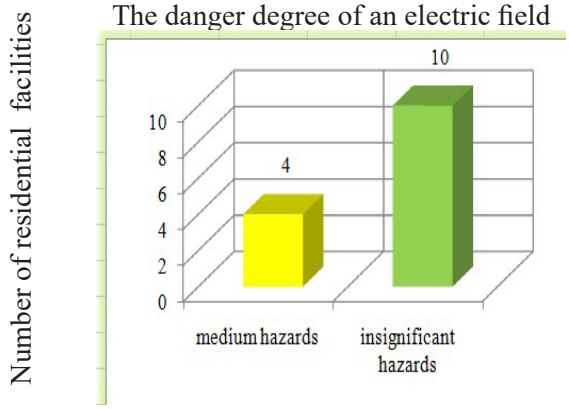
Results and discussion. ESRI ArcGIS geoinformation program allow us define the number of residential objects that are located in the zone of high, medium and insignificant danger of electric and magnetic fields generated by high-voltage power

lines with a voltage of 110 and 220 kV in the Nursat microdistrict, Nazarbayev Avenue and Kazygurt microdistrict was calculated.

Figure 6 shows the number of residential facilities that are in the dangerous zone of electric and magnetic fields in the Nursat microdistrict.



The danger degree of an electric field

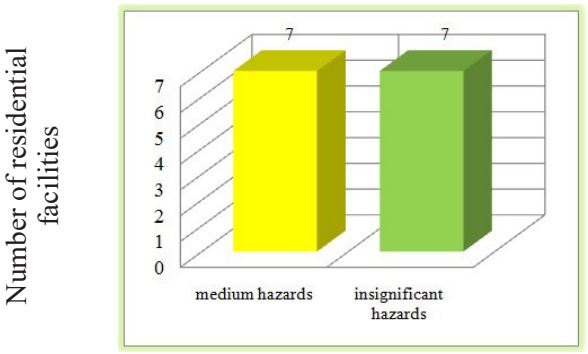


The danger degree of the magnetic field

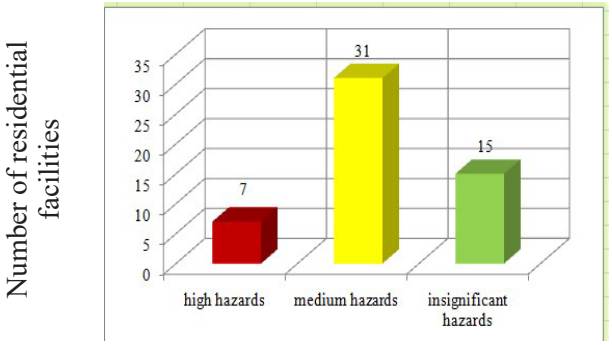
Figure 6. The number of residential facilities within the danger zone of electric and magnetic fields in the Nursat microdistrict.

Figure 6 shows that 3 residential facilities in the Nursat microdistrict are in the insignificant danger zone due to the electric field origin, 4, and 10 residential facilities in the medium and insignificant danger zone, respectively, due to the magnetic field origin.

Figure 7 shows the number of residential buildings that are in the dangerous zone of electric and magnetic fields along Nazarbayev Avenue.



The danger degree of an electric field

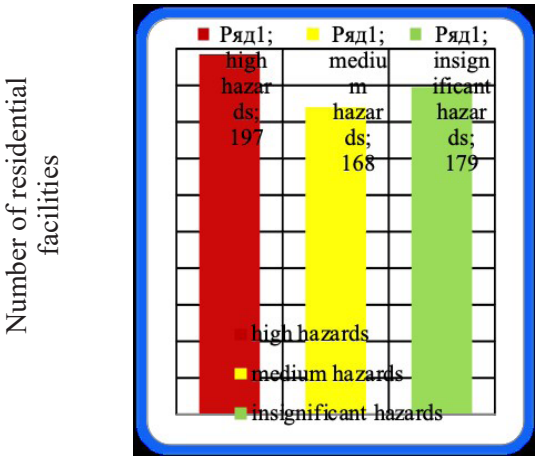


The danger degree of the magnetic field

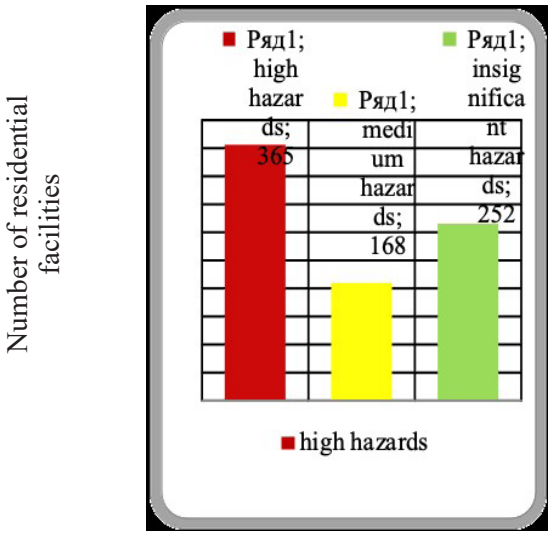
Figure 13. The number of residential facilities that are in the dangerous zone of electric and magnetic fields along Nazarbayev Avenue.

Figure 7 shows that 7 residential facilities are in the area of insignificant risk zone and 7 residential facilities in the medium risk zone of electric field origin, 7.31 and 15 residential facilities, respectively, located in an area of high, average, or insignificant risk for the magnetic field origin in the Nazarbayev prospect.

Figure 8 shows the number of residential facilities located in the dangerous zone of electric and magnetic fields in the Kazygurt microdistrict.



The danger degree of an electric field



The danger degree of the magnetic field

Figure 8 shows that 197,168 and 179 residential facilities, respectively, are in the high, medium, and insignificant dangerous zone due to the electric field origin, and 365,168 and 252 residential facilities, respectively, are in the high, medium, and insignificant dangerous zone due to the magnetic field origin in the Kazygurt microdistrict.

Conclusion. Today, the geoinformation map describing the current situation of the development of electric power networks allows timely and precise determination of the optimality of high-voltage power transmission lines, and increases the level of efficiency and ensures the safety of residential areas that are located around low-frequency energy facilities. In turn, in the last decade, global domestic energy companies have identified and developed new forms of methodology for the use of GIS equipment to justify the laying of high-voltage lines from the point of view of economic efficiency, as well as smoothing the processes of environmental risk and, accordingly, the concern of people who are exposed to carcinogenic risks.

In our case, the necessary maximum permissible levels of electric and magnetic field strength were introduced, which made it possible to visually represent the electromagnetic coverage of certain residential areas in the selected territories. Based on the polygonal grid in the GIS, the number of residential objects that are located around low-frequency energy objects was determined and the residential zones were selectively evaluated according to the degree of influence of the intensity of the electromagnetic field distribution.

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ЭЛЕКТРОМАГНИТТІК СӘУЛЕЛЕНУДІҢ ЖОҒАРЫ ДЕҢГЕЙІ БАР ТҰРҒЫН АУДАНДАРДЫҢ ЭКОЛОГИЯЛЫҚ ЖАҒДАЙЫНЫҢ ЖЕРГІЛІКТІ МОНИТОРИНГІ

Аннотация. Шымкент қаласының өсіп келе жатқан энергетикалық қажеттілігі жаңа энергетикалық тораптардың, жоғары вольтты электр беру желілерінің құрылысына және жүргізілуіне алып келді, олар өз кезегінде тұрғын үй алаптарында канцерогендік қауіп-қатер төндіруі мүмкін факторлардың бірі болып табылады. Өз кезегінде, жаңа энергетикалық нысандарды салу кезінде энергетикалық компаниялар мен жобалаушылар жобада таңдалған аумақтардың ерекшеліктерін және экологиялық және санитарлық - эпидемиологиялық талаптарды ескере отырып, көп факторлы объект пен зерттеу объектісіне айналатын тұрғындар санын, сондай-ақ жоғары кернеулі электр желілерін бағыттау тұрғысынан оңтайлы шешімдерді таңдаған кезде тұрғын үй аймақтарының картасын ұсынуы керек.

Біздің жағдайда осындай объектілер ретінде Нұрсат шағын ауданы, Назарбаев даңғылы және Қазығұрт шағын ауданы таңдалды, олар кернеуі 110 және 220 кВ жоғары вольтты электр беру желілерінен туындайтын электромагниттік сәулеленудің таралуы тұрғысынан ластанған аумақтар болып табылады.

Жаңа буынның заманауи ақпараттық технологияларын енгізу электромагниттік сәулеленумен ластанатын негізгі аймақтарды дәл бағалауға және алдын-ала анықтауға, оның әсер ету дәрежесіне сәйкес электр және магнит өрісінің градиенттерін анықтауға, сондай-ақ геоақпараттық бағдарламаның функционалды ерекшеліктерін қолдануға мүмкіндік беретін құрылымдарды қолдана отырып, ішінара канцерогенді және экологиялық қауіпке ұшырайтын объектілер болып табылатын тұрғын үй объектілерінің саны анықталды.

Түйін сөздер: картографиялық қамтамасыз ету, спутниктік мониторинг, көшелерге ашық ақпараттық қол жеткізу, тірек нүктелерінің координаталары, геолокалдық деректер, полигоналдық тор.

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ЛОКАЛЬНЫЙ МОНИТОРИНГ ЭКОЛОГИЧЕСКОЙ ОБСТАНОВКИ ЖИЛЫХ РАЙОНОВ С ПОВЫШЕННЫМ УРОВНЕМ ЭЛЕКТРОМАГНИТНОГО ИЗЛУЧЕНИЯ

Аннотация. Растущая энергетическая потребность города Шымкент привела к строительству и введению новых энергетических узлов, высоковольтных линий электропередач, которые возводятся и проводятся вокруг жилых районов, подвергающихся экологическому и канцерогенном риску. В свою очередь, при возведении новых энергетических объектов энергетическим компаниям и

проектровщикам следует представить в проекте картографию жилых зон, с дополнением особенностей выбранных территорий и численности населения, которые становятся многофакторным объектом и предметом исследования при учете экологических и санитарно-эпидемиологических требований, а также при выборе оптимальных решений с точки зрения маршрутизаций линий электропередач высокого напряжения. В нашем случае в качестве таких объектов были выбраны микрорайон Нурсат, проспект Назарбаева и микрорайон Казыгурт, которые являются загрязненными жилыми зонами с точки зрения распространения электромагнитного излучения, порождаемые высоковольтными линиями электропередач, напряжением 110 и 220 кВ.

Внедрение современных информационных технологий нового поколения позволило точечно оценить и предопределить основные зоны заражения электромагнитного излучения, установить градиенты электрического и магнитного поля по степени ее воздействия. Также применением функциональных особенностей геоинформационной программы было определено количество жилых объектов, которые отчасти и являются объектами, подвергающиеся канцерогенному и экологическому риску.

Ключевые слова: картографические обеспечение, спутниковый мониторинг, открытый информационный доступ улиц, координаты опорных точек, геолокальные данные, полигональная сетка.

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NEWS
OF THE NATONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5227
Volume 3, Number 447 (2021), 53-58 **https://doi.org/10.32014/2021.2518-170X.62**

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THE ANALYSIS OF SLIDING SURFACE IN ALO WATERSHED, GORONTALO DISTRICT, INDONESIA

Abstract. Alo watershed is the sub-watershed within the system of Limboto watershed which directly disembogues to Limboto Lake. Land degradation happened in the Alo watershed is caused by the agricultural system that does not apply land conservation techniques such as terracing and mounds and it triggers erosion and landslide. The method used in this research is geoelectric method with Wenner Alpha configuration; while the data analysis utilizes resistivity imaging method which produces two-dimensional cross-sectional images. In total, there are seven trajectories with a length of 170-180 meters each. The result of the research presents the slip surfaces of 7 locations are located in 3-17 meters depth with the inclination of 11° -79° trending dominantly northwest and one location trending southeast.

Keywords: Alo Watershed, Gorontalo, Sliding Surface

Introduction. There are not many pieces of research covering landslides in Gorontalo province. The latest research shows that the landslides occur in there are rotational slide, planar slide, slide flow, and rock block slide. The landslides are commonly affected by the slope and surface shape of the slope [1]. Alo watershed is the sub-watershed located in Limboto basin system which directly disembogues into Limboto Lake. Alo watershed is one of the largest sediment contributors to Limboto Lake of 0.0342 kg/sec. According to the latest survey conducted by JICA study team, annual sediment volume is estimated around 5.04 x 106 m^3/year (or 5,500 m^3/km^2/year). Therefore, if the incoming sediment volume cannot be controlled, it is predicted that within 25 years the Limboto Lake will be filled with sediment [2]. Alo watershed has the biggest sediment contribution of 947,187.87 ton and its SDR reaches 0.59. It reveals that 59% of the eroded sediment will get into Limboto Lake. As the result, the lake will be a land because of silting process. Alo watershed located on Tibawa sub-district has various levels of erosion ranging from very low, low, medium, and high risk. The trigger of these levels of erosion risk is inappropriate utilization of the land [3].

According to the Regional Geological Map of Tilamuta Sheet, scale 1:250,000 [4], Alo watershed is composed from tertiary and quaternary rocks. The rock formations in the Alo watershed are Diorite Bone (Tmb), Bilungala volcanic rock (Tmbv), Dolokapa Formation (Tmd), Pinogu Volcanic Rock (TQpv), and Reef Limestones (Q1). Referring to the latest research, the name of new limestone formation is Limboto Limestone Formation. This formation consists of two to three microfacies with shallow marine paleobathymetry that have undergone tectonic uplift [5,6]. The slope on Alo watershed is dominated by gentle slopes with slopes ranging from 8 – 15% with a percentage area of 3.14%, and slopes of 15 – 25% are 25.74%. Land usage in Alo watershed is dominated by arid agricultural land with an area percentage of 38.07%, secondary forest of 21.29%, plantation of 14.78%, shrubs of 20.30%, paddy field of 4.17%, and residential area of 1.38%. In general, the practice of agricultural land management in this area has not applied a land conservation technique. The social condition of Alo watershed community in terms of educational level, education level of people residing in Alo watershed is said to still low. Many people agree that farming areas are open. In addition, many people do not quite know about erosion, but many claims to know about erosion. Habits are carried out from generation to generation in cultivations / agricultural practices. There are 78% of the people living in the Alo watershed who agree to log to create farming areas. In cultivating agricultural area, 86% of farmers do not make changes in land cultivation practices and only 14% of farmers follow the advancement of land processing techniques [7].

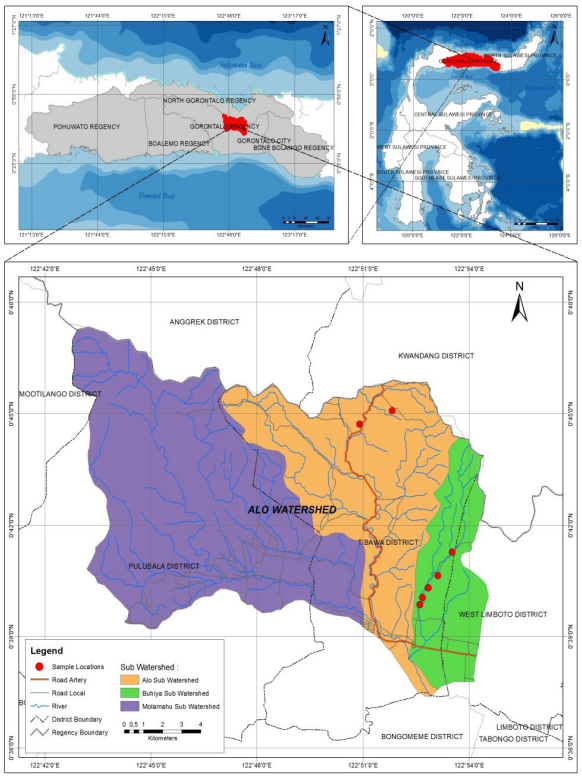

Figure 1. Map of research location in Alo Watershed, Gorontalo District

Methodology. The Alo watershed in the Gorontalo district, with an area of 24,222.41 acres, located at the coordinates of N 00o44' 52.715" and E 122o 49' 33.206' to N 00o 39'59.192" and E 122° 49'12.778" shall be chosen as the research site. The sampling location is in the Tibawa and Limboto sub-districts (Figure 1). Research data is a slip surface that occurs in the Alo sub- watershed. The measurement itself is conducted in seven locations, namely North Isimu Village and Labanu Village, Tibawa Subdistrict, Gorontalo District. Geoelectric measurements are carried out using the Electrical Resistivity Tomography (ERT) method to estimate the boundary or sliding surface below the surface. The ERT method is often used for landslide investigations because the main factors affecting resistance are soil type, porosity and water content [8,9,10,11].

ERT can present 2D and 3D cross-sections of soil and rock resistance distribution, with maximum resolution and depth of measurement depending on the configuration of the electrode [12]. The depth measurement target that can be achieved is approximately 1/5 of the maximum stretch length, i.e. the distance from the first electrode to the last electrode in one line [13]. One measurement line uses the Wenner-Alpha electrode configuration with a stretch length of 180 m for a depth target of about 35 m. Additionally, the acquisition of ERT measurements uses the Wenner-Alpha electrode configuration. The data analysis technique used in this study was a 2D inversion using the 3.54.44 version of RES2DINV based on the least - squares optimization method [14]. Landslide field analysis was performed by adding topographic data to the 2D inversion model using the RES2DINV program [15]. In addition, drill holes BH-01 and BH-02 were added for the calibration and correlation of subsurface resistance prices.

Result and Discussion. The measurement result of the resistivity value and rock type at the research location are shown in Table 1. The data in Table 1 shows that the rock types at 7 locations consist of clay, gravel, sand, limestone and dacite.Geoelectric measurement in research area refers to the inversion result of 2D resistivity imaging on the lines in seven location shown in Figure 2.

Location 1: Geoelectric measurements at location 1 are in North Isimu Village, 180 meters long, with a southwest-northeast trend. The slip plane is usually characterized by a contrasting field between high and low resistance values. Based on the rock resistance value, the slip plane at location 1 is estimated to be in the limestone layer as a layer with a high resistance value. The upper layers of the slip plane with resistance values of less than 674 Ωm were detected or suspected to be clay, gravel and sand layers. The limestone layer, which is a boundary plane or a slip plane, is detected at a depth of about 5-7 meters and has a high resistance of between 674-10,950.5Ωm with an apparent slope of about 8° to the southwest. On the basis of the apparent slope, the actual slope is 47° to the northwest.

Location 2: Geoelectric measurement at location 2 is at North Isimu Village, 180 meters long, with a south-north trend. Based on the rock resistance value, the slip plane at location 2 contains layers of clay, gravel, sand, limestone and dacite. The slip plane at location 2 is estimated to be in the plane of contrast between low and high resistance values. The upper layers of the slip plane with resistance values of less than 692Ωm are thought to be rock layers, i.e. clay, gravel and sand layers. The limestone layer, which is a slip plane, was detected at a depth of about 3 meters and has a high resistance of 692-9,479 Ωm with an apparent slope of about 11° southwest. Based on the apparent slope, the actual slope to the northwest is 79°.

Location 3: Geo-electric measurement at location 3 North Isimu Village with a length of 170 meters trending southwest − northeast. Based on the rock resistance value, the slip plane at location 3 is estimated to be in the contrasting plane between low and high resistance values, i.e. in the limestone layer. A layer of clay, gravel, and sand is thought to be the upper layer of the slip plane, which has a resistance value of less than 796Ωm.The limestone layer, which is a slip plane, is detected at a depth of about 5-8 meters and has a high resistance of 796-10,552.5Ωm with an apparent slope of about 7° to the southwest Based on the apparent slope, the actual slope is 74° to the northwest.

Table 1. Electrical Resistance Value and Types of Rock Layers at the Research Location

No	Location 1 North Isimu Village 1 (0°39'52.6" N, 122°52'36.7" E) - (0°39'55.5" N, 122°52'41.6" E)		Location 2 North Isimu Village 2 (0°40'3.5" N, 122°52'41.4" E) - (0°40'9" N, 122°52'43.3" E)		Location 3 North Isimu Village 3 (0°40'19.6" N, 122°52'51.26" E) - (0°40'24.9" N, 122°52'55.19" E)		Location 4 North Isimu Village 4 (0°40'39.1" N, 122°53'7.1" E) – (0°40'36" N, 122°53'1.89" E)		Location 5 North Isimu Village 5 (0°41'17.41" N, 122°53'31.6" E) - (0°41'21.4" N, 122°53'28.2" E)		Location 6 Labanu Village 1 (0°44'43.3" N, 122°50'57.2" E) - (0°44'45.3" N, 122°50'51.8" E)		Location 7 Labanu Village 2 (0°45'05.2" N, 122°51'07.3" E) - (0°45'05.5" N, 122°51'01.7" E)	
	Electrical Resistance (Ωm)	Type of Layer	Electrical Resistance (Ωm)	Type of Layer	Electrical Resistance (Ωm)	Type of Layer	Electrical Resistance (Ωm)	Type of Layer	Electrical Resistance (Ωm)	Type of Layer	Electrical Resistance (Ωm)	Type of Layer	Electrical Resistance (Ωm)	Type of Layer
1	0 – 27.9	Clay	0 – 13.7	Clay	0 – 7.11	Clay	0 – 15.8	Clay	0 – 4.29	Clay	0-0.89	Clay	0-3.44	Clay
2	27.9 – 54.3	Clay	13.7 – 32.15	Clay	7.11 – 16.5	Clay	15,8 – 34.25	Clay	4.29 – 11.695	Clay	0.89-2.05	Clay	3.44-8.22	Clay
3	54.3 – 80.6	Clay	32.15 – 50.6	Clay	16.5 – 25.9	Clay	34.25 – 52.7	Clay	11.695 – 19.1	Clay	2.05-3.21	Clay	8.22-13	Clay
4	80.6 – 156.8	Clay	50.6 – 118.8	Clay	25.9 – 60.05	Clay	52,7 – 114.35	Clay	19.1 – 51.85	Clay	3.21-7.36	Clay	13-30.9	Clay
5	156.8 – 233	Gravel and Sand	118.8 – 187	Gravel & Sand	60.05 – 94.2	Clay	114,35 – 176	Gravel & Sand	51.85 – 84.6	Clay	7.36-11.5	Clay	30.9-48.8	Clay
6	233 – 453.5		187 – 439.5		94.2 – 218.6	Gravel & Sand	176 – 381		84.6 – 230.3	Gravel & Sand	11.5-26.5	Loamy Sand	48.8-116.4	Gravel & Sand
7	453.5 – 674		439.5 – 692		218.6 – 343		381 – 586		230.3 – 376		26.5-41.5	Loamy Sand	116.4-184	Gravel & Sand
8	674 – 1,310.5	Limestone	692 – 1,122	Limestone	343 – 796		586 – 1,269.5	Limestone	376 – 1,023		41.5-95.25	Gravel & Sand	184-438	Gravel & Sand
9	1,310.5 – 1,947	Limestone	1,122 – 2,562	Limestone	796 – 1,249	Limestone	1.269,5 – 1,953	Limestone	1,023 – 1,670	Dry Gravel	95.25-149	Gravel & Sand	438-692	Gravel & Sand
10	1,947 – 3,788	Limestone	2,562 – 6,020.5	Limestone	1,249 – 2,898.5	Limestone	1,953 – 4,233	Limestone	1,670 – 4,544.5		149-342.5	Gravel & Sand	692-1,649.5	Limestone
11	3,788 – 5,629	Limestone	6,020.5 – 9,479	Limestone	2,898.5 – 4,548	Limestone	4,233 – 6,513	Limestone	4,544.5 – 7,419		342.5-536	Gravel & Sand	1,649,5-2,607	Limestone
12	5,629 – 10,950.5	Limestone	9,479 – 22,277	Dacite	4,548 – 10,552.5	Limestone	6,513 – 14,113	Limestone	7,419 – 20,188		536-1,232.5	Limestone	2,607-6,214	Dacite
13	10,950.5 – 16,272	Dacite	22,277 – 35,075	Dacite	10,552.5 – 16,557	Dacite	14,113 – 21,713	Dacite	20,188 – 32,957	Dacite	1,232.5-1,929	Limestone	6,214-9,821	Dacite
14	16.272 – 31.656	Dacite	35,075 – 82,430	Dacite	16,557 – 38,418.5	Dacite	21,713 – 47,052.5	Dacite	32,957 – 89,681	Dacite	1,929-4,432.5	Dacite	9,821-23,406.5	Dacite
15	31.656 – 47.040	Dacite	82,430 – 129,785	Dacite	38,418.5 – 60,280	Dacite	47,052.5 – 72,392	Dacite	89,681 – 146,405	Dacite	4,432.5-6,936	Dacite	23,406.5-36,992	Dacite
16	> 47.040	Dacite	> 129,785	Dacite	> 60,280	Dacite	> 72,392	Dacite	>146,405	Dacite	> 6,936	Dacite	> 36,992	Dacite

Source: Analysis Result in 2021

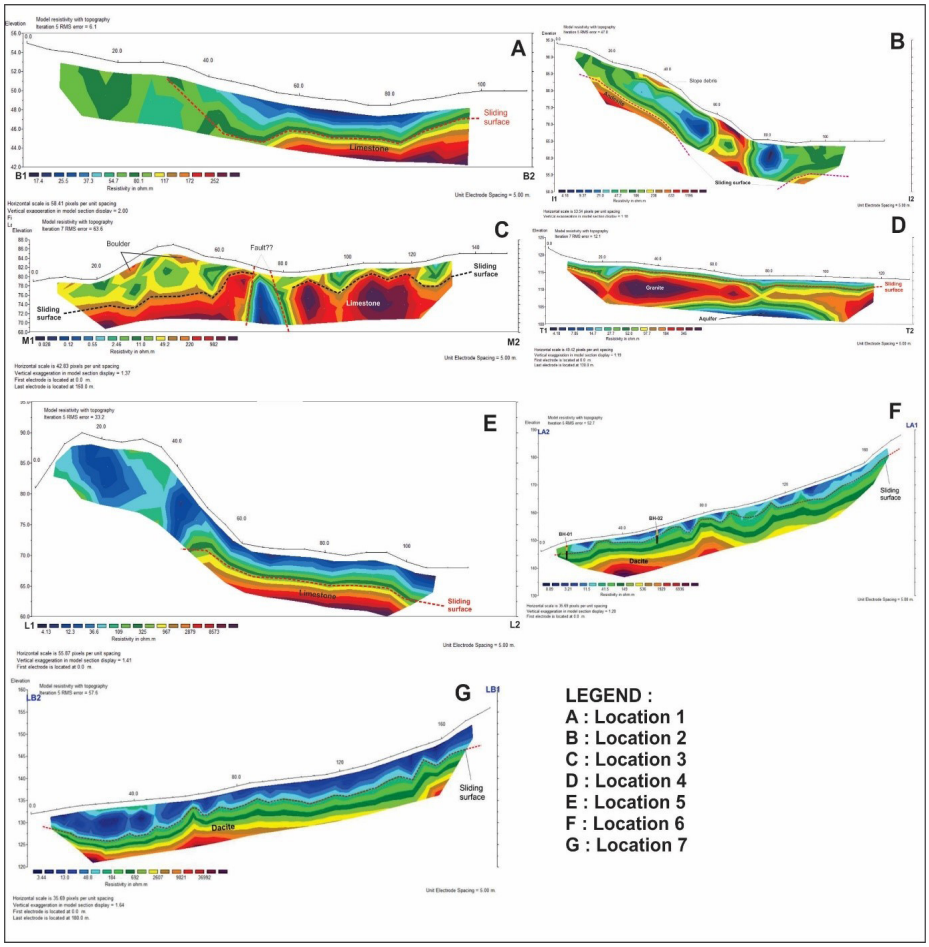

Figure 2. Cross section of 2D resistivity imaging at 7 lines at the research location

Location 4: Geo-electric measurement at location 4 in North Isimu Village with a track length of 180 meters trending northeast - southwest. The limestone layer which is a slip plane is detected at a depth of about 4-5 meters which has a high resistivity ranging from 586-14,113-m with an apparent slope of about 3° to the southwest. Based on the apparent slope, the actual slope is 56 ° trending the northwest.

Location 5: Geo-electric measurement at location 5 in North Isimu Village with a track length of 180 meters trendingsoutheast - northwest. The slip area is estimated to have low and high resistance values, namely in the dacite layer. The upper layers of the slip plane with resistance values of less than 20,188 -m are thought to be layers of clay, gravel, sand and dry gravel. The igneous rock layer of the dacite, which is a slip plane, was detected at a depth of about 17 meters, which has a high resistance of >20,188 -m, with a true dip of about 11° to the southeast.

Location 6: Geo-electric measurement at location6 in Labanu Village with a track length of 180 meters trendingeast - west. The slip area is estimated in low and high resistance values, namely in the dacite layer. The upper layers of the slip plane with resistance values of less than 536Ωm are thought to be layers of clay, loamy sand, gravel and sand. The limestone layer, which is a slip plane, was detected at a depth of about 2 meters, which has a resistance of > 536Ωm, with a true dip of about 13° to the east.

Location 7: Geo-electric measurement at location 7 in Labanu Village with a track length of 180 meters trending east - west.The slip area is estimated in low and high resistance values, namely in the dacite layer. The upper layers of the slip plane with resistance values of less than 692Ωm are thought to be layers of clay, gravel and sand. The limestone layer, which is a slip plane, was detected at a depth of about 2-5 meters, which has a resistivity of > 692Ωm, with a true dip of about 11° to the east.

Conclusion. Based on the results of the interpretation and analysis, it can be concluded that the two-dimensional cross-section of the track at locations 1, 2, 3, 4 and 7 is thought to be the structure of the subsurface soil in the form of clay, gravel and sand. The line at location 5 has a subsurface layer of dry gravel under the sand. The track at location 6 has a sub-surface layer of loamy sand under the layer of clay. The slip plane is interpreted as a limestone layer in lines 1, 2, 3, 4, 6 and 7, while the slip plane in line 5 is assumed to be in a dacite igneous rock layer. The results showed that the landslide slip fields at 7 locations were approximately 3-17 meters deep with a slope angle of 11o -79^{o} with trending dominantly northwest and one location with a southeast trend.

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АЛО СУ ҚОЙМАСЫНДАҒЫ СЫРҒАНАУ БЕТІН ТАЛДАУ, ГОРОНТАЛО АУДАНЫ, ИНДОНЕЗИЯ

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АНАЛИЗ ПОВЕРХНОСТИ СКОЛЬЖЕНИЯ В ВОДОРАЗДЕЛЕ АЛО, РАЙОН ГОРОНТАЛО, ИНДОНЕЗИЯ

Аннотация. Водораздел Ало - это суб-водораздел в системе водораздела Лимбото, который непосредственно сливается с озером Лимбото. Деградация земель, произошедшая в водосборном бассейне Ало, вызвана сельскохозяйственной системой, которая не применяет методы сохранения земель, такие как террасирование и насыпи, что вызывает эрозию и оползни. Метод, используемый в этом исследовании, является геоэлектрическим методом с конфигурацией Альфа Веннера, в то время как анализ данных использует метод визуализации удельного сопротивления, который создает двумерные изображения поперечного сечения. Всего существует семь траекторий, длиной 170-180 метров каждая. В результате исследования представлены поверхности скольжения в 7 местах, расположенных на глубине 3-17 метров с наклоном 11о-79^{o}, направленным преимущественно на северо-запад, и в одном месте, направленном на юго-восток.

Ключевые слова: водораздел ало, Гронтало, поверхность скольжения.

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NEWS
OF THE NATONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5227
Volume 3, Number 447 (2021), 59-64 **https://doi.org/10.32014/2021.2518-170X.63**

UDC 658.567.1

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ASSESSMENT OF LAND RESOURCE POTENTIAL AND SOLID WASTE RECYCLING METHODS

Abstract. This paper analyzes the environmental load exerted by the solid waste landfills of Turkistan and Kentau cities and the villages of the Sauran district of the Turkistan region. The data of morphological analysis of MSW composition stored in the territories of these landfills are presented. This paper aims to present the possibility of reducing the amount of some waste types deposited at landfills on the basis of their direct use as secondary raw materials for various purposes. The possibility of using solid waste components in greenhouses and other facilities construction has been shown by recycling plastic and glass bottles, as well as other industrial waste. On the basis of experimental data, it was concluded that with widespread introduction of waste recycling, by saving materials, it will make it possible to reduce the cost of economic facilities construction and to minimize the harmful impact of waste on environment.

Key words: solid waste landfills, Turkistan region, harmful impact, secondary raw materials, polyethylene terephthalate, recycling, building materials.

The actuality of the problem. Municipal solid waste (MSW) is one of the dangerous sources of environmental pollution [1-3]. The relevance of studying the solid waste landfills impact on the environment lies in the formation of negative processes of microbiological, sanitary-hygienic and sanitary-toxicological nature on the mentioned territories and in nearby residential areas. The environmental problems associated with these types of waste are still not fully resolved in all countries of the world [4-6]. The composition of MSW contains ecologically hazardous components of various natures. The qualitative and quantitative composition of generated waste is associated with the life standard of the population, with the development of infrastructure and types of production activities.

To solve the solid waste problems and an urgent task of its solving are to change the existing ways of handling them. Disposal of solid waste in landfills and rubbish dumps is widely practiced all over the world due to low capital and operating costs. As the analysis of statistical data has shown, more than 90% of solid waste in Kazakhstan is sent to storage or burial in landfills [7-8], which poses a threat to the environment. At present, the number of landfills in the republic exceeds 2,000, including 181 officially authorized solid waste landfills in the Turkistan region with project documents. At the same time, the number of unauthorized landfills is more than the number of landfills. Unfortunately, storage and disposal of solid waste in landfills remains the simplest and cheapest way to remove waste in Kazakhstan. This method does not provide environmental protection of the atmosphere, soil, surface and ground waters pollution, does not prevent, but, on the contrary, promotes the spread of rodents, insects and disease-causing microorganisms.

The negative impact of waste in landfills and rubbish dumps is due to the formation of biogas (methane content ≤60%), as well as leachate during heavy precipitation. A significant threat to the environment is posed by fires or smoke pollution, while especially toxic dioxins, furans and other substances are released into the atmosphere. Furans and dioxins contribute to disorganization of processes in the body, namely, they cause a disorder of tissue respiration, disrupt metabolic processes in the liver and other organs. By damaging the human immune system, these substances contribute to a number of dangerous diseases. In the affected organs under the action of dioxins, the bioactivation of mutagens, carcinogens, and neutrotoxic poisons already present in the body [9]. This leads not only to the creation of negative impacts on the natural environment objects, including the health of the population, but also to the irreversible loss of valuable secondary material and energy resources [10-12]. In this regard, it becomes necessary to minimize emissions of highly toxic substances into the atmosphere to concentrations not exceeding the values of international standards.

For environmental protection and rational integrated use of natural resources, the most acceptable and relevant are the following types of waste management: recycling, processing and disposal of waste. They obtain specific valuable marketable products. But these issues must be resolved in each case individually, taking into account the economic and technological capabilities of the region.

The aim of this study is the ecological and economic substantiation of ways to reduce the impact of solid waste on the environment both in the urban and agricultural areas of the Sauran (Turkistan region).

Objects and research methods.The research objects of polygons of Kentau and Turkistan cities, 10 polygons of villages in the Sauran district of the Turkistan region and sulfur-containing waste of SKZ-U LLP, sawdust, sintered lump and other residues of solid building materials. A crushing plant was used to treat the waste. While conducting research, we used the main methods, namely experiment and visual fixation. The ecological assessment of target landfill condition and solid waste was carried out in accordance with state regulations and methods.

GANK-4 gas analyzer was used in quarterly determination of the greenhouse atmospheric air content, ozone-depleting and other toxic emissions generated over landfill sites, at the border of the sanitary protection zone and in areas adjacent to the landfill.

Results and discussion. The inconstancy of harmful substances content was identified in field observations of the qualitative and quantitative composition of landfill gases in the atmospheric air directly on the territories of landfills, and in areas adjacent to them up to 1 km. The increased concentrations of greenhouse and toxic gases were observed in the surface air layer with intense smoke. The methane content exceeds the maximum permissible concentration (MPC) in urban landfills in Kentau and Turkistan more than 300 times and higher, in rural areas it shows 20-25 times. Exceeding the MPC values was also found for sulfur (IV) oxide ≥7 times (for the Kentau landfill), nitrogen oxides ≥ 25 (for the Turkistan city landfill).

The high concentrations of methanethiol (also known as methyl mercaptan) is turned up in the process of smoke pollution deserve serious attention. Based on the measurements, we established the presence of this carcinogenic and mutagenic substance in the atmospheric air above the landfills with smoke in the range of 0.007-0.015 mg / m^3 or more (the maximum one-time maximum permissible concentration is 0.0001 mg / m^3). Mercaptans affect the respiratory system and the central nervous system [13]. The qualitative composition and content of harmful gases formed during combustion and smoke pollution depended on the morphological composition of solid waste in landfills.

Awareness of the morphological composition of solid waste is a necessary indicator for characterizing the impact of landfill components on the environment, as well as for the selecting methods for protecting biological resources and the rational integrated use of waste as secondary raw materials. According to the Concept on Kazakhstan's transition to a "Green economy" adopted in May 2013, the share of recycled waste in the country should be 40% in 2030, and 50% by 2050 [14].

According to the transition to a "Green economy" from 2016, the disposal of mercury-containing lamps and devices, scrap metals, waste oils and liquids, batteries, waste electronic devices at landfills is prohibited. Since January 2019, a ban on the disposal of plastic, waste paper, cardboard and other paper waste, glass in landfills came into force. From January 1, 2021, there is a ban on the disposal of construction and food waste [14]. In connection with these prohibitions, it becomes necessary to find new ways of handling solid waste. The results of scientific research to address a number of existing problems associated with plastic and glass bottles, as well as with industrial solid waste are presented in the following part.

As can be seen from Table 1, the composition of municipal solid waste is unstable and varies depending on the season of the year. The amount of components in the total waste stream in urban landfills is very different from the composition of waste in rural landfills. The largest amount of food waste is generated in the summer-autumn period, which can be explained by an increase in the consumption of vegetables and fruits, as well as by preserving them for winter by canning. The increase in polymeric and glass materials in the composition of MSW in the summer-autumn period compared to the winter-spring period is associated with increased consumption of various drinks in hot summer months. The construction waste increases twice in connection with the intensified repair and construction work in summer and autumn months. The main amount of waste belongs to 4 and 5 hazard classes. The moisture content of waste in the summer months is not higher than 1%, in the autumn and winter months it depends on the amount of atmospheric precipitation and ranges from 10-15%.

Table 1 shows the average morphological composition of solid waste in urban and 10 rural landfills of the Turkistan region. Studies were conducted from November 2020 to January 2021.

Table 1 - Characteristics of the morphological composition of solid waste in urban and rural landfills

Components	Average content of MSW components in Kentau and Turkistan and 10 rural landfills of Sauran district by seasons of the year, %					
	Winter-Spring			Summer-Autumn		
	Village	Turkistan	Kentau	Village	Turkistan	Kentau
Food wastes	~10	≥25	~22	~9	~32	~ 30-40
Paper, cardboard	5...8	15...17	7...12	6...10	20...22	≤10
Wood pieces and sawdust	~0,2	2...3	0,5...1	~0,5	3...4	~2
Scrap Metal	≤ 1	≤ 3	до 1	≤ 2	≤ 3	1...3
Textile	5...6	4...5	3...5	4...7	4...5	2...4
Bones	5...10	5...8	3...7	5...15	5...10	2...5
Glass and various containers	3...5	7...10	5...7	10...12	10...15	14
Leather and Rubber	6...9	2...5	10...11	5...7	2...5	2...3
Stones, plaster, slate and other construction waste	≥5	≥10	≥8	≥10	≥20	≥10
Polymer products, including plastic bottles	~10	≥20	≥20	≥15	>25	~23
Wool and animal manure	10...25	2...3	5...10	~10	2...3	≤1

Morphological analysis shows that about 50% of solid waste is a potential secondary resource (Table 1). In all landfills, the content of polymer packaging materials, including plastic bottles, is growing every year. The involvement of such valuable components as paper, cardboard, glass, polymer materials, metals in the secondary circulation will lead to a significant reduction in the need for material and energy resources, as well as reduce their negative impact on the environment.

Disposal of organic waste, such as manure, poultry droppings, food waste, will make it possible to return carbon, nitrogen and other elements into the substances cycle. Organizing production of compost, vermicompost and other fertilizers-ameliorants based on waste will increase the fertility of degraded agricultural fields.

We have carried out a number of works aimed at using plastic and glass bottles and industrial waste without recycling. Photo-captured moments of waste collection and recycling are presented in Figure 1.

Figure 1.Recycling of plastic and glass bottles for building greenhouse walls and observation booth with an winterized field on the territory of Ecology Research Institute Area

Preliminary sorting of solid waste at the generation sources has been carried out to facilitate utilization, which facilitates the separate collection of various types of waste.

Figure 2 shows objects (greenhouse and a house) withused polymer and glass bottles built in the production territory of Ecology Research Institute (Turkistan, Nazarbayev St., 8) at AkhmetYassawi International Kazakh-TurkishUniversity. The remains of unusable cement, plastering materials and sulfur-containing sulfuric acid waste generated of building repairs and constructions were used to fill the bottles.

The principle of creating a warm floor with blocked-up glass and plastic bottles consists in an air gap that fills the cavity of the bottle and acts as a thermal barrier that does not allow cold to enter the room. Glass and plastic bottles prevent cold air from penetrating through the ground. To provide mechanical strength, plastic bottles were filled with sawdust and other waste, and durable glass bottles were used without filling. The bottles were placed in 3 rows in a prepared pit ~ 25 cm deep. A layer of sulfur-containing waste of sulfuric acid production was covered at the pit bottom and the thorough tamping and leveling was carried out. Seroperlite-containing waste has an insecticidal property, which prevents the termite and other insects accumulation. Crushed stone, screenings or sand can be used to create a compacted layer under the bottles instead of waste, rubble, screenings or sand. The pit bottom and each row of the stacked bottles were covered with a reinforcing mesh for stability and rigidity. Parallel rows of bottles joined neck to neck and bottom to bottom to reduce the headspace between bottles. Then the floor mounted from glass or plastic containers was leveled with a cement screed 5-7 cm high.

Figure 2. Greenhouse and cabin with MSW construction

During the greenhouse construction, plastic bottles were filled with shredded solid waste available to create strength. Then, to fasten the bottles, the pores between them were filled with a solution containing wood ash, slaked lime and ordinary table salt. The optimal way of laying is a chess order, the first row was laid only using cinder block bricks, in the upper rows the brick was alternated with plastic bottles (Figure 1). According to the estimated data, provided that plastic bottles are used instead ofbrickworks, a certain amount of cinder block bricks can be saved. In this facility, every 1000 plastic bottles allowed on average to reduce the consumption of cinder block bricks by 250 pieces.

Conclusions.

1. This paper establishes the plastic bottles applicability as the main material for winterization of walls and floors using the example of a greenhouse and a cabin built on the territory of the Ecology Research Institute at AkhmetYassawi International Kazakh-Turkish University. This approach made it possible to use low-cost construction material (plastic bottles) and avoid the need to look for solutions for the processing of not only these bottles, but also other industrial waste (sulfur-containing waste, sawdust, unusable plaster materials, cement and other residues of various waste) used to fill them.

2. Direct use of plastic bottles without recycling as a building material avoids the release of them into the environment and reduces waste amount. In addition, waste recycling will make it possible, with widespread introduction, to reduce the economic facility construction costs by saving materials.

3. At last this paper verifies the use of various solid waste types and industrial waste of regional origin as secondary raw materials will make it possible to make specific decisions on waste management, adapted to local social, economic and technical potentials.

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ҚАТТЫ ТҰРМЫСТЫҚ ҚАЛДЫҚТАРДЫ ҚАЙТА ҚӘДЕГЕ АСЫРУ ТӘСІЛДЕРІ МЕН ПОЛИГОНДАРДЫҢ РЕСУРСТЫҚ ӘЛЕУЕТІН БАҒАЛАУ

Аннотация. Бұл мақалада Түркістан, Кентау қалалары мен Түркістан облысының Сауран ауданындағы ауылдардың қатты тұрмыстық қалдықтар полигондарының қоршаған ортаға тигізетін экологиялық жүктемесі талданған. Осы полигондардың аумағында сақталған қатты тұрмыстық қалдықтар (ҚТҚ) құрамына морфологиялық талдаулардың мәліметтері келтірілген. Полигондарда жинақталған қалдықтардың кейбір түрлерін оларды әртүрлі мақсаттағы екінші реттік шикізат ретінде тікелей пайдалану негізінде азайту мүмкіндігі көрсетілген. Полиэтилентерефталат (ПЭТ) пен шыны бөтелкелерді, сондай-ақ басқа өндірістік қатты қалдықтар компоненттерін қайта өңдеу арқылы жылыжайлар мен басқа да нысандардың құрылысында пайдалану мүмкіндігі көрсетілген. Тәжірибелік мәліметтер негізінде қалдықтарды қайта өңдеуді кеңінен енгізе отырып, материалдарды үнемдеу арқылы шаруашылық құрылыс нысандарының шығындарын азайтуға және сонымен бірге қалдықтардың қоршаған ортаға зиянды әсерін барынша азайтуға мүмкіндік беретіндігі зерттелген.

Түйін сөздер: қатты тұрмыстық қалдықтар полигоны, Түркістан облысы, зиянды әсер, екіншілік шикізат, полиэтилентерефталат, қайта өңдеу, құрылыс материалдары.

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ОЦЕНКА РЕСУРСНОГО ПОТЕНЦИАЛА ПОЛИГОНОВ И СПОСОБЫ РЕЦИКЛИНГА ТВЕРДЫХ БЫТОВЫХ ОТХОДОВ

Аннотация. В статье проанализирована экологическая нагрузка, оказываемая полигонами твердых бытовых отходов городов Туркестан, Кентау и сел Сауранского района Туркестанской области на окружающую природную среду. Приведены данные морфологического анализа состава ТБО, складируемые на территориях этих полигонов. Показана возможность сокращения количеств депонируемых на полигонах некоторых видов отходов на основе их непосредственного использования в качестве вторичного сырья для различного назначения. Путем рециклинга ПЭТ и стеклянных бутылок, а также других производственных отходов показана возможность применения компонентов ТБО при строительстве теплиц и других объектов. На основе экспериментальных данных сделан вывод о том, что при широком внедрении рециклинг отходов позволит за счет экономии материалов удешевить строительство хозяйственных объектов и одновременно минимизировать вредное воздействие отходов на окружающую среду.

Ключевые слова: полигоны твердых бытовых отходов, Туркестанская область, вредное воздействие, вторичное сырье, полиэтилентерефталат, рециклинг, строительные материалы.

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NEWS
OF THE NATONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5227
Volume 3, Number 447 (2021), 65-71 **https://doi.org/10.32014/2021.2518-170X.64**

UDC 669.018.2
IRSTI29.19.13

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QUANTITATIVE ASSESSMENT OF THE YIELD STRESS OF FERRITE-PEARLITIC STEELS BY STRUCTURE PARAMETERS

Abstract. In various sectors of the economy, requirements are imposed on the quality of metallurgical products. The event that improves the quality of metallurgical products - thermomechanical treatment (TMT). TMT allows reducing the specific consumption of steel, increasing the service life, reliability and durability of products, which is tantamount to an increase in the volume of finished metal products.

The problem of applied materials science is the establishment of a quantitative relationship between the structure and properties of steels and alloys, it underlies the development and creation of new effective ways to improve the operational characteristics of metal products. In the production of long products, (TMT) is increasingly used, which is a combination of two methods of strengthening steels: deformational by plastic deformation and thermal by phase transformations.

Revealing the features of the properties of heat-treated steels makes it possible to approach the solution of this problem. The main mechanisms of hardening are solid solution hardening by alloying with relatively cheap alloying elements (Mn, Si) and dislocation and precipitation hardening using hardening heat treatment and microalloying of steel with carbide and nitride-forming elements V (C, N).

The article quantifies the approximate contribution of various strengthening mechanisms to the yield stress of carbon and low-alloy steels. For St5ps steel (hot-rolled state), the yield stress is given by solid-solution and grain-boundary hardening (37.4.0% and 28.6%), in low-alloy steel 16G2AF (36.7% and 27.1%), the role of dispersion hardening (28.0%).Thermomechanical treatment of steel grade St.5ps leads to an increase in the value of dislocation hardening up to 27.6% due to an increase in the density of dislocations and the retention of most of the dislocations in the rolled stock during accelerated cooling of hot-deformed austenite.

Key words: hardening mechanisms, yield stress, thermomechanical treatment, accelerated cooling, plasma hardening, phase components, grain size.

Introduction. As is known, the establishment of a quantitative relationship between the structure and properties of metallic materials is one of the main problems of applied materials science, since it underlies the development and creation of new effective ways to improve the performance of products. So, at present, thermomechanical treatment (TMT) is increasinglyused in the production of long products, which is a combination of two effective methods of hardening: deformation from plastic deformation and thermal from phase transformations. The attention of researchers is also drawn to the fact that when using TMT according to the interrupted quenching mode, a layered structure is formed in the surface layers of rolled products, which can be classified as structural composites with their advantages.

Revealing the features of the formation of the structure and properties at the yield point of steels subjected to different heat treatment allows one to approach the solution of this problem [1].

The purpose of this work is to quantify the yield stress of low-carbon and low-alloy steels in terms of chemical composition and structure parameters, to compare the calculated values with the data of the corresponding GOST to obtain information about the existing strengthening mechanisms after one or another treatment and alloying [2,3].

Models description and parameter estimation. The initial data for calculating the yield point of steel used data on the chemical composition, the distribution of constant and alloying impurities between the phases and quantitative parameters of the structure: grain size, the ratio of phase and structural components, their distribution, distance between strengthening particles, dislocation density, etc [4,5].

Note that such estimates of the yield stress are rather not quantitative, but semi-quantitative, since a number of simplifications and assumptions in the theory of the hardening mechanisms themselves are adopted in the calculation, which do not allow a rigorous quantitative assessment of the yield stress of steel. Thus, in the theory of dislocation hardening, an important role is played by the precise determination of the dislocation density; however, the calculations neglect a decrease in the dislocation density in the process of foil thinning in transmission electron

microscopy, or the distribution of dislocations over the volume of the material is assumed to be homogeneous and isotropic, although in fact this does not correspond to reality. For deformation-thermally hardened steels, the dislocation density (according to literature data) is approximately$\rho=109 cm^{-2}$ [6,7].

The reliability of the calculated dispersion hardening is largely determined by the reliability of the determination of the interparticle distance - λ, since it is precisely this that is included in the Orowan calculation equation -$\Delta\sigma=(9,8*103/\lambda)$ ln 2λ. The difficulty lies in the fact that it is practically impossible to measure the interparticle distance -λ in the images, therefore it can be calculated through other measured parameters: the volume fraction - f and the diameter of the strengthening particles - D; $\lambda = D*(\pi/6f)1/2$ [8,9].

The determination of the volume fraction of phases by the method of point analysis is based on the proposition that the fraction of randomly applied points on the micrograph falling on the image of the phase under study is equal to the volume fraction of this phase. $f_\alpha = n_\alpha / n_0$, where n_α –is the number of points that fall on the sections of phase α; n0 – is the total number of points plotted on the microstructure image. A comparative analysis of the role and contribution of various mechanisms of hardening to the total yield stress of carbon and low-alloy steels was carried out according to the methodology proposed in [4]. The investigated steels differ not only in chemical composition, but also in the hardening heat treatment used.The magnitude of the individual components of hardening and their contribution to the total yield stress of these steels were determined using the known empirical formulas given below. The coefficients required for the calculation are taken from the specified literature data. In this case, the calculated values of the yield stress of the studied steels were compared with the data of GOST 5781, GOST 10884, and GOST 19282 to obtain information on the applicability of the method for assessing the yield stress by structural parameters. Determination of structure parameters (pearlite content in steel, inter-plate spacing, ferrite grain diameter, size and volume fraction of the carbonitride phase, etc.) to assess the yield stress was performed by quantitative metallography methods using a Neophot 21 optical microscope and an UEMV-100 electron microscope [10].

The calculation is based on the principle of additivity of hardening mechanisms, which has been confirmed by many researchers in many steels. The essence of this principle is that the contribution of individual hardening mechanisms to the total yield stress of a polycrystalline material is summed up.

As you know, the yield point of steel is determined by the Hall-Petch ratio, which for tensile conditions has the form:

$$\sigma_T = \sigma_i + k_y * d^{-1/2} \qquad (1)$$

where σ_i- the frictional stress of the crystal lattice during the movement of dislocations inside grains, i.e. intragranular hardening without taking into account the contribution of grain boundaries (such as a single crystal) to the yield stress;

$k_y d^{-1/2}$ - grain boundary hardening, where, ky - coefficient characterizing the contribution of grain boundaries to hardening, which are barriers to the advancement of dislocations from one grain to another; according to the literature data, this coefficient is within wide limits, affecting the calculation results (0,57-0,73MPa$\sqrt{м}$), influencing the calculation results, therefore, the proportion of grain boundary hardening was estimated from the nomogram, d - grain diameter [11,12,13].

This expression is applicable with sufficient accuracy to ferritic steels with grains ranging in size from 0,3 to 400 mkm (literature data), from which it follows that the yield stress of the material increases with decreasing grain size.

Intragrain hardening from relation (1) can be represented as:

$$\sigma_i = \sigma_0 + \Delta\sigma_{SS} + \Delta\sigma_P + \Delta\sigma_{SH} + \Delta\sigma_{PH} \quad (2)$$

where irepresents the amount:

1) σ_0 - lattice friction stresses to the motion of free dislocations, taking into account defects in the crystal structure and taking into account a certain amount of interstitial impurities (C + N) in a solid solution for iron-based steels with bcc. lattice $\sigma 0_{\sim 30MPa.}$

Calculated hardening formula: $\sigma_0 = 2 * 10^{-4} G$, Modulus of elasticity for iron G = 84000 MPa.

2) $\Delta\sigma_{ss}$-solid solution hardening with alloying impurities, calculation formula

$\Delta\sigma_т p = \sum Ki * C_i$

whereKi – hardening coefficient determined in special studies on the influence of alloying elements on the hardening of ferrite,

C_i – the concentration of the alloying element in the solid solution (ferrite). In this work, the following (literary)

Ki values are taken to calculate тр:

Element	C+ N	P	Si	Mn	V
K_iMPa/%,	4670	690	86	33	3

As can be seen, interstitial atoms (C + N) strongly strengthen ferrite than substitutional atoms.

3) p - hardening due to the formation of a pearlite component, p=2,4P, where 2,4-empirical coefficient MPa/P%, share of pearlite component in structure,%; depends on the composition of the steel (primarily on the carbon content), the cooling rate during heat treatment. The degree of dispersion of pearlite is determined by the inter-plate distance - Δ., which is the sum of the thicknesses of two adjacent ferrite and cementite plates in pearlite structures (perlite, sorbitite, troostite). Δ changes depending on the cooling rate.Thus, the measured values of the

inter-plate distance for the hot-rolled state of St5Ps Δ= 0,6 mkm, after HTTT (in the unreinforced zone) decreases and amounts to 0,4 mkm [14,15].

4) $\Delta\sigma_{SH}$ - hardening due to the resistance of a gliding dislocation to other dislocations (strain hardening), SH = αM G b ρ1|2 , whereα – коэффициент, is a coefficient depending on the nature of the distribution and interaction of dislocations, is in the range 0,1-0,3. For the considered steels (with a ferritic base), the parameters included in the above equation, according to the literature, are:M=2,75; G = 84000 MPa; vector Burgers b = 0,25nm[16,17].

5) $\Delta\sigma_{PH}$ - hardening caused by dispersed particles of the second phase (dispersion hardening) Calculation formulas: PH = (9,8 *103/λ) ln 2 λ, where, λ - is the interparticle distance; $\lambda = D * (\pi/6f)^{1/2}$

Results obtained and their discussion.

Table 1: Initial data for quantitative assessment of the yield strength of the investigated steel

№	Characteristics of steeltype	The grade of the investigated steels and their heat treatment		
1	Alloying element content in α-Fe, %: Mn Si P V (C+ N)	St5ps	St5ps	16G2AF
		0,55 0,11 0,04 - 0,015	0,58 0,15 0,04 - 0,015	1,5 0,3 0,035 0,11 0,015
2	Strengtheningphase (dispersed particle)	-	-	V(C,N)
3	The proportion of pearlite structures (%) with different-Δ, (for steel after HTTT without taking into account the hardened surface zone)	35 0,6 mkm	43 0,4 mkm	17 0,11 mkm
4	Grain size: (number according to GOST 5639-82) d, mm	6 0,051	9 0,012	9 0,014
5	Volume fraction of dispersed particles, f,%	-	-	0,096
6	Dispersed particle size, D, nm	-	-	30
7	Interparticle distance, λ, nm	-	-	765
8	The nature of the dislocation structure, ρ, sm^{-2}	10^8	10^9	10^8

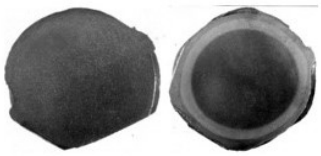
Note. 1. Based on the experimental data, it is assumed that ~ 0.015 (C + N) is dissolved in the ferrite, the rest of the carbon and nitrogen are bound into carbonitrides

2. According to the literature data for deformation-thermally hardened steels, the dislocation density is approximately ρ=10 9sm-2.

As can be seen from the data presented (Tables 1 and 2), the yield stress of steels to which the studied grades belong can be considered as the sum of terms in equation (1). The share of the contribution of individual hardening factors to the total yield strength of steel is not the same and depends on the content of alloying elements and the degree of alloying, the presence and dispersion of the hardening phases, applied thermal, thermomechanical treatment and other factors [18].

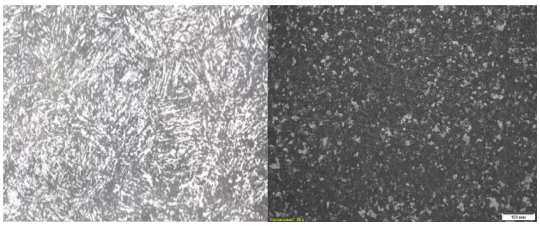
In carbon steel grade St5ps (hot rolled state), the main components of hardening are solid solution and grain boundary hardening, the proportion of which is ~ 66%. In absolute terms, the proportion of these terms is equal to 125,3 MPa and 95,7 MPa. In steel St5ps, subjected to HTTT, a significant contribution to the overall hardening is made by strain (dislocation) hardening. Note that HTTT of reinforcing steel St.5ps with a diameter of 14 mm was carried out according to the scheme of interrupted quenching with self-tempering: the temperature of the end of rolling is 1050^0C, the pause between the end of rolling and the beginning of intensive cooling is 2 s, and the self-tempering temperature is ~500°C. When hardening according to this scheme, the transformation of most of the austenite occurs after the cessation of water cooling; therefore, the main factor determining the obtained properties will be the temperature level after its leveling over the cross section of the reinforcement being hardened. This temperature is usually called the self-tempering temperature. However, this definition is valid only for the surface layers, which, upon cooling in water, underwent a martensitic transformation and are tempered at the leveling temperature, which has a tempering sorbitol structure with a globular shape of cementite particles. For the inner layers, which make up the main part of the section, this temperature (~450-500^0C) is the temperature of austenite decomposition by the diffusion mechanism. Metallographic studies show that at HTTT the structure of the surface layer (~ 3 mm thick) of reinforcement with a diameter of 14 mm is formed as a result of the martensitic γ→α transformation, and the structure of the axial central zone is formed as a result of the diffusion γ→α

transformation, figure 1,2,3 [19,20].



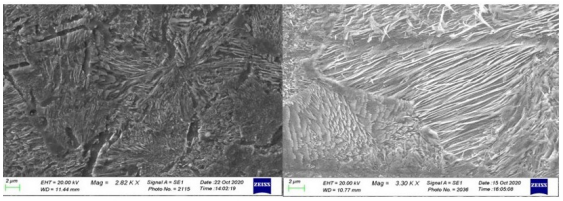
a) b)

Figure 1: Macrostructure (x25) of hot-rolled (a) and heat-strengthened (b) reinforcing steel



a) b)

Figure 2: Microstructure of heat-strengthened reinforcing steel after quenching (a-hardening martensite) and self-tempering at ~ 500^{0}C (b-tempered martensite-sorbitol tempering)



a) b)

Figure 3: Substructure of intermediate (a) and central (b) zones of reinforcing steel after surface hardening (at HTTT)

In steel thermomechanically treated according to the interrupted quenching scheme with subsequent self-tempering, the proportion of strain hardening is 27,6%, absolute value $\Delta\sigma_{SH}$=140MPa. This is apparently explained by an increase in the density of dislocations when hot rolling is combined with subsequent immediate quenching. In this case, intensive cooling suppresses recrystallization processes and fixes a significant part of the dislocations that arise during hot rolling of austenite; the dislocation structure of hot-deformed austenite is inherited by the martensite formed in the process of diffusion-free austenite-martensite transformation. In addition, the refinement of the austenite grain during thermomechanical treatment leads to the refinement of the formed martensite crystals [5-7]. Note that an increase in the yield stress after HTTT (in our case, 27,6%) is also noted in other works [4,10]. Noting the efficiency of the solid-solution hardening mechanism and its applicability, at the same time, it should be emphasized that there is probably some optimal degree of doping α-Fe, because saturation of α-Fe with impurity substitution and interstitial atoms can lead to dangerous elastic deformation of the lattice and fracture toughness of the alloy [21,22].

Table 2: Quantitative assessment of the yield strength of steels with different structural and phase states

№	Indicators	Steelgrade		
		St5ps	St5ps	16G2AF
1	Latticefrictionstress	30/8,9	30/5,9	30/5,6
2	Solidsolutionhardening	125,3 /37,4	129,7 /25,5	169,8 /36.7
3	Strengthening due to pearlite structures	84,0 /25,1	103,2 /20,3	40,8 /7.6
4	Dislocationhardening	-	140 /27,6	
5	Dispersionhardening	-		150 /28,0
6	Grainboundaryhardening	95,7 /28,6	105 /20.7	145 /27.1
7	CalculatedYieldStrength	335	507.9	535.6
8	The value of the yield point according to GOST	285	440	440
9	Difference (in%) of data from GOST and calculated valuewe have the yield point	14,9	13.4	17,8

Note. 1. In the numerator - the absolute value of hardening (MPa), in the denominator - the proportion of hardening due to this mechanism, (in% of the value of the yield stress according to GOST). So, for hot-rolled reinforcing steel St.5ps according to GOST 5781 σ0,2 =285 N/mm^2, for the same steel after HTTT according to GOST 10884 (strength class AT 111C)σ0,2 =440 N/mm2, for steel 16G2AF according to GOST 19282 σ0,2 =440 N/mm^2.

If we take into account that solid solution hardening is caused by the difference between the atomic diameters of ferrite and alloying element and their elastic moduli, then a high proportion of this hardening can be explained by the resistance to moving dislocations from the side of dissolved atoms [23, 24].

In low-alloy steel 16G2AF, the role of precipitation hardening is noticeable – 28,0%, PH=150,0 MPa. As can be seen from table 1, in this steel a dispersed carbonitride phase V (C, N) is formed, which strengthens the ferrite by the Orowan mechanism. It is assumed that the V (C, N) carbonitride phase is incoherent with the (α-Fe) matrix and therefore the V (C, N) precipitates bend around the dislocations, thereby causing precipitation hardening.

The efficiency and prospects of precipitation hardening are also indicated by the effect of dispersed

phases on the grain size. It follows from Table 1 that in steel 16G2AF, in the structure of which there is a dispersed carbonitride phase V (C, N), a finer grain d=0,014 mm is formed. This is explained by the embryonic influence of the V (C, N) particles when passing through the critical points Ac1 andAc3. In addition, the carbonitride phase inhibits the growth of austenite grain upon further heating up to the temperature of dissolution of these phases in austenite. These two circumstances lead to the fact that noticeable refinement of ferrite grains occurs in 16G2AF steel. Thus, dispersed particles of the carbonitride phase V (C, N) in steel cause additional grain boundary hardening [25].

In low-carbon and low-alloy steels, the main phase component is, as you know, ferrite, its share in these steels reaches 70-75%. When a load is applied, deformation begins to develop in ferrite, and pearlite colonies are “barriers” for the movement of dislocations that cause deformation. Therefore, hardening from the pearlite component also makes a certain contribution to the overall hardened state. The tables show that the proportion of hardening from the pearlite content is within wide limits from 7,6% for steel 16G2AF (only~0,16% of carbon) to 20,3% for the fine-lamellar state of pearlite in steel St.5ps due to general grinding structures after HTTT.

It should be noted that non-metallic inclusions can also affect the mechanical properties of these steels. However, their volume fraction in the steels under consideration does not exceed 0,1%, they do not have a hardening effect, and therefore, in this work, the behavior of non-metallic inclusions was not considered [26, 27].

Conclusion. 1. Analysis of the data for the quantitative assessment of the yield stress of carbon and low-alloy steels by structural parameters shows that the main mechanisms of their strengthening are solid solution strengthening by alloying with relatively cheap alloying elements (Mn, Si), as well as dislocation and precipitation hardening using hardening heat treatment and microalloying of steel with carbide and nitride-forming elements V (C, N).

2. The formation of a gradient structure in the surface layer of the product when hot deformation is combined with subsequent quenching in the rolling process flow (HTTT) leads to a significant increase in the yield strength (strength) of steel. In this case, the strengthening of the reinforcing profile is also facilitated by the refinement of the structure of the inner layers of steel. The gradient structure, as shown by numerous studies, excludes the formation of a sharp transition boundary from martensite structures to mixed structures of the pearlite type, which is one of the main factors that increase the contact-fatigue strength of steel.

3. Comparison of the calculated values of the yield point with its value in the corresponding GOST-ah shows a satisfactory difference in values: after normalization – 17,8% for steel 16G2AF and 14,9% for St5ps (Hot-rolled state). After HTTT, the difference between the calculated value of the yield stress and the value according to GOST 19282 is 13,4%. These data indicate the applicability of an approximate quantitative assessment of the yield strength of steel, based on the analysis of the parameters of the formed structure after certain treatments, taking into account the assumptions made.

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ФЕРРИТТІК-ПЕРЛИТТІК БОЛАТТАРДЫҢ АҚҚЫШТЫҚ ШЕГІН ҚҰРЫЛЫМЫНЫҢ ПАРАМЕТРЛЕРІ БОЙЫНША САНДЫҚ БАҒАЛАУ

Аннотация. Қарқынды инновациялық дамуына байланысты экономиканың әртүрлі салаларында үнемі жоғары талаптар металлургия өнімдерінің сапасына қойылады. Дайын металлургиялық өнімнің сапасын жақсарту жөніндегі шаралар арасында маңызды орын термиялық-механикалық өңдеу (ТМӨ) алады. Металдың беріктік сипаттамаларын арттыру арқылы ТМӨ болаттың меншікті шығынын азайтуға, бұйымдардың қызмет ету мерзімін, бөлшектер мен тораптардың сенімділігі мен беріктігін арттыруға мүмкіндік береді, бұл өз кезегінде дайын металл көлемінің ұлғаюына әсер етеді.

Қолданбалы материалтанудың негізгі мәселелерінің бірі болат пен қорытпалардың құрылымы мен қасиеттері арасындағы сандық байланысты орнату болып табылады, себебі ол металл бұйымдарының эксплуатациялық сипаттамаларын жақсартудың жаңа тиімді әдістерін жасау негізделген. Осылайша, қазіргі уақытта илемделген темір бұйым өндірісінде ол (ТМӨ) көбірек қолданылуда, бұл болаттарды беріктендірудің екі тиімді әдісін құрайды: пластикалық деформациядан деформацияланғанға дейін және фазалық түрлендіруден жылулық деформацияға дейін.

Термиялық өңделген болаттардың құрылымы мен қасиеттерінің қалыптасу ерекшеліктерін анықтау осы мәселені шешуге жақындауға мүмкіндік береді. Көміртекті және аз легирленген болаттардың аққыштық шегін құрылымдық параметрлер бойынша сандық бағалауға мүмкіндік беретін мәліметтерді зерттеу келесі ақпаратты көрсетеді: оларды беріктендірудің негізгі механизмдері қатты ерітіндіні салыстырмалы түрде арзан легирлеуші элементтермен (Mn, Si) легирлеу және дислокация арқылы

беріктендіру, және V (C, N) карбидті және нитридті түзетін элементтермен де болатты легирлеу және термиялық өңдеуді қолдану арқылы беріктендіру екенін көрсетеді.

Мақалада әдебиет деректерін талдау және өзіміздің эксперименттік зерттеулер жүргізу негізінде көміртекті және аз легирленген болаттардың аққыштық шегіне әр түрлі беріктендіру механизмдерінің сандық түрде болжамды үлесі бағаланады. Б5ps болаты үшін (ыстықтай илектелген күйде) аққыштық шегіне қатты-ерітінді мен дәннің шектік-түйіршік беріктендіру (37,4,0% және 28,6%) едәуір әсер етеді, ал төмен легирленген 16G2AF болатты беріктендіруге әсері (36, 7% және 27,1%) дисперсиялық беріктендірудің рөлі айтарлықтай (28,0%). Б5ps маркалы болатты термомеханикалық өңдеу дислокациялық тығыздықтың ұлғаюына және жылытылған құрамдағы дислокациялардың көп бөлігінің жеделдетілген салқындатуына байланысты ыстық деформацияланған аустенит жағдайында дислокациялық беріктендіру мәнінің 27,6% дейін өсуіне әкелетіні көрсетілген.

Түйін сөздер: беріктендіру механизмдері, аққыштық шегі, термомеханикалық өңдеу, жылдам салқындату, фазалық компоненттер, астық мөлшері.

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КОЛИЧЕСТВЕННАЯ ОЦЕНКА ПРЕДЕЛА ТЕКУЧЕСТИ ФЕРРИТО-ПЕРЛИТНЫХ СТАЛЕЙ ПО ПАРАМЕТРАМ СТРУКТУРЫ

Аннотация. В связи с инновационным развитием в различных отраслях экономики все более высокие требования предъявляются к качеству металлургической продукции. Важное место среди мероприятий, улучшающих качество готовой металлургической продукции, принадлежит термомеханической обработке (ТМО). Благодаря повышению прочностных характеристик металла, ТМО позволяет сократить удельный расход стали, увеличить срок службы изделий, надежность и долговечность деталей и узлов, что равносильно увеличению объема готовой металлопродукции.

Одной из основных проблем прикладного материаловедения является установление количественной связи между структурой и свойствами сталей и сплавов, поскольку лежит в основе разработки и создания новых эффективных способов повышения эксплуатационных характеристик металлических изделий. Так, в настоящее время при производстве сортового проката все шире применяется (ТМО), представляющая собой совокупность двух эффективных способов упрочнения сталей: деформационного от пластической деформации и термического от фазовых превращений.

Выявление особенностей формирования структуры и свойств сталей, подвергнутых термической обработке, позволяет приблизиться к решению указанной проблемы. Исследование данных количественной оценки предела текучести углеродистых и низколегированных сталей по параметрам структуры показывает, что основными механизмами их упрочнения являются твердорастворное упрочнение путем легирования относительно дешевыми легирующими элементами (Mn, Si) и дислокационное и дисперсионное упрочнения с использованием упрочняющей термической обработки и микролегирования стали с карбидо- и нитридообразующими элементами V(C,N).

В статье на основе анализа литературных данных и собственных экспериментальных исследований количественно оценен ориентировочный вклад различных механизмов упрочнения в предел текучести углеродистой и низколегированной сталей. Установлено, что для стали Ст5пс (горячекатаное состояние) наибольший вклад в предел текучести дают твердо-растворное и зерно-граничное упрочнения (37,4,0% и 28,6%), а в низколегированной стали 16Г2АФ наряду с такими слагаемыми упрочнения (36,7% и 27,1%) заметна роль дисперсионного упрочнения (28,0%). Показано, что термомеханическая обработка стали марки Ст.5пс приводит к росту величины дислокационного упрочнения до 27,6 % за счет роста плотности дислокаций и сохранения большей части дислокаций в прокате при ускоренном охлаждении горячедеформированного аустенита.

Ключевые слова: механизмы упрочнения, предел текучести, термомеханическая обработка, ускоренное охлаждение, фазовые составляющие, размер зерна.

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NEWS
OF THE NATONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5227
Volume 3, Number 447 (2021), 72-76 **https://doi.org/10.32014/2021.2518-170X.65**

UDC 622.817+622.822.22

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SUBSTANTIATION OF DESIGN PARAMETERS OF COAL DUST EXPLOSION CONTAINMENT SYSTEM

Abstract. The aim of the paper is to identify the qualitative and quantitative parameters of seismic waves and accelerations on the mine working contour after an explosion of the gas-and-dust mixture. Information about the formation of seismic waves in the rock mass accommodating the mine working was received using modelling in order to improve the means of containment of explosion of further developed dust-air mixture. The parameters of seismic waves, such as propagation velocity and acceleration, amplitude, and frequency of oscillations of mine working walls, were established for the conditions of the experimental structure, which allows to scientifically substantiating the design parameters of the systems protecting the miners against explosion. The energy of the explosion propagates in the rock mass in the form of a series of peak-like pulses and oscillations with smaller amplitude. Modulus of acceleration is an informational indicator, which suits the most for registration by seismic sensors responding, specifically, to the most powerful peak pulses formed by seismic waves. By revealing the qualitative and quantitative indicators of seismic wave propagation on the mine working contour and in the rock mass, the parameters of seismic sensors of the systems protecting the miners against explosion can be substantiated.

Key words: seismic sensors, explosion containment, mine working, air dust mixture

Several explosions of gas-and-dust mixtures in the coalmines of Ukraine had unacceptably severe consequences. This type of accident is characterized by the spread of explosion for several kilometres along the network of mine workings, reaching neighbouring mining sites. Several explosions happened in the workings of Zasyadko mine lease enterprise in 1999, 2001, 2002, 2007 and as a result, 265 people died and 369 were injured. Accidentsat Skochynskyi mine: 114 people died and 87 were injured in 1991, 1998, 2014. In 1992, 63 people died and 53 were injured at Sukhodolska-Skhidna mine, and 28 and 2 people, respectively, in 2011. In 1994, 30 people died and 27 were injured at Slavianoserbska mine; at Barakov mine, 80 and 7 people, respectively, in 2000; 37 people died and 12 were injured at Krasnolymanska mine in 2004; 8 people died and 28 were injured at Stepova mine in 2017. The data above determine the relevance of the issue of protection of miners from the threats of dust explosions, such as those propagating through the network of mine workings.

Analysis of Recent Research and Publications. The explosions of methane-air and composite gas-and-dust-air mixtures are studied in laboratory settings and at explosive research plants. However, a complete theory that would reveal the mechanism of formation and progress of the explosion does not exist [1].

The ability of dust of different coal strata to explode is evaluated using laboratory instruments, mainly, calorimeters. It is confirmed that as the particle size of coal dust decreases, its burning rate increases.Particles of coal dust with a size of 44 μm and 37 μm have a higher burning rate when compared to other sizes [2]. The analysis of laboratory experiments proved that dust with a fractional composition of 63…94 μm possesses the most explosive properties[3]. This may be due to the polymodal composition of dust deposits, which leads to the simultaneous reaction of different fractions of fuel [4]. The Indian scientists found that minimum ignition temperature decreases with the concentration of coal dust until it reaches the stoichiometric concentration. [5]. Laboratory studies have shown that the overall pressure ratio was doubled when 6% of the methane mixture was added to 30 g/m^3 of coal dust, and it increased by 60% when the ignition source power of 10 kJ was used instead of 1 kJ. [6]. There have been attempts to investigate the use of an increased volume chamber (38 l) to test coal dust explosions[7]. Complex researches, a combination of computer modelling and calorimetric experiments,

have been used to study the influence of the nature of air currents on the nature of explosive combustion of coal airborne dust. [8]

The addition of inert materials can significantly reduce the explosive properties of the mixture, until it burns out. This is achieved, for example, by a water curtain, which removes dust from the air stream, thereby reducing its accumulation in the ventilation networks of mines [9]. Another way to reduce the explosiveness of gas-and-dust mixtures is to add a sufficient amount of non-combustible components, such as shale powder [10]. The shale barriers and water curtains are the most common ways of explosion protection of mine workings. They consist of easily collapsible or overturning tanks with liquid or dispersed solid extinguishing agents, which are installed on shelves or suspended under the roof across the mine workings [10, 11]. The disadvantage of the known means is the inertia inherent in the mechanical circuit "extinguishing agent - tank - curtain drive - air compressed with shock front." This shortcoming is partially eliminated in automatic explosion containment systems, which use the energy of compressed gas or liquid for the rapid formation of a protective cloud in the void of emergency working [12]. The issue of increasing the response of the device for containment of coal dust explosions remains relevant. During the experimental explosions, the Polish researchers recorded the velocity of the fronts, mainly 300…700 $m \cdot s^{-1}$ [13], where the highest recorded velocity of the shock front along the mine working in the conditions of experimental mine galleries in some cases did not exceed 1,800…1968 $m \cdot s^{-1}$ [4]. It is significantly smaller in real-life conditions due to uneven dust deposition, dehydration of mine workings, etc. Geophysical studies of the velocity ($m \cdot s^{-1}$) of seismic waves in sedimentary rocks (sandstones, shales, limestones) have established that it is in the following ranges: for p-waves (*VP*): 1,500…6,000; s-waves (*Vs*): 600…3,500. [14].

The authors suggested the use of a higher velocity of seismic waves relative to the shock front for early detection of explosions and activation of explosion warning and suppression systems, and proposed a coal dust explosion containment system (DECS) (Fig. 1) [15]. Seismic sensor D_D is embedded into the wall of the mine working at a distance L_2 from pipeline 6, which exceeds the radius L_1 of seismic sensors response to rock oscillations by several times. Another sensor D_O is embedded into the wall of mine working next to the exhaust pipeline 6. Electrical cables for transmitting signals from seismic sensors are connected to the amplifier 7. The cables for transmission of control signals from amplifier 7 are connected: to the valves with electric drives 2 and 5, the means of sound and light alarm 8, as well as the lock 9, which holds the barrier 10 suspended under the roof. The possibility of lowering barrier 10 is implemented by means of a hinge 11, which connects the barrier with the side rocks. When coal dust explodes, a shock front of compressed air is formed in the mine working. The flame front behind the shock front moves at a distance of several meters with the detonation combustion of the air dust mixture. The explosion front propagates through the mine working with a velocity not less than the sound velocity in the air, Vf =330 $m.s^{-1}$. Part of the energy of the shock front is transmitted to the rocks surrounding the mine working, they form seismic waves that propagate in the rock mass with a velocity of Vs = 2,500… 3,000 $m.s^{-1}$, which is several times the velocity of the shock front. However, due to natural and man-made fractures of rocks, seismic waves are scattered and absorbed, thus the radius of propagation is limited, and at a certain distance greater than L_1 from the shock front their power is insufficient to excite the seismic sensor. The additional sensor Dd is triggered a few seconds before the seismic waves reach the main sensor, D_o. The signal from the additional sensor D_d is sent via cable to amplifier 7, where the command is generated to turn on the sound and light alarm 8, as well as to trigger the locks 9 holding the barrier 10. Light and sound alarms alert people about the presence of explosion and the need to activate self-rescuers and proceed to shelters or take safe positions behind barrier 10. The miners will have more than five seconds to do so; this amount of time cannot be provided by the known means of combating coal dust explosions. The issue of substantiation of the DECS main technical parameters, e.g., distance L_2 of placement of the additional sensor D_d from the main one, D_o, establishment of radius where the sensor will respond to seismic waves L_1, remains unresolved. It is equally important to establish the frequency range and amplitude of seismic oscillations to which the sensor has to respond. The sensor has to be capable of separating explosions from other types of oscillations of the rock mass, such as blasting, transport and other shocks.

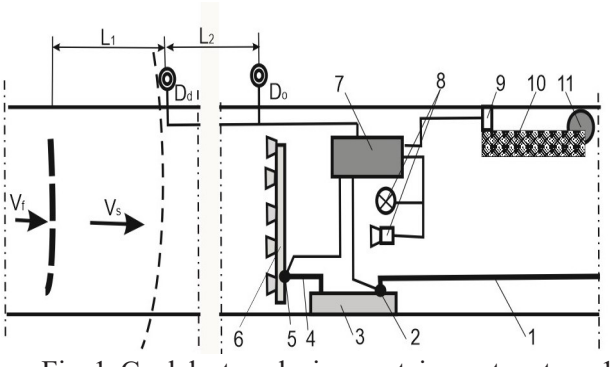


Fig. 1. Coal dust explosion containment system: 1 - pipeline for compressed gas supply; 2,5 - electrically driven valves; 3 - tank with fire extinguishing agent; 4,6 - pipeline; 7 - amplifier; 8 - sound and light alarm; 9 - lock; 10 - barrier; 11 - hinge; D_d, D_o - additional and main seismic sensors; L_1 - radius of sensor response to seismic waves; L_2 - distance between the sensors; V_f, V_s - velocity of propagation depending on the explosion front and seismic waves

The aim of the paper is to identify the qualitative and quantitative parameters of seismic waves and accelerations on the mine working contour after explosion of gas-and-dust mixture, in order to substantiate the parameters of sensitive elements of the miners' protection system. The research method is modelling with the help of finite-difference mathematical-computer modelling of four-dimensional (*x,y,z,t*) dynamic process of formation and propagation of seismic waves from explosion in experimental virtual mine working.

Based on the required accuracy of calculations and taking into account the limitations of computer technology, the authors created a virtual structure that has the shape of a vault, 3 m wide, 4.5 m high. The length of the structure is 50 m. It is covered with a six-meter layer of rock with physical and mechanical properties close to sandstones: modulus of elasticity: 6×104, MPa; Poisson's ratio: 0.275; density: 2,900 kg/m^3. The structure's lower surface has a rigid connection with the ground, the rest is free. Spatially developing explosion of coal dust was simulated by a series of consecutive detonation of explosive charges (explosives) each weighing four kilograms, with an interval of 2.5.10^{-3} s. This corresponded to the supersonic velocity of the shock front 400 m.s^{-1}. The modelling technique is given in more detail in [16].To determine the parameters of velocities and accelerations, the parameters of the motion of four points were fixed using the contour of the vaulted shape (Fig. 2a). In order to do so, three measuring boundaries along the length of the working at distances 6; 12.5; 19 m from the source of the explosion (Fig. 2b), as well as at the ends of the mine working, were selected.

During the study, the result of the explosion of the first several explosive charges was considered. This measurement method was adopted in order to avoid distortion caused by the reflection of waves on the surface of the structure and its ends when the oscillations reach these surfaces. The advantage of this method of explosion modelling is not only the ability to obtain indicators of absolute and relative deformations of the walls and rocks surrounding it, but also the ability to estimate the dynamic parameters of deformations, namely velocity and acceleration, their amplitude, frequency, phase, moduli, etc.

Results. A feature common to all velocity components relative to the coordinate axes is the presence of two stages, caused by the explosion of the specifically primary explosive, which is characterized by lack of synchrony and in-phase motion of control points 1-4 on the walls (Fig. 3). The duration of the first stage is approximately 0.025… 0.04 s. In the transverse directions x and z, the velocities of the points had an oscillating tendency with an amplitude from ± (2…6) e^{-03} to ± (10…12)e^{-03}, m.s^{-1}. In the longitudinal direction y, besides the oscillations, there is a clear tendency for the predominance of velocities towards the direction of the explosion. The maximum deviation V_y was observed after (0.1… 0.12) e^{-0}3, s, it was about (-5 e-03), m.s^{-1}.

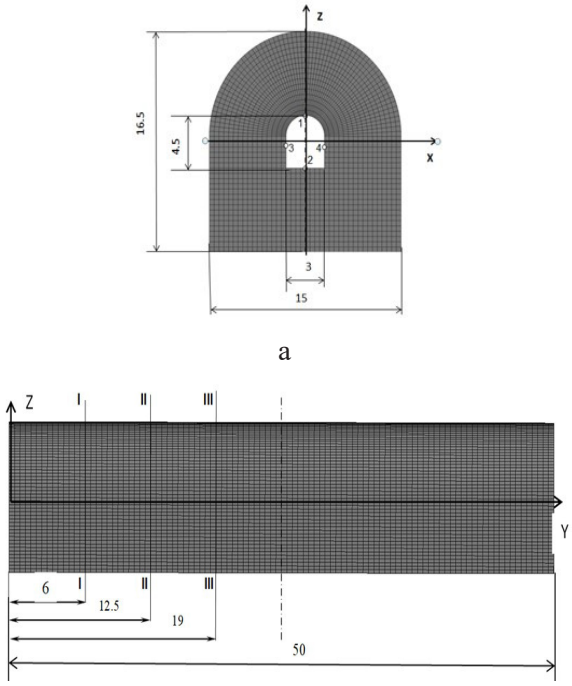
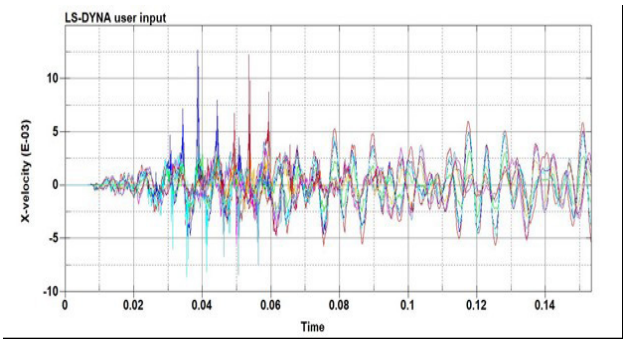
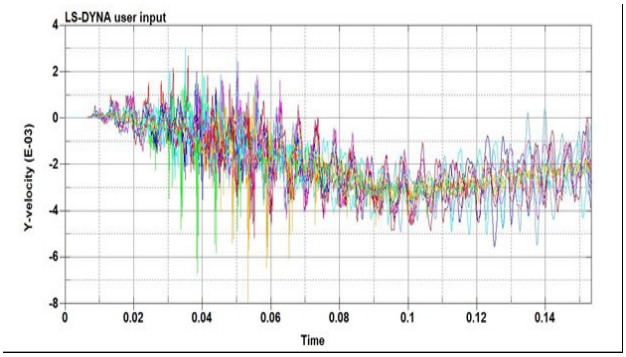


Fig. 2. Construction of a virtual structure (a - vertical cross-section; b - side view): I-I, II-II, III-III - boundaries of measuring the movement of points 1, 2, 3, 4 on the mine working contour

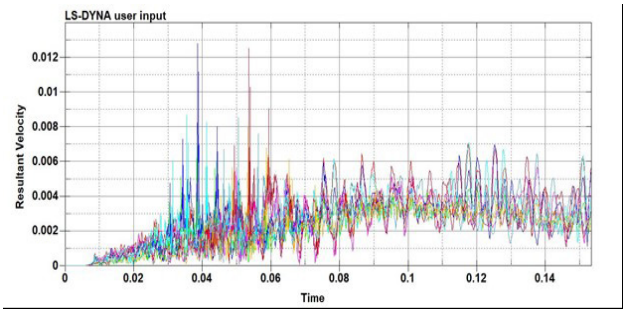
At the first stage, single peak jumps of individual points were observed, but the general picture indicates a tendency to zero total deviation of points from the initial state. That is, s-waves prevail. The secondary stage of velocity dynamics is characterized by a more orderly nature of motion. All control points on the mine working surface oscillate synchronously and in phase. In the transverse directions, horizontal x and vertical z, the amplitude of oscillations does not exceed ±(2…4)*e^{-03} and ±(1…2)*e^{-03}, m.s^{-1}, respectively. This difference is due to the design features of the structure. In the longitudinal direction y, in addition to the oscillating motion, the motion towards the propagation of the explosion along the mine working is traced first, and then in the opposite direction. This is a manifestation of p-waves.



a



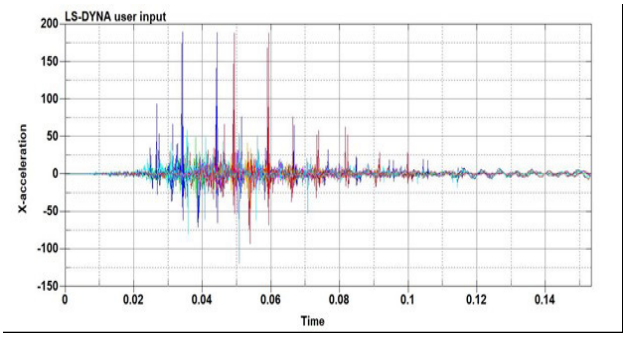
b)



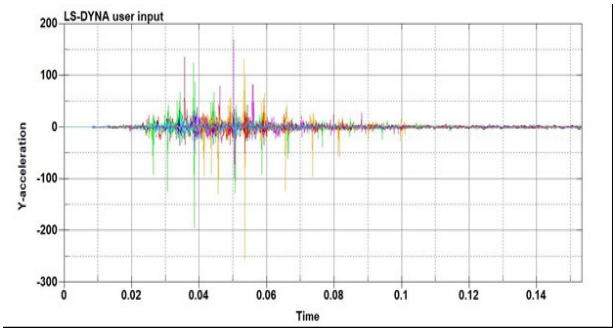
c)

Fig. 3. Velocity (m·s-1) of movement of the points of the mine working contour in the horizontal V_x (a) and longitudinal V_y (b) directions and the modulus of velocities (c) at a distance of 19 m from the source of the explosion; colours of trajectories of points according to Fig. 1a: 1 - red; 2 - green; 3 -dark-blue; 4 - blue

Waves of the secondary stage are inherently inertial self-oscillations of the structure, which are the consequences of external impact, specifically the detonation of explosive charges. This is confirmed by the dynamics of accelerations (Fig. 4).



a)



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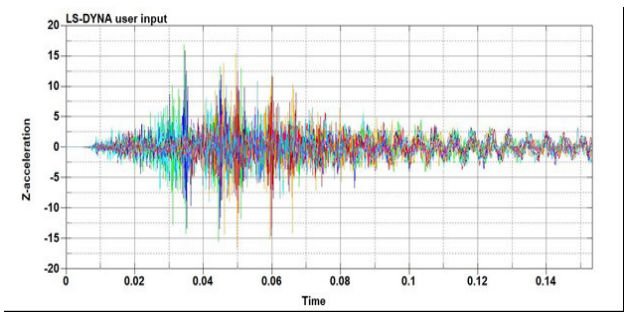

c)

Fig. 4. Acceleration ($m \cdot s^{-2}$) of the points of the mine working contour in the horizontal D_x (a), longitudinal D_y (b) and transverse D_z (c) directions at a distance of 19 m from the source of the explosion; colours of trajectories of points 1-4 as in Fig. 3

These data indicate that the acceleration of control points on the surface of the experimental mine working occur only under the influence of the energy of explosions. The subsequent oscillatory process is due to the inertial redistribution of energy, and has a rapidly decaying nature. The design of the experimental structure (see Fig. 2) limits the movement of the particles of the medium in the horizontal directions x and y, and meet the conditions that exist in real-life mining to a certain degree. There are individual peaks with an amplitude of ±100…200 $m \cdot s^{-2}$ in these directions, but the main part of the harmonics has parameters up to ±25 $m \cdot s^{-2}$. The duration of excitation of rock thickness particles is up to 0.045 s after the explosion, followed by attenuated acceleration of oscillations.

In the vertical direction z, the possibility of movement of particles of the medium is less limited, because the upper part of the structure has no restrictions in terms of motion. This confirms the nature of the accelerations in the vertical direction (see Fig. 4c), they are characterized by a smaller amplitude of peak oscillations (up to ±15 $m \cdot s^{-2}$), the main part of the harmonics has ± 5 $m \cdot s^{-2}$, but the duration of oscillations reaches 0.07 s.

In real-life mine conditions, when choosing means of monitoring the oscillations of the rock mass under the action of explosions of gas-and-dust mixtures, it is difficult to install such a device that senses oscillations in certain directions. Therefore, it is advisable to consider a more versatile indicator, i.e. the dynamics of the modulus of acceleration (Fig. 5).

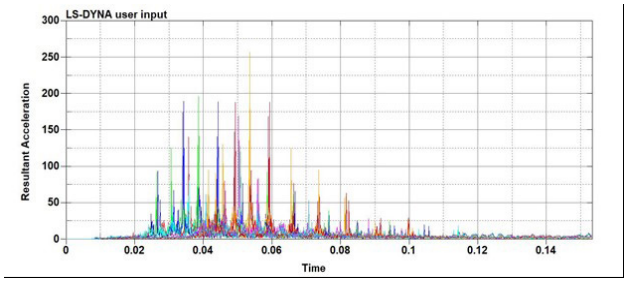

Fig. 5. Moduli of accelerations ($m \cdot s^{-2}$) of the points of the mine working contour, the rest of the data are similar to those in Fig. 3

Unlike the modulus of velocity (see Fig. 3c) the modulus of acceleration tends to fade in the second stage, which allows to identify a single explosion relative to other types of earthquake. 0.02 s after a single explosion at a distance of 19 m from the explosive charge, the beginning of the acceleration of the indicator the points of the mine working contour (see Fig. 5) was observed. Within the time frame from 0.02 to 0.08 s up to 15…18 peaks with an amplitude of 50…250 m·s-2, i.e. with a frequency of about 300 Hz, occurred. These are the most powerful pulses that could move in the rock mass at the greatest distance from the source of the explosion. The bulk of the oscillations had an amplitude of 10…25 m·s-2, and propagated over a much shorter distance. This pattern of rock shifts is typical of the conditions of drilling and blasting of methane. The seismic sensor emits a single signal lasting up to 0.05 s. In contrast, during the propagation of the explosion front of the gas-and-dust mixture in the rock mass, the train of such oscillations is felt. A signal receiver needs to be set to receive about ten pulses for a short time, up to, e.g., 0.3…0.5 s, which automated systems must identify as gas-and-dust explosion.

The nature of the motion of seismic waves during the formation of a gas-and-dust explosion (Fig. 6) and its movement with the velocity of about 400 $m.s^{-1}$ along the mine working is considered in the research. The modelling results indicate a gradual increase in the velocity of seismic waves with the development of a gas-and-dust explosion from 0 at the place of initiation to 2,600 $m.s^{-1}$when hypocentre of explosion moves to 20 m. With further movement of the explosion front, the velocity of the seismic wave remained almost constant at the level of 2,600 $m.s^{-1}$. The obtained results confirm the statement made by the authors about the expediency of using seismic waves to detect gas-and-dust explosions at the early stages and to create conditions for containment of threats to miners [16].

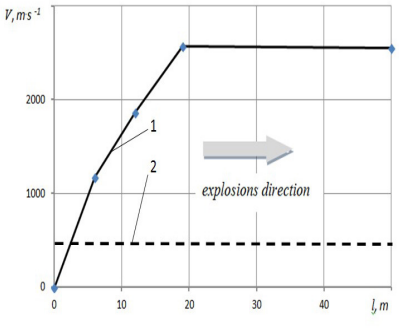

Fig. 6. Dynamics of change of velocities of seismic (1) and shock (2) waves directed along the length of experimental mine working

They allow to substantiate the time parameters of DECS, specifically the size of the required tju and the available tav time to ensure the protection of miners. The value of the required time tju consists of the intervals required for: person's reaction to light and sound alarms tr, activation of personal self-rescuer ti, finding shelter in protective niches or other places ts, etc. Some types of the actions above can be performed sequentially, while others can be performed simultaneously. In real-life conditions, their duration is influenced by several various factors. In the first approximation, we can assume that the total value of tju $=t_R+t_l+t_s$ can be from three to six seconds. The available time tavis determined by the DECS technical parameters, specifically by the interval from the registration of the explosion to the activation of alarm and protective devices, and the creation of safe conditions for people. The safety condition is the that tav must exceed t_{ju}. The available time for the system shown in Fig. 1 can be determined based on the established parameters of seismic and explosive waves. Thus, the time from the registration of the explosion by the additional sensor D_d (see Fig.1) to the activation of the valve 5 feeding the extinguishing agent to the sprinklers 6 is determined by the length of the explosion front from the moment of registration to the protective device with the velocity of Vf, and is $t_1=(L_1+L_2)/Vf$. When determining the tav, the loss of time tin for the activation of the DECS electrical and mechanical elements should be considered. These losses can be about a few tenths of a second.

There are two main DECS modes of operation. In the first mode, the system not only blocks the propagation of the explosion along the mine working, but also reduces such threats as pressure, toxic gases, high temperatures, etc. for the miners.Thus, to ensure the safety of miners, the following condition must be met:

$$t_{av}>t_{ju}, \text{ or } (L_1+ L_2)/V_f- t_{in}>t_r+t_i+t_s. \quad (1)$$

In the inequality above, some indicators are constants (Vf,L1,tin), others (tr,ti,ts) can be practiced until they become automatic and minimal. The parameter of inequality, which could be actually adjusted, is the indicator L_2 which is a DECS constructive parameter.

As an example, let's consider an option of the system with the following parameters: V_f=400 $m.s^{-1}$; L_1=600 m; L_2=1,800 m;tin=0.5 s; (t_r+t_i+ts)=5 s. After substitution, we obtain tav=(600+1,800)/400-0.5=5.5 s, t_{ju}=5 s, i.e. the requirement tav>tju is met.

In the second mode, DECS can be used as a means of containment of explosions in the unattended mine workings ($t_r+t_i+t_s$=0), then inequality (1) takes the following form:

$$(L_1+ L_2)/V_f>t_{in}. \quad (2)$$

This determines that the available time must exceed the time required for the activation of hydro-pneumomechanical elements, i.e. the formation of a cloud that stops the fire and the installation of a barrier

occurs before the approach of the explosion front. Given that the duration of tin for the activation of the DECS electrical and mechanical elements is about 0.5 s, less sensitive seismic sensors may be used. For example, when L_1 = 200 m, and the additional sensor is installed closer (L_2 = 300 m), the available time tavwill be 1.25 s, which is much longer than the time required to get the DECS into operation.

The studies have shown the validity of the hypothesis underlying the coal dust explosion containment system in terms of the possibility to use seismic waves for early detection of an emergency situation. Rough calculations indicate the technical possibility of increasing the level of protection of miners from the effects of threats of dust explosion in the mine workings.

Conclusions. Computer modelling of the energy dissipation process of coal dust explosions give a qualitative and some quantitative idea of the mechanism of propagation of velocities and accelerations of seismic waves on the periphery of the experimental mine working. These data can be used to test the means of containment of coal dust explosions, but in order to use them in real-life conditions, the radius of sensor response to seismic waves (L_1) should be additionally determined in mine conditions. Preferably, the sensor has to respond structurally to the moduli of acceleration of train of seismic waves, so that to distinguish the dust explosion from other drivers of seismic oscillations of the rock mass.

Information on the formation of seismic waves in a rock mass accommodating a mine working was further developed, which became the basis for improving the means of containment of explosions of air dust mixture. The parameters of seismic waves, such as propagation velocity and acceleration, amplitude and frequency of oscillations of mine working walls, were established for the conditions of the experimental structure, which allows to scientifically substantiating the design parameters of the systems protecting the miners against explosion. The energy of the explosion propagates in the rock mass in the form of a series of peak-like pulses and oscillations with smaller amplitude. Modulus of acceleration is an informational indicator, which suits the most for registration by seismic sensors responding, specifically, to the most powerful peak pulses formed by seismic waves. By revealing the qualitative and quantitative indicators of seismic wave propagation on the mine working contour and in the rock mass, the parameters of seismic sensors of the systems protecting the miners against explosion can be substantiated.

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КӨМІР ШАҢЫНЫҢ ЖАРЫЛЫСТАРЫН ОҚШАУЛАУ ЖҮЙЕСІНІҢ ҚҰРЫЛЫМДЫҚ ПАРАМЕТРЛЕРІН НЕГІЗДЕУ

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ОБОСНОВАНИЕ КОНСТРУКТИВНЫХ ПАРАМЕТРОВ СИСТЕМЫ ЛОКАЛИЗАЦИИ ВЗРЫВОВ УГОЛЬНОЙ ПЫЛИ

Аннотация. Целью работы является раскрытие качественных и количественных параметров сейсмических волн и ускорений на контуре горной выработки, в которой произошел взрыв газопылевой смеси. Для усовершенствования средств локализации взрывов пылевоздушной смеси дальнейшего развития получили сведения по формированию сейсмических волн в горном массиве, вмещающем горную выработку. Для условий экспериментального сооружения установлено параметры сейсмических волн, такие как скорость и ускорение распространения, амплитуда и частота колебаний стенок горной выработки, что позволяет научно обосновать конструктивные параметры систем защиты горнорабочих от действия негативных факторов взрыва. Энергия взрыва распространяется в горном массиве в виде серии пикообразных импульсов и колебаний с меньшей

амплитудой. Наиболее пригодным для фиксации, информативным показателем, на который должны реагировать сейсмические датчики является модуль ускорения, а, точнее, на наиболее мощные образованные сейсмическими волнами пиковые импульсы. Раскрытие качественных и количественных показателей распространения сейсмических волн по контуру горной выработки и в горном массивы позволяет обосновать параметры сейсмических датчиков системы защиты горняков от негативных факторов взрыва.

Ключевые слова: сейсмические датчики, локализация взрыва, горная выработка, пылевоздушная смесь.

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NEWS
OF THE NATONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5227
Volume 3, Number 447 (2021), 80-86 **https://doi.org/10.32014/2021.2518-170X.66**

УДК 550.8
МРНТИ38.59.01;

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СИСТЕМЫ ОЦЕНКИ И УПРАВЛЕНИЯ РЕСУРСАМИ УГЛЕВОДОРОДОВ (PRMS)

Аннотация. Ресурсы углеводородов – это те количества углеводородов, которые существуют в естественных условиях на поверхности Земли или в недрах. При рассмотрении ресурсов оценивают количества углеводородов как в уже известных, так и в еще не открытых скоплениях. Оценки ресурсов направлены на те количества, которые потенциально могут быть извлечены и реализованы на рынке в ходе реализации коммерческих проектов. Система управления ресурсами углеводородов предусматривает систематический подход к оценке количеств углеводородов, оценке проектов и представлению результатов в рамках универсальной классификации.

При поведении геолого-разведочных работ (ГРР) неизбежно возникают неопределенности и риски. Прогнозные оценки запасов углеводородов также выполняются в условиях неопределенности. В настоящее время нефтяные компании перед началом выполнения ГРР стремятся минимизировать риски и снять некоторые неопределенности. В целях повышения эффективности проведения ГРР предлагается использовать несколько методов оценки прогнозных запасов по разведочным скважинам. В современном нефтегазовом мире наиболее распространенной является классификация Общества инженеров-нефтяников (SPE) – PRMS (Petroleum Resources Management System) – система управления запасами и ресурсами жидких, газообразных и твердых углеводородов.

Технологии поисков и разведки, разработки, добычи и подготовки углеводородов постоянно развиваются и улучшаются. Комитет SPE по запасам нефти и газа (Oiland Gas Reserves Committee, OGRC) находится в постоянном контакте с заинтересованными организациями, чтобы поддерживать имеющиеся определения и методические указания в соответствии с развивающимися технологиями и требованиями промышленности.

Ключевые слова: нефть, пласт, запасы, классификация запасов SEC/PRMS, система управления, методы оценки ресурсов.

Введение. PRMS – наиболее распространённая в мире система учёта, классификации и управления углеводородами и их запасом. Расшифровывается аббревиатура следующим образом: PetroleumResources Management System, что на русский язык можно дословно перевести как Система Управления Нефтяными Ресурсами.

PRMS (Petroleum Resources Management System) – система оценки нефтяных ресурсов, в прошлом – Общество инженеров-нефтяников (SPE). Система учитывает не только возможность обнаружения нефти и газа в месторождении, но и экономическую эффективность их извлечения.

Запасы оцениваются по 3 категориям: «доказанные», «вероятные» и «возможные» (3P – proved, probable, possible).

Международные стандарты PRMS принимают во внимание не только вероятность того, что углеводороды имеются в наличии в данной геологической формации, но и экономическую целесообразность извлечения запасов (включая такие факторы, как затраты на геологоразведку и бурение, постоянные эксплуатационные расходы, затраты на транспортировку продукции, налоги, преобладающие цены на продукцию, а также другие факторы, влияющие на конкурентоспособность отдельно взятой залежи).

В настоящее время определения PRMS и связанную с ними систему классификации широко используют в мире в соответствии с требованиями поддержки нефтегазовых проектов или управления портфелями активов. На PRMS опираются в целях государственной отчетности и регуляторного раскрытия информации в разных юрисдикциях. В указанных выше целях она предоставляет технические условия для углеводородов в контексте Рамочной классификации ресурсов ООН (UNFC), которые учитывают специфику данного ресурса. Эти определения обеспечивают

единую меру сопоставления, позволяют снизить влияние субъективности при оценке ресурсов и направлены на повышение прозрачности в международном общении по вопросам ресурсов углеводородов [1-3].

Материалы и методы. Под углеводородами понимают природные смеси, состоящие из углеводородов в газообразном, жидком или твердом состоянии. Они также могут содержать и неуглеводородные компоненты, такие как наиболее часто встречающиеся углекислый газ, азот, сероводород или сера. В редких случаях содержание неуглеводородных компонентов может превышать 50%.

Термин «ресурсы», используемый в настоящем документе, охватывает все количества УВ, естественно залегающие в земной коре или на поверхности, как открытые, так и неоткрытые (как извлекаемые, так и неизвлекаемые), а также уже добытые количества. Кроме того, он включает все виды УВ независимо от того, относят ли их в настоящее время к традиционным или нетрадиционным ресурсам.

Система классификации ресурсов PRMS представлена графически на рисунке 1. Согласно системе, ресурсы разделены на открытые и неоткрытые, в которых далее выделены классы извлекаемых ресурсов: Добыча, Запасы, Условные Ресурсы и Перспективные Ресурсы, а также неизвлекаемые УВ.

Запасы – это количества УВ, которые предполагается коммерчески извлечь в результате реализации проектов разработки известных залежей с заданной даты при определенных условиях.

Условные Ресурсы – это количества УВ, оцениваемые на определенную дату как потенциально извлекаемые из известных залежей при реализации проекта (проектов) разработки, который не считается в настоящее время коммерчески целесообразным из-за наличия одного или нескольких условных ограничений. Условные Ресурсы сопряжены с шансами на ввод в разработку. К Условным Ресурсам могут относиться, например, такие проекты, для которых в настоящее время нет подходящего рынка, или, когда коммерческая добыча зависит от технологии, находящейся в разработке, или залежь недостаточно изучена для того, чтобы определенно судить о коммерческой целесообразности.

Условные Ресурсы подразделяют на категории согласно диапазону неопределенности в оценках и относят к подклассам согласно зрелости проекта и/или его состоянию с точки зрения экономической целесообразности.

Общие начальные геологические количества УВ(ОНГУ) – это суммарные количества УВ, оцененные как первоначально содержащиеся в природных скоплениях, открытых и неоткрытых, до начала добычи.

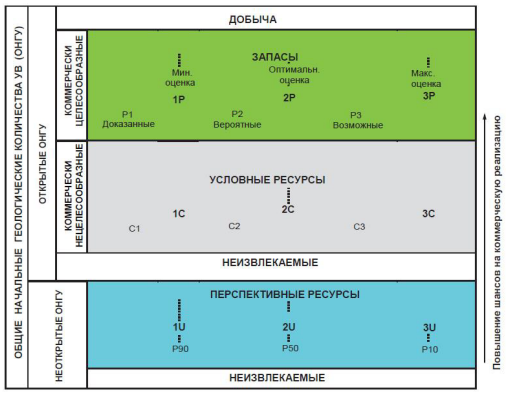

Рисунок 1. Схема классификации ресурсов УВ

Процесс оценки ресурсов включает определение проекта или проектов добычи, реализуемого на одной или нескольких залежах УВ, оценку количеств ОНГУ и той их части, которая может быть добыта в рамках каждого проекта, и классификацию проекта (проектов) в соответствии со степенью их зрелости или шансами на достижение стадии коммерческой реализации. [1-3]. Оценка чистых извлекаемых ресурсов в рамках настоящей, основанной на проектах, классификации, предусматривает рассмотрение следующих источников информации (см. Рисунок 2).

Рисунок 2. Схема оценки ресурсов

Условные ресурсы определяются как «объемы углеводородов, потенциально извлекаемых, согласно оценке на определённую дату, из известных залежей, но добыча которых в настоящее время представляется экономически нецелесообразной». Условные Ресурсы могут включать:

1) проекты, не имеющие реального рынка сбыта продукции,

2) проекты, зависящие от технологий, которые ещё находятся в стадии разработки, или

3) проекты, находящиеся на ранней стадии оценки.

Извлекаемые запасы определяются как «объемы углеводородов, которые предполагается экономически эффективно добыть из известных залежей, начиная с заданной даты и при определенных условиях».

Эти запасы, в свою очередь, должны удовлетворять четырем критериям, они должны быть: 1) открытыми,

2) извлекаемыми,

3) экономически эффективными,

4) остаточными на заданную дату, равно как связанными с конкретным проектом разработки [4-6].

Разработка универсальных определений и указаний для категоризации и классификации запасов углеводородов необходима для того, быть достичь такой стандартизации, которая обеспечила бы полное взаимопонимание как между отдельными специалистами, так и между компаниями или странами. К сожалению, инженеры, геологи и геофизики, занимающиеся оценкой запасов и ресурсов какой-либо компании или страны, обязаны руководствоваться разными методиками и требованиями к отчетности, число которых велико. Оценка запасов и ресурсов – сложный процесс, в который вовлекаются разные технические дисциплины, и который опирается на сочетание различных знаний, опыта и суждений. В процессе оценки запасов и ресурсов на решения, принимаемые оценщиком, оказывают влияние как результаты интерпретации технических данных, так и его понимание используемых определений запасов и ресурсов. Достоверную и надежную оценку запасов оценщик может дать только на основе знания правил и методик, наиболее подходящих для решения конкретных задач, стоящих перед ним. По мере глобализации нефтегазовой промышленности важность разработки общего понимания базовых “правил”, лежащих в основе разных классификационных систем, значительно возросла.Системы классификации запасов и ресурсов призваны позволить оценщику отслеживать динамику разведки и разработки залежи, месторождения или выполнения проекта по мере получения новой технической информации или изменения экономической ситуации. В большинстве систем используется терминология, отражающая этапность проекта, начиная с оконтуривания начального объекта, через подтверждение его продуктивности разведочным бурением до подсчета запасов и ввода в разработку и в итоге от начальной добычи до истощения объекта [4-6].

Количества нефти и газа обычно оценивают и распределяют по категориям согласно степени уверенности в их извлечении из отдельных залежей в целом или их частей. Такие оценки называют оценками на уровне залежи. Их суммируют, когда требуется получить оценку для месторождения, объекта собственности или проекта. Дальнейшее суммирование применяют для того, чтобы получить общую оценку на уровне региона, страны или компании; ее называют «оценкой ресурсной базы». Распределение неопределенности для индивидуальных оценок на каждом из этих уровней может изменяться в широком диапазоне в зависимости от геологических условий и стадии освоения ресурсов. Такой процесс накопленного суммирования обычно называют агрегирование [4-6].

Результаты и обсуждение. Независимо от того, какие аналитические методы применяются, целью является выразить диапазон неопределенности относительно извлекаемых ресурсов УВ. И здесь основополагающим принципом является понимание, что надежность оценок зависит от объема и качества исходной информации.

При использовании любого метода по мере того, как при удалении от площади с доказанной продуктивностью уверенность относительно оцениваемых извлекаемых количеств снижается, возрастает неопределенность. Рассматривая диапазон неопределенности в величине добычи по проекту, оценщику следует учитывать неопределенности по всем компонентам проекта, включая прогнозы добычи из существующих и будущих скважин. Кроме того, чем более разнообразна исходная информация – данные каротажа и анализа керна, сейсмика или история добычи – тем выше уверенность в оценках ресурсов.

Методы оценки можно условно охарактеризовать как детерминированные, геостатистические и вероятностные. При комплексном анализе неопределенности допускается их применять совместно.

Экономическая оценка ресурсов на основе проектов опирается на прогноз будущей добычи и связанного с ней чистого потока денежных средств для каждого проекта по состоянию на дату оценки. Данные потоки денежных средств следует дисконтировать по определенной ставке. Сумму дисконтированных потоков денежных средств называют «чистой приведенной стоимостью» (ЧПС, NPV) проекта. Эти расчеты должны опираться на определенный коммерческий узел учета и отражать следующие компоненты:

- прогнозные объемы добычи за определенные периоды времени;

- оценки величин и графика понесения затрат по проекту в связи с разработкой, добычей доставкой продукции до коммерческого узла учета, включая затраты на ликвидацию, демонтаж и рекультивацию (ЛДР), на основании будущих объемов затрат, ожидаемых компанией;

- оценки дохода от добычи, основанные на прогнозируемых оценщиком будущих ценах на соответствующую продукцию, с учетом имеющихся контрактов на товарные поставки или хеджинговой компенсации в отношении цены, свойственные данному объекту собственности, включая ту часть затрат и доходов, которая приходится на долю компании;

-прогнозируемые ставки подлежащих уплате компанией налогов на добычу и налогов, связанных с доходами и пользованием недрами;

-период реализации проекта, который ограничен сроком действия прав на экономическую долю или уверенно обоснованной оценкой соответствующего срока, обычно заканчивающегося при наступлении первого из пределов: технического, контрактного или экономического;

- обоснованная ставка дисконтирования, применяемая в компании на момент выполнения оценки. [7-8].

Об экономической целесообразности проекта судят на основании расчета, выполненного при нулевой ставке дисконтирования (т.е., без дисконтирования). Экономически целесообразным считается проект, который характеризуется положительным накопленным недисконтированным чистым потоком денежных средств. Добыча в рамках проекта рентабельна, когда доход от реализации добываемой продукции в соответствии с долей компании превышает производственные расходы. Количества УВ в рамках проекта являются рентабельно извлекаемыми, когда чистый доход от внедряемого добычного проекта превышает чистые расходы, приходящиеся на долю компании. Затраты на ЛДР при оценке рентабельности добычи исключаются.

Экономическую эффективность проверяют, применив прогнозный сценарий, который позволяет рассчитать поток денежных средств на основании прогнозируемых компанией экономических условий (включая изменение затрат и цен на продукцию, темпа инфляции и рыночных факторов). В своих прогнозах оценщику следует учитывать и фиксировать документально те допущения, которые компания считает обоснованно ожидаемыми в течение всего срока реализации проекта. Для прогнозируемых затрат и доходов допускается прогнозировать инфляцию, дефляцию или уточнение рыночных условий [7-8].

Прогнозы, основанные исключительно на текущих экономических условиях, оценивают с применением условий, осредненных за определенный период времени (включая исторические цены и затраты). Период, принимаемый по умолчанию при осреднении цен и затрат, равен одному году. Однако в случае, когда в предыдущие 12 месяцев наблюдалось скачкообразное изменение, должно быть обосновано использование показателей за более короткий отрезок времени, учитывающий такой скачок. В проектах разработки, характеризующихся большим количеством скважин и длительной программой действий, при оценке ресурсов может быть оправдано применение кривой обучения, которая позволяет прогнозировать улучшения с точки зрения либо длительности выполнения работ, либо затрат на них, либо обоих этих показателей, при условии, что эти улучшения подтверждены практическими свидетельствами и зафиксированы оценщиком. Уверенность в возможности получить такую экономию должна быть учтена при подготовке диапазона неопределенности относительно оценок объема добычи и величины ЧПС (NPV).

При экономическом анализе проекта рассматриваются все затраты, включая обязательства по ЛДР, если только они особым образом не исключены по условиям контракта. Затраты на ЛДР не включаются в расчет при определении рентабельной извлекаемости или того момента, когда проект достигает своего предела рентабельности. Затраты на ЛДР также могут приводиться в отчете в иных целях, таких как стоимостная оценка объекта собственности при его продаже или приобретении, планирование разработки месторождения, бухгалтерский учет будущих обязательств или в других соответствующих обстоятельствах, когда выполняется оценка ресурсов. Компания отвечает за предоставление оценщику необходимой документации, подтверждающей наличие финансирования, достаточного для покрытия будущих затрат и обязательств по ЛДР в соответствии с условиями контракта [9-10].

На рисунке 3 показан профиль чистого потока денежных средств для некоторого простого проекта. Накопленный чистый поток по проекту превышает обязательства по ЛДР, и, таким образом, удовлетворяется требование экономической эффективности, необходимое для отнесения проектных количеств УВ к классу Запасы. Период рентабельной добычи по проекту (т.е., рентабельной извлекаемости) ограничен пределом рентабельности, когда достигается максимальное значение накопленного чистого потока денежных средств, до принятия в расчет обязательств по ЛДР.

Сравнивая и противопоставляя общую структуру, терминологию и основные принципы разных систем классификации запасов углеводородов, оценщик может получить более глубокое представление об обеих схемах и привнести тем самым необходимую степень сравнимости в процесс оценки запасов и ресурсов.

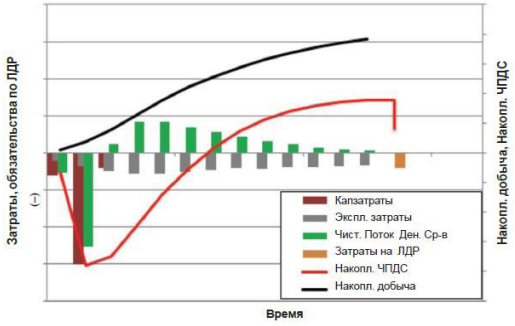

Рисунок 3. Экономический прогноз проекта разработки

При прогнозировании геолого-технических параметров смещение оценок представляет собой более серьезную проблему, чем их значительная неопределенность [9-10]. Источник смещения обычно приводит к занижению оценки. На практике любая ошибка может вызвать потери для инвестора. Результатом завышения оценки является увеличение инвестиций в проекты, а занижение оценок может заставить компанию инвестировать слишком мало или вообще отказаться от инвестирования [9-10].

Вывод. Повышение эффективности геологоразведочных работ может быть достигнуто за счет прогнозирования запасов углеводородов на наиболее перспективных участках. Для выбора таких участков должна быть достаточно высокая степень уверенности в оценке запасов, которую можно достичь путем прогнозирования оценки запасов различными методами. Оценив эффективность проведения геологоразведочных работ путем сравнения результатов оценки, полученных по прогнозным разведочным скважинам, с фактическими, можно отметить следующие основные аспекты снижения рисков и неопределенностей при оценке запасов углеводородов на прогнозных ловушках:

– использование детерминистской оценки в сочетании с вероятностной способствует повышению точности оценки и снижению геологических рисков;

– применение на практике несколько методов оценки прогнозных запасов дает возможность обеспечить взаимную проверку надежности результатов и получить лучшую оценку запасов ловушки;

– анализ результатов проведения геологоразведочных работ и сравнение прогнозных данных с фактическими позволяет выявить основные причины недостижения или перевыполнения прогноза, что в свою очередь дает возможность в будущем усовершенствовать прогнозные оценки и выйти компании на более высокий качественный уровень при восполнении минерально-сырьевой базы.

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КӨМІРСУТЕГІ РЕСУРСТАРЫ БАҒАЛАУ ЖӘНЕ БАСҚАРУ ЖҮЙЕЛЕРІ (PRMS)

Аннотация. Көмірсутек ресурстары-бұл жер бетінде немесе жер қойнауында табиғи жағдайда болатын көмірсутектердің мөлшері. Ресурстарды қарастыру кезінде белгілі және әлі ашылмаған кластерлердегі көмірсутектердің мөлшері бағаланады. Ресурстарды бағалау коммерциялық жобаларды іске асыру барысында нарықта алынуы және сатылуы ықтимал шамаларға бағытталған. Көмірсутектер ресурстарын басқару жүйесі көмірсутектер санын бағалауға, жобаларды бағалауға және әмбебап жіктеу шеңберінде нәтижелерді ұсынуға жүйелі көзқарасты көздейді.

Геологиялық барлау жұмыстарын (ГБЖ) жүргізу кезінде белгісіздіктер мен тәуекелдер туындайтыны сөзсіз. Көмірсутек қорларын болжамды бағалау да белгісіздік жағдайында орындалады. Қазіргі уақытта мұнай компаниялары ГБЖ - ын бастамас бұрын тәуекелдерді азайтуға және кейбір белгісіздіктерді жоюға тырысады. ГБЖ жүргізудің тиімділігін арттыру мақсатында барлау ұңғымалары бойынша болжамды қорларды бағалаудың бірнеше әдістерін пайдалану ұсынылады. Қазіргі мұнай-газ әлемінде мұнайшы-инженерлер қоғамының (SPE) – PRMS (Petroleum Resources Management System) – сұйық, газ тәріздес және қатты көмірсутектердің қорлары мен ресурстарын басқару жүйесінің жіктелуі кең таралған.

Көмірсутектерді іздеу және барлау, игеру, өндіру және дайындау технологиялары үнемі дамып, жетілдіріліп отырады. Мұнай және газ қорлары жөніндегі SPE комитеті (Oil and gas Reserves Committee, OGRC) дамушы технологиялар мен өнеркәсіп талаптарына сәйкес қолда бар анықтамалар мен әдістемелік нұсқауларды қолдау үшін мүдделі ұйымдармен үнемі байланыста болады.

Түйін сөздер: мұнай, қабат, қорлар, қорларды жіктеу SEC/PRMS, басқару жүйесі, ресурстарды бағалау әдістері.

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PETROLEUM RESOURCES MANAGEMENT SYSTEMS(PRMS)

Abstract. Hydrocarbon resources are those quantities of hydrocarbons that exist naturally on the earth surface or in the subsurface. When considering resources, quantities of hydrocarbons both in known and undiscovered accumulations are estimated. Resource estimates are aimed at those quantities that can potentially be extracted and sold in the market during the implementation of commercial projects. The petroleum resource management system provides systematic approach to estimating quantities of hydrocarbons, evaluating projects and presenting results under the scope of universal classification.

During exploration, uncertainties and risks inevitably arise. Forecast estimates of hydrocarbon reserves are also performed under conditions of uncertainty. At present oil companies strive to minimize risks and remove some uncertainties before starting exploration work. In order to increase the efficiency of exploration, it is proposed to use several methods of forecast reserves estimation for exploration wells. The most widespread in modern oil and gas industry is classification of the Society of Petroleum Engineers (SPE) - Petroleum Resources Management System (PRMS) - liquid, gaseous and solid hydrocarbons reserves and resources management system.

Technology for prospecting and exploration, development, production and treatment of hydrocarbons is constantly evolving and improving. The SPE Oil and Gas Reserves Committee (OGRC) is in constant contact with stakeholder organizations to keep existing definitions and guidelines up to date with evolving technology and industry requirements.

Key words: oil, reservoir, reserves, SEC/PRMS reserves classification, management system, resource estimation methods.

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NEWS
OF THE NATONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5227
Volume 3, Number 447 (2021), 87-93 **https://doi.org/10.32014/2021.2518-170X.67**

UDC 625.8:625.76.089.2.002.5

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IMPROVING THE METHODS OF MILLING GAUGE ON HIGHWAYS

Abstract. Machines for milling asphalt concrete surfaces appeared on the highways of the Republic of Kazakhstan about ten years ago. Before that, the replacement of the old asphalt pavement took place under the deafening crack of jackhammers. Road cutters made it possible to replace this outdated technology with profiling of asphalt concrete surface.

This type of work consists in removing the asphalt coating layer by cold milling. Typical characteristics of the road milling cutter: working speed of 5-7 m /min, sufficient power, traction and stability to ensure accurate maintenance of the working depth from 3.5 mm to 5 cm; automatic leveling system using a leveling beam or string; automatic control of the milling depth using guide slides; the ability to maintain a given transverse slope; auxiliary equipment for the selection of crushed material (asphalt granulate) at a given processing speed; the width of the working area of the milling strip is 2-4 m.

Profiling of old asphalt pavement is an automatically controlled process of cold milling it to restore a given transverse and longitudinal profile, remove bumps, potholes, wear zones, as well as other coating defects, and as a result, obtain a surface that allows for the immediate start of movement or the laying of a fresh coating. Modern road cutters allow you to plan the old coating, texture its surface, giving it the lost coupling and noise protection properties, remove the old coating layer by layer (with an accuracy of up to mm) or immediately to the full depth, carefully open the places of laying underground pipelines and communication lines, release the old coating manholes and even level concrete floors in industrial premises.

In this paper, this problem is supposed to be solved by presenting the road cutter as an automated road transport and technological manipulator operating in generalized technological coordinates for the repair of road surfaces with variable track age and due to the transition from elastic (power) to rigid (coordinate) closure of the technological scheme for milling track gauges.

Key words: Road milling cutter, Road machinery, Gauge, Cutting element, Cutting ring.

Introduction. Rutting on highways is one of the main reasons leading to an increase in the risk of road accidents, reduces the comfort and economic efficiency of using motor roads. For example, the variation of the track reaches up to 17 cm in height and up to 35 cm in width. Track formation is classified mainly into wear, deformation, and combined. After rain, the track is filled with water, which creates a dangerous effect of aquaplaning the wheels of vehicles. All this causes the need for milling the road surface during repairs and reconstruction /1,2,7,8/.

Over the past more than twenty years, the road technology has been modified. Accordingly, the requirements for the technology of road surface profiling, including milling, should be revised, justified and supplemented. The creation of automated road milling cutters (ARC) made it possible to implement track milling operations much easier and more efficiently as part of road repair and road safety measures.

Therefore, the topic of improving the methods of track milling is relevant, and therefore the problem of improving the efficiency of repair of road surfaces based on the use of ARC is relevant /3,4,5/.

Methods. Industry-specific road guidelines for identifying and eliminating ruts of non-rigid road clothing are considered. The document is devoted to the calculation and forecasting of track formation on non-rigid road clothing. The method of calculation and prediction of coleoptere involves collecting and processing data; by-layer calculation of the residual (plastic) deformation; component of the calculation of depth gauge with the accumulation of permanent deformation; the calculation of the component of depth to-Lea due to the accumulation of residual deformation and structural damage; calculation of

the relative depth of the track due to the accumulation of residual deformations in the bitumen-containing layers.

This technique makes it possible to assess the uniformity of the coating.

In the world practice, various equipment for measuring the evenness of the road surface has been developed, depending on the principle of operation and design. In Kazakhstan, the most widespread are labor-intensive manual measurement methods using portable slats of various lengths.

Two approaches to measuring gauge parameters, developed by scientists of the Moscow Automobile and Road State Technical University using a three-meter rack and a status assessment scale, road to horn in terms of gauge parameters, were considered.

The paper deals with the formation of criteria for generalized forces, coordinates and work for the working bodies of automated road cutters. This creates a multi-connectivity and multi-contour interaction of the control vector with the vector of the driving influences and perturbations.

Two control modes are offered for the ARC control system: operator and non-operator. For implementation without operator mode, two software methods can be used: positional and power. The main types of ARC control (taking into account the similar practice of using technological robots) are divided into - cycle, positional and contour.

On the basis of the idea underlying the device for measuring the longitudinal micro-profile of roads, the concept of improving the quality of milling was put forward by eliminating from the resulting micro profile irregularities in the wavelength of which affect the vibration load of a person, this effect in milling is obtained due to a long-base chassis. The promise of this idea is confirmed by numerical experiments of modeling the use of the device.

The efficiency of laser technologies application in installation of laser scanners on road cutters was analyzed.

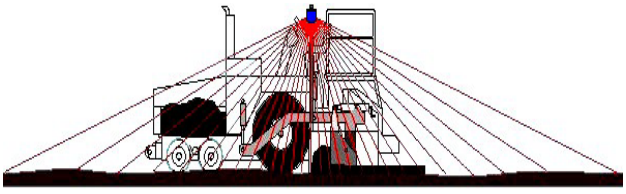


Figure 1 - RSS scanning system installed on asphalt laying

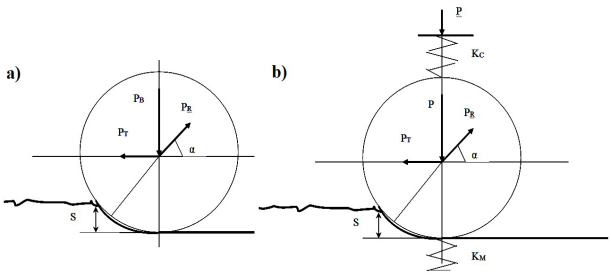
The traditional software and hardware of road cutters and the principle of their operation with these positioning and basing systems are considered. The modern RSS system (Road Scanning System), based on ultrasonic sensors and first introduced on asphalt liners, is described in detail. The concept of positioning road cutters using stationary laser posts is considered. Features of laser scanning systems arrangement on mobile units are presented. Laser scanning rangefinders operate on the principle of measuring the range to the spot on the surface based on either measuring the time interval between the sent and reflected signal, or measuring the phase shift.

Figure 2 - The result of milling the protrusions during the power circuit control

The necessity of switching from a power closure to a coordinate closure is justified, based on the general picture of the forces acting on the milling drum. An example of the result of milling a bulge by the method of elastic (power) closure of the technological scheme for milling a track and its bulges is shown in Figure 2. In the automatic system, a power-circuit control with feedback was used for manually set correction variable increments of the level of adjustment of the milling drum bearings.

It is established that as a result of power milling with vertical force stabilization, the processed (milled) surface turns out to be buried, in the form of a chute, and also uneven. The unevenness is primarily due to the fact that force deformations are produced during milling, caused by the variable height of the rollers of the track bulges, which is depicted by the displacements of the characteristic in Figure 2.

An analogy was made between similar processes in metalworking (milling) and asphalt concrete milling. A diagram of the forces acting on the milling drum is shown in Figure 3.



a - the scheme of forces in milling; b - the scheme of forces with elastic elements

Figure 3 - Diagram of the forces acting on the milling drum

PB - pressure force on the tool (drum); PT - longitudinal thrust force; PR - is the reaction force from the shear layer; S - s the thickness of the layer to be cut; α-angle between reaction force of cut layer and horizon. You can see that:

$$\alpha = \arccos\left(\frac{R}{R - 0{,}5 * S}\right) \quad 1)$$

Force opposing longitudinal movement of the:

$$P_{RT} = P_R \cos\alpha \quad 2)$$

Lifting force:

$$P_{RB} = P_R \sin\alpha \quad 3)$$

The reaction force PR depends on the thickness of the shear layer, the speed of the longitudinal movement and the modulus of elasticity of the pavement material. The analysis of forces will not be complete, if we do not take into account the elastic characteristics of the system. The gravity of system P and two elastic elements of KC - hardness of ARC system and KM - gesture-bone of pavement are added. Analysis of the elastic interaction system of the cutter - tool - of the treated coating shows that provided that the stiffness of the material KM is greater than the stiffness of the mechanical system of the road cutter Kc, the elastic system of the road cutter will deform to a greater extent, and accordingly the milling drum will rise from the given zero treatment line. If the KM is larger than some critical value, determined by the weight of the road cutter in terms of the pressure exerted on the drum axis, not only the tool, but the entire ARC will rise above the zero treatment line. In this case, the tool (drum) will enter the "glide" mode. On the other hand, when the stiffness of the material is reduced and the pressure on the side of the road cutter is maintained, the milling drum will be buried more than a predetermined value.

The dashed line shows the level of pavement prior to milling. The idea of the MTC system is offered (a mill - the tool - a covering), mathematical modeling of process of milling is carried out and the mathematical dependence allowing to determine the optimum depth of milling taking into account elasticity of the MTC system is developed.

The differential removal equation by milling the variable allowance of the re-mounted pavement, depending on the influencing factors, can be recorded, taking into account the results of the work of Professor A.N.Vasin /6/, as:

$$\frac{dz}{d\tau} = S - \frac{dy}{d\tau} \quad 4)$$

where dτ is the elementary time period; *S* - speed of movement of working tool of road cutter; *dy* - elementary elastic deformation of the process system (pre-cutting cutter - tool - road surface); *z* - allowance removal value

Nominal actual speed of pavement allowance removal:

$$S_Z = S - S_{ó} \quad 5)$$

where *Sy* - is the rate of elastic deformation.

$$J_{\text{ÔÒ}} = \frac{P_y}{y} \quad J_P = \frac{P_y}{S_Z} \quad 5)$$

where JTC - is the rigidity of the technological system "road cutter - tool - road surface"; JP - estimation of rigidity of the gauge recesses; Py - normal cutting force; y - is the driving force of the milling cutter working element movement during elastic deformation.

The results of mathematical modeling of the removal of the allowance depending on the time, the speed of movement of the ARC cutting tool, the assessment of the rigidity of the road surface bulges and the rigidity of the technological system are shown in Figure 4. The results show, for example, that the feed rate of 100 mm/min (1.66 mm/s) corresponds to the milling allowance (discharge height) for the steady state in the diap zone up to 50 mm (3000/60 = 50) /7,8,9/.

As a result of the conducted research, it was found that the problems of controlling the milling of the track and its protrusions on existing road cutters arise from the lack of feedback, so it is possible to build an adaptive road surface milling system if the milling system is supplemented with feedback sensors and appropriate software. The principle of operation of the software complex of computational modeling is proposed, which allows determining the recommended height of the removed allowance of the track bulge for the initial conditions of the steady-state mode. The software package of computational modeling allows us to determine the recommended increase in the height of the removed gauge allowance for the initial conditions of the steady-state mode:

$$\Delta Z = b\int_0^{\tau} S_Z d\tau = S\int_0^{\tau}\left(1 - e^{-\frac{J_{T.C.}}{J_P}\tau}\right)d\tau = S\left(\tau - \int_0^{\tau} e^{-\frac{J_{T.C.}}{J_P}\tau} d\tau\right) = S\left[\tau - \frac{J_P}{J_{\tau}}\left(1 - e^{-\frac{J_{\tau}}{J_P}\tau}\right)\right] \quad 6)$$

where ΔZ - is the increment of the height of the track clearance allowance to be removed, and b - is the adjustment coefficient (from 0 to 1,0).

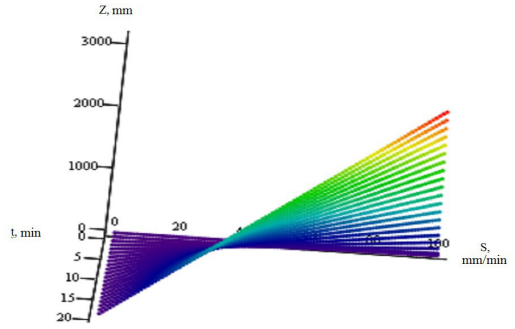
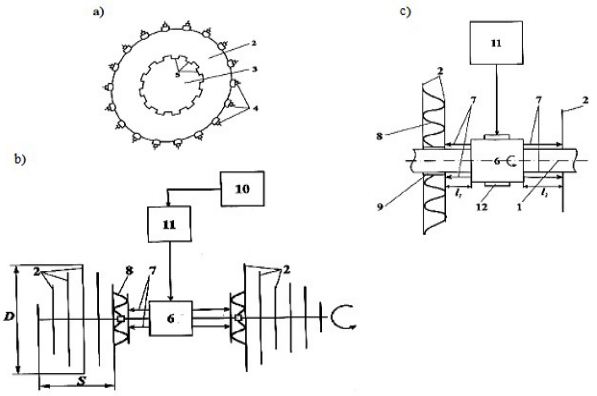


Figure 4 - Results of numerical simulation of the milling process

In this way, the goal of improving the accuracy of milling the track and its edges on the road using a road cutter can be realized by improving the milling

technology and ensuring the required properties of the road cutter in real conditions of changes in the dimensional and mechanical parameters of the road surface and the operating modes of the cutter.



a - cutting ring; b - milling drum; c - ring with elastic-deformable element;

1-cylindrical body; 2-cutting rings; 3-mounting holes; 4-cutting element; 5-rectangular spline surfaces;

6-adjustable drive device;7-rods; 8-elastic-deformable elements; 9-landing holes; 10-depth sensor;

11-micro-processor control device; 12-current collector;

Figure 5 - Milling drum design

A schematic diagram of the control of an automatic milling machine is proposed, which consists in expanding the functionality of a road milling machine operating in the construction and road construction machines (Figure 5).

Milling drum containing a cylindrical body with cutting rings in the form of discs with the base mounting holes located on the peripheral parts of the disc cutting elements in the form of rotating cutters, characterized in that the mounting holes of the cutting rings from further prepared rectangular spline surfaces on the outer surface of the case is made additionally rectangular spline slots with minimal clearance at the width groove interacting with rectangular spline surfaces of the holes of the cutting rings, the composition of the milling drum included Central symmetrically along the axis of the drum is adjustable drive unit with extendable along the axis of the drum in both directions stocks that interacts with end surfaces closer to the stocks located to cutting rings with locking reached lengths of extension rods, elastic deformed elements in the form of, for example, one- or two-wavelength thin-walled corrugated elements with a Central base to bore, gauge the depth of milling and microprocessor-based control device, with cutting ring combined in different configurations correspond to the maximum depth of cut layer sets variously diametrically opposed cutting rings, elastic deformed elements are placed between the cutting rings with the opportunity to interact with their end surfaces, and the sensor output of milling depth is associated with the input of the microprocessor, the output of which is connected to the input of the adjustable drive device.

As a result of the work of the road machine with the proposed milling drum, due to the feedback from the milling depth sensor and the regulating correlating effect from the sliding rods, the required milling depth of the defective layer of the road surface is removed with a high quality of surface treatment of the road section under repair. By changing the configuration of the sets of cutting rings, it is possible to remove any amount of allowance (depth of milling), provided that the force load on the cutting elements of the rings is uniform and their wear is minimal.

Results. Experimental studies of automated road milling cutter control methods and practical results are presented. After processing the results of the experiment, mathematical dependences were obtained (the feed force on the milling depth and feed speed, the average value of the milling resistance was determined, the drive power was determined taking into account the tool diameter and the angular speed of rotation.

The experimental stand is implemented on the basis of a horizontal milling machine by changing it and equipping it with a removable table for fixing asphalt concrete samples (Figure 6). The model of the road milling cutter is a typical set milling cutter. A procedure for measuring deformations and measuring vibrations of a sample of asphalt pavement using a universal magnetic measuring head has been developed.

Two series of experiments were carried out with elastic (Figure 6, a) and rigid (Figure 6, b) closure. In the first case, a 20 mm thick rubber sheet was placed between the clamping device and the milling machine table. In the second case, the clamping device was rigidly attached to the table of the milling machine. A disc cutter, a sample of asphalt concrete with an uneven surface, was selected. Milling was carried out towards the direction of movement of the surface to be processed

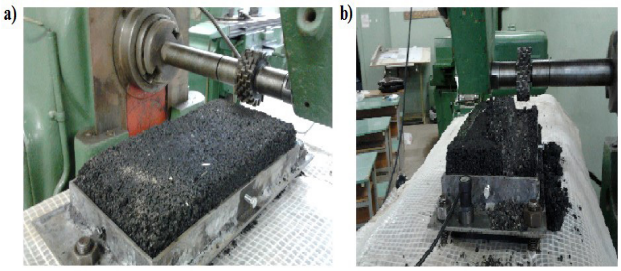


Figure 6 - Experiment on simulation milling of asphalt concrete samples

Two modes were investigated:

- with an elastic element (rubber). The fastening was carried out by a clamp with a submerged elastic element. In this case, there was an increased spread of deviations in the milling dimensions and an increase in the average height of the milled surface.

- in the case when the sample with asphalt concrete

was fixed rigidly, lower average values and a variation in the deviation of the milling size by 1.9-2.3 times were observed. This confirms the effectiveness of the transition from force closure to coordinate closure or displacement control. Simulation (computational modeling) was carried out) in which different control methods were compared with pulsating sub-adjustments.

On the vertical axis, the number of measurement points is plotted in increments of 0.1 mm, and on the horizontal axis, the number of the measurement point is plotted. The KP-514 mobile road diagnostic laboratory (before and after the use of the Wirtgen road milling cutter) was used for driving along a 1200-meter section of the highway. Based on the results of the passes, the values of evenness for each 50 m of the measured section were obtained. The variance of the samples of the average evenness values for the measured section with a length of 1200 m and the standard deviations for the initial and milled road surface confirm the effectiveness of the method.

Conclusion.

The milling machines mass-produced by leading companies and the modern technologies of road surface milling developed on their basis are best suited for performing a whole range of specific practical tasks for the repair of road surfaces with variable trackage.

Proposals have been developed to select optimal methods for milling road surfaces with variable dimensional and mechanical characteristics and new arrangements of road cutters based on non-mechanical kinematic connections.

An improved technology for using a road cutter as an automatized road technological manipulator is proposed, which realizes correlation of the level of dimensional adjustment with vertical changes in the position of the working tool and formalized adaptive pulsating climbs of the dimensional adjustment of the tool based on feedback on deviations of the level of milled over the required values.

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АВТОМОБИЛЬ ЖОЛДАРЫНДАҒЫ ЖОЛТАБАНДЫ ФРЕЗЕРЛЕУ ӘДІСТЕРІН ЖЕТІЛДІРУ

Аннотация. Асфальтбетон жамылғыларын фрезерлеуге арналған көліктер Қазақстан Республикасының автокөлік жолдарында шамамен он жыл бұрын пайда болды. Бұған дейін ескі асфальт жамылғысын ауыстыру ұру балғаларының құлақ тесер шуының арқасында жүзеге асырылатын. Жол фрезалары бұл ескірген технологияны асфальтбетон жамылғысын профильдеумен алмастыруға мүмкіндік берді.

Жұмыстың бұл түрі суық фрезерлеу әдісімен асфальт жамылғысы қабатын алып тастауға келіп тіреледі. Жол фрезасының типтік сипаттамалары: жұмыс жылдамдығы 5-7м/ мин, 3,5 мм-ден 5 см-ге дейін өңдеу тереңдігін дәл сақтауды қамтамасыз етуге қажетті жеткілікті қуат, тарту күші және орнықтылық; нивелирлеу арқалығының немесе сырықтың көмегімен автоматты теңестіру жүйесі; бағыттаушы арналардың көмегімен фрезерлеу тереңдігін бақылаудың автоматты жүйесі; берілген көлденең еңісті ұстап тұру мүмкіндігі; берілген өңдеу жылдамдығы кезінде ұсақталған материалды (асфальт түйіршігін) таңдауға арналған қосалқы жабдық; фрезерлеу жолағының жұмыс аймағының ені 2-4 м.

Ескі асфальтбетон жамылғысын профильдеу - бұл берілген көлденең және бойлық профильді қалпына келтіру, төмпешіктерді, шұңқырларды, тозу аймақтарын, сондай-ақ жамылғының басқа да ақауларын алып тастау және нәтижесінде қозғалысты жылдамдатып бастауға немесе жаңа жамылғы төсеуге мүмкіндік беретін бетті алу үшін оны суық фрезерлеудің автоматты түрде басқарылатын процесі. Қазіргі заманғы жол фрезалары ескі жамылғыны тегістеуге, оның бетін текстуралауға, оған жоғалтқан ілінісу және шуылдан қорғау қасиеттерін бере отырып, ескі жамылғыны қабаттап (мм-ге дейінгі дәлдікпен) немесе бірден бүкіл тереңдікке алуға, жерасты құбырлары мен байланыс желілерін төсеу орындарын мұқият ашуға, құдықтар люктерін ескі жамылғыдан босатуға және тіпті өндірістік ғимараттардағы бетон едендерді тегістеуге мүмкіндік береді.

Зерттеліп отырған жұмыста бұл мәселені жол фрезасын ауыспалы жол жамылғыларын жөндеу үшін жалпыланған технологиялық координаталарда жұмыс істейтін автоматтандырылған жолдық көліктік-технологиялық манипулятор ретінде ұсыну арқылы және жолтабан шығарғыштарды фрезерлеудің технологиялық сұлбасының серпімді (күштік) тұйықталуынан қатаң (координаталық) тұйықталуға өту арқылы шешу болжамы қарастырылған.

Түйін сөздер. Жол фрезасы, жол техникасы, жолтабан, кескіш элемент, кескіш сақиналар.

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СОВЕРШЕНСТВОВАНИЯ МЕТОДОВ ФРЕЗЕРОВАНИЯ КОЛЕИ НА АВТОМОБИЛЬНЫХ ДОРОГАХ

Аннотация. Машины для фрезерования асфальтобетонных покрытий появились на автомобильных дорогах Республики Казахстан около десяти лет назад. До этого замена старого асфальтового покрытия происходила под оглушающий треск отбойных молотков. Дорожные фрезы позволили заменить эту устаревшую технологию профилированием асфальтобетонного покрытия.

Данный вид работ заключается в удалении слоя асфальтового покрытия методом холодного фрезерования. Типовые характеристики дорожной фрезы: рабочая скорость 5-7 м/мин, достаточная мощность, тяга и устойчивость для обеспечения точного выдерживания глубины обработки от 3,5 мм до 5 см; автоматическая система выравнивания при помощи нивелировочной балки или струны; автоматическая система контроля глубины фрезерования при помощи направляющих салазок; возможность поддержания заданного поперечного уклона; вспомогательное оборудование для подбора измельченного материала (асфальтового гранулята) при заданной скорости обработки; ширина рабочей зоны полосы фрезерования 2-4 м.

Профилирование старого асфальтобетонного покрытия - это автоматически управляемый процесс его холодного фрезерования для восстановления заданного поперечного и продольного профиля, удаления бугров, выбоин, зон износа, а также других дефектов покрытия, и в итоге получения поверхности, допускающей немедленное начало движения или укладку свежего покрытия. Современные дорожные фрезы позволяют планировать старое покрытие, текстурировать его поверхность, придавая ей утерянные сцепные и шумозащитные свойства, снимать старое покрытие послойно (с точностью до мм) или сразу на всю глубину, аккуратно вскрывать места прокладки подземных трубопроводов и линий связи, освобождать от старого покрытия люки колодцев и даже выравнивать бетонные полы в производственных помещениях.

В работе данную проблему предполагается решить за счет представления дорожной фрезы, как автоматизированного дорожного транспортно-технологического манипулятора, работающего в обобщенных технологических координатах для ремонта дорожных покрытий с переменной колейностью и за счет перехода от упругого (силового) к жесткому (координатному) замыканию технологической схемы фрезерования выпоров колеи.

Ключевые слова: дорожная фреза, дорожная техника, колея, режущий элемент, режущие кольца.

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NEWS
OF THE NATONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5227
Volume 3, Number 447 (2021), 94-99 **https://doi.org/10.32014/2021.2518-170X.68**

UDC 556.18

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SPECIFIC FEATURES OF FLOW FORMATION AND WATER USE IN THE CATCHMENT AREAS IN THE TOBOL RIVER BASIN

Abstract. On the basis of long-term information and analytical materials of the RSU Tobyl-Torgai Basin Inspectorate for Regulation of the Use and Protection of Water Resources of the Water Resources Committee of the Ministry of Agriculture of the Republic of Kazakhstan, characterizing the use of water resources in the economic sectors of administrative districts and cities of the Kostanay region, the conditions for the formation of surface flow and regional features of water use in the catchments of the Tobol river basin were determined.To assess the change in the average annual discharge in the catchments of the Tobol River basin under the influence of natural and anthropogenic activities, integral curves of average annual discharge were determined for the hydrological stations of Akkarga, Grishenka, Kostanay, and Milyutinka, which showed that in the period under consideration from 1996 to 2005, there was a slight increase in the average annual discharge for all hydrological stations under consideration, and from 2006 to 2017 - their constant decline, which is a signal to ensure the safety of economic activities in the region. To assess the peculiarities of water use in the catchments of the Tobol River basin, the volumes of water consumption by housing and public services, industry and agriculture were used, which gradually decrease over the period of 1996-2016, since the industry is mainly located in the cities of Lisakovsk, Kostanay and Rudny. and agriculture in Kamystinsky, Zhitikarinsky, Denisovsky, Taranovsky, Kostanaysky, Karabalyksky, Fedorovsky and Mendikarinsky districts is developing within the dryland cultivation, which determines the type of linear trend, which is characterized by a polynomial equation of third order.

Key words: river, basin, flow, expenditure, water, resources, water use, analysis, evaluation, method, trend.

Relevance. The catchments of the river basins of the steppe zone of Northern Kazakhstan, as a kind of component of geographic objects, perform to a certain extent environment-forming functions as a regulator of the water regime of landscapes, maintaining the ecological balance of natural systems. One of the main features of the river basins of the steppe zone, formed due to the melting of snow cover and atmospheric precipitation, determines their hydrological and hydrochemical specificity, that is, a close connection between the formation of flow and the landscape systems of the catchment area of river basins. At the same time, the main function of the catchment area of the river basins of the steppe zone, belonging to the system of small rivers, is the natural possibility of flow formation, providing the generation of ecological, economic and social environments, which seem to be the spatial bases of management of natural resources and environmental engineering. In this regard, the problem of water security has recently acquired special relevance to meet the needs for water resources of all categories of water users, including by increasing the rationality and ensuring the complexity of water use.

The goal of the researchis to analyze and assess the natural conditions for the formation of water resources in the catchment basins of the Tobol River and to identify the spatial features of the water use arrangement to optimize management decisions in the field of water use.

Target of study. The Tobyl River is one of the main waterways of Northern Kazakhstan, where the runoff formation zone is located on the eastern spurs of the Southern Urals, 10 km southwest of the Sarzhan village and flows into the Irtysh River from the left bank near the city of Tobylsk. The catchment basin of the Tobyl River is 395 thousand km^2, of which part 121 thousand km2 of its catchment area is located within the Kostanay region, and the total length of the river is 1591 km, of which 682 km is the upper river[2].

Research materials and methods. To achieve the objectives set there are used a basin approach, the method of an integrated study of geographical objects, mathematical statistics and hydrological calculations, based on linear trend using the Microsoft Excel.

On the basis of the obtained system of mathematical equations using the Microsoft Excel program, the

restoration of annual flows in the catchment area of the Tobol River basin at the hydrological stations of Akkarga, Grishenka, Kostanay and Milyutinka for the years 1996-2017 are shown in Figure 2.

As can be seen from Figure 2, the trend of the long-term course of hydrological flow in the catchments of the Tobol River basin at the hydrological stations of Akkarga, Grishenka, Kostanay and Milyutinka shows for the period under consideration that, on a spatial-temporal scale, there is a decrease in annual flow under the influence of natural and anthropogenic activities.

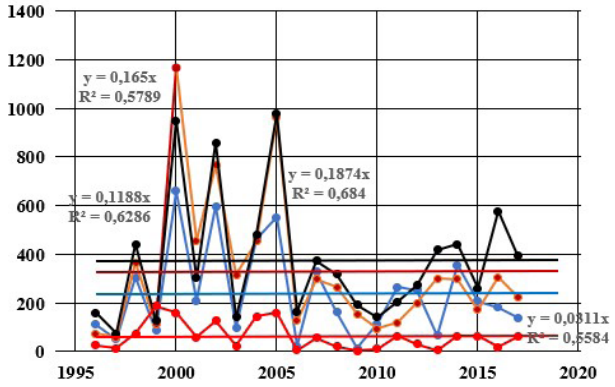

Figure 2 - The long-term progress of hydrological flow in catchments of the Tobol river basin (ordinate - annual flow volume (mln m^3); the abscissa - years; hydrological positions: 1- Akkarga 2- Grishenkov; 3- Kostanay; 4- Milyutinka)

To identify the peculiarities of water use in the catchment areas of the Tobol River basin, long-term information and analytical materials of the RSU Tobyl-Torgai Basin Inspectorate for the Regulation of the Water Resources Use and Protection of the Water Resources Committee of the Ministry of Agriculture of the Republic of Kazakhstan, characterizing the use of water resources in the sectors of the economy of administrative regions and cities of Kostanay region, located within the river basin proper, that is, for housing and public services, industry and agriculture (table 2).

Table 2 - Trend of water use by administrative districts in the catchment areas of the Tobol river basin, million m^3

Years	Trend of water use in the economy in the Tobol river basin, million m^3			
	Housing and public services	Industry	Agriculture	Total
1996	104.42	37.39	78.12	219.93
1997	90.77	37.05	48.71	176.53
1998	81.39	22.66	28.54	132.59
1999	70.86	21.41	16.42	108.79
2000	68.20	19.15	19.99	107.34
2001	58.29	15.40	19.50	93.19
2002	52.20	19.47	16.47	88.14
2003	54.14	19.31	17.21	90.66
2004	47.36	34.57	15.39	97.32
2005	42.22	22.74	13.87	80.20
2006	51.07	21.19	16.16	85.42
2007	42.35	28.69	12.96	87.03
2008	46.29	29.93	9.64	85.86
2009	43.11	30.18	10.09	84.61
2010	42.24	29.60	10.47	83.31
2011	41.98	27.48	9.60	79.06
2012	40.57	27.35	13.74	81.66
2013	42.23	34.21	12.12	88.78
2014	42.50	37.46	14.10	93.79
2015	38.77	32.35	15.14	86.26
2016	36.82	33.20	14.72	84.74

To determine the level of water situation, I.A. Shiklomanov proposed an indicator of specific available water supply (thousand m^3/year per person or km^3/year per million people), which determines not only the shortage of water resources, but also allows one to judge the overall state of water resources in the natural conditions of their formation and functioning [2].

In this case, the indicator of available water supply (PB) in the catchment areas of river basins is determined by the formula [2]:

$$PB=[1-(W_{бвв}/W_{ор})]$$

где $W_{ор}$ – real water resources of river basins, km^3/year; $W_{бвв}$ - irretrievable water consumption, km^3/year.

The water expenditure module of river basins was determined by the formula: $K_i=Q_i/Q_{cr}$ where Q_i– the average annual river water expenditure of year; Q_{cr}- the average long-term annual river discharge.

The estimated water flow in river basins is determined by the following equation: $p=[m/(n+1)]\cdot 100$, where m - ordinal number of order; n - quantity of order.

Research results. On the basis of long-term information and analytical materials of the RSU Tobyl-Torgai Basin Inspectorate for Regulation of Water Resources Use and Protection of the Water Resources Committee of the Ministry of Agriculture of the Republic of Kazakhstan, covering the years of 1996-2017 and the use of the method of hydrological calculations, the hydrological characteristics of the flow of the catchments of the Tobol river basin were determined for the hydrological stations of Akkarga, Grishenka, Kostanay and Milyutinka to reveal their

territorial differences in the space-time scale.

To evaluate the change in the average annual discharge in the catchments of the Tobol River basin under the influence of natural and anthropogenic activities, the integral curves of the average annual discharge were determined for the hydrological stations of Akkarga, Grishenka, Kostanay and Milyutinka (Figure 3).

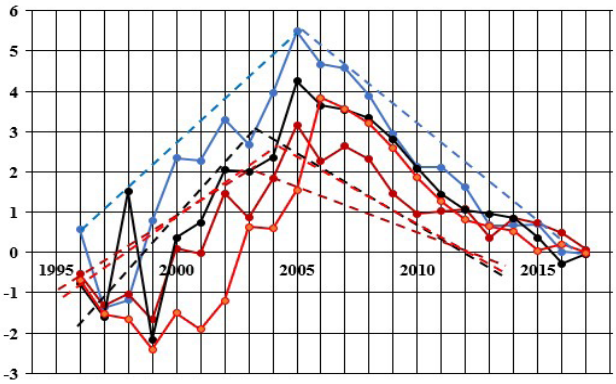

Figure 3- Integral difference curve of average annual flow in the catchments of the Tobol River basin (ordinate - integral difference curve; abscissa - years; hydrological stations: 1- Akkarga; 2- Grishenka; 3- Kostanay; 4- Milyutinka; trend in the area of maximum discharge by hydrological posts: 5- Akkarga; 6- Grishenka; 7- Kostanay; 8- Milutinka)

As can be seen from Figure 3, the shown differential integral curves of the average annual water flow of the Tobyl River, constructed from the hydrological stations of Akkarga, Grishenka, Kostanay and Milyutinka, describing the course of the accumulated difference $\sum_{i=1}^{n}(K_{cp}^{-1})$ in time show that the slope of the trend line atpositive value corresponds an increase in the average annual flow of the river in this period of time, and with a negative value corresponds to a decrease in the average annual flow.

The equation for the trend line for hydrological stations is as follows:

- at the Akkarga hydrological station: positive slope (Kp-1)=0,0009·t R^2=0,4525) and negative slope (Kp-1)=0,0014·t; (R^2=0,7564)
- at the Grishenka hydrological station: positive slope (Kp-1)=0,0001·t (R^2=0,0369) and negative slope (Kp-1)=0,0008·t (R^2=0,7721);
- at the Kostanay hydrological station: positive slope (Kp-1)=0,0004·t (R^2=0,7955) and negative slope (Kp-1)=0,0012·t (R^2=0,4525);
- at the Milyutinka hydrological station: positive slope (Kp-1)=0,0004·t (R^2=0,3005) and negative slope (Kp-1)=0,0011·t (R^2=0,7814);

Thus, until 2005 in the catchment basins of the Tobol River there has been a slight increase in the average annual water flow at all hydrological stations under consideration, and since 2006, their constant decrease, which is a signal to ensure the security of economic activities in the region.

The concept of "available water supply" mean not only ensuring the water consumption schedule of the population, but also providing the natural components of the landscape system and sectors of the region's economy with water resources. To evaluate the available water supply of the catchment area of the Tobol river basin, they are conditionally divided into two water-resources regions, that is, the upper reaches (from the flow formation zone to the Kostanay hydrological station) and the midstream (from the Kostanay hydrological station to Milyutinka) and within their determination of the level of water resources use in the economic sectors region (Figure 4).

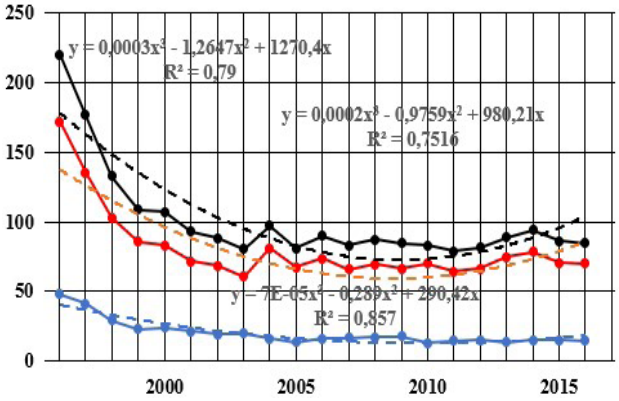

Figure 4 - Trend of water use by water-resources regions in the catchments of the Tobol river basin (mln.m^3) with linear trends (1-upstream water; 2- midstream; 3-catchment area of the river basin) (ordinate - volume of water consumption in economic sectors; abscissa - years)

The peculiarities of water use in the catchments of the Tobol River basin are determined by the volume of water consumption by housing and public services, industry and agriculture, which are gradually decreasing over the period 1996-2016, since industry is mainly located in the cities of Lisakovsk, Kostanay and Rudny, and agriculture in Kamystinsky, Zhitikarinsky, Denisovsky, Taranovsky, Kostanaysky, Karabalyksky, Fedorovsky and Mendikarinsky areas is developing within the dry farming, which determines the type of linear trend, which are described by a polynomial equation of third order, having the following shape:

- for the upper water of the river:

$$W_{бвв}=7E\text{-}0,5\cdot t^3\text{-}0,289\cdot t^2+290,42\cdot t;$$

- for middle reach:

$$W_{бвв}=0,0002\cdot t^3\text{-}0,9759\cdot t^2+980,21\cdot t;$$

- for the catchment of the river basin:

$$W^{бвв}=0,0003\cdot t^3\text{-}1,2647\cdot t^2+1270,4\cdot t.$$

Based on the information and analytical materials given in Tables 1 and 4, the predictive calculations

were made to determine the available water supply in the water-resources regions of the catchment areas of the Tobol River basin (Table 4).

Table 5 - Ecological indicators of specific available water supply in the catchment area of the Tobol river basin by water-resources regions

Years	Tobol water-resources regions		
	Upper reaches ofcatchment areas of the Tobol River		
	Actual water resources (W_{op}, mln. m^3)	Irretrievable water consumption ($W_{бвв}$, mln m^3)	Available water supply indicators (PB)
1996	111.00	48.31	0.565
1997	52.00	41.13	0.209
1998	306.0	29.54	0.903
1999	87.37	23.25	0.734
2000	659.19	24.22	0.963
2001	209.40	21.74	0.896
2002	596.00	19.58	0.967
2003	98.70	19.81	0.799
2004	463.6	16.06	0.965
2005	552.00	13.85	0.975
2006	23.97	16.52	0.311
2007	328.02	16.91	0.948
2008	162.75	17.35	0.893
2009	12.62	18.07	- 0.432
2010	114.17	13.33	0.883
2011	266.20	15.00	0.943
2012	252.95	15.07	0.940
2013	66.86	13.95	0.791
2014	356.40	15.52	0.956
2015	207.85	15.46	0.926
2016	181.00	14.93	0.918

Years	Tobol water-resources regions		
	Upper reaches ofcatchment areas of the Tobol River		
	Actual water resources (W_{op}, mln. m3)	Irretrievable water consumption ($W_{бвв}$, mln m3)	Available water supply indicators (PB)
1996	72.54	171.62	-1.366
1997	58.35	135.46	-1.321
1998	365.3	103.05	0.718
1999	111.02	85.54	0.230
2000	1171.20	83.12	0.929
2001	457.30	71.45	0.843
2002	766.40	68.56	0.910
2003	314.50	70.85	0.774
2004	454.20	81.26	0.821
2005	962.00	67.35	0.929
2006	127.00	73.53	0.421
2007	298.00	65.92	0.779
2008	264.00	69.68	0.736
2009	155.00	66.54	0.571
2010	95.00	69.98	0.263
2011	119.00	64.06	0.461
2012	200.00	66.59	0.667
2013	299.00	74.83	0.749
2014	297.00	78.27	0.736
2015	172.00	70.80	0.588
2016	305.00	69.81	0.771

As can be seen from Table 5 giving the available water supply in the catchments of the Tobol river basin by water-resources regions, show that in the upper reaches the available water supply indicator ranges from 0.209 to 0.967, which corresponds to values from low water supply to high water supply depending on the water content of the river, and in the middle reaches, their quantitative values range from -1.336 to 0.929, which shows a very high available water supply.

Discussion of results. The practical significance of evaluating the conditions for the formation of surface flow in the catchments of the Tobol River basin and the peculiarities of their use in the sectors of the regional economy resides in the fact that the research results focus on solving applied problems of increasing the efficiency and quality of management decisions in the water resources use and protection. The database obtained in the course of the study on the structure and trend of water use and available water supply indicators in the catchment areas of the Tobol River basin on a space-time scale may become a basic component for further research in the field of increasing and efficiency of water resources use, ensuring the standard quality of drinking water and wastewater treatment, protection of water bodies, as well as making timely management decisions towards achieving and maintaining a state of sustainable and environmentally safe water use.

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ТОБЫЛ ӨЗЕНІ БАССЕЙНІНІҢ СУ ЖИНАУ АЛАБЫНДА АҒЫНДЫ ҚАЛЫПТАСТЫРУ ЖӘНЕ СУДЫ ПАЙДАЛАНУ ЕРЕКШЕЛІКТЕРІ

Аннотация. Қостанай облысының әкімшілік аудандары мен қалаларының экономика салаларында су ресурстарын пайдалануды сипаттайтын Қазақстан Республикасы ауыл шаруашылығы Министрлігі су ресурстары комитетінің «су ресурстарын пайдалануды реттеу және қорғау жөніндегі Тобыл-Торғай бассейндік инспекциясы» РММ көпжылдық ақпараттық-сараптама материалдарының негізінде Тобыл өзені бассейнінің жер үсті ағынын қалыптастыру шарттары және суды пайдаланудың өңірлік ерекшеліктері айқындалған. Табиғи және антропогендік қызметтердің әсерінен Тобыл өзені бассейнінің су жинауларындағы орташа жылдық шығынының өзгеруін бағалау үшін Аққарға, Гришенка, Қостанай және Милютин гидрологиялық бекеттері бойынша орташа көп жылдық шығыстардың интегралдық қисықтары айқындалды, олар қаралып отырған кезеңде 1996 жылдан 2005 жылға дейін барлық қаралып отырған гидрологиялық бекеттер бойынша судың орташа жылдық шығынының біршама ұлғаюын, ал 2006 жылдан 2017 жылға дейін олардың тұрақты төмендеуі байқалғанын көрсетті, бұл өңірдің шаруашылық қызметінің қауіпсіздігін қамтамасыз ету сигналы болып табылады.

Тобыл өзені бассейнінің су жинауларында суды пайдалану ерекшеліктерін бағалау үшін тұрғын үй-коммуналдық шаруашылықтың (көрсетілетін қызметтің), өнеркәсіптің және ауыл шаруашылығының су тұтыну көлемі пайдаланылды, олар 1996-2016 жылдардардан бері біртіндеп азайып келеді, өйткені өнеркәсіп негізінен Лисаковск, Қостанай және Рудный қалаларында орналасқан, ал ауыл шаруашылығы Қамысты, Жітіқара, Денисов, Таран, Қостанай, Қарабалық, Федоров және Меңдіқара аудандарында богарлы жер өңдеу шеңберінде дамуда, бұл үшінші ретті полиноминалды теңдеумен сипатталатын желілік трендтің түрін айқындайды.

Түйін сөздер: өзен, бассейн, ағын, шығыс, су, ресурстар, суды қолдану, талдау, бағалау, әдіс, тренд.

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ОСОБЕННОСТИ ФОРМИРОВАНИЯ СТОКА И ВОДОПОЛЬЗОВАНИЯ НА ТЕРРИТОРИЯХ ВОДОСБОРОВ БАССЕЙНА РЕКИ ТОБОЛ

Аннотация. На основе многолетних информационно-аналитических материалов РГУ «Тобыл - Торгайская бассейновая инспекция по регулированию использования и охране водных ресурсов» Комитета по водным ресурсам Министерства сельского хозяйства Республики Казахстан, характеризующих использование водных ресурсов в отраслях экономики административных районов и городов Костанайской области определены условия формирования поверхностного стока и региональные особенности водопользования водосборах бассейна реки Тоблол. Для оценки изменения среднегодового расхода в водосборах бассейна реки Тобол под влиянием природных и антропогенных деятельностей определены интегральные кривые среднемноголетних расходов по гидрологическим постам Аккарга, Гришенка, Костанай и Милютинка, которые показали, что в рассматриваемый период с 1996 до 2005 года наблюдается некоторое увеличение среднегодовых расходов воды по всем рассматриваемым гидрологическим постам, а с 2006 года до 2017 года - постоянное их снижение, что является сигналом обеспечения безопасности хозяйственной деятельности региона.

Для оценки особенностей водопользования в водосборах бассейна реки Тобол использованы объемы водопотребления жилищно-коммунального хозяйства (услуги), промышленности и сельского хозяйства, которые за рассматриваемый период 1996-2016 годов постепенно уменьшаются, так как промышленность в основном расположена в городах Лисаковск, Костанай и Рудный, а сельское хозяйство в Камыстинском, Житикаринском, Денисовском, Тарановском, Костанайском, Карабалыкском, Федоровском и Мендикаринском районах развивается в рамках богарного земледелия, что определяет вид линейного тренда, который характеризуется полиноминалным уравнением третьего порядка.

Ключевые слова: река, бассейн, сток, расход, вода, ресурсы, водопользование, анализ, оценка, метод, тренд.

Комитета по водным ресурсам Министерства сельского хозяйства Республики Казахстан, характеризующих использование водных ресурсов в отраслях экономики административных районов и городов Костанайской области определены условия формирования поверхностного стока и региональные особенности водопользования водосборах бассейна реки Тоблол. Для оценки изменения среднегодового расхода в водосборах бассейна реки Тобол под влиянием природных и антропогенных деятельностей определены интегральные кривые среднемноголетних расходов по гидрологическим постам Аккарга, Гришенка, Костанай и Милютинка, которые показали, что в рассматриваемый период с 1996 до 2005 года наблюдается некоторое увеличение среднегодовых расходов воды по всем рассматриваемым гидрологическим постам, а с 2006 года до 2017 года - постоянное их снижение, что является сигналом обеспечения безопасности хозяйственной деятельности региона.

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Ключевые слова: река, бассейн, сток, расход, вода, ресурсы, водопользование, анализ, оценка, метод, тренд.

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I**NEWS**
OF THE NATONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5227
Volume 3, Number 447 (2021), 100-103 **https://doi.org/10.32014/2021.2518-170X.69**

SSN 2224-5278
UDC 621.395.019
IRSTI 47.00.00

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USING OF VIRTUAL PRIVATE NETWORK TECHNOLOGY FOR SIGNAL TRANSMISSION IN CORPORATE NETWORKS

Abstract. This paper discusses some modes of signal transmission for corporate systems using the technology of virtual private networks VPN. A very important property of tunnels is the ability to differentiate different types of traffic and assign them the necessary service priorities. In this work, research has been carried out and comparative characteristics of signal transmission modes using virtual networks have been obtained to identify the effectiveness of the network in various modes of organizing a virtual network, and to optimize a virtual network in order to identify an effective method for organizing a VPN. Also, the work analyzes the specifics of the work of corporate information systems and networks intended for their maintenance, showed that for building a corporate network it is advisable to use virtual private network (VPN) technology, which makes it possible to ensure the fulfillment of the basic requirements for the security and quality of customer service and applications and the current state and direction of development of VPN technology when creating new generation corporate networks, while highlighting the main tasks that need to be addressed when creating a network. Some features of setting up an IPSec VPN server for corporate networks are considered.

Key words: corporate networks, VPN (Virtual Private Network), tunneling, traffic, point-to-point connection, server, router

Introduction. The transmission of corporate data over a public network such as Internet is often a threat to the security of an enterprise network, which is especially important for corporate systems. In addition, for corporate networks, the quality of user service, the provision of a given set of services and guarantees, which is not always easy to provide in public networks, are important.

To solve these problems, the technology of virtual private networks VPN (Virtual Private Network) can be used. This technology transforms connections in public packet networks into secure channels with guaranteed bandwidth, providing security and a wide range of services at an acceptable cost of the established connections. Therefore, this technology is in demand by many enterprises and organizations that do not have their own network resources, primarily corporate organizations due to its cost-effectiveness, availability and security.

The relevance of this issue lies in the peculiarities of large geographically distributed corporate networks: in the use of global connections and the integration of individual local networks of branches of an enterprise and computers of its remote employees with a central local network; serving a large number of heterogeneous users. All these features make it expedient to develop networks using VPN technology, which allows combining security requirements for the provided system services. However, its effective application requires the solution of a number of special problems associated with the choice of the structure of the network, the organization of the work of users and networks, ensuring the required level of data protection and the required characteristics of transmission and processing of information [1,2].

To date, there is a fairly rich practical experience in creating large corporate networks based on VPN technology, however, theoretical substantiation of the proposed solutions is required. As a rule, in each specific case, its own original solutions are required, due to the specifics of the network and the corporation, which must be evaluated using sufficiently universal methods and models.

Ensuring an appropriate level of information exchange security can be achieved through the complex use of organizational, technical, hardware-software and cryptographic protection means, as well as the implementation of continuous control over the effectiveness of the implemented information security measures.

Virtual networking which based on internet has several advantages:

- it provides scalable support for remote access to local network resources, allowing mobile users to communicate over local telephone lines with ISPs and thus enter their corporate network;
- when organizing remote access for users to a local network, the need for modem pools is eliminated, and remote access traffic can be managed in the same way as any other Internet traffic;
- costs for information exchange through an open external environment are reduced.

Experimental part. The ubiquity of IP-based networks, their versatility and cost effectiveness make these networks a more attractive VPN foundation for most businesses and organizations. In addition, QoS (Quality of Service) protocols and technologies such as RSVP, DiffServ and MPLS are beginning to be widely implemented in dedicated IP networks. According to many experts, VPN is one of the most important technologies that enterprises are using and will use in the near future. The significance of this technology for any enterprise, and even more so for budgetary organizations, is primarily due to the economic benefits that are associated with its implementation. Infonetics Research estimates that a VPN can save a company between 20% and 40% for site-to-site and 60% to 80% savings for remote users respectively. Tasks are considered here which arise when creating a network and analyze the modes of signal transmission. At its core, VPN (Virtual Private Networks) has many of the properties of a leased line, but it is deployed within a public network such as the Internet. With the tunneling technique, data packets are broadcast over the public network as over a normal point-to-point connection. A kind of tunnel is established between each pair of "transmitter-receiver of data" - a secure logical connection that allows encapsulating data from one protocol in packets of another. A very important property of tunnels is the ability to differentiate different types of traffic and assign them the necessary service priorities. [2,3,4,5]. These properties are considered in this research.

Let us compare the characteristics of the modes of signal transmission using virtual networks to determine the effectiveness of the network under various modes of organizing a virtual network, and to optimize the virtual network in order to identify an effective method for organizing a VPN.

Experiment results. The research was carried out by the method of network analysis using WireShark and TCPdump programs. The network analysis will be carried out by assessing bandwidth, connection speed, security, and the effect of frame and packet size on network performance, and the effect of a broadcast storm on network health.

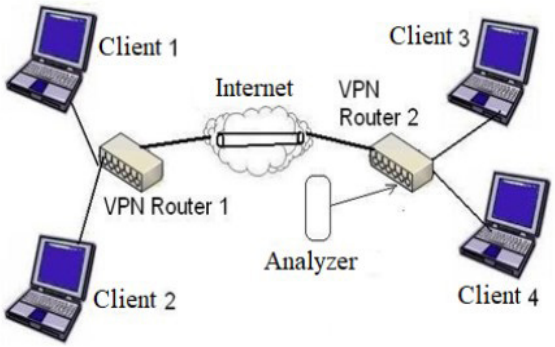

Figure 1 - Diagram of the organization of the experiment

The experimental setup is shown in Figure 1, where two VPN routers are installed and they are connected to each other by an Internet channel with a bandwidth of 18 Mbit / s, then a VPN tunnel is organized between them. Clients connect to two routers. Using the network analyzer programs (WireShark, TCPdump) configured for Router 2, we scan and analyze the VPN network in three different modes of operation of the Point to Point Tunneling Protocol VPN server (PPTP0):

1 Mode.

PPTP clients located in the WAN segment of the router connected to the router, after which standard speed tests were performed. Testing was carried out with one PPTP client. Test results are shown below. Figure 2 shows the results of the PPTP server network for the first client (1-client), where the following paths are indicated:

- LAN path → WAN - where traffic goes from the LAN segment computer to the PPTP client in the WAN segment;
- LAN path - this traffic goes from the PPTP client in the WAN segment to the computer in the LAN segment fdx path - full duplex - traffic goes in both directions.

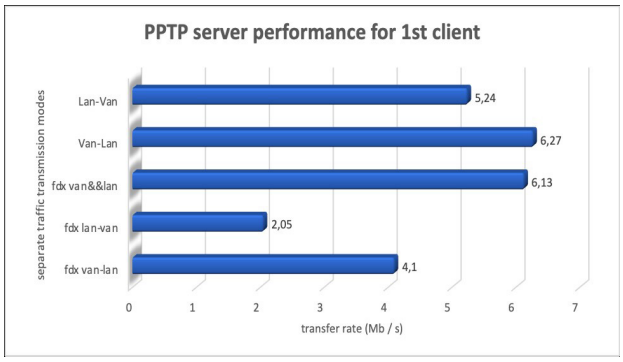

Figure 2 - PPTP server performance for the 1st client

Along the abscissa axis, transfer rate (Mb / s),

Separate traffic transmission modes along the ordinate.

The transfer results reflect the maximum speed: 6.27 Mbps is not slow enough compared to the speed

without using a VPN, especially when you consider that traffic is not encrypted.

2 mode.

L2TP (L2TP (Layer 2 Tunneling Protocol) VPN Server: Setting up an L2TP VPN server does not fundamentally differ from setting up a PPTP VPN server and encryption is also not supported. Performance testing was carried out in the same way as when testing the PPTP VPN server.

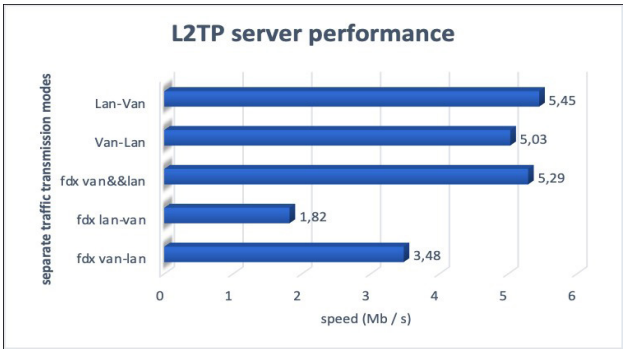

Figure 3 - L2TP server performance, 1 client, - speed (Mb / s) on the abscissa, - individual traffic transmission modes on the ordinate

Maximum speed: 5.45 Mbps - not slow enough when you consider that encryption is not supported.

3 mode.

IPSec VPN server: Some of the specifics of configuring an IPSec VPN server is that when static keys are set, you can use DES and 3DES encryption, and with dynamic key exchange, the configuration interface does not allow you to select the type of encryption, later it turned out that during dynamic key exchange, traffic encrypted using the AES algorithm.

Definitions:

– router - Internet router Level One FBR-1411TX;

– Gentoo - a computer with Gentoo Linux 2.6.11 installed;

– fdx - full duplex mode;

– along the abscissa axis, the speed (Mb / s);

– on the ordinate axis separate traffic transmission modes.

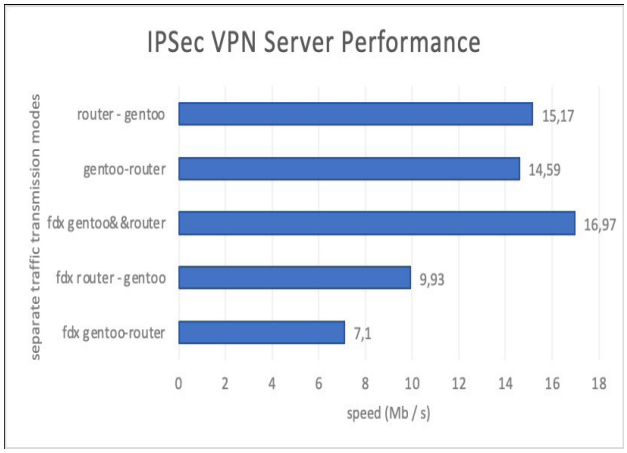

Figure 4 - Performance of IPSec VPN server, 1 tunnel, AES encryption

Maximum speed: 16.97 Mbps - sufficient speed for organizing a VPN, especially when compared with the operation of PPTP and L2TP VPN servers, which use slower speeds and no encryption.

Conclusion. An analysis of the specifics of the operation of corporate information systems and networks intended for their maintenance has shown that for building a corporate network it is advisable to use virtual private network (VPN) technology, which allows ensuring the fulfillment of the basic requirements for security and quality of customer service and applications.

The analysis of the current state and direction of development of VPN technology made it possible to draw a conclusion about the prospects of its application in the creation of corporate networks of a new generation, while highlighting the main tasks to be solved when creating a network.

Comparative characteristics of signal transmission modes using virtual networks are obtained to identify the effectiveness of the network in various modes of organizing a virtual network, and to optimize a virtual network in order to identify an effective method for organizing a VPN.

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КОРПОРАТИВТІК ЖЕЛІЛЕРДЕ СИГНАЛ БЕРУ ҮШІН ВИРТУАЛДЫ ЖЕКЕ VPN (VIRTUAL PRIVATE NETWORK) ТЕХНОЛОГИЯСЫН ҚОЛДАНУ

Аннотация. Бұл жұмыста виртуалды жеке желілер VPN (Virtual Private Network) технологиясын қолдана отырып корпоративті жүйелер үшін сигнал берудің кейбір режимдері қарастырылған. Туннельдердің өте маңызды қасиеті - бұл трафиктің әртүрлі түрлерін ажырата білу және оларға қажетті қызмет көрсету басымдықтарын тағайындау. Жұмыста виртуалды желіні ұйымдастырудың әр түрлі режимдерінде желінің тиімділігін анықтау үшін және виртуалды желіні оңтайландыру үшін виртуалды желілерді қолдана отырып сигнал беру режимдерінің салыстырмалы сипаттамалары алынды және виртуалды желіні тиімді түрде анықтады. VPN ұйымдастыру әдісі. Сондай-ақ,

жұмыста корпоративті ақпараттық жүйелер мен оларға қызмет көрсетуге арналған желілер жұмысының ерекшеліктері талданды, корпоративті желіні құру үшін виртуалды жеке желі (VPN) технологиясын қолданудың орынды екендігі көрсетілді, бұл базалық жүйенің орындалуын қамтамасыз етеді, тұтынушыларға қызмет көрсету мен қосымшалардың қауіпсіздігі мен сапасына қойылатын талаптар, жаңа буын корпоративті желілерді құру кезінде VPN технологиясының қазіргі жағдайы мен даму бағыты, сонымен бірге желіні құру кезінде шешілуі керек негізгі міндеттерді атап өту керек. Корпоративтік желілер үшін IPSec VPN серверін орнатудың кейбір ерекшеліктері қарастырылады.

Түйін сөздер: корпоративтік желілер, виртуалды жеке желілер VPN (виртуалды жеке желі), туннельдеу, трафик, нүктеден нүктеге қосылу, сервер, маршрутизатор

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ИСПОЛЬЗОВАНИЕ ТЕХНОЛОГИИ ВИРТУАЛЬНЫХ ЧАСТНЫХ СЕТЕЙ VPN (VIRTUAL PRIVATE NETWORK) ДЛЯ ПЕРЕДАЧИ СИГНАЛОВ В КОРПОРАТИВНЫХ СЕТЯХ

Аннотация. В данной работе рассмотрены некоторые режимы передачи сигналов для корпоративных систем при использовании технологии виртуальных частных сетей VPN (Virtual Private Network). Очень важным свойством туннелей является возможность дифференциации различных типов трафика и назначения им необходимых приоритетов обслуживания. В работе проведены исследования и получены сравнительные характеристики режимов передачи сигналов с помощью виртуальных сетей для выявления эффективности работы сети при различных режимах организации виртуальной сети, и для оптимизации виртуальной сети с целью выявления эффективного метода организации VPN. Также в работе проведены анализы специфики работы корпоративных информационных систем и сетей, предназначенных для их обслуживания, показал, что для построения корпоративной сети целесообразно применять технологию виртуальных частных сетей (VPN), которая позволяет обеспечить выполнение основных требований по безопасности и качеству обслуживания клиентов и приложений и современного состояния и направлении развития VPN- технологии при создании корпоративных сетей нового поколения, при этом выделены основные задачи, требующие решения при создании сети. Рассмотрены некоторые особенности настройки IPSec VPN-сервера для корпоративных сетей.

Ключевые слова: корпоративные сети, виртуальные частные сети VPN (Virtual Private Network), туннелирование, трафик, двухточечное соединение, сервер, роутер.

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I**NEWS**
OF THE NATONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5227
Volume 3, Number 447 (2021), 104-111 **https://doi.org/10.32014/2021.2518-170X.70**

UDC622.73:681.516.7

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PRESENTATION OF CRUSHING AND GRINDING COMPLEX AS SYSTEM WITH DISTRIBUTED PARAMETERS FOR ADAPTIVE CONTROL OF ORE DRESSING PROCESSES

Abstract. The article proposes representation of crushing and grinding complex in form of a system with distributed parameters of the reducing function of the processed raw materials size in order to increase the energy efficiency of entire ore preparation process. Despite the fact that many different automated control systems for domestic and foreign production technological process are now used in the ore preparation processes, there is still a need to solve the problems of optimal control of such objects in order to both reduce energy costs and improve the quality of the final product.

In terms of energy consumption, grinding processes are superior to crushing processes, so it is necessary to consider the crushing and grinding complex as a whole to increase the whole process energy efficiency. Since the processes of crushing, grinding and classification are purely random and at any time are characterized by transient probabilities, and the crushing and grinding complex occupies a large area and is geographically distributed in space, it should be considered as a system with distributed parameters of raw material size reduction, recyclable. Redistribution of loads between the individual components of this complex in accordance with the current characteristics of processed ore and the state of process equipment allows to reduce the load on the final stage - it is grinding, which in turn contributes to the overall reduction of energy consumption.

The peculiarity of this approach is the need for the formation of spatial-temporal controls on basis of spatially distributed control of the object, the use of appropriate feedback signals and regulators with spatially distributed control effects.

Key words: adaptive control, crushing and grinding complex, distributed parameters, function of ore size reduction

Introduction. Up to 70% of the electricity consumed by the mining and processing plant is used for the operation of crushing and grinding ore. Its consumers are crushing and grinding complexes, which include several stages of crushing and grinding, which carry out consistent reduction in size of the ore in order to fully disclose the useful component. The desire to reduce these costs leads to new modern solutions, in particular, to the use of adaptive systems of coordinated management of technological stages of reducing the size of the ore. It should be noted that important in economic terms is not only the optimal performance of the crusher in the processing of ore, but also the rate of stable operation with the smallest size of the final crushed product. Since the energy costs of grinding cycles significantly exceed the costs of crushing, and the efficiency of mills significantly depends on the product homogeneity, so obtaining a homogeneous composition of incoming ore becomes a priority.

Related work. Many works are devoted to the issue of optimal management of ore preparation processes. Thus, in [1] a method of controlling the crushing and grinding complex is given, according to which the change of crusher productivity on the source ore is carried out by measuring the power consumed by the crusher motor and changing the material supply to the crusher by the deviation of the measured value cone. The disadvantage of this method is the low control efficiency, because the level of measured power consumed by the crusher engine depends on the physicochemical properties of the source ore and contains in its spectrum perturbing effects that distort the actual load characteristics and crusher performance. Also, changing the frequency of oscillations of the cone leads to faster wear. Work [2]

illustrates the method of control of the crushing and grinding complex, according to which the loading of ball mills with ore implements the principle of stabilization of ore flow, supplied by the operator or by signals from automatic control systems of the processing line. The disadvantage of this method is the low control efficiency, because the level of loading of the mill is constantly changing and does not provide maximum performance of the mill on the finished size class at its output. The simplest and most common is a method of estimating the flow of sands using measurements of active current or power of the drive motor of the spirals of the hydraulic classifier [3]. However, its error is more than 30% in the range of performance due to the presence of disturbances, which does not allow to recommend it for widespread use. The most appropriate is a method of controlling the crushing and grinding complex, which includes its presentation in the form of a model of series-connected crushing and grinding units [4]. The disadvantage of this method is the use for mathematical description of the particle size distribution of ore using the Rosin - Rammler equation in General, as this equation has a fundamental disadvantage - it does not meet the boundary conditions.

The purpose of this article is to present the crushing and grinding complex in structure with distributed parameters form, the formation of a coordinated adaptive control of the multi-stage process of reducing ore size, providing with minimal energy consumption formation and maintenance of optimal characteristics of the control object that change significantly over time.

Presentation of the main research material. The most effective control effect for changing the product size in cone crushers is to change the width of the unloading slit. As shown in a number of works with increasing width of the unloading gap, the productivity of the cone crusher increases (Fig. 1), power consumption at a given consumption of output power decreases significantly (Fig. 2), and the size of the crushed product increases (Fig. 3) [5,6].

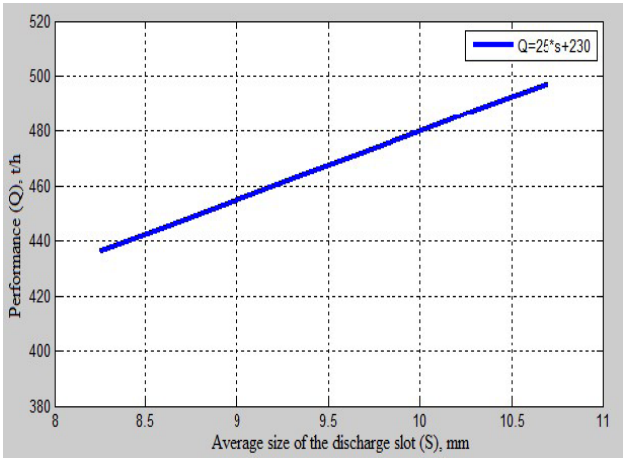

Figure 1 – Dependence of cone crusher productivity on discharge slot average size

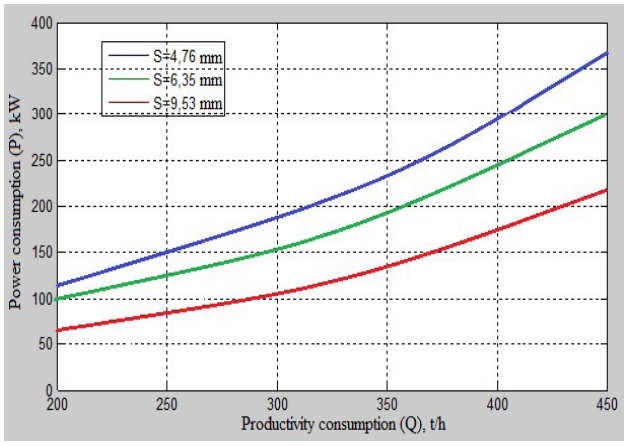

Figure 2 – Dependence of power consumption on the power upply costs with following crusher discharge slot

From the above it follows that if you maintain a constant power consumption and the width of the unloading slit, with more power the product is larger. At the same time there is a big increase in circulating loading [7,8]. This means that the consumption of feed ore must be significantly reduced to avoid overloading the cycle. To optimize the crushing process for the new technological situation, it is necessary to redistribute the load between the stages of crushing [9]. The latter approach is very important for the redistribution of the load from one stage of crushing to another in the implementation of a coordinated management of the multi-stage process of reducing the size of the ore.

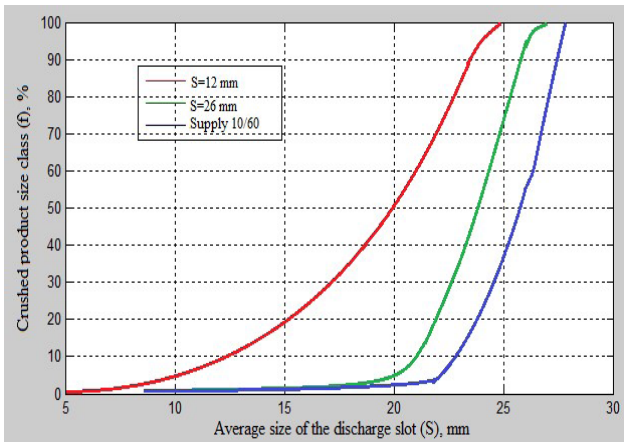

Figure 3 – Dependence of the size of the crushed product of the cone crusher on the width of the discharge slot

Since the processes of ore preparation are random and at any time are characterized by transient probabilities, and the crushing complex is territorially distributed in space and there is a change in the particle size distribution of ore, it can be argued that the size parameter is distributed over the object "ore that is being processed ", and the complex itself should be considered as a structure with distributed parameters [10]. The processed ore consists of particles of certain size classes, and taking into account the uneven ore flow in different technological

areas with simultaneous movement of ore mass from stage to stage, the behavior of the system is described by differential equations, each of which describes a separate class and stage of processed ore. and by particle size distribution [11]. We introduce additional notation: Qicx – is productivity of the original product; Qp – is productivity in unloading the unit; Qtr – is conveyor belt productivity; Fi (x, t) is the function of ore size distribution in the i-th class, k1-k4 are the coefficients that characterize the particle size distribution of the size classes.

$$(\partial Q_{1j}(x,t))/\partial t = k_1 (Q(P,j)(x,t) - Q_{ij}(x,t)) + k_2 (Q_{ucx,j})(x,t) - Q_{ij}(x,t)) + k_3 (Q_{2,j}(x,t) - Q_{1,j})(x,t)), \quad 1)$$

$$(\partial Q_{ij}(x,t))/\partial t = k_3 (Q_{i+1,j}(x,t) - Q_{ij}(x,t)) + k_3 (Q_{i-1,j})(x,t) - Q_{ij}(x,t)) + k_3 (Q_{1,j}x,t) - Q_{1,j})(x,t)), \quad 2)$$

$$(\partial Q_{nj}(x,t))/\partial t = k_4 \cdot (Q_{TP}(x,t) - Q_{nj}(x,t)) + k_3 \cdot Q_{n-1,j}(x,t) - Q_{nj}(x,t)) \quad 3)$$

$$(\partial F_{1j}(x,t))/\partial t = k_5 (F_{2j}(x,t) - F_{1j}(x,t)) + k_6 (Q_{ucx,j})(x,t) - Q_{ij}(x,t)) F_{1j}(x,t), \quad 4)$$

$$(\partial F_{ij}(x,t))/\partial t = k_6 \cdot (F_{i+1,j})(x,t) - F_{ij}(x,t)) + k_6 \cdot (F_{i-1,j})(x,t) - F_{ij}(x,t)), \quad 5)$$

$$(\partial F_{nj}(x,t))/\partial t = k_6 \cdot (F_{n-1,j})(x,t) - F_{nj}(x,t)). \quad 6)$$

The algorithm for such system developing is shown in Fig.4.

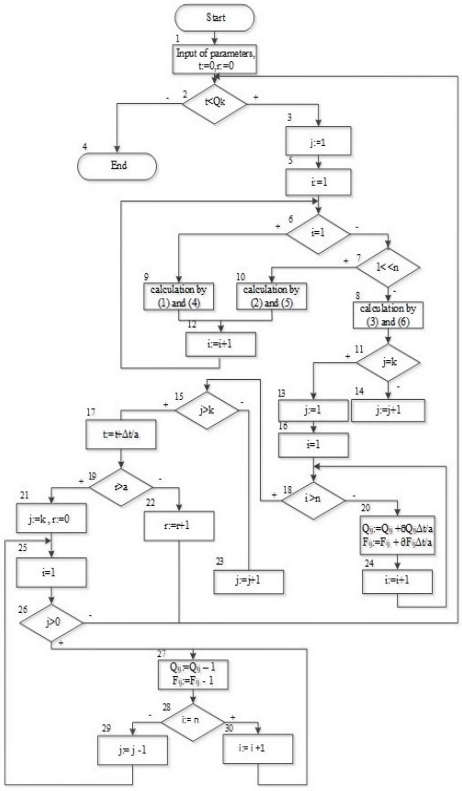

Figure 4 – Algorithm for developing systems with different parameters

The peculiarity of the algorithm is that it contains, in addition to the time cycle (beginning of the cycle block 2) and the size class (beginning of the cycle - block 6) another nested cycle by stage number (beginning of the cycle and its verification blocks 12,16). The cycles are nested in each other, due to which the distribution of the calculated parameters is achieved. Differential equations describing the system are in blocks 8,9,10 and are nested in cycles by size class and stage number. That is, on each cycle it is necessary to calculate separately changes not only characteristics on a size class of processed ore, but also on each stage.

To solve the problem of optimization of large dynamic systems, characterized by interactions between their components, used decomposition-coordination approach, which involves the transformation of the system structure by decomposing the global system and control tasks into many separate subsystems and individual subtasks [12]. To solve a global problem, two- or multi-level structures with coordinating variables are used, which reduces the complexity of their solution by reducing the main problem to a number of subtasks, each of which is smaller and easier to solve. The proposed procedure for the synthesis of decentralized management in the form of a structure with distributed parameters is based on the work [13-15]. Thus, for the synthesis of optimal control of the complex it is necessary to form subsystems of the lower level of control of each stage of the technological process as a structure with distributed parameters and control of the upper level, which realizes the achievement of the general criterion of optimality. This approach involves the decomposition of the control problem (CS) into temporal (TS) and spatial (SS) synthesis in a closed loop control system with distributed parameters (Fig. 5). In such a system, the loops in the TS block can be configured as normal closed control loops, in which the transfer functions describe the dynamics between the input and output sequences [15].

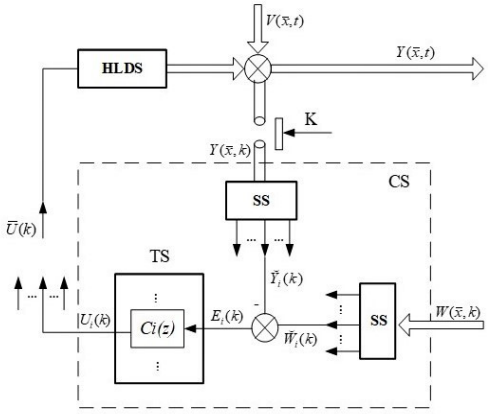

Figure 5 – Closing the control loop with different parameters

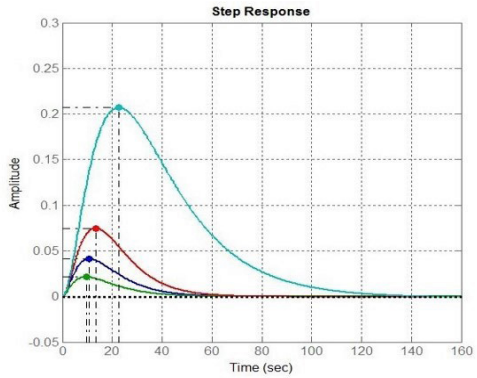

Figure 6 – Influence of the static transfer coefficient of the control object model on the quality of the transient process: K1 = KH; K2 = 2KH; K3 = 0,5KH; K4 = 0,1KH

Fig. 5 uses the following notation: K – sample shaper, – perturbation, – distributed adjustable variable, – selective distributed adjustable variable, – parameters of approximation of the adjustable variable, – impact of the task, – parameters of approximation of the impact of the task, – management error, – concentrated variable controllers, – concentrated control variables.

Analysis of the results of synthesis of the optimal linear-quadratic controller in the closed control loop TS shows high qualitative characteristics, the control synthesis is performed by solving a spatial problem based on approximation of the distributed objective control function and time - by optimizing the closed control loops SISO with concentrated parameters. Fig. 6 shows the influence of variations in the static transmission coefficient of the control object model on the quality of the transition process in a closed control loop TS at different values of K. For coordinated control separating stages the complex, method is optimization of nonlinear dynamical systems with a decentralized control structure is used, which applies the principle of minimizing generalized work [14,15] and the decomposition-coordination approach proposed in [16]. In which controllers of local subsystems receive current information about their subsystem and information about the trajectories of reference models of all other subsystems. Such a scheme is classified as an adaptive decentralized control scheme with model coordination and guarantees not only the stability of a closed system, but also asymptotic tracking of given reference trajectories with zero error in the presence of uncertainties in subsystems and relationships.

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For coordinated control of individual stages of the complex, the method of optimization of nonlinear dynamical systems with a decentralized control structure is used, which applies the principle of minimizing generalized work [14] and the decomposition-coordination approach proposed in [15] in which controllers of local subsystems receive current information about their subsystem and information about the trajectories of reference models of all other subsystems. Figures 7–8 show for example the coordinating and resulting actions under this control law.

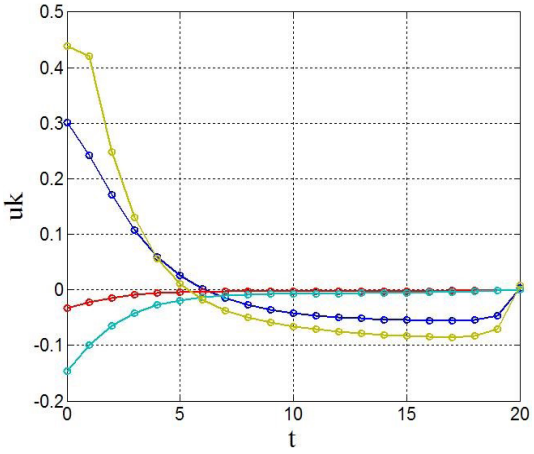

Figure 7 – Coordinating controls uk(t)

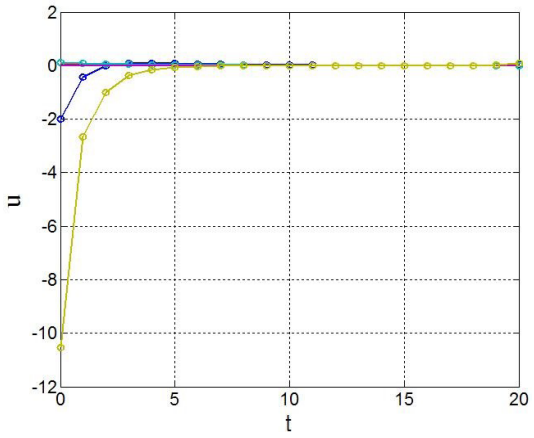

Figure 8 – The resulting control actions u(t)

The use of the considered approach for solving optimization problems of decentralized control of the crushing and grinding complex made it possible to make iterative procedures for synthesizing algorithms more efficient and obtain better convergence rates compared to traditional ones [13,17].

Model coordination of local subsystems allows, on the one hand, to reduce the complexity of calculating optimal controls, and on the other, provides the system with additional robustness properties in the presence of various uncertainties

in the system model, while remaining within the optimality for the nominal system model [18,19].

In Fig. 9 is a functional diagram of the ore preparation process control system based on a model with distributed parameters, which consists of a distributed regulator 1, which receives correction information from

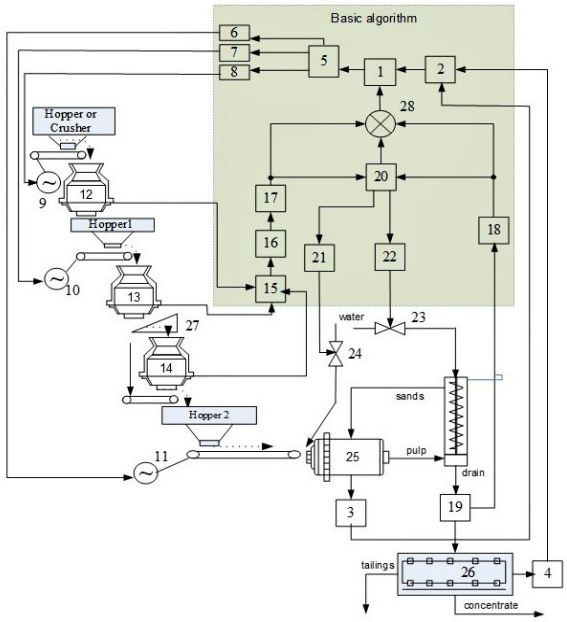

Figure 9 – Functional block diagram of the ore preparation process control system

the second unit 2 of calculations of the ratio of parameters of the consumed active power from the active power sensors of the ball mill drive motors 3 and the magnetic separator 4 respectively, and the output of the distributed regulator is connected in series to the unit 5 of the implementation of the coordinated control of ore performance regulators 6, 7, 8, which, controlling the speed of feeders 9, 10 11 corresponding stages 12, 13, 14, change the productivity of the technological line for ore in such a way as to provide an optimal mode of processing raw materials, subsystems for collecting information from technological sensors 15, which receives information about the level of filling and productivity of the corresponding stages of crushing, connected in series with the unit 16 of transformation and rationing, the output of which is connected to the input of the unit 17 calculation of parameters of the ore distribution function by size, the second Block 18 calculation of parameters of the ore distribution function by size to the input of which the sensor 19 of the content of class 74 microns is connected in the drain of the classifying device, the outputs of two blocks of calculation of parameters of the ore distribution function by size are connected to the input of the block 20 calculation of the ratios of granulometric characteristics, one of the outputs of which is connected to the regulator 21 the control position of the water supply valve 22 in the classifying device of the first stage of grinding 23, and the second output together with the outputs of the units of calculation of parameters of the ore distribution function by size is connected to the adder 24, which is connected to the second input of the distributed regulator.

The main part of the algorithm works as follows [18]. Information about the state of the technological process coming from subsystem 15 collecting information from sensors of productivity and filling level at the first 12, second 13 and third 14 stages of crushing passes primary processing and transformation into a convenient form for further operations in the block 16 transformation and rationing, after which it falls into the first Block 17 calculations of parameters of the function of distribution by size of raw materials that are processed.

Since for effective control it is advisable to consider the crushing and grinding complex as a single whole, so the device contains the second Block 18 calculations of parameters of the ore distribution function by the size of the first stage of grinding, the input of which receives information from the sensor 19 of the content of the class 74 microns in the drain of the classifying device, and the output is connected to the block 20 calculations of the ratio of granulometric characteristics, to which the first block 17 calculations of parameters of the ore distribution function by the size of all stages of crushing. Using the data of the calculation blocks 17 and 18 in the block 20 for calculating the ratio of granulometric characteristics, the optimal control characteristic of the regulator 21 connected to its output controlling the position of the water supply valve 22 in the classifying device of the first stage of grinding 23 is calculated, which further maintains the calculated ratio. The output of the block 20 is also connected to the adder 24 to which the outputs of blocks 17, 18 are connected for calculating the parameters of the ore distribution function by size of all stages of crushing and grinding, respectively, and the output of the adder 24 is connected to a distributed regulator 1, which performs coordinated control of the distributed process. Correction of the parameters of the distributed regulator 1 is carried out by the second unit 2 calculation of the ratios of the parameters of the active power consumed 3 consumed by the ball mill drive motor and the active power sensor 4 consumed by the magnetic separator drive motor, which acts as a natural indicator of the quality of the technological process. Moreover, the maximum value of the active power consumed by the drive electric motor of the magnetic separator corresponds to the maximum productivity of the complex of extracted magnetic iron and is determined by the optimal values of the degree of filling of the mill with ore, balls, pulp density in the mill, and the drain density of the classifying device. The output of the distributed regulator 1 is connected to the control unit 5 of the ore productivity

regulators, which, using an integral criterion, forms a coordinated control of the multi-stage process of reducing the ore size by a crushing and grinding complex, taking into account the speed of formation of certain ore size fractions, productivity and unit costs for the production of a unit of the initial product of each stage. The control signals of the unit 5 are sent to the regulators 6, 7, 8 of the ore productivities of the corresponding stages, which control the speed of feeders 9, 10 and 11, changing the productivity of the technological ore treatment line in such a way as to ensure with minimal energy consumption the formation and maintenance of optimal productivity and granulometric composition of the initial products of interconnected crushing and grinding units.

Conclusion. Method for controlling a crushing and grinding complex, which includes presenting it as a model of series-connected crushing and grinding units, as well as managing their productivity based on the formed model, which differs in that the model is crushing - the crushing complex is represented as a multi-stage structure with distributed parameters of the ore size reduction function, each stage of which is characterized by an area of optimal productivity, specific energy consumption and resource intensity, and the lowest energy consumption per unit of the initial product of the crushing and grinding complex is achieved by controlling its productivity and the degree of reduction of the size of each stage.

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РУДАҒЫ ДАЙЫНДАЛУ ПРОЦЕССТЕРІН БЕЙІМДЕП БАСҚАРУ ҮШІН БӨЛІНГЕН ПАРАМЕТРЛЕРІМЕН ҚҰРЫЛЫС ТҮРІНДЕ ҰНДАУ-ҰСАТУ КЕШЕНІНІҢ ҰСЫНЫСЫ

Аннотация. Мақалада бүкіл кенді дайындау процесінің энергия тиімділігін арттыру мақсатында кен көлемін кішірейту функциясында таралған параметрлері бар жүйе түрінде усату – ұнтақтау кешенін ұсыну ұсынылған. Қазіргі кезде кенді дайындау процесінде отандық және шетелдік өндірістің технологиялық процесін басқарудың әртүрлі автоматтандырылған жүйелері қолданылып жатқанына қарамастан, энергия шығындарын азайту үшін де, өсіру үшін де мұндай объектілерді оңтайлы басқару мәселелерін шешу қажеттілігі бар соңғы өнім сапасының тиімділігі. Энергия тұтыну тұрғысынан ұнтақтау процестері ұсақтау процестерінен жоғары, сондықтан бүкіл процестің энергия тиімділігін арттыру үшін ұсақтау және ұнтақтау кешенін тұтас қарастыру қажет.

Ұсақтау, ұнтақтау және жіктеу процестері тек кездейсоқ болғандықтан және кез-келген сәтте ауысу ықтималдығы мен сипатталады, ал усату және ұнтақтау кешені алкен аумақты алып, кеңістікте географиялық таралған, он таралған параметрлері бар жүйе ретінде қарастыруға болады. Осы кешеннің жекелеген компоненттері арасындағы жүктемелерде өңделген кеннің ағымдағы сипаттамаларына және технологиялық жабдықтың күйіне сәйкес қайта бөлу соңғы сатыдағы – ұнтақтау кезіндегі жүктемені азайтуға мүмкіндік береді, бұл өз кезегінде энергия шығындарының жалпы төмендеуіне ықпал етеді .

Бұл тәсілдің ерекшелігі – объектіні кеңістіктік үлестірілген басқару негізінде кеңістіктік – уақыттық басқару элементтерін қалыптастыру, кері байланыс сигналдарымен кеңістіктік бөлінген басқару әрекеттері бар контроллерлерді қолдану қажеттілігі.

Түйін сөздер: адаптивні бақылау, ұсату және ұнтақтау кешені, үлестірілген параметрлер, кен мөлшерін азарту функциясы.

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ПРЕДСТАВЛЕНИЕ ДРОБИЛЬНО-ИЗМЕЛЬЧИТЕЛЬНОГО КОМПЛЕКСА В ВИДЕ СТРУКТУРЫ С РАСПРЕДЕЛЕННЫМИ ПАРАМЕТРАМИ ДЛЯ АДАПТИВНОГО УПРАВЛЕНИЯ ПРОЦЕССАМИ РУДОПОДГОТОВКИ

Аннотация. В статье предлагается представление дробильно-измельчительного комплекса в виде системы с распределенными параметрами в функции сокращения крупности руды с целью повышения энергоэффективности всего процесса рудоподготовки. Несмотря на то, что в настоящее время в рудоподготовительных процессах используется множество различных автоматизированных систем управления технологическим процессом отечественного и зарубежного производства, по-прежнему существует необходимость решения задач оптимального управления такими объектами с целью как снижения затрат энергии, так и повышения эффективности качества конечного продукта. С точки зрения энергопотребления процессы измельчения превосходят процессы дробления, поэтому

необходимо рассматривать дробильно-измельчительный комплекс в целом, чтобы повысить энергоэффективность всего процесса.

Поскольку процессы дробления, измельчения и классификации являются чисто случайными и в любой момент характеризуются переходными вероятностями, а дробильно-измельчительный комплекс занимает большую площадь и географически распределен в пространстве, его можно рассматривать как систему с распределенными параметрами в функции сокращения крупности руды. Перераспределение нагрузок между отдельными компонентами этого комплекса в соответствии с текущими характеристиками перерабатываемой руды и состоянием технологического оборудования позволяет снизить нагрузку на завершающую стадию - измельчение, что в свою очередь способствует общему снижению энергозатрат.

Особенностью данного подхода является необходимость формирования пространственно-временных элементов управления на основе пространственно-распределенного управления объектом, использования соответствующих сигналов обратной связи и регуляторов с пространственно-распределенными управляющими воздействиями.

Ключевые слова: адаптивное управление, дробильно-измельчительный комплекс, распределенные параметры, функция сокращения крупности руды.

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I**NEWS**
OF THE NATONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5227
Volume 3, Number 447 (2021), 112-117 **https://doi.org/10.32014/2021.2518-170X.71**

UDC 266.276.3

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CAUSES AND ANALYSIS OF WATER ENCROACHMENT OF SOME OFFSHORE FIELDS PRODUCTS OF AZERBAIJAN

Abstract. The results of researches of the water encroachment of some offshore fields (Neft Dashlary, Guneshli, Pirallahi, Darwin Banka, Apsheron Banka, Western Apsheron, etc.) of the Republic of Azerbaijan, most of which are at a late stage of development, have been presented. These fields are represented by weakly cemented and loose reservoirs of heterogeneous structure, in which there is an uneven fluid flow. Water breakthrough occurs through high-permeability layers, and layers with low permeability are involved in development to a less extent. Subsequent attempts to involve them in the development process cause an irrational increase in the volume of injected water, which leads to product encroachment. The type of reservoir, characterized by the presence of fracture zones, contributing to the flow of water from the aquifers to the producing wells, as well as improving their hydrodynamic connection with the injection wells, also contributes to the growth of the rate of watering. The geological and technological reasons for the water encroachment have been determined. The heterogeneity of the above mentioned deposits has been proven. It is indicated that an additional reason for the early water encroachment of production wells is the violation of the annulus tightness. Maintaining high rates of oil production is achieved by bringing in new production wells, while most of the watered wells are retired from operation without having exhausted their potential. It is proposed to carry out the measures that will ensure isolation of the most washed out zones and depleted areas of the main productive layer of the field. Methods of selective water isolation and flow diversion technologies should be carried out, first of all, in wells with an increased density of current reserves in order to obtain additional oil production and increase the oil recovery factor, as well as in wells with a high fluid flow rate.

Key words: oil, injection wells, profile alignment, depression, tightness of the annulus, weakly cemented and loose reservoirs, water encroachment rate, efficiency of repair and isolation works

Introduction. The main deposits of the Republic of Azerbaijan have entered the late stage of development, which is accompanied by a high water encroachment in well production, with significant reserves of residual oil. Large volumes of associated water dictate the use of additional energy resources. This forces oil companies to implement large-scale methods of enhanced oil recovery and take measures to limit the production of associated water. To reduce the water encroachment of the well production, the technologies of profile alignment of the injectivity of injection wells and repair - isolation works (RIW) in production wells are usually used. Taking into account the massive water encroachment of products and the rise in prices for field geophysical research, there is a need to search for simple and cheap methods.

The nature of the water encroachment of the produced products is influenced by many factors related, on the one hand, to the geological structure and reservoir properties of the layer the physicochemical properties of oil and displacing fluid, on the other hand, to the used well placement system, the technology of their construction, and operating modes. Under the conditions of increasing depressions, a large number of wells are flooded due to water breakthrough through individual high-permeability layers of the developed object, violation of the tightness of the annular space, and also due to pulling up the bottom water cones. In addition, many oil deposits have water-oil zones and wells located in these zones, from the very first days of operation, they begin to give watered production. Premature watering of wells reduces the final oil recovery and causes large unproductive costs for production, transportation of associated water and for the fight against corrosion of production equipment [1,2].

Methods. From the point of view of water encroachment the fields of the Apsheron Peninsula and a number of offshore fields, represented by weakly cemented and loose reservoirs of heterogeneous structure, in which uneven fluid flows are observed, are of interest. Water breakthrough occurs through high-permeability layers, and layers with low permeability are involved in development to a less extent. Subsequent attempts to involve them in the development process cause an irrational increase in the volume of injected water, which leads to water encroachment in the production. The type of

reservoir, characterized by the presence of fracture zones, facilitating the flow of water from the aquifers to the producing wells, as well as improving their hydrodynamic connection with injection wells [3], also contributes to an increase in the rate of watering.

Field and analytical studies show that the main geological and physical factors that determine the anticipatory watering of oil wells are:

- high ratio of the viscosities of reservoir oil and injected water;
- permeable heterogeneity or fracturing of the formation, causing the early breakthrough of the injected water to the producing wells;
- the water-floating nature of the reservoir with a small thickness, or in the absence of a clay bridge between the differently saturated parts of the section, which causes the wells to be flooded with bottom water through behind-the-casing flows or coning of oil-water contact
- Leakage of the production string or the well bottom.

The negative effect of the permeable heterogeneity of the reservoir on the efficiency of water flooding is also enhanced by capillary forces (their effect increases with a decrease in the permeability of productive rocks), the swelling of clay cement of productive rocks in contact with the injected water, clogging of the bottom hole formation zone of injection wells with mechanical impurities [4].

Research. For 2016-2020, the results of the repair and insulation works (RIW) of "Neft Dashlary" OGPD were studied. During this period, 103 repair and isolation works were carried out at the "Neft Dashlary" field, the data on the horizons of which are presented in Fig. 1.

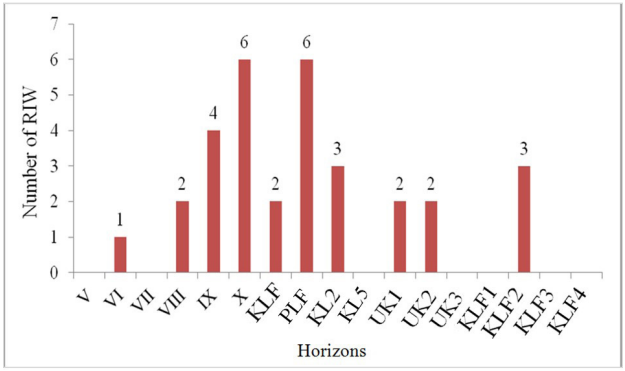

Fig.1. Distribution of RIW by horizons for the period 2016-2020 at the "Neft Dashlary" field

As it is seen from figure 1, most of the RIW were carried out in water injection facilities (VIII, IX, X, PF, UG_2) and lower horizons (UG_1, UG_2, UG_3, UG4).

The effectiveness of the RIWs carried out for 2016-2020 was presented in Fig. 2.

At the Neft Dashlary field, there are 371 wells in the operating fund. In most of them, there is an intense manifestation of water.

Watering of well production during operation is an expected process. Attention is drawn to the fact that, due to objective and subjective (long-term operation of overpasses and their failure) reasons, it is impossible to fight against encroachment, and this leads to incomplete use of potential oil and gas production rates.

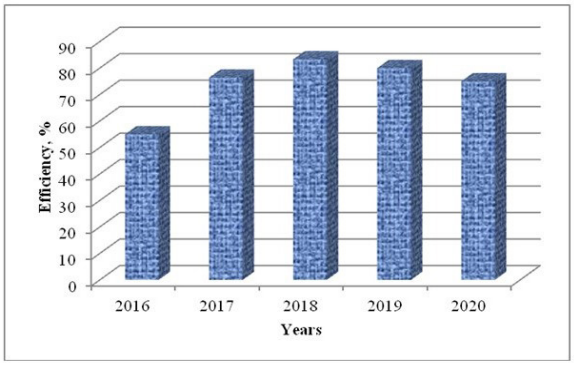

Fig.2. Efficiency of RIW by years for the period 2016-2020 at the "Neft Dashlary" field.

All this in the future may adversely affect the technical and economic indicators during the development of the field. In addition, watering of products leads to accelerated corrosion of down hole and surface equipment and becomes the reason for their premature failure.

Figure 3 shows the distribution of the operating well stock (371 wells) by the degree of water encroachment.

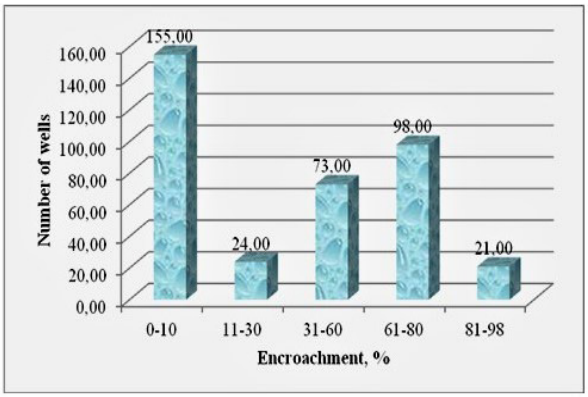

Fig.3. Distribution of the operating well stock by the degree of water encroachment.

In the period from 2016-2020, 1630 tons of oil were additionally produced due to the regulation of water inflow by the elastic-strength mass (ESM). The data of this event are shown in figure 4.

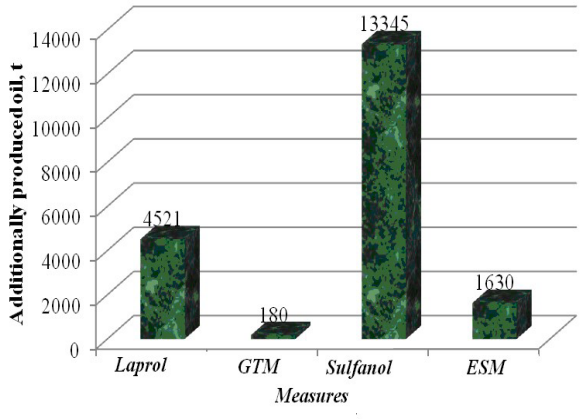

Fig.4. Additional oil produced as a result of conducting RIW

Carried out researches show that the primary cause of well failure is water containing corrosive elements, produced together with oil. These aggressive media include sulfur and hydrogen compounds, hydrogen sulfide (H_2S) and carbon dioxide (CO_2), as well as salts dissolved in formation water.

At the 28 May OGPD, two fields are being developed - Guneshli and Zhiloy. For 2016-2020, the results of the repair and insulation works (RIW) were studied. During this period, 77 RIW were carried out on the Guneshli field, and 39 RIWs on the Zhiloy field. Repair and insulation works carried out during this period are shown in Figure 5.

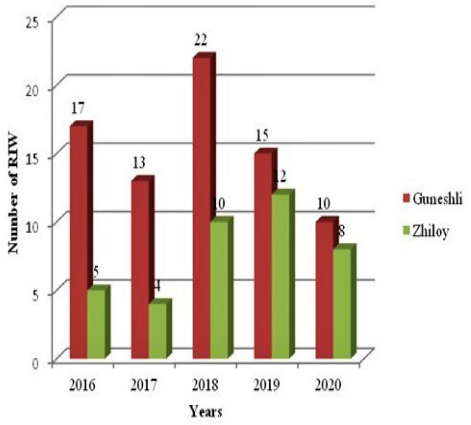

Fig.5. RIW conducted for the period 2016-2020

The collected field materials indicate that the efficiency of the exploration and survey work carried out for the period 2016-2020 was: at the Guneshli field -53-77%, at the Zhiloy field -0-50% (Fig.6).

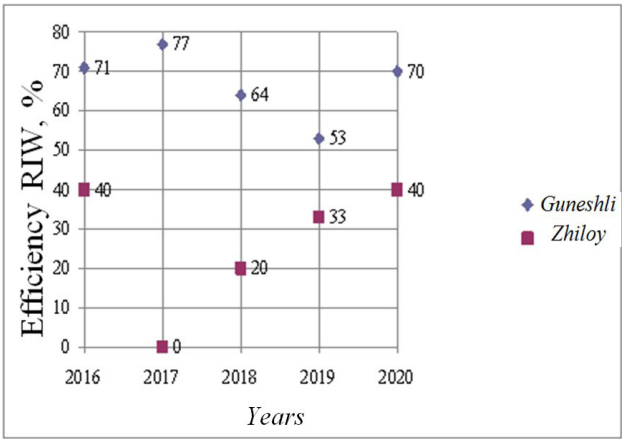

Fig.6. The efficiency of the conducted RIW for the period 2016-2020 at the Guneshli and Zhiloy fields

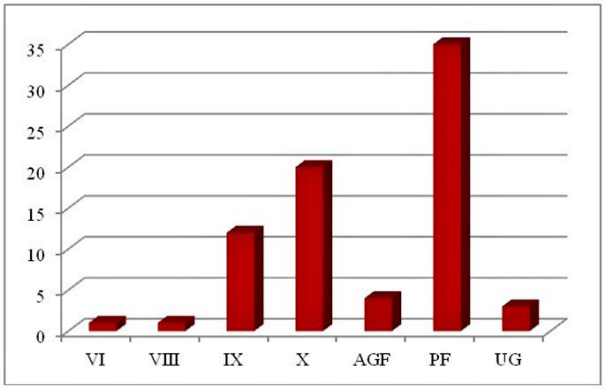

Fig.7. Distribution of RIW for the Guneshli field.

Since the efficiency of RIW for the Guneshli and Zhiloy fields varies in a large interval, the efficiency of RIW for individual horizons was analyzed. The distribution of RIW for the Guneshli field is shown in figure 7. As it can be seen from figure 7, most of the RIW falls on horizons IX, X and the Formation Pererive (FP).

At present, Апsheronneft Oil and Gas Production Directorate develops the Pirallakhi, Darwin Banka, Gyurgyan-Sea, Western Apsheron and Apsheron Banka fields. The analysis of RIW was carried out at these fields for the period 2016-2020. The dynamics of RIW changes is shown in figure 8.

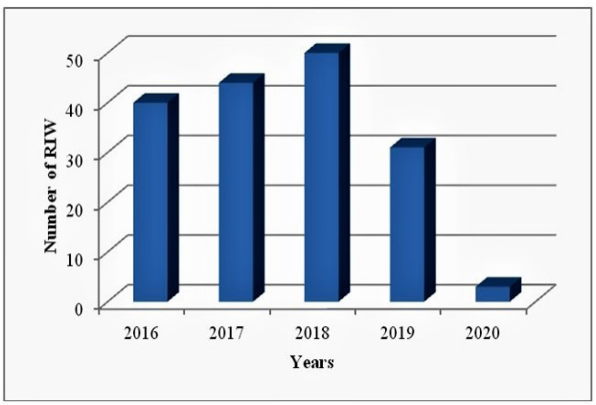

Fig.8. Dynamics of RIW changes for the period 2016-2020

According to figure 8, over the past 5 years, there has been an increase in RIW performance.

At Apsheronneft OGPD for the period 2016-2020, the results of overhaul are presented in the table 1.

Table 1

Overhaul results at Apsheronneft OGPD for the period 2016-2020

Serial number	Years	GTM name	GTM quantity	Cement consumption, t
1	2	3	4	5
1	2016	RIW	24	48
2	2017	-//-//-	23	69
3	2018	-//-//-	38	90
4	2019	-//-//-	22	85
5	2020	-//-//-	26	60
Σ			133	352

Serial number	Materials used during GTM	Measures		Additionally produced oil, t
		factual	efficiency	
	6	7	8	9
1	conventional cement used during 24 measures	24	11	3995
2	conventional cement used during 23 measures	23	12	3337
3	conventional cement used during 38 measures	38	21	5160
4	conventional cement used during 22 measures	22	10	3400
5	conventional cement used during 26 measures	26	15	3500
Σ	133	133	69	9392

As it can be seen from Table 1, 133 RIW performances have been held. 69 of the measures taken were effective. In most of the activities carried out, conventional oil well cement was used for RIW, and a small amount was made by other compositions (polymer-cement mortars based on Laprol). The effectiveness of the measures taken was 51%.

An additional reason for the early watering of production wells is the violation of the tightness of the annulus. Maintaining high rates of oil production is achieved by bringing in new production wells, while most of the watered wells are retired from operation without exhausting their potential. Carrying out regular activities for monitoring the development allows timely to identify the causes of annulus overflows. High-quality repair and isolation works can extend the service life of old wells and significantly reduce operating costs.

Conclusion.

1. Efficient exploration and survey work in producing wells should be the priority types of measures to ensure the design indicators of oil reserves recovery.

2. Technological measures should ensure the isolation of the most washed out zones and depleted areas of the main productive layer of the field through the development and implementation of new water-insulating compositions and technologies that ensure the limitation of the mobility of reservoir and injected waters and a change in the directions of filtration flows.

3. Geological and technological measures for the use of selective water isolation methods and flow diverting technologies should be carried out, first of all, in wells with an increased density of current reserves, in order to obtain additional oil produced and increase oil recovery factor, as well as in wells with a high liquid flow rate, indirectly confirming the presence in the productive perforated interval of a watered high-permeability interlayer and indicating the potentially high efficiency of geological and technical measures in terms of reducing the volume of associated water.

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ӘЗІРБАЙЖАННЫҢ КЕЙБІР ТЕҢІЗ КЕН ОРЫНДАРЫ ӨНІМДЕРІНІҢ СУЛАНУ СЕБЕПТЕРІ МЕН ТАЛДАУЫ

Аннотация. Әзірбайжан Республикасының кейбір Теңіз кен орындарын (Дашлары Нефті, Гюнешли, Пираллахи, Дарвин Банкі, Апшерон банкі, Батыс Апшерон және т.б.) суландыруды зерттеу нәтижелері ұсынылған, олардың көпшілігі игерудің кеш сатысында. Бұл кен орындары құрылымы жағынан біртекті емес, әлсіз цементтелген және борпылдақ коллекторлармен ұсынылған, оларда сұйықтық ағындарының біркелкі еместігі байқалады. Судың жоғары өткізгіш қабаттардан өтуі байқалады, ал өткізгіштігі төмен қабаттасулар аз дәрежеде дамуға қатысады. Оларды әзірлеу процесіне тартудың кейінгі әрекеттері айдалатын су көлемінің иррационалды өсуіне әкеледі, бұл өнімнің суланауына әкеледі. Суландыру қарқынының өсуіне коллектор түрі де ықпал етеді, ол сулы қабаттардан өндіруші ұңғымаларға судың ағуына, сондай-ақ олардың айдау ұңғымаларымен гидродинамикалық байланысын жақсартуға ықпал ететін жарықшақты аймақтардың болуымен сипатталады, суланудың геологиялық және технологиялық себептері белгіленеді. Жоғарыда аталған кен орындарының гетерогенділігі дәлелденді. Өндіруші ұңғымалардың өнімдерін ерте суландырудың қосымша себебі-бағанадан тыс кеңістіктің тығыздығының бұзылуы. Мұнай өндірудің жоғары қарқынын ұстап тұруға жаңа өндіруші Ұңғымаларды пайдалануға беру арқылы қол жеткізіледі, бұл ретте суландырылған ұңғымалардың көпшілігі өз әлеуетін сарқылмастан пайдаланудан шығады. Ең көп жуылған аймақтарды және кен орнының негізгі өнімді қабатының қазылған учаскелерін оқшаулауды қамтамасыз ететін оқшаулау іс-шараларын жүргізу ұсынылады. Селективті су оқшаулау және ағысты тоқтататын технологиялар әдістері, ең алдымен, қосымша өндірілген мұнай алу және мұнай алу коэффициентін арттыру мақсатында ағымдағы қорлардың тығыздығы жоғары ұңғымаларда, сондай-ақ сұйықтық бойынша дебиті жоғары ұңғымаларда жүзеге асырылуы тиіс.

Түйін сөздер: мұнай, айдау ұңғымалары, Профильді теңестіру, депрессия, бағана сыртындағы кеңістіктің герметикалығы, әлсіз цементтелген және борпылдақ коллекторлар, сулану қарқыны, жөндеу-оқшаулау жұмыстарының тиімділігі.

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ПРИЧИНЫ И АНАЛИЗ ОБВОДНЁННОСТИ ПРОДУКЦИИ НЕКОТОРЫХ МОРСКИХ МЕСТОРОЖДЕНИЙ АЗЕРБАЙДЖАНА

Аннотация. Представлены результаты исследований обводнённости некоторых морских месторождений (Нефт Дашлары, Гюнешли, Пираллахи, Банка Дарвина, Банка Апшерон, Западный Апшерон и т.д.) Азербайджанской Республики, большинство из которых находятся на поздней стадии разработки. Эти месторождения, представленные неоднородными по строению слабосцементированными и рыхлыми коллекторами, в которых наблюдается неравномерность потоков жидкости. Происходит прорыв воды по высокопроницаемым пропласткам, а пропластки с малой проницаемостью вовлекаются в разработку в меньшей степени. Последующие попытки вовлечения их в процесс разработки вызывают нерациональное увеличение объёмов закачиваемой воды, что и приводит к обводнению продукции. Росту темпов обводнения способствует и тип коллектора, характеризующийся наличием зон трещиноватости, способствующих перетоку вод из водоносных горизонтов к добывающим скважинам, а также улучшению их гидродинамической связи с нагнетающими скважинами. Установлены геологические и технологические причины обводнённости. Доказана неоднородность вышеупомянутых залежей. Указано, что дополнительной причиной раннего обводнения продукции добывающих скважин является нарушение герметичности заколонного пространства. Поддержание высоких темпов добычи нефти достигается вводом в эксплуатацию новых добывающих скважин, при этом большинство обводнившихся скважин выбывает из эксплуатации, не исчерпав свой потенциал. Предлагается проведение изоляционных мероприятий, которые обеспечат изоляцию наиболее промытых зон и выработанных участков основного продуктивного пласта месторождения. Методы селективной водоизоляции и потокоотклоняющих технологий должны осуществляться, в первую очередь, на скважинах с повышенной плотностью текущих запасов, с целью получения дополнительно добытой нефти и увеличения коэффициента извлечения нефти, а также на скважинах с высоким дебитом по жидкости.

Ключевые слова: нефть, нагнетательные скважины, выравнивание профиля, депрессии, герметичность заколонного пространства, слабосцементированные и рыхлые коллектора, темп обводнения, эффективность ремонтно-изоляционных работ.

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NEWS
OF THE NATONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5227
Volume 3, Number 447 (2021), 118-123 **https://doi.org/10.32014/2021.2518-170X.72**

ISSN 2224-5278
UDC 621.45

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MODIFICATION OF COATINGS BASED ON Al2O3 WITH CONCENTRATED ENERGY FLOWS

Abstract. This paper presents the study results of structural-phase composition and mechano-tribological properties of Al_2O_3 coatings after exposure of concentrated energy flows. Revealed that the treated coatings are generally characterized by high microhardness compared to the initial coating. Determined that after treatment with detonation and air-plasma action is observed an increase in the intensity of α-Al_2O_3 reflexes. Established that the increasing hardness of detonation coatings is associated with an increasing density of the material and the recovery of the α-phase Al_2O_3 in the composition of the protective layer under the influence of thermal activation of the surface. Determined that after treatment with detonation and plasma exposure is observed an increase in the intensity of reflexes α-Al_2O_3. Established that the treatment with detonation and air-plasma action leads to a decrease in the friction coefficient. The obtained data indicate that the tribological characteristics of coating based on aluminium oxide can be improved by exposure to concentrated energy flows. Established that coatings treated with plasma action showed high tribological properties.

Key words: Detonation spraying, plasma spraying, hardness, wear resistance, coating.

1. Introduction. Obtaining coatings with high-performance characteristics that provide increased products reliability and durability in extreme conditions characterized by improved mechanical loads, wear, corrosion, aggressive media, and cyclic exposure is a fundamental task of the industry.

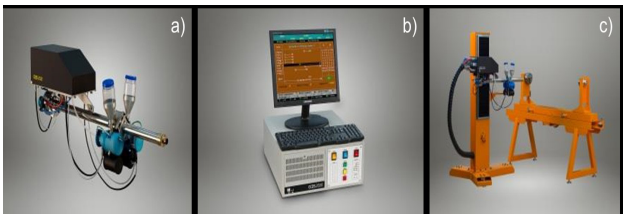
To increase the adhesive strength, reduce porosity, eliminate non - molten powder particles in the coating structure and provide an even distribution of micro-hardness on the depth of the hardened layer is used re-melting of the coating with concentrated energy sources [1-3].

The technological capabilities analysis of processing main methods with concentrated energy sources (electric arc, electron beam, laser, plasma and induction) [4], which can be used for repeated high-energy effects on the structure of plasma coatings, showed that when re-processing current conductive plasma coatings have a clear advantage high-energy heating with high-frequency currents [5-7]. A characteristic feature of this process is that the heating source is volumetric, and energy is released in the surface layer, the thickness of which is determined by the current frequency, electrical resistivity and thermal physical characteristics of the coating material. Selecting the relevant frequency of the generator allows concurrent heating throughout the entire thickness of the applied coating.

In this connection, we conducted experiments on the treatment of aluminium oxide coating with concentrated energy flows

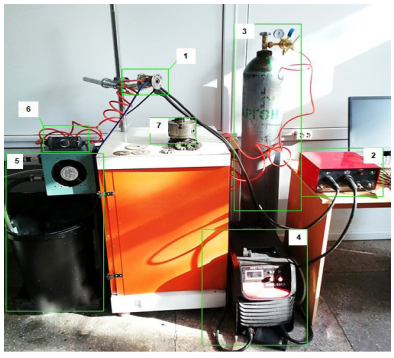
2. Research Method. 12H18N10T stainless steel was chosen as a substrate. The samples were sandblasted before coating. Corundum powders (α-Al2O3) were used to obtain coatings from aluminum oxide. The particle size of the powder is up to 22-45 μm.

Detonation coatings were obtained on a computerized complex of new generation detonation spraying CCDS2000 (Computer Controlled Detonation Spraying) [8-10]. CCDS2000 allows applying coatings from a wide range of materials to various substrates. The main elements of the complex are shown in figures 1.



a) working body (gun), consisting of a barrel, a gas distribution block and powder dispensers; b) block control based on an industrial computer; c) gun complete with three coordinates manipulator
Figure 1 – Detonation complex CCDS2000

Surface modification of coatings was carried out using detonation and plasma action. The detonation effect was carried out on the CCDS2000 detonation complex by detonating a gas explosion without using powder. The expense of working gases is at an average frequency of shots in 4 Hz no more: acetylene 4-7; propane butane mixture 2...3,5; oxygen 10...12; nitrogen 10...15 m3/h. Nitrogen was used as a carrier gas. Plasma action was carried out on the set up (Figure 2) of plasma spraying at atmospheric pressure [11]. The figure shows a general view of the plasma installation. Experiments on plasma treatment were carried out without using powder in the following mode: the movement speed is 2-30 mm / s, the distance between the plasmatron and the product is 45-55 mm, the diameter of the spray spot is 10-25 mm. The heating temperature of the parts during spraying does not exceed 150-200°C. The working pressure of the gas (air) is 0.2-0.3 MPa.



1 - plasmatron, 2 - process control unit, 3 - gas supply cylinder, 4 - power supply system, 5 - cooling system, 6 - bifurcated powder supply channel with expansion barrel, 7 - sample holder. 8 - compressor.
Figure 2 – Installation for plasma coating

Table 1 shows the modes of obtaining coating Al2O3 and its modification by detonation and plasma action.

Table 1-Technological parameters for obtaining and modifying Al_2O_3 coatings

Processing type	Barrel filling volume, %	Distance, mm	Shots number	Delay time between shots, s	Working gas	Arc current, A	
Detonation spraying of Al_2O_3 coatings	63	250	20	1	-	-	-
Treatment of Al_2O_3 coatings by the detonation action	80	250	20	0,25	-	-	-
Treatment of Al_2O_3 coatings by plasma action	-	200	-	-	Ar	135	40

The microhardness of the samples was measured by methods indentation of a diamond indenter on a PMT-3M (LOMO, Russia) device in accordance with GOST 9450-76 [12], at a load of 200 g and an exposure time of 10 s. The study of the surface microstructure was carried out on a scanning electron microscope Vega3 (Tescan, Brno, Czech Republic). The research phase composition of the samples was studied by X-ray diffractometer X'PertPro (Philips Corporation, Nederland) using CuKα radiation. The shooting was carried out in the following modes: tube voltage U = 45 kV; tube current I = 35 mA; exposure time 1s; shooting step $\Delta 2\theta \sim 0.02°$ and $2\theta = 10–90°$. Tribological tests for sliding friction were performed on a high-temperature tribometer TRB3 (Anton Paar Srl, Peseux, Switzerland) using the standard "ball-disc" technique (international standards ASTM G 133-95 and ASTM G 99). Sample tests for abrasive wear were carried out on an experimental stand (Figure 2 a) for testing for abrasive wear when frictional against not hard fixed abrasive particles according to the scheme "rotating roller-flat surface" by GOST 23.208-79, which coincides with the American standard ASTM C 6568. The wear resistance of the test material was estimated by the weight loss of the samples during the test. The measurement of hardness and elastic modulus was determined by the indentation method on the NanoScan - 4D compact (FSBI TISNCM, Russia) nanotoughness tester in accordance with GOST R 8.748-2011 and ISO 14577 indentation with a load of 0.1 N.

3. Research results and discussion. Figure 3 shows a comparative graph of the microhardness distribution over the depth of samples with Al_2O_3 coated which treated by detonation and plasma action. The treated coatings are generally characterized by high microhardness compared to the original coating. High hardness is observed on the surface of the coating, and as it approaches the surface of the substrate, the hardness decreases.

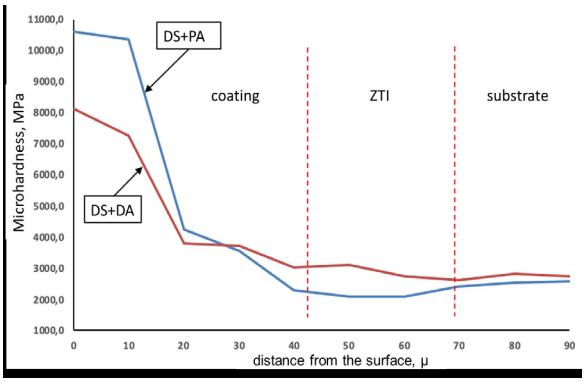


Figure 3 – Graph of the hardness distribution over the depth of Al_2O_3 coatings

Morphology analysis of the cross-section of coatings showed that detonation coatings based on Al_2O_3 after treatment with detonation action (Figure 4) only slightly smoothes the roughness of the powder layer. After treatment with plasma action (Figure 5), it leads to a noticeable decrease in roughness, which makes it possible to deposit Al_2O_3 coatings that are uniform in thickness and form a coating with a size of inhomogeneities of 1.0 microns. Plasma heating of Al_2O_3 coatings causes intensive melting, partial sputtering and degassing of the treated sections of the protective layer. Distribution maps of elements along the line obtained by the SEM method with energy dispersion analysis clearly confirm the mutual penetration of the coating and substrate elements (Figure 6 and Figure 7). Since the depth of this penetration is significant, in this case, it can be argued that we are observing the development of radiation-stimulated diffusion.

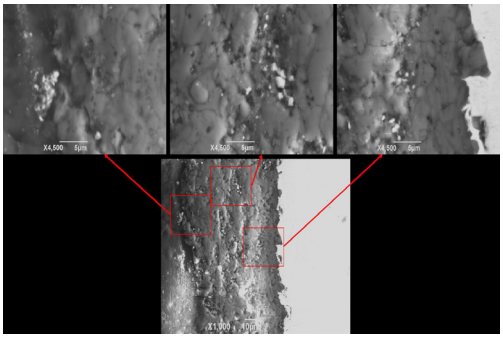


Figure 4 – Detonation coatings based on Al_2O_3 after treatment with detonation action

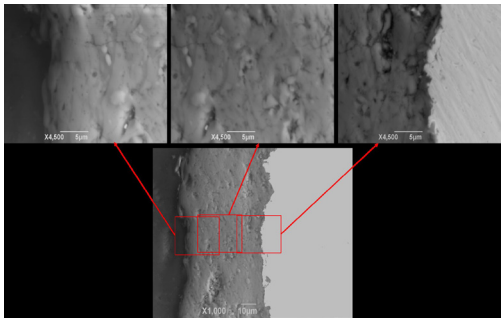


Figure 5 – Detonation coating based on Al_2O_3 after plasma treatment

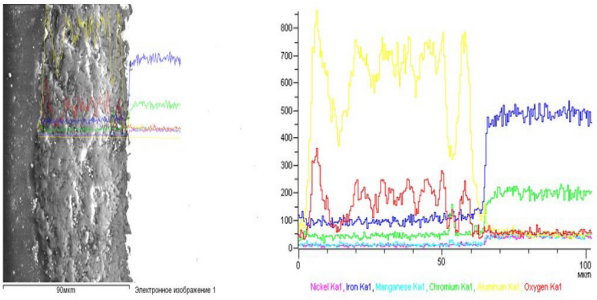


Figure 6 – Distribution of elements along the Al_2O_3-based coating line after treatment by the detonation action

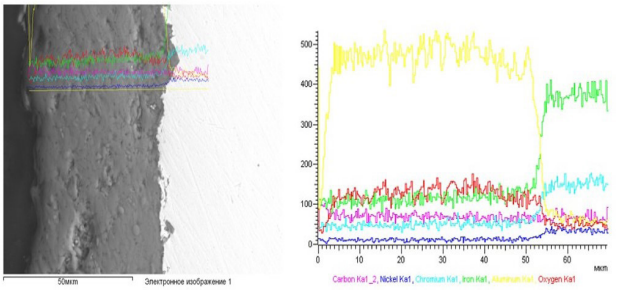


Figure 7 – Distribution of elements along the Al_2O_3-based coating line after treatment by plasma action

Figure 8 shows the results of tribological tests of aluminium oxide coatings obtained by the combined method. The figure shows that after detonation and plasma action, the wear intensity decreases, as well as the mass loss after the abrasive wear test. This indicates an increase in the wear resistance of coatings. At the same time, coatings treated with plasma action showed high indicators of tribological properties.

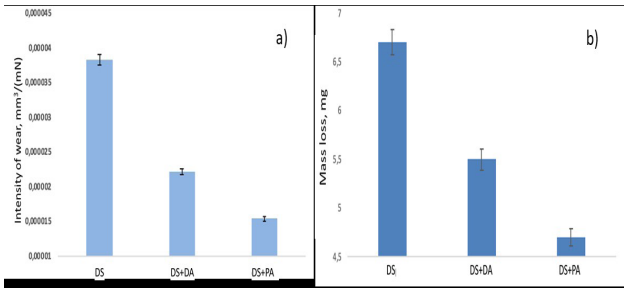


Figure 8 – Results of tribological tests by methods of testing according to the scheme ball-disk (a) and abrasive wear test (b)

Figure 9a shows the diffractograms of the aluminium oxide coating obtained by the combined method. Visible that after treatment with detonation and plasma action is observed an increase in the intensity of α-Al_2O_3 reflexes. The increased hardness of coatings is associated with increased density of the material and the recovery of α-phase Al_2O_3 in the composition of the protective layer under the influence of thermal activation of the surface.

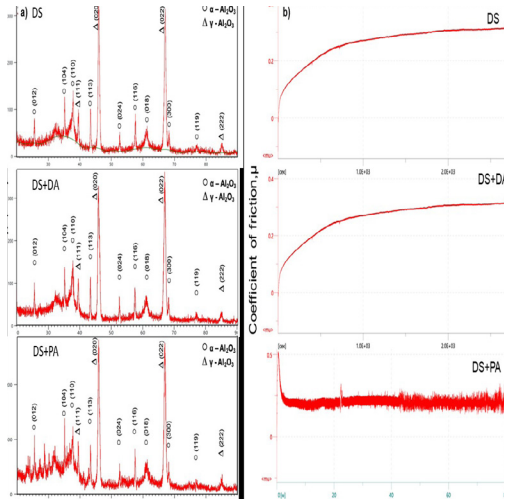


Figure 9 – Diffractogram and curves of the friction coefficient of Al_2O_3 coatings obtained under different deposition modes.

Figure 9b shows the friction coefficient curves. Visible from the figure that the treatment with detonation and air-plasma action leads to a decrease in the friction coefficient. Reducing the friction coefficient will have a positive effect on the wear resistance of aluminium oxide coatings.

4. Conclusion

The effect of modification by concentrated energy flows of Al_2O_3 coatings was studied obtained by the detonation method. The study showed that after treatment with plasma exposure roughness of Al_2O_3 coatings decreased, and after treatment with detonation exposure, the roughness practically does not change. After detonation and plasma exposure is observed an increase in the volume fraction of α-Al2O3, and this is especially noticeable when treated with plasma exposure. The results of experimental studies have shown that the surface treatment of coatings with detonation and plasma exposure leads to an increase in micro-hardness and wear resistance. It is determined that after plasma exposure, the wear intensity 2 times decreases, and the friction coefficient decreases by 30%. An increase in the tribological properties of Al_2O_3 coatings is associated with an increase in the volume fraction of α - Al_2O_3.

ACKNOWLEDGMENTS

The article uses the results obtained with the support of grant funding of the Ministry of Education and Science of the Republic of Kazakhstan, grant AP09058615

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Al2O3 НЕГІЗІНДЕГІ ЖАБЫНДАРДЫ КОНЦЕНТРАЦИЯЛАНҒАН ЭНЕРГИЯ АҒЫНДАРЫМЕН МОДИФИКАЦИЯЛАУ

Аннотация. Бұл жұмыста концентрацияланған энергия ағындарының әсерінен кейін Al_2O_3 жабындарының құрылымдық-фазалық құрамын және механикалық-трибологиялық қасиеттерін зерттеу нәтижелері келтірілген. Өңделген жабындар, бастапқы жабынмен салыстырғанда жоғары микро қаттылықпен сипатталады. Градиент жабындарының қаттылығының жоғарылауы материалдың тығыздығының жоғарылауымен және бетінің термиялық активтенуінің әсерінен қорғаныс қабатының құрамындағы Al_2O_3 α-фазасының төмендеуімен байланысты екендігі анықталды. Al_2O_3 жабындыларын плазмалық қыздыру қорғаныш қабатының өңделген телімдерінің қарқынды еруін, жартылай тозаңдануын және газсыздандыруын тудыратыны анықталды. Детонациялық және ауа-плазмалық әсермен өңдеу үйкеліс коэффициентінің төмендеуіне әкелетіні анықталды. Алынған мәліметтер концентрацияланған энергия ағындарының әсерінен алюминий оксиді негіздегі жабынның трибологиялық сипаттамаларын арттыруға болатындығын көрсетеді. Трибологиялық қасиеттердің жоғары көрсеткіштері ауа-плазмалық әсермен өңделген жабындарды көрсетті. Трибологиялық сипаттамалардың жоғарылау себептері негізінен α-Al_2O_3 көлемдік үлесінің артуымен байланысты екендігі анықталды.

Түйін сөздер: детонациялық тозаңдату, плазмалық тозаңдату, қаттылық, тозуға төзімділік, жабын.

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МОДИФИЦИРОВАНИЕ ПОКРЫТИЙ НА ОСНОВЕ Al2O3 КОНЦЕНТРИРОВАННЫМИ ПОТОКАМИ ЭНЕРГИИ

Аннотация. В данной работе представлены результаты исследования структурно-фазового состава и механико-трибологических свойств покрытий Al_2O_3 после воздействия концентрированными потоками энергии. Обработанные покрытия в целом характеризуются высокой микротвердостью по сравнению исходным покрытием. Установлено, что повышение твердости градиентных покрытий связано с увеличением плотности материала и восстановлением α-фазы Al_2O_3 в составе защитного слоя под влиянием термической активации поверхности. Установлено, что плазменное нагревание покрытий Al_2O_3 вызывает интенсивное плавление, частичное распыление и дегазацию обработанных участков защитного слоя. Определено, что после детонационного и воздушно-плазменного воздействия уменьшается интенсивность изнашивания, а также потеря массы после испытания на абразивное изнашивание. Установлено, что обработка детонационным и воздушно-плазменным воздействием приводит к уменьшению коэффициента трения. Полученные данные свидетельствуют о том, что путем воздействия концентрированными потоками энергии можно повысить трибологические характеристики покрытия на основе оксида алюминия. Определено, что высокие показатели трибологических свойств показали покрытия, обработанные воздушно-плазменным воздействием. Установлено, что причины повышения трибологических характеристик в основном связано с увеличением объемной доли α-Al_2O_3.

Ключевые слова: детонационное напыление, плазменное напыление, твердость, износостойкость, покрытие.

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NEWS
OF THE NATONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5227
Volume 3, Number 447 (2021), 124-128 **https://doi.org/10.32014/2021.2518-170X.73**

UDC 62-83:669.02/09
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STABILITY OF ANONLINEAR SYSTEM «FREQUENCY CONVERTER-ASYNCHRONOUS MOTOR»

Abstract. In modern industry, various industries are widely used frequency converters (FC) to control the speed of rotation of asynchronous motors. Widely used frequency converters that feed asynchronous motors allow you to optimize production, reduce electrical energy consumption, increase the service life of equipment, etc.

The article considers the system "frequency converter-asynchronous motor" as a complex nonlinear automatic control system. On the basis of the linearized transfer function of the frequency converter and the asynchronous motor, the block diagram of the open system "frequency converter - asynchronous motor"is made. The mathematical description of the system is written by algebraic controls in symbolic form.

A program for generating the transfer function and calculating the roots of the characteristic equation using the MATLAB application package is presented.

To determine the stability of the frequency converter - asynchronous motor system, a program is compiled where the stability of the system is determined by the characteristic roots of the equation. The transient curve of the speed and torque of an asynchronous motor confirms the adequacy of the block diagram "frequency converter-asynchronous motor" and its mathematical description.

Key words: frequency converter, asynchronous motor, nonlinear system, electric drive, autonomous voltage inverter.

Introduction. It is known that frequency converters are electronic devices that are used to convert the frequency parameters of an electric current [1-4]. Frequency converters have acquired the greatest practical application for controlling the speed of rotation of synchronous and asynchronous (SD and AD) electric motors [5, 6]. The use of frequency converters for controlling electric motors makes it possible to optimize production, reduce electrical energy consumption and increase the service life, etc., of the connected equipment to the "frequency converter – asynchronous motor" (Frequency converter - AD) system [6-8].

Currently, the field of use of the "Frequency converter - AD" system is very wide, starting in equipment from the food industry, ending with the mining and metallurgical, oil industry [1, 6].

The main part. Frequency converters used in an adjustable electric drive, depending on the structure and principle of operation of the power part, are divided into [2, 7, 9]:

- with an explicit DC intermediate (or simply an IF with a DC intermediate);
- with direct connection (without DC intermediate).

To date, frequency converters with a DC intermediate link in the market of the Republic of Kazakhstan account for almost 93% of the total frequency converters. Therefore, the article considers only this type of IF, while the rectifiers, as part of the converters, are unmanaged, i.e. on power diodes.

Figure 1 shows a typical scheme of a low-voltage frequency converter with an autonomous voltage inverter (AVI), as it has received the greatest distribution, supplied by different manufacturers [6, 7, 9].

In this scheme, a three-phase AC voltage is fed to the input of three phase uncontrolled rectifier output which is fed to the input of the filter (F), after entering AVI, where the voltage U_d is converted to three-phase voltage variable voltage U=var and with a variable frequency f=var. Autonomous voltage inverters of low-voltage converters are made on the basis of power bipolar transistors with an isolated IGBT gate. The control system provide spulse-width modulation (PWM) of the voltage applied to the motor windings.

The use of Frequency converters in equipment provides a smooth start, smooth control of the speed of rotation of the AD both down and up from the main speed, smooth braking, increases the service life of both the engine and the equipment, increases efficiency and cos φ, etc.[1, 6, 7, 10].

The mathematical description of an asynchronous motor (AD) as a link in an automatic control system presents considerable difficulties, since the stator and rotor windings are magnetically connected by design. When the motor rotates, the relative position of the windings continuously changes, and the mutual inductance between them changes accordingly. This leads to a non-linear equation of the electric motors. In this regard, for the synthesis of ACS, it is convenient to represent dynamic models of AD in the form of transfer functions or structural schemes [11-14].

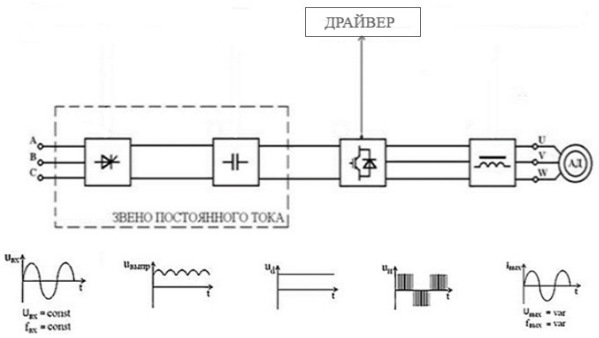

Figure 1-Typical diagram of a low-voltage frequency converter with a self-contained voltage inverter (AVI)

Figure 1-Typical diagram of a low-voltage frequency converter with a self-contained voltage inverter (AVI) In the process of designing an electric drive system, a frequency converter – asynchronous motor (FC – AD) with the desired motor speed transients, determining the stability of the system is one of the necessary design tasks. The block diagram of the FC-AD system with voltage feedback of the frequency converter is shown in Figure 1 in Simulink Matlab [15, 16].

Figure 2 block diagram of the linearized system of the electric FC-AD presents the dynamic parts of the system with transfer functions in the form [1]: for engine $W_1(s) = 1/T_m$ – и $W_2(s) = b(T_a s + 1)$, and reverse are covered by a single connection to the frequency Converter $W_3(s) = K_P(T_P s + 1)$. – As a voltage regulator if the open on the speed of the motor system FC-AD entered nonlinear correction device (similar even with variable structure). providing a significant increase in the stability range of the system [12]. The following designations are introduced in the block diagram of Figure 2 [7, 14, 17]:

b – modulus of rigidity of the mechanical characteristic of AD;

T_m – electromechanical time constant AD;

T_q – electromagnetic time constant of the stator and rotor circuits AD;

k_P – transmission ratio of the frequency converter;

T_P – the time constant of the frequency Converter;

$T1_1$, T_2 – the time constant of the filter;

k_{Oc-} the ratio of the feedback voltage inverter.

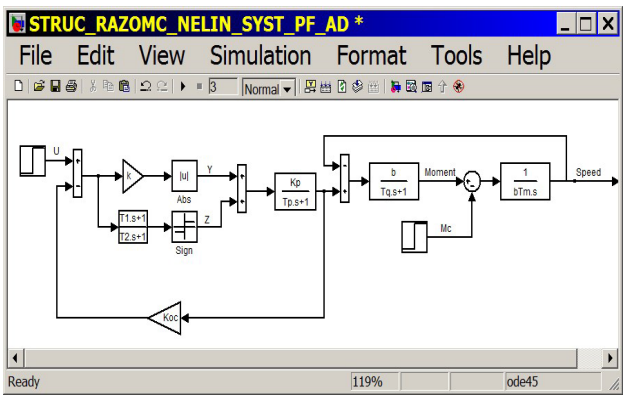

Figure 2-Block diagram of an open FC-AD system

The stability of an open nonlinear FC-AD system is considered on the basis of the transfer function of the system using Matlab functions [15, 16]. To do this, using the transfer functions of the links of the system, we transform them into algebraic equations in symbolic form, taking into account the connections of the dynamic and nonlinear links of the system.

According to the transfer function $W_1(s) = 1/bTm\,s$ of the engine link, the algebraic equation of the link in symbolic form takes the following form [18]:

$$x_1 - W_1 x_2 = 0 \qquad (1)$$

where $x_1 = \omega$ – angular velocity of AD; $x_2 = M_{\acute{Y}}$ – the electromagnetic moment of AD.

An algebraic equation in the symbolic form of the second engine link, with a subordinate function $W_2(s) = b(T_q s + 1)$, it will be recorded:

$$x_1 + (1/W_2)x_2 - x_3 = 0 \qquad (2)$$

where $x_3 = U_R$ – output voltage of the frequency converter.

An algebraic equation in the symbolic form of a frequency converter, with a transfer function

$W_3(s) = k_R\ (T_R\ s+1)$, it has the form:

$$(1/W_3)x_3 - (Y+Z) = 0, \qquad (3)$$

where $Y = |k_o|$; $Z = sign(W_4 \cdot x_0)$, $W_4(s) = (T_1 s+1)(T_2 s+1)$, $x_o = u - k_o x_3$, x_0 – error of the voltage stabilization system at the frequency converter output, $W_4(s)$ – transfer function of the inertial-forcing link, u – setting effect.

Taking into account the replacement of the nonlinear equation $Y = |k_o|$, from the point of view of the convenience of solving the stability problem with the help of Matlab, on a nonlinear equation $F(x) = k*(x_o^2/x_o)$, the equation $Y = |k_o|$ it will be written in the following form:

$$Y = (k\cdot(u - k_o x_3)^2(k\cdot(u - k_o x_3) \qquad (4)$$

The equation $Z = sign(W_4 \cdot x_0)$ it should be written as [19]:

Determination of the stability of the open – speed FC-AD system is carried out on the basis of the program for calculating the transfer function of the system and Matlab functions. The program for determining the stability of the system is shown in Figure 3.

The program for determining the stability of the FC – AD system is compiled in the algorithmic language Matlab. Thecalculationprocedureisasfollo ws:

1.In the program using the command enter (line 1) character variables with the name of the transfer functions of the system.

2. Using the function symbolic objects are formed with the name: $f1, f2, fh, fq$ è $f3$ - names of equations in symbolic form.

3. Function Matlabcalculates the transfer functions of the system in symbolic form for each variable.

4. The initial parameters of the FC-AD system and the FC voltage stabilization system are entered from the 8th to the 9th line.

5. From the 10th to the 13th lines, the transfer functions of the system are introduced, which are used after calculating the transfer functions for each variable.

6. Function *eval* (line 14) converts a given string transfer function to a transfer function with a numerator and denominator.

7. From the 18th to the 24th lines form the graphs of the transients of the asynchronous motor.

```
1  syms w1 w2 w3 w4
2  f1=sym('(1/w1)*x1-x2');
3  f2=sym('x1+(1/w2)*x2-x3');
4  fh=sym('(1/w3)*x3-sign(w4*(u-k0*x3))');
5  fq=sym('-k2*((u-k0*x3)^2)/(u-k0*x3)');
6  f3=sym(fh+fq);
7  [x1,x2,x3]=solve(f1,f2,f3);
8   b=25; Tm=0.2; k1=1/(b*Tm);; Tq=0.05; k2=0.5;
9  Kp=20; Tp=0.001; T1=0.02; T2=0.08; k0=0.1; u=5;
10 n1=[k1]; m1=[1 0]; w1=tf(n1,m1);
11 n2=[b]; m2=[Tq 1]; w2=tf(n2,m2);
12 n3=[Kp]; m3=[Tp 1]; w3=tf(n3,m3);
13 n4=[T1 1]; m4=[T2 1]; w4=tf(n4,m4);
14 R1=eval(x1); R2=eval(x2);
15 q1=minreal(R1)
16 q2=minreal(R2);
17 p0=pole(q1)
18 t=[0:0.01:3];
19 [y1,t]=step(q1,t);
20 [y2,t]=step(q2,t);
21 subplot(211),plot(t,y1),title('Speed  W(t)')
22 xlabel('Time (c)'), ylabel('y)'), grid
23 subplot(212),plot(t,y2),title('Moment M(t)')
24 xlabel('Time (c)'), ylabel('y)'), grid
```

Figure 3. Program for determining the stability of the FC – AD system

The calculated transfer function of the FC – AD system has the form [7, 20]:

```
Transfer function:
              7e006
---------------------------------
s^3 + 2020 s^2 + 4.01e004 s + 2e005
```

The roots of the characteristic equation of the transfer function of the system, calculated by the program with the function (line 21) MATLAB have the following form:

```
p0 =

   1.0e+003 *

  -2.0000
  -0.0100
  -0.0100
```

The roots of the characteristic equation have negative real parts, according to [6] the system is stable, which is also confirmed by the transients of the speed and torque of the asynchronous motor, shown in Figure 3.

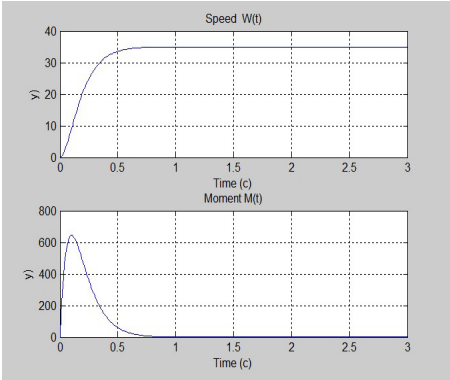

Figure 4-Graphs of the transients of the speed and torque of the asynchronous motor

Conclusions.

1. The formation of the transfer function of an open nonlinear system frequency converter-asynchronous motor is possible only on the basis of the algebraic equations of the system in symbolic form.

2. The calculation of the roots of the characteristic equation for determining the stability of the system should be carried out using the **MATLAB** function *pole.*

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«ЖИІЛІК ТҮРЛЕНДІРГІШ – АСИНХРОНДЫ ҚОЗҒАЛТҚЫШ» БЕЙСЫЗЫҚТЫ ЖҮЙЕСІНІҢ ОРНЫҚТЫЛЫҒЫ

Аннотация. Әр түрлі салалардағы қазіргі заманғы өнеркәсіпте асинхронды қозғалтқыштардың айналу жылдамдығын реттеу үшін жиілік түрлендіргіштері (ЖТ) кеңінен қолданылады. Асинхронды қозғалтқыштардың кең таралған жиілік түрлендіргіштері өндірісті оңтайландыруға, электр энергиясын тұтынуды азайтуға, жабдықтың қызмет ету мерзімін арттыруға және т. б. мүмкіндік береді.

Бұл мақалада «жиілік түрлендіргіш – асинхронды қозғалтқыш» жүйесі күрделі сызықты емес автоматты басқару жүйесі ретінде қарастырылады. Жиілік түрлендіргіш пен асинхронды қозғалтқыштың сызықты берілу функциясы негізінде «ЖТ - АҚ» ашық жүйесінің құрылымдық диаграммасы жасалды. Жүйенің математикалық сипаттамасы алгебралық басқару арқылы символдық түрде жазылған.

MATLAB қолданбалы пакетін қолдана отырып, берілу функциясын қалыптастыру және сипаттамалық теңдеудің түбірлерін есептеу бағдарламасы келтірілген.

«Жиілік түрлендіргіш-асинхронды қозғалтқыш» жүйесінің орнықтылығын анықтау үшін теңдеудің сипаттамалық түбірлері арқылы жүйенің орнықтылығын анықтайтын бағдарлама жасалды. Асинхронды қозғалтқыштың жылдамдығы мен моментінің өтпелі қисығы «жиілік түрлендіргіш - асинхронды қозғалтқыш» құрылымдық схемасының сәйкестігін және оның математикалық сипаттамасын растайды.

Түйін сөздер: жиілік түрлендіргіші, асинхронды қозғалтқыш, бейсызықты жүйе, электр жетегі, автономды кернеу инверторы.

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УСТОЙЧИВОСТЬ НЕЛИНЕЙНОЙ СИСТЕМЫ «ПРЕОБРАЗОВАТЕЛЬ ЧАСТОТЫ – АСИНХРОННЫЙ ДВИГАТЕЛЬ»

Аннотация. В современной промышленности разных отраслей широко применяются преобразователи частоты (ПЧ) для регулирования скорости вращения асинхронных двигателей. Широко распространенные преобразователи частоты, питающие асинхронные двигатели, позволяют оптимизировать производство, снизить потребление электрической энергии, увеличить срок службы оборудования и т.д.

В статье рассмотрена система «преобразователь частоты – асинхронный двигатель» как сложная нелинейная система автоматического управления. На базе линеаризованной передаточной функции преобразователя частоты и асинхронного двигателя составлена структурная схема разомкнутой системы «ПЧ - АД». Математическое описание системы написано алгебраическими управлениями в символьном виде.

Приведена программма образования передаточной функции и расчета корней характеристического уравнения с помощью прикладного пакета MATLAB.

Для определения устойчивости системы ПЧ – АД составлена программа, где характеристическими корнями уравнения определяется устойчивость системы. Кривая переходного процесса скорости и момента асинхронного двигателя подтверждает адекватность структурной схемы «ПЧ - АД» и ее математическое описание.

Ключевые слова: преобразователь частоты, асинхронный двигатель, нелинейная система, электропривод, автономный инвертор напряжения.

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NEWS
OF THE NATONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5227
Volume 3, Number 447 (2021), 129-136 **https://doi.org/10.32014/2021.2518-170X.74**

UDC 621.928

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INTEGRATED STUDY OF THE EFFICIENCY OF GRINDING MATERIAL IN AN IMPACT-CENTRIFUGAL MILL

Abstract. The analysis of existing methods of air classification of crushed bulk materials is carried out, priority directions of their development and improvement are identified, the hardware design of these methods and the main approaches to the calculation of air classifiers are studied. The conclusion is made about a rather isolated motion of particles in the working volume of the classifier at optimal performance. The prospects of dry separation methods and the progressiveness of creating multistage gravitational classifiers have been established. Theoretical studies of the separation process in a gravity classifier with overflow shelves have been carried out. The regularities of the process of separation of bulk materials in air classifiers have been established, reliable methods have been developed for calculating their technological and design parameters in order to create highly efficient and productive industrial plants. Theoretical dependencies and differential equations are obtained, which characterize the influence on the separation mechanism of technological and design parameters of the classifier. The results of solving the equations of motion made it possible to determine the main design parameters of the apparatus based on the technological requirements for productivity and the dispersed composition of the final products. On the basis of theoretical research, analytical relationships and differential equations have been developed that describe the separation process in a gravity classifier with overflow shelves. The use of these equations made it possible to simulate the air flow in the classifier, to obtain a field of air flow velocities for any design and technological parameters. This, in turn, shows the direction of movement of particles of different sizes or densities and makes it possible to estimate the boundary size of separation, and also allows you to study the interaction of the air flow with the material being separated in a wide range of technological and design parameters of the classifier, and, ultimately, to determine the boundary size separation and particle size range of the resulting fractions of the finished product. The relationship between technological and design parameters of the apparatus is theoretically determined.

Key words: material, crushing, particle, classification, device, fraction, hydrodynamics, gravitation, flowability, flow.

1. Introduction. Modern production places high demands on the quality of powdered materials, at the same time the imperfection of crushing processes does not always allow to obtain a product with desired properties. Therefore, in technological processes for preparation of bulk materials, especially in crushing systems, special devices are often needed – classifiers or separators. The main purpose of the classifier is to divide the material passing through it into two or more fractions with the predominant content in each fraction of particles of the required size or density range.

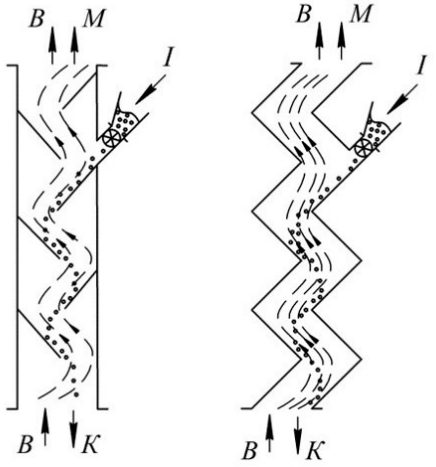
More progressive are dry methods of separation, carried out, most often, in devices with air flows or, if necessary, flows of inert, flue or other gases. The tendency of transition to the dry methods of production in many branches of domestic and foreign industry shows the promise of air classification.

To obtain dry powders of a given granulometric composition with a particle size of about 1 mm or less, the air classification is the main of all known sorting methods. Currently, various designs of air classifiers are exploited in industry, however most of them are characterized by low efficiency and low, about 60 – 70%, degree of extraction of the target product from polydisperse powder. The low degree of extraction of the target product often adversely affects other technological processes. For example, when crushing the material in mills operating in a closed cycle, due to the low efficiency of the classifier, the finished product is sent to grinding again, which leads to decrease in productivity and high energy consumption of the mill unit.

Therefore, the establishment of regularities in the process of separation of bulk materials in the air classifiers, the development of reliable methods for calculating their technological and design parameters in order to create highly efficient and productive

industrial installations is a very urgent task for many industries.

2. Literature data analysis and problem definition. Currently, the most common are air gravitational classifiers with transfer shelves (Fig. 1, a) and Zigzag classifiers (Fig. 1, b) [1, 2].



a – classifier with transfer shelves;

b – Zigzag classifier.

Fig. 1. Schemes of multistage gravitational classifiers

Many researchers were engaged in the creation of multistage gravitational classifiers, the literature presents experimental data and results of industrial operation of many structures of this type, indicating their high efficiency [1-6]. At the same time, the results of theoretical studies do not allow to fully calculate such devices. As a rule, calculation methods are tied to a specific technological process or a product of the same type [4, 5]. This hinders the introduction of cascade and shelf classifiers in other technologies and indicates the relevance of research in this direction.

Deterministic and stochastic models are among the main approaches to modeling and calculating the aerodynamic classification.

The stochastic models are based on the use of probability theory to calculate the dynamics of material flow. The most significant results in this direction were obtained by M.D. Barsky [1] and S.G. Ushakov [6] in the study of gravitational and centrifugal classifiers. By now, the stochastic models were further developed in the works of many scientists [5, 7, 8], and various approaches to modeling the classification of disperse systems were developed. One of the promising approaches is an approach based on the theory of Markov chains, which was used in the works of Yu.I. Makarov [9-11], and is now widely used in modeling many physicochemical processes [7]. The main advantage of the stochastic models is to obtain formulas for constructing a separation curve (Tromp curve), which reflects the probability of a particle of a certain size falling into a large or small product and is the main technological characteristic of the classifier [1].

The deterministic models are based on differential equations of the granular medium motion in a carrying flow. Some researchers consider this direction unpromising due to the many assumptions made in modeling [7]. The most significant of them are that, firstly, the particle moves under the action of not only deterministic, but also numerous random forces (collision, turbulence, etc.), which are difficult to take into account even in a generalized form, and secondly, the constraint of particle motion is not taken into account [7]. However, many believe that these assumptions are not critical in creating engineering methods for calculating real structures, when the model is presented not only with requirements for accuracy and reliability, but also for availability of use for a wide range of specialists of the relevant profile [4, 5, 12-14]. For example, experimental data indicate an effective classification with a mass ratio of solid and gas phase of approximately 1:1 [2]. Taking into account the difference in densities, it can be concluded that particles are quite separate in the working volume of the classifier with optimal performance. In addition, the deterministic models allow, based on the analysis of the results of solving the equations of motion, to determine many design parameters of the devices, based on the technological requirements for performance and dispersion composition of the final products. Therefore, methods of deterministic modeling are common and evolving at present, the same approach was used in the theoretical study of the multistage shelf classifier design.

3. Research objectives and tasks. The objective of the work is to study the process of fractionation of crushed material in the gravitational classifier.

To achieve this objective, it is necessary to solve the following tasks:

- simulate the motion of a continuous carrying medium in the device;
- investigate the interaction of the air flow with particles of the material to be separated;
- based on the obtained data, determine the patterns of motion of these particles and the possibility of their falling into a small or large fraction.

4. Methods of modeling the process of fractionation of crushed material in the gravitational classifier. To model the motion of air in the classifier, the Navier – Stokes equation was used for viscous media, which is written in the vector form as

$$\rho\, dc/dt = M - gradp + \mu \Delta c, \qquad 1)$$

where ρ – density of the medium, kg/m^3; c – velocity vector; M – vector of bulk forces; p – pressure, Pa; μ – dynamic viscosity, Pa · s; Δ – Laplace operator.

The Navier – Stokes equation was supplemented with the flow continuity equation

$$\partial\rho/\partial t+\mathrm{div}(\rho c^{-})=0, \quad 2)$$

and the equation of state

$$\rho=pM/RT, \quad 3)$$

where *M* – molar gas mass, g/mole; *R* – universal gas constant; *T* – absolute temperature, *K*.

Since direct numerical simulation in solving equations (1) - (3) requires substantial time resources in calculating turbulent flows, there was used the standard turbulence model k-ε [15-17]. Here, the Navier – Stokes equation is transformed into a form in which the influence of the average velocity fluctuation (in the form of turbulent kinetic energy) and the process of reducing this fluctuation due to viscosity (dissipation) are added.

In the adopted model, the viscous shear stress tensor is defined as [18–19]

$$\tau_{ij} = \mu\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i} - \frac{2}{3}\frac{\partial u_k}{\partial x_k}\delta_{ij}\right) - \frac{2}{3}\rho k\delta_{ij}, \quad (4)$$

where μ – dynamic viscosity, Pa · s; u – velocity, m/s; x – coordinate, m; – Kronecker delta function; k – turbulent kinetic energy.

The dynamic viscosity μ is calculated as the sum of the coefficients of dynamic viscosity μl and turbulent viscosity μt.

The coefficient of turbulent viscosity is calculated by the dependence [10]

$$\mu_t = f_\mu \frac{C_\mu \rho k^2}{\varepsilon}, \quad (5)$$

where fμ, Cμ – coefficients; ε – turbulence energy dissipation.

Cμ coefficient is recommended to be taken equal to 0.9 [18]. fμ coefficient is found by the formula

$$f_\mu = \left(1 - e^{-0{,}025R_y}\right)^2 \left(1 + \frac{20{,}5}{R_T}\right), \quad (6)$$

where R_y, R_T- variables defined by the expressions

$$R_y = \frac{\rho\sqrt{k}y}{\mu_l}, \quad R_T = \frac{\rho k^2}{\mu_l \varepsilon}, \quad (7)$$

where y – distance from the local averaged flow volume to the wall of the computational domain, m.

The turbulent kinetic energy k and the dissipation of this energy ε are found by solving two equations:

$$\frac{\partial \rho k}{\partial t} + \frac{\partial}{\partial x_k}(\rho u_k k) = \frac{\partial}{\partial x_k}\left(\left(\mu_l + \frac{\mu_l}{\sigma_k}\right)\frac{\partial k}{\partial x_k}\right) + S_k, \quad (8)$$

$$\frac{\partial \rho \varepsilon}{\partial t} + \frac{\partial}{\partial x_k}(\rho u_k \varepsilon) = \frac{\partial}{\partial x_k}\left(\left(\mu_l + \frac{\mu_l}{\sigma_\varepsilon}\right)\frac{\partial \varepsilon}{\partial x_k}\right) + S_\varepsilon, \quad (9)$$

where S_k, S_ε- characteristics of the kinetic energy pulsations and dissipation of this energy, calculated by the expressions:

$$S_k = \tau_{ij}\frac{\partial u_i}{\partial x_j} - \rho\varepsilon - \mu_l\left(\frac{g_i \partial \rho}{\sigma_B \rho \partial x_i}\right), \quad (10)$$

$$S_\varepsilon = C_{\varepsilon 1}\frac{\varepsilon}{k}\left(f_1 \tau_{ij}\frac{\partial u_i}{\partial x_j} + \mu_l C_B\left(\frac{g_i \partial \rho}{\sigma_B \rho \partial x_i}\right)\right) - C_{\varepsilon 2} f_2 \frac{\rho\varepsilon^2}{k}, \quad (11)$$

where $C_{\varepsilon 1}$=1,44, $C_{\varepsilon 2}$=1,92, σ_ε=1,3, σ_k=1 – empiric coefficients; *f1, f2* – variables depending on the coefficients of dynamic and turbulent viscosity, determined by the following formulas:

$$f_1 = 1 + \left(\frac{0{,}05}{f_\mu}\right)^3, \quad f_2 = 1 - e^{-R_T^2}. \quad (12)$$

Using the above equations allows to simulate the air flow in the classifier, to obtain the air flow velocity field with any design and technological parameters.

5. The results of computer experiment based on mathematical models. The equations obtained were solved using computational hydrodynamics in the SWFlowSimulation software [18]. One of the typical air flow patterns is shown in Fig. 2.

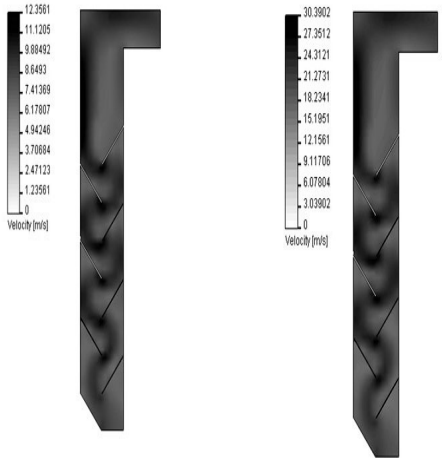
To study the motion of particles of the material along inclined shelf of the classifier, a design scheme was drawn up (Fig. 3).

The following basic forces act on the particle moving along the inclined shelf.

The force of gravity

$$G = mg, \quad (13)$$

where m-mass of the particle, kg; g-free fall acceleration, m/s^2.



a) b)

a) – air velocity per classifier section 2 m/s;

b) – air velocity per classifier section 5 m/s

Fig. 2. Air flow velocity profiles in the shelf classifier

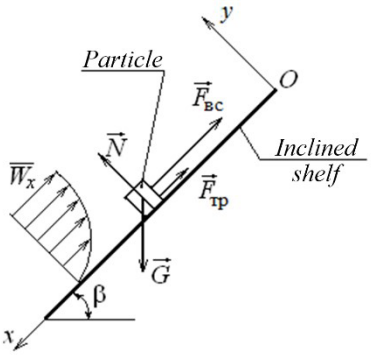


Fig. 3. Scheme of forces acting on the particle locatedon the inclined shelf classifier

The force of friction

$$F_{тр} = fN, \quad (14)$$

where f- coefficient of friction of the particles on the blade surface; N-supporting force, H.

The supporting force N is equal in our case, based on the condition of non-motion with respect to the axis y (Fig. 4), to the expression

$$N = G\cos\beta. \quad (15)$$

The force oı aeroɑynamıc resistance to the motion of the particle from the medium is determined by the dependence

$$F_{вс} = \xi S\frac{v_{rel}^2}{2}\rho_g, \quad (16)$$

where ς – aerodynamic resistance coefficient; S – midsection of the particle, m2; v_rel– relative velocity (ambient velocity of the particle with the flow), m/s; ρ_g– gas (air) density, kg/m3.

The relative velocity v_relcan be found as the difference between the velocities of the particle along the inclined shelf and the air flow (Fig. 4):

$$v_{rel} = \frac{dx}{dt} - W_x, \quad (17)$$

where W_x- air velocity around the particle, m/s.

In the turbulent flow regime, the gas velocities profile in the channels with a sufficiently high accuracy is described by the dependence

$$\frac{W_x}{W_{max}} = \left(\frac{y}{R}\right)^{\frac{1}{7}}, \quad (18)$$

where W_max - maximum velocity on the channel axis, m/s; y – current coordinate (Fig. 2), m; R – conditional radius of the channel, m.

The maximum velocity along the channel axis, i.e. with y=R is determined by the expression

$$W_{av} = 0{,}85W_{max}, \quad (19)$$

where w_av - average gas velocity along the channel section, m/s, is calculated as the ratio of the gas flow to the cross sectional area of the channel.

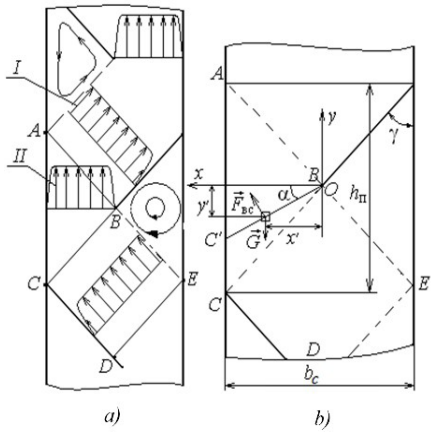
Thus, the equation for the particle motion along the inclined shelf surface relative to the axis x can be written as

$$\frac{d^2x}{dt^2} = g(1 - f\cos\beta) - \xi S\frac{v_{rel}^2}{2m}\rho_g. \quad (20)$$

The equation (20) was solved by the numerical method in the mathematical package Matlab 6.0 [20]. The obtained data on the velocity of the material particles' falling from the inclined shelf, depending on their properties, size, shelf length, were used as initial conditions for subsequent equations of motion.

At the second stage of calculations using the scheme shown in Fig. 4, the material particles' motion in the upward air flow was considered.

The material's particle after its separation from the inclined shelf is affected by two main forces: the force of gravity, constant in magnitude and direction, and the air resistance force.



a – air motion scheme; b – scheme of forces acting on the material particle

Fig. 4. Motion of the material particles and air flow in the classifier's space

In the course of the air motion between the inclined shelves, two characteristic sections can be distinguished: section I, limited with BCDE contour, where the average velocity and direction of the air motion are constant (Fig. 4, a); and section II, limited with ABC contour, where the air flow turns around 90° (Fig. 4, a) and during this turn the average air velocity constantly changes, since the free section area changes.

Note that in the classifier construction under the study, the working columns have a square shape, and the inclined shelves overlap a half of the cross section. Such a design allows to obtain the highest quality separation, as evidenced by the experimental studies [1].

In the fixed coordinate system Oxy, the equations of the particle motion can be written as

$$m\frac{d^2x}{dt^2} = (F_{вс})_x,$$
$$m\frac{d^2y}{dt^2} = (F_{вс})_y - m \cdot g, \quad (21)$$

where (F_"вс")_x,(F_"вс")_y– projections of the air resistance force on the coordinate axis.

The projections of the air resistance force on the coordinate axis are determined from the expressions

$$(F_{вс})_x = \xi S \frac{(v_{rel})_x v_{rel}}{2} \rho_g,$$
$$(F_{вс})_y = \xi S \frac{(v_{rel})_y v_{rel}}{2} \cdot \rho_g. \quad (22)$$

Based on this equation of motion, the material particles in section I (Fig. 3, a) will be written as

$$\frac{d^2x}{dt^2} = \xi S \frac{(v_{rel})_x v_{rel}}{2m} \rho_г,$$
$$\frac{d^2y}{dt^2} = \xi S \frac{(v_{rel})_y v_{rel}}{2m} \cdot \rho_г - g. \quad (23)$$

The projections of the relative velocity with (9) will be equal

$$(v_{rel})_x = \frac{2Q \sin\gamma \cos\ \gamma}{b_c^2} - \frac{dx}{dt},$$
$$(v_{rel})_y = \frac{2Q \sin^2\gamma}{b_c^2} - \frac{dy}{dt}. \quad (24)$$

The full magnitude of the relative velocity

$$v_{rel} = \sqrt{\left(\frac{2Q \sin\gamma \cos\ \gamma}{b_c^2} - \frac{dx}{dt}\right)^2 + \left(\frac{2Q \sin^2\gamma}{b_c^2} - \frac{dy}{dt}\right)^2} \quad (25)$$

If the material particle is carried away by the air flow to section II (ABC contour, Fig. 5, a), then its motion is calculated using the same differential equations (23), which are supplemented by the dependence, taking into account the flow turn

$$\alpha = \text{arctg}\left(\frac{y}{x}\right) \quad (26)$$

The empiric relationship was used to calculate the aerodynamic resistance coefficient ξ over the entire range of Reynolds numbers [10]

$$\xi = 0{,}386 \cdot 1{,}325^{(lg\, Re^2 - 3{,}87)^2}. \quad (27)$$

The solution of the obtained equations by the numerical methods using previously established data on the distribution of the air flow velocities allows to simulate the material particles' motion in the classifier's working area with its various technological and design parameters. This, in turn, shows direction of motion of particles of different size or density and makes it possible to estimate the boundary size of the separation.

6. Discussion of the research results. Based on the performed modeling, it was possible to determine the zigzagging of air motion in the classifier, which allows to make a conclusion about a diverse cross-flow classification. In addition, it was found that, unlike the average flow velocity, its value in the core of the flow is several times higher, and, consequently, a higher intensity of impact on the incoming material.

The initial polydisperse material is fed, as a rule, into the middle part of the classifier to the supply shelf. In this case, the material particles move along the inclined shelf, then fall into the upward air flow and, depending on various factors, either fall onto the underlying shelf or are carried up with the air. Thus, the material particles' motion was studied in two stages: at the first, the material particles' motion along the inclined shelf was studied, and at the second, the particles' motion in the air flow before contact with the next shelf (according to the scheme in Fig. 1, a). The results of the first stage of research were the initial conditions for the next stage and so on up to the border of the classifier's working area.

The results of the study of the air flow interaction with the material particles to be divided and determination of the regularity of motion of these particles possibly falling into the fine or coarse fraction, carried out by the calculation hydrodynamics methods, based on the results obtained on the distribution of the air flow velocities, allowed to simulate the particles' motion in the classifier taking into account various technological and design parameters. The data obtained allow to determine the direction of motion of particles of both different size and density, which, in turn, makes it possible to estimate the boundary size of the separation.

It should be noted that the research results will also be valid for Zigzag type classifiers, since the mechanism of motion of the upward air flow and its interaction with the material particles is similar to that observed in classifiers with the transfer shelves.

6. Conclusions. 1. The study of the process of fractionation of the crushed material in the gravitational classifier using the simulation method allows to describe the air flow in the classifier using equations, to obtain the air flow velocity field for any design and technological parameters.

2. In the course of the research, the equations of the material particles' motion in the air classifier with the transfer shelves were developed, which solution using computer numerical methods allows to investigate the interaction of the air flow with the material to be divided in a wide range of technological and design parameters of the classifier, and, ultimately, to determine the boundary size of the separation and the particle size range of the finished product's resulting fractions.

3. The modeling showed that in the classifier the air moves in a zigzag manner, therefore, there is a multiple cross flow classification. The velocity in the core of the flow can be many times higher than the average flow velocity, which allows to intensively affect the source material.

4. Solving the obtained equations of the material particle's motion in the classifier and the aerodynamic resistance coefficient by the numerical methods using the obtained data on the distribution of the air flow velocities, allows to simulate the material particles' motion in the working area of the classifier with its various technological and design parameters. The information obtained makes it possible to determine the direction of motion of particles of different size or density, as well as to estimate the boundary size of the separation.

ӘОЖ621.928

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ГРАВИТАЦИЯЛЫҚ ЖІКТЕУІШТЕ ҰСАҚТАЛҒАН МАТЕРИАЛДЫ ФРАКЦИЯЛАУ ПРОЦЕСІН МОДЕЛЬДЕУ

Аннотация. Ұсақталған сусымалы материалдарды әуеде жіктеудің қолданыстағы әдістеріне талдау жасалады, оларды дамыту мен жетілдірудің басым бағыттары анықталады, осы әдістердің аппараттық рәсімделуі және ауа жіктеуіштерін есептеудің негізгі тәсілдері зерттеледі. Қорытынды оңтайлы өнімділік кезінде жіктеуіштің жұмыс көлеміндегі бөлшектердің жеткілікті оқшауланған қозғалысы туралы жасалады. Құрғақ бөлу әдістерінің болашағы және көп сатылы гравитациялық жіктеуіштерді құрудың прогрессивтілігі анықталды. Толтырғыштары бар гравитациялық жіктеуіштерді бөлу процесінің теориялық зерттеулері жүргізілді. Ауаның жіктеуіштерінде сусымалы материалдарды бөлу процесінің заңдылықтары анықталды, жоғары тиімді және өнімді өндірістік кәсіпорындар құру үшін олардың технологиялық және жобалық параметрлерін есептеудің сенімді әдістері жасалды. Жіктеуіштің технологиялық және есептік параметрлерінің бөлу механизміне әсерін сипаттайтын теориялық тәуелділіктер мен дифференциалдық теңдеулер алынады. Қозғалыс теңдеулерін шешу нәтижелері өнімділікке технологиялық талаптарға және соңғы өнімдердің дисперсті құрамына сүйене отырып, аппараттың негізгі құрылымдық параметрлерін анықтауға мүмкіндік берді. Теориялық зерттеулер негізінде толып жатқан сөрелер мен ауырлық күшін жіктеуіште бөлу процесін сипаттайтын аналитикалық байланыстар мен дифференциалдық теңдеулер жасалды. Осы теңдеулерді қолдану жіктеуіштегі ауа ағынын модельдеуге, кез-келген жобалық және технологиялық параметрлерге ауа ағынының жылдамдықтарының өрісін алуға мүмкіндік берді. Бұл өз кезегінде әртүрлі көлемдегі немесе тығыздықтағы бөлшектердің қозғалу бағытын көрсетеді және бөлінудің шекара өлшемін бағалауға мүмкіндік береді, сонымен қатар ауа ағынының кең ауқымында бөлініп жатқан материал мен өзара әрекеттесуін зерттеуге мүмкіндік береді. Аппараттың технологиялық және жобалық параметрлерінің ара қатынасы теориялық тұрғыдан анықталған.
Түйін сөздер: материал, ұсақтау, бөлшек, жіктеу, аппарат, фракция, гидродинамика, ауырлық күші, ағындылық, ағын.

УДК 621.928

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МОДЕЛИРОВАНИЕ ПРОЦЕССА ФРАКЦИОНИРОВАНИЯ ИЗМЕЛЬЧЕННОГО МАТЕРИАЛА В ГРАВИТАЦИОННОМ КЛАССИФИКАТОРЕ

Аннотация. Проведен анализ существующих способов воздушной классификации измельченных сыпучих материалов, выявлены приоритетные направления их развития и совершенствования, изучено аппаратурное оформление этих способов и основные подходы к расчетам воздушных классификаторов. Сделан вывод о достаточно обособленном движении частиц в рабочем объеме классификатора при оптимальной производительности. Установлена перспективность сухих способов разделения и прогрессивность создания многокаскадных гравитационных классификаторов. Выполнены теоретические исследования процесса разделения в гравитационном классификаторе с пересыпными полками. Установлены закономерности процесса разделения сыпучих материалов в воздушных классификаторах, разработаны надежные методики расчета их технологических и конструктивных параметров с целью создания высокоэффективных и производительных промышленных установок. Получены теоретические зависимости и дифференциальные уравнения, характеризующие влияние на механизм разделения технологических и конструктивных параметров классификатора. Результаты решения уравнений движения позволили определить основные конструктивные параметры аппаратов исходя из технологических требований к производительности и дисперсному составу конечных продуктов. На основании теоретических исследований разработаны аналитические зависимости и дифференциальные уравнения, описывающие процесс разделения в гравитационном классификаторе

с пересыпными полками. Использование данных уравнений позволило смоделировать течение воздуха в классификаторе, получить поле скоростей воздушного потока при любых конструктивных и технологических параметрах. Это, в свою очередь, показывает направление движения частиц различного размера или плотности и дает возможность оценить граничный размер разделения, а также позволяет исследовать взаимодействие воздушного потока с разделяемым материалом в широком диапазоне технологических и конструктивных параметров классификатора, и, в конечном итоге, определить граничный размер разделения и диапазон размеров частиц получаемых фракций готового продукта. Теоретически определена взаимосвязь технологических и конструктивных параметров аппарата.

Ключевые слова: материал, измельчение, частица, классификация, аппарат, фракция, гидродинамика, гравитация, сыпучесть, поток.

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ISSN 2518-170X (Online), ISSN 2224-5278 (Print)

Редакторы: *М. С. Ахметова, Р. Ж. Мрзабаева, Д. С. Аленов*
Верстка на компьютере *В.С. Зикирбаева*

Подписано в печать 15.06.2021.
Формат 60x881/8. Бумага офсетная. Печать – ризограф.
4,6 п.л. Тираж 211. Заказ 3.

Национальная академия наук РК
050010, Алматы, ул. Шевченко, 28, т. 272-13-18, 272-13-19