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Satbayev University

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ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН
Satbayev University

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DEVELOPMENT OF HEAT STORAGE MATERIALS BASED ON COMMODITY PARAFFINS

Abstract. Heat storage materials on the basis of liquid paraffins and their narrow fractions with the set temperature of phase transition and the increased heat capacity for enclosing the structures of buildings are received. A method of formulating compositions heat-storage materials with melting temperatures below 25^0C and increased heat capacity from a mixture of narrow fractions of commodity paraffins is proposed. The technique of obtaining heat-storage materials on the basis of commodity paraffin by mixing components, in obtaining HSM with specified thermal characteristics, the research of component composition, physico-chemical and thermophysical properties, in the research of their operational properties. The technical conditions for the obtained heat- storage materials on the basis of commodity paraffins are developed and the possibility of their application in the enclosing structures of buildings is substantiated. The developed heat-storage material with the set operational properties provides energy saving due to increase of heat capacity and intensity of heat exchange of enclosing designs of buildings.

Key words: heat-storage materials, thermal properties, phase transition, paraffin, fraction.

Introduction. One of the solutions of regulating the dynamics of cooling of buildings is the use of heat accumulators in enclosing structures. Heat accumulators allow to smooth out daily unevenness and to save energy consumption for heating.

Currently, batteries apply with the using heat- storage materials (HSM) phase transition to maintain a constant temperature in the building. In this case, there is a need to obtain heat- storage materials with a melting point close to 25^0C, for their use in the enclosing structures of buildings to regulate the heat in their rooms.

One of the key points of reducing energy consumption in construction is the use of the achievements of scientific and technological progress in the production of energy-saving building materials, structures and equipment, as well as improving the heat-shielding qualities of building envelopes [1]. The development of such a scientific and experimental direction in construction as the creation of buildings with efficient use of energy is associated with the accumulation of heat in the enclosing structures of buildings, which leads to the formation of a new direction in the production of energy-saving building materials, such as heat storage materials [2-4].

A promising and economically feasible direction in the production of heat storage materials is the development of new energy-saving materials with a hidden form of energy storage, which include phase-transfer heat storage materials [5-8]. In the transition from solid state to liquid heat storage materials behave like traditional storage materials, their temperature rises when they absorb heat [9]. In contrast to the known heat-accumulating materials in phase-transition heat-storage materials, heat transfer occurs due to the creation of a crystalline structure, and accumulation occurs due to the destruction of the structure during melting. Our analysis of the thermophysical properties of thermal storage materials showed that the

most accessible, widely produced by industry in the process of oil refining material are solid and liquid commodity paraffins and their narrow fractions. They can be used to obtain heat storage materials with a melting point up to 250 C.

Materials and methods. Two methods of obtaining heat-storage material that is given thermophysical properties were used in the studies.

- obtaining a material with a melting point of 250C by mixing liquid and solid commercial paraffin in various ratios;
- obtaining by mixing several individual n-alkanes of a material with the required melting temperatures and high enthalpy of melting and phase transition (200-225j/g).

The developed heat storage material based on commercial paraffin was obtained by mixing the initial liquid and solid paraffin in various mass fractions. Determination of the mass fraction of mixing the initial liquid and solid paraffin was made in accordance with the recommendations of the work [10]. Mixing of commercial liquid and solid paraffin and their fractions were performed at a temperature of 40-500C and thorough mixing of the composition with a mixer in the laboratory in accordance with figure 1-2.

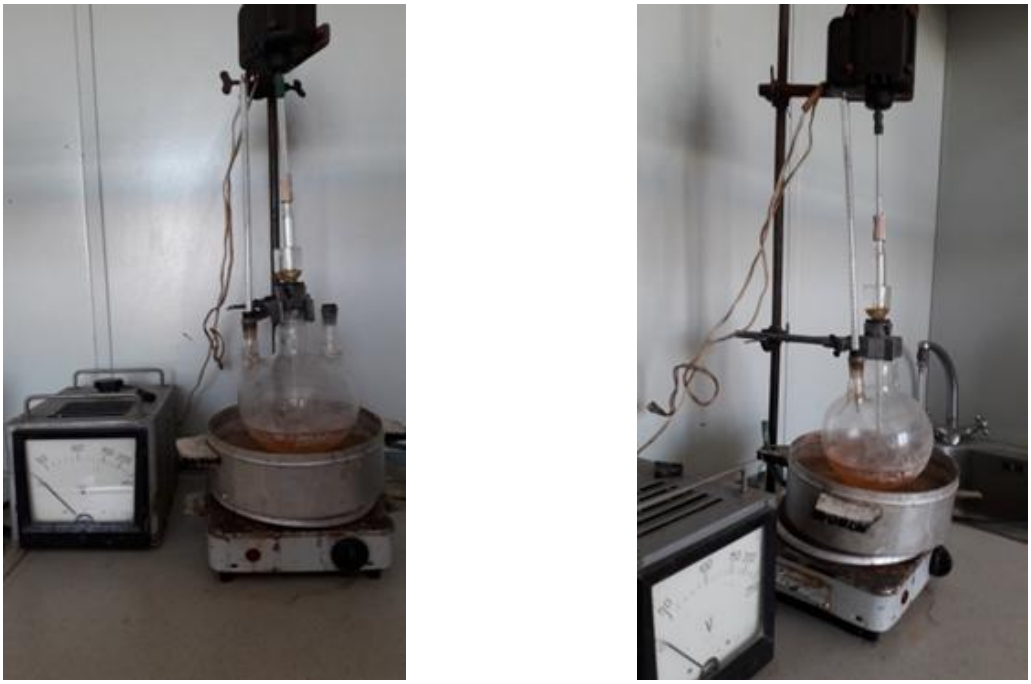


Figure 1 – Laboratory device for producing paraffin compositions

Figure 2 – Non-standard equipment for producing paraffin compositions

Table 1 presents data on samples of heat-storage materials prepared for laboratory research, obtained by mixing in different mass fractions of commercial liquid and solid paraffin.

Table 1 – the Composition and properties of heat storage materials obtained by mixing liquid and solid paraffin.

HSM	Components	Content % mass	Temperature		
			Melting	Beginning	The end
HSM -35	$C_{14}H_{30}$ - $C_{17}H_{36}$	55,5	35	47	30
	$C_{18}H_{38}$ – $C_{21}H_{44}$	44,5			
HSM -25	$C_{14}H_{30}$ - $C_{17}H_{36}$	99,4	25	44	21
	$C_{18}H_{38}$ – $C_{21}H_{44}$	10,6			
HSM -20	$C_{14}H_{30}$ - $C_{17}H_{36}$	25,9	20	42	12
	$C_{18}H_{38}$ – $C_{21}H_{44}$	74,1			
HSM 15	$C_{14}H_{30}$ - $C_{17}H_{36}$	16,7	15	35	7
	$C_{18}H_{38}$ – $C_{21}H_{44}$	83,3			

As shown from data in table 1.2 by mixing commodity liquid and solid paraffin in various ratios, it is possible to obtain heat-storage materials with the required melting points.

Results and discussion. As indicated, heat-storage materials of a given thermal properties can be obtained by mixing in different ratios of individual n-alkanes. To allocate fusible fractions from the composition of commercial paraffin, a method based on sequential extraction of fractions with solvents or their mixtures differing in solubility parameters was used [11-13].

According to the method, the paraffin suspension was placed in a two-headed flask with a nozzle, in one throat of which a Schott filter was soldered. The nozzle is a glass tube length from 15 to 20 mm and with an outer diameter of 6-8 mm, internal – 4-6 mm.

Paraffin melts in a flask with a nozzle. And then it cools. In this case, the nozzle in the flask is constantly shaken in order to obtain thin paraffin on the nozzle. Next, a certain amount of methyl ethyl ketone is poured into the flask. After careful mixing and holding for 6 hours, the solvent is poured through a Schott filter into a preliminary weighted porcelain cup. The solvent from the porcelain cup is distilled off, and the fraction is weighed. A mixture of methyl ethyl ketone and toluene in a ratio of 75:25 is poured into the flask [14]. Similarly, the first is allocated the second fraction, the third, etc. The melted temperature was determined by the selected paraffin fractions.

Using the developed method, the product commodity paraffin was fractionated and the fraction with a low melting point was isolated.

It was noted that for individual n-alkanes and their mixtures, the melting enthalpy includes both the enthalpy of the actual melting and the enthalpy of the phase transition to the crystal state.

For individual n-alkanes, the temperature limit in which heat is absorbed or released is 5–70 °C for even n-alkanes and 8–110 °C for odd n-alkanes.

By mixing several individual n-alkanes, it is also possible to obtain heat-storage materials with the required melting temperatures and with the enthalpy of melting and phase transition at the level of 180-220 j/g.

The following requirements are applied on heat-storage materials with a melting – crystallization phase transition:

- the required melting point;
- the maximum enthalpy of melting and phase transition in the crystal state during the transition of the heat-storage material from the solid state to the liquid state and vice versa;
- a small difference in melting and crystallization temperatures, as well as high stability of these temperatures.

Based on these requirements (melting point and high enthalpy of melting and phase transition), heat-storage materials HSM-25-1 and HSM -25-2 were made by mixing individual n-alkanes, as well as HSM -25-3 by mixing commercial liquid and solid paraffin.

From the literature it is known that to obtain the smallest difference of temperatures of melting and phase transition mix of the neighboring n-alkanes, however, in this case the melting temperature and phase transition enthalpy of melting of mixtures of n-alkanes are not averages of the individual components.

It is also noted that the use of a large number of components to obtain a heat-storage material with the required properties reduces the enthalpy of melting and phase transition in the crystal state, and, consequently, the total enthalpy.

When using solid paraffin as a heat-storage material, the heat of crystallization and phase transition in the crystal state is usually used. In work [15-20] it is shown that solid paraffin has two phase transitions: in the crystalline state with the release and absorption of heat, as well as the release and absorption of heat during melting and evaporation. When a solid paraffin is heated, it undergoes phase transformations in the crystalline state, resulting in an increase in heat capacity, and when a higher temperature is reached, the paraffin melts, and its heat capacity again sharply increases.

In the crystal state before the phase transition and in the liquid molten state, the heat capacity of paraffin monotonically increases with rising temperature.

It should be borne in mind that the influence of the melting temperature of paraffin has little effect on their heat capacity, and the heat capacity of paraffin in the solid state is close to the heat capacity in the liquid state.

The melting temperatures and enthalpy values of the melting and phase transition, j / g, developed by HSM-25-1, HSM -25-2 and HSM -25-3 are presented in table 2.

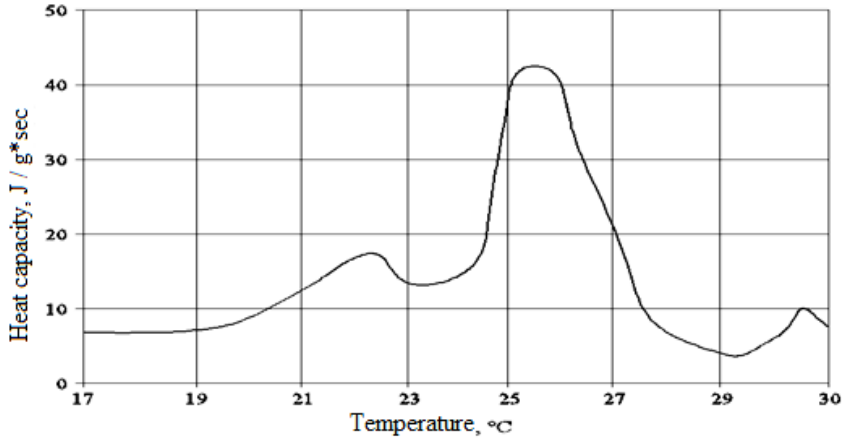
Table 2 – Enthalpy of melting and phase transition developed HSM

Characteristic	HSM-25-1	HSM-25-2	HSM-25-3
The melting temperature according to Zhukov, ^{0}C	23-25	24-25	22-29
Molecular mass	247,76	247,79	242,3
Enthalpy of melting $\Delta H_{melting}$, J/g	168,7	171,2	161,3
Phase transition enthalpy ΔH_{phase}, /g	35,7	34,8	20,03
The sum of the enthalpies of melting $\Delta N_{melting}$ and the phase transition ΔN_{phase}, J / g	204,4	206,0	181,33

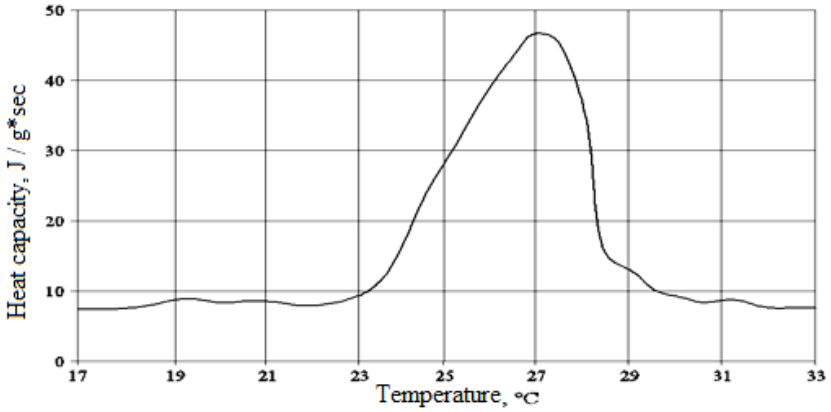
As shown from data in table 2 HSM-25-1 and HSM-25-2 have rather high amounts of heat of fusion and phase transition (from 204.4 to 206.0 J / g). The mixing of solid and liquid paraffins in the production of heat-storage material (HSM-25-3), as shown from the table 2, leads to a decrease in the melting enthalpy, the phase transition in the crystal state and the total enthalpy (their sum). The expansion of the components in the mixture HSM leads to a decrease in the amount of enthalpy.

Therefore, the wider the fractional composition HSM, the lower the enthalpy of melting and in a wider range of temperatures melting occurs.

Graphs of changes in the heat capacity of HSM -25-1 and HSM-25-2 obtained by mixing individual n-alkanes are shown in accordance with figure 3.



a)



b)

a – HSM-25-1, b – HSM-25-2
Figure 3 – Dependences of heat capacity HSM-25-1 and HSM-25-2 on temperature

Graphs of changes in the heat capacity of HSM-25-1 and HSM-25-2 from the temperature of figure 3 shows that the heat capacity HSM changes according to the melting and phase transformations at different temperatures, as well as melting HSM occurs in a certain temperature range.

The gas chromatographic composition of HSM-25-3, obtained by mixing liquid and solid paraffins, is a relatively narrow fraction containing more than 6 individual n-alkanes with an admixture of hydrocarbons.

Conclusion. In this regard, heat-storage materials obtained by mixing liquid and commercial solid paraffin have lower melting enthalpy compared to HSM-25-1 and HSM-25-2 obtained by mixing individual n-alkanes. Heat-storage materials obtained by mixing liquid and commercial paraffins, with an average molecular weight of 240.0 to 242.0 have a melting enthalpy of 158.0 to 162.0 j / g and a phase transition enthalpy in the crystal state of 19.3 to 20.03 j / g, respectively. The decrease in the enthalpy of melting and phase transition in HSM-25-3 is explained by the lower content of n-alkanes (90.4 - % by weight) and the content of impurities not related to n-alkanes (7.8 - % by weight). The content of hydrocarbons that do not belong to h-alkanes and hydrocarbons that do not crystallize in conditions HSM, as well as the wide fractional composition of the mixture of commercial liquid and solid paraffins significantly reduce the amount of the enthalpy of melting and phase transition of the heat-storage material.

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ТАУАРЛЫ ПАРАФИНДЕР НЕГІЗІНДЕ ЖЫЛУ АККУМУЛЯЦИЯЛАУШЫ МАТЕРИАЛДАРДЫ ӘЗІРЛЕУ

Аннотация. Сұйық парафин мен оның тар фракциялары негізінде фазалық өту температурасымен және ғимараттардың қоршау конструкциясына жоғары жылу сыйымдылығымен жылу жинайтын материалдар алынды. Балқу температурасы 25^0С төмен және тауарлы парафиндердің тар фракцияларының қоспасынан жоғары жылу сыйымдылығы бар жылу жинайтын материал композицияларын құру әдісі ұсынылған. Компоненттерді араластыру арқылы тауарлы парафиндер негізінде жылу жинайтын материалдарды алу, берілген жылу техникалық сипаттамалары бар ТАМ алу, компонент құрамын, физико-химиялық және жылу

физикалық қасиеттерін зерттеу, олардың пайдалану қасиеттерін зерттеу әдісі әзірленді. Тауарлық парафиндер негізінде жылу жинақтайтын материалдарға техникалық шарттар алынды және оларды ғимараттардың қоршау конструкцияларында қолдану мүмкіндігі негізделген. Берілген пайдалану қасиеттері бар әзірленген жылу жинақтағыш материал ғимараттардың қоршау конструкцияларының жылу сыйымдылығы мен жылу алмасуының қарқындылығын арттыру есебінен энергия үнемдеуді қамтамасыз етеді. Бастапқы сұйық және қатты парафинді араластыру массалық үлесін анықтау жұмыс ұсынымдарына сәйкес жүргізілді. Тауарлық сұйық және қатты парафин мен фракцияларын араластыру 40-500 с температурада және зертханалық жағдайда құрамы мұқият араластырылды.

Берілген жылу қасиеттері негізінде жылу жинайтын материалдар жекелеген Н-алкандардың түрлі қатынасында араластыру арқылы алынуы мүмкін. Тауарлық парафин құрамында жылдам балқитын фракцияларды бөлу үшін оның еріткіші немесе ерігіштік параметрлері бойынша ерекшеленетін қоспаларымен біртіндеп алуға негізделген әдіс қолданылды. Әзірленген әдістеме бойынша өнімнің тауарлы парафинін фракциялап, балқу температурасы төмен фракцияны бөліп алды. Жекелеген Н-алкандар мен олардың қоспалары үшін балқыту энтальпиясы нақты балқу энтальпиясын да, фазалық өту энтальпиясын да кристалды жағдайға қосады. Жеке Н-алкандар үшін жылу жұтылатын немесе бөлінетін шекті температура жұп Н-алкандар үшін 5-70 ° С және тақ Н-алкандар үшін 8-110 ° С құрайды. Осы талаптарды ескере отырып (балқу температурасы және балқу мен фазалық өтудің жоғары энтальпиясы) жеке Н-алкандарды араластыру жолымен ЖЖМ-25-1 және ЖЖМ-25-2, сондай-ақ тауарлық сұйық және қатты парафинді араластыру арқылы ЖЖМ-25-3 жылытқыш материалдар дайындалды. Қатты парафинді қыздырғанда ри кристалдық күйдегі фазалық түрленуге ұшырайды, жылу сыйымдылығын ұлғайтады, ал жоғары температураға жеткен кезде парафин балқиды және жылу сыйымдылығы қайтадан күрт өседі. 2-кестеде көрсетілгендей, жылу жинайтын материалды (ЖЖМ-25-3) өндіру барысында қатты және сұйық парафиндерді араластыру балқу энтальпиясының, кристалдық жағдайға фазалық ауысу мен жалпы энтальпияны (олардың қосындылары) азайтады. HSM қоспасындағы компонентер кеңейгенде энтальпия мөлшері азаяды.

Демек, ЖЖМ фракциялық құрамы кеңейген сайын, еріту энтальпиясы соғұрлым төмендеп, ұлғайған температура диапазонында балқиды. Температурадан ЖЖМ-25-1 және ЖЖМ-25-2 жылу сыйымдылығының өзгеру графиктері ЖЖМ-дың жылу сыйымдылығы түрлі температурада балқу мен фазалық өзгерістерге байланысты өзгеретінін, сондай-ақ ЖЖМ-дың балқуы белгілі бір температуралық интервалда жүретінін көрсетеді. Сұйық және қатты парафиндерді араластыру арқылы алынған ЖЖМ-25-3 газохроматографиялық құрамы көмірсутектер қоспасы бар 6-дан астам жеке Н-алкан кездесетін салыстырмалы тар фракцияны білдіреді. Осыған байланысты сұйық және тауарлы қатты парафинді араластыру арқылы алынған жылу жинайтын материалдар жеке Н-алкандардың араласуы негізінде алынған HSM-25-1 және HSM-25-2 салыстырғанда балқыту энтальпиясы төмендейді. Сұйық және тауарлы парафиндерді араластыру жолымен алынған, орташа молекулалық массасы 240,0-ден 242,0-ге дейін жылу жинайтын материалдардың 158,0-ден 162,0 Дж / г-ға дейін еріту энтальпиясы және кристалды күйдегі фазалық ауысу энтальпиясы тиісінше 19,3-тен 20,03 Дж / г-ға дейінгі аралықта болады. Балқу энтальпиясының және ЖЖМ-25-3 фазалық ауысудың төмендеуі Н-алкандардың (90,4 Мас.%) және Н - алкандарға жатпайтын қоспалардың (7,8 мас.%) Н-алкандарға жатпай-тын көмірсутектердің және НСМ жағдайында кристалданбайтын көмірсутектердің құрамы, сондай-ақ тауарлық сұйық және қатты парафиндер қоспасының фракциялық құрамы балқу энтальпиясының және жылу аккумолдайтын материалдың фазалық өту шамасын айтарлықтай төмендетеді.

Түйін сөздер: жылу аккумляциялаушы материалдар, жылу техника қасиеттері, фазалық өту, парафиндер, фракция.

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РАЗРАБОТКА ТЕПЛОАККУМУЛИРУЮЩИХ МАТЕРИАЛОВ НА ОСНОВЕ ТОВАРНЫХ ПАРАФИНОВ

Аннотация. Получены теплоаккумулирующие материалы на основе жидких парафинов и их узких фракции с заданной температурой фазового перехода и повышенной теплоемкостью для ограждающих конструкций зданий. Предложен метод составления композиций теплоаккумулирующих материалов с температурами плавления ниже 25^0С и повышенной теплоемкостью из смеси узких фракций товарных парафинов. Разработана методика получения теплоаккумулирующих материалов на основе товарных пара-

финов путем смешения компонентов, в получении ТАМ с заданными теплотехническими характеристиками, исследовании компонентного состава, физико-химических и теплофизических их свойств, в исследовании их эксплуатационных свойств. Получены технические условия на теплоаккумулирующие материалы на основе товарных парафинов и обоснована возможность их применения в ограждающих конструкциях зданий. Разработанный теплоаккумулирующий материал с заданными эксплуатационными свойствами обеспечивает энергосбережение за счет повышения теплоемкости и интенсивности теплообмена ограждающих конструкций зданий. Определение массовой доли смешивания исходного жидкого и твердого парафина производилось в соответствии с рекомендациями работы.Смешивание товарного жидкого и твердого парафина и их фракций осуществляли при температуре 40-500С и тщательном перемешивании состава смесителем в лабораторных условиях.

Как указано, теплоаккумулирующие материалы с заданными тепловыми свойствами могут быть получены путем смешивания в различных соотношениях отдельных Н-алканов. Для выделения легкоплавких фракций из состава товарного парафина был использован метод, основанный на последовательном извлечении фракций растворителями или их смесями, различающимися по параметрам растворимости. По разработанной методике товарный парафин продукта фракционировали и выделяли фракцию с низкой температурой плавления. Было отмечено, что для отдельных Н-алканов и их смесей энтальпия плавления включает как энтальпию фактического плавления, так и энтальпию фазового перехода в кристаллическое состояние. Для отдельных Н-алканов предельная температура, при которой тепло поглощается или выделяется, составляет 5-70 ° С для четных Н-алканов и 8-110°С для нечетных Н-алканов. Исходя из этих требований (температура плавления и высокая энтальпия плавления и фазового перехода), были изготовлены теплоаккумулирующие материалы ГСМ-25-1 и ГСМ-25-2 путем смешивания индивидуальных Н-алканов, а также ГСМ-25-3 путем смешивания товарного жидкого и твердого парафина. ри нагревании твердого парафина он претерпевает фазовые превращения в кристаллическом состоянии, приводящие к увеличению теплоемкости, а при достижении более высокой температуры парафин плавится, и его теплоемкость снова резко возрастает. Смешение твердых и жидких парафинов при производстве теплоаккумулирующего материала (ГСМ-25-3), Как видно из таблицы 2, приводит к уменьшению энтальпии плавления, фазового перехода в кристаллическое состояние и общей энтальпии (их суммы). Расширение компонентов в смеси HSM приводит к уменьшению величины энтальпии.

Следовательно, чем шире фракционный состав ГСМ, тем ниже энтальпия плавления и в более широком диапазоне температур происходит плавление. Графики изменения теплоемкости ГСМ-25-1 и ГСМ-25-2 от температуры показывают, что теплоемкость ГСМ изменяется в зависимости от плавления и фазовых превращений при различных температурах, а также плавление ГСМ происходит в определенном температурном интервале. Газохроматографический состав ГСМ-25-3, полученный смешением жидких и твердых парафинов, представляет собой относительно узкую фракцию, содержащую более 6 индивидуальных Н-алканов с примесью углеводородов. В связи с этим теплоаккумулирующие материалы, полученные смешением жидкого и товарного твердого парафина, имеют более низкую энтальпию плавления по сравнению с HSM-25-1 и HSM-25-2, полученными смешением индивидуальных Н-алканов. Теплоаккумулирующие материалы, полученные путем смешивания жидких и товарных парафинов, со средней молекулярной массой от 240,0 до 242,0 имеют энтальпию плавления от 158,0 до 162,0 Дж / г и энтальпию фазового перехода в кристаллическом состоянии от 19,3 до 20,03 Дж / г соответственно. Снижение энтальпии плавления и фазового перехода в ГСМ-25-3 объясняется более низким содержанием Н-алканов (90,4 Мас.%) и содержанием примесей, не относящихся к Н - алканам (7,8 мас.%). Содержание углеводородов, не относящихся к Н-алканам, и углеводородов, не кристаллизующихся в условиях НСМ, а также широкий фракционный состав смеси товарных жидких и твердых парафинов существенно снижают величину энтальпии плавления и фазового перехода теплоаккумулирующего материала.

Ключевые слова: теплоаккумулирующие материалы, теплотехнические свойства, фазовой переход, парафины, фракция.

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РЕЗУЛЬТАТЫ ИССЛЕДОВАНИЙ УСОВЕРШЕНСТВОВАННОЙ ГИДРОСТРУЙНОЙ НАСОСНОЙ УСТАНОВКИ

Аннотация. Дано обоснование классификации гидроструйных насосных установок, разработка экспериментального образца усовершенствованной гидроструйной насосной установки, обосновано проведение экспериментальных исследований – определение подачи полезной $Q_{гн}$ в зависимости от подачи используемого центробежного насоса $Q_н$ для двух вариантов насосной установки, работающих по традиционной и альтернативной технологии водоподъёма , определение потерь напора $h_{сні}$ и коэффициентов трения $\xi_{сні}$ в струйных насосах, повышение коэффициента эжекции $К_э$ от параметра закрутки S подвода воды в приёмную камеру струйного насоса и на лабораторные испытания гидроструйной насосной установки для сельскохозяйственного водоснабжения и обводнения пастбищ. Приведены результаты экспериментальных исследований и лабораторных испытаний экспериментального образца усовершенствованной гидроструйной насосной установки, разработанной в НАО КазНАУ. Дан анализ результатов сравнительных испытаний гидроструйной насосной установки для двух вариантов технологического процесса: альтернативного и традиционного с повышением полезной подачи альтернативного варианта в 2-4 раза, снижением потребного напора в 1,5-2 раза и повышения КПД в 1,1-2 раза.

Целью исследования является получение результатов по обоснованию классификации гидроструйных насосных установок, по проведению экспериментальных исследований и лабораторных испытаний усовершенствованной гидроструйной насосной установки, работающей по альтернативной технологии водоподъёма, позволяющей снизить потребный напор насосной установки, повысить полезную подачу и увеличить КПД усовершенствованной гидроструйной насосной установки.

На основании анализа выполненных работ и патентных исследований по технологиям водоподъёма из подземных водоисточников гидроструйными насосными установками и разработанных по ним конструкций, предложена обоснованная классификация гидроструйных насосных установок, которая позволяет, в зависимости от поставленной задачи, правильно выбрать необходимую конструктивно-технологическую схему, тип струйного насоса и его исполнение при разработке необходимых эффективных типоразмеров гидроструйной насосной установки.

Представлена схема испытательного стенда и экспериментального образца усовершенствованной гидроструйной насосной установки с измерительным оборудованием и приборами для проведения экспериментальных исследований и лабораторных испытаний на стендовой скважине.

Ключевые слова: классификация, гидроструйная насосная установка, экспериментальное исследование, результат, лабораторное испытание, сравнительный анализ испытания, подача, напор, КПД.

Введение. В системе сельскохозяйственного водоснабжения и обводнения пастбищ в Казахстане для подъёма воды из подземных водоисточников ранее широко использовались гидроструйные насосные установки, состоящие из центробежного насоса, установленного на поверхности земли и насосной части со струйным насосом, опущенных во внутрь скважины под динамический уровень воды. Преимуществом которых по сравнению с другими насосными установками аналогичного назначения является высокая эксплуатационная надёжность насосной части, а основным недостатком – низкий общий КПД до 0,18 – 0,44 из-за высокого потребного давления для выполнения технологического процесса водоподъёма, которые могут быть устранены посредством использования усовершенствованной гидроструйной насосной установки, работающей по альтернативной технологии водоподъёма, позволяющей снизить потребный напор насос-

ной установки в 1,5 – 2 раза, повысить полезную подачу в 2-4 раза и увеличить КПД в 1,1-2 раза [1-4]. Классификация гидроструйных насосных установок не разрабатывалась, что затрудняло выбрать эффективную конструктивно-технологическую схему гидроструйной насосной установки. Экспериментальные исследования и лабораторные испытания по технологии водоподъёма из скважин с использованием усовершенствованной гидроструйной насосной установки не проводились, однако практическое применение раздельно каждого процесса имело место: подсос воды использовался в струйных насосах [1-4], в технологии беструбного водоподъёма [5] и погружных электронасосов со всасывающими устройствами [6], в эрлифтных водоподъёмниках [7], при этом использование каждого процесса имеет положительный результат и актуален в прикладных исследованиях.

Цель исследования: получение результатов по обоснованию классификации гидро-струйных насосных установок, по проведению экспериментальных исследований и лабораторных испытаний усовершенствованной гидроструйной насосной установки, работающей по альтерна-тивной технологии водоподъёма, позволяющей снизить потребный напор насосной установки в 1,5-2 раза, повысить полезную подачу в 2-4 раза и увеличить КПД в 1,1-2 раза.

Метод. В работе использовались патентные исследования с обзором работ, которые выполнялись по существующим методикам: выявлением близких аналогов, анализом существующих работ и использованием их в разработке [8,9]. Экспериментальные исследования проводились по изучению технологического процесса водоподъёма из скважин, протекающих процессов в используемых струйных насосах – определение подачи полезной в зависимости от подачи центробежного насоса, определение потерь напора и коэффициентов трения в струйных насосах, коэффициента эжекции и проверке достоверности полученных теоретических предпосылок [10].

Результаты и обсуждение. На основании анализа выполненных работ и патентных исследований по технологиям водоподъёма из подземных водоисточников гидроструйными насосными установками и разработанных по ним конструкций, предложена обоснованная классификация гидроструйных насосных установок (рисунок 1), которая позволяет, в зависимости от поставленной задачи, правильно выбрать необходимую конструктивно-технологическую схему, тип

Рисунок 1 – Классификация гидроструйных насосных установок

струйного насоса и его исполнение при разработке необходимых эффективных типоразмеров гидроструйной насосной установки [1-4,10].

Согласно обоснованной классификации, гидроструйные насосные установки разделены по технологии водоподъёма и конструктивно-технологическим схемам их исполнения, отличительным техническим и технологическим способам водоподъёма на типы и подтипы [10].

На основании обоснованной классификации разработан усовершенствованный экспериментальный образец гидроструйной насосной установки для проведения экспериментальных исследований и лабораторных испытаний.

Испытательный стенд и экспериментальный образец усовершенствованной гидроструйной насосной установки были разработаны для проведения экспериментальных исследований по традиционной и альтернативной технологии водоподъёма из скважин с использованием струйных насосов для подсоса воды и атмосферного воздуха, и проведения лабораторных испытаний гидроструйной насосной установки.

Экспериментальные исследования и лабораторные испытания экспериментального образца усовершенствованной гидроструйной насосной установки проведены на специально подготовленном испытательном стенде с измерительным оборудованием и приборами (рисунок 2) [10].

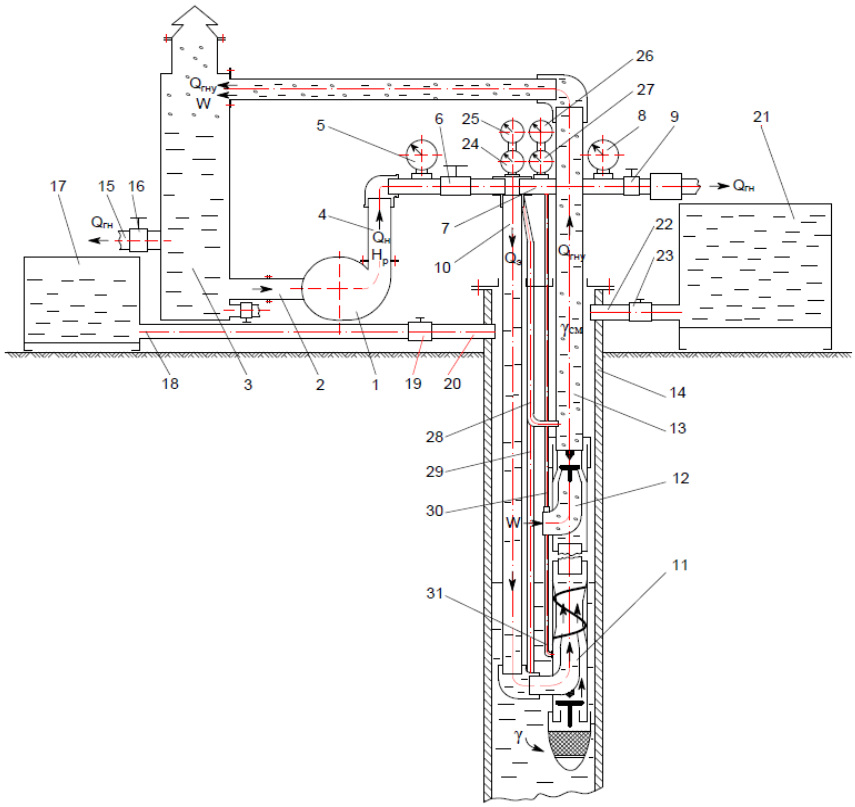


Рисунок 2 – Схема испытательного стенда и экспериментального образца усовершенствованной гидроструйной насосной установки с измерительным оборудованием и приборами

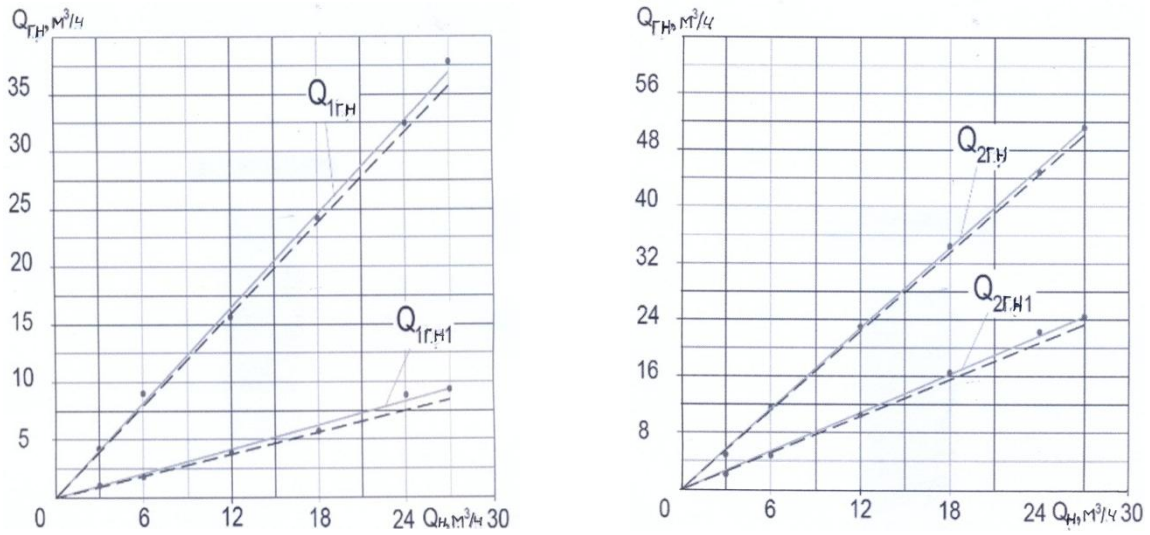
Испытательный стенд (см. рисунок 2) состоит из центробежного насоса 1, всасывающего патрубка 2, ёмкости приёмной 3, напорного патрубка центробежного насоса 4, манометра центробежного насоса 5, задвижки насоса 6, трубы отводной 7, манометра отводной трубы 8, задвижки отводной 9, трубопровода нагнетаемого 10, струйного насоса для подсоса воды 11, струйного насоса для подсоса атмосферного воздуха, водоподъёмного трубопровода 13, стендовой скважины 14, трубы отвода воды из ёмкости 15, задвижки ёмкости приёмной 16, мерной емкости замера полезной подачи для варианта 2 17, отводной трубы мерной ёмкости 18, задвижки мерной ёмкости для варианта 2 19, отводного патрубка 20, мерной емкости для варианта 1 21, отводной трубки 22, задвижки мерной ёмкости для варианта 1 23, образцового манометра струйного насоса с подсосом воды 24, образцового манометра струйного насоса с подсосом воздуха 25, вакуумметра струйного

насоса с подсосом воздуха 26, вакуумметра струйного насоса с подсосом воздуха 27 и соединительных гидрошлангов манометров и вакуумметров 28,29,30,31.

Экспериментальные исследования проведены на экспериментальном образце гидроструйной насосной установки с центробежным насосом СР 220 В с параметрами: подача $Q_н$ = 3-27 м^3/ч при напоре $H_р$= 37,5- 25 м, потребляемая мощность $N_н$ = 1,7 – 3,2 kВт и КПД $Ƞ_н$ = 0,18 – 0,60 и струйными насосами с оптимальными параметрами активных и пассивных сопел: $D_{са1}$ =35 мм, $D_{сп1}$=56 мм, $D_{са\ 2}$=56 мм, $D_{сп\ 2}$ = 26,5мм.

Результаты экспериментальных исследований технологического процесса гидроструйной насосной установки представлены графиками (рисунок 3) - зависимость: полезной подачи гидроструйной насосной установки $Q_{гн}$ от подачи $Q_н$ центробежного насоса СР 220 В: $Q_{1гн1}$ - по традиционной технологии водоподъёма (а) вариант 1) и $Q_{1гн}$ - по альтернативной технологии водоподъёма (а) вариант 1) ; $Q_{2гн1}$ - по традиционной технологии водоподъёма (б) вариант 2) и $Q_{2гн}$ - по альтернативной технологии водоподъёма (б) вариант 2).

В результате исследований установлено, что подача гидроструйной насосной установки полезная составляет: для традиционной технологии водоподъёма (см. рисунок 3 а) $Q_{1гн1}$ = 6–9 м^3/ч (вариант 1) и (см. рисунок 3 б) $Q_{2гн1}$ = 16,2–24,3 м^3/ч (вариант2) и для альтернативной технологии водоподъёма (см. рис.3а и рис.3б) $Q_{1гн}$ = 24–36 м^3/ч (вариант1) и $Q_{2гн}$ = 34,2–51,3 м^3/ч (вариант 2) при изменении подачи центробежного насоса от 18 м^3/ч до 27 м^3/ч при высотах водоподъёма Н = 20 – 30 м и коэффициенте эжекции струйного насоса с подсосом воды: для варианта 1 $K_{Э1} = 0{,}5$, для варианта 2 $K_{Э1} = 0{,}9$ [9,10,11,12].



$Q_{1гн1}$ - по традиционной технологии водоподъёма (а) вариант 1) и $Q_{1гн}$ - по альтернативной технологии водоподъёма (а) вариант 1) ; $Q_{2гн1}$ - по традиционной технологии водоподъёма (б) вариант 2) и $Q_{2гн}$ - по альтернативной технологии водоподъёма (б) вариант 2)

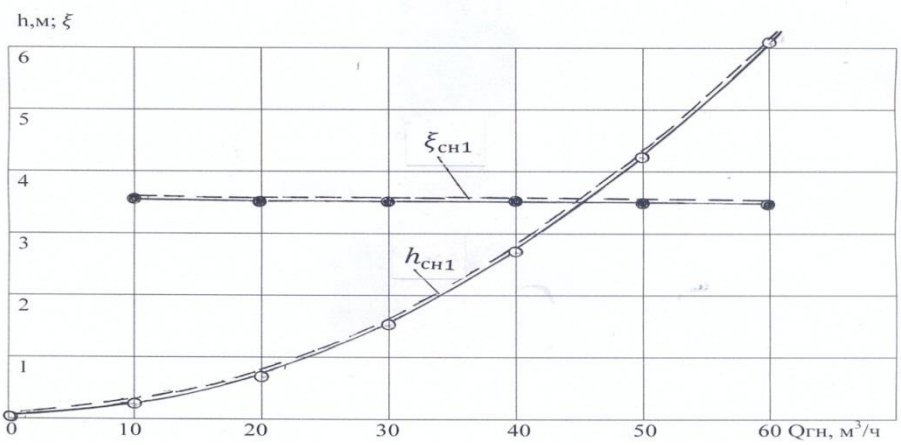
Рисунок 3 – Зависимость полезной подачи гидроструйной насосной установки $Q_{гн}$ от подачи $Q_н$ центробежного насоса СР 220 В

Достоверность теоретических формул, приведённых на графиках зависимостей $Q_{гн}$ = f($Q_н$), подтверждены экспериментально (расхождение не превышает 3-5%). Из графиков (см. рис. 3 а) и б) явно прослеживается преимущество альтернативной технологии водоподъёма с использованием усовершенствованной гидроструйной насосной установки по сравнению с традиционной технологии водоподъёма.

Результаты исследований по определению потерь напора $h_{снi}$ и коэффициентов трения $\xi_{снi}$ в струйных насосах гидроструйной насосной установки представлены графиками зависимостей $h_{снi}$, $\xi_{снi}$ =f($Q_{гнуi}$) для двух вариантов насосных установок: сельскохозяйственного водоснабжения (вариант1) при проектной подаче насосной установки $Q_п$ = 25 м^3/ч (рисунок 4) и обводнения

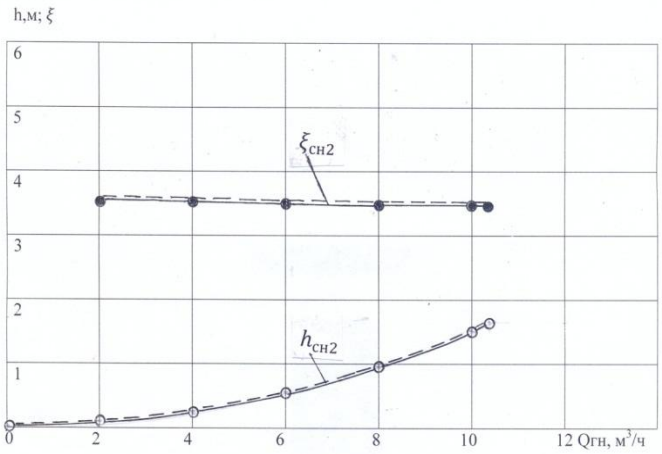
пастбищ (вариант 2) при проектной подаче насосной установки $Q_п$ = 3,6 м^3/ч (рисунок 5), из которых следует, что потери напора $h_{снi}$ в струйных насосах с увеличением подачи гидроструйной насосной установки $Q_{гнуi}$ увеличиваются при постоянном значении их основных параметров – внутренних диаметров активных сопел $D_{сai}$ =const, которые составили для гидроструйной насосной установки сельскохозяйственного водоснабжения (вариант 1) при изменении подачи от 25 м^3/ч до 61,3 м^3/ч $h_{сн}$= 1,2м - 6,1м и $\xi_{сн}$=3,4-3,6, а для гидроструйной насосной установки обводнения пастбищ (вариант 2) при изменении подачи от 3,6 м^3/ч до 10,3 м^3/ч $h_{сн}$= 0,2 м - 1,6 м и $\xi_{сн}$=3,4-3,6.

Расхождения экспериментальных значений $h_{снi}$ и $\xi_{снi}$ от теоретических не превышают 2-3 %. Экспериментально определены вакуумные напоры в струйных насосах с подсосом воды $H_{вак1}$ и с подсосом атмосферного воздуха $H_{вак2}$, которые составили от 1,38 м до 7,5 м при средних значениях соответственно 1,9 м и 5,8 м. Достоверность теоретических формул по определению вакуумного напора $H_{вак1}$ и $H_{вак2}$, подтверждено экспериментально (расхождение составляет до 3-5%).



_____ теоретические ------- - экспериментальные

Рисунок 4 – Зависимости потерь напора $h_{снi}$ и коэффициентов трения $\xi_{снi}$ в струйных насосах от подачи $Q_{гнуi}$ гидроструйной насосной установки сельскохозяйственного водоснабжения (вариант 1)



_____ теоретические ------- - экспериментальные

Рисунок 5 – Зависимости потерь напора $h_{снi}$ и коэффициентов трения $\xi_{снi}$ в струйных насосах от подачи $Q_{гнуi}$ гидроструйной насосной установки обводнения пастбищ (вариант 2)

Исследования позволили выявить, что достигаемый положительный эффект в конструкции с вихревым подводом всасываемой жидкости значительно больше, чем для конструкции с обычным прямоточным подводом, на основании чего можно полагать о предпочтительности применения данной конструкции в случаях, когда требуется увеличить подачу струйного насоса.

Полагая, что коэффициент эжекции зависит от интенсивности передачи энергии активного потока пассивному, заключили, что чем больше активный поток передаст кинетическую энергию пассивному, тем эффективнее используется поверхность активной струи, которая является рабочей, тем больше значение коэффициента эжекции [11,12].

Экспериментальные данные показали, что закрутка всасываемого потока оказывает сильное влияние на рабочие характеристики струйных насосов.

При увеличении степени закрутки увеличивается интенсивность смешения потока, возникают большие градиенты давления в радиальном и осевом направлениях, что приводит к увеличению коэффициента эжекции.

Кроме того, критерием оценки повышения коэффициента эжекции К для закручивающего (вихревого) способа подвода воды в приёмную камеру пассивного сопла струйного насоса является параметр закрутки S (рисунок 6).

Параметр закрутки S представляет собой безразмерное отношение осевой компоненты потока момента количества движения к произведению осевой компоненты потока количества движения и эквивалентного радиуса сопла [9]. Параметр закрутки также может быть представлен в виде: $S = \frac{G/2}{1-(G/2)^2}$, где $G = U_w/U_0$ - отношение окружной компоненты скорости к осевой .

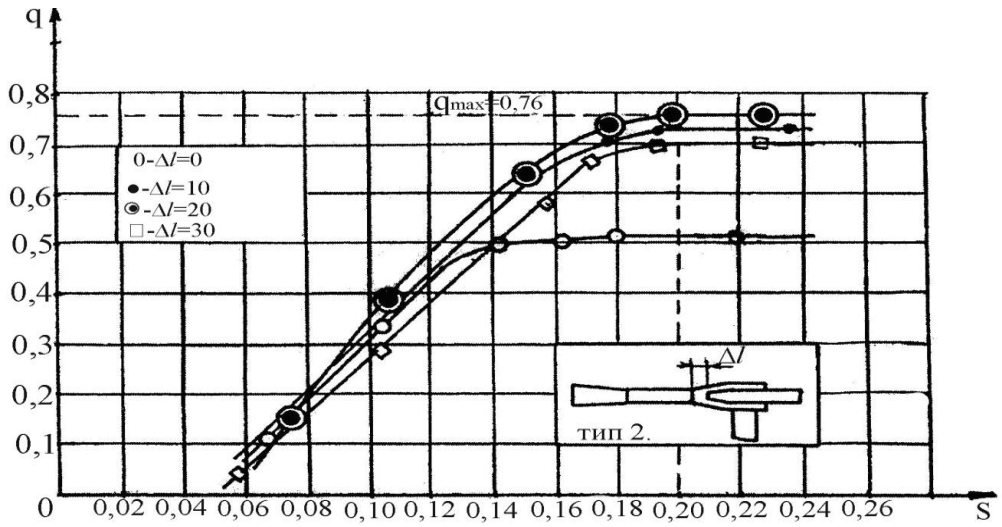


Рисунок 6 – Зависимость коэффициента эжекции $К_э$ от параметра закрутки S для закручивающего (вихревого) способа подвода воды в приёмную камеру пассивного сопла струйного насоса

На графиках (см. рис.6) даны экспериментальные зависимости коэффициента эжекции $К_э$ от параметра закрутки S для закручивающего (вихревого) способа подвода воды в приёмную камеру пассивного сопла струйного насоса при разных значениях расстояния от активного сопла до смесительной камеры $\Delta\ell$ = 0;10 мм; 20мм и 30 мм , из которых следует , что коэффициента эжекции $К_э$ повышается при всех значениях $\Delta\ell$ при увеличении параметра закрутки S до S=0,20 (критического значения), после чего дальнейшее увеличение параметра закрутки не влияет на увеличение коэффициента эжекции, максимальный коэффициент эжекции $К_э$ изменяется от 0,52 до 0,76, оптимальное значение $\Delta\ell$ = 20 мм.

Даны результаты лабораторных сравнительных испытаний гидроструйной насосной установки с использованием центробежного насоса СР 220В для двух вариантов технологического процесса (традиционного и альтернативного) для сельскохозяйственного и пастбищного водоснабжения [15].

Лабораторные испытания показали, что гидроструйная насосная установка для сельскохозяйственного водоснабжения по альтернативной технологии водоподъёма превосходит по всем параметрам гидроструйную насосную установку, работающей по традиционной технологии водоподъёма: подача оптимальная Q1гн =24-36 $м^3$/ч выше Q1гн1 =6-9 $м^3$/ч в 4 раза, потребный напор $Н_{1гн}$ =12,5-18,75м ниже $Н_{1гн}$ =25-37,5 м в 2 раза; оптимальное значение КПД Ƞ 1гн=0,38-0,40

выше $Ƞ_{1гн1}$=0,19-0,20 в 2 раза. В результате сравнительного анализа доказана эффективность использования гидроструйной насосной установки, работающей по альтернативной технологии водоподъёма [10].

Лабораторные испытания показали, что гидроструйная насосная установка для пастбищного водоснабжения по альтернативной технологии водоподъёма также превосходит по всем параметрам гидроструйную насосную установку, работающей по традиционной технологии водоподъёма: подача оптимальная $Q_{2гн}$ =34,2 -51,3 м^3/ч выше $Q_{2\ гн}1$ =16,2-24,3 м^3/ч в 2,1 раза, потребный напор $H_{2гн}$ =12,5-18,5м ниже $H_{1гн}$ =25-37,5 м в 2 раза; оптимальное значение КПД $Ƞ_{2гн}$=0,55-0,57 выше $Ƞ_{2гн1}$=0,52-0,54 в 1,1 раза. В результате сравнительного анализа доказана эффективность использования гидроструйной насосной установки для обводнения пастбищ, работающей по альтернативной технологии водоподъёма [10].

Выводы. 1. В результате проведённых экспериментальных исследований усовершенствованного образца гидроструйной насосной установки определены зависимости подачи гидроструйной насосной установки полезной $Q_{гн}$ от подачи $Q_н$ центробежного насоса СР 220 В для варианта 1 и варианта 2 технологического процесса при использовании струйного насоса с подсосом воды и от совместного использования струйных насосов с подсосом воды и атмосферного воздуха, которые показали преимущество гидроструйной насосной установки, работающей по альтернативной технологии водоподъёма в увеличении полезной подачи и КПД и снижении потребного напора насосной установки Нгну.

2. На основании лабораторных сравнительных испытаний гидроструйной насосной установки с использованием центробежного насоса СР 220В для двух вариантов технологического процесса: традиционного и альтернативного для сельскохозяйственного водоснабжения и обводнения пастбищ доказана эффективность её использования по альтернативной технологии водоподъёма по сравнению с традиционной в снижении потребного напора в 1,5-2 раза, повышении полезной подачи в 2-4 раза и увеличении КПД в 1,1-2 раза.

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ЖЕТІЛДІРІЛГЕН ГИДРОАҒЫНДЫ СОРАП ҚОНДЫРҒЫСЫН ЗЕРТТЕУ НӘТИЖЕЛЕРІ

Аннотация. Ғылыми мақала гидроағынды сорап қондырғыларын жіктеуді негіздеуге, жетілдірілген гидроағынды сорап қондырғыларының тәжірибелік үлгісін жасауға бағытталған, эксперименттік зерттеулер жүргізу – дәстүрлі және балама су көтеру технологиясымен жұмыс істейтін сорғы қондырғысының екі нұсқасы үшін пайдаланылатын $Q_н$ орталықтан тепкіш сорғының берілуіне байланысты пайдалы $Q_{гн}$ анықтау, ағынды сорғыдағы $h_{сні}$ қысым шығынын және $ξ_{сні}$ үйкеліс коэффициенттерін айқындау, $К_э$ эжекция коэффициентін ағынды сорғының қабылдау камерасына су берудің S бұрылу параметрінен және ауылшаруашылығы суымен жабдықтауға және жайылымды суландыруға арналған гидроағынды сорап қондырғысын зертханалық сынақтан өткізу. «ҚазҰАУ» КЕАҚ-да әзірленген жетілдірілген гидроағынды сорап қондырғысы эксперименттік зерттеулері мен зертхана сынақтарының эксперименттік үлгісінің нәтижелері келтірілген. Технологиялық процестің екі нұсқасы: балама нұсқаның пайдалы берілуін 2-4 есе арттыру, қажетті қысымды 1,5-2 есе төмендету және ПӘК 1,1-2 есе арттыру негізінде балама және дәстүрлі гидроағынды сорап қондырғының салыстырмалы сынақтарының нәтижелеріне талдау жасалды.

Зерттеудің мақсаты – гидроағынды сорап қондырғысын жіктеуді негіздеу, сорғы қондырғысының қажетті қысымын төмендетуге, пайдалы берілісті арттыруға және жетілдірілген гидроағынды сорап қондырғысының тиімділігін арттыруға мүмкіндік беретін балама су көтеру технологиясымен жұмыс істейтін жетілдірілген гидроағынды сорап қондырғысына тәжірибелік, зертханалық зерттеулер жүргізу.

Жұмыста қолданыстағы әдістеме бойынша орындалған жұмыстарға шолу жасау арқылы патенттік зерттеулер пайдаланылды: жақын аналогтарды анықтау, қолданыстағы жұмыстарды талдау және оларды әзірлеуде пайдалану.

Тәжірибелік зерттеулер ұңғымадан су көтерудің технологиялық процесін, пайдаланылған ағынды сорғыдағы процестерді зерттеу бойынша жүргізілді, яғни орта тепкіш сорғының берілуіне байланысты пайдалы берілісті анықтау, ағынды сорғыдағы қысым мен үйкеліс коэффициенттерінің жоғалуын, эжекция коэффициентін анықтау және алынған теориялық дұрыстығын тексеру.

Гидроағынды сорап қондырғыларымен және соның негізінде жасалған конструкциямен жерасты су көзінен су тарту технологиялары бойынша орындалған жұмыстар мен патенттік зерттеулерді талдау негізінде гидроағынды сорап қондырғыларының негізделген жіктемесі ұсынылған, аталған міндетке байланысты қажетті құрылымдық-технологиялық схеманы, ағынды сорғы түрін және гидроағынды сорап қондырғысының қажетті тиімді өлшемін әзірлеуде оның орындалуын дұрыс таңдауға мүмкіндік береді.

Сынақ стендінің схемасы және стендтік ұңғымада эксперименттік зерттеулер мен зертханалық сынақтар жүргізуге арналған өлшеу жабдықтары мен аспаптары бар жетілдірілген гидроағынды сорап қондырғысының эксперименттік үлгісі ұсынылған.

Түйін сөздер: жіктеу, гидроағынды сорап қондырғысы, тәжірибелік зерттеу, нәтиже, зертханалық сынақ, салыстырмалы сынақ талдауы, қысым, ПӘК.

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RESEARCH RESULTS OF THE IMPROVED HYDRAULIC JET PUMPING UNIT

Abstract. The scientific article is aimed at substantiating the classification of hydraulic jet pumping units, developing an experimental model of an improved hydraulic jet pumping unit, conducting experimental studies - determining the useful flow Qгн depending on the flow rate of the centrifugal pump used Qн for two variants of the pumping unit operating according to the traditional and alternative technology of water lifting, determination of the head losses hсні and friction coefficients ξсні in jet pumps, increasing the ejection coefficient Ke from the swirl parameter S of water supply to the intake chamber of the jet pump and laboratory tests of the hydraulic jet pumping unit for agricultural water supply and irrigation of pastures. The results of experimental studies and laboratory tests of an experimental model of an improved water-jet pumping unit, developed at NAO KazNAU, are presented. An analysis is given of the results of comparative tests of a hydraulic jet pumping unit for two variants of the technological process: an alternative and a traditional one with an increase in the effective supply of an alternative option by 2-4 times, a decrease in the required pressure by 1.5-2 times and an increase in efficiency by 1.1-2 times.

The aim of the study is to obtain results to substantiate the classification of hydraulic jet pumping units, to carry out experimental studies and laboratory tests of an improved hydraulic jet pumping unit operating according to an alternative water lifting technology, which allows to reduce the required head of the pumping unit, increase the useful flow and increase the efficiency of the improved hydraulic jet pumping unit.

The work used patent research with a review of works that were carried out according to existing methods: identifying close analogues, analyzing existing works and using them in development. Experimental studies were carried out to study the technological process of water rise from wells, the processes occurring in the used jet pumps - determining the useful flow depending on the flow of a centrifugal pump, determining the pressure losses and friction coefficients in jet pumps, the ejection coefficient and checking the reliability of the theoretical assumptions obtained.

Based on the analysis of the work performed and patent research on technologies for lifting water from underground water sources by hydraulic jet pumping units and designs developed for them, a substantiated classification of hydraulic jet pumping units is proposed, which allows, depending on the task at hand, to correctly choose the necessary structural and technological scheme, type of jet pump and its implementation in the development of the required effective standard sizes of the hydraulic jet pumping unit.

The scheme of the test bench and the experimental model of the improved hydraulic jet pumping unit with measuring equipment and instruments for conducting experimental research and laboratory tests on a bench well is presented.

Key words: classification, hydraulic jet pumping unit, experimental study, result, laboratory test, comparative analysis of the test, flow rate, head, efficiency.

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HYDROLYTIC REGULATION OF COMPONENT PROPERTIES

Abstract. The article provides an assessment of the dairy farming need in the Russian Federation and the Republic of Belarus in calves feed. The main global trends aimed at providing young animals with high-quality food means are considered.

Various variants of directed hydrolysis of calf milk replacer (CMR) protein components intended for feeding young animals in the first months of life are analyzed.

The possibilities of reducing the soy proteins antigenic activity, which are widely used at present in the CMR formulations for feeding young farm animals, are discussed.

The results of experimental work and patents are presented, which describe the most widely used approaches to the production of enzymatic hydrolysates of proteins with desired properties, as well as the assessment of their biological activity and immunochemical properties. The issues of using various enzyme preparations of bacterial, fungal and animal origin for hydrolysis of colostrum proteins and plant sources of protein raw materials for the CMR production are considered.

Key words: CMR, soy proteins, hydrolysis methods, anti-nutritional substances, antigenicity, immunoglobulins, bacterial proteases.

Introduction. Optimization of the dairy herd development is largely determined by the cow's lactation duration, the availability of a forage base that provides balanced nutrition for animals of different age categories. In particular, in order to increase the commercial milk production, an annual replenishment of young animals in a dairy herd is required at the level of about 40 heads per 100 cows, and one calf needs to be fed balanced nutritional components equivalent to 300-350 liters of milk. Based on this and taking into account the total number of cows, the milk needs for feeding calves in the Russian Federation is 1.3 million tons, and in the Republic of Belarus - 0.4 million tons [1,2].

The determining factors for effective calves rearing are their health state, as well as the weight and age of the first calving, which largely depends on the colostrum and feeds quality in the first three months of life [3].

Soy proteins characteristics for calf milk replacer (CMR). In order to increase the milk marketability and the economy of agricultural production, calf milk replacers (CMR) are used for feeding young animals. Their release is carried out using a variety of technologies [4], which have their own advantages and disadvantages. The desire to improve the balance and nutritional value of CMR is the subject of ongoing research in this area, especially in the search for new sources of raw materials and biotechnological methods of their directed transformation. The development of research and theoretical generalizations in the field of new competitive feed types for young agricultural animals is relevant, including by obtaining products of higher quality, as well as the selection and implementation of optimal for this dehydration technology methods, resource and energy conservation [5,6].

In particular, to achieve the above goals and expand the range of functional properties, a promising direction is the use of specially treated soybean seeds. When creating and optimizing the composition of such specialized products, certain advantages can be achieved due to biotechnological transformation of components based on their fermentation [7]. This is due to the fact that this process, as is known [8,9], causes the proteins degradation with the formation of peptides with different molecular weights. This approach can be rather effective method for modifying the CMR protein components in the desired direction.

In addition, it should be borne in mind that a significant factor affecting the CMR protein components quality are their antigenic properties, the level of which can also be regulated by enzymatic treatment [10].

Soybean antigenic proteins include glycinin and β-conglycinin. When feeding young agricultural animals with diets containing soy protein, a small part of it is not digested and through the gaps between the terminal epithelial cells falls into the lymph and blood. These molecules, possessing significant antigenic activity, stimulate the immune system, leading to the occurrence of specific antigen-antibody reactions and delayed hypersensitivity mediated by T-lymphoid cells. Therefore, at present, the goal of research is to develop methods for reducing the soy proteins immunoreactivity. Several strategies have been developed to prevent food allergies, including feed handling and plant breeding. These researches indicate, inter alia, that certain types of immunomodulators, such as vitamin C and linoleic acid, can specifically block the IgE-mediated anaphylaxis, which may provide new insights into effective soy allergy prevention, and possibly other many food allergies [10].

In work [11], the antigenic soybean seeds activity subjected to heat treatment by boiling for 30 and 60 minutes was studied. It has been shown that heat treatment reduces the soy proteins ability to bind IgE, which contributes to an increase in the end products safety.

In work [12], the content of glycine protein in industrial soy products, which is an immunodominant soy allergen, was studied. Soy flour gave the highest protein antigenicity (32 mg/g of extracted protein), and soy protein isolate and concentrate, respectively, 29 mg/g of extracted protein and 24 mg/g of extracted protein. Among soybean consumer products, soy milk showed the greatest antigenicity, varying from 7 to 23 mg/g of extracted protein, followed by pace (8 mg/g of extracted protein), soy infant formula (3.4 mg/g of extracted protein) and soy "cheese products" (0.50 mg/g of extracted protein). In consumer products such as Korean miso, soy sauce, soy nuts, "soy meat" hamburgers, textured soy protein, antigenicity (detection limit = 0.45 ng) was not found [12].

It is significant that soy products subjected to severe heat treatment under high pressure (texturates) and fermented soy products (soy sauce) show a minimum level of antigenicity.

In connection with the above, these studies confirm that the use of protein hydrolysis technologies is of significant interest in the creation of new CMR types.

In general, the destruction of biopolymers by enzymes is one of the fundamental phenomena in nature, freeing structural elements for the new biopolymer molecules synthesis. Hydrolysates are widely used in food production, including as biologically active food additives, special food and feed products and ingredients. Hydrolysis technologies make it possible to more efficiently use of waste products that process agricultural raw materials.

In the patent literature for the soybean enzymatic hydrolysates production, various enzymes and technological methods are proposed that provide products with the specified properties.

There is a known method for intensifying mass transfer processes for obtaining a protein hydrolyzate from soy flour, which consists in preparing a suspension with a dry matter content of 6-12%, suspension hydrolysis with a mushroom protease to a hydrolysis degree of 20-40% and subsequent hydrolysis with papain to hydrolysis degree of 30- 45%. The total duration of the hydrolysis is 2.5-4 hours. The resulting hydrolyzate is separated and dried to a moisture content of 9.4%, the product contains 65-68% crude protein [13].

To obtain a protein hydrolyzate from soy flour, a method is proposed [14], processing flour from cereals, legumes and oilseeds, or a mixture thereof for enzymatic treatment when obtaining protein hydrolysates, including grinding the specified flour to a particle size of at least one dimension less than 50 microns, with provided that at least 50% of these particles are less than 25 microns in size.

The known method [15] of soy product obtaining, based on the hydrolysis of soybean raw materials suspension by pectinase and cellulase for 5 hours. The resulting product contains 22% of sugars, while their content in the starting material is 0,77%.

The patent [16] describes the preparation of a milk replacer from vegetable protein and carbohydrate sources using an enzyme having multiple carbohydrase activities.

To obtain protein-carbohydrate solutions, mixtures of enzyme preparations with both proteolytic and cellulase or amylase activities are also used. Thus, the patent [17] proposes a method for obtaining soluble (not forming colloidal masses) proteins fractions and carbohydrates by sequential hydrolysis of proteins and carbohydrates.

According to the method [18], the components are extracted from a pre-barothermally treated raw material with a developed surface area, which facilitates the enzyme's access to the attack sites. In the described process, the initial substrate concentration during enzymatic hydrolysis can reach 25-30%, which leads to the formation of more concentrated protein and carbohydrate nature products.

The characteristic methods described above, naturally, have their advantages and disadvantages. At the same time, the variety of approaches in order to ensure effective soybean components biotransformation by fermentation indicates that the achievement of truly optimal solutions in this area is still ahead and requires further research.

In the literature, the regularities and properties of soy protein hydrolysates are investigated, aimed in particular at reducing the soy proteins antigenic activity.

In a review article [8], the physicochemical, organoleptic, immunochemical (residual antigenicity) characteristics of proteins enzymatic hydrolysates from various sources are given. It is argued that the necessary decrease in the hydrolysate's antigenicity used in the hypoallergenic food products composition for medicinal purposes is achieved at values not higher than 10^{-5} relative to the original protein antigenicity, which requires a membrane ultrafiltration stage.

In the work [19], enzymatic hydrolysis of defatted soy flour was carried out with three different proteases (Flavourzyme 1000 L, Novozym FM 2.0 L, and Alcalase 2.4 L FG). The highest hydrolysis degree (DH 39.5) was observed with the Flavourzyme enzyme. Soy flour hydrolysates have been used to study the functional proteins properties (foaming and gel formation). Hydrolysis with Flavourzyme enzyme showed the best foaming and gelling properties of soy proteins. It was also found that the enzymes used degraded both conglycinin and soybean glycinin. During fermentation with Alcalase and Novozym proteases, the highest concentration of the following free amino acids was observed in the hydrolyzate - histidine (30%), leucine (24%) and tyrosine (19%), and during Flavourzyme hydrolysis - arginine (22,1%), leucine (10,6%) and phenylalanine (12,9%) [20].

Of interest are studies aimed at studying the immunomodulatory protein hydrolysates properties.

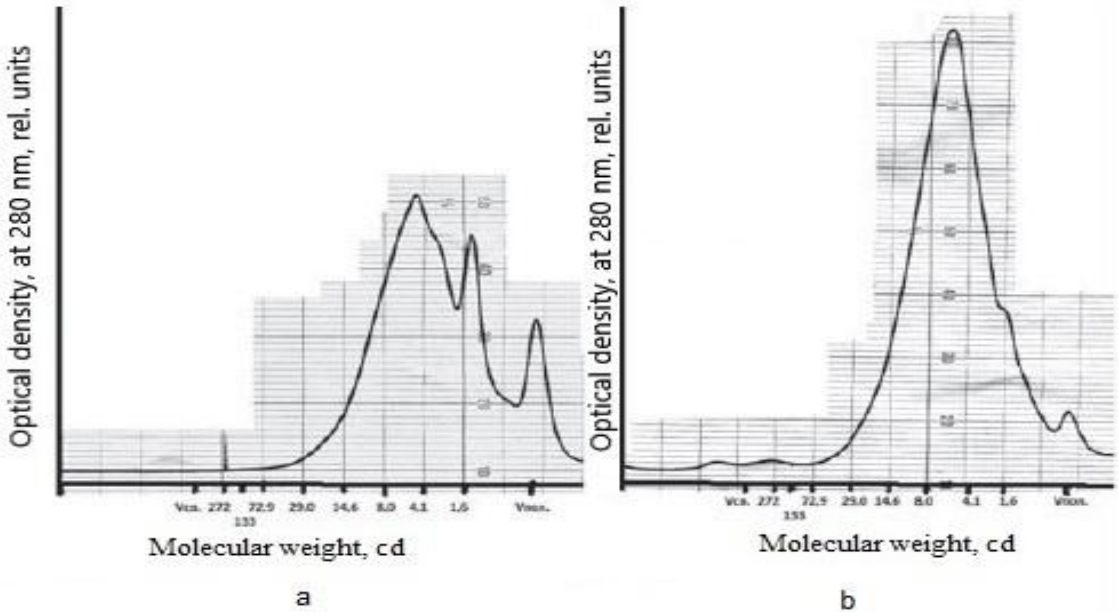
In particular, in the study of soy protein hydrolysates with a degree of hydrolysis from 42% to 87%, obtained using such enzymes as Alcalase, Flavourzyme, Trypsin, Papain, Protease A and Peptidase R, it was shown that the maximum immunomodulatory activity is positively charged peptides [21]. Such peptide mixtures are promising for use in specialized products with high immunomodulatory activity.

The research carried out in this direction is complemented by the joint work of specialists of the Federal Research Center for Nutrition and Biotechnology and All-Russian Scientific Research Institute of Dairy Industry on the soy protein isolate hydrolysis by the pancreatin enzyme in a protein/enzyme ratio of 50:1 and 20:1 (by mass proportion of dry matter). Fermentation was carried out at a temperature of (50±1 °C) with constant stirring, the pH of the reaction medium was maintained in the range of 7,4-7,6 by potassium and sodium hydroxide solutions titration in a ratio of 2:1 for 5 hours, and sampling for chromatographic analysis was carried out after 1,3 and 5 hours. The enzyme was inactivated by heating the mixture to 75 °C for 15 minutes. Then the mixture was centrifuged for clarification [21].

The obtained results served as the basis for the development of a soy protein hydrolysate pilot batch in order to develop technological modes in semi-industrial conditions.

For hydrolysis, as well as in laboratory studies, a 5% solution of soy protein isolate was used. The hydrolysis was carried out in a circulating mode using a setup equipped with a reservoir with a stirrer and a thermal shirt, as well as a dispersant with a built-in centrifugal pump. The process was carried out by dissolving soy protein isolate in water to obtain a solution of 5% concentration. The enzyme pancreatin was added to the soy protein isolate solution in a protein/enzyme ratio of 50:1. Hydrolysis was carried out at a temperature of (51±1 °C) for 3 hours, after which the enzyme was inactivated at a temperature of (75±1 °C) in 20 minutes. The hydrolyzate was dried on a spray dryer Niro-Atomizer (Denmark) with a capacity of 20 kg of evaporated moisture per hour at temperatures of incoming air in the range of 160-165 °C, leaving 80-85 °C.

The resulting product is a finely dispersed powder of light cream color, with a mass fraction of moisture of 9.5%, readily soluble in water, with a slight bitter-salty taste and a characteristic odor. The osmolality of the reduced 1% hydrolysate solution was 32 mol/kg. In laboratory conditions, experiments were carried out to reduce the bitterness and osmolality of the obtained hydrolyzate using a nanofiltration unit, which made it possible to reduce the hydrolyzate osmolality to 26 mmol/kg and practically eliminate the bitterness. The obtained results are confirmed by the data of exclusion chromatograms of the produced hydrolyzate before and after nanofiltration (figure).



Soy protein hydrolyzate size exclusion chromatography
Size exclusion chromatography of soy protein enzymatic hydrolyzate before and after nanofiltration:
a -Enzymatic hydrolyzate of soy protein isolate-Supro (EHSPI-Supro) before nanofiltration;
b - Enzymatic hydrolyzate of soy protein isolate-Supro (EHSPI-Supro) after nanofiltration

Conclusion and deductions. It can be noted that the above review materials and the obtained experimental data indicate the prospects for further technologies development and improvement for the biotransformation of plant protein-containing raw materials based on their hydrolysis by enzymes and bacterial starters in order to obtain products with improved functional properties, including those aimed at reducing anti-nutritional factors. At the same time, for a specific application, it is required to expand the range of use of protein-containing sources of plant raw materials, further search for the most effective types of enzyme preparations and bacterial starters, development and optimization of resource-saving technological parameters of raw material processing, as well as improving the objective finished products testing depending on their final destination.

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КОМПОНЕНТТЕР ҚАСИЕТІН ГИДРОЛИТИКАЛЫҚ РЕТТЕУ

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ГИДРОЛИТИЧЕСКОЕ РЕГУЛИРОВАНИЕ СВОЙСТВ КОМПОНЕНТОВ

Аннотация. В статье приведена оценка потребности молочного животноводства Российской Федерации и Республики Беларусь в кормах для телят. Рассмотрены основные мировые тенденции, направленные на обеспечение молодняка качественными кормовыми средствами.

Анализируются различные варианты направленного гидролиза белковых компонентов заменителей цельного молока (ЗЦМ), предназначенных для выпойки молодняка в первые месяцы жизни.

Описаны характерные способы ферментации компонентов сои, которые имеют свои преимущества и недостатки. В то же время разнообразие подходов в целях обеспечения эффективной биотрансформации компонентов сои путем их ферментации свидетельствует о том, что достижение действительно оптимальных решений в этой области еще впереди и требует дальнейших исследований.

Обсуждены возможности снижения антигенной активности соевых белков, широко использующихся в настоящее время в рецептурах ЗЦМ для питания молодняка сельскохозяйственных животных.

Приведены результаты совместных работ специалистов ФГБУН «ФИЦ питания и биотехнологии» и ФГАНУ «ВНИМИ» по проведению гидролиза изолята соевых белков ферментом панкреатин, полученные результаты послужили основанием для выработки опытной партии гидролизата соевого белка в целях отработки технологических режимов в полупромышленных условиях.

Приведены результаты экспериментов в лабораторных условиях по снижению горечи и осмоляльности гидролизата из соевых белков с использованием нанофильтрационной установки, что позволило снизить осмоляльность гидролизата и практически ликвидировать горечь. Результаты подтверждены данными эксклюзионных хроматограмм выработанного гидролизата до и после нанофильтрации.

Приведены результаты экспериментальных работ и патентов, в которых описаны наиболее широко используемые подходы к получению ферментативных гидролизатов белков с заданными свойствами, а также оценки их биологической активности и иммунохимических свойств. Для получения белково-углеводных растворов применены различные смеси ферментных препаратов, обладающие как протеолитической, так и целлюлазной или амилазной активностями и получение растворимых (не образовывающих коллоидных масс) фракций белков и углеводов путем последовательного гидролиза белков и углеводов.

Предложены различные способы приготовления заменителя молока из растительного белка и углеводных источников с использованием фермента, имеющего множественные карбогидразные активности.

Приведены результаты исследований, которые подтверждают, что стадия мембранной ультрафильтрации способствует снижению относительной антигенности гидролизатов до минимальных значений, используемых в дальнейшем в составе гипоаллергенных пищевых продуктов лечебного назначения

Рассмотрены вопросы использования различных ферментных препаратов бактериального, грибкового и животного происхождения для гидролиза белков молозива и растительных источников белкового сырья для производства ЗЦМ.

Установлено, что расширение спектра использования белоксодержащих источников растительного сырья требует дальнейший поиск наиболее эффективных видов ферментных препаратов и бактериальных заквасок, отработка и оптимизация ресурсосберегающих технологических параметров обработки сырья, а также совершенствования объективного тестирования готовых продуктов в зависимости от их конечного назначения.

Ключевые слова: соевые белки; способы гидролиза; антиалиментарные вещества; антигенность; иммуноглобулины; ферменты; бактериальные закваски.

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ОСОБЕННОСТИ И ПУТИ ДЕКАРБОНИЗАЦИИ ЭКОНОМИКИ КАЗАХСТАНА

Аннотация. В статье подчеркивается неизбежность образования CO_2 при производстве тепловой и электрической энергии со сжиганием органического топлива и анализируются источники генерации углекислого газа на энергетических объектах Казахстана. Обсуждаются реализуемые в короткие сроки технологии производства электрической и тепловой энергии со сниженной генерацией углекислого газа. Показан возможный метод количественной оценки уровня выбросов CO_2 для условий Казахстана через использование удельного расхода условного (углеродного) топлив на производстве как единицы тепловой и/или электрической энергии. Приведены ряд доступных и относительно дешевых технологических решений, которые при реализации могут заметно снизить выбросы углекислого газа. Отмечено, что эти технологии могут быть реализованы административным и экономическим путем и приведены формулировки требуемых решений Правительства. Для каждой из предлагаемой технологии приведена оценка возможных объемов снижения выброса углекислого газа и указаны трудности, которые могут встретиться при реализации.

Рассмотрена схема определения степени участия конкретной страны в глобальной карбонизации и показано, что в зависимости от метода «разнесения» общего объема выбросов конкретной страны, одна и та же страна может оказаться как в числе благополучных стран, так и в ряду стран, к которым необходимо применять строгие «углеродные» налоги. Отмечается, что определение доли конкретной страны в виде объемов выбросов с единицы площади территории страны представляется более «справедливой» с учетом глобального характера загрязнения.

Ключевые слова: энергетика, экономика, карбонизация, технологии, генерация доля, снижение.

С момента освоения человеком огня образование углекислого газа стало неотъемлемой частью при производстве и потреблениии различных видров энергии. В связи с этим декарбонизация экономики стала одной из востребованных направлений в области охраны окружающей среды, особенно по глобальному изменению климата. Во всем мире, в том числе и в Казахстане, уровень «карбонизационного» воздействия на атмосферу относительно объективно и досточно достоверно определяется в области энергетики. Например, для экспертной оценки объема выбросов CO_2 от производства тепловой и/или электрической энергии можно использовать удельный расход условного топлива на производство единицы этих видов энергии. При применении этого показателя (на уровне 0,3 кг у.т.) можно определить, что при производстве 1 кВт час электричества в Казахстане генерируется примерно 1 кг углекислого газа и приемлемым допущением такую же величину можно принять и при производстве 1 ккал тепловой энергии.

В результате, для Казахстана, производящего 100 млрд электрической энергии в год и примерно такое же количество тепловой энергии, ежегодные выбросы CO_2 могут составить 200 млн тонн или около 80 тонн в год с каждого квадратного километра территории. При таком определении участия страны в глобальном загрязнении Казахстан вполне относится к благополучным странам.

При этом Казахстан имеет большие технологические врозможности для снижения выбросов CO_2 в частности, в области энергетики. Заметное снижение выбросов позволит развивать экономику стрпаны без ограничения по потреблению требуемого вида энергии.

Экспертно можно предположить, что по объему применения когенерации при производстве электрической и тепловой энергии, при которой имеет место уменьшенная генерации CO_2, Казахстан входит в число первых 5 стран в мире. С другой стороны, Казахстан по структуре своей энергетики имеет возможность разработки и реализации программы по существенному снижению уровня выбросов CO_2 при «традиционной» технологии производства электрической и тепловой энергии. Очевидно, что при этом, в первую очередь следует рассматривать технологии, реализация которых возможно в очень короткие сроки по вполне приемлемой стоимости. В их число несомненно могут быть включены:

- перевод всех котельных, работающих на природном газе на совместное производство электрической и тепловой энергии через установку газотурбинных установок и/или газопоршневых агрегатов [1}- своего рода миниТЭЦ. Это решение может быть быстро реализовано чисто административным путем, например, принятием решения Правительства об ограничении поставок газа котельным, производящих только тепловую энергию, начиная с 2022 года. Такое решение присутствует в некоторых Европейских странах (Дания и другие). Одновременно можно принять решение, которое будет экономически стимулировать этот режим, например, в виде постановления Правительства Казахстана об обязательном приобретении этого электричества по повышенной цене по аналогии с приобретением электричества от источников на возобновляемой энергии. При таком подходе срок окупаемости установки газовых агрегатов малой мощности для котельных окажется на уровне 3 лет. Можно также объявить, что это правило (приоритетное приобретение электричества от котельных) будет действовать до 2025 года. Можно будет уверенным, что сочетание такого административного и экономического решений существенно ускорит реализацию этой технологии. Снижение выбросов только в городе Алматы - свыше 200 тысяч тонн в год.

- принуждение всех паротурбинных ТЭС, сжигающих природный газ на переход в режим ПГУ [2]. Это решение может быть реализовано практически теми же путями, которые предлагались для газовых котельных. Возможный объем снижения выбросов при производстве по этой технологии может составить около 1 млн тонн в год.

- установку турбодетандеров (имеющих высочайшую маневренность – на уровне гидравлических турбин) на всех узлах газовой сети в местах перехода с более высокого давления на пониженное давление. Эта технология применяется в России и в Узбекистане, и в Казахстане может быть реализовано упомянутыми административными и экономическими методами. Возможное снижение выбросов CO_2 - несколько сотен тонн в год.

Можно отметить, что все перечисленные технологии давно известны и реализованы на многих энергетических объектах стран мира и СНГ, в Казахстане пока отсутствуют. Другими, менее известными, но вполне реализуемыми технологиями снжения генерации CO_2 могут быть:

- максимальный перевод отопления многоквартирных домов и промышленных предприятий на комбинированное водяное/воздушное отопление [1]. Привлекательность этой технологии состоит в возможности реализации везде, где присутствует водяное отопление (которое превалирует в Казахстане). Однако это технологическое решение в отличие от предшествующих пока имеет очень ограниченное применение, даже в мире. В Казахстане уже имеется несколько промышленных предприятий, которые реализовали это решение (снижение потребления тепловой энергии на 10-15 процентов от общего объема «отопительной» тепловой энергии). Эта технология, в определенной степени, разработана в Алматинском университете энергетики и связи имени Гумарбека Даукеева, академиком Алияровым Б.К. Очевидно, что объем снижения будет более 1 млн тонн за отопительный период.

- развитие «гибридного общественного транспорта» – аналог гибридных легковых автомобилей со снижением потребления бензина более чем в три раза – сотни тонн снижения выбросов CO_2 в сутки, только в Алматы. Для реализации этой технологии требуется совсем немного – принять решение об организации их производства в стране. Вполне можно ожидать начала этого производства примерно через 6 месяцев от начала финансирования проекта. Определенные наработки в этом направлении уже проводятся в Казахстане, и такое предложение направлено в акимат г. Алматы академиком Алияровым Б.К.

- развитие централизованного кондиционирования воздуха через генерацию холода на основе использования тепла дымовых газов и адсорбционных и/или компрессионных машин уже

применяется в ряде стран. Однако его применение в Казахстане встретится примерно теми же трудностями, которые указывались при обсуждении комбинированного отопления. Снижение выбросов CO_2 (только в Алматы) может составить свыше 100 тысяч тонн за период работы кондиционеров. Дополнительным выигрышем этой технологии для потребителей может быть возможность поступления охлажденного воздуха во все комнаты и его включения только в используемом помещении.

- развитие тепличных хозяйств и/или животноводческих ферм на основе сбросного, практически «дармового» тепла от конденсационных ТЭС – трудно прогнозировать объем снижения CO_2 - но ясно, что много.

Имеются еще несколько технологий, требующих проведения более глубоких исследований, по которым имеются также некоторые наработки.

Очевидно, что реализация указанной программы позволит Казахстану быстро уменьшить объем выбросов CO_2 и соответственно углеродные налоги будут снижены, что будет способствовать повышению конкурентой возможности казахстанской экспортной продукции с относительно большим потреблением электрической энергии – производство цветных и редкоземельных металлов и ферросплавов.

Видимо, мировому сообществу необходимо принять определенные решения по «справедливому» установлению степени участия конкретной страны в глобальном загрязнении выбросами CO_2. Например, если определять выбросы на одного жителя страны, то по минимальному объему выбросов на первом месте окажется, несомненно, Бангладеш, за ним расположатся Индия и другие страны – с большим населением при малом потреблении электрической и тепловой энергии. Наверное, в число «благополучных» стран попадут и некоторые Европейские страны (Чехия, Нидерланды и другие).

Однако при пересчете загрязнения на выбросы с единицы площади, та же Бангладеш (даже при нынешнем минимальном потреблении электричества и тепла) уйдет из первого места в район первых 20 стран. На «благополучные» места выйдут страны с большой территорией: Россия, Австралия, Канада и другие.

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ҚАЗАҚСТАН ЭКОНОМИКАСЫН ДЕКАРБОНИЗАЦИЯЛАУДЫҢ ЕРЕКШЕЛІКТЕРІ МЕН ЖОЛДАРЫ

Аннотация. Мақалада жылу және электр энергиясын органикалық отын жағу жолымен өндіргенде міндетті түрде CO_2 газының пайда болуы жайында баса айтылған және мысал ретінде Қазақстандағы энергетикалық нысандарда газ шығару көлемін анықтау жолдары қарастырылған. Жылу мен электрдің бір өлшемі шығарылғанда жұмсалатын шартты отын (көміртектік) көлемі арқылы пайда болатын көмір қышқыл газ көлемін анықтауға болатыны көрсетілген. Жылу мен электр өндіргенде пайда болатын CO_2 көлемі азырақ болатын және жылдам уақытта ендіруге жарамды технолгиялар келтірілген және кемудің нақты көлемі анықталған. Сондай-ақ, осы технологияларды ендірудегі әкімшілік және экономикалық ынталандыру жолдары да аталған әрі осыған қажетті Үкімет шешімдері де келтірілген. Ұсынылатын технологиялар қолданылғанда CO_2 газының кему көлемі де есептелген, ықтимал қиындықтар да аталған.

Мақалада белгілі бір елдің әлемді ластау үлесін анықтаудың «әділ» жолын анықтау қажеттігі көрсетілген. Есептеу жолына қарай, белгілі бір нақты ел біресе «дұрыс» ел қатарына «кіріп» немесе «дұрыс емес» ел атануы мүмкін. Мысал ретінде алғанда, егер ластанған зат шығарындысының келтірілген көлемін ел тұрғындарының санына қарай сәйкестендіре есептегенде әлемді ластандыру үлесі аз елдер қатарындағы алғашқы орынға Бангладеш, келесі орында Үндістан сияқты жер көлемі аз, халық саны көп елдер шығатыны сөзсіз. Ластанған зат шығарындысының келтірілген көлемі жер көлеміне қарай есептелсе, онда алғашқы орынға Ресей, Канада, Австралия шығады. Осыған сәйкес ластану үлесін жер көлемінің бір өлшеміне сәйкестендіре қарастырудың «әділ» болатыны айтылған.

Түйін сөздер: энергетика, экономика, карбондау, технология, үлес генерациясы, төмендету.

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FEATURES AND WAYS OF DECARBONIZATION ECONOMY OF KAZAKHSTAN

Abstract. The article emphasizes the inevitability of the formation of CO2 in the production of thermal and electric energy with the combustion of fossil fuel and analyzes the sources of carbon dioxide generation at power facilities in Kazakhstan. Technologies for the production of electrical and thermal energy with reduced generation of carbon dioxide, which are being implemented in a short time, are discussed. A possible method for quantifying the level of CO2 emissions for the conditions of Kazakhstan is shown, through the use of the specific consumption of conventional (carbon) fuels for production as a unit of thermal energy and / or electricity. A number of available and relatively cheap technological solutions are presented, which, when implemented, can significantly reduce carbon dioxide emissions. It is noted that these technologies can be implemented administratively and economically, and the formulations of the required decisions of the Government are given. For each of the proposed technologies, an assessment of possible volumes of reduction of carbon dioxide emissions is given and difficulties that may be encountered during implementation are indicated.

A scheme for determining the degree of participation of a particular country in global carbonation is considered and it is shown that, depending on the method of "spreading" the total volume of emissions of a particular country, one and the same country can be both among prosperous countries and among a number of countries to which it is necessary to apply strict "carbon" taxes. It is noted that the determination of the share of a particular country in the form of emissions per unit area of the country's territory seems to be more "fair" taking into account the global nature of pollution.

Key words: energy, economics, carbonation, technology, generation, share, decline.

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ACCEPTANCE TESTS OF THE SOFTWARE AND TECHNICAL COMPLEX OF THE HIGH-PRECISION SATELLITE POSITIONING SYSTEM IN THE KACHARSKY MINE

Abstract. The world development of science and technology prompts many countries to use their own modern coordinate systems, determined on the basis of satellite measurements. Moreover, the modern system must be characterized by its openness and unity for the entire territory of the country. One of the main problems arising during the creation and operation of our own high-precision positioning satellite systems in the Republic of Kazakhstan are: the lack of domestic satellite equipment, specialized software and test methods for the software and hardware complex.

A unique opportunity appeared in the development and testing of the software and hardware complex of the high-precision satellite positioning system at the Kacharsky open pit thanks to the funding of the Science Committee of the Ministry of Education and Science of the Republic of Kazakhstan through grants for scientific and technical projects for 2018–2020 (grant No. AP05136083) and co-financing of the private partner JSC «SSGPO».

The article presents the results of technical solutions for the implementation of a high-precision satellite positioning system, in particular, the creation of a permanent base station (BS) of global navigation satellite systems (GNSS) at operating open pit. The primary purpose of the work is to provide high-precision positioning of an open field in order to determine geodetic coordinates using modern satellite navigation technologies in real-time and post-processing. This development continues the path of introducing the elements of Industry 4.0, which is currently being carried out at the Kacharsky open pit.

Key words: GNSS, satellite high-precision positioning system, mine, base station of differential correction (BSDC), acceptance tests, center of differential correction (DCC).

Introduction. This article presents the results executed during acceptance tests for the introduction of a high-precision satellite positioning system into commercial operation at the Kacharsky open pit. The tests were carried out in joint cooperation with the project co-executor (Institute of space technique and technology) and a private partner (JSC «SSGPO»).

In particular, the following works were implemented in the tasks of solving the problems of commissioning:

- installation and adjustment works of the base station of differential correction (BSDC);
- preliminary tests of differential correction center (DCC);
- preliminary tests of the high-precision satellite positioning system;
- trial operation of a high-precision satellite positioning system;
- acceptance tests of a high-precision satellite positioning system for commercial operation.

Installation and adjustment works of the base station of differential correction. A permanent geodetic point with the name "Base" was installed on the roof of the administrative building (AB) during the installation process. At this geodetic point, a GNSS antenna was mounted along with the corresponding cables, which is part of the BSDC.

The following locations were checked in the process of testing: a geodetic point on the parapet of the AB; navigation and transmitting complexes of BSDK on the buildings of the AB, the Control room, as well as on the antenna mast near the Control room (see figure 1). The compliance of the location of the geodetic point and the complexes of the BSDC were checked in accordance with the requirements of technical, industrial safety and working-design documentation of the SVSN (high-precision satellite navigation system) [1,2].

The possibilities of functioning, operability, and technical characteristics of the three complexes of the BSDC were tested separately and in general when the BSDC was operating as one system. The tests were accomplished on the BSDC complexes, which are considered to have passed the tests: after turning on the equipment as part of the BSDC, they operate in a normal mode and do not give false information in any operating modes. The parameters correspond to the established operating modes of the equipment as part of the BSDC, the characteristics correspond to the data specified in the operational documentation for these products.

Based on the results of checking the functional purpose of the BSDC and checking the operability and technical characteristics of the BSDC, the following was revealed:

– the obtained technical characteristics of the tested complexes of the BSDC correspond (do not exceed) the declared by BSDC developer;

– operability and compliance with the specified technical characteristics of the BSDC are confirmed by the Protocol of installation and adjustment works;

– fabrication and installation of a geodetic point in accordance with the requirements of SSGPO is confirmed by the Protocol of installation and adjustment works.

Installation and adjustment works of this stage were successfully carried out in the fall of 2019.

Pilot and industrial tests of the system were performed in August 2020 and are presented below.

Figure 1 – VHF antennas of the BSDC transmitting complex on the Control's room antenna mast

Preliminary tests of the center for differential correction. The Center for Differential Correction (DCC) is a software and hardware complex for controlling and monitoring the state of the base station of differential correction (BSDC), which in turn refers to systems for receiving and processing navigation signals, as well as issuing correcting satellite navigation information. The DCC is also used to receive, process, and transmit satellite navigation parameters via the Internet.

Preliminary tests of the DCC were carried out in connection with the completion of work on the creation of a differential correction center (DCC) for the base station of differential correction (BSDC).

The purpose of the tests was a comprehensive check of the operability of the hardware and software of the DCC, as well as checking the functionality during its interaction and joint performance of tasks with the BSDC.

Preliminary tests were performed according to the following list of testing the functions of the DCC, presented in figure 2.

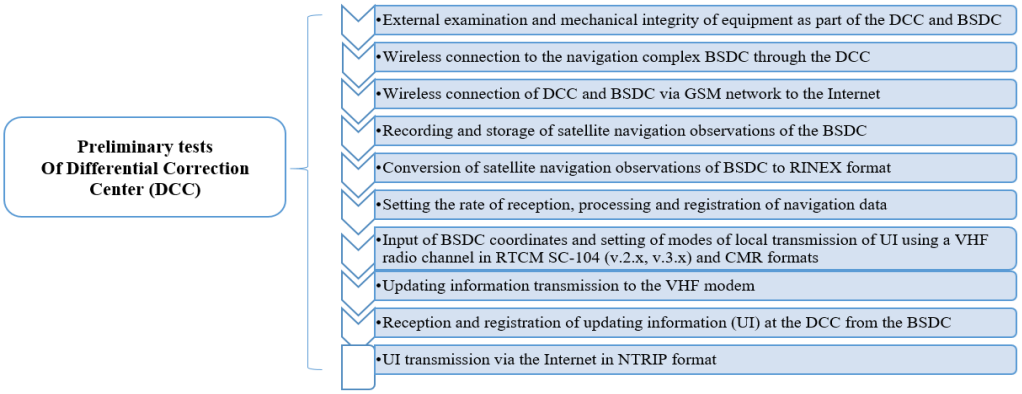

Figure 2 – List of testing the functions of the DCC

Failures, failures and emergencies in the work of the DCC were not revealed during the tests.

Results and conclusions on preliminary tests of the DCC:

– hardware and software of the DCC effectively interact with the BSDC and allow the BSDC to perform the functions assigned to it;

– the functionality of the DCC fully covers the functionality of the software (S) described in the project documentation "Specification of the BSDC", "Manual for the operation of the BSDC" and "Operator's manual for the processing of satellite measurement data".

Preliminary tests of the high-precision satellite positioning system. The purpose of the preliminary tests was a comprehensive check of the operability of the hardware and software of the high-precision positioning system (HPPS), which consists of three parts, namely the base station of differential correction (BSDC), the center of differential correction (DCC) and the geodetic point "Base" on the roof of the Mine Administration.

During the preliminary tests, systematic discrepancies in the measurements of the GNSS rover were revealed when using corrections from the BSDC and the “basa kachar” base station, previously installed at the Kacharsky mining complex. The reason for the discrepancy was the binding of the “basa kachar” base station to the local coordinate system (LCS) of the Kacharsky mine, while the installed BSDC was linked to the international coordinate system ITRF-2014. On the recommendation of the representatives of JSC «SSGPO», the coordinate values entered in the BSDC were changed by binding to the local frame of reference of the Kacharsky open pit in order to eliminate the discrepancies.

Arbitrary points have been measured by a rover in the study area to compare coordinates and elevations in the LCS when receiving corrections through VHF channels from the “basa kachar” and BSDC base. The results of calculating the discrepancies in the measurement values at 12 randomly selected points and the analysis of these discrepancies are presented in table 1.

As can be seen from Table 1, the discrepancies were systematic. On average, the differences were 1.996 meters north, 2.281 meters east and 1.293 meters in height, with a variation coefficient of 0.85% north, 1% east, and 7% in height. Therefore, it was assumed that the reason for the discrepancies was the displacement of the centers of the coordinate systems relative to which the rover coordinates were measured using corrections from two different base stations. The reason for the discrepancy was the definition and assignment of coordinates of the base "basa kachar" and BSDC in different coordinate systems. The coordinates "basa kachar" were determined in the LCS of the Kacharsky open-pit mine, while the coordinates of the BSDC, according to the previously made draft and technical design, were determined in the international coordinate system ITRF-2014 [3,4].

The coordinates of the BSDC were redefined and set this time in the LCS of the Kacharsky open pit to eliminate the discrepancy. Particularly, it was decided to determine and set the coordinates of the phase center of the GNSS antenna of the BSDC using the differential correction operation relative to the base station "basa kachar". This operation included joint processing of satellite navigation measurements in the RINEX format, made simultaneously for 6 hours on the basis of "basa kachar" and BSDC. New coordinates for the BSDC were determined and set as a result of the operation.

Table 1 – Analysis of discrepancies between measurements at corresponding points

Measurement name	North (X, meters)	East (Y, meters)	Height (meters)
1	1,974	-2,319	1,008
2	2,003	-2,279	1,317
3	1,997	-2,287	1,341
4	1,993	-2,288	1,326
5	1,987	-2,304	1,333
6	1,975	-2,297	1,331
7	1,984	-2,297	1,320
8	2,000	-2,255	1,312
9	1,991	-2,288	1,311
10	2,037	-2,244	1,302
11	2,010	-2,270	1,304
12	2,002	-2,248	1,313
Expected value	1,9960833	-2,28133	1,293167
Dispersion	0,0002875	0,000534	0,008205
Standard deviation	0,0169569	0,023114	0,090581
The coefficient of variation	0,0085	-0,01013	0,070046

The discrepancies in the measurements of the GNSS rover when using corrections from the BSDC and the base station "basa kachar" were minimized and constitute an acceptable error within the normal range after setting the new coordinates.

Trial operation of a high-precision satellite positioning system. The purpose of the trial operation was to determine the actual values of the quantitative and qualitative characteristics of the high-precision positioning system and the readiness of the mine surveyor service to work in the conditions of its functioning, to determine the actual efficiency of the hovercraft, as well as to correct the corresponding working design documentation.

During the trial operation the following components were checked: technical; software and information support for HPPS; according to the lists presented in figure 3.

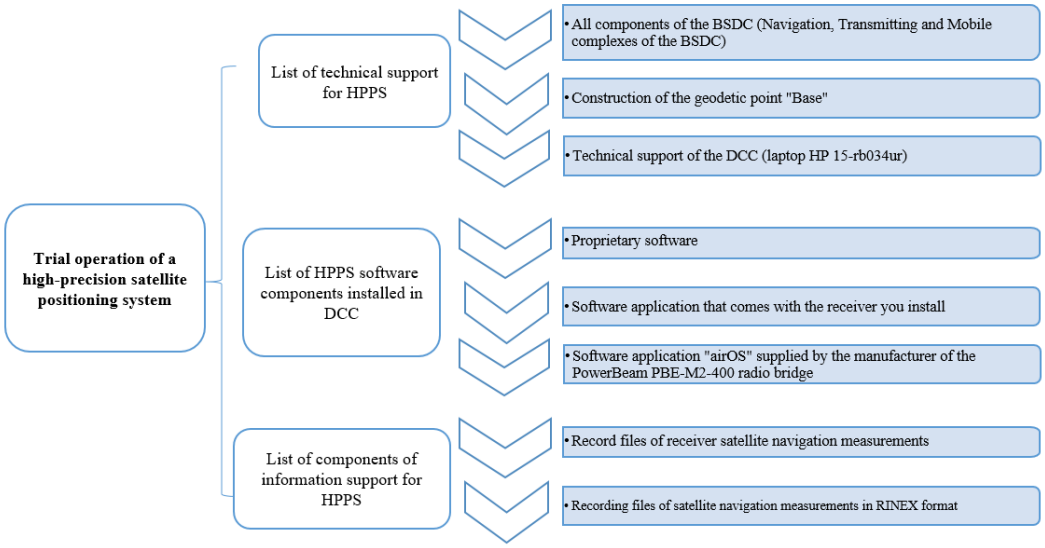

Figure 3 – List of tests during trial operation

The following verification results were obtained: the trial operation program was completed in full; the mine surveying service of the Kacharsky mining complex has high competence when performing work using the functionality of the HPPS; HPPS and its technical documentation are ready for commissioning.

Acceptance tests of the high-precision satellite positioning system into commercial operation. BSDC and DCC were developed as a result of the creation of a high-precision satellite positioning system (see figure 4). BSDC is a ground-based fixed station for receiving and processing GLONASS/GPS/BeiDou signals. The base station of differential correction is intended for the automated reception of navigation signals, processing, storage, and provision of navigation data to consumers in the served area, as well as for transmission of navigation data and service information to the DCC. The satellite navigation antenna of the BSDC was fixed in the geodetic point "Base" on the roof of the mine administration. The "Base" point is included in the geodetic reference network of the Kacharsky field of JSC SSGPO, the coordinates of which were in SC WGS-84 and consequently recalculated in SC ITRF-2014 in order to link to the international geodetic network IGS and to the local coordinate system.

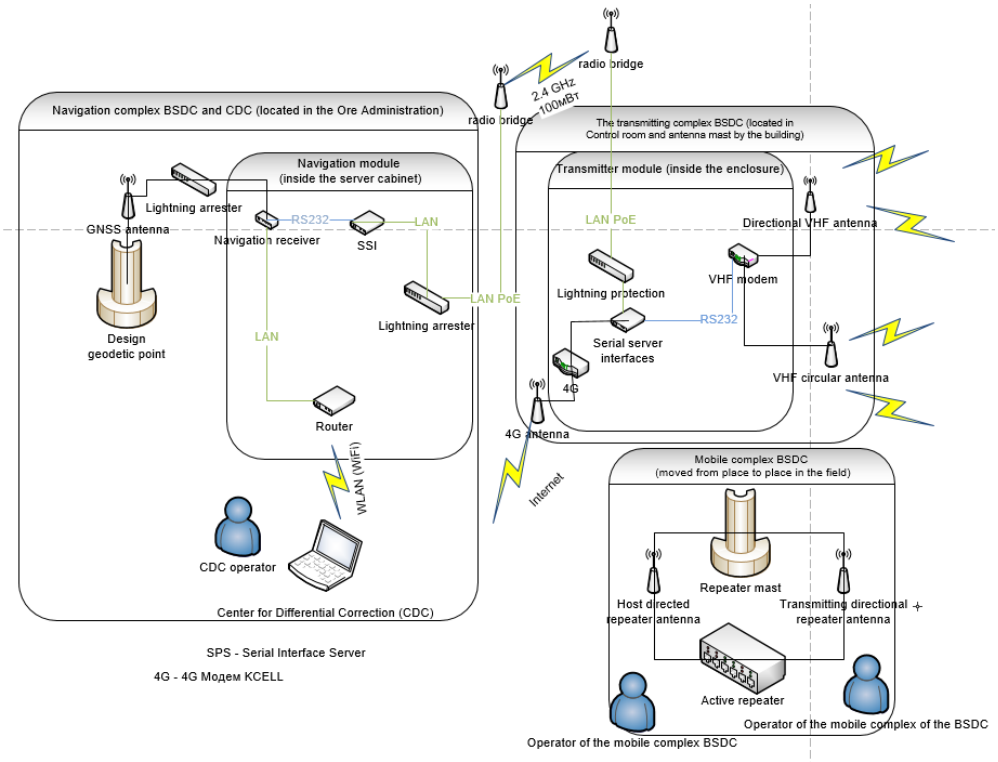

Figure 4 – Location of the BSDC complexes

The scientific and technical level of the development of this system corresponds to the world level of development of permanent GNSS base stations. The developed system and its technical documentation were taken into commercial operation.

Conclusion. The significance of this project is to ensure high-precision positioning of mining allotments and will allow solving two main problems of open-pit mining in the near future: increasing labor productivity through the introduction of digital technologies and significantly increasing the industrial and environmental safety of mining operations [5]. The experience of implementing a high-precision positioning system at the Kacharsky field makes it possible to use it at other mining enterprises in Kazakhstan.

It should be noted that there is an increased interest abroad in solving engineering-geodetic and cadastral problems based on the technology of Continuously Operating Reference Station (CORS). CORS was implemented in the United States by the National Geodetic Service (NGS) in 1995. In 2008, CORS united more than 1500 stations of various organizations throughout the country and continues to expand rapidly [6,7]. These stations are independently operated. Each owner provides his data to the NGS service,

which analyzes, processes, and distributes them free of charge for post-processing [8,9]. The authors see the same development prospects when creating a unified coordinate, time, and navigation support system for our country. Considering the scale of the use of satellite technologies when performing engineering-geodetic and cadastral works, equalizing the coordinates of single base stations and creating permanent reference networks in the territory of the Republic of Kazakhstan is an urgent task [1].

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ҚАШАР КАРЬЕРІНДЕ ДӘЛДІГІ ЖОҒАРЫ СПУТНИКТІК ЖАЙҒАСТЫРУ ЖҮЙЕСІНІҢ БАҒДАРЛАМАЛЫҚ-ТЕХНИКАЛЫҚ КЕШЕНІН ҚАБЫЛДАУ СЫНАҚТАРЫ

Аннотация. Ғылым мен техниканың әлемдік даму жағдайы көптеген елді жерсеріктік өлшеулер негізінде анықталған өздерінің заманауи координаттар жүйесін қолдануға итермелейді. Сонымен қатар, қазіргі заманғы жүйе бүкіл ел үшін өзінің ашықтығы мен бірлігі арқылы сипатталуы керек. Қазақстан Республикасында тиесілі жоғары дәлдікті жерсеріктік жайғастыру жүйелерін құру және пайдалану кезінде туындайтын негізгі мәселенің бірі – отандық жерсеріктік аппаратураның, мамандандырылған бағдарламалық қамтылым мен бағдарламалық-техникалық кешенді сынау әдістемесінің болмауы.

ҚР БҒМ Ғылым комитетінің 2018-2020 жылдарға арналған ғылыми-техникалық жобаларға гранттар (№AP05136083 грант) желісі бойынша қаржыландыру және «ССКӨБ» АҚ жеке әріптесін қоса қаржыландыруының арқасында Қашар карьерінде дәлдігі жоғары жерсеріктік жайғастыру жүйесінің бағдарламалық-техникалық кешенін әзірлеу мен апробациялауда бірегей мүмкіндік пайда болды.

Әзірленген дифференциалды түзетудің базалық станциясы навигациялық сигналдарды автоматты қабылдауға, қызмет көрсетілетін аумақтағы навигациялық деректерді өңдеуге, сақтауға және тұтынушыларға ұсынуға, сондай-ақ навигациялық деректер мен қызметтік ақпаратты сараланған түзету орталығына беруге арналған. Дифференциалды түзетудің базалық станциясының (ДТБС) спутниктік навигациялық антеннасы кен басқармасының төбесіндегі «База» геодезиялық пунктіне бекітілді. «База» пункті «СК-84 координаттары IGS халықаралық геодезиялық желісіне және жергілікті координаттар жүйесіне байланыстыру мақсатында ITRF-2014 СК қайта есептелген «ССКӨБ» АҚ Қашар кен орнының тірек геодезиялық желісіне кіреді.

Мақалада Қашар карьерінде өнеркәсіптік пайдалануға жоғары дәлдікті жерсеріктік жайғастыру жүйесін енгізу үшін қабылдау сынақтарын жүргізуде орындалған нәтижелер ұсынылған. Сынақтар жобаның бірлескен орындаушысымен (Ғарыштық техника және технологиялар институты) және жеке серіктеспен («ССКӨБ» АҚ) бірлесіп жүргізілді. Атап айтқанда, дифференциалды түзету базалық станциясының монтаждау және іске қосу-жөндеу жұмыстары; дифференциалды түзету орталығының алдын ала сынақтары; жүйенің алдын ала және тәжірибелік сынақтары жүргізілді.

Дифференциалды түзету орталығының (ДТО) функцияларын тестілеу және тәжірибелік пайдалану кезінде тексеру жүргізілген тізбелер келтірілген. Жүргізілген сынақтардың негізгі міндеттері мынадай: ДТО-ның техникалық және бағдарламалық қамтамасыз етуінің жұмысқа қабілеттілігін кешенді тексеру, сондай-ақ ДТО-ның өзара екіжақты қатынасы мен міндеттерін ДТБС-мен бірлесіп орындау кезінде оның функционалдығын тексеру; жоғары дәлдікті позициялау жүйесінің (ЖПЖ) техникалық және бағдарламалық қамтамасыз етулерінің жұмысқа қабілеттілігін кешенді тексеру; жоғары дәлдікті позициялау жүйесінің сандық және сапалық сипаттамаларының нақты мәнін және маркшейдерлік қызметтің жұмыс істеу жағдайындағы жұмысқа дайындығын айқындау, ЖПЖ нақты тиімділігін анықтау, сондай-ақ тиісті жұмыс конструкторлық құжаттамасын түзету.

Осы жүйені әзірлеудің ғылыми-техникалық деңгейі ҒНСЖ тұрақты жұмыс істейтін базалық станцияларын әзірлеудің әлемдік деңгейіне сәйкес келеді. Әзірленген жүйе және оның техникалық құжаттамасы өнеркәсіптік пайдалануға қабылданды.

Жалпы жұмыстың негізгі мақсаты – нақты уақыт және өңдеуден кейінгі режимде заманауи серіктік навигациялық технологиялар арқылы геодезиялық координаталарды анықтау үшін ашық кен орнын жоғары дәлдікті жайғастырумен қамтамасыз ету. Қазіргі уақытта Қашар карьерінде жүзеге асырылып жатқан әзірленген жүйе (ЖПЖ) Индустрия 4.0 элементтерін енгізу жолын жалғастыруда.

Түйін сөздер: ҒНСЖ, жоғары дәлдікті позициялаудың спутниктік жүйесі, карьер, дифференциалды түзетудің базалық станциясы (ДТБС), қабылдау сынақтары, дифференциалды түзету орталығы (ДТО).

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ПРИЕМОЧНЫЕ ИСПЫТАНИЯ ПРОГРАММНО-ТЕХНИЧЕСКОГО КОМПЛЕКСА СИСТЕМЫ ВЫСОКОТОЧНОГО СПУТНИКОВОГО ПОЗИЦИОНИРОВАНИЯ НА КАЧАРСКОМ КАРЬЕРЕ

Аннотация. Мировое развитие науки и техники побуждает многие страны применять собственные современные системы координат, определенные на основе спутниковых измерений. При этом современная система должна характеризоваться своей открытостью и единством для всей территории страны. Одними из основных проблем, возникающих при создании и эксплуатации собственных спутниковых систем высокоточного позиционирования в Республике Казахстан, являются: отсутствие отечественной спутниковой аппаратуры, специализированного программного обеспечения и методики испытаний программно-технического комплекса.

Благодаря финансированию Комитета науки МОН РК по линии грантов на научно-технические проекты (грант № AP05136083) на 2018–2020 гг. и софинансированию частного партнера АО «ССГПО», появилась уникальная возможность в разработке и апробировании программно-технического комплекса системы высокоточного спутникового позиционирования на Качарском карьере.

Разработанная базовая станция дифференциальной коррекции предназначена для автоматизированного приёма навигационных сигналов, обработки, хранения и предоставления потребителям навигационных данных на обслуживаемой территории, а также для передачи навигационных данных и служебной информации в центр дифференциальной коррекции. Спутниковая навигационная антенна базовой станции дифференциальной коррекции (БСДК) была закреплена на геодезическом пункте «База» на крыше рудоуправления. Пункт «База» входит в опорную геодезическую сеть Качарского месторождения АО «ССГПО», координаты которой в СК WGS-84 были пересчитаны в СК ITRF-2014 с целью привязки к международной геодезической сети IGS и в местную систему координат.

В статье представлены результаты, выполненные при проведении приёмочных испытаний для введения системы высокоточного спутникового позиционирования в промышленную эксплуатацию на Качарском карьере. Испытания проводились совместно с соисполнителем проекта (Институт космической техники и технологий) и частным партнером (АО «ССГПО»). В частности, были проведены: монтажные и пусконаладочные работы базовой станции дифференциальной коррекции; предварительные испытания центра дифференциальной коррекции; предварительные и опытные испытания системы.

Приведены перечни, по которым проводилось тестирование функций центра дифференциальной коррекции (ЦДК) и проверки при опытной эксплуатации. Основные задачи проведенных испытаний заключаются в следующем: комплексная проверка работоспособности технического и программного обеспечений ЦДК, а также проверка функциональности ЦДК при его взаимодействии и совместном выполнении задач с БСДК; комплексная проверка работоспособности технического и программного обеспечений системы высокоточного позиционирования (СВП); определение фактических значений количественных и качественных характеристик системы высокоточного позиционирования и готовности маркшейдерской службы к работе в условиях его функционирования, определение фактической эффективности СВП, а также корректировка соответствующей рабочей конструкторской документации.

Научно-технический уровень разработки данной системы соответствует мировому уровню разработок постоянно действующих базовых станций ГНСС. Разработанная система и ее техническая документация приняты в промышленную эксплуатацию.

Основной целью всей работы является обеспечение высокоточным позиционированием открытого месторождения, для определения геодезических координат с помощью современных спутниковых навигационных технологий в режимах реального времени и постобработки. Данная разработка продолжает путь внедрения элементов Индустрии 4.0, который в настоящее время осуществляется на Качарском карьере.

Ключевые слова: ГНСС, спутниковая система высокоточного позиционирования, карьер, базовая станция дифференциальной коррекции (БСДК), приемочные испытания, центр дифференциальной коррекции (ЦДК).

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EXPERIMENTAL SUBSTANTIATION OF SOIL SELECTION IN RECONSTRUCTION OF A MAIN GAS PIPELINE

Abstract. The results of complex geotechnical studies aimed at creating a temporary soil dam for the reconstruction of the main gas pipeline are conducted. Based on the study of the properties of the three types of soils that are in the vicinity, the technical-economical efficiency and prediction of the compaction of the recommended soil are substantiated. The choice of soil laid in the dam should be carried out on the basis of the study of the properties of soils and feasibility study. Technical-economical assessment is impossible without knowledge of the characteristics of the soil, which were obtained in laboratory conditions. Three series of experiments were performed for this: determination of soil density; determination of the angle of repose; determination of soil filtration coefficient. The parameters were investigated in the course of the experiments, on which the quality of the soil dam depends to the greatest extent: density; angle of repose during dumping; filtration properties (filtration coefficient). Based on an analysis of the current situation, proceeding on environmental requirements and considerations of economic feasibility, it was proposed to fill in a temporary embankment to allow the piles to be loaded by driving, and to make it out of medium-sized sand composing the surface thickness in a given area. On the assumption of the technological requirements of the reconstruction, the dam should be 5 m high and 36 m high on the top and 51 m high on the bottom. Based on experimental-analytical researches, a motivated choice of soil is substantiated, which made it possible to obtain an economic effect confirmed by the act.

Key words: dam, embankment, soil density, angle of slope, filtration coefficient, artificial sandy foundations, laying of sandy foundations, compacted bulk soils, quality control, monitoring of the formed foundation, geotechnical indicators driven pile.

Introduction. The need to reconstruct the passage of the main gas pipeline through the Syr-Darya river is associated with the destruction of the support of the metal trestle No. 19 and the roll of six more supports No. 13, 16, 17, 18, 20 and 21, caused by the movement of ice in 2008**.**

The impossibility of exploitation the gas pipeline after its damage is confirmed by a technical examination of the condition of the supports of LLP «Constructor Sapa» and an act of inspection of the gas pipe itself by specialists of the exploitation organization.

Each support, according to the initial project, is made of 4 metal driven piles from a pipe with a diameter of 426 x 10 mm, loaded to the depth of 17 m, with support in a paleogene-neogene layer.

The grillage of pile supports is 3.5 x 1.5m in size of design and 0.95m in height, made of welded metal structures, is located above the water level in height of 5 m. Each pile is a sheath, reinforced and concreted after driving. Piles are interconnected by metal bonds.

The overpass has been in trouble-free exploitation for about 25 years, right up to the above damage caused by ice drift. Only those supports located in the deep water of the river bed were destroyed.

According to the justifications of the construction organization carrying out the reconstruction of the overpass, the structure of the restored supports (the amount of piles, the dimensions of the foundations, the

material, the type of piles and the grillage) and the local experience in the construction of piles are proposed to leave the former, adopted in accordance with the original version and confirmed its operational suitability for a number of years [1]. To make an additionally protective structures (icebreakers) in the most dangerous places to prevent repeated damage to the pier supports during the flood and ice drift.

However, it seemed problematic to choose a method of piling, because there is no necessary surfacing means, and, in addition, creation of a structure is required with a 5 m exit of piles above the water level (with a high grillage).

Based on an analysis of the situation, proceeding on environmental requirements and considerations of economic feasibility [2-12], it was proposed to fill in a temporary embankment to allow the piles to be immersed by driving, and to make it out of local soil. On the assumption of the technological requirements of the reconstruction, the dam should be 5 m high and 36 m high on the top. The size of the base of the embankment will depend on the type of soil being poured. The required dimensions of the embankment mainly depend on the angle of repose and the strength characteristics of the soil to be filled [13-18]. Based on local conditions, the following can be used: sand of medium size (SMS), medium density (EGE-3), which forms the channel of the Syr-Darya river; fine sand (FS), loose (EGE-2; 2a), located in the immediate vicinity of the river; loams lying 30 km away from the dam.

Methods. In the first series of experiments, the determination of soil density was carried out according to the standard method. All experiments in this series tests were repeated five times and were carried out on medium sand and fine sand initially in a dry state. . In this case, four states of each of the sands were artificially created: minimal compaction (by simply pouring soil into the cutting ring); weak compaction; strong compaction; possible maximum compaction. Moreover, knowing the mass of soil to create the minimum and maximum compaction, a weak and strong compaction with equidistant intermediate values was modeled.

In the second series of tests, the angle of repose of SMS and FS was also determined by the standard method. For dry and water-saturated loose sands, the value of the angle of repose practically coincides with the angle of internal friction. In the air-dry state $\varphi = 30 \ldots 40$, under water $\varphi = 24 \ldots 33$.

The third series of experiments was devoted to the determination of the coefficient of soil filtration. At this point, due to the information obtained in experiments on determining the density and angle of repose of SMS and FS, is already set a definite opinion about the preference for using SMS for dumping the dam. However, the question of the filtration coefficient, its dependence on the density of soil laying, the possibility of water penetrating through the body of the dam, etc., remained unclarified. Therefore, in this series of experiments, the main attention is paid to the study of the filtration coefficient of SMS. At the same time the value was determined depending on the density of SMS laying, which was created similarly to the experiments in the first series, that is, with: minimal, weak, strong and maximum compaction. Laboratory tests to determine the filtration coefficient for SMS and FS were carried out according to standard methods. The experiments were carried out with triplicate determination at various values of the hydraulic gradient J and the average value was found. In each test the measurements were carried out at 7-8 different positions of the water level in ballon and the obtained data were averaged.

Results. In accordance with the report on engineering-geological conditions in this area, fine and medium-sized sandy soils dominate from the surface without distinct facial borders (EGE No. 1,2,3), which are lined with clays from a depth of 16 m. On the left bank sandy soils are covered by a layer of up to 1.5 m macroporous loam of solid consistency.

According to the nomenclature and physical-mechanical properties of soils, four engineering-geological elements (EGE) were identified within the transition area: EGE-1 – macroporous loam, subsiding (the subsidence of the loam from its own weight when soaking is 0.0 cm, the type of soil conditions of the site within the left bank by subsidence is the first); EGE-2 - fine sand, loose; EGE-2^a - fine sand, medium density; EGE-3- sand of medium fineness, medium density; EGE-4 –not swelling clay.

According to the results of the first series of tests was obtained the dependence of soil density on the degree of created compaction (figure 1).

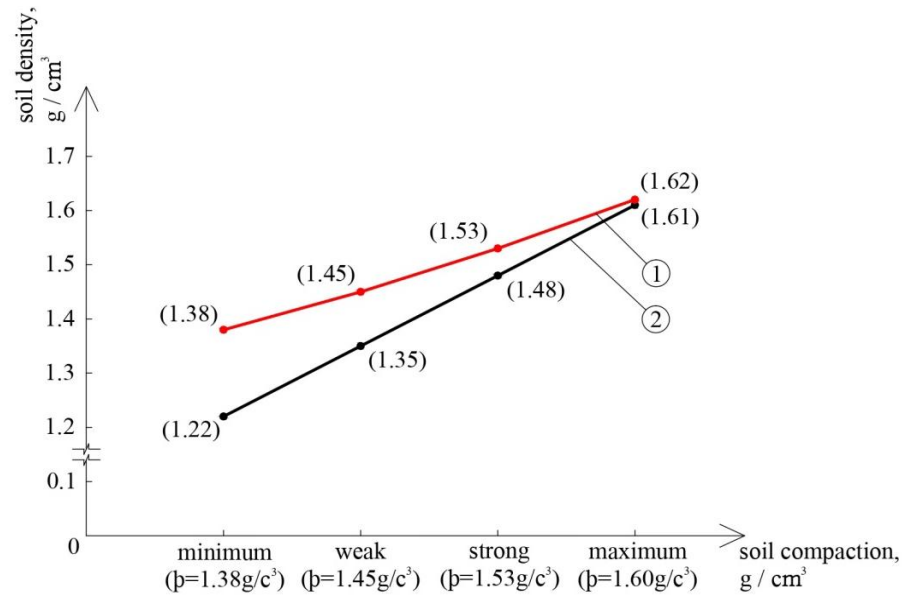

Figure 1 – The dependence of soil density (ρ) on the degree of compaction being created:
1 - for sand of medium size; 2 - for fine sand

Comparing the density values of SMS and FS simulated in laboratory conditions with the corresponding data obtained by LLP «Inzhenernyye izyskaniya» from samples of a natural undisturbed structure, can mention the natural state for SMS the density is 1.58 g/cm^3, and for FS- 1.52-1.54 g/cm^3, which corresponds to the state under laboratory conditions between strong and maximum compaction.

Therefore, we can make an intermediate conclusion that when laying in a dry state SMS is preferable for laying it in a dam in comparison with FS, in that this soil surpasses FS in almost all stages of its compaction. From the data it is also seen that the addition of the same soil masses to the same volume gives an uneven increment (in %) of the density. So, for SMS, the maximum increment ρ was for strong compaction, and for FS, for weak compaction it continued to fall from 10.7% to 9.5% (figure 2).

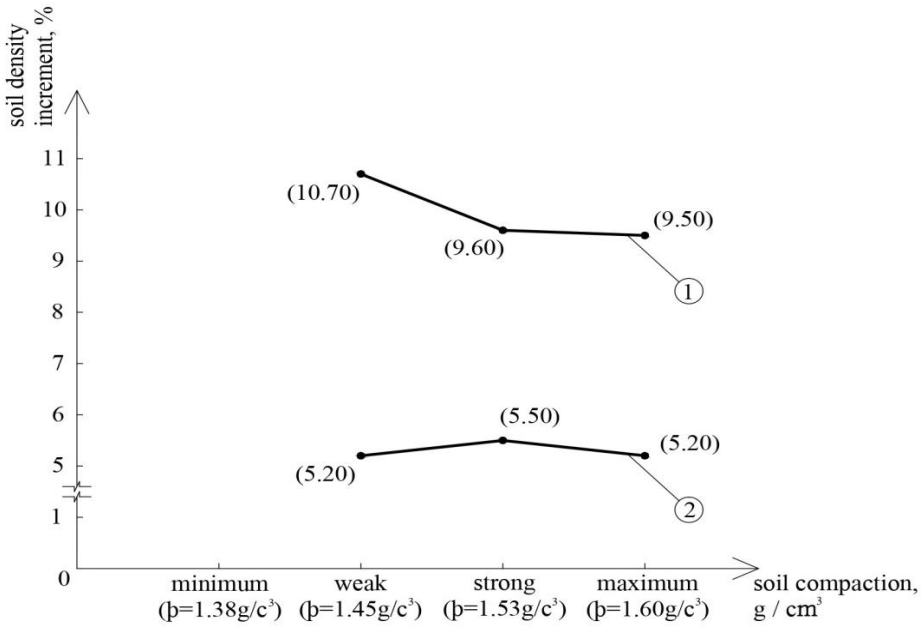

Figure 2 – The dependence of the increment of soil density on the degree of compaction:
1 - for sand of medium density; 2 - for fine sand

Interesting data were obtained when working with soils (SMS and FS), in conditions of their full saturation with water. By preliminary experiments, when soil samples of a disturbed structure were saturated with water so that it protruded to the surface and completely covered the soil, and then merged.

The density was reached so high that it is not possible to immerse the cutting ring with the efforts of a person's hands (without hammering). Experimentally obtained: ρ_1 = 1.53 g/cm^3; ρ_2 = 1.89 g/cm^3.

As a result of the second series of experiments, it was found that the angle of repose of the FS was greater than that of SMS α_{av}^{SMS} = 27,99° < α_{av}^{FS}=31,34 ° (Δ = 12,6 %).

This ratio is observed for the averaged values of SMS and FS in the dry state $\alpha_{av.dry}^{SMS}$ = 31,50 ° < $\alpha_{av.dry}^{FS}$ = 31,34 (Δ = 11,3 %).

And in a water-saturated state $\alpha_{av.wat.}^{SMS}$= 24,48° < $\alpha_{av.wat.}^{FS}$= 27,61° (Δ = 12,8 %).

The obtained average value of the angle of repose α SMS turned out to be less than the angle of internal friction of the soil φ determined by LLP «Inzhenernyye izyskaniya» α_{av}^{SMS} = 27,99° < φ^{SMS} = 32-35° (Δ = 20%).

And the average value of the angle of repose α FS is greater than the angle of internal friction φ determined by LLP «Inzhenernyye izyskaniya» φ_{av}^{FS} = 31,34° > φ^{FS} = 26 - 29° (Δ = 14 %).

Although it is noted in the technical literature that α and φ can be fairly close to each other, these experiments have established the above-mentioned difference.

Based on the analysis of the experiments, the following results were obtained.

Determination of the angle of repose in the instrument "Box of Coulomb" can be determined quite unambiguously for dry loose soils and for clean sands in a soaked state .In the case of soaking loose soils, which along with the friction forces have some proportion of the adhesion forces between the particles, it is not possible to accurately determine the angle of repose due to the curvature of the inclined plane of the caving prism.

Comparison of the slope angles of medium-sized sand and fine sand showed that medium-sized sand is more preferable for dumping dams with the given sizes of top, bottom and height from the point of view of technical-economic feasibility.

Conclusion. The data obtained during the study indicate that SMS has a more predictable behavior when laying it in a dam, compared with FS. It was expressed in the fact that the FS unevenly mixes in water (spreading out over fractions), flows worse into the form, having viscosity, holds water for a longer time, it is necessary to exert more efforts when mixing it with water, etc. These experiments allowed us to make an important conclusion - about the possibility of creating a dam by washing the soil with a dredger. Moreover, the decisive argument in favor of SMS is that it can be taken directly from the bottom of the river, while deepening the channel, which contributes to a greater flow of water. That is, the probability of preserving the dumped body of the dam is more likely. While FS should be transported from the shore, a dam should be created, which due to the above reasons, will have less stable construction properties than with soaked SSM. With the obvious economic advantages of the first method, the factor of the time of the production of work, which is advantageous in the case of using the SMS plays an important role.

A comparative analysis of the behavior of the two types of soil allows us to conclude that in the case of medium density sand, the forces that keep the slope are friction forces, and in the case of fine sand, the friction and adhesion forces. Due to the presence of adhesion forces the prism from fine sand does not immediately settle in the water, but remains for some time until the bonds that cause the adhesion forces between the particles are destroyed by the water penetrating into the ground. The presence of adhesion forces should also explain the curvilinear character of the collapse prism, which was observed in all five-fold repeated experiments.

This once again raises the question of the number and places of sampling the required number of samples in the case of testing heterogeneous soils, the presence of which is explained by the absence of clear facies boundaries between individual layers of the base as a result of annual changes in the regimes of the water sources of the Syr-Darya river.

The results of studies of the filtration properties of soils were obtained in laboratory conditions on samples of broken structure at a previously selected packing density. The results are presented in figure 3, from which it is seen that with an increase in the compaction of SMS, the value of the filtration coefficient became smaller, especially this strongly affected the first stage of compaction during the transition from minimal compaction to weak.

The obtained curve (figure 4) indicates that, as the SMS is condensed filter coefficient decreases. This is most pronounced in the first interval (þ = 1.3772 to þ = 1.454), Δ_1 = 42%.

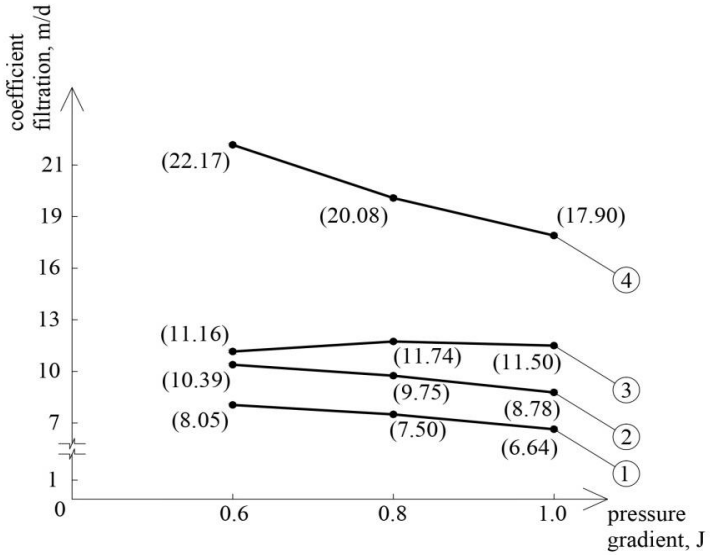

Figure 3 – The dependence of the filtration coefficient on the hydraulic gradient at:
1 - maximum SMS compaction; 2 - strong compaction of SMS; 3- weak compaction of SMS;
4 - minimal compaction of SMS.

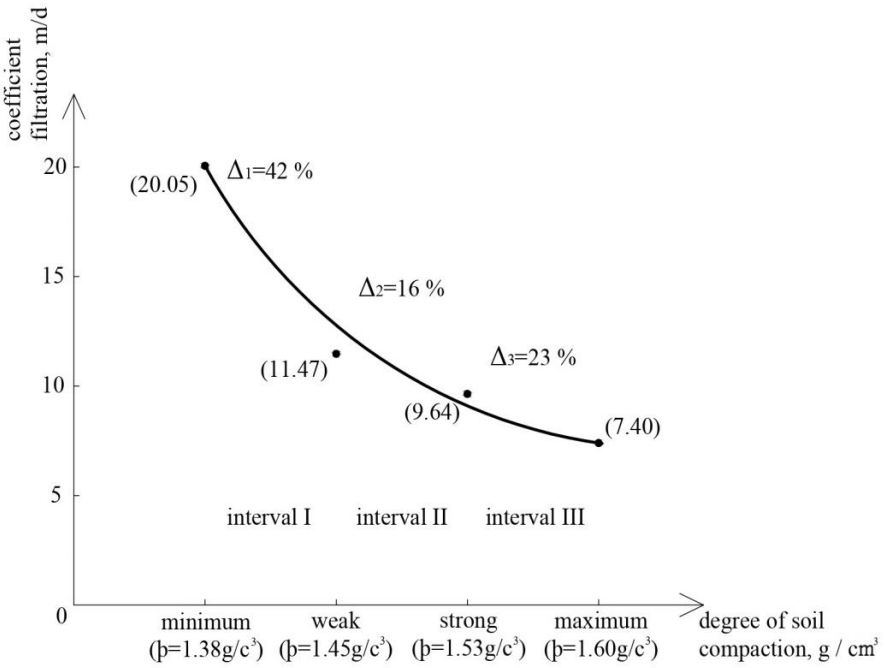

Figure 4 – The dependence of the filtration coefficient on the density of SMS

In the second interval (þ = 1.454 to þ = 1.53), K_f decreases slows down, Δ_2 = 16%, and in the third interval (þ = 1.53 to þ = 1.60) it increases, Δ_3 = 23%.

The value of the filtration coefficient obtained by LLP «Inzhenernyye izyskaniya» is $K_f = 10_{m\,/\,day}$ for SMS in its natural state. Referring this value to the conditions of the tests performed, it can be seen that this value will be between weak and strong soil compaction. Based on this, it can be stated that the data of LLP «Inzhenernyye izyskaniya» are in good agreement with laboratory determination of the filtration coefficient made in the third series of experiments.

The data obtained from three series of experiments made it possible to carry out a comparative analysis and make a conclusion about the construction properties of SSM and FS.

When laying in a dry state, SMS is preferable for laying it in a dam as compared with FS, since this soil in almost all stages of its compaction surpasses FS.

SMS has a more predictable behavior when laying it in a dam, in comparison with FS, which makes it possible to create a dam by washing the soil with a dredger. Moreover, the decisive argument in favor of SMS is that it can be taken directly from the bottom of the river, while deepening the channel, which contributes to a greater flow of water. That is, the probability of preservation of the dump body of the dam is more likely. At the same time, FS should be transported from the shore by dump trucks and with additional compaction, either by rolling or tamping, which, when water gets from the river bed, makes this operation practically impossible and leads to large material costs.

Comparison of the slope angles of SMS and FS showed that sand of medium size is more preferable for dumping the dam with the given sizes of top, bottom and height from the point of view of technical-economic feasibility.

Sand of medium size, composing the riverbed, has a more homogeneous structure, and the fine sand located in the floodplain of the river is heterogeneous. It requires the processing of more samples in laboratory conditions and its construction properties are more difficult to predict.

Comparison in experiments on determining the filtration coefficient showed that SMS, regardless of the degree of compaction, will pass water, which when forming a dam, on the one hand, will have a negative effect - the removal of small particles (the phenomenon of suffusion), and on the other hand - positive: for due to the passage of water through the body of the dam, the pressure of the water mass on the embankment structure will be slightly reduced as a whole (the probability of its destruction is reduced).

The FS has a lower filtration coefficient, and therefore, when a dam is formed from it, the water consumption in the remaining part of the river, which is not blocked by the dam, will significantly increase. In view of this, should expect an increase in the water level to the dam and, accordingly, erosion of the edge of the dam with the supposed destruction of the edge of the dam.

Considering the above, it should be counted possible to use local soil for filling temporary embankments for the purpose of production of piling, subject to the following conditions:

- must be laid with a density of at least 1.65 g / cm^3 the soil of the embankment;
- must be confirmed by preliminary laboratory tests the possibility of compacting the UCS to the required density;
- a layer-by-layer check of the actual density of its laying is required during the filling of the embankment;
- to use preferably a copra with minimal dynamic effects to reduce its impact on the artificial base for the production of piling works;
- should be carried out pile driving by installing the coper on a wooden platform to reduce the specific pressure on the ground and distribute the effort over a larger area;
- should be carried out work at the lowest water level in the river;
- comply strictly with the requirements of current regulations for the production of construction and installation works and safety regulations.

The recommendations were transmitted to the construction organization that carried out the reconstruction of the gas pipeline. Taking them into account, work on the construction of a temporary dam was optimized: the choice of the type of soil for the body of the dam; the method of laying it; the achieved density and the angle of the natural slope. As a result of the introduction of scientific research into the practice of construction, an economic effect was obtained, which was confirmed by the implementation act. The gas pipeline is currently in exploitation.

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МАГИСТРАЛЬДЫ ГАЗ ҚҰБЫРЫН ҚАЙТА ЖАҢАРТУ БАРЫСЫНДА ТОПЫРАҚ СҰРЫПТАУДЫҢ ЭКПЕРИМЕНТАЛЬДЫ НЕГІЗДЕМЕСІ

Аннотация. Мақалада магистральды газ құбырын қайта құру үшін уақытша топырақ бөгетін құруға бағытталған эксперименттік-талдамалық зерттеу нәтижелері келтіріледі.

Газ құбырының тірегі Сырдария өзеніндегі мұздың сөгілу барысында зақымдалған. Қада тіректерін қалпына келтіру үшін уақытша үйінді төсеу ұсынылды. Қолжетімді жақын орналасқан топырақтың үш түрінің қасиетін зерттеу негізінде ұсынылған топырақтың техникалық-экономикалық тиімділігі мен тығыздығының болжамы негізделеді.

Бөгетке салынатын топырақты таңдау топырақ қасиеттерін зертханалық зерттеу және техникалық-экономикалық негіздеме негізінде жүзеге асырылады. Бөгетті қайта жаңарту жөніндегі жұмыстарды жүргізудің технологиялық талаптарына сүйене отырып, биіктігі 5 м және биіктігі 36 м болуы тиіс. Үйіндінің қажетті габариттері ең алдымен табиғи еңіс бұрышынан және төгілетін топырақтың беріктік сипаттамаларынан қабылдануы тиіс. Жергілікті жағдайға байланысты орташа ірілігі, тығыздығы бар, Сырдария өзенінің арнасын шектейтін құм; өзенге тікелей жақын орналасқан ұсақ, борпылдақ құм; бөгеттен 30 км қашықтықта жатқан саздақ пайдаланылуы мүмкін.

Тәжірибенің бірінші сериясында тығыздықты анықтау жұмыстары жүргізілді. Бұл ретте құмның төрт жағдайы жасанды түрде пайда болды: аз нығыздау; әлсіз нығыздау; күшті нығыздау; ең жоғары мүмкін нығыздау. Тәжірибенің екінші сериясында құрғақ және суға қаныққан топыраққа арналған табиғи еңіс бұрышы анықталды. Эксперименттің үшінші сериясы бөгет арқылы суды ағызу мәселесін зерттеу үшін топырақты сүзу коэффициентін анықтауға арналды.

Эксперименталды-аналитикалық зерттеу нәтижелері негізінде экологиялық сипаттағы талаптарға және экономикалық мақсаттылық ұғымдарына сүйене отырып, қада қағу жұмыстарын жүргізу мақсатында өзен құмынан уақытша үйінді себу ұсынылды. Үйінді биіктігі 5 м, төменгі жағы бойынша 51 м, үстіңгі жағы бойынша 14 м болуы қажет.

Сүзу коэффициентін анықтау бойынша тәжірибені салыстыру орташа іріліктегі құм тығыздау дәрежесіне қарамастан суды өткізетінін көрсетті. Бұл бөгетті формациялау кезінде бір жағынан теріс әсерге – ұсақ бөлшектерді шығаруға (суффозия құбылысы), ал екінші жағынан оң әсерге – бөгет денесі арқылы су өткізу есебінен жалпы үйінді конструкциясына су массасының қысымы және оның бұзылу ықтималдығы біршама төмендейді. Ұсақ құмда сүзу коэффициенті аз, сондықтан бөгетті қалыптастыру кезінде одан бөгетсіз өзеннің қалған бөлігіндегі судың шығыны едәуір артады. Осыған орай, су деңгейінің бөгетке дейін көтерілуін және тиісінше бөгеттің шетін алдын ала қирата отырып, шетін шайып кеткенін күту керек.

Жоғарыда айтылғанды ескере отырып, жергілікті топырақты қада қағу жұмыстарын жүргізу мақсатында уақытша үйінді бөртпесі үшін пайдаланған жөн. Ол үшін уақытша бөгет орнату бойынша жұмыстар оңтайландырылды, яғни бөгет денесіне арналған топырақ түрін таңдау, оны төсеу әдістемесі, қол жеткізілетін тығыздық және табиғи еңіс бұрышы.

Ғылыми зерттеулерді құрылыс тәжірибесіне енгізу нәтижесінде экономикалық нәтиже алынды. Қазіргі уақытта газ құбыры табысты пайдаланылуда.

Түйін сөздер: бөгет, үйінді, топырақ тығыздығы, табиғи еңіс бұрышы, сүзу коэффициенті, құмды жасанды негіздер, құмды негізді төсеу, тығыздалатын үйінді топырақтар, сапаны бақылау, қалыптасатын негізді бақылау, қадалы іргетастың геотехникалық көрсеткіштері.

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ЭКСПЕРИМЕНТАЛЬНОЕ ОБОСНОВАНИЕ ПОДБОРА ГРУНТА ПРИ РЕКОНСТРУКЦИИ МАГИСТРАЛЬНОГО ГАЗОПРОВОДА

Аннотация. Приводятся результаты экспериментально-аналитических исследований, направленных на создание временной грунтовой дамбы для реконструкции магистрального газопровода.

Опоры газопровода были повреждены при ледоходе реки Сыр-Дарья. Для восстановления свайных опор было предложено произвести отсыпку временной насыпи. На основе изучения свойств трех видов грунтов, находящихся в доступной близости, обосновывается технико-экономическая эффективность и прогноз уплотняемости рекомендуемого грунта.

Выбор грунта, укладываемого в дамбу, осуществляется на основании лабораторных исследований свойств грунтов и технико-экономического обоснования. Исходя из технологических требований производства работ по реконструкции, дамба должна быть высотой 5 м и размером по верху 36 м. Размер основания насыпи зависит от вида отсыпаемого грунта. Необходимые габариты насыпи должны быть приняты главным образом от угла естественного откоса и прочностных характеристик отсыпаемого грунта. Исходя из местных условий могут быть использованы: песок средней крупности, средней плотности, слагающий русло реки Сыр-Дарьи; песок мелкий, рыхлый, находящийся в непосредственной близости от реки; суглинки, залегающие на удалении 30 км от дамбы.

В первой серии опытов проводилось определение плотности. При этом искусственно создавалось четыре состояния каждого из песков: минимальное уплотнение; слабое уплотнение; сильное уплотнение; максимально возможное уплотнение. Во второй серии опытов определялся угол естественного откоса для сухих и водонасыщенных грунтов. Третья серия экспериментов была посвящена определению коэффициента фильтрации грунтов для изучения вопроса просачивания воды через дамбу.

На основании результатов экспериментально-аналитических исследований, исходя из требований экологического характера и соображений экономической целесообразности, было предложено произвести отсыпку временной насыпи из речного песка путем его намыва с целью производства сваебойных работ. Насыпь рекомендовано выполнить высотой 5 м, размером по низу – 51 м, по верху – 14 м.

Сопоставление опытов по определению коэффициента фильтрации показало, что песок средней крупности независимо от степени уплотнения будет пропускать воду. Это может привести при формировании дамбы, с одной стороны, к отрицательному воздействию – выносу мелких частиц (явление суффозии), а с другой стороны – к положительному воздействию: за счет пропуска воды через тело дамбы будет несколько снижено в целом давление массы воды на конструкцию насыпи и снизится вероятность ее разрушения. У песка мелкого меньше коэффициент фильтрации и поэтому при формировании дамбы из него значительно увеличится расход воды в оставшейся части реки, не перегороженной дамбой. Ввиду этого, следует ожидать повышения уровня воды до дамбы и соответственно размыванию края дамбы с предположительным разрушением края дамбы.

Учитывая вышеизложенное, следует считать возможным использование местного грунта для отсыпки временной насыпи с целью производства сваебойных работ. Для чего были оптимизированы работы по устройству временной дамбы – выбор типа грунта для тела дамбы, методика его укладки, достигаемая плотность и угол естественного откоса.

В результате внедрения научных исследований в практику строительства был получен экономический эффект. В настоящее время газопровод успешно эксплуатируется.

Ключевые слова: дамба, насыпь, плотность грунта, угол естественного откоса, коэффициент фильтрации, песчаные искусственные основания, укладка песчаного основания, уплотняемые насыпные грунты, контроль качества, контроль формируемого основания, геотехнические показатели, забивная свая.

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POLYMER WASTES' FLOTATION SEPARATION RESEARCH RESULTS

Abstract. For separation of plastic wastes (polyamide (PA), acrylonitrile butadiene styrene (ABS) and polystyrene (PS), a flotation method is proposed. Using this method, the effect of concentration of surface-active substances (surfactants), which were used as polidocanol, sulphanole and a mixture of surfactants containing sodium laureth sulfate and diethanolamide, was studied.

The research results analysis of the flotation separation of a mixture of crushed plastic wastes was carried out according to the calculated values of the extraction of a floated component ε and the purity of a concentrate β. It was noted that the maximum extraction of the floated component depends on the polymer and surfactant type. A mixture of surfactants at lower concentrations allows to achieve greater extraction of the floated component with less foaming ability.

The research results on the extraction of polystyrene from the air flow rate at various concentrations of surfactants' mixture show that the extraction has a maximum at a certain air flow rate. At low air flow rates, the working volume of liquid is not saturated enough with gas bubbles. If the optimal value of air flow rates is exceeded, many gas bubbles are formed that are not involved in the flotation process.

The research results on the extraction of polystyrene from the aerated liquid layer height at various concentrations of surfactants' mixture show that, at a low height of the aerated liquid layer, the probability of collision of a plastic particle with an air bubble is low and some potentially floated particles seek the bottom of an apparatus without having time to collide with an air bubble.

When assessing the influence of liquid temperature on the flotation process, it was found that increasing the liquid temperature above 20°C leads to a sharp decrease in ABS and PS extraction. This is explained by the fact that the dependence of the surfactants' foaming ability on the temperature is characterized by solubility curves and for most surfactants they have an extremum.

Key words: flotation, plastic wastes, surface-active substances, concentration, air flow rate, liquid layer height, temperature.

Introduction. In the world there is a constant increase in the consumption of polymer materials (PM) [1,2], which occupy a leading position in terms of production of raw materials.

The accelerated growth in the production of polymer materials and the expansion of their applications in various industries is explained by their manufacturability, ease, convenience, cost-effectiveness, safety, a set of valuable operational properties and high aesthetics. Plastics are serious competitors to glass, ceramics and metal [3].

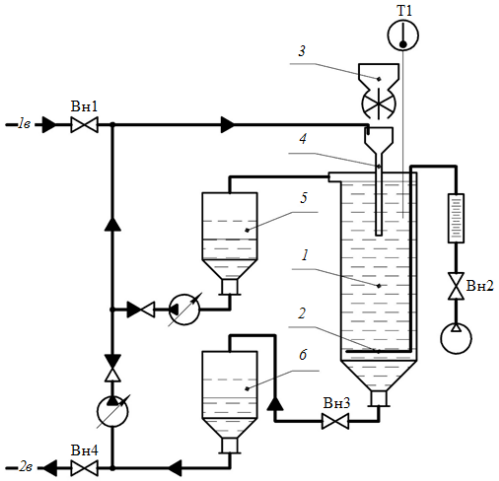
At the same time, the use of products from polymer materials certainly causes waste formation. The increase in PM production and consumption inevitably entails an increase in the amount of their wastes.

In recent years, the problem of processing plastic wastes has taken an important place in the world, since the bulk of wastes is destroyed by inefficient methods [4-8].

Promising processes for the separation of PM are flotation based on various wettability, since they are quite simple in hardware and reliable. This requires the presence of surface-active substances and gas bubbles in the working volume of an apparatus [9,10].

Experimental plant and research methodology. A diagram of the laboratory-scale plant of a column flotation apparatus with pneumatic aeration of liquid to study the effect of the main process parameters on the flotation separation of a mixture of crushed plastics is shown in figure 1.

The plant includes the reservoir *1* for carrying out the flotation process, which is filled with water from the line *1в* using the valve Вн1. Inside the reservoir *1*, at its bottom, the aerator *2* is fixed for introducing air into the working volume of the apparatus in the form of bubbles. The working volume of the apparatus is the volume of liquid between the aerator and the foam layer (liquid surface). The aerator is installed in the lower part of the apparatus with the ability to adjust the plant's depth to determine the optimal aerated liquid height. The air flow rate supplied from the compressor to the reservoir *1* is regulated by the valve Вн2 and is controlled by a rotameter.



1 – reservoir; *2* – aerator; *3* – bladed batcher; *4* – feeder; *5*, *6* – separators; Вн1–Вн4 – valves; T1 – thermometer. Flows: *1в* – water to fill the reservoir; *2в* – water drain

Figure 1 – A diagram of the laboratory-scale plant of a column flotation apparatus with pneumatic aeration of liquid

The feeding of crushed plastics is regulated by the bladed batcher *3*, in the body of which a rotor with radial blades made of elastic material is installed, which prevents its jamming. The feeding is organized through the feeder *4* in the middle part of the column with the ability to control the depth of feeding to study its effect on the flotation process. For a better independent outflow of the resulting foam product (concentrate) from the liquid surface and its overflow from the column for further processing, the laboratory plant provides for a constant circulation of circulating liquid. The circulating liquid is fed to the column through the feeder *4*, which prevents particles of crushed plastics from getting stuck in it. To separate solid and liquid phases of the foam product, the separator *5* is used, and for tails, the separator *6* is used when opening the valve Вн3. The separators *5* and *6* also serve to accumulate a buffer volume of the circulating liquid, necessary for its constant circulation using pumps. The liquid, if necessary, is drained from the plant through the line *2в* with the help of the valve Вн4 valve. The liquid temperature in the reservoir *1* is measured by the thermometer T1.

The experimental research technique consists in the following sequence of actions.

1. Prepare in advance a sample of the studied crushed plastics with the mass $m_{\text{исх}}$. Due to the complexity of further manual sorting of the concentrate in a multilateral study of the flotation process, it is recommended to apply a sample of a mixture of crushed plastics weighing about 10 g. In the laboratory plant, it is possible to study the dependences of the extraction of certain types of plastics on physical and operational factors, while the flotation is fed with the sample $m_{\text{исх}}$ containing one type of crushed plastic. It is also possible to study the separation of a mixture of several types of crushed plastics. In the second case, the sample $m_{\text{исх}}$ should contain particles of crushed hydrophobic plastic with the mass $m_{\text{исх}}^{\text{фл}}$ and particles of crushed hydrophilic plastic with the mass $m_{\text{исх}}^{\text{ос}}$. When studying the separation of plastics, it is recommended to feed for the flotation a mixture of plastics in a ratio of 1:1, since the literature cites the fact that the most complex mass ratio for separating the components of a mixture is generally 1:1.

2. At the beginning of work with the laboratory plant, shown in figure 3.1, it is necessary to open the valve Вн1 and fill it with water from the line *1в*, while separators *5* and *6* are also filled with the buffer volume of the circulating liquid.

3. When filling the plant with water, introduce the required amount of surfactants, which are mixed in the liquid flow during its feeding and subsequent circulation.

4. Using adjustable pumps, install the required circulation of the circulating liquid.

5. Turn on the compressor and, opening the valve Вн2, feed air to the working volume of the apparatus through the perforated aerator *2*, which is installed to the required depth. Due to the aerator, the air will be evenly distributed over the cross section of the apparatus in the form of small bubbles.

6. Using the valve Вн2, establish the air flow rate necessary for the experimental study, controlling its value with the rotameter.

7. In the mechanical bladed batcher *3*, pour the pre-prepared sample of crushed plastics with the mass $m_{\text{исх}}$.

8. Turn on the mechanical bladed batcher *3* and feed the material. In this case, the particles enter the feeder, washed by the circulating liquid, and then into the working volume of the apparatus. As a result of the flotation, a part of the crushed particles falls into the foam product, and the other part – in the sediment. The three-phase foam product due to the constant circulation of the circulating liquid by gravity pours over the upper edge of the column and enters the separator *5* to separate the solid phase – the concentrate.

9. After the flotation process is over (when there will be no material particles in the working volume of the apparatus), close the valve Вн2 and stop the circulation of the circulating liquid by the adjustable pumps, turning them off.

10. Select the concentrate from the separator *5* and dry it.

11. After drying the concentrate, determine its mass $m_{\text{конц}}$. When studying the separation of the mixture of several types of crushed plastics from the dried concentrate with the mass $m_{\text{конц}}$, it is necessary to select the floated component (particles of hydrophobic plastic) and also determine its mass $m_{\text{конц}}^{\text{фл}}$.

12. The accumulated sediment, as necessary, is discharged from the bottom of the column to the separator *6* using the valve Вн3, and it is manually removed from the separator *6*.

Thus, to study the influence of a certain parameter on the flotation process, a series of experiments is carried out in which only the studied parameter changes, and the remaining conditions are maintained constant. After the series of experiments with one parameter, the next series is carried out, in which the influence of another parameter on the flotation process is studied.

Since the geometric characteristics of the experimental plant are not universal, it is customary to reduce the air flow rate fed to the apparatus and measured by the rotameter to a unit of cross-sectional area of the apparatus.

Research results. To analyze the research results of the flotation separation of the mixture of crushed polymer materials, the extraction of the floated component ε and the concentrate purity β were calculated using the formulas presented below in [11]:

$$\varepsilon = \frac{m_{\text{конц}}^{\text{фл}}}{m_{\text{исх}}^{\text{фл}}} \cdot 100\%, \tag{1}$$

$$\beta = \frac{m_{\text{конц}}^{\text{фл}}}{m_{\text{конц}}} \cdot 100\%, \tag{2}$$

where $m_{\text{конц}}^{\text{фл}}$ – the mass of the floated component (particles of crushed hydrophobic plastic) in the concentrate, kg; $m_{\text{исх}}^{\text{фл}}$ – the mass of the floated component (particles of crushed hydrophobic plastic) in the initial sample, kg; $m_{\text{конц}}$ – the mass of the concentrate, kg.

The experimental research results were processed in the form of graphical dependences of the flotation indices on the concentration of various types of surfactants, shown in figures 2-5.

As can be seen from Figures 2-5, the extraction has a maximum at a certain concentration of surfactants, namely: about 10^{-2} kg/m^3 for ABS using sulphanole and polidocanol; less than $3 \cdot 10^{-3}$ kg/m^3 for ABS using the surfactants' mixture; $5.41 \cdot 10^{-3}$ kg/m^3 for PS using the surfactants' mixture.

The presence of the maximum extraction of the floated component ε in figures 2-5 suggests the regularity of the effect of the surfactants' concentration on the extraction of the floated component. This can be explained by the same nature of the dependence of foaming ability on the surfactants' concentration. At a concentration higher than the maximum, the foam formation decreases due to the difficulty of the surfactants' diffusion into the surface layer [12]. However, the foaming ability of the surfactants is not determinative in this case, since, as can be seen from Figures, the value of the surfactants' concentration at which the maximum extraction of the floated component is achieved depends on the polymer and surfactant type.

A positive feature is that the maximum polymer extraction is achieved with a rather low concentration of the surfactants [13,14]. Moreover, the surfactants' mixture at lower concentrations allows to achieve greater extraction of the floated component which in the same way affects the foaming ability [15].

According to the results of calculations of the extraction of the floated component ε and the concentrate purity β from the air flow rate during the flotation separation of the mixture of crushed polyamide and acrylonitrile butadiene styrene using various surfactants, the dependences shown in Figures 6-8 were obtained.

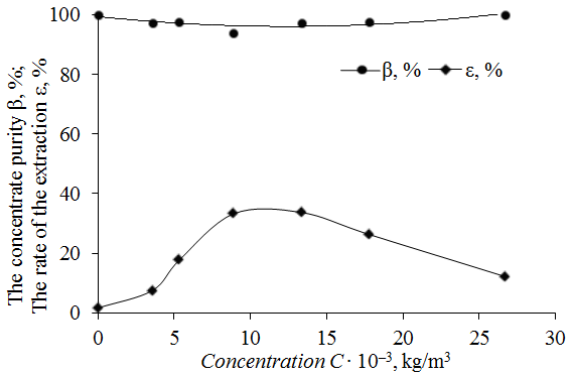


Figure 2 – Dependences of the concentrate purity and the ABS extraction on the sulphanole concentration at the air flow rate of 0.062 $m^3/(min \cdot m^2)$

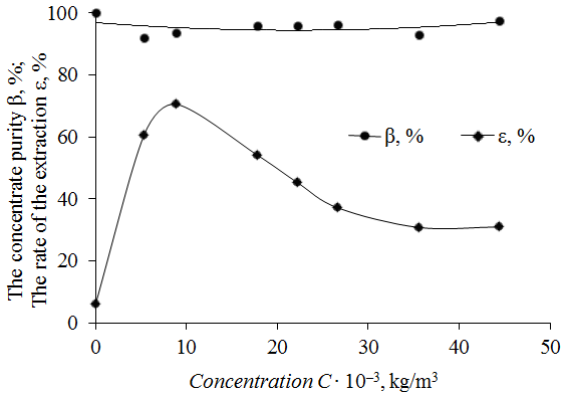


Figure 3 – Dependences of the concentrate purity and the ABS extraction on the polidocanol concentration at the air flow rate of 0.062 $m^3/(min \cdot m^2)$

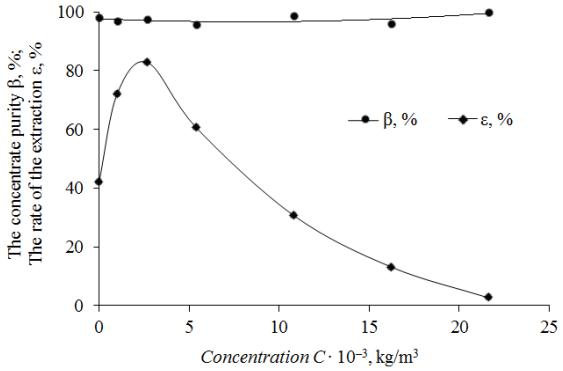


Figure 4 – Dependences of the concentrate purity and the ABS extraction on the surfactants' concentration at the air flow rate of 0.104 $m^3/(min \cdot m^2)$

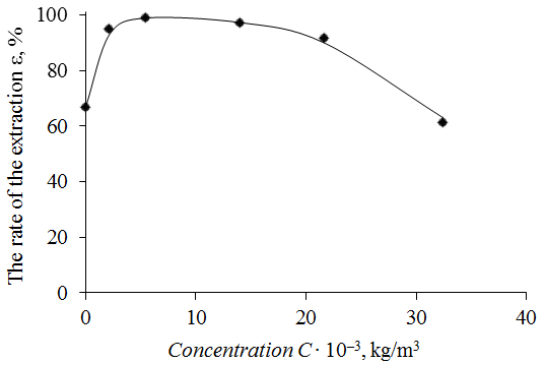


Figure 5 – Dependences of the PS extraction on the surfactants' concentration at the air flow rate of 0.072 $m^3/(min \cdot m^2)$

Further, according to the research results presented in [16], the dependences of PS extraction on the air flow rate are presented, obtained at the surfactants' mixture concentration of $5.41 \cdot 10^{-3}$ and $16.22 \cdot 10^{-3}$ kg/m^3 (figure 9).

As can be seen from figures 6-9, the extraction has a maximum at a certain air flow rate. The presence of the maximum extraction of the floated component in these Figures suggests a characteristic effect of the air flow rate on the polymer flotation process. At low air flow rates, the process is inefficient, since the working volume of the liquid is not saturated enough with gas bubbles. If the optimal value of air

flow rate is exceeded, many gas bubbles are formed that are not involved in the flotation process. Such bubbles moving through the liquid can create turbulent flows that impede the flotation of particles. When moving in the turbulent liquid flow, the "bubble – particle" complex is prone to destruction, as particles and bubbles have different inertia (mass) [17].

Also, from the above dependences, it may be concluded that the value of the air flow rate at which the maximum extraction of the floated component is achieved depends on the polymer and surfactant type. The nature of the air flow rate effect at different concentrations of surfactants does not change – only the extraction of the floated component changes.

When using polidocanol, the maximum ABS extraction is 17% higher than when using sulphanole, and reaches 70.5%. However, the concentrate purity in this case is reduced by 2.5%, namely, to 93.5% [18]. When using the mixture of surfactants containing sodium laureth sulfate and diethanolamide, the ABS extraction reaches 95%, and the concentrate purity – 98.7%. And when using the same surfactants' mixture during the PS flotation, its extraction reaches 99%.

To determine the optimal aerated layer height of the working liquid from the experimental data presented in [16], the dependences of the PS extraction on the surfactants' concentration were determined for different heights of the aerated liquid layer, which are shown in figure 10.

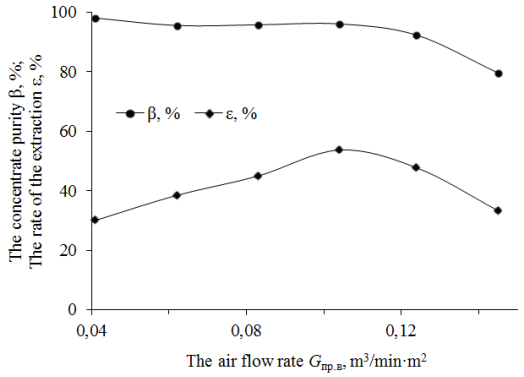


Figure 6 – Dependences of the concentrate purity and the ABS extraction on the air flow rate at the sulphanole concentration of $11.56 \cdot 10^{-3}$ kg/m^3

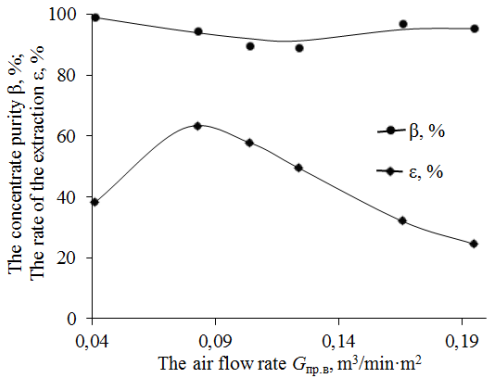


Figure 7 – Dependences of the concentrate purity and the ABS extraction on the air flow rate at the polidocanol concentration of $8.89 \cdot 10^{-3}$ kg/m^3

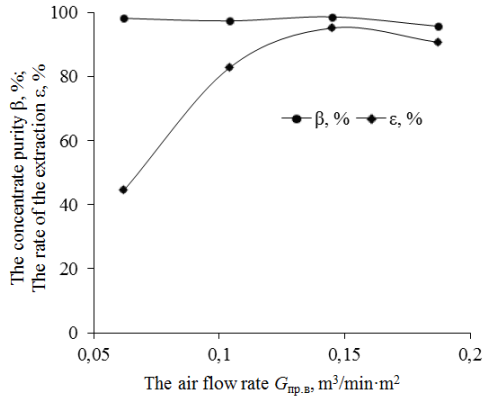


Figure 8 – Dependences of the concentrate purity and the ABS extraction on the air flow rate at the surfactants' mixture concentration of $2.7 \cdot 10^{-3}$ kg/m^3

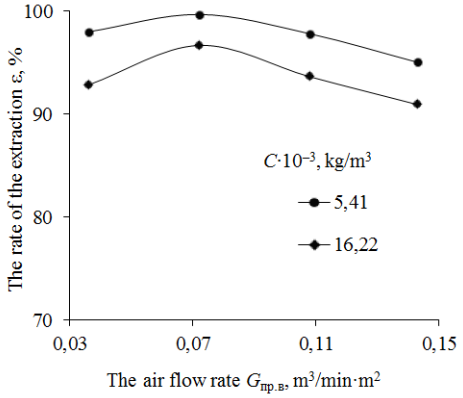


Figure 9 – Dependences of the PS extraction on the air flow rate at various surfactants' mixture concentration

As can be seen from Figure 10, the PS extraction has a maximum at a low surfactants' concentration, namely, $5.41 \cdot 10^{-3}$ kg/m^3, and reaches 99% with a sufficient height of the aerated liquid layer.

At a low height of the aerated liquid layer, the probability of collision of a plastic particle with an air bubble is low and some potentially floated particles seek the bottom of the apparatus without having time to collide with an air bubble. The optimal height of the processed liquid layer H_o corresponds to a certain air flow rate. And when the height of the liquid layer is less than the optimal ($H_ж < H_o$), the achievement of the required extraction rate of the dispersed phase is possible, for example, with an increase in the air flow rate [19].

In order to more clearly display the effect of the aerated liquid layer height on the PS extraction, the corresponding dependences were obtained at the surfactants' concentration of $2.16 \cdot 10^{-3}$ and $5.41 \cdot 10^{-3}$ kg/m^3, shown in figure 11.

As can be seen from figure 11, a sufficient height of the aerated liquid layer is 0.5-0.6 m; its further increase does not have a strong effect on the PS extraction. Exceeding the optimal aerated liquid layer height leads to an increase in the material consumption of the apparatus and an increased consumption of the working liquid and surfactants, as well as to an extension of the path of movement of the "bubble – particle" complexes, which can increase the probability of their destruction [19].

The graphical dependences given above were obtained without additional heating of the working liquid (about 10-15°C). In assessing the effect of the liquid temperature on the flotation process, the experimental research was carried out, the results of which are reflected in [16]. After processing the results of these experimental research, the dependences of the ABS and PS flotation indices on the liquid temperature *t* were plotted, shown in figures 12, 13.

As can be seen from figures 12 and 13, increasing the liquid temperature above 20°C leads to a sharp decrease in the ABS and PS extraction. It should be noted that in figures 12 and 13 there is a pattern of the influence of the liquid temperature on the floated components' extraction. This is, probably, explained by the fact that the dependence of the surfactants' foaming ability on the temperature is characterized by the solubility curves and for most surfactants they have an extremum [20,21]. It is likely that an increase in the temperature of the solution leads to the dehydration of the dissolved surfactant molecules. Moreover, they separate as an individual macrophase, which leads to a decrease in the number of surfactant molecules involved in the flotation process.

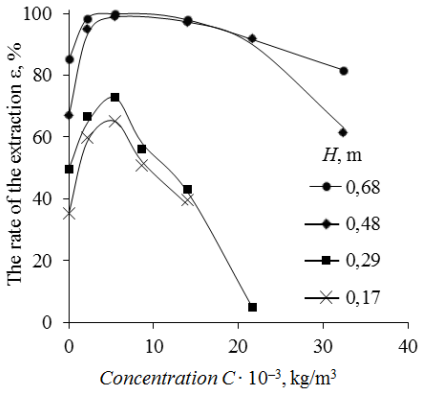


Figure 10 – Dependences of the PS extraction on the surfactants' mixture concentration at different heights of the aerated liquid layer

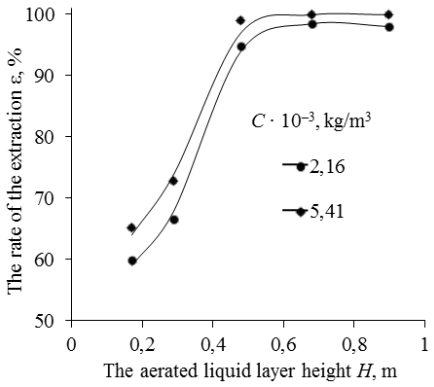


Figure 11 – Dependences of the PS extraction on the aerated liquid layer height at different surfactants' mixture concentration

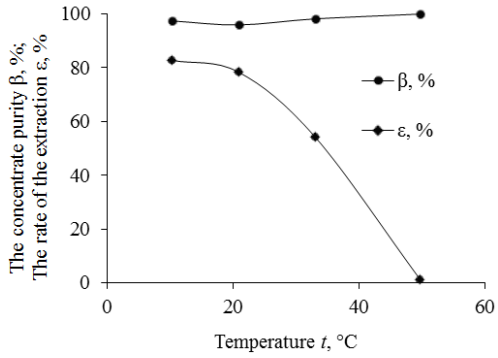


Figure 12 – Dependences of the concentrate purity and the ABS extraction on the liquid temperature at the surfactants' mixture concentration containing sodium laureth sulfate and diethanolamide, $2.7 \cdot 10^{-3}$ kg/m^3 and at the air flow rate of 0.104 m^3/min·m^2

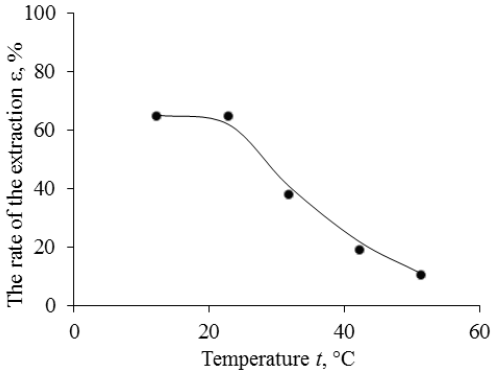


Figure 13 – Dependence of the PS extraction on the liquid temperature when the aerated liquid layer height is 0.17 m, the surfactants' mixture concentration is $5.41 \cdot 10^{-3}$ kg/m^3 and the air flow rate is 0.072 m^3/h·m^2

Conclusions. For separation of plastic wastes (polyamide, acrylonitrile butadiene styrene and polystyrene, the flotation method is proposed. Using this method, the effect of the surface-active substances' concentration, which were used as polidocanol, sulphanole and the mixture of surfactants containing sodium laureth sulfate and diethanolamide, was studied.

According to the research results, it was noted that the maximum extraction of the floated component depends on the polymer and surfactant type. A positive feature is that the maximum polymer extraction is achieved with a rather low concentration of surfactants. The mixture of surfactants at lower concentrations allows to achieve greater extraction of the floated component with less foaming ability.

The research results on the extraction of the floated component from the air flow show that its maximum extraction depends on the polymer and surfactant type. The nature of the air flow rate effect at different concentrations of surfactants does not change – only the extraction of the floated component changes.

The research results on the extraction of the floated component from the aerated liquid layer height show that the certain air flow rate corresponds to the optimal height of the processed liquid layer, and when the liquid layer height is less than the optimal, the required degree of the dispersed phase extraction is possible, for example, with increasing the air flow rate.

When assessing the influence of the liquid temperature on the flotation process, it was found that increasing the liquid temperature leads to a sharp decrease in the floated component extraction. This is explained by the fact that the dependence of the surfactants' foaming ability on the temperature is characterized by the solubility curves and for most surfactants they have an extremum.

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ПОЛИМЕРЛІК ҚАЛДЫҚТЫҢ ФЛОТАЦИЯЛЫҚ БӨЛІНУІН ЗЕРТТЕУ НӘТИЖЕЛЕРІ

Аннотация. Пластмасса қалдықтарын бөлу үшін (полиамид (ПА), акрилонитрилбутадиенстирол (АБС) және полистирол (ПС) флотациялық әдіс ұсынылды. Көрсетілген тәсілді пайдалана отырып, құрамында натрий лауретсульфаты және диэтаноламид бар синтанол, сульфанол және ПБЗ қоспасы қолданылған беттік белсенді заттардың (ПАЗ) шоғырлану әсері зерттелді.

Пластмассаның ұсақталған қалдық қоспасының флотациялық бөлінуінің зерттеу нәтижелерін талдау флотацияланатын компонент шығарудың есептелген мәні және таза β концентраты бойынша жүргізілді. Флотацияланатын компонент алу полимер мен ПБЗ түріне байланысты екендігі атап өтілді. Оң ерекшелігі, ПБЗ-ның аса төмен концентрациясы барысында полимерлер шығарылады. ПБЗ қоспасы аз концентрацияда флотацияланатын компонентті көбік шығаруда көбірек алуға мүмкіндік береді.

ПБЗ қоспасының түрлі концентрациясында полистиролды ауа шығынынан бөліп алуды зерттеу нәтижелері ауаның көп шығым шығаратынын көрсетеді. Ауаның аз шығымында сұйықтық мөлшері газ көпіршіктерімен жеткіліксіз түрде қанығады. Ауа шығымының оңтайлы мәнінен асқанда флотация процесіне қатыспайтын газ көпіршіктері пайда болады. Көпіршіктер сұйықтық арқылы бөлшек флотациясына кедергі келтіретін турбулентті ағын жасай алады. Сұйықтықтың турбуленттік ағынында қозғалғанда «көпіршік – бөлшектер» кешені қирауға бейім келеді, себебі бөлшектер мен көпіршіктер түрлі инерционды (масса) болады. ПБЗ түрлі шоғырлануы барысында ауа шығынының әсер ету сипаты өзгермейді, яғни флотацияланатын компонентті алу жағдайы ғана өзгереді.

ПБЗ қоспасының түрлі концентрациясы барысында сұйықтықтың аэрирленетін қабатының биіктігінен полистиролды алуды зерттеу нәтижелері сұйықтықтың аэрирленетін қабат биіктігінде пластмассаның бөлшектің ауа көпіршігімен араласу ықтималдығы аз және кейбір әлеуетті флотацияланатын бөлшектер ауа көпіршігімен араласпай-ақ аппараттың түбіне түсіріледі. Өңделетін сұйықтық қабатының оңтайлы биіктігіне ауаның белгілі бір шығымы сәйкес келеді.

Флотация процесіне сұйықтық температурасының әсерін бағалау кезінде сұйықтық температурасының 20°С-тан жоғары көтерілуі АБС және КС шығымын күрт төмендетеді. Бұл ПБЗ көбіктеу қабілетінің температураға тәуелділігі ерігіш қисығымен сипатталады және ПБЗ көпшілігі үшін олар экстремумға ие. Ерітінді температурасының жоғарылауы ПБЗ ерітілген молекулалар дегидратациясына әкеп соқтыруы мүмкін.

Бұл ретте олар жеке макрофаз түрінде бөлінеді, бұл флотация процесіне қатысатын ПБЗ молекулалар санын төмендетеді.

Түйін сөздер: флотация, пластмасса қалдықтары, беттік белсенді заттар, концентрация, ауа шығыны, сұйықтық қабатының биіктігі, температура.

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РЕЗУЛЬТАТЫ ИССЛЕДОВАНИЙ ФЛОТАЦИОННОГО РАЗДЕЛЕНИЯ ПОЛИМЕРНЫХ ОТХОДОВ

Аннотация. Для разделения отходов пластмасс (полиамида (ПА), акрилонитрилбутадиенстирола (АБС) и полистирола (ПС)) предложен флотационный способ. С использованием указанного способа изучено влияние концентрации поверхностно-активных веществ (ПАВ), в качестве которых использовались синтанол, сульфанол и смесь ПАВ, содержащая лауретсульфат натрия и диэтаноламид.

Анализ результатов исследований флотационного разделения смеси измельченных отходов пластмасс проводился по рассчитанным значениям извлечения флотируемого компонента ε и чистоты концентрата β. Отмечено, что максимальное извлечение флотируемого компонента, зависит от типа полимера и ПАВ. Положительной особенностью является то, что максимальное извлечение полимеров достигается при довольно низкой концентрации ПАВ. Смесь ПАВ при меньших концентрациях позволяет достичь большего извлечения флотируемого компонента при меньшей пенообразующей способности.

Результаты исследований извлечения полистирола от расхода воздуха при различной концентрации смеси ПАВ показывают, что извлечение имеет максимум при некотором расходе воздуха. При малых расходах воздуха рабочий объем жидкости недостаточно насыщается пузырьками газа. При превышении оптимального значения расхода воздуха образуется много газовых пузырьков, не участвующих в процессе флотации. Пузырьки, двигаясь через жидкость, могут создавать турбулентные потоки, препятствующие флотации частиц. При движении в турбулентном потоке жидкости комплекс «пузырек – частица» склонен к разрушению, поскольку частицы и пузырьки имеют различную инерционность (массу). Характер влияния расхода воздуха при различной концентрации ПАВ не изменяется – изменяется лишь извлечение флотируемого компонента.

Результаты исследований извлечения полистирола от высоты аэрируемого слоя жидкости при различной концентрации смеси ПАВ показывают, что при малой высоте аэрируемого слоя жидкости вероятность столкновения пластмассовой частицы с пузырьком воздуха низкая и некоторые потенциально флотируемые частицы опускаются на дно аппарата, так и не успев столкнуться с пузырьком воздуха. Оптимальной высоте слоя обрабатываемой жидкости соответствует определенный расход воздуха.

При оценке влияния температуры жидкости на процесс флотации установлено, что повышение температуры жидкости выше 20°С приводит к резкому снижению извлечения АБС и ПС. Это объясняется тем, что зависимость пенообразующей способности ПАВ от температуры характеризуется кривыми растворимости и для большинства ПАВ они имеют экстремум. Вероятно, повышение температуры раствора приводит к дегидратации растворенных молекул ПАВ. При этом они выделяются в виде отдельной макрофазы, что приводит к снижению количества молекул ПАВ, участвующих в процессе флотации.

Ключевые слова: флотация, отходы пластмасс, поверхностно-активные вещества, концентрация, расход воздуха, высота слоя жидкости, температура.

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INVESTIGATION AND MANAGEMENT OF FIRE RISKS AT SITES WITH APPLICATION OF TRANSLUCENT BUILDING STRUCTURES

Abstract. On the base of analyses on the development of the construction industry as well as fires occurring in Kazakhstan, the article justifies the areas of fire prevention related to technical regulation that is the certification of materials, construction structures and engineering systems.

The translucent building structures have increasing application in modern construction techniques. For such structures, the most vulnerable indicator is the fire resistance limit. A technical solution is offered to increase this indicator by using water irrigation. On the base of existing international and national regulatory documents, a number of methods has been developed for experimental determination of the actual fire resistance limit by cooling of structures with water in case of fire.

Large-scaled fire researches have been carried out to determine the actual limit of fire resistance of the translucent partition made of tempered glass "Float" with the thickness of 12 mm, M1 grade both in the presence of water irrigation and in the absence thereof. The tests were carried out under standard and actual fire conditions. Optimal parameters of water irrigation are determined. On the base of research results, it is proposed to improve the construction standards in this field as well as methodological documents in the field of certification tests.

Key words: fire safety, translucent structures, fire tests, fire resistance.

Introduction. The objective criterion for the socio-economic development of society is the indicators of construction industry. Modern Kazakhstan demonstrates clearly this thesis. According to statistical data, the scope of the performed construction works is growing every year in the country. The growth rates is shown in the diagram (figure 1) [1].

Moreover, the crucial part of commissioned construction sites refers to the social welfare and residential facilities. Thus, in 2019 it was completed the construction of 45515 new buildings, where 42739 buildings are residential and 2776 buildings are non-residential, it has commissioned for operation of 71 comprehensive schools, 69 pre-schools, 35 outpatient clinics and three hospitals [1].

The capacity within the construction industry allows to design and build unique objects, both in terms of architectural design as in application of new, unique materials, structures and systems. Along with its indisputable importance for the country, the construction industry has a high risk of dangerous factors. The extensive application of new modern substances, materials and articles, produced from them having high fire hazard class, leads to increase the potential ignition sources and increase the risk of exposure of their dangerous factors to humans, increase in the size of socio-economic and environmental consequences from them.

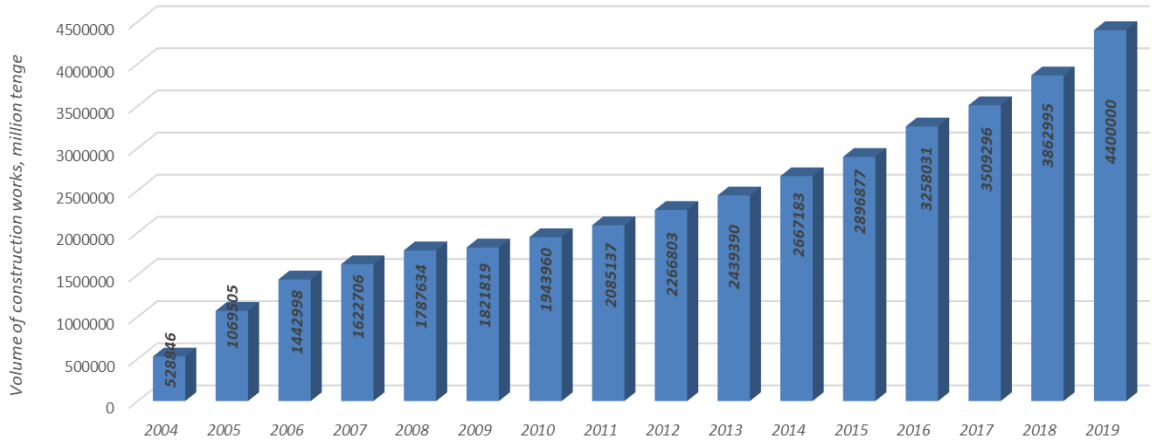

Figure 1 – Statistical data on the scope of construction works performed in the Republic of Kazakhstan from 2004 to 2019

According to the data from the Committee of Emergency Situations of the Ministry of Internal Affairs of the Republic of Kazakhstan for 2019 there are registered 9 415 fires in the residential sector of the country which has caused material damage in the amount of more than 1.52 billion tenge. In the case of fires, 280 people died and 322 were injured, representing 85.8 and 82.5 percentages of total fire victims respectively. Fires in housing and public buildings account for more than 70% of the total number of fires in the country [2].

Figure 2 and 3 show the diagrams of fire distribution by the objects occurred in 2018-2019 and the dynamics of fires in the residential sector over the last 5 years [2]. Despite the downward trend in fires in recent years, the total number of fires remains quite high. These data force us to look for new ways on improvement of fire prevention.

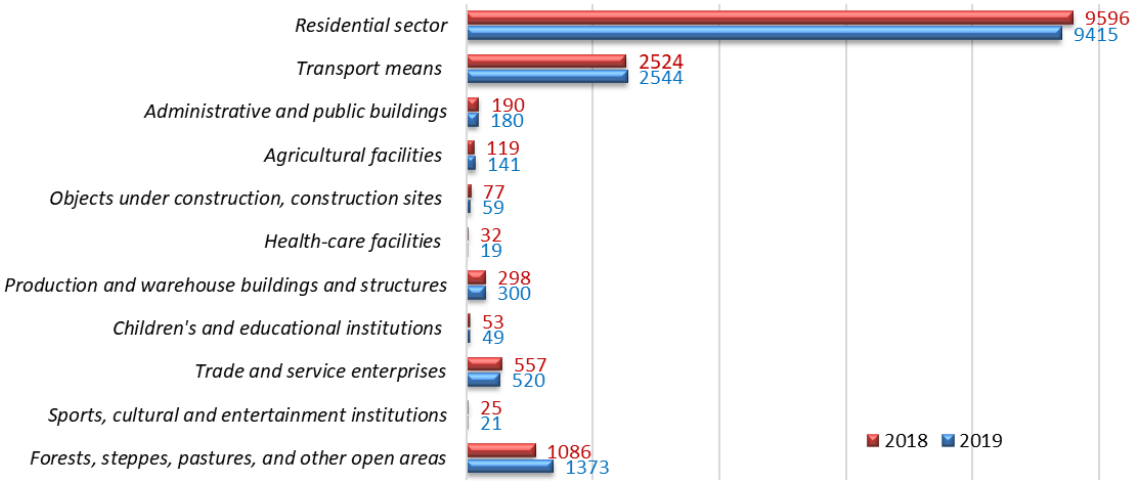

Figure 2 – Fire distribution occured by objects

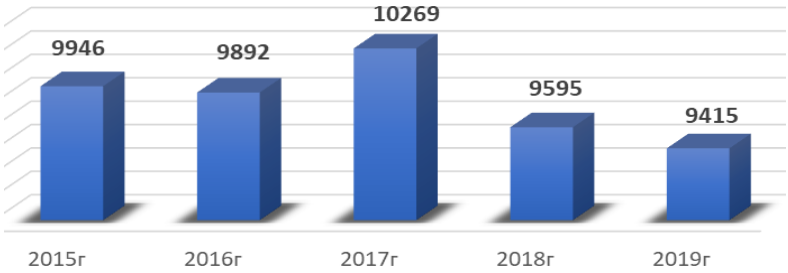

Figure 3 – Fire dynamics in the residential sector over the last 5 years

Fire safety issues continue to be sufficiently relevant as evidenced by publications both domestic and foreign [3-6].

The provision of fire safety of buildings and structures at the design, construction and commissioning stages is an extremely important task, because the mistakes made are sometimes not reversible.

In the context of solving the challenges of reducing the pressure on business, minimizing the control and oversight functions of state bodies, including state fire authorities, ensuring the safety of products and services supplied to the market, the technical regulation system is becoming a technological process. Its main tasks include ensuring the safety of products and processes for human life and health and the environment, ensuring the national security, preventing the actions that mislead the consumers about product safety and quality, etc. [7].

Construction facilities, especially those with mass presence of people, as a rule unique on architectural solution and use of modern technological materials and constructions, should comply with requirements of technical regulations on the "General requirements for fire safety " and "Requirements for the safety of fire-fighting equipment for the protection of objects " [8, 9]. They should be built with certified construction structures, finishing materials and building engineering equipment, including fire protection systems to ensure the required level of safety. Requirements to ensure an adequate level of fire safety also apply to the elements of filling the openings of buildings and partitions.

Methodology. In connection with it, experimental and theoretical researches on fire hazard indicators and limits of fire resistance of translucent building structures have been carried out (hereinafter - TBS) as well as the influence on these indicators of irrigation by the fire sprinklers of the automatic extinguishing system. The object of the research is a translucent building structure made of thermostatic glass.

Fire resistance problems, including glass structures, have been investigated by other authors [10-14] using different mathematical modelling methods [15-19].

Our earlier analysis of the mathematical models for predicting the behaviour of TBS in fire conditions for the purpose to determining their limits for fire resistance both in normal condition and in water irrigation has shown the need for large-scale fire tests [20].

For fire researches, a number of criteria and parameters for the fire resistance of the translucent partition have been developed including a research of the dynamic effects of water irrigation on TBS, fire resistance in standard and real fire conditions, real fire conditions, fire resistance during irrigation of the automatic water-extinguishing system in standard fire conditions.

The basic regulatory document for testing is National Standard of the Republic of Kazakhstan ST RK 2219-2012 "Civil Structures. Constructions for enclosing structures and filling openings with the light-transmitting elements. Fire resistance test procedure" [21]. This document sets out in full the methodology and tools for the fire test. To conduct the tests, the standard methodology has been refined and validated, and the laboratory installation has been supplemented by system of water irrigation and drainage from the installation of unused water.

In order to obtain reliable results of experimental researches, the development of methods and direct tests were carried out together with the laboratory of "RD-Fire Group" LLP which is accredited for conducting such tests.

In the course of fire tests, it was tested TBS made of tempered glass "Float" with the thickness of 12 mm, M1 grade producer: Russia.

Experimental researches. The first experiment was carried out for the TBS made of tempered glass "Float" with a thickness of 12 mm, M1 grade, mounted in the opening of the test-stand without using water irrigation. Figure 4 shows a fragment of full-scale fire tests. Figure 5 shows the temperature schedule of the kiln during the cellulosic fire test in which it is clear that by 8 minutes the actual temperature has begun to exceed the design temperature for the standard (hydrocarbon) fire.

It has been established that the maximum average volume temperature of the cellulose fire was 560°C, and at this temperature the glass fracture does not occur. The above-mentioned average fire temperature occurs at 16 minutes of fire with a fire load corresponding to 50 kg/m^2 for public buildings when converted to wood. It follows from this that the fire resistance limit of E15 glass without irrigation will guarantee safe evacuation of people through the emergency exit routes without exposure to the dangerous fire factors associated with the destruction of the partition. However, the limit on the fire resistance of E15 glass allows to guarantee with great margin of the stability of the glass partition for the

time required for the supply of water from the automatic fire extinguishing installation which is equal to 180 sec.

Figure 6 shows the dynamics of temperature changes on the non-heated surface of the sample as well as its average and maximum values. On the graph the horizontal straight lines correspond to the critical temperatures at which the thermal insulation capacity of TBS made from the tempered glass is lost at the 10th minute.

Figure 4 – Fragment of test to determine the actual fire resistance limit of glass under the real fire load

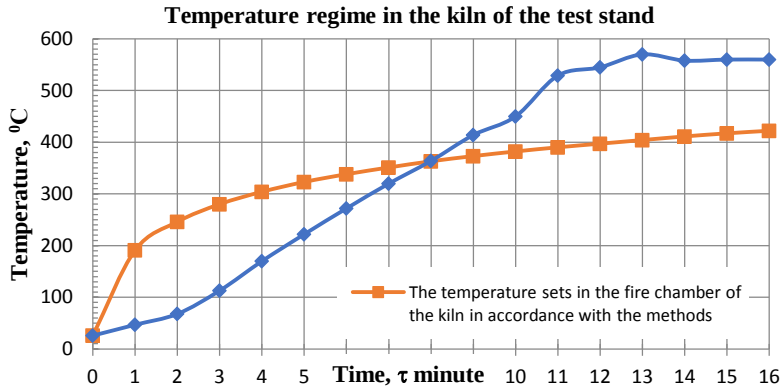

Figure 5 – Temperature regime in the kiln of the test - stand.

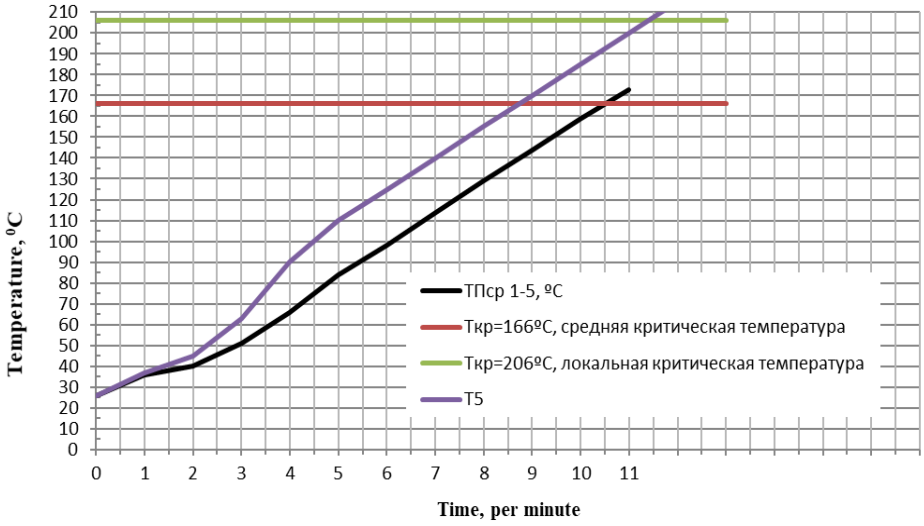

Figure 6 – The results of temperature measurements on the non-heated surface of the sample

A structural failure was recorded at 16 minutes of the experiment.

Thus, based on the results of the passed tests, the actual limit of fire resistance for TBS was determined from the tempered glass "Float" without the effect of water irrigation, it was 10 minutes on the base of heat-insulating capacity and 15 minutes on the base of structure integrity loss.

The next round of experiments was carried out with the water irrigation of TBS. The temperatures set in the fire chamber of the kiln during this test are shown in figure 7. We would like to note that the positive effect of irrigation is achieved if the whole structure is included in the irrigation map.

The graph (see figure 7) shows that the actual fire temperature in the fire chamber when using irrigation is reduced by 2.4 times relative to the temperature of the standard fire. For example, the maximum average temperature in the fire chamber of the kiln was equal to 369 °C at 46 minutes and the temperature on the non-combustible surface of the glass being irrigated was equal to 166 °C (see figure 8). In view of the above we can make the following conclusion:

- irrigation of the glass partition allows to reduce the average volume temperature of the fire by 2.4 times;

- within 46 minutes the temperature of the glass partition does not reach the critical values at which it is predicted possible collapse. (T_f = 166 °C ≤ T_{kr} = 560 °C, where T_f is the actual temperature, T_{kr} is the critical temperature at which the structure breaks down);

- The maximum permissible value of heat flow density W (radiation) for 46 minutes corresponding (3.5 ± 0.2) kW/m^2, is not reached. (see figure 9).

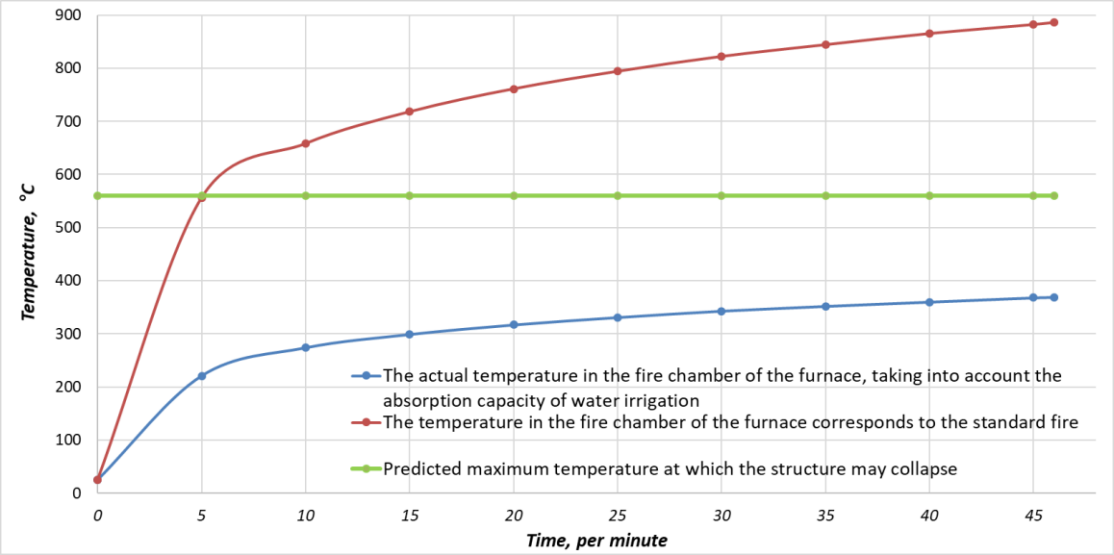

Figure 7 – Temperature regime in the fire chamber of the test stand when using surface irrigation of the glass partition

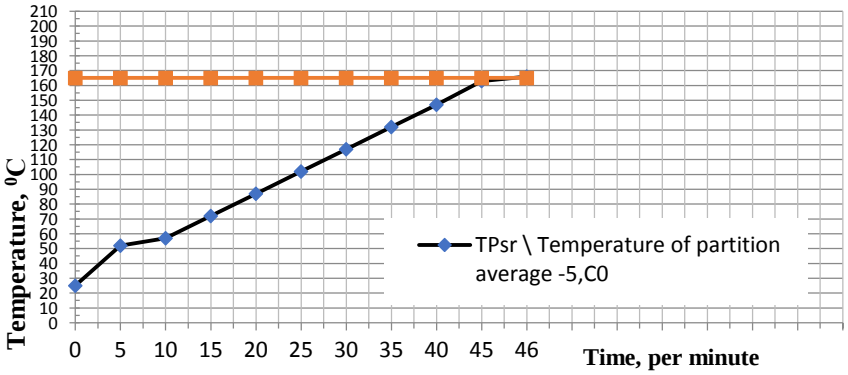

Figure 8 – The results of temperature measurements on the non-heated surface of the sample using irrigation.

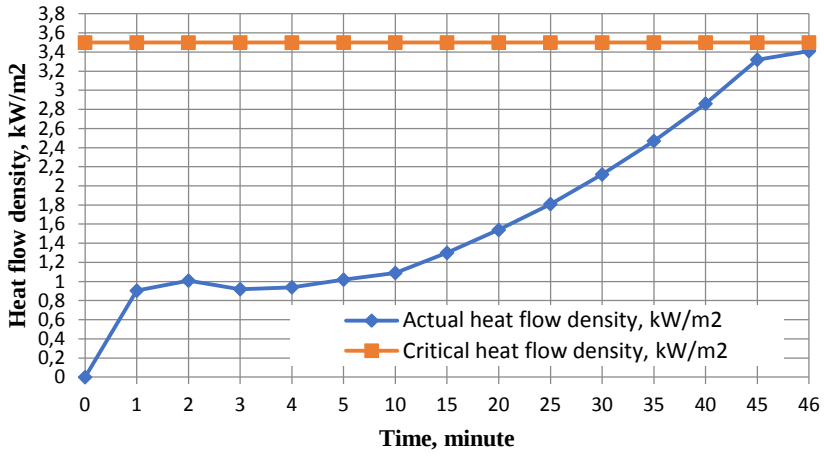

Figure 9 – The results on measurements of the thermal insulation loss (W) due to reaching the achievement of permissible heat flow density (radiation)

During the hydraulic tests on the effects of water irrigation on the glass structure, it is established that vibration occurred to its leakproofness is not recorded.

Conclusion. The conducted researches provide us with grounds to propose rationing the fire resistance limits of translucent building structures to water irrigation provided that the whole structure will be included in the irrigation map as well as to improve the methods of testing systems of "translucent building structure – water irrigation" for fire resistance.

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ЖАРЫҚ ӨТКІЗГІШ ҚҰРЫЛЫМДАРДЫ ҚОЛДАНУ НЕГІЗІНДЕ ӨРТ ҚАТЕРІН ЗЕРТТЕУ ЖӘНЕ БАСҚАРУ

Аннотация. Мақалада құрылыс индустриясының дамуы, Қазақстанда болып тұратын өрт жағдайы бойынша мәліметтер келтірілген. Аталған мәліметтер талдамасы құрылыс, сондай-ақ, қоғамдық және тұрғын-жай ғимарат мақсатындағы нысандарда адамға қауіпті факторлардың туу қатерін жоғары дәрежелеу қорытындысын жасауға мүмкіндік береді. Өрт қауіпсіздігін қамтамасыз ету мәселелерінің Қазақстанда және басқа елдерде өзектілігі айқындалуда.

Өрт жағдайын талдау негізінде өрттің алдын алу бағытының бірі техникалық реттеуге байланысты болып келеді, атап айтқанда, материал, құрылыс құрылымы және инженерлік құрылғылар мен жүйелердің құрылым саласында қолданылатын міндетті сертификаттау қамтылады. Өрт қауіпсіздігі көрсеткіштері бойынша сынақта негізделген сертификаттау құрылыста қолданылатын объектілер, әсіресе, адамдардың ауқымды қатысуы, технологиялық материалдар мен құрылымдардың техникалық регламент талаптарына сәйкес келуін қамтамасыз етеді. Өрт қауіпсіздігін жеткілікті деңгейде қамтамасыз ету бойынша талаптар ғимарат ойығы мен қалқанын толтыру элементтеріне жатады.

Заманауи құрылыста бірегей сәулет объектілерін қолдану үшін жарықөткізгіш құрылыстық құрылымдар көп қолданылады. Мұндай құрылымдар үшін әлсіз көрсеткіштер өртке төзімділік шегі болып саналады.

Жарықөткізгіш құрылымдардың өртке төзімділік көрсеткішін арттыру тәсілінің бірі болып суландыруды қолдану бойынша техникалық шешім ұсынылады.

Ғимараттағы өрттің жылу режимінің қолданыстағы математикалық моделінің талдамасы, әсіресе, сумен салқындату әсерінің есебімен, ірі ауқымды эксперименттік зерттеу жүргізу қажеттілігін көрсетті. Бұрын өткізілген эксперименттер зертханалық категорияға жатады және ғимараттар бойынша өрттің алдын алуға бағытталған нормативті талаптарды жеткілікті қамти алмайды.

Құрылыс құрылымдарының отқа төзімділігінің нақты шегін анықтау ортасында қолданыстағы ұлттық стандарттар қолданылмайды, себебі өрт кезінде суландыру үрдісін қарастырмайды. Сондықтан қолданыстағы халықаралық және ұлттық нормативтік құжаттар негізінде өрт кезінде құрылымдарды сумен салқындату арқылы нақты шегін эксперименттік анықтау бойынша әдістер қатары өңделді.

Зерттеу барысында жарықөткізгіш қалқанының өртке төзімділігінің нақты шегін анықтау бойынша өрттік полигондық, ірі ауқымды зерттеулер келтірілген, суландыру барысында М1 маркалы, 12 мм қалыңдықты, «Флоат» термошыңдалған шыны арқылы орындалған. Сынақтар стандартты және нақты өрт кезінде жүргізілді. Зерттеу жүргізу кезінде стандартты және нақты өрт шарттары шығарылды:

Зерттеу нәтижесінде анықталды:

1. Шыны 560 °С целлюлозалы өрттің орташа көлемді температура кезінде сынбайды. Ағашқа санағанда 50 кг/м^2 қоғамдық ғимарат үшін сәйкесінше өрттік жүктеу кезінде жоғарыда көрсетілген өрттің орташа көлемді температурасына жетуі өрттің 16 минутында орын алады. Суландыру есебінсіз Е15 шынының өртке төзімділік шегі қалқандардың бұзылуына байланысты өрттің қауіпті факторларының әсерінсіз эвакуациялау жолдары бойынша адамды қауіпсіз эвакуациялауға кепілдік береді. Сонымен қатар Е15 әйнегінің өртке төзімділік шегі 180 сек. тең өрт сөндірудің автоматты қондырғысынан қажетті суды беру үшін шыны қалқанның тұрақтылығын қамтамасыз етеді.
2. Зерттеуде жарықөткізгіш құрылымдарын суландыру жұмыстары пештің от камерасында температуралық режим стандартты өрт режиміне сәйкес келді. Бұл ретте суландыру кезінде от камерасындағы өрттің нақты температурасы стандартты өрт температурасына қатысты 2,4 есе төмендейді. Шыны қалқан температурасы 46 минутта оның ықтимал құлау болжамы сыни мәнге жетпейді.

Зерттеулер нәтижесі бойынша оңтайлы суландыру параметрлері анықталды. Зерттеу нәтижелері негізінде мұндай ортадағы құрылыстық нормалаудың жетілдіру жолдары, сондай-ақ сертификатталған сынақ ортасындағы әдістемелік құжаттар ұсынылады.

Түйін сөздер: өрт қауіпсіздігі, жарық өткізгіш құрылымдар, өрт сынағы, өртке төзімділік.

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ИССЛЕДОВАНИЯ И УПРАВЛЕНИЕ ПОЖАРНЫМИ РИСКАМИ НА ОБЪЕКТАХ С ПРИМЕНЕНИЕМ СВЕТОПРОЗРАЧНЫХ КОНСТРУКЦИЙ

Аннотация. В статье приведены данные по развитию строительной индустрии, а также по пожарам, происходящим в Казахстане. Анализ представленных данных позволяет сделать выводы высокой степени риска возникновения опасных факторов для людей на объектах строительства, в особенности зданиях общественного и жилого назначения. Вопросы обеспечения пожарной безопасности продолжают быть достаточно актуальными как в Казахстане, так и в других странах.

На основе анализов пожаров обосновывается, что одним из направлений работы по профилактике пожаров является направление, связанное с техническим регулированием, а именно обязательной сертификацией применяемых в строительной отрасли материалов, строительных конструкций и инженерного оборудования и систем. Сертификация, основанная на испытаниях по показателям пожарной опасности, обеспечит соответствие применяемых при строительстве объектов, в особенности с массовым пребыванием людей, технологичных материалов и конструкций требованиям технических регламентов. Требования по обеспечению достаточного уровня пожарной безопасности относятся и к элементам заполнения проемов зданий и перегородок.

В современном строительстве, как правило, для уникальных по архитектурному решению и использованию объектов, все большее применение находят светопрозрачные строительные конструкции. Для таких конструкций наиболее уязвимым показателем является предел огнестойкости.

Одним из способов повышения показателя предела огнестойкости светопрозрачных конструкций предлагается техническое решение по применению водяного орошения.

Анализ существующих математических моделей теплового режима пожара в помещении, особенно с учетом эффекта охлаждения водой, показал необходимость проведения крупномасштабных экспериментальных исследований. Ранеепроводимые эксперименты относятся к категории лабораторных и не могут в

достаточном объеме обосновать нормативные требования, направленные на предотвращение пожара по зданию.

Действующие национальные стандарты в области определения фактического предела огнестойкости строительных конструкций не могут быть применены, потому что не предусматривают процесс водяного орошения при пожаре. Поэтому на основе существующих международных и национальных нормативных документов разработан ряд методик по экспериментальному определению фактического предела огнестойкости при охлаждении светопрозрачной конструкции водой при пожаре.

В ходе исследований проведены крупномасштабные, огневые исследования по определению фактического предела огнестойкости светопрозрачной перегородки, выполненной из термозакаленного стекла «Флоат», толщиной 12 мм, марки М1 как при наличии водяного орошения, так и при его отсутствии. При проведении исследований воспроизводились условия стандартного и фактического пожара.

В результате исследования определено:

1. Разрушения стекла при максимальной среднеобъемной температуре целлюлозного пожара 560 °С не происходит. Достижение вышеуказанной среднеобъемной температуры пожара возникает на 16 минуте пожара при пожарной нагрузке, соответствующей для общественных зданий 50 кг/м^2 при перерасчете на древесину. Предел огнестойкости стекла Е15 без учета орошения позволит гарантировать безопасную эвакуацию людей по эвакуационным путям без воздействия на них опасных факторов пожара, связанных с разрушением перегородки. Вместе с тем, предел огнестойкости стекла Е15 позволяет с большим запасом гарантировать обеспечение устойчивости стеклянной перегородки на время необходимого для подачи воды от автоматической установки пожаротушения равной 180 сек.

2. При исследованиях с применением водяного орошения светопрозрачных конструкций температурный режим в огневой камере печи соответствовал режиму стандартного пожара. При этом фактическая температура пожара в огневой камере при использовании орошения снижается в 2,4 раза по отношению к температуре стандартного пожара. Температура стеклянной перегородки в течении 46 минут не достигает критичных значений, при которой прогнозируется ее возможное обрушение.

По результатам исследований определены оптимальные параметры водяного орошения.

На основе результатов исследований предлагаются пути совершенствования строительного нормирования в данной сфере, а также методических документов в области сертификационных испытаний.

Ключевые слова: пожарная безопасность, светопрозрачные конструкции, огневые испытания, огнестойкость.

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DYNAMICS OF HEAVY VIBRATING MACHINES TAKING INTO ACCOUNT INSTABILITY IN TIME OF THEIR PARAMETERS

Abstract. Underground mining of uranium ores consists of several technological processes, one of the most important of which is the release of broken rock from the working excavation zone and loading it into transportation vehicles. The issue of increasing the intensity of production requires a simultaneous increase in the productivity of all production processes, including the production of mineral raw materials. At the same time, it is necessary to create both a high-performance and a safe process. This problem is successfully solved by the use of vibration machines with elastic links made of elastomeric materials, which, along with an increase in productivity, can reduce energy consumption and the number of freezes. An integrated approach was used, which includes analytical studies and results of industrial tests of vibratory feeders for underground mining and delivery of uranium ores and building materials. On the basis of the developed algorithm and synergistic model of fatigue microfracture of rubber links in vibratory feeder, mathematical equations were obtained, which made it possible to describe dynamics of feeders with time-depending parameters; when solving the integro-differential equation of the oscillatory system, the dependence of the amplitude characteristics of the feeder on the time of its operation is obtained. An original algorithm and synergistic model were developed, and on their basis, a mathematical apparatus was created, which allowed determining change of amplitude of vibratory feeder oscillations during its operation. On the basis of analytical calculations, a method was developed and introduced for predicting changes of parameters change of oscillation amplitudes of vibratory feeder used for underground mining and feeding of uranium ores.

Key words: vibratory feeder, vibrations, synergetic model, fatigue failure.

Introduction. During the long-term operation of mining machines, the physical and mechanical properties of elastic links based on elastomeric materials do not remain constant, but change significantly due to aging of the material from a long cyclic load or the action of an active external environment, for example, radiation fluxes. This leads to a change in the parameters of the machines themselves and the disruption of technological processes [1-5].

The presence of experimental data on changes in the basic mechanical properties of elastic links over time, such as shear modulus G and dissipation coefficient ψ for given loading conditions, significantly simplifies the calculation of vibratory machines. However, such experimental information is in most cases absent since to obtain it requires a variety of and fairly lengthy studies. Below we consider an algorithm that allows one to determine the mechanical characteristics with a minimum of experimental data, taking into account the microdestruction that develops in elastic links.

The purpose of the work is the development of a synergetic model and algorithm for calculating vibration feeders taking into account the instability in time of their parameters; confirmation of the analytical model by the results of industrial tests.

Method. In this paper, we consider the dynamics of heavy mountain vibrating feeders of the VOF type (vibrating ore feeders) working under the rubble for the production and delivery of uranium ores. Structurally, VOF vibrating feeders are a single-mass oscillatory system; prismatic rubber elements of the RMB type (rubber-metal blocks) serve as elastic links. During operation, such elements experience simple shear deformations; their physical and mechanical parameters are unstable in time: the shear modulus increases, and the dissipation coefficient decreases. Such a change is mainly associated with aging processes inherent in all elasto-hereditary materials, which include rubber [6-10].

The calculation algorithm described below uses the Walpole method developed for composite materials [11,12], which consists in the fact that the characteristics of the material are determined averaged by the characteristics of the main material, the characteristics of the material of the inclusions and depending on the concentration of these inclusions.

In our case, the main material is intact rubber, and the inclusion material is the microdestruction that develops in the main material.

It was previously shown [13] that for cases when instantaneous modulus $\hat{G}_0'$ of initially homogeneous material and elastic modulus of inclusions $\hat{G}_1'$ do not depend on time, and when inclusions in material are only of one type, then instantaneous value of effective moduli $\hat{G}_{ef}'$ of non-uniform material, i.e. material with different inclusions, can be represented as:

$$\hat{G}_{ef}' = \hat{G}_1' + (1-p)(\hat{G}_0' - \hat{G}_1'):\left[\hat{I} + p\left(\overline{\hat{G}_0'} + \hat{G}_1'\right)^{-1} : (\hat{G}_0' - \hat{G}_1')\right]^{-1}, \text{ Pa}, \quad (1)$$

where $\hat{G}_1'$ is tensor of inclusion elastic modulus, Pa; $\overline{\hat{G}_0'}$ is isotropic tensor, which is connected with the tensor of the moduli $\hat{G}_0'$ of the material basic matrix by the known ratio [14], Pa; p is total concentration of inclusions in typical volume of material; $\hat{I}$ is identity tensor.

Hence, value of $\hat{G}_{ef}'$ can be obtained after determining $\hat{G}_1'$ and $\hat{G}_0'$, and performing appropriate mathematical operations.

With the help of physical model of rubber fracturing [15] under the action of cyclic loading, we obtain ratio for effective modulus of the rubber in question, whose mechanical properties change significantly as a result of structuring processes: shear modulus increases, and dissipation factor decreases. It should be noted that in this paper, only one macroscopic characteristic of rubber is considered, namely, effective shear modulus. Despite availability of experimental data, it is impossible to take into account dependence of dissipative properties on developing fracture directly in the general algorithm because of absence of well-developed mathematical apparatus.

With taking into account experimental information mentioned above [15], let's accept the following synergistic model of fatigue fracture of rubber elements. Sample is a set of material points, each of them features the same properties as the source material. Process of accumulation and development of microfractures is interpreted as formation, in the initially homogeneous and isotropic material, of some areas with inclusions (areas containing fractures) with new properties, though identical in all areas.

When calculating the effective modulus, a number of assumptions is made; rubber in the initial state is homogeneous and isotropic; the modulus of the resulting inclusions is n times larger than the modulus of the base material; developing inclusions are mathematically characterized by a matrix of elastic moduli similar to the matrix of elastic moduli of the base material; the elastic modulus of the material inclusions is independent of time.

Taking into account the proposals made, and presenting the independent components of stress tensor in the form of a six-dimensional column matrix [16], matrix of elastic moduli $\hat{G}_0'$ can be written in the following way

$$\hat{G}_0' = \begin{Vmatrix} 2E/3 & 0 & 0 & 0 & 0 & 0 \\ 0 & 2E/3 & 0 & 0 & 0 & 0 \\ 0 & 0 & 2E/3 & 0 & 0 & 0 \\ 0 & 0 & 0 & 2E/3 & 0 & 0 \\ 0 & 0 & 0 & 0 & 2E/3 & 0 \\ 0 & 0 & 0 & 0 & 0 & 2E/3 \end{Vmatrix}, \text{ Pa}, \tag{2}$$

matrix of elastic moduli of microdamages can be written as

$$\hat{G}_1' = \begin{Vmatrix} 2En/3 & 0 & 0 & 0 & 0 & 0 \\ 0 & 2En/3 & 0 & 0 & 0 & 0 \\ 0 & 0 & 2En/3 & 0 & 0 & 0 \\ 0 & 0 & 0 & 2En/3 & 0 & 0 \\ 0 & 0 & 0 & 0 & 2En/3 & 0 \\ 0 & 0 & 0 & 0 & 0 & 2En/3 \end{Vmatrix}, \text{ Pa}, \tag{3}$$

where E is elastic modulus of medium, Pa.

To obtain the values of the moduli $\hat{G}_{ef}'$ by the formula (1), it is necessary to determine all the tensor quantities included in this expression and perform the corresponding mathematical operations with them. So, the components of the tensor $\hat{G}_0'$ are presented in the form

$$G_{0ijkl} = \frac{\mu(\lambda+6\mu)}{3\lambda+8\mu}\delta_{ij}\delta_{kl} + \frac{\mu(9\lambda+14\mu)}{2(3\lambda+8\mu)}\left(\delta_{il}\delta_{ik} + \delta_{jl}\delta_{ik}\right), \text{ Pa}, \tag{4}$$

and tensor itself has the following form

$$\hat{G}_0' = \begin{Vmatrix} 10E/9 & E/9 & E/9 & 0 & 0 & 0 \\ E/9 & 10E/9 & E/9 & 0 & 0 & 0 \\ E/9 & E/9 & 10E/9 & 0 & 0 & 0 \\ 0 & 0 & 0 & E & 0 & 0 \\ 0 & 0 & 0 & 0 & E & 0 \\ 0 & 0 & 0 & 0 & 0 & E \end{Vmatrix}, \text{ Pa}, \tag{5}$$

where λ and μ are the Lame coefficients for basic medium, s^{-1}; δ are the Kronecker symbols; i, j, k, l = 1, 2, 3.

Tensor operations: sum of tensors, inverse tensor and convolution of tensors are performed according to the known formulas for tensor analysis [16]. Finally, we get the following expression for

$$\hat{G}_{ef}' = \begin{Vmatrix} A & 0 & 0 & 0 & 0 & 0 \\ 0 & A & 0 & 0 & 0 & 0 \\ 0 & 0 & A & 0 & 0 & 0 \\ 0 & 0 & 0 & B & 0 & 0 \\ 0 & 0 & 0 & 0 & B & 0 \\ 0 & 0 & 0 & 0 & 0 & B \end{Vmatrix}, \text{ Pa}. \tag{6}$$

Here, the following expressions are accepted

$$A = \frac{2E}{3}\left[n + \frac{(1-p)(1-n)\Delta}{\Delta + p\Delta_1(1-\Delta)}\right], \text{ Pa}; \qquad B = \frac{2E}{3}\left[n + \frac{(1-n)(1-p)\left(n+\frac{3}{2}\right)}{\left(n+\frac{3}{2}\right) + p(1-n)}\right], \text{ Pa};$$

$$\Delta = \left[4\left(n+\frac{5}{3}\right)^3 - \frac{1}{3}\left(n+\frac{5}{3}\right) + \frac{1}{9}\right]; \quad \Delta_1 = 4\left(n+\frac{5}{3}\right)^2 - \frac{1}{9}. \tag{7}$$

When $n = 0$, i.e. in the absence of any fractures, effective modulus coincides with the modulus of the source material; when $n = 1$, effective modulus coincides with the modulus of microdamages. These conclusions are natural as they follow from the very statement of the problem and validate correctness of the made calculations.

In this way, dependences of stresses and strains on the magnitude of microfractures, which are developing in the material, can be obtained. And relation between the deformation γ and stress τ in this case is expressed as

$$\tau = \hat{G}'_{ef} \cdot \gamma \text{ , Pa,} \tag{8}$$

where

$$\hat{G}'_{ef} = G_{in}\left[n + \frac{(1-n)(1-p)\left(n+\frac{3}{2}\right)}{\left(n+\frac{3}{2}\right)+p(1-n)}\right] \text{, Pa.} \tag{9}$$

Here, G_{in} is initial value of the source material modulus, Pa.

Results and discussion. Let's use the obtained results for calculation of effective modulus of RMB type elements made of 2959-type rubber (on the basis of natural caoutchouc with filling of 45 mass parts of black carbon), for which initial value of rubber dynamic is G_{in} = 1.60 MPa (at an oscillation angular frequency ω = 60-80 rad/s). Let's use the previously obtained in [6, 8-10] experimental results on time-dependent change of the shear modulus for elements made of rubber 2959, and let's assume that n = 1.2.

Let's consider a concrete example. Let it be necessary to predict a change of oscillation amplitude in ore vibratory feeder of the VPR-4m type, elastic links of which are made in the form of shift elements of the RMB type. Parameters of vibratory feeder are as follows: mass of vibrating elements is m = 3770 kg; oscillation angular frequency is ω = 101.5 rad/s; initial value of instantaneous shear modulus for rubber is G_{in} = 1.76 MPa; and dissipation coefficient is ψ = 0.31.

Equation for the vibrating elements movements in the vibratory feeder is

$$m\ddot{x} + C_t x = P\sin\omega t \text{ ,} \tag{10}$$

where m is mass of the work member, kg; C_t is reduced stiffness of the main elastic links, N/m; P is exciting power, N; ω is loading angular frequency, rad/s; t is time, s.

The solution of equation (10) is expressed as

$$x = a\sin(\omega t - \varphi), \tag{11}$$

where x is coordinate, m; φ is phase, rad.

Express the dependence of the amplitude of the conveyor oscillations as follows

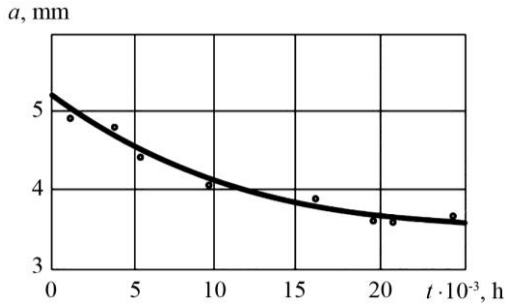
$$a = \frac{Q}{m\sqrt{\left\{\omega_0^2\left[1 - A_1(\omega)\right] - \omega^2\right\}^2 + B_1^2(\omega)\omega_0^4}} \text{ .} \tag{12}$$

Here a is amplitude of oscillations, m; Q is the force of inertia, N; ω_0 is natural vibration angular frequency of an ideally elastic system, rad/s; $A_1(\omega)$ and $B_1(\omega)$ are rheological characteristics of rubber (cosine and sine Fourier transform of a fractional exponential function) [6].

Values for effective modulus were determined from the dependence $G_{ef} \sim p/p_{kr}$ by the formula (9), rate of critical fracture p_{kr} = 5,6 was taken according to the experimental data obtained in [6], and kinetic curve $p(t)$ was also obtained experimentally on model samples with long-term cyclic loading.

Time dependence of vibratory feeder amplitude calculated in this way is shown in figure and, as it is seen, satisfactorily coincides with experimental data [6]. This coincidence confirms the suitability of the proposed method for calculating mechanical characteristics of vibration machines, the elastic links of which change their parameters over time. As it is seen, oscillation amplitude decreased from 5.2 mm to 3.7 mm after 24,000 hours and led to degradation of vibratory feeder productivity.

It should be noted that in engineering practice, change of oscillation amplitude in vibratory machines during their long-term operation is quite frequent phenomenon. In practice, this undesirable phenomenon is usually eliminated by changing frequency of drive oscillations or, in case of excessive stiffness, by replacing elements in the elastic suspension.



Change of oscillation amplitude of the VPR-4m vibratory feeder
at long-term operation: the points is experimental data, the line is calculated curve

Conclusions. 1. A synergistic model and algorithm were developed for calculating vibratory feeders for drawing and feeding uranium ores with taking into account time-dependent instability of elastic suspension parameters.

2. When solving the integro-differential equation of the oscillatory system and taking into account the unstable in time rheological parameters of the rubber elements of the elastic suspension of the feeder, the dependence of its oscillation amplitude on the operating time is obtained; calculation results satisfactorily coincide with the data of industrial tests.

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ПАРАМЕТРЛЕРІ УАҚЫТЫНДАҒЫ ТҰРАҚСЫЗДЫҚТЫ ЕСКЕРЕТІН АУЫР ДІРІЛ МАШИНАЛАРЫНЫҢ ДИНАМИКАСЫ

Аннотация. Уран кенін жерасты өндіру бірнеше технологиялық үдерістерден тұрады, олардың ең маңыздысының бірі – сынған тау жыныстарын тазарту кеңістігінен шығару және оны көлік құралдарына тиеу. Өндіріс қарқындылығын арттыру мәселесі барлық өндірістік үдерістердің, оның ішінде минералды шикізат өндірісінің өнімділігін бір уақытта арттыруды талап етеді. Сонымен бірге жоғары тиімділікті де, қауіпсіз үдерісті де құру қажет. Бұл мәселе эластомерлік материалдардан жасалған серпімді байланысы бар діріл машиналарын қолдану арқылы сәтті шешіледі, бұл жағдай өнімділіктің жоғарылауымен бірге энергия шығынын және қатып қалу санын азайтуға мүмкіндік береді.

Әртүрлі технологиялық мақсат үшін діріл технологиясын жасаудың әлемдік тәжірибесін зерттеу оның негізінен минералды бетінде өңдеу үшін қолданылатындығын көрсетті. Жерасты жағдайында діріл технологиясын қолдану әлемдік тәжірибеде іс жүзінде жоқ, сонымен қатар бұл мәселе бойынша ғылыми әдебиеттер де кездеспейді.

Жұмыста уран кенін өндіру және жеткізуде блокада астында жұмыс істейтін VPR типтегі ауыр діріл беретін фидерлер (діріл кенін беру) динамикасын қарастырамыз. Құрылымдық тұрғыдан алғанда, VPR дірілдеткіштері – біртекті массалы тербеліс жүйесі; BRM типтегі призмалық резеңке элементтер (резеңке-металл блоктар) серпімді буын ретінде қызмет етеді. Жұмыс кезінде мұндай элементтер қарапайым ығысу деформацияларына ұшырайды; олардың физикалық және механикалық параметрлері уақыт бойынша тұрақсыз: ығысу модулі жоғарылайды, ал ыдырау коэффициенті төмендейді. Мұндай өзгеріс негізінен резеңке кіретін барлық эласто-тұқым қуалайтын материалдарға тән қартаю үдерісіне байланысты болып келеді.

Аналитикалық зерттеулерді және уран кенін, құрылыс материалдарын жерасты қазып шығаруда және дірілді өнеркәсіптік сынау нәтижелерін қоса қанда кешенді тәсіл қолданылды. Әзірленген алгоритмге және тербелмелі бергіштің резеңке байланыстары микрокрекингінің синергетикалық моделіне сүйене отырып, уақытты тұрақсыз параметрлермен қоректендіргіштер динамикасын сипаттауға мүмкіндік беретін математикалық теңдеулер алынды; тербелмелі жүйенің интегро-дифференциалдық теңдеуін шешкенде фидердің

амплитуда сипаттамаларының жұмыс уақытына тәуелділігі алынады. Түпнұсқа алгоритм және синергетикалық модель жасалды және олардың негізінде математикалық аппарат құрылды, ол жұмыс кезінде діріл бергіштің тербеліс амплитудасының өзгеруін анықтауға мүмкіндік береді. Аналитикалық есептеу негізінде діріл бергіштің тербеліс амплитудасы параметрлерінің өзгеруін болжау әдісі жасалды және енгізілді. Бұл әдіс уранды шахтада жұмыс істеп тұрған VPR-4 м діріл бергішінің тербеліс амплитудасының өзгеруін есептеу үшін руданы төгу және арбаларға тиеу кезінде пайдаланылды. Мұндай фидерлердің жұмыс мерзімі шамамен 2-3 жыл. Үш вибраторлы фидер жұмысының бүкіл кезеңінде (шамамен 30 мың сағат) жұмыс органдары тербелістерінің амплитудасы мен жиілігін өлшеу бойынша эксперименттік зерттеулер жүргізілді. Алынған есептеу нәтижелері өндірістік сынақ нәтижелері бойынша қанағаттанарлық деңгейде.

Түйін сөздер: діріл бергіш, діріл, синергетикалық модель, шаршау.

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ДИНАМИКА ТЯЖЁЛЫХ ВИБРАЦИОННЫХ МАШИН С УЧЁТОМ НЕСТАБИЛЬНОСТИ ВО ВРЕМЕНИ ИХ ПАРАМЕТРОВ

Аннотация. Подземная разработка урановых руд состоит из нескольких технологических процессов, одним из наиболее важных из которых является выпуск отбитой горной массы из очистного пространства и погрузка её в средства транспортировки. Вопрос повышения интенсивности добычи требует синхронного повышения производительности всех процессов добычи, в том числе и выпуск минерального сырья. При этом необходимо создавать как высокопроизводительный, так и безопасный процесс. Эта проблема успешно решается применением вибрационных машин с упругими звеньями из эластомерных материалов, которые наряду с увеличением производительности позволяют снизить энергоёмкость и количество зависаний.

Изучение мирового опыта создания вибрационной техники различного технологического назначения показало, что преимущественно она используется для переработки минерального на поверхности. Применение вибрационной техники в стеснённых подземных условиях в мировой практике практически отсутствует, а также отсутствует и научная литература по данному вопросу.

В статье рассматривается динамика тяжёлых горных вибрационных питателей типа ВПР (вибрационные питатели рудные), работающих под завалом на выпуске и доставке урановых руд. Конструктивно вибропитатели ВПР представляют собой одномассную колебательную систему; упругими звеньями служат призматические резиновые элементы типа БРМ (блоки резинометаллические). При эксплуатации такие элементы испытывают деформации простого сдвига; их физико-механические параметры во времени нестабильны: модуль сдвига увеличивается, а коэффициент диссипации уменьшается. Такое изменение связано в основном с процессами старения, присущими всем упруго-наследственным материалам, к которым относится и резина.

Использован комплексный подход, включающий аналитические исследования и результаты промышленных испытаний вибропитателей при подземной добыче и доставке урановых руд и строительных материалов. На основе разработанных алгоритма и синергетической модели усталостного микроразрушения резиновых звеньев вибропитателя получены математические уравнения, позволяющие описать динамику питателей с нестабильными во времени параметрами; при решении интегро-дифференциального уравнения колебательной системы получена зависимость амплитудной характеристики питателя от времени его эксплуатации. Разработан оригинальный алгоритм и синергетическая модель и на их основе создан математический аппарат, позволяющий определить изменение амплитуды колебаний вибропитателя в течение его эксплуатации. На основе аналитических расчётов разработан и внедрён метод прогнозирования изменения параметров амплитуды колебаний вибропитателя. Этот метод использован для расчёта изменения амплитуды колебаний вибрационного питателя типа ВПР-4м, работающего в урановом руднике под завалом при выпуске руды и погрузке её в вагонетки. Длительность эксплуатации таких питателей примерно 2-3 года. На протяжении всего времени эксплуатации трёх вибропитателей (около 30 тысяч часов) проводились экспериментальные исследования по замеру амплитуды и частоты колебаний их рабочих органов. Полученные результаты расчёта удовлетворительно совпадают с результатами промышленных испытаний.

Ключевые слова: вибропитатель, колебания, синергетическая модель, усталостное разрушение.

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FIRE RISKS OF PUBLIC BUILDINGS

Abstract. The complex research method is used in the work, which includes: analysis and generalization of scientific achievements in the field of fire safety, application and processing of statistical data; application as analytical methods of research by collecting, generalizing and analyzing the current normative documents of the State Emergency Service of Ukraine and statistical methods of probability theory, geospatial, mathematical modeling, methods of system analysis.

Research Object: The risk of death from fire in public buildings and structures.

The purpose of the work is risk evaluation of death from fires in public buildings.

Research methods. The complex method of researches is used in the work, which includes: analysis and application of statistical methods of data processing, verification of reliability of the obtained results, mathematical modeling and other analytical methods.

The concept of the risk is described in the article and the main normative documents are outlined that treat them. The basic methods and methods of risk assessment for public buildings are analyzed.

Fire risk assessment is the calculation of individual fire risk for residents, staff and visitors in a public building. The numerical expression of an individual fire risk is the frequency of exposure of hazardous fire factors to a person in a building or structure. The frequency of exposure to hazardous fire factors is determined for fire-hazardous situations, which are characterized by the greatest danger to the life and health of people in the building.

The CFAST program simulated the occurrence of limit concentrations of hazardous factors during fires for two typical public buildings. It is also suggested how to evaluate the results on a specific color scale that allows you to create risk maps for visualization. The draft methodology proposes to consider the follow-up time of fire and rescue units when determining the evacuation time.

The main methods and methodologies of risk assessment for buildings and public facilities have been analyzed. For two facilities, the risk of death from fire in buildings and facilities has been estimated. The results of evaluation have been suggested in a color scale, which allows creating maps to visualize the risks. The simulation of the limit concentrations of hazardous factors during the fires for two typical public facilities has been done in CFAST software.

Mapping the risks of death from a fire in the appropriate group in the appropriate colors allows you to build a map of the risks of death from a fire and fire and rescue workers know the possible risks and dangers of the objects.

The start time of the evacuation, in the absence of warning systems, is determined depending on the time the fire and rescue units follow to the fire site.

The proposed calculation methodology and visualization tools allow the rescuer, who makes the decision, to comprehensively assess the situation during the design and to avoid the possible consequences of an emergency, which will increase the level of security.

Key words: risk, hazardous factors, CFAST, integrated model, public buildings, mapping.

Introduction. According to the annual fire statistics data from the departments of the State Emergency Service (SNS) of Ukraine, the situation with fires in public buildings in Ukraine is complicated. More than 60 thousand fires are registered in Ukraine annually. 2-3 thousand people die in fires. Such significant number of fires and deaths requires application of new approaches to fire hazard assessment and reduction, particularly risk-oriented ones.

At the beginning of the new millennium, a concept of "safety culture" [1] emerged and has been successfully developing. It grounds on educating responsibility of people for their safety in all spheres of their activity. Undoubtedly, safety is one of the most important conditions of a human life and the most important principle of society's existence. In the course of any human activity there is always a danger factor, so for many years, the European Union members and other advanced countries of the world have been focusing attention on security issues. In order to increase the level of safety, scientifically based prognostication methods and principles of risk management in the main areas of human activity have been developed.

Risk is a probabilistic value that allows evaluation and recognition of unwanted events that may occur. In [2], risk is a quantitative characteristic of the possibility of a particular hazard occurrence or its consequences, which is measured in corresponding units of measurement. Each hazard can be characterized by many different risks that assess the various aspects and parameters of this hazard: for example, on the one hand, the frequency of its occurrence, on the other, the nature and extent of the consequences of the danger.

Subject of research: Risks of death from fires in public buildings and facilities.

The purpose of the paper is to assess the risk of death from fires in public buildings and facilities.

Materials and Methods. A complex method of research is used in the paper, which includes: analysis and application of statistical methods of data processing, verification of the reliability of the results, mathematical modeling and other analytical methods.

To calculate the risks based on the available methodology [3, 4], the company "Sitis" has designed software to calculate the value of individual fire risk, namely: "Sitis: FLOUTEK VD", "Sitis: BLOCK", "Sitis: VIM" and "Sitis: Sprint" [4], "EPOS: Indeline 1.01". They provide an opportunity to identify the main factors of a fire to assess fire risks in buildings and facilities, in particular, those which are aimed for public usage.

PyroSim [5] is software with a user-friendly graphical interface to model the dynamics of the development of hazardous fire factors by field-based method of Fire Dynamics Simulator (FDS).

The FDS (Fire Dynamics Simulator) software [6] implements a calculated hydrodynamic model of heat and mass transfer during combustion. FDS solves the Navier-Stokes equation for low-velocity temperature-dependent flows. Particular attention is paid to the spread of smoke and heat transfer during the fire.

Smokeview [7] is software that reproduces FDS results in the form of animated images. The software can visually simulate fire and smoke. The three-dimensional representation of the physical model makes it possible to estimate the visibility within the depicted premises.

The CFAST model [8] is designed to assess the dynamics of fire hazards in residential, public and industrial buildings and facilities. Also, the model can be used to determine the design parameters of fire systems – natural or artificial anti-smoke ventilation, fire alarm. The mathematical model of CFAST grounds on the Cauchy problem for a system of ordinary differential equations. The system includes the equation of conservation of mass, energy (the first law of thermodynamics), the ideal gas law, the ratio of density to internal energy [8].

Results and Discussion. Risk assessment includes risk analysis, which in turn consists of the following steps:

1. identification of hazard (threats, possible undesirable events, sources);
2. vulnerability analysis (causes, consequences);
3. description of the risk by using probabilities and expected values.

When analyzing fire hazards of the facility under protection, it is necessary to identify and analyze all the fire risks inherent in the object first, then evaluate their current values, determine the permissible values for all fire risks and adopt the necessary technological solutions for risk management.

After that, it is necessary to select or develop methods and technologies to manage each risk, use them and thus provide the fire safety of the facility under protection.

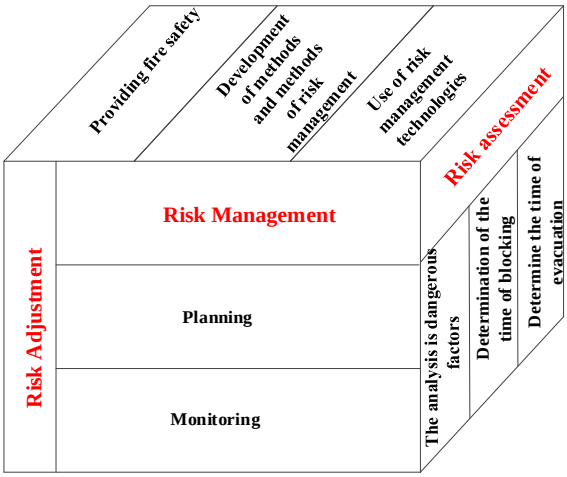

Figure 1 – Risk management and assessment

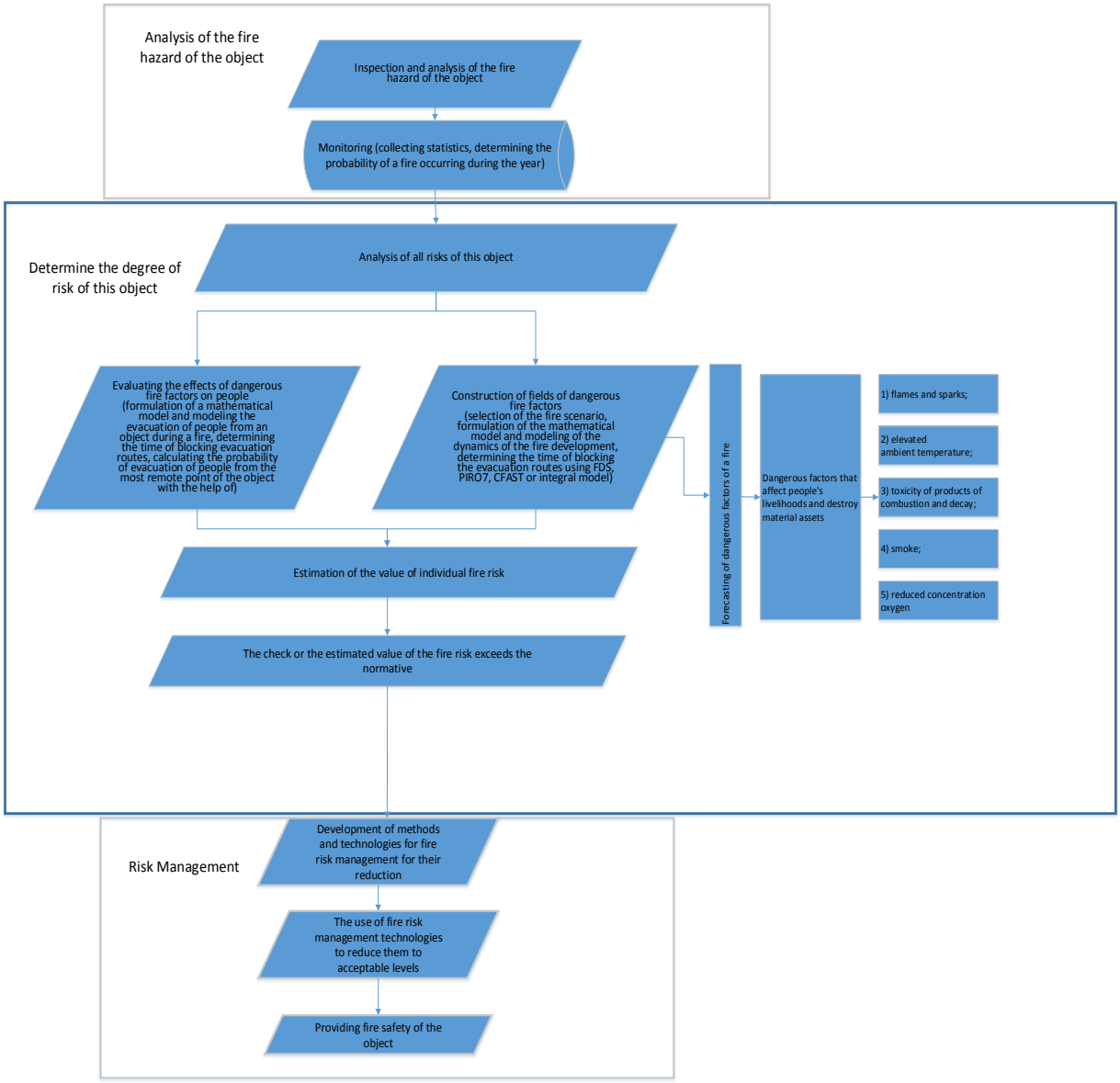

Figure 2 – Risk management

The action plan is developed and the priority of management decisions for risk reduction is determined.

Different gradations are used for risk assessment: insignificant, acceptable, high, and unacceptable. Acceptable risk is often used along with the term a reasonable risk. When the system has criteria of unacceptable risk then measures or technological solutions are introduced to reduce the level of risk to an acceptable level.

The EN 954-1 regulations define five levels of protection (B, 1, 2, 3, 4) that relate to 5 risk classes associated with 3 unprotected risk characteristics:

The calculation of fire risks is carried out separately for each group of public buildings.

The Methodology for determining the fire risk in buildings and facilities of various classes of functional fire hazard [3] is applied to calculate the risk of death from fires. It contains analytical methods for determining the individual risk of death from fires and verification of compliance with the permissible values, is used, if:

$$Q_b \leq Q_h, \tag{1}$$

the statistical value of the individual fire risk of death in a fire, Q_h=10^{-6} dead people / (people · per year) – normative value for the facility, and Q_b – estimated value of the individual fire risk of death in a fire. In case there are fire prevention measures in a public building, the individual fire risk Q_b is calculated by the formula

$$Q_b = Q_n \cdot P_{pr}(1 - P_e)(1 - P_{p.z.}) \tag{2}$$

Q_n – average value of probability of a fire in a public building of a certain class during a year; P_{pr} – the probability presence of people in the building; P_e – the probability evacuation of people from the building; $P_{p.z.}$ – coefficient for the compliance with fire protection aimed at ensuring safe evacuation during a fire with regulatory requirements for fire safety.

The time of occurrence of hazardous fire factors has been calculated by the integrated model according to the methodology.

According to the integrated model of the methodology, it is believed that a fire occurs in the room next to the main evacuation exit – in the office of a warden. Fire load – office furniture, paper documentation and carpet (Article 66 Appendix 7 of Methodology database of typical fire load – Furniture + paper (0,8) + carpet (0,2)). Room dimensions: 6x4,2x2,4 m. The room has access from the corridor and from another room. Doors have access from the corridor by which the evacuation is done through the main exit. The fire occurs when the children are in their groups in the sleeping quarters, which are located most distantly from the evacuation exits.

The received results:

- for the t_{cr} O_2 = 25,37 c;
- for the CO – t_{cr} CO = 31,35 c;
- for the HCL – t_{cr} HCL = 38,44 c.

Since the integral model makes it possible to determine the hazardous factors of a fire only for one room without spreading it to others, CFAST two-zone model is used to determine the dangerous factors of a fire in a kindergarten. It simulates fires in buildings more efficiently than an integral one and defines the maximum time of occurrence of fire hazardous factors, which allows determining the required time of the fire and rescue units to arrive to the scene of call and the necessary evacuation time to ensure safety of people [8].

According to the calculation results:

- limited visibility in the cabinet 1 with the seat of the fire and the adjacent room (storeroom 1) will come within 0,25 min after the start of a fire, and a decrease in the concentration of oxygen limit values in the storeroom 1 will come in 1,5 min;
- limited visibility on staircase 1 and staircase 2 will occur in 1,7 and 2,5 min respectively;
- hazardous temperature values on the premises of the seat of the fire will come in 1,2 min, and in the storeroom 1 in 1,5 min.

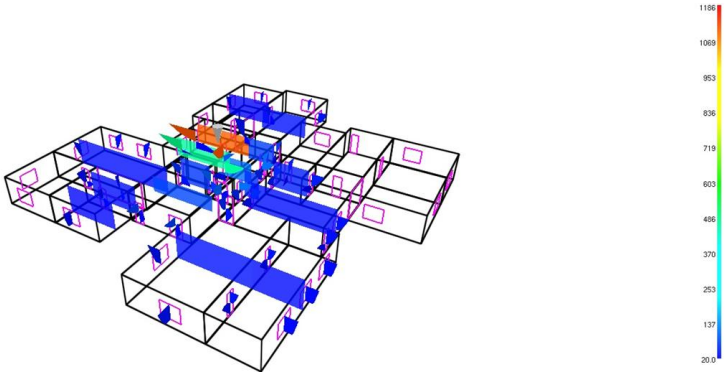

Figure 3 – Development of fire in the office 1

Therefore, among the hazardous fire factors, limited visibility will occur the most quickly, so evacuation from the 2nd floor of the kindergarten building through the staircase is impossible already after 1,7 min (staircase 1) and 2,5 min (staircase 2). Limited visibility in corridor 1 and corridor 2 will occur in 1,25 min.

One of the main problems is the state of fire protection of public buildings, in particular, those of cultural and educational domains. Therefore, we consider in detail the public building aimed at various leisure activities "Lviv State Palace of Aesthetic Education of Youth".

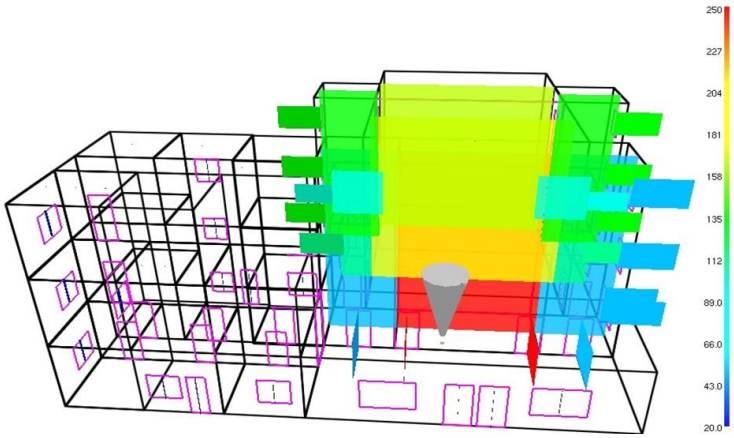

Figure 4 – Time layout of dangerous fire factors in the auditorium
of the Lviv State Palace of Aesthetic Education of Youth

Grounding on the results of calculations, the following has been determined:

1. The medium temperature on the stage will be 260 ºC, in the auditorium 1 – 209 ºC (within 3.8 min in the upper part of the room and 7 min in the lower part of the room), and in the auditorium 2 – 189 ºC (within 4,2 min in the upper part of the room and 7,7 min in the lower part of it).

2. The lack of oxygen will occur on the stage in 6,5 min, in the auditorium 1 – in 7 min, in the auditorium 2 – in 7,2 min, in the staircases 4 and 5 – in 9,5 min, and in the corridors 2 and 3 – in 10 min

3. Limited visibility will occur: on the stage in the upper part of it in 15 seconds and in 2,1 min in the bottom of the room; in the auditorium 1 in its upper part in 16 seconds and in 2,5 min in the bottom of the room; in the auditorium 2 in its upper part in 17 seconds and in 2,6 min in the bottom of the room; in the corridors 2 and 3 in the lower part of it will occur in 2,9 min; in the upper part of the staircases 4 and 5 in 2,1 min and in 2,9 min in the lower part of them (see figure 5).

Therefore, limited visibility will occur the most quickly, so it is necessary to evacuate auditorium 1 and 2 in 2,5 min, to pass through staircases 4 and 5 and corridors 2 and 3 is within 2,9 min. The lack of oxygen in the corridors and staircases will occur in 9,5 and 10 min, respectively.

The calculation of the value of individual fire risk in a kindergarten building has been carried out for this scenario according to the Methodology formula [3].

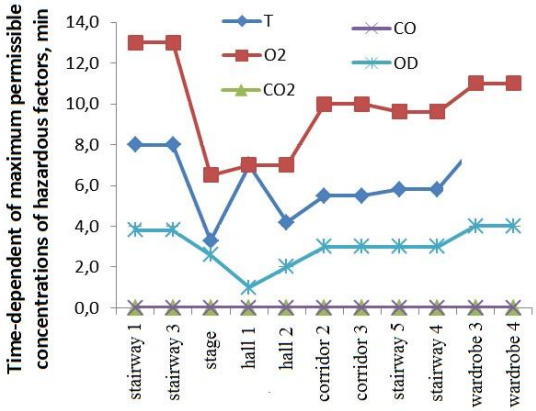

Figure 5 – Time layout of maximum permissible concentrations of hazardous factors and limited visibility in case of fire in the Lviv State Palace of Aesthetic Education of Youth

In the case of open doors from the room of the warden $Q_b = 1 \cdot 10^{-4}$, which exceeds the normative value of risk $Q_{bh} = 10^{-6}$.

Ultimately we get that $Q_b = 9{,}09 \cdot 10^{-8}$ conditions of the closed door from the room of the warden, which does not exceed the normative value of risk $Q_{bh} = 10^{-6}$.

Thus, the use of fire doors can reduce the value of fire risk and ensure timely evacuation. The arrangement of fire alarm systems and anti-smoke protection will allow the timely start of evacuation and its successful procedure.

The calculation of the value of individual fire risk in the building of the Lviv State Palace of Aesthetic Education of Youth has been carried out for this scenario according to the Methodology formula [3].

Finally, we get that $Q_b = 9{,}3 \cdot 10^{-5}$, which exceeds the normative value of risk $Q_{bh} = 10^{-6}$.

Consequently, the individual fire risk exceeds the permissible value, therefore there is a need to develop additional fire prevention measures. For example, it can be equipped with a fire alarm and a fire curtain to detect a fire and put into operation a fire curtain in the auditorium. Their usage will reduce the individual fire risk by promptly informing employees about the fire, which will facilitate safe evacuation and accelerate the arrival of firefighting units to the scene of fire.

Given the closed fire curtain of the stage room, we get that $Q_b = 9{,}1 \cdot 10^{-8}$, which does not exceed the normative value of risk $Q_{bh} = 10^{-6}$. Consequently, the use of a fire curtain can reduce the value of fire risk and timely evacuation. The arrangement of fire alarm systems and fire curtains will allow the timely start of evacuation and successfully carry it out.

Scale of individual fire risk assessment for public buildings

Color [12]	Proposed actions	Level of risk [2, 9-11]	Value
Red	Danger. Immediately take security measures	Unacceptable risk	$\geq 5 \cdot 10^{-4}$
Orange	Very careful. Perform appropriate security measures	High risk	$5 \cdot 10^{-5} \div 5 \cdot 10^{-4}$
Yellow	Carefully. Prepare for appropriate security measures	Acceptable risk	$10^{-6} \div 5 \cdot 10^{-5}$
Green	Security. No action is required	Insignificant risk	$\leq 10^{-6}$

The obtained values of individual fire risk in groups of public buildings are suggested to be evaluated on the scale [2, 9-11] and the main color codes and levels of severity of risks [12], where the orange color (High Risk) is added, which allows outlining the risk limits more precisely and adapting to generally acceptable levels of risk [2, 9-11]. This scale is depicted in the form of table by setting the corresponding colored denotations.

Conclusions:

1. As a result of the calculations carried out according to the Methodology, it has been established that the individual fire risk in the Lviv State Palace of Aesthetic Education of Youth exceeds the

permissible value and makes $Q_b = 9{,}3 \cdot 10^{-5}$, therefore there is a need to develop additional fire prevention measures. For example, the stage should be equipped with a fire curtain to protect the auditorium.

2. By reducing the risk of death from fire to $Q_b = 9{,}1 \cdot 10^{-8}$, it is possible to reduce the evacuation time, which is achieved by using a fire curtain and a fire alarm system in the stage premises of the Lviv State Palace of Aesthetic Education of Youth.

3. The estimated design values of individual fire risk for public buildings are proposed to be evaluated according to the generally accepted scale of the World Health Organization and the main color codes and severity levels established by ISO 22324: 2015, IDT Societal security – Emergency management – Guidelines for colour-coded alerts.

4. The results of the paper are used in the educational process of the Lviv State University of Life Safety within the course "Fire Risks of Critical Infrastructure", which is taught to graduate students majoring in Fire Safety and can be used to prepare normative documents for fire risks assessment.

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ҚОҒАМДЫҚ ҚЫЗМЕТТЕГІ ҒИМАРАТ ПЕН ҚҰРЫЛЫСТАҒЫ ӨРТ ҚАТЕРІ

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ПОЖАРНЫЕ РИСКИ ЗДАНИЙ И СООРУЖЕНИЙ ОБЩЕСТВЕННОГО НАЗНАЧЕНИЯ

Аннотация. В работе использован комплексный метод исследований, включающий в себя: анализ и обобщение научных достижений в сфере пожарной безопасности, применение и обработки статистических данных; применение аналитических методов исследований путем сбора, обобщения и анализа действующих нормативных документов Государственной службы Украины по чрезвычайным ситуациям и статистические, методы теории вероятностей, картографии, математическое моделирование, методы системного анализа.

Объект исследований: риски гибели от пожаров в зданиях и сооружениях общественного назначения.

Целью работы является оценка рисков гибели от пожаров зданий и сооружений общественного назначения.

Методы исследования. В работе использован комплексный метод исследований, включающий в себя: анализ и применение статистических методов обработки данных, проверка достоверности полученных результатов, математического моделирования и других аналитических методов.

В работе раскрыто понятие риска и указаны основные нормативные документы, которые трактуют их. Проанализированы основные методы и методики оценки рисков для зданий и сооружений общественного назначения.

Оценка пожарного риска заключается в расчете индивидуального пожарного риска для жителей, персонала и посетителей в здании или сооружении общественного назначения. Числовым выражением индивидуального пожарного риска является частота воздействия опасных факторов пожара на человека, находящегося в здании или сооружении. Частоту воздействия опасных факторов пожара определяют для пожароопасных ситуаций, которые характеризуются наибольшей опасностью для жизни и здоровья людей в здании.

С помощью программы CFAST выполнено моделирование наступления предельных концентраций опасных факторов при пожарах для двух типовых объектов.

Полученные значения индивидуального пожарного риска по группам общественных зданий предлагается оценивать по соответствующей шкале и по основным цветным кодам и уровням тяжести рисков, где добавлен оранжевый цвет (высокий риск), что позволяет более точно очертить границы риска и адаптировать к обще-приемлемым уровням риска.

Прогнозирование пожарных рисков реализуется на основе предложенной методики расчета пожарных рисков. Для визуализации расчета пожарных рисков погибнуть от пожара для общественных зданий предлагается использовать графические редакторы.

Нанесение на карту рисков погибнуть от пожара в соответствующей группе в соответствующих цветах позволяет построить карту рисков гибели от пожара и работникам пожарно-спасательной службы знать возможные риски и опасности объектов.

Время начала эвакуации, при отсутствии систем оповещения, определять в зависимости от времени следования пожарно-спасательных подразделений к месту пожара.

Предложенная методика расчета и средства визуализации позволяют спасателю, который принимает решение, комплексно оценить обстановку при проектировании и избежать возможных последствий чрезвычайной ситуации, что позволит повысить уровень безопасности.

Ключевые слова: риск, опасные факторы, CFAST, интегрированная модель, общественные здания, картографирование.

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STORAGE OF THE INDUSTRIAL WASTE OF THE MINING AND SMELTING INDUSTRY OF KAZAKHSTAN, LANDFILLS ARRANGEMENT, EFFICIENCY AND OPERATIONAL FEATURES

Abstract. The possibility of organizing the production of bentonite mats as multifunctional watertight screens was thoroughly studied on the basis of the Taganskoye deposit in East Kazakhstan that is represented by three industrial horizons of alkaline, alkaline-earth and pharmaceutical bentonites, by their characteristics being one of the highest quality not only in Kazakhstan, but outside the country as well. Tagansky bentonite has a wide range of applications in various industries due to its unique chemical composition, including as a multifunctional material for the installation of watertight screens in the construction and rehabilitation of waste landfills of various origins. The article raises the question of the use in current practice of mandatory requirements for the arrangement of artificial protective screens during the construction of landfills, which should completely eliminate or minimize pollution of environmental components, the introduction of which could contribute to the development of local production of innovative materials based on Kazakhstan's bentonite deposits.

Key words: mining and smelting industry, natural resources, industrial waste, geomembrane, watertight screen, bentonite mats.

At present, the activity of enterprises of the mining and smelting industry poses a very perceived threat to both the ecosystem as a whole, and the environment of the regions of Kazakhstan. Progressive depletion of ores leads to an increase of the man-made mineral formations in the form of waste, tailing, and slag dumps, and sludge collectors. In this regard, the problems of their safe disposal and storage are of a great relevance for the regions with developed mining and smelting industries.

The richest natural resources of Kazakhstan define the mining industry as one of the main sectors, which constitutes a significant economic value of the country [1]. Kazakhstan is the third country in the world in terms of proven uranium resources localized in six uranium regions: Shu-Sarysu, Syrdarya, Northern Kazakhstan, the Caspian, and Balkhash. Kazatomprom State Holding Company is a leading uranium producer in the world. Kazakhstan plays a major role in the world market of copper, uranium, titanium, ferrous alloys and steel, is a monopolist in the Eurasian subcontinent for chromium. The competitive environment development has a significant influence on the regional market of iron, manganese, coal and aluminum [2].

Mining and processing of minerals is accompanied by the formation of industrial wastes, which include:

- waste and overburden dumps;
- tailing dumps - concentration waste repositories for mineral or coal-containing rocks;

– slag and ash dumps - wastes of pyrometallurgical processing and burning of coal.

The main sources of industrial waste in Kazakhstan are enterprises for:

– mining and concentration of mineral ores, coal;
– large chemical plants;
– metal manufacturers;
– coke and by-product plants;
– thermal coal power plants.

According to the Ministry of Ecology, Geology and Natural Resources, more than 43 billion tons of waste has been accumulated in Kazakhstan, about 600 million tons of which are toxic and this number is increasing by 700 million tons annually, including about 250 million tons of toxic waste [3]. The country has accumulated significant amounts of persistent organic pollutants, chromium and heavy metals such as lead, cadmium and zinc [4].

An average of about 1.500 tons of industrial and municipal waste per country's citizen exceeds the level of waste accumulation by European states. The largest volume weight of wastes are from the mining and concentration plants of Karaganda - 29.4%, East Kazakhstan - 25.7%, Kostanay - 17% and Pavlodar - 14.6% regions. The enterprises engaged in the mining of coal, ferrous metals, and rock phosphates located in Kostanay, Karaganda, Aktobe, East Kazakhstan, Pavlodar, Zhambyl, West Kazakhstan and Atyrau regions have accumulated significant waste dumps from mining and processing industries. According to the Land Balance, as of November 1, 2018, the Republic of Kazakhstan has 248.42 thousand hectares of disturbed lands, which house overburden and rock dumps, tailing and ash dumps, coal and mining quarries, oil fields and pits. The largest number of disturbed lands is in Karaganda, Kostanay, Mangistau, Akmola, East Kazakhstan, Aktobe, and Pavlodar regions. There are environmentally fragile impact areas in all industrial regions: spoil heaps, dumps, quarries of territories disturbed by mining [5].

For instance, the development of gold and rare metal deposits in the area of the North Kazakhstan region causes arsenic and heavy metal pollution of lands. Disposal, neutralization, burial, trans-border transportation of waste is one of the most urgent issues in the country. Up until this day, toxic waste is dumped and stored in various storage facilities, often without observing relevant environmental standards and requirements. Soil, groundwater, and surface waters of many regions are subject to intense contamination as a result of that.

Currently, industrial waste burial at enterprises occurs in accordance with the hazard class outside the industrial site of the entity and the territory of inhabited locality, with the exception of ash and slag dumps/ash dumps of operating power and heating plants, thermal power plants when it is impossible to place them outside the settlement and production site.

Industrial landfills are usually located in pools - gorges, basins, at a distance of several kilometers from the enterprise. Natural clay deposits with low filtering properties are used as the landfill foundation; landfills are fenced off by a dam, which is sluiced from the tails, and additionally strengthened. In the landfill map, the solid phase of the tailings gradually settles, sometimes with the help of specially added reagents — coagulants and flocculants [6].

Despite the requirements strengthening in the field of environmental protection associated with the escalation of land pollution with toxic substances, enterprises strive to cut the cost of arranging landfills, as this significantly affects their economic performance. At the same time, this sector enterprises are offered new technologies and materials that are able to mitigate harmful impact on the environment [7,8]. Basic safety requirements for industrial waste landfills are aimed at minimizing the destruction damage, filtration losses and dusting, as well as the landfills should not obstruct the natural drainage of surface water from the adjacent territory, the bottom and sides must have the necessary, reliable waterproofing layer.

Application of new technologies and modern materials provides the opportunity to optimize the storage of industrial waste, as well as to prevent the penetration of pollutants into the environment when disposing of high hazard class waste by creating multifunctional watertight screens. Modern technologies for isolating the bottom and slopes of containers for waste disposal must meet multifunctional requirements, such as: possess a certain filtration factor throughout the entire period of operation, have thermal and chemical resistance, mechanical strength and structural homogeneity.

However, still, the general traditional materials for their construction are natural clay formations (from loam soil to bentonite-like clays), which may be present in sufficient quantities during the deposit development. Such watertight screens have a number of significant weaknesses: the lack of instrumental methods for monitoring the screen tightness; high risk of screen cracking; weakening of insulating properties; labour consuming construction technology; hence their negative impact on the natural environment.

Recently, the use of geosynthetic membranes has become widespread for the aggressive contents isolation [9]. Polymer watertight screens have a number of unequivocal advantages, including ease of arrangement, relatively low price, and this is a more modern solution in comparison with the traditional construction of landfills for industrial waste, tailing dumps and sludge collectors (figure 1).

Figure 1 – The Use of Geosynthetic Screens in the Development of industrial waste storage

However, the use of geosynthetic membranes does not dismiss the arrangement of combined screens together with a clay cushion, which serves as an additional insulating foundation, increasing reliability and watertight properties, and as a result of the susceptibility of membranes to mechanical damage, their effectiveness significantly increases over the long term.

The best solution for isolating the storage pot technologically is the use of bentonite mats - innovative in properties, which are a combination of polymer geomembranes with a layer of bentonite, a natural mineral component. Bentonite mats are a multifunctional composite material in the form of a needle-punched bracing made of polypropylene fibers, which has inside powder or granules of sodium bentonite - one of the montmorillonite clay types of natural origin, with mat sizes 4-5 m wide and up to 40-50 m long (figure 2).

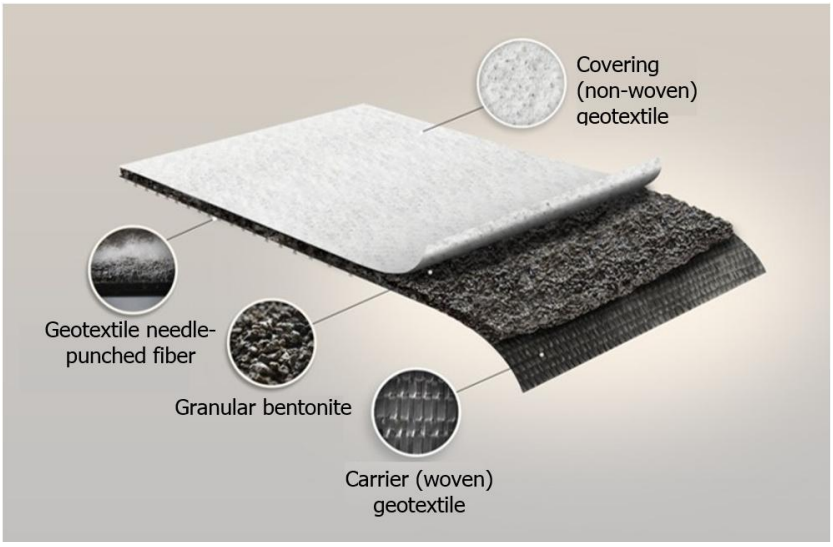

Figure 2 – Bentonite mat structure

The main advantages of liner materials based on sodium bentonite are:

Self-repair - clay closes the damage occurring during the watertight screen installation or operation due to the swelling property when interacting with water, thereby restoring its water-proof properties

High water-proof properties - the filtration rate of bentonite mats of 10^{-11}-10^{-12} m/s characterizes extremely low water permeability.

High strength, resistance to tearing and damage - bentonite mats are resistant to dynamic punctures, shear and soil settlement; they allow the movement of wheeled heavy equipment on them when bedding.

Low footprint - due to its high cation exchange capacity the bentonite clay exhibits sorption properties, absorbing heavy metal ions, halogens.

Cost effective and easy matting -

– does not require special preparation of the foundation;
– no need for welding seams;
– matting is not limited by weather conditions, mats remain flexible at temperatures up to -70 C°.

Durability - the operational period of bentonite mats is comparable with the service life of the structure.

With reference to the long-term functioning of landfills, the impact of which will affect future generations, the availability of already present technical solutions to minimize their adverse effects on the environment, there is a need to revise the design requirements for tailing dumps and process waste landfills.

In modern practice of the construction of landfills, the mandatory requirements for the arrangement of artificial protective screens must be introduced, which should eliminate or narrow down pollution of environmental components.

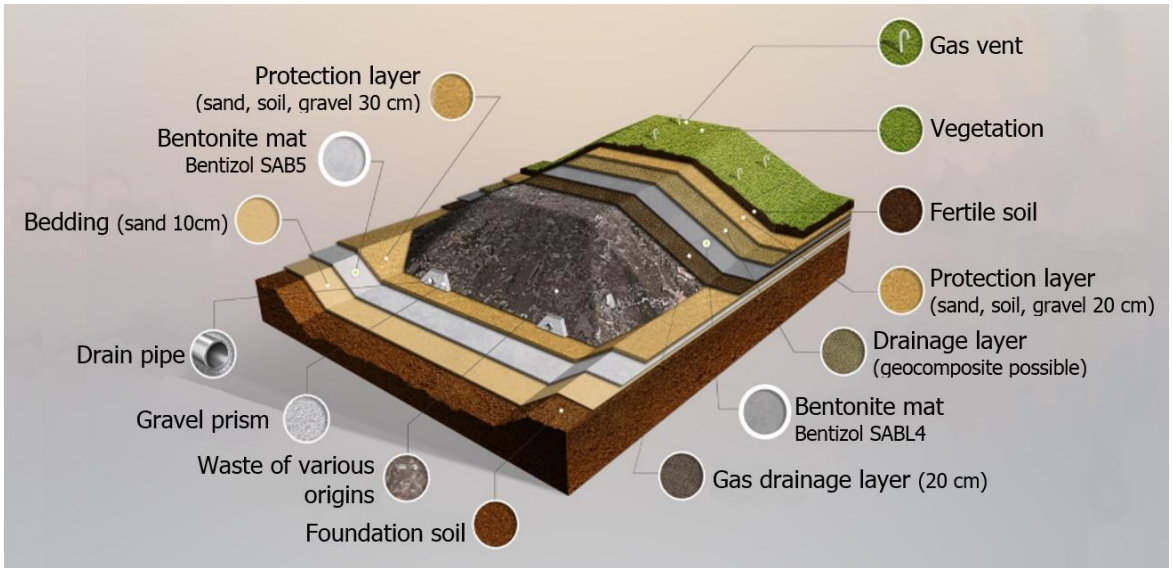

Figure 3 – BentIzol Bentonite Mats Application during Construction and Reclamation of the Landfill

The introduction of such requirements could contribute to the development of local innovative material production based on Kazakhstan's bentonite deposits. For instance, on the basis of the Taganskoye deposit in East Kazakhstan, which is represented by three industrial horizons of alkaline, alkaline-earth and pharmaceutical bentonites. They are one of the highest quality according to their characteristics, both in and out of Kazakhstan. Due to its unique chemical composition, Tagansky bentonite has a wide range of applications in various industries [10,11]. Bentonit Ltd. (Russian Federation) is one of the five world producers of bentonite products who owns the rights to develop the deposit through a subsidiary of Altaiskie Materialy LLP Bentonit Ltd. is considerably experienced in the bentonite mats production under the BentIzol brand, which is a new multifunctional material for the

installation of watertight screens in the construction and reclamation of landfills of various origins. The most effective compared to traditional and polymer materials (figure 3), the production of which can be established in Kazakhstan if there is an appropriate market niche.

Thus, bringing the norms for the arrangement of waterproof and watertight screens to world standards in the construction of industrial waste storage facilities will, on the one hand, solve the problems of their reliability and reduce environmental footprint over the long term, and on the other hand will also help to establish a new innovative production with the creation of the additional employment in Kazakhstan.

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ҚАЗАҚСТАННЫҢ ТАУ-КЕН МЕТАЛЛУРГИЯ САЛАСЫНДАҒЫ ӨНЕРКӘСІП ҚАЛДЫҚТАРЫН САҚТАУ, ПОЛИГОНДАРДЫ ЖАЙҒАСТЫРУ, ТИІМДІЛІГІ МЕН ПАЙДАЛАНУ ЕРЕКШЕЛІКТЕРІ

Аннотация. Қазіргі уақытта тау-кен және металлургия саласындағы кәсіпорындар қызметі тұтастай алғанда экожүйеге де, Қазақстан аймақтарының экологиясына да айтарлықтай қауіп төндіреді. Кеннің прогрессивті жұтаңдануының бос жыныс үйіндісі, қалдық қоймасы, қожды үйінділер және қоқыржинағыш түрінде техногендік құралым көлемін ұлғайтады әкеледі. Жерді улы заттармен ластау процесінің күшеюіне байланысты қоршаған ортаны қорғау саласындағы қатаң талаптарға қарамастан, кәсіпорындар полигондарды ұйымдастыруға жұмсалатын шығынды барынша арзандатуға тырысады, өйткені олардың экономикалық көрсеткіштеріне айтарлықтай әсер етеді. Осыған байланысты қалдық қоймасын, қожды үйінділер мен қоқыржинағыштарды қауіпсіз орналастыру және сақтау проблемалары тау-кен металлургия өнеркәсібі дамыған аймақтарда өте өзекті болып саналады.

Мақалада авторлар Қазақстанның тау-кен және металлургия салаларындағы кәсіпорындар шығаратын өнеркәсіптік қалдық көлеміне талдау жасады. Қазақстан Республикасының тау-кен кәсіпорындарының полигондарында қалдық орналастыруда қолданылатын дәстүрлі және заманауи геосинтетикалық сүзгіге қарсы экран артықшылығы мен кемшіліктері егжей-тегжейлі қарастырылып талданды. Сонымен қатар, авторлар Шығыс Қазақстандағы «Таған» кен орны негізінде, сипаттамаға сәйкес, Қазақстанда ғана емес, одан тыс жерлерде де жоғары сапалы болып келетін сілтілік, сілтілі жер және фармацевтикалық бентониттердің үш өнеркәсіптік горизонтымен ұсынылған көп функционалды сүзгіге қарсы экрандар ретінде бентонит төсеніштерін өндіруді ұйымдастыру мүмкіндігі жете зерделенді. Таған бентонитінің бірегей химиялық құрамына байланысты түрлі салада, соның ішінде шығу тегі әртүрлі полигонды қалпына келтіру және құрылыс кезінде сүзгіге қарсы экранға арналған көпфункциялы материал ретінде кең қолданылады.

Мақалада қазіргі тәжірибеде полигон құрылысы кезінде қоршаған орта компоненттерінің ластануын толығымен жоюға немесе азайтуға тиісті жасанды қорғаныс экрандарын орналастыруға қойылатын талаптар міндетті түрде қолданылуы туралы мәселе көтерілді.

Мұндай талаптарды енгізу Қазақстандағы бентонит кен орындары негізінде жергілікті өндірісте инновациялық материалдарды дамытуға ықпал ете алады.

Түйін сөздер: тау-кен және металлургия саласы, табиғат ресурстары, өндірістік қалдықтар, геомембрана, сүзгіге қарсы экран, бентонит төсеніші.

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ХРАНЕНИЕ ПРОМЫШЛЕННЫХ ОТХОДОВ ГОРНО-МЕТАЛЛУРГИЧЕСКОЙ ОТРАСЛИ КАЗАХСТАНА, УСТРОЙСТВО ПОЛИГОНОВ, ЭФФЕКТИВНОСТЬ И ОСОБЕННОСТИ ЭКСПЛУАТАЦИИ

Аннотация. В настоящее время деятельность предприятий горно-металлургической отрасли несет весьма ощутимую угрозу как для экосистемы в целом, так и для экологии регионов Казахстана. Прогрессирующее обеднение руд влечет увеличение объемов формирования техногенных образований в виде отвалов пустых пород, хвостохранилищ, шлаковых отвалов и шламонакопителей. Несмотря на ужесточение требований в области охраны окружающей среды, связанного с усилением процесса загрязнения земель токсичными веществами, предприятия стремятся к максимальному удешевлению обустройства полигонов, так как это существенно влияет на их экономические показатели. В этой связи, проблемы безопасного размещения и хранения хвостохранилищ, шлаковых отвалов и шламонакопителей являются весьма актуальными для регионов с развитой горнодобывающей и металлургической промышленностью.

В данной статье авторами проведен анализ объемов промышленных отходов предприятий горнодобывающей и металлургической отраслей Казахстана. Подробно рассмотрены и проанализированы ДОСтоинства и недостатки традиционных и современных геосинтетических противофильтрационных экранов, используемых при размещении отходов на полигонах предприятий горнодобывающей промышленности Республики Казахстан. Также авторами детально изучена возможность организации производства бентонитовых матов в качестве многофункциональных противофильтрационных экранов, на базе месторождения «Таганское» в Восточном Казахстане, которое представлено тремя промышленными горизонтами щелочных, щелочноземельных и фармацевтических бентонитов, по своим характеристикам являющихся одними из наиболее высококачественных не только в Казахстане, но и за его пределами. Благодаря уникальному химическому составу, Таганский бентонит имеет широкий спектр применения в самых разных отраслях промышленности в том числе и в качестве многофункционального материала для устройства противофильтрационных экранов при строительстве и рекультивации полигонов отходов различного происхождения.

В статье поднимается вопрос использования в современной практике сооружения полигонов, в обязательном порядке требований по обустройству искусственных защитных экранов, которые должны полностью исключать или сводить к минимуму загрязнение компонентов окружающей среды.

Внесение таких требований могло бы поспособствовать развитию локального производства инновационных материалов на базе бентонитовых месторождений Казахстана.

Ключевые слова: горнодобывающая и металлургическая отрасль, природные ресурсы, промышленные отходы, геомембрана, противофильтрационный экран, бентонитовые маты.

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GEOLOGICAL-AND-TECTONIC CONDITIONS OF FORMATION AND FOCAL MECHANISM OF TORAIGYR-SOGUETY EARTHQUAKE, May 30, 2012

Abstract. The seismic characteristic of Toraigyr-Soguety earthquake is presented. The significant seismic events of the area are demonstrated including Chilik catastrophic earthquake. Geological-and-tectonic conditions of the epicentric areas of Chilik and Toraigyr-Soguety earthquakes are described. Kinematics of neotectonic faults is considered with respect to directions of main stress axes. Two models of focal mechanism of Toraigyr-Soguety earthquake compare with tectonic deformations of the area.

Key words: earthquake, epicentric area, geological-and-tectonic conditions, neotectonic fault, kinematics of fault, main stress (deformations) axes, models of earthquake focal mechanism, fault planes.

Introduction. The epicenter of earthquake with energy class K = 13.7÷14.2 and hypocentral depth H = 20 km was fixed by seismographs of the Seismological Experimental and Methodical Expedition (SEME) of the Ministry of Education and Science of Republic of Kazakhstan at a point on the surface with the coordinates 43° 23` N and 78° 46` E on May 31, 2012, at 3 o'clock, 20 min., 56.7 sec of the local time (On May 30, 2012, at 21 o'clock, 20 min., 56.7 sec of GMT). The surface wave magnitude been measured by a seismograph of the medium-term period amounts to M_S = 5.0, but the longitudinal wave magnitude been measured by a short-period seismograph amounts to Mpva = 6.0. From the GCMT data the surface wave magnitude M_S is equal to 5.4, and the hypocentral depth is equal to H = 27 km [1]. Regarding of geological-and-tectonic conditions the epicenter of the earthquake is projected onto the southern limb of Soguety graben syncline, in 3-5 km to the north from Toraigyr uplift (figure 1). Therefore we are proposing to name that earthquake Toraigyr-Soguety. In the source [2], this earthquake is barely named Soguety, so it does not allow distinguishing between it and others, which would occur in Soguety depression.

It is possible to judge about kinematics of movements along possible planes of ruptures in the focus of Toraigyr-Soguety earthquake using the interpretations of the earthquake focal mechanism of the SEME or the GCMT earthquake catalog. It would be interesting to know, what is the link between parameters of earthquake focal mechanism (EFM), tectonic structure, directions of main stress axes and type of modern movements along active faults in the area of Toraigyr-Soguety earthquake focus? The investigation of formation of Toraigyr-Soguety earthquake attracts particular interest also in connection with one more circumstance. That earthquake is considered to be the strongest in energy (K = 13.7) among all earthquakes recorded by seismographs of SEME in the territory bounded with the coordinates 43° – 44° N and 78° – 80° E since 1950 till 2017 (see table 1).

Table 1 – The earthquakes with energy class 12 and more, which occurred since 1950 till 2017 in the territory bounded with the coordinates 43-44° N and 78-80° E (from the SEME data)

Year	Month	Day	O'clock	minutes	Seconds	Lat.	Long.	Kp	H, km	Mpva
1950	8	8	13	14	0,0	43°12’	79°12’	12,0	?	?
1951	2	17	11	46	14,1	43°18’	78°54’	12,0	?	?
1957	12	20	11	1	26,0	43°00’	78°30’	12,0	30	?
1974	3	4	14	3	56,8	43°53’	78°15’	12,2	?	?
1975	2	12	13	34	52,4	43°10’	78°47’	12,6	25	5,1
1982	8	12	10	39	57,6	43°03’	79°48’	12,1	?	4,5
1986	2	14	1	52	1,0	44°00’	78°12’	12,7	20	4,3
1986	5	10	12	47	41,0	43°53’	78°11’	12,4	10	3,8
1986	7	17	8	15	34,2	43°17’	78°00’	12,4	13	3,9
2012	5	30	21	20	56,7	43°23’	78°46’	13,7	20	6,0

Notes: 1 Dates of the earthquakes are of GMT (Greenwich Mean Time) in table 1 and hereunder.
2 The designations of K, H, Mpva parameters are explained in the text.

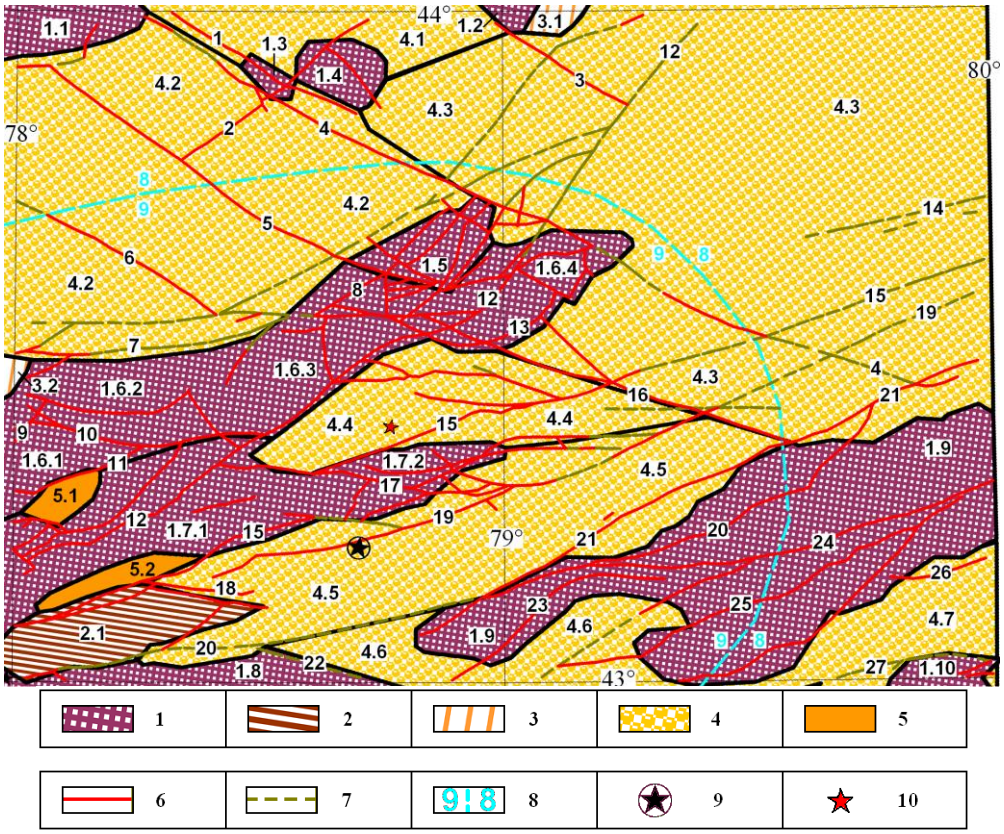

Figure 1 – Neotectonic zoning and seismicity of the area of the epicenter of Toraigyr-Soguety earthquake. Compiler: A. R. Zhdanovich

Neotectonic zoning [3]: **1-5 – epiplatform region, subregion of intense Alpine orogenesis**: 1 – ***arched block uplifts*** (1.1 – 1.4 – uplifts of Dzungar Alatau: 1.1 – Sholak, 1.2 – Katutau, 1.3 и 1.4 – the western and eastern Ulken Kalkans; the orogens of North Tien Shan: 1.5 – 1.7 – uplifts of Zaili Alatau: 1.5 – Balaboguty, 1.6 – Karachin (ridges: 1.6.1 – Karash, 1.6.2 – Bakaidyntau, 1.6.3 – Soguety, 1.6.4 – Ulken Bogetty), 1.7 – Donzhailau (1.7.1 –Sarytau Mountains, 1.7.2 – Toraigyr Mountains), 1.8 – East Kungei, 1.9 – West Ketmen, 1.10 – El’shyn-Buiryk), 2 – ***highlands and mountain plateaus***: 2.1 – Dalaashyk Highland, 3 – ***foothill steps and adyrs*** (3.1 – South Dzungar, 3.2 – Zaili), 4 – ***intermountain troughs*** (4.1 – Konurolen Basin, 4.2 – West Ili graben syncline, 4.3 – Panphilovsk

(East Ili, Dzharkent) graben syncline, 4.4 – Soguety Basin, 4.5 – Zhalanash Basin, 4.6 Karkara (West Kegen) Basin, 4.7 – East Kegen Basin), 5 – ***intermontane depressions*** (5.1 – Asy, 5.2 – Zhinishke); 6-7 – **neotectonic faults** (1 – Kalkan Shift, faults: 2 – Kalkan, 3 – West Katutau, 4 – Chundzha-Dubun (Chundzhin), 5 – Karasai, 6 – Bas-Boroldai (Sorkol'), 7 – Karaturuk, 8 – Balaboguty, 9 – Tauturgen, 10 – Kiikbai-Zhumak, 11 – northwestern branch of Chilik-Kemin Zone, 12 – southeastern branch of Chilik-Kemin Zone, 13 – Boguty, 14 – Ili, 15 – North Dalaashyk, 16 – Boguty-Charyn, 17 – Toraigyr, 18 – Beskaragai, 19 – Karadala-Charyn, 20 – North Kuluktau (Baisorun-Chilik), 21 – North Ketmen, 22 – Zhalanash, 23 – South Kuluktau, 24 – Central Ketmen Zone, 25 – Tuyuk, 26 – South Ketmen, 27 – Chul'adyr Zone): 6 – ***manifested on the surface***, 7 – ***disguised under the sediment cover***; 8-10 – **seismic elements**: 8 – ***boundaries of the zones of normative MSK-64 seismic intensity*** (intensity 8 and 9) ([4], simplified), 9-10 – epicenters of earthquakes: 9 – ***Chilik*** (11.07.1889), Ms 8,1, K 17,9, H 40 km [5], 10 – ***Toraigyr-Soguety*** (30.05.2012), Ms 5,0, K 13,7, H 20 км (from the SEME data)

As is clear from table 1, during the last 68 years the maximal energetic class of sampled earthquakes did not exceed 12.0 over a period of 1950 – 1957 years, 12.6 over a period of 1974 – 1975 years, 12.7 over a period of 1982 – 1986 years. Periods of 1958 – 1973 years, 1976 – 1981 years, 1987 – 2011 years, and 2013 – 2017 years are characterized by relative seismic lull.

Examining the seismic history of the area, we don't have to omit mention of Chilik catastrophic earthquake that occurred on July 11, 1889 in 20 km towards the south-southwest from the focus of Toraigyr-Soguety earthquake at a point on the surface with the coordinates 43° 12` N and 78° 42` E (see figure 1).

Chilik earthquake was of the surface wave magnitude Ms = 8.1, energy class Kp = 17.9, and seismic intensity I_0 = 10 on the International MSK-64 Scale [5-7]. Pleistoseistal area of the Chilik earthquake captured the eastern spurs of the Zaili and Kungei Alatau Ridges, and meridian distance from the eastern coast of Lake Issyk Kul up to the Ili River [5, p. 497]. Widespread rock falls, screes, and lineal seismic dislocations were formed in the mountains. Sizeable damages of the Earth surface were observed on the beach of Lake Issyk Kul, between settlements Uital and Sazonovka. A tsunami wave formed straight in Lake Issyk Kul had flooded the western beach. Pleistoseistal area of the Chilik earthquake is practically the same as the zone of seismic intensity 9 established by I. V. Mushketov on the ground of 60 questionnaires with description of macroseismic destructions of buildings [7, p. 27].

Chilik earthquake had shown itself in such significant scale of macroseismic effect, which was never surpassed by subsequent earthquakes. So the intensity zone of 9 on a statutory map of seismic risk zoning (SRZ) of Kazakhstan Republic of 2006 (see Fig. 1) in many respects repeats the intensity zone of 9 of Chilik earthquake [8].

On the SRZ map the epicenter of the Toraigyr-Soguety earthquake is located within the intensity zone of 9, a bit towards the North from the boundary of the eastern segment of Zaili seismogenerating zone of $M \leq 7{,}0$ [4,8].

The intensity of earth tremor in the epicenter of Toraigyr-Soguety earthquake is estimated by 6 points of the MSK-64 scale, according to the SEME data of macroseismic observation. During earthquake no serious destructions were observed. Only fissures were formed and plaster crumbled in some buildings of Kok-Pek settlement and near Bartogai reservoir.

Geological-and-tectonic conditions of the earthquake area. In figure 1 some neotectonic structures [3] and faults of the epicentric areas of Chilik and Toraigyr-Soguety earthquakes are shown. The Toraigyr uplift, which is nearby to the Toraigyr-Soguety earthquake epicenter, constitutes the eastern termination of the system of Zaili Alatau Ridges. The arches of the Northern Tien Shan – Zaili and Kungei Alatau – are the members of the region of Caledonian folding [9, p. 10]. Ili graben syncline and spurs of Dzungar Alatau are situated northward and present the part of the Zhongar-Balkhash Folding Region with Hercynic basement which arose in the late Paleozoic marginal sea's place during the late Paleozoic and the early Triassic epoch [10, p. 7, 256]. Faults trending to the east-northeast, north-west and north-east had arisen at the times of Hercynic, Caledonian and former cycles of tectogenesis. They are the boundaries of blocks of the consolidated basement [11, p. 187]. Most of the modern morphostructures are inherited from Paleozoic structures [12]. For example, West Ili Graben Syncline is inherited from the eastern part of Ili

Synclinorium of Hercynic age [13, p. 36]. Kungei and Zaili uplifts, and their eastern prolongation – Ketmen uplift – are inherited from Caledonian anticlinoria of the same names. Outcrops of folded Caledonian basement consisting of Cambrian and Ordovician formations stretch in the form of a narrow belt along the fold axis of Ketmen uplift [11, p. 154].

In the regard of features of formation of morphostructures during the Alpine tectonic cycle the Ketmen, Kungei and Zaili uplifts are wholly allocated within the area of the North-Eastern Tien Shan segregated by the Talas-Fergan fault from the South-Western Tien Shan. Vertical movements revealed themselves more actively in the North-Eastern Tien Shan than in the South-Western Tien Shan where horizontal movements prevail [14, p. 62]. In general block-and-folding structures of the Tien Shan Mountains the block faulting and movements along faults are more significant than folding and plicated dislocations [15]. Mountain ridges and depressions (basins) correspond to horst-anticlines and graben-synclines. Territory of the Ketmen, Kungei and Zaili ridges, where seismicity is the highest in Kazakhstan, is referred to as the Almaty Seismically Dangerous Area [16].

O. K. Chediya has singled out in the eastern pericline of the Zaili morphostructure, called him megafold, the third-order structures from south to north: Ili, Donzhailau, and Karachin horst-anticlines [9, p. 187-190]. The same three eastern branches of the Zaili morphostructure were named the Dalaashyk, Sarytau-Toraigyr, and Karash-Boguty uplifts by K. T. Kulikovski and V. F. Shlygina earlier [11, p. 181].

The Ili Horst-Anticline corresponds to the Dalaashyk Highland. The Donzhailau Horst-Anticline is represented by Sarytau and Toraigyr Mountains. The Karachin Horst-Anticline consists of Karash, Bakaidyntau, Soguety, Ulken Bogetty ridges from west to east (see Fig. 1). The Sarytau Mountains are edged by intermontane depressions: the Asy in the north and the Zhinishke in the south. To the east the Zhinishke depression is extended by the large intermountain trough Zhalanash.

That was in the Zhalanash trough, in and around of the Karadala-Charyn fault, on a site of the closest approach of the riverbeds of the Charyn and the Chilik where the epicenter of Chilik catastrophic earthquake was identified by I. V. Mushketov [5,7].

The Soguety Basin and the Toraigyr uplift, like the most neotectonic structures of the region, strike to the east-northeast. The epicenter of Toraigyr-Soguety earthquake, as shown in Fig. 1, is located on the southern limb of Soguety graben syncline, near its axis. The North Dalaashyk fault is the nearest to the epicenter of the Toraigyr-Soguety earthquake and passes at the distance of 3 km to the southeast, setting the southern limb of Soguety graben syncline apart from the Toraigyr uplift. The position of the North Dalaashyk Fault in figure 1 was specified from [17]. Authors of the article [2, p. 144,148] associate the source of Toraigyr-Soguety earthquake with the zone of Kapchagai-Chilik fault striking to the northwest but it isn't confirmed by the current research.

The strike azimuth of the North Dalaashyk fault is equal to 70° both near the epicenter of Toraigyr-Soguety earthquake and over the greater part of the own manifestation. The north limb of the Soguety graben syncline is separated from the Karachin uplift by the southeastern branch of Chilik-Kemin Zone of faults.

Thickness of the Cainozoic deposits amounts to 100 – 400 m, which is based on the data of drilling in the area of the Soguety graben syncline, near epicentre. The Cainozoic sediments are underlain by acid volcanic rocks of the Upper Paleozoic [18]. The bottom of the Cainozoic sedimentary rock sequence of Soguety and Zhalanash graben synclines consists of the Miocene nonsegmented red clay with basal marl exposed in the Charyn canyon. To the north from the Toraigyr Mountains, in the Soguety depression the Miocene is overlaid by Ili strata (N_2^3 *il*). Ili strata are represented by conglomerates, detritus, sandstones by thickness of 40-50 m and siltstone, which changes the sequence to the north from the mountains [19, p. 43,48].

There was a lake in the Soguety depression where lacustrine sediments were accumulated before the end of the Middle Pleistocene (B.C. 110,000) [20]. Starting from the Upper Pleistocene, after a debacle of the lake dam, deluvial, alluvial, and proluvial facies have been forming the upper part of the Quaternary sequence.

As shown in figure 1, first-rate arched block uplifts, intermountain and intermontane basins strike according to the azimuth about 70°-80°, towards the east-northeast. This direction is referred to as the

Tienshan [12]. Neotectonic faults of the Tienshan direction are marked in the relief in the form of tectonic scarps, which divide slopes of the Zaili Alatau into longitudinal latitudinal steps.

Previously we have executed statistical analysis of fault systems of Northern Tien Shan and Dzhungariya [21]. The average strike azimuth of neotectonic faults of the Tienshan system, being calculated like a weighted average, taking into account the length of each fault, equals to 74.89° [22, p. 67].

Such regional faults as the Central Ketmen, North Kuluktau (Baisorun-Chilik), North Ketmen, Karadala-Charyn, North Dalaashyk, Chilik-Kemin, and Karaturuk (see figure 1) edge limbs of horst-anticlines at the margins with neighbouring parts of depressions or pass across the paraxial parts of horst-anticlines and graben-synclines, and also strike towards the east-northeast. Listed above faults are tectonically movable; they stretch for a hundred kilometers and are surrounded by intensively fissured rocks of about several km wide. Chilik-Kemin fault is a crust-cutting disjunctive structure cutting the Earth's crust up to its floor, up to depth of 50 km [23]. The other faults are plunged down into the Earth's crust, as a rule, up to depth of 10-15 km, keeping within limits of granite-gneiss layer.

Majority of the earthquake focuses of the Almaty Seismically Dangerous Area is distributed in the range of 5-20 km of depths and is confined within some deep faults and large-scale branch faults, being renovated at the newest time [16,23,24]. According to Kurskeyev A. K., geological medium at a depth of 5-20 km is in brittle-elastic condition and is capable of accumulation of great tectonic strain, promoting the strongest earthquakes such as historical ones: Vernyi (1887, M_{LH} = 7.3), Chilik (1889, M_{LH} = 8.3), Kemin (1911, M_{LH} = 8.2), Suusamyr (1992, M_{LH} = 7.3) and others. The plastic-viscous layer of the Earth's crust (below 25 km) is good to form the sources of smaller dimensions and, conformably, of less energy [24, p. 63-65].

The system of strike-slip faults trending towards NW exerts appreciable influence on the neotectonic structures of Northern Tien Shan and Dzhungariya. Statistical analysis of this strike-slip faults' system, which is referred to as the Chu-Ili [23, p. 62], reveals that the average strike azimuth of that system, being calculated like a weighted average, taking into account the length of each fault, equals to 302.37° [22, p. 67]. In the area of investigation such NW faults as West Katutau, Chundzha-Dubun (Chundzhin), Karasai, Boguty-Charyn, Bas-Boroldai (Sorkol'), Kalkan Shift, and others (see figure 1) are considered to be strike-slip faults with right-lateral component [12, 21-23]. NW shifts by length of 20 - 150 km become morphologically apparent in periclines of arched block uplifts, highlands, intermountain and intermontane depressions. Some right-lateral strike-slip faults crossing morphostructures displace their parts in different directions. At the neotectonic stage a reconstruction of the ancient tectonic plan ensues from forcing of NW shifts.

The Kalkan Shift situated on the south periphery of uplifts of Dzungar Alatau (see in the upper (northern) part of figure 1) strikes towards the north-west (azimuth 300°) and crosses Permian stratovolcano Kalkan, which was active in the Eocene and the Oligocene, during its Alpine regeneration [20]. At the present time stratovolcano is divided by the Kalkan Shift into 2 parts: the western and eastern Ulken Kalkans.

As shown in figure 1, the Kalkan Shift is characterized by right-lateral (dextral) component of shifting and displaces the parts of the puy (stratified cone) made of Permian dacite and andesite tufas in different directions over a distance of 10 km.

Analyzing the geological structures of Dzungar Alatau and adjacent depressions including Ili one, L. K. Didenko-Kislitsina has established that Dzungar Alatau is the autonomous epiplatform Pliocene-Quaternary orogen [13].

If we connect the beginning of displacement of stratovolcano Kalkan with the beginning of the Pliocene (B.C. 5.8m), the strike-slip rate along the Kalkan Shift is estimated at 10 km / 5.8 m years = 1 000 000 cm / 5 800 000 years = 1.7 mm/a.

If to consider system of NW shifts from the north to the south in the following sequence: the West Katutau fault, Kalkan Shift, Chundzha-Dubun fault, Karasai fault, et cetera, it is easy to determine that they are located regularly every 20-30 km (see figure 1). This indicates that segment of the Earth's crust covering front ranges of the South Dzungaria and the eastern virgations of the Zaili Alatau are in the condition of tangential compression.

We can find out from the right-lateral shifting along the Kalkan Shift striking to the azimuth 300° that the azimuth of axis of tangential compression is equal about 345°. For this purpose it is enough to combine the azimuth of striking 300° and theoretical corner 45° between a plane of a fault and an axis of compression, as it takes place for both fault planes and main axes of compression and stretching [25]. It is obvious that any faults being perpendicular to the axis of compression, striking to the azimuth 345°-270° = 75°, will develop like thrusts and underthrust faults. Consequently, the component of a motion down and upward along the dip line should prevail among faults with the Tienshan direction (75±5°). Really, as appears from [11, p. 187], the faults with the Tienshan direction and more scarce faults striking to the NE develop like upthrow-shifts with the left-lateral displacement and quite often are transformed into upthrusts. Planes of faults, striking towards ENE and NE, often dip under mountain structures at angle about 70-80°.

Earthquake focal mechanism (EFM). Let's consider two solutions of focal mechanism of Toraigyr-Soguety earthquake represented in figure 2. The first EFM is from the SEME data (see figure 2, A). The second EFM is from the Global Catalog of earthquakes (see figure 2, B) [1]. After that we'll compare two solutions of EFM with each other and collate them with kinematics of the nearest neotectonic faults. Table 2 includes parameters of three Main (Principal) Stress Axes and two possible fault planes for each variant of two EFM.

Additionally, we have estimated a shear angle and components of unit vector of movement on the plane (D_x and D_θ) by applying the method stated in [25].

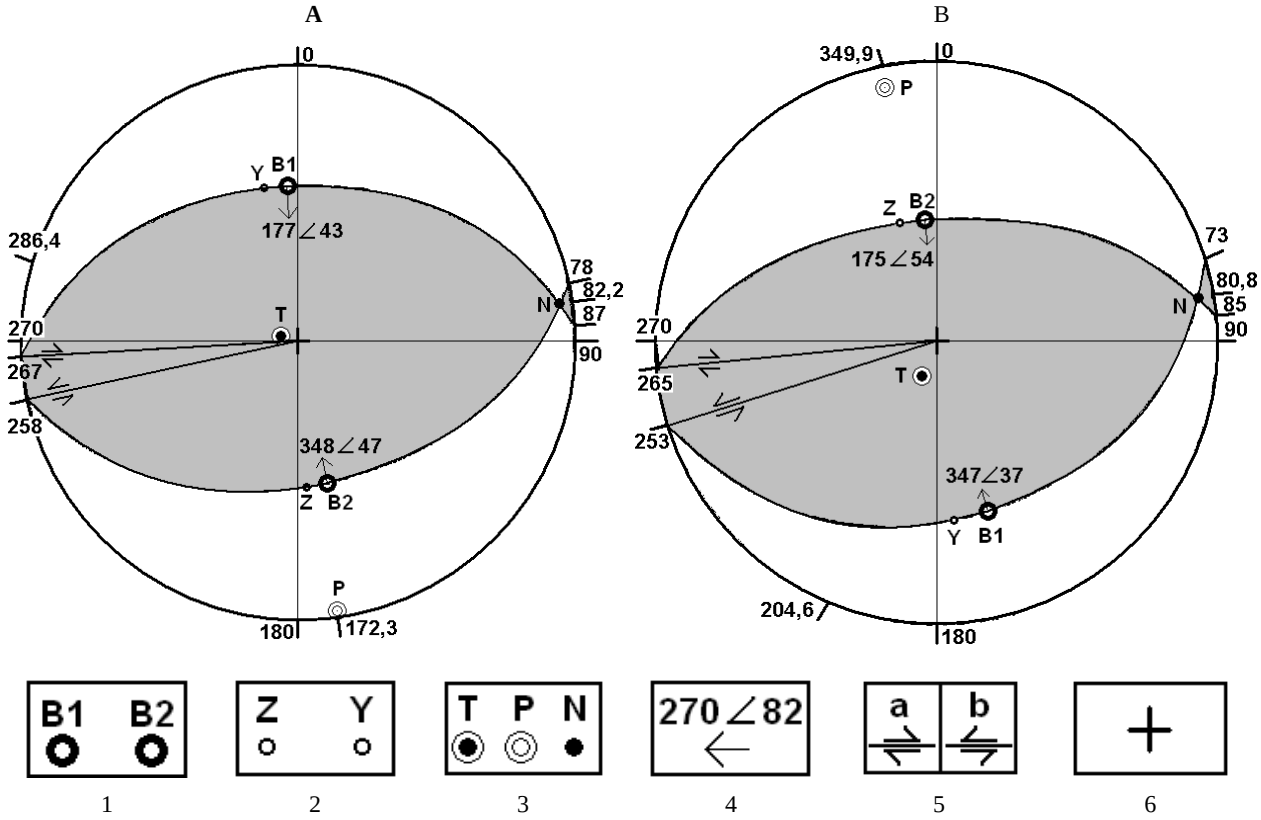

Figure 2 – The stereograms of focal mechanism of Toraigyr-Soguety earthquake (30.05.2012) on the upper hemisphere of the Schmidt's net: from the SEME data (A) and from the GCMT data [1] (B). Compiler: A. R. Zhdanovich
1 – vertices of fault planes: of the first one (B1), of the second one (B2); 2 – poles of fault planes (Motion Axes): of the first one (Z), of the second one (Y); 3 – Principal Axes of Strain: Axis of Tension (T), Axis of Pressure (P), Neutral Axis (N); 4 – direction of dip and dip angle of a fault plane; 5 – directions of shifts on a map: of right-lateral (dextral) shift (a), of left-lateral (sinistral) shift (b); 6 – the center of the diagram

Table 2 – The solutions of focal mechanism of the Toraigyr-Soguety earthquake (30.05.2012).
Compiler: A. R. Zhdanovich

Data source	Parameters of the Principal Axes of Strain, being calculated from the positions of the fault planes						The fault planes							
	Pressure, P		Tension, T		Neutral, N (B)		Parameters from the data sources					Calculated parameters		
	Azm	α	Azm	α	Azm	α	№	STR	Ψ	θ, Dip	SLIP	SHEAR	D_x	D_θ
SEME	172,3	88,0	286,4	4,9	82,2	85,5	1	87	177	43 S	98	6,6	0,1146	0,9934
							2	258	348	47 NW	84	-6,1	-0,1069	0,9943
GCMT [1]	349,9	81,5	204,6	10,4	80,8	84,2	1	73	343	37 NW	80	-9,7	-0,1683	0,9857
							2	265	175	54 S	97	7,2	0,1253	0,9921

Note. The designations listed in Table 2: Azm – azimuth of the extremity of an axis in the upper hemisphere; α - angle of approach (α = 90 – pl, where pl – angle of plunge); STR – strike azimuth of a fault plane; Ψ – direction of dip of a fault plane; θ, Dip – angle of dip of a fault plane; SLIP – a slip angle (Rake [1]); SHEAR – a shear angle; Dx – component of movement in the direction of the strike line; Dθ – component of movement in the direction of the dip line.

As follows from figure 2 and table 2 two solutions of focal mechanism from the SEME and GCMT data are practically the same. In the regard of kinematics of the motion, two possible fault planes are interpreted like upthrow-shifts with dominance of component of movement in the direction of the line oriented up-rake (D_θ = 0.99, see table 2) and with circumvertical axis of tension (angle of approach α is 4.9° (SEME) and 10.4° (GCMT)). The significant fluctuations of the azimuth of the tension axis (286.4° (SEME) and 204.6° (GCMT)) are related to its circumvertical position and sensitivity of the azimuth to deviation of the axis from the vertical position even over a small angle.

The axis of pressure P is close to horizontal (angle of approach is 88.0° (SEME) and 81.5° (GCMT)), with its extremity directed in the upper hemisphere towards SSE (Azm 172.3° (SEME)) or in an opposite direction, towards NNW (Azm 349.9° (GCMT)). The Neutral Axis N is the most stable; it's striking towards ENE (82.2° (SEME) and 80.8° (GCMT)) at an abrupt angle to the vertical (85.5° (SEME) and 84.2° (GCMT)).

In table 2, from directions of dip (Ψ) we can realize that the first fault plane from the SEME data with Ψ = 177° corresponds to the second fault plane from the GCMT data with Ψ = 175°, and inversely, the second fault plane from the SEME data with Ψ = 348° corresponds to the first fault plane from the GCMT data with Ψ = 343°. The discrepancy of numbers of fault planes is due to the fact, that the fault planes are numbered in ascending strike azimuths of planes. But strike azimuth of plane is being determined by various ways in SEME or GCMT practice. To get a strike azimuth of a fault plane in SEME practice they use the direction of that extremity of a strike line, along which an observer sees a perched block on the right [25, p. 54]. In the GCMT catalogue they mean that a perched block is located on the left of an observing line.

The fault plane dipping to the SSE (177° or 175°) has got positive estimate of component of movement in the direction of the strike line Dx (0.1146 (SEME) or 0.1253 (GCMT)), and therefore, includes the right-lateral motion. The other fault plane dipping to the NNW (348° or 343°) has got negative estimate of component of movement in the direction of the strike line Dx (-0.1069 (SEME) or -0.1683 (GCMT)) and includes the left-lateral motion.

The first fault plane from the SEME data or the second fault plane from the GCMT data is the right-lateral upthrow-shift striking to the azimuth 87° or 265° (in northern bearing: 85°). The second fault plane from the SEME data or the first fault plane from the GCMT data is the left-lateral upthrow-shift striking to

the azimuth 258° (in northern bearing: 78°) or 73°. It is the fault plane that is close to the striking azimuth 70° of the North Dalaashyk fault.

It's possible to estimate only theoretically an average absolute size of displacement along the fault (d) [25] in the focus of the Toraigyr-Soguety earthquake due to there is no information about opening of the fault on the surface. In the capacity of an estimate of the absolute size of displacement they can exploit average amplitude of displacement along the fault (a) calculated according to correlation dependence between amplitude and magnitude.

For example, the formula of V. S. Khromovskikh [5]:

$$M_{LH} = \lg a + 7, \quad (1)$$

where M_{LH} – is a magnitude, being measured according to maximal horizontal amplitudes of the surface waves, implies that

$$a = 10^{(M-7)}, \text{ m}. \quad (2)$$

Magnitudes M_{LH} и M_S are linking by simple relation [21]:

$$M_{LH} = M_S + 0{,}1. \quad (3)$$

For example, for M_S = 5.4 from the data of [1], we'll get M_{LH} = 5.5. The average amplitude of displacement along the fault amounts to:

$$d = a = 10^{(5{,}5-7)} = 10^{(-1{,}5)} = 3.2 \text{ cm}. \quad (4)$$

Absolute values of motion along the fault in the direction of the strike line (d_x) and in the direction of the dip line (d_θ) can be calculated formulaic by using values of components of movement in the direction of the strike line (D_x) and in the direction of the dip line (D_θ), being listed in table 2:

$$d_x = D_x \times d = \sin \text{SHEAR} \times d, \quad (5)$$

$$d_\theta = D_\theta \times d = \sin \text{SLIP} \times d. \quad (6)$$

For example, absolute values of motion along the first fault plane (from the GCMT data [1]), which is the left-lateral upthrow-shift striking to the azimuth 73°, oriented closely to the azimuth 70° of the North Dalaashyk fault, are estimated by formulas (5) and (6), taking into account the values of D_x and D_θ from the table 2:

$$d_x = -0.1683 \times 3.2 \text{ cm} = (-5) \text{ mm}, \; d_\theta = 0.9857 \times 3.2 \text{ cm} = 3.2 \text{ cm}.$$

Evidently, displacement of 3.2 cm at the hypocentral depth (H) of 20 ÷ 27 km could not be manifested on the surface.

Conclusions. 1. In the area of Toraigyr-Soguety and Chilik earthquakes spatial orientation of modern morphostructures (ridges and depressions) and faults, inherited from Paleozoic structures, coincides with Tienshan, ENE direction (weighted average is 74.89°). Movements along the shifts of Chu-Ili, NW direction (weighted average is 302.37°) take the second place by influence on the morphology and dynamics of neotectonic structures.

2. The epicenter of the Toraigyr-Soguety earthquake that happened on May 30, 2012 is located on the southern limb of Soguety graben syncline, to the north from the Toraigyr uplift, at the distance of 3 km towards North from the central axis of the North Dalaashyk fault, striking to the azimuth of 70°.

3. Two solutions of focal mechanism from the SEME and GCMT data are practically the same. Two possible fault planes are interpreted like upthrow-shifts with dominance of positive component of movement in the direction of the line oriented up-rake (0.99). The one fault plane trending to the ENE (85÷87° in northern bearing) and dipping at angle of about 43° ÷ 54° towards SSE (175÷177°) has got positive estimate of component of movement in the direction of the strike line (0.1146÷0.1253) and is considered to be the right-lateral upthrow-shift. The other fault plane trending to the ENE (73÷78° in northern bearing) and dipping at angle of about 37÷47° towards NNW (343 ÷348°) has got negative estimate of component of movement in the direction of the strike line ((-0.1069) ÷ (-0.1683)) and is considered to be the left-lateral upthrow-shift.

4. The focal mechanism of the Toraigyr-Soguety earthquake reveals that the fault plane trending to the azimuth of 73÷78° and dipping at angle of about 37÷47° to the azimuth of 343÷348°, interpreted like the left-lateral upthrow-shift, is close to the striking azimuth 70° of the North Dalaashyk fault located near to the epicenter. Therefore, the North Dalaashyk fault trending towards ENE is able to be the left-lateral upthrow-shift with dominance of the motion oriented up-rake. If taking the left-lateral upthrow-shift trending to the azimuth of 73° (the first fault plane from the GCMT data [1]) as corresponding rupture in the source, the absolute value of motion in the direction of the line oriented up-rake is estimated at 3.2 cm.

5. Analysis of two focal mechanisms of the Toraigyr-Soguety earthquake, brought to your attention in this article, reveals that the axis of pressure P is close to horizontal (angle of approach is 88.0÷81.5°) and strike azimuth ranges between 349.9 and 352.3° in northern bearing.

6. Displacement of the western and eastern Ulken Kalkan uplifts in different directions along the Kalkan Shift with striking azimuth of 300° is characterized by right-lateral (dextral) component of shifting and the average strike-slip rate is estimated at 1.7 mm / a during the last 5.8m years. To satisfy the progress condition of shifting towards the azimuth of 300° the most probable value of striking of the axis of compression (pressure) is 345°.

7. An assumption of the left-lateral shifting and motion oriented up-rake along the first-rate faults striking towards ENE and the right-lateral shifting along the faults striking towards NW fits the geological-and-tectonic and seismological data being set in this paper and testifies to existence of circumhorizontal tangential compression directed approximately from NNW towards SSE (azimuths of 345-353°) in the area of the epicenters of Chilik and Toraigyr-Soguety earthquakes.

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ТОРАЙҒЫР-СӨГЕТІ ЖЕР СІЛКІНІСІ ОШАҒЫНЫҢ МЕХАНИЗМІ МЕН ГЕОЛОГИЯЛЫҚ-ТЕКТОНИКАЛЫҚ АХУАЛЫНЫҢ ҚАЛЫПТАСУЫ, 2012 ж. 30 мамыр

Аннотация. Торайғыр-Сөгеті жер сілкінісінің эпиорталығы Қазақстан Республикасының Алматы облысында 2012 жылдың 30 мамырында, нүктедегі 43° 23` с. е. және 78° 46` ш. б. координаттарымен, Гринвич бойынша 21 с. 20 мин. 56,7 сек. тіркелді. Жер сілкінісінің энергетикалық сыныбы (Кр) 13,7 ÷ 14,2, магнитудасы (М) 5,0 ден 6,0 дейін, гипоцентр тереңдігі 20-27 км деп бағаланып, топырақты соғу үдемелілігі (I_0) MSK-64 халықаралық сейсмикалық шкала бойынша 6 балды құрады. Жер сілкінісі энергиясы бойынша осы аумақта 1889 жылдың 11 шілдесінде Торайғыр-Сөгеті жер сілкінісі эпиорталығынан 20 км-де өткен Шелек жер сілкінісінен (Кр = 17,9, М = 8,1, I_0 = 10) кейінгі 43° – 44° ендік пен 78° – 80° бойлық арасында болған қатты жер дүмпуі болып есептеледі. Шелектегі жер сілкінісі кезінде Іле және Күнгей сілемі жоталарында көптеген жарықшақ, жылжыма мен бойлық сейсмикалық дислокациялар, ал Ыстықкөл көлінде цунами толқыны орын алды. Торайғыр-Сөгеті жер сілкінісінің эпиорталығы Сөгеті опырықты-синклинінің оңтүстік қанатындағы, Торайғыр көтерілімінен 3,5 км солтүстікке қарай, азимут бойынша 70° созылып жатқан және эпиорталыққа жақын Солтүстік Далаашық жарылымынан солтүстік-батысқа қарай 3-5 км-де орналасқан. Сөгеті ойпаты мен Торайғыр көтерілімі Іле Алатауы жоталар жүйесінің шығыс жақ аяғында орналасқан. Іле көтерілімі солтүстік-шығыс Тянь-Шанға енеді де, каледонды антиклинорияға ұласады. Ең үлкен күмбезді-бұдырлы көтерілімі, тауаралық және тауішілік ойпаттар азимут бойымен шамамен 70°-80°, ШСШ бағытында созылып жатыр, оны тяньшандық деп атайды. Тяньшандық бағытының неотектоникалық өңірлік жарылымдары рельефте Іле Алатауының беткейін бойлық дерлік ендік сатыларға бөлетін тектоникалық кертпештер түрінде байқалады. Шелек-Кемін жарылымы жер қыртысын түбіне дейін 50 км тереңдікке дейін кесіп өтеді; тяньшандық бағытының басқа жарылымы гранит-гнейс қабатынан аспай, жер қыртысынан 10-15 км тереңдікке түседі. СБ Шу-Іле жүйесінің оң жақ бүйірлік ығысу әсерінен ежелгі құрылымдық жоспардың неотектоникалық қайта құрылуы орын алып, неотектоникалық құрылымдар морфологиясы өзгереді. Батыс және шығыс Үлкен-Қалқан көтерілімдерінің түрлі бағыттағы 10 км Қалқан бойынша 300° азимутпен сырғып созылуы соңғы 5,8 миллион жыл ішінде шамамен орташа 1,7 мм жылдамдықпен оң жақ қозғалысымен сипатталады. 300° созылған жылжыманы дамыту үшін сығу өсін 345° азимут бойынша созу тууы ықтимал. Торайғыр-Сөгеті жер сілкінісі жарылымының нодальді жазықтығы (ЖНЖ) құлама-өрлеме сызығы бойындағы араласу векторының оң компоненттері басымдылығымен ығысу-жылжуы деп түсіндіріледі (0,99). Бір

ЖНЖ ШСШ (85° ÷ 87° солт румбке) созылуы, ООШ азимутты құламасы (175° ÷ 177°), 43° ÷ 54° құлау бұрышымен оң жаққа қарай ығысып жылжиды және созылу сызығы бойындағы араласудың оң компонентті векторы 0,1146 ÷ 0,1253 диапазонды қамтиды. Екінші ЖНЖ ШСШ (73° ÷ 78° солт румбке) созылуы, ССБ азимутты құламасы (343° ÷ 348°), (37° ÷ 47°) құлау бұрышымен сол жаққа қарай ығысып жылжиды және оның созылу сызығы бойындағы араласудың теріс компонентті векторы – (-0,1069) ÷ (-0,1683). Бұл нодальді жазықтық Солтүстік Далаашық жарылымының 70° созылу азимутына жақын. Сондықтан да Солтүстік Далаашық жарылымы ығыспалы араласу компоненттері басымдығымен сол жақтық ығысу-жылжу жағдайы орын алады. Ошақтағы 73° созылмалы жарылым жазығының сол жақтық ығысу-жылжуды қабылдау барысында құлама-өрлеме сызығының бағыты бойынша араласудың абсолютті шамасы 3,2 см деп бағаланады. Сығу өсі субгоризонтальді болса, оның бұрышы тігінен 88,0° ÷ 81,5°, құрайтындығы, ал солтүстік румбтағы созу азимуты 349,9°-дан 352,3° дейін құбылатындығы анықталды. Созудың ШСШ ірі жарылымы бойынша сол жақтағы ығысу-жылжу қозғалысына және созудың СБ ығысуы бойынша оң жақтық қозғалыстың орын алуы үшін мақалада баяндалған геологиялық-тектоникалық және сейсмологиялық мәліметтер арқылы нақтыланады, сонымен қатар олар осы ауданда 345° – 353° азимут бойынша бағытталған, субгоризонтальді тангенциалды сығылудың Торайғыр-Сөгеті және Шелекте болған жер сілкінісі эпиорталығының болатынын айғақтауы мүмкін.

Түйін сөздер: жер сілкінісі, эпиорталық аудан, геологиялық-тектоникалық ахуал, неотектоникалық жарылым, жарылым кинематикасы, кернеудің басты өсі (деформация), жер сілкініс ошағының механизм моделі, жарылымның нодальді жазықтығы.

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ГЕОЛОГО-ТЕКТОНИЧЕСКИЕ УСЛОВИЯ ФОРМИРОВАНИЯ И МЕХАНИЗМ ОЧАГА ТОРАЙГЫР-СОГЕТИНСКОГО ЗЕМЛЕТРЯСЕНИЯ 30 мая 2012 г.

Аннотация. Эпицентр Торайгыр-Согетинского землетрясения зафиксирован 30 мая 2012 г., в 21 ч. 20 мин. 56,7 сек. по Гринвичу в Алматинской области Республики Казахстан в точке с координатами 43° 23` с. ш. и 78° 46` в. д. Энергетический класс землетрясения (Кр) оценивается в 13,7 ÷ 14,2, магнитуда (М) – от 5,0 до 6,0, глубина гипоцентра – от 20 до 27 км, интенсивность сотрясения грунта (I_0) по международной сейсмической шкале MSK-64 составила 6 баллов. Это землетрясение является самым сильным по энергии на территории, заключенной между широтами 43° – 44° и долготами 78° – 80°, после Чиликского землетрясения (Кр = 17,9, М = 8,1, I_0 = 10 баллов), которое произошло 11 июля 1889 г. в 20 км к ЮЮЗ от эпицентра Торайгыр-Согетинского землетрясения. Во время Чиликского землетрясения в восточных отрогах Заилийского и Кунгейского хребтов сформировались многочисленные обвалы, осыпи и линейные сейсмодислокации, а в оз. Иссык-Куль – волна цунами. Эпицентр Торайгыр-Согетинского землетрясения расположен на южном крыле Согетинской грабен-синклинали, в 3-5 км к северу от Торайгырского поднятия, в 3 км к северо-западу от Северо-Далаашикского разлома, ближайшего к эпицентру и простирающегося по азимуту 70°. Согетинская впадина и Торайгырское поднятие расположены на восточном окончании системы хребтов Заилийского Алатау. Заилийское поднятие входит в Северо-восточный Тянь-Шань и унаследовано от одноименного каледонского антиклинория. Крупнейшие сводово-глыбовые поднятия, межгорные и внутригорные впадины простираются по азимуту около 70°-80°, в ВСВ (тяньшаньском) направлении. Неотектонические региональные разломы тяньшаньского направления выражены в рельефе в виде тектонических уступов, которые разделяют склоны Заилийского Алатау на продольные субширотные ступени. Чилик-Кеминский разлом рассекает земную кору до подошвы на глубину 50 км; остальные разломы тяньшаньского направления погружаются в земную кору на глубину 10-15 км, не выходя за пределы гранито-гнейсового слоя. Под воздействием правосторонних сдвигов чу-илийской системы СЗ простирания происходит неотектоническая перестройка древнего структурного плана, изменяется морфология неотектонических структур. Смещение на 10 км в разные стороны западного и восточного Улькен-Калканских поднятий по Калканскому сдвигу с азимутом простирания 300° характеризуется правосторонним движением приблизительно со средней скоростью 1,7 мм / год на протяжении последних 5,8 млн. лет. Для развития сдвига с простиранием 300° наиболее вероятно простирание оси сжатия по азимуту 345°. Нодальные плоскости разрыва (НПР) Торайгыр-Согетинского землетрясения интерпретируются как сдвиго-взбросы с преобладающей положительной

компонентой вектора смещения вдоль линии восстания-падения (0,99). Одна НПР является правосторонним сдвиго-взбросом с простиранием на ВСВ (85° ÷ 87° в северных румбах), с азимутом падения на ЮЮВ (175° ÷ 177°), углом падения 43° ÷ 54° и положительной компонентой вектора смещения вдоль линии простирания в диапазоне 0,1146 ÷ 0,1253. Другая НПР является левосторонним сдвиго-взбросом с простиранием на ВСВ (73° ÷ 78° в северных румбах), с азимутом падения на ССЗ (343° ÷ 348°), углом падения 37° ÷ 47° и отрицательной компонентой вектора смещения вдоль линии простирания в диапазоне (-0,1069) ÷ (-0,1683). Эта нодальная плоскость близка по азимуту простирания 70° к Северо-Далаашикскому разлому. Поэтому Северо-Далаашикский разлом может являться левосторонним сдвиго-взбросом, с преобладающей взбросовой компонентой смещения. При принятии левостороннего сдвиго-взброса с простиранием 73° плоскостью разрыва в очаге абсолютная величина смещения по направлению линии падения-восстания оценивается в 3,2 см. Выявлено, что ось сжатия субгоризонтальна, ее угол с вертикалью составляет 88,0° ÷ 81,5°, а азимут простирания в северных румбах колеблется от 349,9° до 352,3°. Допущение левосторонних сдвиго-взбросовых движений по крупнейшим разломам ВСВ простирания и правосторонних движений по сдвигам СЗ простирания согласуется с геолого-тектоническими и сейсмологическими данными, изложенными в статье, и может свидетельствовать о наличии в районе эпицентров Торайгыр-Согетинского и Чиликского землетрясений субгоризонтального тангенциального сжатия, направленного по азимуту 345° – 353°.

Ключевые слова: землетрясение, эпицентральный район, геолого-тектонические условия, неотектонический разлом, кинематика разлома, главные оси напряжений (деформаций), модель механизма очага землетрясения, нодальные плоскости разрыва.

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NEW METHODS TO PROTECT YEAR-AROUND OPERATION CANALS FROM SNOW

Abstract. On the canals of year-around operation, severe snowdrifts concentrated on the surface of the ice cover simultaneously affect both thermal and static loads. When ice melts intensively from the lower surface in areas of accumulation of snow masses, and also due to an increase in the static load from snow, longitudinal cracks form on the ice. The snow saturated with water rising up along the cracks, and a gradual sinking of the snow-ice mass occurs. All this leads to decrease in canal capacity, and in some cases to complete blockage of the flow section by snow-ice mass. The purpose of the paper is to find new ways to protect the canal drift and create an impervious canal profile in areas heavily covered in snow. Snow deposition in the canal bed occurs gradually, starting from the edge of canal closest to the snow collection basin side, followed by an increase in the snowdrift shaft in the direction of the wind as snow blizzard arrives to the canal. We propose the method of protecting the canals from snowdrifts by changing the transverse profile of the canal in the sections highly covered by snow. The transverse canal profile is changed by adding a berm to it with a slope coefficient equal to the coefficient the leeward slope and a height equal to the depth of the canal from the leeward slope depending on exact establishing the limit position of the surface of the snowdrifts, at which the canal is blown without snow deposition, regardless of the amount of snow transfer. The proposed methods can be applied in areas of snow transfer on watering and irrigation canals designed for year-around operation.

Key words: ice cover, berm, slope coefficient, canal depth, snow deposition.

Introduction. On the canals of year-around operation, powerful snowdrifts concentrated on the surface of the ice cover simultaneously affect both thermal and static loads. As ice melts intensively from the lower surface in areas of accumulation of snow masses, and also due to an increase in the static load from snow, longitudinal cracks form in the ice. The snow is saturated with water rising up along the cracks, and a gradual sinking of the snow-ice mass occurs. All this leads to a decrease in canal capacity, and in some cases to complete blockage of the flow section by snow-ice mass.

In such areas, a powerful blockage field is formed, which prevents the flow of water through the water supply path below this section. Above the ice jam, the water level rises sharply, which leads to emergency situations. On the Irtysh-Karaganda canal, over the period of its operation, such phenomena have been repeatedly observed. For example, in the winter of 1971-1972, on canal No. 38 (146-155 km of the route) as a result of blockage of the flow section of the canal by snow-ice accumulations, a powerful ice jam with a total length of about 5 km was formed. As a result of this phenomenon, water supply through the canal was stopped until the end of April. Attempts to eliminate the jammed area with an explosion or mechanical cleaning by excavators did not produce the expected effect. Firstly, the access roads to the canal were covered with snow, secondly, the length of the boom of power shovel of the excavator did not allow to completely clear the canal and, thirdly, the snow jam area was quite long (3830 m). they succeeded in eliminating the snow jam area with a series of dynamic pumping only after the onset of thaws before the flood (the third decade of April).

In 1974-1978 VNIIG was engaged in the research of the issue and development of snow protection measures on the Irtysh-Karaganda canal. In their work, a detailed analysis of the causes of snow-ice difficulties on canals of year-around operation was given and a set of engineering measures to prevent them was proposed. The essence of these measures is the construction of contour snow lines in the form of fences and forest belts. They also proposed a method for arranging a section of a canal not covered by snow, including the construction of an additional canal passing in a deep excavation for accumulation of snow [1].

In recent years, scientists of the Kazakh Scientific Research Institute of Water Management and the Taraz State University named after M.Kh. Dulati have dealt with issues of snow protection of hydraulic structures, including canals. On the basis of long-term field and laboratory research carried out on existing canals, as well as analysis and generalization of the experience of snow protection means at other objects of the national economy, methods of protection of hydraulic structures from snow wreaths are proposed [2-4].

Materials and methods. For a specific section of the canal, considering the volume of snowfall unlimited, we can determine the state of the maximum filling of the canal bed with snow. But not always the amount of incoming snow to the canal is sufficient for its filling to the limit position. If the total volume of snow arriving during the winter period is less than the maximum accumulating capacity of the canal, then its cross section is not completely filled to the maximum position, but partially. In order to estimate the parameters of snow wreath during partial drift from the maximum possible, having data on the volume of snowdrifts and the geometric parameters of the canal cross section, it is necessary to establish the sequence of filling (dynamics of drift) of the canal with snow as snow mass arrives. The dynamics of snowdrift is closely related to the occurrence of a blizzard [5].

Snow deposition in the canal bed occurs gradually, starting from the canal edge closest to the snow collection basin side, followed by an increase in the snowdrift shaft in the direction of the wind as blizzard snow arrives at the canal. This picture of the sequence of filling the canal bed with snow during blizzards is fully confirmed by the results of field research performed on existing canals [6]. Figure 1 shows the profile of snowdrift in the canal named after K.I. Satpayev as it fills during the winter.

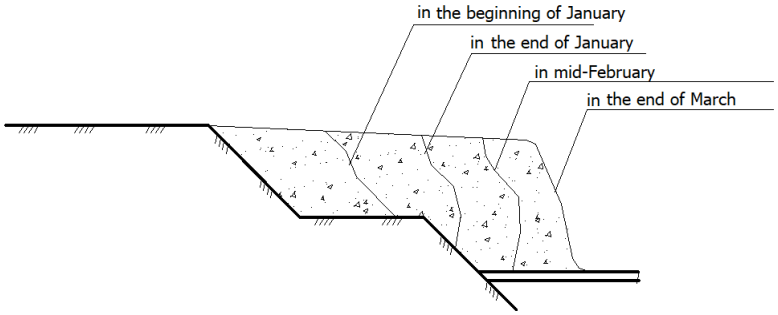

Figure 1 – Snowfall profile in canal bed

As can be seen from figure 1, the front edge of the unfinished snow drift is a steep slope with a peak-like protrusion in the upper part. Incomplete snow drifts are limited during blizzards from above by a straight flow, in the front edge – by a circulation flow. A peak-like protrusion of snowdrift is formed at the junction of these two flows.

Significant practical importance in evaluating the maximum snow tolerance of canals, is the exact establishment of the extreme position of the surface of the snowdrift (snow slope). Snowdrifts in the canal bed from all sides, except for the upper surface, form a circle around the cross section of the canal and take its form. Having determined the position of the snow slope and having data on the design parameters of the canal cross section, with sufficient accuracy we can determine the cross-sectional area or the volume of snowdrift per unit length of the canal, and estimate the load from the snowdrifts on the ice cover. As observations have shown, the slopes of snowdrifts fluctuate in rather large limits depending on various factors. First of all, the slope of the surface of the snowdrift depends on the speed of the incident flow, at which the drift was formed on the physicomechanical properties of the snow particles involved in the snowdrift transport.

Snowdrift transfer begins with the appearance of a critical speed. The condition for the onset of particle surface transfer is expressed by A.K. Dune [5] (Eq. 1):

$$v_n < \alpha \sqrt{s_0 \left(\frac{\rho_s}{\rho}\right) g\delta + \frac{\tau_\varepsilon}{\rho}} \quad (1)$$

where v_n – wind speed at which particle transfer is not yet occurred; α – dimensionless coefficient depending on the characteristics of the surface vortex layer and the wind velocity profile; S_0 – volume concentration of particles on the surface of the snow cover; ρ_s, ρ – accordingly, the mass density of particles and air, g – gravity acceleration, m/s^2; δ – particle size, m; τ_ε – adhesion between particles and the underlying surface.

The purpose of the laboratory test was to study the effect of snowdrift on open reclamation canals. For this, such instruments and devices were used. Mechanical fan system: tangential helical ventilation unit YGFC60.183, electric voltage 220V, 50Hz, 0.27A; power 25W, rotation speed 1300 rpm, air flow 140 m^3/h, drum diameter 60 mm, drum length 183 mm (figure 2).

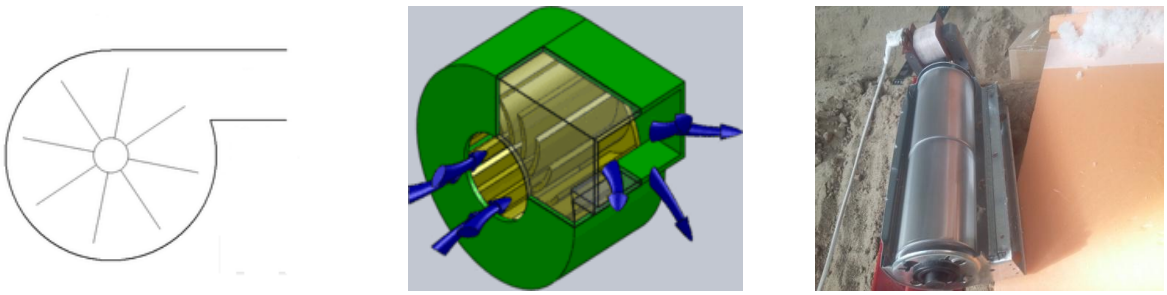

Figure 2 – Tangential helical ventilation unit

During the experiments, 4 ventilation units were used. The units were arranged for the S12-MK research stand. The ventilation unit speed was determined by an electronic anomometer and its maximum value reached 6.2 m/s. Turning on the tangential ventilation unit, the model was aimed at snow, which was directed into the opposite open reclamation canal (figure 2). Two types of canal model were made of penoplex material: a trapezoidal section with a length of 120 cm, a slope of 1:1, a depth of 11 cm and a width of 16 cm, as well as a canal model passing through a recess.

Results and discussion. According to the results of field observations of various authors, snow transport begins at wind speeds in the boundary layer of 2-5 m/s [2,5,7-14]. The formula for the initial snow transfer rate (1) is valid for horizontal terrain. On canals, the surfaces of snowdrifts, depending on their location, have positive or negative slopes relative to the direction of the wind. If the slope of the surface of the snowdrift in the direction of the wind is directed downward, then more favorable conditions are created for the movement of snow particles, which occurs at lower flow rates, compared with horizontal terrain. In such cases, the snow slope at the extreme position becomes steeper.

Let`s onsider the condition for the formation of the marginal snowdrift from the windward side of the spoil band. The wind stream, approaching the spoil band, smoothly goes around it from above. According to the experimental data from the continuity of flow (Eq. 2) stream jets around a spoil bank change their direction:

$$\psi_{(y)} = \int_0^y v dy\,, \quad (2)$$

The speed at each point of the jet can be divided into horizontal and vertical components v_x and v_y. The steeper the slope, the greater the vertical component. The resultant velocity is (Equation 3):

$$v = \sqrt{v_x^2 + v_y^2}\,. \quad (3)$$

The windward slope of the spoil band can be divided into two zones: the snow deposition zone and the snow blowing zone. In the deposition zone, the vertical velocity component v_y deflected by the slope, less than the hydraulic size of snowflakes ω. During snowstorms, in case of horizontal terrain, wind simultaneously acts by force (Eq. 4):

$$P_w = \frac{Kv^2}{2g} \tag{4}$$

and friction force in the opposite direction to the wind, equal (Eq. 5):

$$P_{fr} = Gf_{fr}, \tag{5}$$

where v – wind speed; G – snowflake weight; f_{fr} – coefficient of friction of snowflakes on the underlying surface.

When the condition is met $P_w \leq P_{fr}$ snowflake is at rest. With increasing wind force at $P_w > P_{fr}$ snowflake will be transferred. On inclined terrain (both on the ascent and on the descent), the conditions for equilibrium and transfer of snowflakes are different compared to horizontal terrain. The force of the wind acting on sloping terrain, taking into account (Eq. 6) equals (Eq. 7):

$$v^{\varphi} = \frac{U^{(\varphi)}}{cos\,\varphi} \tag{6}$$

$$P_w^{(\varphi)} = \frac{K(U^{\varphi})^2}{2g\,cos^2\,\phi}, \tag{7}$$

where φ – the angle of inclination of the underlying surface; $U^{(\varphi)}$ – horizontal component of wind speed.

The friction force of snowflakes on the underlying surface on an incline is (Eq. 8):

$$P_{fr}^{(\varphi)} = G\left(cos\,\varphi\, f_{fr} \pm sin\,\varphi\right). \tag{8}$$

In formula (8), the plus sign corresponds to the ascend, and the minus sign to the descent of the underlying surface in the direction of the wind. The value of the critical wind speed, respectively, for the windward and leeward slopes, we find from the condition of equality of forces acting on the snowball (Eq. 9) or horizontal component (Eq. 10):

$$v_{cr}^{(\varphi)} = v_{cr}\sqrt{cos\varphi \pm \frac{sin\,\varphi}{f_{fr}}} \tag{9}$$

$$U_{cr}^{(\varphi)} = v_{cr} \cdot cos\,\varphi\,\sqrt{cos\varphi \pm \frac{sin\,\varphi}{f_{fr}}} \tag{10}$$

where v_{cr} – critical wind speed corresponding to the beginning of snow transfer, v_{cr} = 3 – 5 m/s; $U_{cr}^{(\varphi)}$ – horizontal component of speed corresponding to the beginning of snow transfer.

On an inclined surface with a descent, the friction force of a snowflake on the underlying surface decreases compared to horizontal terrain, while when climbing it increases. Having determined the value of the initial snow transfer rate, and using the law of a rectilinear increase in the thickness of the boundary layer, we can find the slope coefficient of the snow drift. The equation of averaged turbulent motion in the boundary layer by G.N. Abramovich [15] obtained in the form of the formula (Eq. 11):

$$\frac{U}{U_0} = 0.017^{-\phi} + 0.6623e^{\frac{\phi}{2}}cos\left(\frac{\sqrt{3}}{2}\right)\phi + 0.228^{\frac{\phi}{2}}sin\left(\frac{\sqrt{3}}{2}\right)\phi \tag{11}$$

We have filed applications to obtain patents for a utility model for such methods and designs as, a method of protecting canals from snowdrifts, a method of protecting canals passing in recesses from snow drifts, a method of protecting canals from snowdrifts and groundwater, a device for accelerating ice formation on a canal [5,17-19]. A method of protecting canals passing in the recesses from snow drifts [17]. The proposed method of snow protection is implemented as follows. Cut the ground of the windward (2) edge at a distance (Eq. 12) from the edge of the recess with a slope $m_0 h \sin\alpha$ as shown in Figure 2.

$$L = m_0 h \sin\alpha \tag{12}$$

With such transverse profiles, snowdrifts fill only ditch (6) and on the transitional part (1) of the canal non-accumulative snow transfer during snowstorms is provided. The principle of the method of protecting the canals passing through the recesses from snow drifts is as follows. The transverse profiles of the canals

passing through the recesses consist of the transitional part of canal (1), the slope of the recess (2), the line for cutting the windward edge of the recess (3), the line of limiting snow drift before the cutting of the windward edge (4), the contour of the soil cut of the windward edge (5) and deposition of snow drift in the ditches (6) (figure 3).

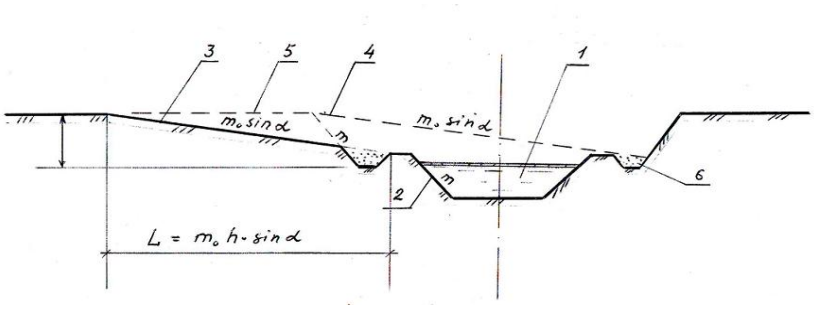

Figure 3 – The protection scheme of the canals passing on the recesses from snowdrifts

The snow shaft is formed in the recesses with a certain slope, called the natural slope of the snow drift m_0, numerically equal to 8-12, depending on the wind speed and the initial snow transfer speed. In oblique winds, due to the preservation of the slope in the direction of the wind, the coefficient of natural slope of the snowdrift, taken along the normal to the recess, is equal to $m_0 h \sin\alpha$, where α – is the angle of attack of the wind. In this case, when the slopes of the underlying surface are corresponding to $m_0 h \sin\alpha$, snow deposits during snowstorms will not occur.

The method to protect the canal from snowdrifts and groundwater [18] by placing forest belts along the canal differs from other methods in a way that placed along the irrigation and watering canals plantings of well-blown forest strips without shrubs protects from the prevailing wind, preventing the accumulation of snowdrifts and snow and rise in groundwater possible from this. Such conditions are created when the forest belts protect the canals well from snow drifts and a significant part of the vertical filtration flow from the canals supplying groundwater will be intercepted by the roots of the trees and the harmful effects of irrigation water will be suspended.

Larger canals of year-around operation, designed to transport water in the early spring, suffer, as a rule, from snowdrifts. Smaller canals, operating only during the growing season, usually suffer from drifts by products of wind erosion – soil, saltwort plants, garbage [1]. The characteristics of the canal network are considered from the perspective of their influence on the wind flow. Having estimated the nature of the wind flow around the canal cross sections, we can predict the canal insertion. In areas of recesses with an intermediate berm, a decrease in the wind velocity in the boundary layer occurs at a certain distance from the canal, depending on which side the central bogie passes, that is, a wide intermediate berm. The widths of the intermediate berm are 1.0 and 8.0 respectively.

At the zero marks, the “dip” of the wind flow into the recess occurs directly from the edge of the recess of the canal. In the latter case, the width of the recess at the top is small, it is equal, respectively, to the width of the canal at the top, whereas in the previous case (with an intermediate berm), the decrease begins at some distances from the canal bed. In the sections of the cut-and-fill-embankment and embankment, the canal bed is raised above the level of the adjacent terrain. Therefore, the wind stream before flowing around the recess of the canal, narrows vertically, due to heap in bulk. The narrowing of the flow in turn causes a corresponding local increase in flow rate. The unevenness of the relief and the non-compliance of the general slope of the site with a longitudinal slope of the canal bottom is primarily the reason for such a wide variety of types of canal sections according to the conditions of the canal's location relative to the earth's surface. For this reason, even over the length of one canal, several types of sections can be found, according to the location of their canal relative to the mark of the adjacent territory.

Conclusions. The aim of the research was to create an uncoverable canal profile in areas heavy snow coverage. Snow deposition in the canal bed occurs gradually, starting from the edge of canal closest to the snow collection basin side, followed by an increase in the snowdrift shaft in the direction of the wind as blizzard snow arrives to the canal. This picture of the sequence of filling the canal bed with snow during blizzards is fully confirmed by the results of field tests performed on existing canals. Having established

the patterns of snowdrift formation, having information about the amount of snow entering the canal, the speed of winter winds and the state of the snow cover for a specific area, we can calculate the snowdrift parameters with sufficient accuracy for any date and at any stage of snow removal.

The paper gives the theory, methods, research results, new methods and designs of patents for a utility model for such methods and designs as, a way to protect canals from snowdrifts, a way to protect canals passing through recesses from snowdrifts, a way to protect canals from snowdrifts and groundwater, a device to accelerate ice formation on the canal. These designs of the proposed devices are quite possible using available technical means based on the current level of technology and knowledge, because its design is quite simple, and the implementation of such devices has long been well mastered by relevant enterprises at various levels.

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ЖЫЛ БОЙЫ ҚОЛДАНЫСТАҒЫ КАНАЛДАРДЫ ҚАР БАСҚЫНЫНАН ҚОРҒАУДЫҢ ЖАҢА ӘДІСТЕРІ

Аннотация. Жыл бойы қолданыстағы каналдағы мұз жамылғысының бетіндегі қатты омбы қар жылулық және статикалық салмаққа бір уақытта әсер етеді. Қар жиналған жердегі беткі қабаттың астында мұз қарқынды ерігенде және қардан статикалық салмақтың ұлғаюына байланысты мұз бетінде созылған жарықтар пайда болады. Суланған қар жарық бойымен жоғары көтеріліп, қар мен мұз массасы жайлап төмен түсе бастайды. Мұз бетіндегі қар басқынының үлкен көлемдегі концентрациясы әсерінен мұз кептелістері пайда болып, каналдың өткізгіштік қабілеті төмендейді, ал кейбір жағдайларда тіптен тоқтап қалады. Көктем уақытында омпы қардың қарқынды еруі ағынды судың қосымша мөлшерінің пайда болуына ықпал етеді, ал бұл ірі каналдарда судың тепе-теңдігін сақтауда маңызды рөл ойнайды және ол көктемгі уақытта сумен қамтамасыз етуді жоспарлау кезінде ескерілуі тиіс. Сонымен қатар күртік қар еріген кезде қар суынан жер каналдары бермдері мен еңістерінің белсенді микроиінтіректі эрозиясы байқалады. Басты ғимараттан суды алу кезінде еріген қар ағыны көлемінің азаюы көктемде апаттық жағдайға әкелуі мүмкін. Аталған мәселелер мақаланың өзектілігін көрсетеді. Соңғы жылдары Қазақ су шаруашылығы ғылыми-зерттеу институты мен М.Х. Дулати атындағы Тараз мемлекеттік университетінің ғалымдары гидротехникалық құрылымдарды, соның ішінде каналдарды қардан қорғау мәселелерімен айналысып келеді. Іс жүзіндегі каналдарда жүгізілген көпжылдық далалық және лабораториялық зерттеулердің, сонымен қатар халық шаруашылығының өзге объектілерінде қардан қорғау тәсілдерін қолдану тәжірибесін жалпылау мен талдау негізінде қар басқынынан гидротехникалық құрылымдарды қорғаудың тәсілдері ұсынылып отыр.

Мақаланың мақсаты – каналды қар басудан қорғаудың және қатты қар басқан учаскелердегі каналдың өткізбейтін пішінін құрудың жаңа әдістерін табу. Аталмыш мәселені зерттеудегі басты әдіс іс жүзінде бар каналдарда жүргізілген натуралық сынақтар болып саналады. Бұл боранда каналдың қарға толу тізбегінің келесідей бейнесін анықтауға мүмкіндік берді. Канал арнасына қардың толуы кезең-кезеңмен орын алады, яғни қар жинауға арналған бассейніндегі ең жақын орналасқан каналдың шетінен басталып, күртік қар қалыңдығы жел бағытына сай және қарлы боранның каналға жақындауына байланысты бірте-бірте өседі.

Эксперименттерге қарай отырып келесідей қорытынды жасауға болады: каналдарды қар басудан қорғайтын конструкцияға берілген патент тиімділігін көрнекі түрде дәлелдеді. Нәтижесінде қатты қар басқан учаскелердегі каналдың көлденең пішінін өзгерту арқылы каналдарды күртік қардан қорғаудың әдісі ұсынылып отыр. Каналдың көлденең пішіні қар көшкіні көлеміне тәуелсіз, қарсыз да үрленетін канал болған жағдайда күртік қар бетінің шектік қалпын дәл анықтауға байланысты ық болатын жаға еңісі коэффициентіне тең еңістік коэффициентімен және ық болатын жаға еңісінен басталатын канал тереңдігіне тең биіктікке сай үйіндіні қосу арқылы өзгертілген.

Ұсынылып отырған әдістер жыл бойы пайдалануға есептелген суару және суландыру каналдарындағы қар басқан учаскелерде қолданыла алады. Техникалық күй, құрылым материалдары мен жабдықтардың жеткілікті болуы, сонымен қатар заманауи технологиялар мен білім ұсынған әдісті күртік қар таралған учаскелерде іс жүзінде қолдануға мүмкіндік береді. Осыған ұқсас конструкцияларды ендіруді әртүрлі деңгейдегі сәйкес кәсіпорындар әлдеқашан жақсы игерген.

Түйін сөздер: мұз жамылғысы, берма, еңістік коэффициенті, канал тереңдігі, қар тұндыру.

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НОВЫЕ СПОСОБЫ ЗАЩИТЫ ЗАНОСИМОСТИ КАНАЛОВ КРУГЛОГОДИЧНОГО ДЕЙСТВИЯ

Аннотация. Сильные сугробы на каналах круглогодичной эксплуатации, сосредоточенные на поверхности ледяного покрова, одновременно влияют как на тепловые, так и на статические нагрузки. При интенсивном таянии льда с нижней поверхности в местах скопления снежных масс, а также из-за увеличения статической нагрузки от снега на льду образуются продольные трещины. Снег, насыщенный водой, поднимается вверх по трещинам и происходит постепенное опускание снежно-ледяной массы. Концентрация больших объемов заносов на поверхности ледяного покрова приводит к снижению пропускной способности каналов из-за образования ледяных заторов, а в некоторых случаях и к их полной остановке. Интенсивное таяние сугробов в весенний период приводит к образованию дополнительного объема стока, который играет важную роль в водном балансе крупных каналов и который необходимо учитывать при планировании водоснабжения в весенний период. Также при таянии сугробов наблюдается активная микрорычажная эрозия откосов и берм земляных каналов от талой воды. А занижение объема стока от талого снега при заборе воды из головного сооружения может привести к аварийным ситуациям весной. Перечисленные проблемы и делает данную статью актуальной. В последние годы ученые Казахского научно-исследовательского института водного хозяйства и Таразского государственного университета имени М.Х. Дулати занимались вопросами снегозащиты гидротехнических сооружений, в том числе каналов. На основе многолетних полевых и лабораторных исследований, проведенных на существующих каналах, а также анализа и обобщения опыта применения снегозащитных средств на других объектах народного хозяйства, предложены способы защиты гидротехнических сооружений от снежных венцов.

Целью статьи является поиск новых способов защиты канала от заноса и создания непроницаемого профиля канала на участках, сильно покрытых снегом. Ведущим методом к иследованию даной проблемы стали натурные испытания, проведенные на существующих каналах. Они позволили выявить следующую картину последовательности заполнения канала снегом во время метели. Отложение снега в русле канала происходит постепенно, начиная с края канала, ближайшего к краю бассейна для сбора снега, с последующим увеличением вала сугроба по направлению ветра по мере приближения снежной метели к каналу.

Из экспериментов можно сделать вывод, что полученный патент на конструкцию против снежного покрова каналов, наглядно доказал свою эффективность. В результате предлагается способ защиты каналов от сугробов путем изменения поперечного профиля канала на сильно заснеженных участках. Поперечный профиль канала изменен путем добавления к нему насыпи с коэффициентом уклона, равным коэффициенту подветренного уклона, и высотой, равной глубине канала от подветренного откоса, в зависимости от точного установления предельного положения поверхности сугробов, при котором канал продувается без снега, независимо от количества снегопереноса.

Предлагаемые способы могут применяться на участках снегопада на поливных и оросительных каналах, рассчитанных на круглогодичную эксплуатацию. Техническое состояние, наличие достаточного количества строительных материалов и оборудования, а так же современные технологии и знания позволяют реализовать предложенный способ на участках распространения сугроба. Внедрение подобных конструкций давно хорошо освоено соответствующими предприятиями различного уровня.

Ключевые слова: ледяной покров, берма, коэффициент уклона, глубина канала, осаждение снега.

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MATHEMATICAL MODEL OF SUBSTANTIATION OF THE GEOLOGICAL AND COMMERCIAL STRUCTURE FOR CONDUCTING TRIAL OPERATION AT THE "ZHANATALAP" PRODUCTION FIELD

Abstract. The relevance of the problem stated in the paper is conditioned by fact that in the last decade, scientific and technological progress in the sphere of petroleum field geology was closely related to the use of advanced science-intensive geoinformational technologies based on modern database management systems. In this regard, the paper considers the general principles of constructing systems for geological and commercial field analysis and oil fields development regulation. The main goal of trial operation is to obtain direct information about the production capabilities of project sites and their geological and geophysical characteristics, sufficient to justify the optimum quantity of recoverable oil reserves and ensure effective reservoir and production engineering, as well as substantiation of the reservoir regime, identification of production facilities and assessment of the prospects for the development of oil production at the field. The leading method of this issue is the substantiation of a geologic model, which allows us to consider this problem as a purposeful and organised modelling method to improve the conduct of trial operation in the Aptian and Middle Jurassic productive horizons. The results of pressure transient analysis were obtained. The terms of trial operation and the volumes of oil production, average daily withdrawals are substantiated, the issues of equipment and technology of oil production, drilling and well development are considered.

Key words: geological processes, complex structure, forecast of dynamics, development process, production wells.

Introduction. The variety of geological objects and methods of their study leads to the fact that the result of geological research is very heterogeneous in nature of information: verbal (descriptive), graphic (cartographic), digital. The inaccessibility of geological objects for direct observation is the reason that geology, as a theoretical discipline, developed in the conditions of an almost complete absence of experimental data and for many years was considered a purely descriptive science. Geological processes and formations have specific features that largely determine the methodology for their study [1-9]: geological processes represent a set of physical, chemical and biological natural phenomena, between which there are complex causal relationships, therefore, the properties of geological formations depend on many factors, are characterised by strong variability, and the objects themselves, as a rule, have a very complex structure; geological processes are long, and geological formations are of considerable size and hidden in the depths, which excludes the possibility of their complete and comprehensive study by direct observation.

The complexity and heterogeneity of the objects under study of the Earth sciences forces us to consider them as natural systems. Geological processes belong to the class of dynamical systems, i.e. systems that change their state in time, and geological formations, due to the slow course of geological

processes, in most cases can be considered as static systems, the properties of which are constant in time [10,11]. The elements of dynamic geological systems are either individual factors (parameters) influencing the course of the geological process, or relatively simple natural phenomena (processes), which are considered as components of a more complex process [12-15].

The main goal of trial operation is to obtain direct information regarding the production capabilities of objects and their geological and geophysical characteristics, sufficient to justify the optimum value of recoverable oil reserves and ensure reliable design of field development, as well as justification of the reservoir regime, identification of production facilities and assessment of the prospects for the development of oil production at the field. The task of trial operation is to determine the limiting value of sustainable production rates during operation. First of all, indicator curves and pressure build-up are taken for new wells [16-18].

The optimum regime is considered to be the one that provides the highest cumulative oil production over an equal time interval without a clearly pronounced tendency to decrease in production rate. In general, to perform the tasks of trial operation, namely, for the full implementation of the research program in order to further study the geological and physical characteristics of the productive horizons and the production capabilities of wells (determination of reservoir pressures, recovery time, saturation pressure, optimal reservoir operation and assessment of elastic energy potential of reservoir system), the trial operation period is taken as 2 years [19].

Materials and methods. The significance and purpose of trial operation determines the acquisition of the necessary information about the production capabilities of facilities and their geological and geophysical characteristics, sufficient to justify the optimal value of recoverable oil reserves and ensure reliable design of field development, as well as justification of the reservoir regime, selection of production facilities and evaluation of the prospects for the development of oil production in field. The initial information for drawing up a model of trial operation of the "Zhanatalap" production field was the data of the field exploration obtained as a result of testing, dynamic well testing and well logging in individual wells [3,20,21].

The main task of the trial operation is to determine the limiting value of sustainable production rates during exploitation. First of all, indicator curves and pressure build-up are taken for new wells [4]. The optimal mode is considered to be the one that provides the highest cumulative oil production over an equal time interval without a clearly pronounced tendency to decrease in production rate. In general, to perform the tasks of trial operation, namely, for the full implementation of the research program in order to further study the geological and physical characteristics of the productive horizons and the production capabilities of wells (determination of reservoir pressures, recovery time, saturation pressure, optimal reservoir operation and assessment of elastic energy potential of reservoir system), the trial operation period is taken as 2 years [5].

All studies were carried out in wells with free-flow production method at various modes, with a change in chokes. Measurements of pressure changes were performed with devices PPH-161, PPS-25 and CAMT-02. The data processing of the nozzle studies was carried out using the specialised software product PanSystem. During the exploration period at the "Zhanatalap" field, all wells were tested by swabbing (changing water to oil) and by level tracking. The tests were carried out in 6 wells in 4 horizons, incl. Middle Jurassic horizons J2, J2-I, J2-II were tested in wells S-4PO, R-21PO, R-22PO, R-25PO and S-23PO. The Aptian horizon was tested in the S-4PO well. The opening of the productive horizons was carried out in a sealed well with hollow-carrier perforators – 89 mm. The density of the perforation ranges from 10 to 13 holes per 1 running metre. During testing, measurements of dynamic and static levels, oil and liquid flow rates were obtained.

Results and discussion. Based on the results of graphical-analytical curve-fitting, the following reservoir parameters were determined: flow model, permeability, skin factor, reservoir and bottomhole pressures, piezoconductivity and reservoir conductivity.

On the Aptian horizon (K1a), in the course of testing in well S-4PO, an interval of 550-557 m was investigated. During testing, 63.6 m^3 of pure oil was obtained. Further, hydrodynamic studies were carried out in the well with a method of steady-state filtration mode (IPR and PRC curves) on 23-26.12.2006. For the veracity of results of the work performed, a calculation was carried out using the method of indicator diagram construction. The bottomhole pressure – 4.97 MPa, the drawdown – 1.12 MPa. The interpolated

reservoir pressure – 6.08 MPa. According to the research results, the calculated filtration properties of the formation had the following values: permeability k – 1.25 μm^2; piezoconductivity χ – 0.025 m^2/s; reservoir conductivity kh/μ – 0.55 μm^2*m/mPa*s; reservoir temperature T_{re} – 29.6 ºC; the skin factor has a value of 10.3, which characterises the contaminated state of the bottomhole zone of the well. It is necessary to carry out geological and technical measures to clean up the bottomhole zone; estimated productivity index K_{pr} – 30.41 t/day*MPa.

The Middle Jurassic horizon (J2) was tested in the S-4PO well in the interval of 593-597 m and in the R-24PO well in the 613-617 m interval. In the S-4PO well, 50.0 m^3 of pure oil was recovered during testing. According to the results of the hydrodynamic studies carried out on November 14-16, 2006 by the method of steady-state filtration (EMI survey and PRC curve), interpolated reservoir pressure – 6.73 MPa, average bottomhole pressure – 6.36 MPa. Pressure measurements were carried out with a PPS-25 device. Reservoir temperature T_{re} – 31.3 °C; The filtration properties of the formation had the following values: permeability k – 2.07 μm^2; piezoconductivity χ – 0.031 m^2/s; reservoir conductivity kh/μ – 0.34 μm^2*m/mPa*s; the skin factor had a value of -2.82, which characterises the good condition of the bottomhole formation zone; estimated productivity index K_{pr} – 63.84 t/day*MPa.

The R-24PO well produced 46.8 m^3 of pure oil during testing. On 06-08.12.2006, hydrodynamic studies were carried out in the well using the method of steady-state filtration. Pressure measurements were carried out with a PPS-25 device. Based on the results of the studies, reservoir bottomhole pressures and filtration properties of the bottomhole formation zone were determined. Reservoir pressure – 7.02 MPa, bottomhole pressure – 6.6 MPa. Accordingly, the drawdown – 0.42 MPa. The filtration properties of the formation had the following values: permeability k – 0.63 μm^2; piezoconductivity χ – 0.021 m^2/s; reservoir conductivity kh/μ – 0.92 μm^2*m/mPa*s; the skin factor had a value of -2.66, which characterises the good condition of the bottomhole formation zone; estimated productivity index K_{pr} – 50.96 t/day*MPa.

I – Middle Jurassic horizon (J2-I) was tested in 4 wells. In the S-4PO well, sampling was carried out in the interval of 613.5-616.5 m using the swabbing method 57.0 m^3 of pure oil was recovered. According to the results of hydrodynamic studies carried out on July 11-14, 2006 by the method of steady-state filtration, the reservoir pressure – 7.03 MPa, bottomhole pressure – 6.32 MPa. Accordingly, the drawdown – 0.7 MPa. Filtration properties of the reservoir were equal to the following values: permeability k – 0.14 μm^2; piezoconductivity χ – 0.029 m^2/s; reservoir conductivity kh/μ – 0.7 μm^2*m/mPa*s; the skin factor had a value of -2.02, which characterises the good condition of the bottomhole formation zone; estimated productivity index K_{pr} – 38.62 t/day*MPa;

As of 01-02.10.2006, well S-4PO was tested in the interval of 606-608 m. 17.0 m^3 of pure oil was recovered. According to the results of testing and pressure build-up, interpolated reservoir pressure – 6.79 MPa, bottomhole pressure – 5.52 MPa. Drawdown – 1.27 MPa. Reservoir temperature T_{re} – 31.7 °C. The filtration properties of the formation had the following values: permeability k – 0.68 μm^2; piezoconductivity χ – 0.018 m^2/s; reservoir conductivity kh/μ – 0.39 μm^2*m/mPa*s; the skin factor had a value of -5.84, which characterises the good condition of the bottomhole formation zone; estimated productivity index K_{pr} – 21.4 t/day*MPa. Studies of I – Middle Jurassic horizon (J2-I) in the well R-21PO were carried out on 02-04.11.2006 in the intervals of 648-652, 655-658 m. During the sampling process, 40.7 m^3 of pure oil was recovered. Hydrodynamic studies were carried out by the method of steady-state filtration modes (EMI survey and PRC curve). According to the research results, the interpolated reservoir pressure – 7.53 MPa, the average bottomhole pressure – 7.09 MPa. Reservoir temperature T_{re} – 33.5 °C. Accordingly, the drawdown – 0.7 MPa. Filtration properties had the following values: permeability k – 0.09 μm^2; piezoconductivity χ – 0.009 m^2/s; reservoir conductivity kh/μ – 0.43 μm^2*m/mPa*s; the skin factor had a value of -3.98, which characterises the good condition of the bottomhole formation zone; estimated productivity index K_{pr} – 23.71 t/day*MPa. In the well R-22PO, testing was carried out on 05-08.11.2006 in the interval of 601-614 m. 78.0 m^3 of pure oil was produced. According to the results of hydrodynamic studies, interpolated reservoir pressure – 6.73 MPa, bottomhole pressure – 6.45 MPa. Drawdown – 0.68 MPa. Reservoir temperature T_{re} – 31.0 °C. Filtration properties had the following values: permeability k – 0.33 μm^2; piezoconductivity χ – 0.008 m^2/s; reservoir conductivity kh/μ – 0.65 μm^2*m/mPa*s; the positive value of the skin factor of 3.89 is due to the strong pollution of the

bottomhole formation zone. It is necessary to carry out geological and technical measures to clean up the bottomhole zone; estimated productivity index K_{pr} – 37.56 t/day*MPa.

II – Middle Jurassic horizon (J_2-II) was tested in wells R-25PO and S-23PO. In the well R-25PO, studies were carried out on January 13-15, 2007 in the interval of 667-669 m. 41.7 m^3 of pure oil were recovered. According to the results of hydrodynamic studies, interpolated reservoir pressure – 7.02 MPa, average bottomhole pressure – 7.48 MPa. Correspondingly, the drawdown – 0.28 MPa. Reservoir temperature T_{re} – 33.5 °C. Filtration properties had the following values: permeability k – 0.24 μm^2; piezoconductivity χ – 0.05 m^2/s; reservoir conductivity kh/μ – 1.11 μm^2*m/mPa*s; the value of skin factor was -2.37, which characterises the good condition of the bottomhole formation zone; estimated productivity index K_{pr} – 37.56 t/day*MPa. Similar study was carried out in the S-23PO well. Testing was carried out on 31.01.-02.02.2007 in the interval of 692.5-695.5 m. During testing, 34.8 m^3 of pure oil was produced. According to the results of hydrodynamic studies, interpolated reservoir pressure – 7.02 MPa, average bottomhole pressure – 6.99 MPa. Accordingly, the drawdown – 0.5 MPa. Reservoir temperature T_{re} – 34.8 °C. Filtration properties had the following values: permeability k – 0.21 μm^2; piezoconductivity χ – 0.044 m^2/s; reservoir conductivity kh/μ – 0.96 μm^2*m/mPa*s; estimated productivity index K_{pr} – 52.9 t/day*MPa. At the Aptian horizon (K1a), reservoir pressure at the middle of the perforated interval – 6.08 MPa. Average productivity index – 30.41 t/day*MPa. The average permeability coefficient – 1.25 μm^2, the hydraulic conductivity coefficient – 0.55 μm^2*m/mPa*s, and piezoconductivity coefficient – 0.025 m^2/s.

In the Middle Jurassic horizon (J2), reservoir pressure at the middle of the perforated interval – 6.86 MPa. Productivity index – 58.12 t/day*MPa. The average value of permeability coefficient – 1.43 μm^2, coefficient of hydraulic conductivity – 0.6 μm^2*m/mPa*s, piezoconductivity coefficient – 0.027 m2/s. On the I-Middle Jurassic horizon (J2-I), reservoir pressure at the middle of the perforated interval – 7.1 MPa. Productivity index – 29.95 t/day*MPa. The average value of permeability coefficient – 0.29 μm^2, coefficient of hydraulic conductivity – 0.54 μm^2*m/mPa*s, and piezoconductivity coefficient – 0.017 m2/s. On II – Middle Jurassic horizon (J2-II), reservoir pressure at the middle of the perforation – 7.48 MPa. Productivity coefficient 57.84 t/day*MPa. Average permeability coefficient 0.23 μm^2, hydraulic conductivity coefficient – 1.05 μm^2*m/mPa*s, piezoconductivity coefficient – 0.048 m^2/s. In general, for the I- project site, the average reservoir pressure – 7.29 MPa, productivity index – 43.9 MPa. The filtration properties have the following meaning: the permeability – 0.26 μm^2, the coefficient of hydraulic conductivity is 0.8 μm^2*m/mPa*s, and piezoelectric conductivity coefficient is 0.032 m^2/s. Taking into account the occurrence, the number of deposits and productive strata, the physicochemical properties of oils and reservoir properties in the section of this field, 2 project sites of trial operation are identified: Project site I – Middle Jurassic horizons – J2-I + J2-II; Project site II – Aptian and Middle Jurassic horizons – K1a + J2. The main base is project site I, which contains 76.9% of reserves. The initial geological and physical characteristics of the production facilities are given in the table 1.

Table 1 – Initial geological and physical characteristics of productive objects

Parameters	Project site I	Project site II
Average depth, m	599-628.5	669-695.5
Water-oil contact, m	IX 617 m – X 648 m	IX 641 m – X 714 m
Accumulation type	fault block reservoir	fault block reservoir
Reservoir type	terrigenous	terrigenous
Oil and gas bearing area, ths. m^2	364	707
Mean gross thickness, m	20	36
Average oil-saturated thickness, m	9	20
Porosity, unit fraction	0.28	0.33
Average saturation with oil (gas), unit fraction	0.71	0.76
Permeability, μm^2	0.26	1.34
Net-to-gross ratio, unit fraction	0.35	0.45

Continuation of table 1		
Average number of permeable intervals, unit fraction	2	5
Reservoir temperature, °C	29.6	33.5
Reservoir pressure, MPa	5.95	7.45
Oil viscosity in reservoir conditions, mPa*s	23	16
Oil density in reservoir conditions, g/cm^3	0.857	0.8369
Density of degassed oil, g/cm^3	0.88	0.866
Formation volume factor, unit fraction	1.042	1.056
Content of sulphur, %	0.36-	0.61
Resins and asphaltenes, %	11.4	8.38
Paraffin, %	0.84	2.42
Bubble-point pressure, MPa	4.55	5.0
Gas/oil ratio, m^3/t	23.4	27.7
Water density in reservoir conditions, g/cm^3	1.18	1.12
Average productivity, m^3/(day*MPa)	43.9	44.26
Initial balance oil reserves, ths. tonnes (approved by GKZ RK), C1 + C2 including category C1 including category C2	 895 569 326	 2978 2256 722
Initial recoverable oil reserves, ths. tonnes (approved by GKZ RK), C1 + C2 including category C1 including category C2	 294.9 180 114.9	 1072.5 812.5 260
Oil recovery factor, unit fraction including category C1 and C2	 0.33	 0.36

The oil deposits in the reservoir are consolidated, tectonically-screened and closed on all sides. Taking into account the hydrogeological conditions of the region during the field development, the manifestation of an elastic-water-pressure regime should be expected. At the same time, it is likely that in the initial period of development, the activity of the formation zone will manifest itself after a certain decrease in formation pressure within the reservoir. One of the main tasks in drawing up a project for a trial operation of a field development is to assess the productivity of deposits under elastic-water-pressure conditions over a period necessary for a sufficiently complete study of a productive formation characteristics and assess the feasibility of creating a system for maintaining reservoir pressure. In this study, based on the results of the numerical solution of the differential equation of the elastic regime for a homogeneous reservoir, the dimensionless functions *p(p, τ), q(p, τ)* and *Q(p, τ)*. The forecast of the dynamics of reservoir pressure on the boundaries of the reservoir is performed at a given constant fluid withdrawal. This basically corresponds to the conditions of mechanised well operation (Eq. 1):

$$P(t) = P_o - \frac{q \cdot \mu}{2\pi kh} \cdot \bar{P}(\tau)\,, \qquad (1)$$

where: P_o – pressure on the external boundary (initial reservoir pressure); q – given fluid withdrawal; μ – viscosity of fluid (water) in reservoir conditions; k – reservoir permeability; h – formation thickness; $p(p, \tau)$ – dimensionless function tabulated for different values of p; $p = R_k/R_r$ – the ratio of the radius of the feed loop to the design gallery radius.

In calculations, the boundaries of the deposit are presented as a circular gallery (table 2).

Table 2 – Calculation of changes in the weighted average reservoir pressure in the reservoir during trial operation

Development years	On project site I				On project site II			
	τ	P(τ)	ΔP_{con}, MPa	$P_{re,}$ MPa	τ	P(τ)	ΔP_{con}, MPa	$P_{re,}$ MPa
2008	0.000144	0.000344	0.000159	7.286	0.001250	0.002983	0.000282	5.874
2009	0.000216	0.000516	0.000238	7.281	0.001876	0.004469	0.000238	5.866

However, due to the high viscosity of reservoir oil, with an increase in the stock of producing wells within the boundaries, the reservoir pressure will significantly decrease, which will lead to a decrease in well productivity. In this regard, it becomes necessary to predict changes in reservoir pressure within the deposit boundaries. To assess the decrease in the initial flow rates of wells during the development of deposits in the natural elastic drive, it is necessary to have a dependence of the formation pressure drop not only on the oil-bearing contour, but also in the recovery zone in the central part of the deposits. Reservoir pressure at any given point in the formation during development is determined by (Eq. 2)

$$P_t = P_0 - \sum_{i=1}^{n} P_i \tag{2}$$

where: P_0 – initial reservoir pressure; P_i – decrease in reservoir pressure from the operation of one of the existing wells or increase in pressure from the operation of injection wells and the impact of the edge water zone (Eq. 3):

$$Pi = \frac{q_i \mu_н}{4\pi\kappa h}\left[Ei\left(-\frac{r_i^{\,2}}{4\aleph t} \right) \right] \tag{3}$$

where: $Ei\left(-\frac{r_i^2}{4\aleph t}\right)$ – integral exponential function (tabulated), q_i – flow rate of well i; r_i – distance from the target point to the i well.

The rest of the formula is the same as in the (1). In technological calculations, one option is considered, where the initial flow rates are determined at the bottomhole pressure of 4.55 MPa, which corresponds to the bubble point pressure. Well production rate is calculated by the formula (Eq. 4):

$$Q = K_{pro} * h_t * \Delta P, \tag{4}$$

where: K_{pro} – productivity per 1 meter of thickness; h_t – oil-saturated thickness; ΔP – drawdown.

For all project wells, design depths of up to 700 m have been established, which ensure the penetration of the J2-II horizon at full capacity with a sufficient drilling sump for equipping the bottom of the production string. Wells No. 101-111 are built in advance. They must perform the task of exploratory wells. Pressure, temperature and gas/oil ratio. First of all, indicator curves and pressure build-up curves are taken for new wells [3,4,8].

Conclusions. The calculation results reveal that with those relatively small fluid withdrawals from the deposits that can be achieved when new wells and previously drilled wells are put into operation, the pressure drop will be insignificant. Within the oil-bearing contours of the deposits, the mutual influence of wells and the change in reservoir pressure can be significant, since the viscosity of the reservoir oil is taken on average equal to 20 mPa*s. In connection with the above, it is necessary: upon completion of the drilling of the first wells, take and examine depth samples of oil in two wells No. 106, No. 105 on the VIII block; perform experimental water injection into one well, which must be selected from the producing during trial operation.

From the above calculation results it follows that the trial operation of the "Zhanatalap" field can be carried out in a natural elastic water drive without maintaining reservoir pressure. According to the objectives of the trial operation, it is necessary to provide for reliable control over the change in the technological parameters of the well operation, filtration and field characteristics of the reservoir system, to monitor the change in bottomhole pressure, formation pressure, temperature and gas factor. First of all, indicator curves and pressure build-up are measured for new wells.

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«ЖАҢА ТАЛАП» КЕН ОРНЫНЫҢ АПТ ЖӘНЕ ОРТА ЮРАЛЫҚ ӨНІМДІ ГОРИЗОНТТАРЫН СЫНАМАЛЫҚ ПАЙДАЛАНУ МАҚСАТЫНДА ГЕОЛОГИЯЛЫҚ-КӘСІПШІЛІК ҚҰРЫЛЫМЫН НЕГІЗДЕУДІҢ МАТЕМАТИКАЛЫҚ МОДЕЛІ

Аннотация. Геологиялық объектілер мен оларды зерттеу әдістерінің сан алуандығы сөздік, графикалық, сандық секілді ақпарат түрлеріне байланысты геологиялық зерттеу нәтижесінің түрлі болуына әкеледі. Тікелей бақылау жүргізуде геологиялық объектілердің жетімсіздігінің себебі – геологияның теориялық пән ретінде тәжірибе жүзінде эксперименттік деректер пайда болмаған уақытта дамуы мен ұзақ жылдар бойы сипаттамалы ғылым ретінде саналып келуі. Мақалада қарастырылатын мәселенің өзектілігі соңғы онжылдықта мұнай кен орны геология саласындағы ғылыми-техникалық прогрестің деректер базасын басқарудың заманауи жүйесіне негізделген алдыңғы қатарлы ғылымды қажетсінетін геоақпараттық технологиялармен тығыз байланысты болуында. Осыған орай, мақалада кен орындарын талдаудың геологиялық-өндірістік жүйе құрылымының жалпы қағидаттары мен мұнай кен орындарын әзірлеуді реттеу қарастырылған. Мәселен, қойнауқаттың есептік моделін негіздеу; мұнай кен орындары геологиясының негіздері; өнімді қойнауқаттардың коллекторлық сипаттамасын зерттеу саласындағы ғылыми-зерттеу мен жобалық жұмыс нәтижелері; геологиялық-техникалық шаралар тиімділігін талдау, көмірсутек қорларын өндіруді талдау; үзіліссіз геологиялық өндірістік процестерді пайдалану мен құру қолданылды.

Тәжірибелік пайдаланудың негізгі мақсаты – өндірілетін мұнай қорының оңтайлы көлемін негіздеу және өндіру, коллекторды тиімді жобалаумен қамтамасыз ету, сонымен қатар коллектор режимін негіздеуге, өндірістік объектілерді анықтау мен кен орнындағы мұнай өндіруді дамытудың болашағын бағалауға жеткілікті жобалық алаңдардың өндірістік мүмкіндіктері мен олардың геологиялық-геофизикалық сипаттамасы жөнінде тікелей деректер алу. Оңтайлы режим болып саналатыны – шығымның төмендеуіне қатысты нақты айқындалған үрдіссіз теңдей уақыт аралығында жиналған ең көп мұнай өндіруді қамтамасыз ететін режим. Жалпы тәжірибелік пайдалану міндеттерін орындау үшін, дәлірек айтатын болсақ, ұңғымалардың өндірістік мүмкіндіктері (қойнауқат қысымын, қалпына келу уақытын, қанығу қысымын, қойнауқатты оңтайлы пайдалануды анықтау мен қойнауқат жүйесінің серпімді энергиясының әлеуетін бағалау) мен өнімді горизонттың геофизикалық сипаттамасын алдағы уақытта зерттеу мақсатында зерттеу бағдарламасын толығымен жүзеге асыру үшін тәжірибелік-өндірістік пайдаланудың мерзімі 2 жыл болып қабылданған.

Берілген мәселені шешудің басты әдісі орта юра дәуірі кезеңінің өнімді горизонттарында тәжірибелік-өндірістік пайдалануды жетілдіру мақсатында аталмыш мәселеге мақсатты бағытталған және ұйымдастырылған модельдеу әдісі ретінде қарауға мүмкіндік беретін геологиялық үлгіні негіздеу болып саналады. Қойнауқат және беткі флюидтердің физико-химиялық қасиеттері мен мұнай қоры талданды. Зерттеулер сүзгілеудің орныққан режимінде жүргізіліп, қойнауқаттың негізгі сүзгілеу сипаттамасын, жүйенің энергетикалық күйі мен оның уақыт аралығындағы өзгерістер сипаттамасын алу мақсатында қысымды қалпына келтірудің қисығы түсірілді. Барлық зерттеулер түрлі режимде еркін ағымда, дроссельдері өзгертіліп тұрған күйінде жұмыс атқарған ұңғымаларда жүргізілді. Бүріккіштерді зерттеу деректерін өңдеу арнайы PanSystem бағдарламалық өнімін қолдану арқылы жүзеге асырылды.

Бейстационар қысымды талдау нәтижелері алынды. Тәжірибелік пайдаланудың мерзімі мен мұнай өндіру көлемі, орташа тәуліктік іріктеу негіздемесі берілді, жабдықтау және өндіру технологиясының, бұрғылау мен ұңғымаларды игеру мәселелері қарастырылды. Кен орнын әзірлеуді, ұңғымалар мен ұңғыма жабдықтарының пайдаланылуы және күйін бақылау бойынша шаралар ұйымдастыру ұсынылып жатыр.

Түйін сөздер: геологиялық процестер, күрделі құрылым, динамика болжамы, әзірлеу үрдісі, өндіруші ұңғымалар.

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МАТЕМАТИЧЕСКАЯ МОДЕЛЬ ОБОСНОВАНИЯ ГЕОЛОГО-ПРОМЫСЛОВОЙ СТРУКТУРЫ ДЛЯ ПРОВЕДЕНИЯ ПРОБНОЙ ЭКСПЛУАТАЦИИ ПО АПТСКОМУ И СРЕДНЕЮРСКИМ ПРОДУКТИВНЫМ ГОРИЗОНТАМ МЕСТОРОЖДЕНИЯ «ЖАНАТАЛАП»

Аннотация. Многообразие геологических объектов и методов их изучения приводит к тому, что результат геологических исследований очень разнороден по характеру информации: словесный, графический, цифровой. Недоступность геологических объектов для непосредственного наблюдения является причиной того, что геология как теоретическая дисциплина развивалась в условиях практически полного отсутствия экспериментальных данных и долгие годы считалась чисто описательной наукой. Актуальность поставленной в статье проблемы обусловлена тем, что в последнее десятилетие научно-технический прогресс в области геологии нефтяных месторождений был тесно связан с использованием передовых наукоемких геоинформационных технологий, основанных на современных системах управления базами данных. В связи с этим в статье рассмотрены общие принципы построения систем геолого-промышленного анализа месторождений и регулирования разработки нефтяных месторождений. В качестве примеров использовались: обоснование расчетных моделей пласта; основы геологии нефтяных месторождений; результаты научно-исследовательских и проектных работ в области изучения коллекторских характеристик продуктивных пластов; анализ эффективности геолого-технических мероприятий, анализ извлечения запасов углеводородов; создание и эксплуатация постоянно действующих геологических производственных процессов.

Основная цель опытной эксплуатации – получение прямой информации о производственных возможностях проектных площадок и их геолого-геофизических характеристик, достаточной для обоснования оптимального количества извлекаемых запасов нефти и обеспечения эффективного проектирования коллектора и добычи, а также обоснование коллектора режим, определение производственных объектов и оценка перспектив развития добычи нефти на месторождении. Оптимальным считается режим, обеспечивающий наибольшую накопленную добычу нефти за равный промежуток времени без четко выраженной тенденции к снижению дебита. В целом для выполнения задач опытной эксплуатации, а именно для полной реализации программы исследований с целью дальнейшего изучения геолого-физических характеристик продуктивных горизонтов и производственных возможностей скважин (определение пластовых давлений, времени восстановления, давление насыщения, оптимальная эксплуатация пласта и оценка потенциала упругой энергии пластовой системы) срок опытно-промышленной эксплуатации принят 2 года.

Ведущим методом решения данной проблемы является обоснование геологической модели, позволяющей рассматривать данную проблему как целенаправленный и организованный метод моделирования для совершенствования проведения опытно-промышленной эксплуатации в продуктивных горизонтах средней юры. Проанализированы физико-химические свойства пластовых и поверхностных флюидов, запасы нефти. Исследования проводились в установившемся режиме фильтрации – снятие кривой восстановления давления для получения основных фильтрационных характеристик пласта, энергетического состояния системы и его изменений во времени. Все исследования проводились в скважинах, работающих таким образом, свободный поток при различных режимах, с изменением дросселей. Обработка данных исследований форсунок проводилась с помощью специализированного программного продукта PanSystem.

Получены результаты анализа нестационарного давления. Обоснованы сроки опытной эксплуатации и объемы добычи нефти, среднесуточных отборов, рассмотрены вопросы оборудования и технологии добычи, бурения и освоения скважин. Рекомендуются мероприятия по мониторингу разработки месторождения, состояния и эксплуатации скважин и скважинного оборудования.

Ключевые слова: геологические процессы, сложное строение, прогноз динамики, процесс разработки, добывающие скважины.

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RELIABILITY CRITERION AND A MODEL FOR DETERMINING THE OPTIMAL SPEED OF MOVEMENT ON AUTOMOBILE ROADS IN WINTER SLIDING CONDITIONS

Abstract. The article presents a model for establishing the optimal speed of movement on highways, taking into account the determination of the braking distance in winter slippery conditions. According to the research results, it was established that the main criterion for the formation of road accidents on highways in winter slippery conditions is the drivers' underestimation of the adhesion qualities of road surfaces.

The main criterion of the model under consideration is the interaction of the car wheel (braking distance) with the road (adhesion coefficient) and is a complex that characterizes the stability of the car rolling over on slippery surfaces and the driver's actions in making an effective decision and the duration of the reaction time. In the proposed mathematical model, the accident rate on a slippery road is estimated by the coefficient of adhesion of icy road surfaces, the value of the load or the average wheel pressure. Also, the frequency of load application, the amount of deflection of the coating (at an air temperature above +20 ° C), rolling resistance, the coefficient of adhesion of the car wheel to the coating. One of the main characteristics of the model is a subsystem - the average pressure $p = Q / S$ (S is the area of the imprint of the wheel, cm²), etc. Thus, in the process of analyzing the results of the causes of road traffic accidents, the factors of the driver's reliability and the decisions made will be taken into account, which depend on the speed of vehicles in any condition of the road surface.

Key words: icy road surface, coefficient of adhesion, road traffic accident (RTA), reliability criteria, braking distance.

Introduction. One of the critical periods for choosing the optimal speed on highways is winter, especially when the friction coefficient drops below 0.3. With such values, the choice of means of dealing with ice or other types of slipperiness is not always effective. Under such conditions, road and municipal services, in agreement with the Road Patrol Bodies, are often forced to limit the speed of vehicles to a critical level, i.e. up to 40 km / h and below. In this case, drivers select a driving mode based on an analysis of information on road conditions. The safe speed in this section, depending on the conditions (geometric parameters of the road, means of regulation, traffic intensity, roadside space), during the movement varies within wide limits. The reliability of the driver's work and his efficiency can be maintained at the required level only if the volume of incoming information, i.e. the level of slipperiness is within optimal limits. Thus, the level of information determines the emotional state of drivers, on which traffic safety depends. From the data obtained by the researchers [1], it follows that about 80% of road accidents occur due to the emotional instability of drivers (intense excitement, irritation, anger), leading to errors.

Based on the foregoing, driving a modern car makes high demands on the psyche of the driver. In such cases, the driver is required to be objective in order to quickly perceive road conditions, evaluate and react to their changes and perform all the actions necessary to drive a car [2-4].

Traffic safety on the roads depends on the trouble-free operation of all links of the "driver - car - road - environment" complex (VADS). The reliability of the operation of this complex must be ensured, on the one hand, by the technical reliability of the vehicle, the technical perfection of the road, and, on the other, by the reliability of the driver's actions in various road traffic situations. The reliability of the driver as an operator of the VADS system, which depends on the amount of information load, changes during the working day not only from the increase in fatigue, but also under the influence of road conditions and the situation [2,4-6].

There are three main groups of factors that determine the reliability of the driver at high speed on slippery surfaces.

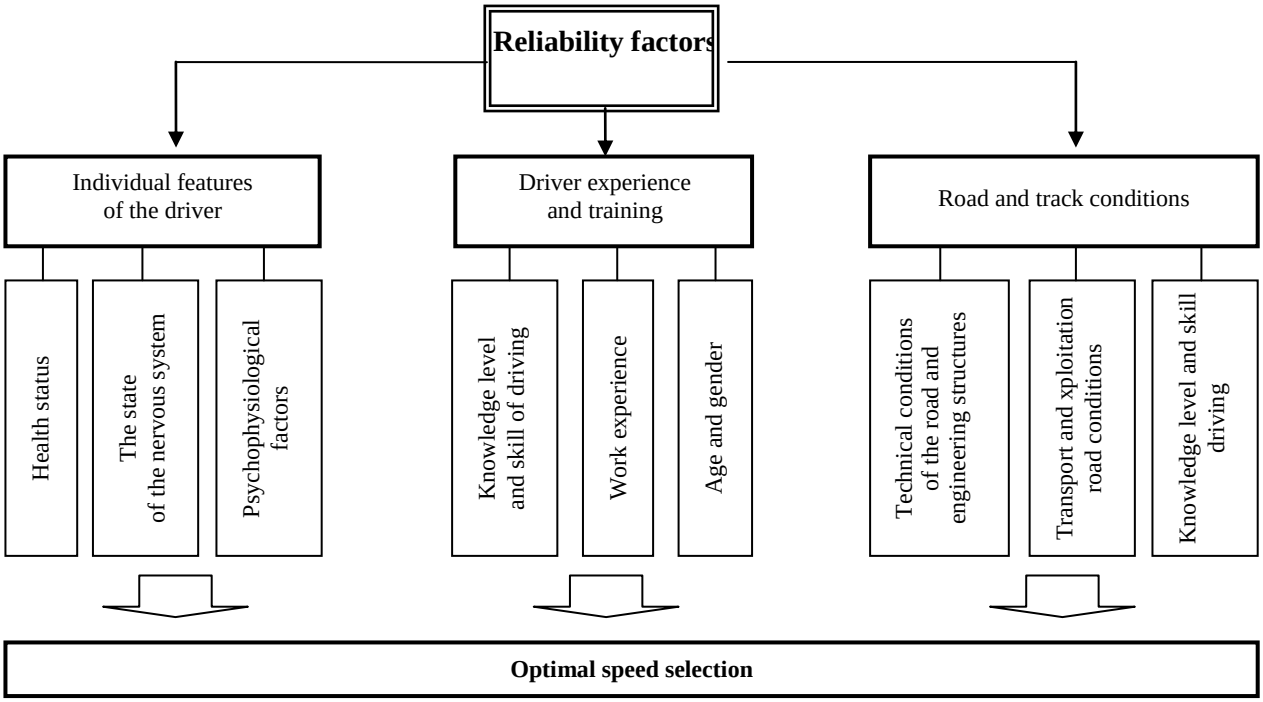

Figure 1 – Driver reliability factors at high-speed driving mode

The interaction of the car and the road is a complex, the analysis of which allows one to assess the stability of the car, the influence of the external environment on driving conditions and mechanical effects on road clothes. The accident rate on a slippery road is estimated by the coefficient of adhesion of icy road surfaces, the value of the load or the average pressure over the area of the wheel imprint. p; load application frequency; deflection (deformation) of the coating l; rolling resistance f; Coated wheel grip φ. One of the main characteristics of the interaction of the subsystem is the average pressure $p=Q/S$, where S – wheel footprint area, sm^2 etc.

Distinguish between the area of the imprint of the wheel along the contour in the form of an ellipse and along the tread protrusions. When determining average pressure, it is common to take into account the area of the indentation over the tread ridges. In calculations $p=K_{ж}p_{в}$ when calculating p the area of the print is conventionally taken as a circle with a diameter D, equal to the area of the ellipse.

Figure 2 presented a model for determining the length of the stopping distance of vehicles depending on the condition of the coatings using the theoretical foundations given in the sources [7-10].

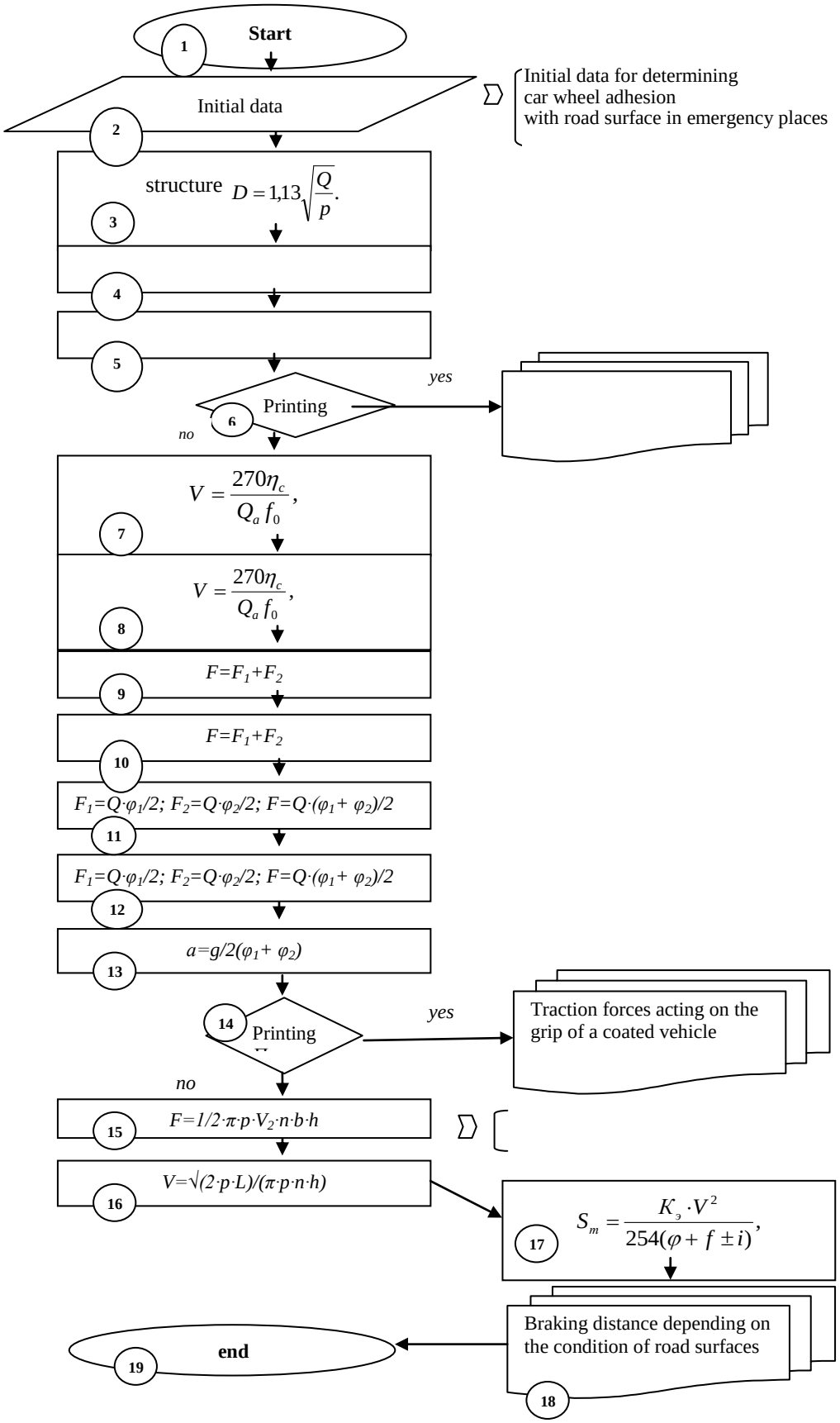

Figure 2 – Model for determining the length of the stopping distance of transport means and factors acting on its level

In the proposed model (figure 2) for different types of surfaces, the values of the rolling resistance coefficients will have different values, which significantly affects the rollover of the car. For example, for rolled snow of the shoulder, the rolling resistance coefficient is $f_2=0,06\text{-}0,1$. In this case $F_2>F_1$, where F_2 - sliding force with a reinforced shoulder and F_1 – with asphalt concrete pavements.

$$F_2=Q\cdot(\varphi_2+f_2)/2, \quad (1)$$

So the total slip resistance is:

$$F=Q\cdot(\varphi_1+\varphi_2+f_2)/2. \quad (2)$$

If the car moved off with two wheels on a snow-covered roadside and the driver did not have time to brake, in this case, the cause of overturning will not be the difference in adhesion coefficients, but the difference in the rolling resistance coefficients of the coating and the snow-covered shoulder. Since the rolling resistance coefficient of asphalt concrete pavements (0.01-0.02) is 3-10 times less than the rolling resistance coefficient of a snow-covered shoulder (0.06-0.1). Here the total rolling resistance will be equal to:

$$F=F_1+F_2= Q\cdot(f_1+f_2)/2. \quad (3)$$

The results of calculations to determine the forces acting on the wheels of a car under various conditions of road surfaces are given in table 1. Based on the calculation and field measurements, the relationship between the coefficient of adhesion (slipperiness) and the length of the stopping distance was established (figure 3).

Table 1 – Calculation results

V, km/h	Adhesion coefficient		Rolling resistance coefficient		Forces acting on the wheels of the car, kg		
	on the cover	on the sidelines	on the cover	on the sidelines	F_1	F_2	F
20	0,1	0,2	0,02	0,06	1160	1520	2680
	0,3	0,4	0,06	0,12	1910	2292	4202
	0,7	0,5	0,10	0,18	2600	2780	5380
50	0,1	0,2	0,02	0,06	1012	1190	2202
	0,3	0,4	0,06	0,12	1476	1650	3126
	0,7	0,5	0,10	0,18	2100	2270	4370
80	0,1	0,2	0,02	0,06	675	765	1440
	0,3	0,4	0,06	0,12	1347	2100	3447
	0,7	0,5	0,10	0,18	1700	2460	4160

The results of the above calculations show the following: the value of the coefficient of adhesion directly depends on the speed of movement of vehicles and the length of the braking distance. For example, when the speed of a car is equal to $V_n=80$ *km/h* and braking distance $L_{m.n}=40$ *m*, adhesion coefficient take value $\varphi=0,4$. This value of the adhesion coefficient for a commercial vehicle corresponds to $V_{гр}=60$ *km/h* and braking distance $L_{m.n}=42$ *m*.

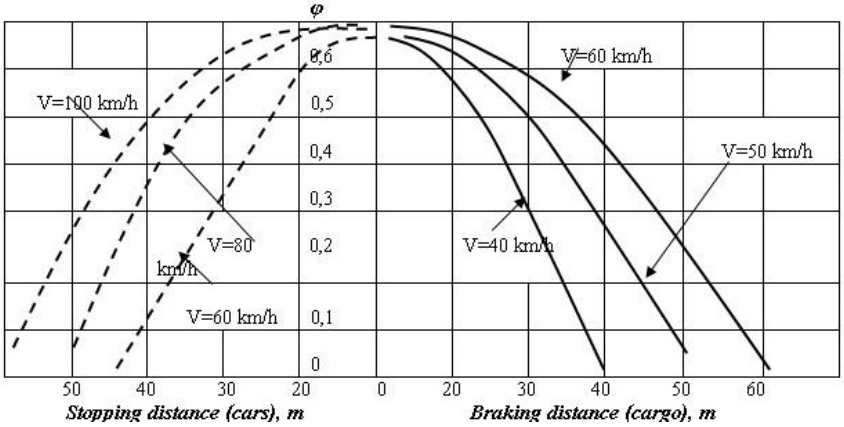

Figure 3 – The relationship between the coefficient of adhesion and the length of the braking distance of the vehicle at different speeds

Consider another example on this nomogram, where at the speed of a car 60, 80, 100 km/h and the value of the adhesion coefficient, which is also φ = 0.4, the braking distance corresponds to different braking distances: 29 m, 40 m и 46 m respectively. However, in places where an accident occurs, traffic police officers do not often pay the necessary attention to such details. In the places of the accident, they first measure the length of the stopping distance, then estimate, i.e. determine the value of the speed of movement. Indeed, at the same time, they did not take into account one of the main indicators affecting the length of the braking distance, these are: the total weight of the car, the type of cargo, the drag coefficient and the elasticity of the rubber of the car wheel.

Summary. Thus, the main criterion for the formation of road accidents is the drivers' underestimation of the adhesion qualities of road surfaces. This primarily occurs during winter slipperiness. In addition, when accounting for road accidents in places of their commission, employees of the Traffic Police often make mistakes in determining the reasons for their commission.

For example, when the road is slippery, the employees of the Traffic Police in the accident card mark them as "ice", but in fact slipperiness is classified into several types: loose (dry, wet, wet) snow, snow roll, glassy ice, etc. ... The values of adhesion coefficients for different types of slipperiness are different and the length of the braking distance depends on this indicator, which is absent in the accident protocols. In addition, it should be noted that even a high reaction of the driver does not allow shortening the braking distance with a low coefficient of adhesion of the coating.

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БЕРІКТІК ҚАҒИДАСЫ ЖӘНЕ ҚЫСҚЫ ТАЙҒАҚ ЖАҒДАЙЫНДА АВТОМОБИЛЬ ЖОЛДАРЫНДАҒЫ ОҢТАЙЛЫ ЖЫЛДАМДЫҚТЫ ҚАБЫЛДАУ ҮЛГІСІ

Аннотация. Мақалада қысқы тайғақ кезіндегі автомобильдің тежеу жолының ұзақтығына қатысты оңтайлы жылдамдығын анықтау үлгісі келтірілген. Зерттеу нәтижелері бойынша ЖКО туындауының негізгі қағидалары, яғни апаттық жағдай көлік жүргізушісінің жол бетіне түскен түрлі тайғақ түріне тиісті баға бере алмайтындығы анықталды.

Бүгінде Қазақстанның автомобиль жолдарында туындап, қысқы тайғақтағы жол-көлік оқиғаларын (ЖКО) саралау мен тіркеу автожол саласында өзекті мәселеге айналды. Өйткені, бұл жағдайда апат туындауына келесі екі фактор тікелей әсер етеді: көлік құралдарының тежеу жолының деңгейі мен жүргізушінің аталған уақытта күрделі психофизиологиялық қысымға түсуі. Алайда жол апаты орын алған телімдегі апаттық хаттама толтыру сәтінде жоғарыда аталған екі фактор ескерілмей қалады да, апаттың негізгі себепкері жүргізуші болып қалады.

Қарастырылып отырған математикалық үлгіде автомобиль (тежеу жолының ұзындығы) мен жол (ілініс коэффициентінің деңгейі) негізгі қағида болып қабылданады және олар тайғақ жол жамылғысындағы автомобильдің аударылып кетуіне тежеу болуы және жүргізушінің әрекет ету уақыт шамасындағы оңтайлы шара қабылдауы арқылы сипатталатын өте күрделі процестерді білдіреді. Осылайша математикалық үлгіде тайғақ жолдағы апатқа сәйкес ілініс коэффициентімен, білікке түсетін жүктememен немесе дөңгелектегі орта қысымдағы оның жамылғы ізімен анықталады. Сол сияқты бұл процесс жамылғының серпіліс модулімен (ауа температурасының +20 ^{o}C-тан жағары кезінде), тербеліске қарсылық коэффициентімен, жол мен дөңгелек арасындағы ілініс коэффициентімен де сипатталады. Осы аралық жүйеде дөңгелек ішіндегі ауа қысымы $p=Q/S$ өрнегі арқылы есептеледі (мұндағы S – дөңгелек табанының жол бетіне түскен ізінің ауданы, см^2) және т.б. Сөйтіп, жол телімінде орын алған ЖКО-ның себептерін анықтауда кез келген күйде жамылғы бетіндегі жүргізушінің дайындығы мен қабылданған шешімі есепке алынады.

Апат деңгейі, жоғарыда көрсетілгендей, қысқы тайғақ жол жамылғыдағы ілініс коэффициентімен бағаланады жән сонымен қатар, білікке түсетін жүктememен немесе дөңгелек қысымымен p, қозғалыс кезінде жүктеменің әсер ету жиілігімен, жол төсемінің серпімділік модулімен, теңселіске қарсы тұру f және ілініс коэффициенттерімен φ айқындалады.

Мақалада ұсынылып отырған математикалық алгоритм негізінде анықталған нәтижелер ілініс коэффициенті мен тежеу жолының ұзындығы арасындағы қатынасты жол жамылғыларының қысқы тайғақ күйі негізіндегі жылдамдық шамасына орай анықтауға мүмкіндік берді. Осыған орай, авторлар ЖКО саралау мен

тіркеу кезінде жоғарыда аталған көрсеткіштер міндетті түрде ескерілуі тиіс екендігін ұсынады, себебі оларға қатысты апаттың саны мен ауыртпалығы белгіленеді. Мысалы, жеңіл көлік үшін жылдамдығы $V_л$=*80 км/сағ. және тежеу жолының ұзындығы* $L_{т.п}$=*40 м болатын жағдайдағы жол жамылғысының ілініс коэффициенті* φ=*0,4, ал ЖКО туындауына қатысты тәуекелдік деңгей* $C_р$=*3 болады* (ілініс коэффициенті φ=*0,79* жағдайда $C_р$=*1*). Жүк көлігінің жылдамдығы $V_{гр}$=60 км/сағат және тежеу жолының ұзындығы $L_{т.п}$=*42 м* жағдайда ілініс сапасы мен тәуекелдік коэффициенті жеңіл автомобильдегі жағдайға тең болады.

Түйін сөздер: сырғақ жол жамылғысы, ілініс коэффициенті, жол-көлік оқиғалары (ЖКО), беріктік қағидалары, тежеу жолының ұзындығы.

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КРИТЕРИЙ НАДЕЖНОСТИ И МОДЕЛЬ ОПРЕДЕЛЕНИЯ ОПТИМАЛЬНОЙ СКОРОСТИ ДВИЖЕНИЯ НА АВТОМОБИЛЬНЫХ ДОРОГАХ В УСЛОВИЯХ ЗИМНЕЙ СКОЛЬЗКОСТИ

Аннотация. В настоящее время на автомобильных дорогах Казахстана возникают проблемы, связанные с учетом дорожно-транспортных происшествий (ДТП) на покрытиях с зимней скользкостью. В таких случаях на уровень аварийности влияют два фактора: удлинение тормозного пути транспортных средств и повышение психофизиологического напряжения водителя. Однако при существующих методах заполнения протоколов на месте происшествия эти два фактора практически не учитываются, поэтому главным объектом причины ДТП остается водитель.

В статье приведена модель установления оптимальной скорости движения на автомобильных дорогах с учетом определения длины тормозной пути в условиях зимней скользкости. По результатам исследований установлено, что главным критерием образования ДТП на автомобильных дорогах в условиях зимней скользкости является недооценка водителями сцепного качества дорожных покрытий.

Главным критерием рассматриваемой модели является взаимодействие колеса автомобиля (длина тормозного пути) с дорогой (коэффициентом сцепления) и представляет собой сложный комплекс, характеризующийся устойчивостью автомобиля опрокидыванию на скользком покрытий, и действиям водителя в принятии эффективного решения и продолжительности времени реакции. В предлагаемой математической модели уровень аварийности на скользкой дороге оценивается коэффициентом сцепления оледенелых дорожных покрытий, величиной нагрузки или средним давлением колеса. Также частотой приложения нагрузки, величиной прогиба покрытия (при температуре воздуха выше +20 ^{o}C), сопротивлением качению, коэффициентом сцепления колеса автомобиля с покрытием. Одной из основных характеристик модели принята подсистема – среднее давление $p=Q/S$ (S – площадь отпечатки колеса, см^2) и т.п. Таким образом, в процессе анализа результатов причин образования ДТП будут учтены факторы надежности водителя и принятых решений, зависящие от скорости движения транспортных средств при любом состояний дорожного покрытия.

Уровень аварийности на скользкой дороге оценивается коэффициентом сцепления оледенелых дорожных покрытий, величиной нагрузки или средним давлением по площади отпечатка колеса p, частотой приложения нагрузки, прогибом (деформацией) покрытия, сопротивлением качению f, сцеплением колеса с покрытием φ. Одна из основных характеристик взаимодействия подсистемы – среднее давление $p=Q/S$, где S – площадь отпечатка колеса, см^2 и т.п.

В статье также приведены результаты расчетов, определенные на основе прилагаемой модели и получена прямая зависимость между коэффициентом сцепления и длиной тормозного пути автомобиля при движении транспортных средств, при различных скоростях движения. Таким образом, авторами предлагается при анализе ДТП учесть вышеперечисленные показатели, от которых зависит их число и тяжесть. Например, при скорости движения легкового автомобиля, равной $V_л$=*80 км/ч* и длине тормозной пути $L_{т.п}$=*40 м*, коэффициент сцепления примет значение φ=*0,4,* при этом степень риска совершения ДТП равен $C_р$=*3* (при φ=*0,79* – степень риска $C_р$=*1*). Это значение коэффициента сцепления для грузового автомобиля соответствует при $V_{гр}$=60 км/ч и длине тормозного пути $L_{т.п}$=*42 м*, при этом степень риска остается равным к легковому автомобилю, т.е. $C_р$=*3*.

Ключевые слова: обледенелое дорожное покрытие, коэффициент сцепления, дорожно-транспортное происшествие (ДТП), критерии надежности, длина тормозного пути.

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DEVELOPMENT AND JUSTIFICATION OF A HYDRO-IMPULSE METHOD FOR INCREASING ORE PERMEABILITY IN CONDITIONS OF URANIUM BOREHOLE PRODUCTION

Abstract. The technology of downhole uranium production used at mining enterprises in Kazakhstan is described, the factors affecting the decrease in the filtration characteristics of productive formations are studied in detail, and an effective method is described for increasing the downhole uranium production. The applied methods of intensification of downhole production at uranium mining enterprises are considered, the positive and negative aspects of the electroplasma and chemical methods are discussed. Calculations of the working values of the hydro-wave method of destruction of clogging formations in the well and the parameters of the solution supply during repair and restoration work are presented. Based on the calculation of the operating parameters, a diagram of the dependence of the operating cycle of the hydropercussion machine on the flow rate of the water supplied to the machine is constructed. The developed 3D model of the hydropercussion apparatus for increasing the permeability of the productive horizon is presented. The advantages of the use of the hydrodynamic method for restoring the permeability of the productive horizon in the conditions of downhole uranium production in difficult mining and geological conditions are disclosed. The optimal parameters for intensification of downhole uranium production in difficult mining and geological conditions are recommended, and a method for using a hydropercussion apparatus in combination with traditional methods of well regeneration is developed.

Key words: Borewell, filter, clogging, hydraulic impulse, hydraulic machine, shock body.

Introduction. The technology of downhole uranium mining provides for the dissolution of a useful component at the location of the ore body, followed by the removal of the formed compounds by a moving stream of solvent from the injection well to the extraction well [1,2]. The practice of operating systems of geotechnical wells during the operation of uranium deposits by the method of underground drillhole leaching of uranium (ISL) shows that over time there is a decrease in their productivity. One of the main reasons for the decrease in the throughput of technological wells is an increase in hydraulic resistance and a decrease in the filtration characteristics of the reservoir as a result of the formation of clogging, due to the precipitation of substances dissolved in technological solutions, or mechanical movement of particles of the ore-bearing horizon, as well as gas release. The experience of operating such wells at the enterprises of the National Atomic Company (NAC) Kazatomprom JSC shows that the main reason for the decrease in their productivity and resource is the clogging processes of the rocks in the near-filter zone (NFZ) of the wells and the filters themselves.

Mechanical clogging is due to the overlap of the water intake openings of the filters with sand, clay, gravel and the clogging of the pore channels of the formation with mechanical suspensions. Sand and clay deposited in the well partially or completely overlap the filter. Also, clogging of the filter and the near-filter zone of the formation with drilling fluids containing clay particles can be attributed to mechanical

clogging. In this case, the swelling of clay material in the aquatic environment and a change in the structure of the pore space of the formation [3].

Chemical, ion exchange and gas types of clogging are caused by a change in the chemical composition of formation waters as a result of the influence of chemical materials used in ISL. The presence of dissolved calcium, magnesium and iron cation exchangers in water and a violation of carbon dioxide equilibrium leads to the formation of hardly soluble precipitates. Intensive precipitation of carbonate sediments occurs in the filter zone, and with distance from them, the intensity of precipitation decreases [4]. When leaching solutions interact with ore-bearing rocks in the liquid phase, there is an accumulation (in addition to ore) of a number of elements that make up the main rock-forming minerals. The amount and kinetics of the transition of these elements into productive solutions depends on the type of leaching agent, its concentration, redox potential, temperature, solubility of rock-forming minerals, and the size of the active surface of mineral particles, which largely determines the intensity of mass transfer in the solution-rock system.

In most cases, sediments, clogging filters and near-filter zones of wells are multicomponent and can simultaneously contain salts of iron, manganese and their hydroxides, calcium and magnesium carbonates, silicic acid and sulfides, as well as sand and clay. They are deposited on the surface of the filters and in the pores of the adjacent aquifers by gravity or adsorbed by surface tension forces. Over time, sludge is dehydrated and compacted. Deposits have a loose-porous and conglomerate structure and at different stages of formation and are characterized by different strength and activity to enter into a reaction. The formation of conglomerate-like sediments is associated with the processes of chemical and mechanical cementation adjacent to the filter of aquifers or gravel sprinkling with chemical deposits.

The main methods for restoring or increasing the permeability of bottomhole zone rocks during recovery and restoration work (RRW) are physical, chemical and combined. When choosing the RRW technology, one should proceed from the possibility of each method of declogging of filters and near-filter areas of wells. Also, when choosing a workover method, it is necessary to take into account hydrogeological conditions, drilling technology, well structure, filter and other characteristic factors of the field.

Review of literary sources. To restore the flow rate of wells by destroying and dispersing clogging deposits, which prevent the filtration of solutions in the reservoir in difficult mining and geological conditions, electrohydrodynamic methods of well regeneration are widely used. Table 1 shows the main methods used for the regeneration of wells in the conditions of ILS of uranium.

Table 1 – Applied RRW methods at uranium mining enterprises

The nature of the impact	Implementation method	Main purpose
Hydrodynamic	Compressor pumping	Removal of mud, mechanical suspended particles and impurities from the bottomhole formation zone (BHZ)
	Electroplasma	Removal of fine dust particles and clay materials from the BHZ
Chemical	Sulfuric acid	Dissolution of ferrous and aluminum chemical deposits
	Clay-acid	Dissolution of carbonate and silicon chemical and mechanical deposits
Combined	Reagent treatments with mechanical action	Removal of sand plugs from the columns and filter section of the well, dissolution of chemical deposits, intensification by swabbing, clarification of solutions by compressor pumping.

Analysis of the effectiveness of the impact of the electrohydroimpact (EH) method on the bridging deposits from the literature 5, 6, based on the creation of elastic resonant vibrations by electric discharges affecting the reservoir. Multiple sequential impulse vibrations in a wide range of frequencies are designed to destroy and disperse bridging formations and deep penetration and create new fractures in terigenic and carbonate reservoirs of different porosity and permeability. Also, during EH - treatment of a well, a low-frequency and ultra-low-frequency effect on the formation and its excitation at dominant frequencies at a considerable distance from the well occurs, which increases the permeability of solutions in the rock. In an electric explosion, a breakdown occurs between the electrode gap, in which the solution is located, with the formation of a rupture channel, the pressure in the channel increases, which is accompanied by its expansion. After the discharge stage, the channel turns into a gas bubble, which initially expands and then contracts under the pressure of hydrostatic pressure, creating alternating fluid movements. The main advantage of this method is that wells with filters made of almost any material, including asbestos-cement,

nylon or vinyl plastic pipes, can be treated with EH-treatment. Processing filters made of various materials requires changing the parameters of the power and pressure of the shock wave, its duration and the number of pulses per 1 m of its length, which determine the efficiency of the electric shock treatment of the filter. The pressure of the shock wave is mainly determined by the discharge voltage of the coaxial cable and the discharge gap in the downhole discharge device, adjustable up to 80 MPa, with a frequency of 1-10 Hz. The duration of the shock wave depends mainly on the capacity of the capacitor bank. However, the increased requirements for safe work practices, due to high voltage, provide for special training and additional equipment and devices, registration of work permits for maintenance personnel, which reduces the productivity of work and reduces the productivity of the installation

In articles 7, 8, reagent methods for restoring the productivity of wells are presented, related to chemical methods of regeneration. Reagent methods of stimulating the formation are based on the reaction of aqueous solutions of acids with clogging formations, dissolution and removal of the reaction products outside the well, usually by airlift pumping. The choice of the type and method of reagent regeneration depends on many factors, which are determined by the composition and condition of the clogging sediment, the design of the filter and its condition, the structure of the treated surface. Regardless of the method of supply, hydrochloric acid HCl is widely used for well regeneration, effectively dissolving ferrous (Fe_2O_3, $Fe(OH)_3$, FeS) and carbonate ($CaCO_3$, $MgCO_3$) bridging formations. The optimal working concentration of the hydrochloric acid solution is selected taking into account the dissolving ability and the rate of dissolution of the rock and the neutralization of the acid in the composition, corrosiveness and the magnitude of the formation pressure. In the practice of chemical treatment of wells, the method of reagent baths and the method of cyclic pressing into the formation are usually used. The reagent bath method involves pouring an acid solution at the wellhead, which, under the influence of diffusion processes, penetrates the filter circuit. Application of this method does not require additional equipment and sealing of the well head. The method of cyclic pushing of an aqueous acid solution into the formation is more effective than the method of reagent baths, however, it requires the installation of additional equipment, lowering of pipes and sealing of the well head. The practice of using chemical reagents in the regeneration of wells showed low efficiency of methods with especially difficult formation conditions (increased carbonate content of CO_2> 2%), sandiness of the well. There is no possibility to regulate the uniformity of filter cleaning both along the length and along the depth of the near-filter zone, since in the process of pressing with working solutions the reagent moves along the most permeable sections of the near-filter zone. In sealed, impermeable cemented formations, reagent methods require additional intensification of the process by hydrodynamic methods, since this allows to induce deep processes of acid-rock interaction.

Calculation and justification of operating parameters. The experience of the regeneration of geotechnical wells in carbonate blocks shows that the main reason for the low efficiency of many development methods is that each of them is aimed at solving a single problem: clay mud formation, filter and wellbore zone cleaning. It is necessary for the development to be comprehensive and include operations to restore the permeability of the near-filter zone and clean the filter from various kinds of sediment formation. These requirements are met by the pulse-wave method of regeneration, based on the action on the formation by hydraulic impulses in a solution of chemical reagents.

The generation of hydraulic impulses in a hydroimpact machine involves the use of hydraulic shocks that occur when the valve closes the fluid flow, produced by a striker on the anvil of the machine associated with a destructive tool. In this case, the most optimal solution would be to place generators in the filter zone of the well, i.e. generators must be submerged in the well. When creating a hydraulic impulse, due to the small gaps between the body of the transmitter and the production string of the well, due to the high velocity of the ascending flow and the inertial properties of the liquid, a pressure drop is created and the bridging agents are removed along with the liquid, i.e. In addition to the transfer of force, the liquid medium additionally removes destroyed bridging agents from the impact zone, which allows processing a significant part of the volume of the filter zone.

Based on the above parametric data, the average values of the frequency and energy of impacts, as well as the developed power of the hydraulic impact machine, were determined. The frequency of blows was determined by the formula 1. The energy of the blow is calculated by the formula 2.

$$n = \frac{1}{T}, \tag{1}$$

where: T – time of cycle, s.

$$W = \frac{m_б \cdot V_б}{2}, \quad (2)$$

where: $m_б$ – striker weight; Vб - striker speed during different stages of the cycle, cm/s; the mass of the striker is determined from expression 3.

$$m_б = \frac{G_б}{g}, \quad (3)$$

where: g – acceleration of gravity, 9,81 m/s^2;

The theoretical power of the machine is calculated from expression 4.

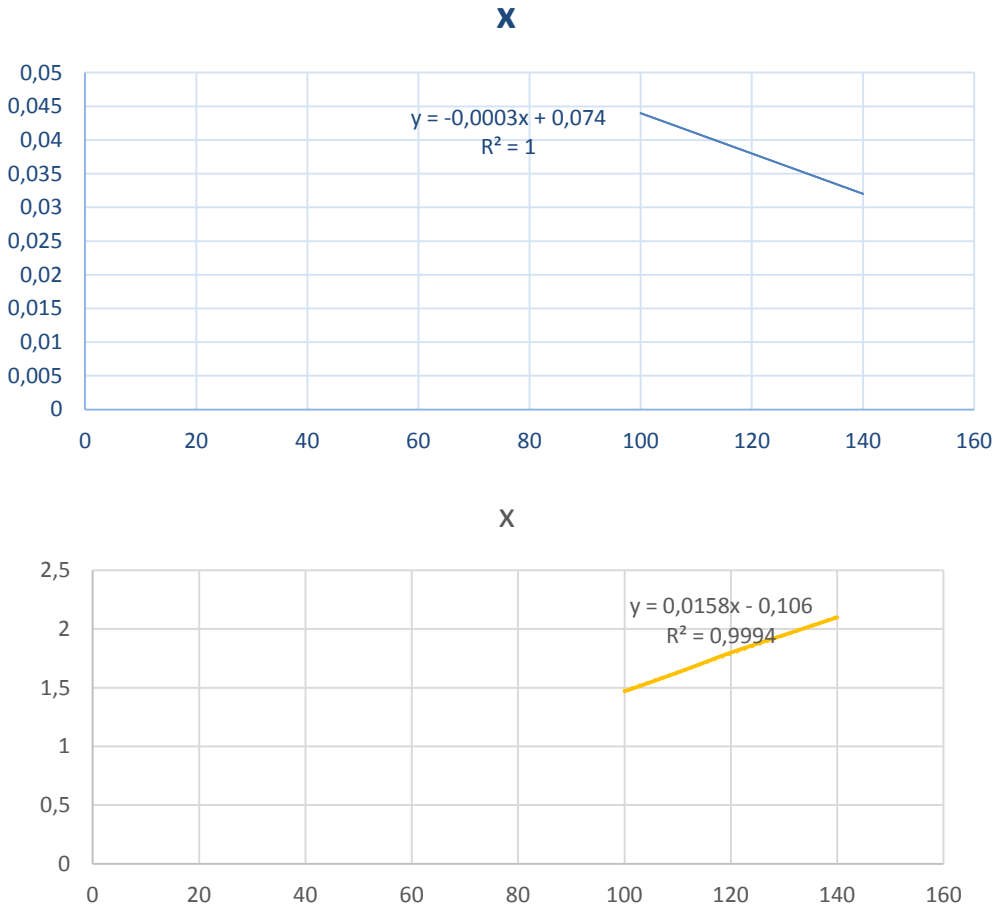
$$P = \frac{W \cdot n}{102}, kW. \quad (4)$$

The results are summarized in table 2.

Table 2 – Data of the dependence of the generator parameters on the flow rate of the supplied water

Water supply consumption *Q, l/min*	Total cycle time, *T, s*	Impact frequency *n, 1/s*	Striker pre-impact speed, $V_б$, *m/s*	Impact energy *W, J*	Theoretical machine power *P, kW*
100	0,044	22,7	1,47	6,5	0,14
120	0,038	26,3	1,80	9,7	0,25
140	0,032	31,2	2,10	13,2	0,40

Based on the calculated data obtained, graphs of the dependence of T, $V_б$, and P on Q were built. The graph is shown in figure 1.



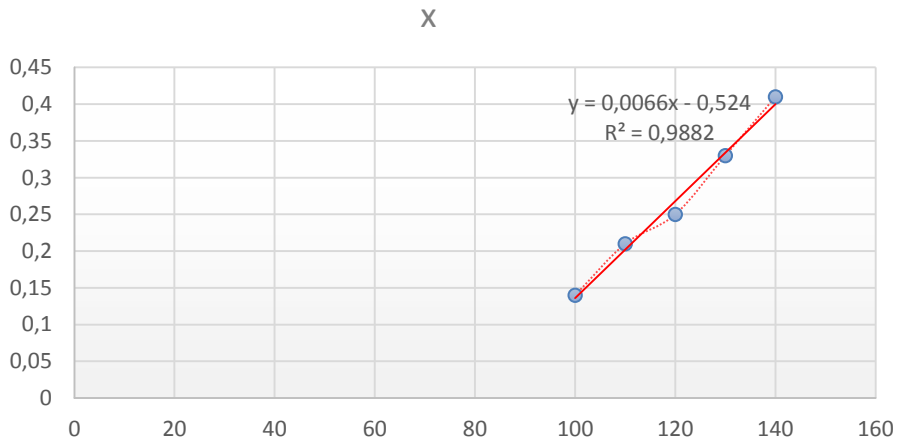


Figure 1 – Dependences of the operating cycle indicators of the hydraulic hammer machine on the flow rate of water supplied to the machine. 1 – $T = f(Q)$ graph; 2 – $V_{б.} = f(Q)$ graph; 3 – $P = f(Q)$ graph

The analysis of the given graphs showed that with an increase in water consumption, almost all cycle indicators increase, affecting the power of the machine, first of all, the pre-impact speed of the striker. A decrease in cycle time causes an increase in the pulse frequency, which also contributes to an increase in machine power.

According to the calculated values obtained and in accordance with the specific conditions of the well, a prototype of the hydroimpact apparatus was built, shown in figure 2.

a b

Figure 2 – Diagram of a hydroimpact apparatus. a - 3D, b - in section. Where: 1 – body; 2 - connecting adapter; 3 - valve; 4 - sanding rings; 5 - spring; 6 - nozzle holes.

When flushing fluid is supplied through a continuous hose from HDPE to the bottomhole through adapter 2, flushing fluid creates pressure on the surface of valve 3, which, compressing the spring 5, moves until a jet of flushing fluid is fired through the side radial nozzle holes. The valve backstroke is provided when the mud pump pulsates, and the oscillating back and forth movement of the valve is equal to the pulsation per minute of a standard exploration mud pump. The failure-free operation of the device is ensured by the minimum number of moving parts relative to each other, the presence of sanding rings on the valve's working surface and, accordingly, by the simplicity of the design.

Conclusion. When the front of the reflected wave approaches the surface of the half-space, a wave arises that travels to the obstacle. As a result of the action of this wave, the compression of the medium is replaced by tension, the sign of the stress changes, and as a result, the sign of deformation. Multicomponent media do not withstand tensile deformations exceeding a certain critical value, which is different in bridging agent with different chemical compositions. Therefore, discontinuity occurs, and the tensile stresses corresponding to the rupture are usually of the order of the atmosphere.

In one-dimensional motions with hydro-impulse waves, all parameters depend on one single spatial coordinate and on time. The main sought functions are, in the general case, the stress tensor components, the density or volumetric deformation of the medium, and the mass velocity of the shock fluid, and the determining parameters are the constants entering the model equations and the boundary and initial conditions of the problem. In a medium with bulk viscosity, the result of the impact action will directly depend on the properties of the medium, the maximum pressure achieved and, in addition, on the wavelength. In media with bulk viscosity, the energy losses of waves can be different depending on their duration, respectively, the shorter the wave is, the smaller the losses during its propagation. This is an important property of viscous media.

From the analysis of wave propagation, it follows that at all considered distances the wave remains linearly shock, the maximum values of stress, strain and particle velocity are achieved at the front. Behind the front, all these quantities decrease, the voltage is distributed according to a linear law, the other parameters according to nonlinear laws, more slowly than the voltage. The lag of the extreme values of the deformation and the pulse velocity relative to the stress will not take place, however, a lag and decrease of these values behind the wave front is possible. The wave parameters at the front (precursor) both with a further decrease and with an increase in the voltage behind the shock can be obtained analytically without solving the problem as a whole.

The use of a hydropercussion wave directly, which creates alternating pressures on the inner cavity of the filter and then near the filter zone from the downhole hydropercussion machine, is the most promising direction for increasing the efficiency of RRW in technological wells. The use of the hydraulic impulse method of influencing the sealed formation zone during RRW of geotechnical wells is promising and cost-effective by reducing the time spent on the technological process and increasing the turnaround cycle.

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УРАНДЫ ҰҢҒЫМАЛЫҚ ӨНДІРУ ЖАҒДАЙЫНДА КЕННІҢ ӨТКІЗГІШТІГІН АРТТЫРУДЫҢ ГИДРОИМПУЛЬСТІК ӘДІСІН ӘЗІРЛЕУ ЖӘНЕ НЕГІЗДЕУ

Аннотация. Ұңғыманың түп аймағының сүзгісінің ішкі қуысында ауыспалы қысым жасайтын гидросоққылы машинаның әсер ету әдісінің сипаттамасы мен жұмыс принципі келтірілген, бұл сүзгілердің де, сүзгі аймағының да колматациясын төмендетуге көмектеседі.

Қазақстанның өндіруші кәсіпорындарында қолданылатын уранды ұңғымалық өндіру технологиясы сипатталған, өнімді қабаттардың сүзгілік сипаттамаларын төмендетуге әсер ететін факторлар жан-жақты зерделенген, сондай-ақ ұңғымалық уранды өндіруді арттырудың тиімді әдісі сипатталған. Уран өндіруші кәсіпорындарда ұңғымалық өндіруді қарқындатудың қолданылатын әдістері қаралды, электр көзді және химиялық әдістің оң және теріс жақтары талқыланды. Ұңғымадағы кольматациялық түзілімдерді бұзудың гидро толқындық әдісінің жұмыс мәндерінің және жөндеу-қалпына келтіру жұмыстарын жүргізу кезінде ерітінділерді беру параметрлерінің есептері келтірілген. Жұмыс параметрлерін есептеу негізінде гидравликалық соққы машинасының жұмыс циклы көрсеткіштерінің машинаға берілетін су шығынына тәуелділігі диаграммасы жасалды. Өнімді горизонттың өткізгіштігін арттыру үшін гидросоққылы машинаның 3D моделі келтірілген. Күрделі тау-кен геологиялық жағдайларда уранды ұңғымалық өндіру жағдайларында өнімді горизонттың өткізгіштігін қалпына келтірудің гидросоққылы әдісін қолданудың артықшылықтары ашылды. Күрделі тау-кен геологиялық жағдайларда уранды ұңғымалық өндіруді қарқындатудың оңтайлы параметрлері ұсынылды және ұңғымаларды қалпына келтірудің дәстүрлі әдістерімен үйлесімде гидросоққылы машинаны қолдану әдістемесі әзірленді.

Сүзгінің өткізу қабілетін және технологиялық ұңғымалардың сүзгі жанындағы аймағын (ЖҰШ) қалпына келтірудің негізгі міндеттерінің бірі қабаттың динамикасын, сондай-ақ олардың үдеуін, жылдамдығын және ығысуын ескере отырып, тұйықталған ортаға әсер ететін оңтайлы жүктемелерді айқындау болып табылады. Барлық осы шамалар тек қана тосқауылға түсетін толқынның параметрлеріне ғана емес, сонымен қатар кедергінің инерциялық және жиілік қасиеттеріне де байланысты. Уран кенін өндіру және эксперименттік зерттеулер кезінде технологиялық ұңғымалардың сүзгіш аймағын декольматациялау үшін гидроимпульсті

әдісті пайдалану шарттарына қатысты теориялық ережелер жүргізілді және негізделді. Гидропульстердің ұңғымалық генераторы арқылы жүзеге асырылатын гидропульстік әсер ортаның қасиетіне байланысты ағын қысымының гидропульсі ұңғыманың осінен 0,3 метрге дейінгі қашықтыққа таралуы мүмкін. Гидроимпульстік ағындардың әсерінен қабаттың сүзгі аймағының колматантының бұзылуы ауыспалы циклдік тербелістің салдарынан болатындығы көрсетілген. Гидродинамикалық модель су толқындарының әсерінен сүзгі қабатының өткізгіштігінің өзгеру процесін сипаттайды. Гидродинамикалық модельдің көмегімен есептерді шешкен кезде ұңғымада және резервуардың кольматантты аймағында гидроимпульсті толқындардың таралу сипатын графиктер түрінде зерттеу үшін теңдеулер алынды.

Бұл гидросоққылы машинаның талқандау қабілеті теориялық және компьютерлік модельдеумен расталды. Келесі нәтижелер алынды. Біріншіден, гидросоққылы машина декольматацияны жоғарылатудың басқа құралдарына қарағанда әлдеқайда тиімді. Екіншіден, соққының әсері соққы элементінің қысымы мен соғу жиілігіне байланысты. Үшіншіден, импульстік ағын неғұрлым үлкен болса, оның талқандау қабілеті соғұрлым жоғары болады. Төртіншіден, импульстік ағынды құралдың саптамасының диаметрін азайту арқылы көбейтуге болады. Бесіншіден, гидравликалық соққы жоғары қаттылықтың кольматациясының жойылуын тездетуге көмектеседі, ал аз цементтелген жыныстардың бұзылуы импульстік ағынның жоғарылауымен едәуір күшейтілуі мүмкін. Әзірленген импульстік гидросоққылы машина терең және көлденең ұңғымалардағы бұрғылау жылдамдығының төмендігі, шламды алып тастау сияқты мәселелерді шешудің жаңа идеясын ұсынады деген қорытындыға келдік.

Түйін сөздер: ұңғыма, сүзгі, кольматация, гидроимпульс, гидро машина, соққы денесі.

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РАЗРАБОТКА И ОБОСНОВАНИЕ ГИДРОИМПУЛЬСНОГО МЕТОДА ПОВЫШЕНИЯ ПРОНИЦАЕМОСТИ РУД В УСЛОВИЯХ СКВАЖИННОЙ ДОБЫЧИ УРАНА

Аннотация. Приведено описание и принцип действия метода воздействия гидроударной машины, создающей знакопеременные давления на внутренней полости фильтра призабойной зоны скважины, которая способствует снижению кольматации как самих фильтров, так и прифильтровой зоны (ПФЗ).

Описана технология скважинной добычи урана, применяемая на добычных предприятиях Казахстана, подробно изучены факторы, влияющие на снижение фильтрационных характеристик продуктивных пластов, а также описан эффективный метод, повышения скважинной добычи урана. Рассмотрены применяемые методы интенсификации скважинной добычи на уранодобывающих предприятиях, обсуждены положительные и отрицательные стороны электроплазменного и химического метода. Приведены расчеты рабочих значений гидроволнового метода разрушения кольматационных образований в скважине и параметров подачи растворов при проведении ремонтно-восстановительных работ. На основе расчета рабочих параметров построена диаграмма зависимости показателей рабочего цикла гидроударной машины от расхода подаваемой в машину воды. Приведена разработанная 3D модель гидроударного аппарата для повышения проницаемости продуктивного горизонта. Раскрыты преимущества применения гидроуданого метода восстановления проницаемости продуктивного горизонта в условиях скважинной добычи урана в сложных горно-геологических условиях. Рекомендованы оптимальные параметры интенсификации скважинной добычи урана в сложных горно-геологических условиях и разработана методика применения гидроударного аппарата в сочетании с традиционными методами регенерации скважин.

Одной из основных задач восстановления пропускной способности фильтра и прифильтровой зоны технологических скважин (ПСВ) является определение оптимальных нагрузок, действующих на закольматированную среду, с учетом динамики пласта, а также их ускорений, скоростей и смещений. Все эти величины существенно зависят не только от параметров волны, падающей на кольматантную преграду, но и от инерционных и частотных свойств самой преграды. Была проведена и обоснованы теоретические положения применительно условиям использования гидроимпульсного метода для декольматации прифильтровой зоны технологических скважин при добыче урановых руд и экспериментальных исследований. Гидроимпульсное воздействие, осуществляемое через скважинный генератор гидроимпульсов, в зависимости от свойства среды, гидроимпульса давления потока может распространяться на расстояние до 0,3 метра от оси скважины. Показано, что разрушение кольматанта прифильтровой зоны пласта под действием гидроимпуьсных струи происходит за счет знакопеременного циклического колебания. Составлена гидродинамическая модель опи-

сывающей процесс изменения проницаемости прифильтрового пласта под воздействием гидроударных волн. При решении задач с помощью гидродинамической модели, получены уравнения для исследования характера распространения гидроимпульсных волн в скважине и кольматантной зоне пласта в виде графиков.

Разрушающая способность этого гидроударника была подтверждена теоретически и компьютерной моделированиеми. Были получены следующие результаты. Во-первых, этот гидроударник намного эффективнее, чем другие инструменты для повышения декольматации. Во-вторых, ударный эффект зависит от давления и частоты удара ударного элемента. В-третьих, чем больше импульсная струя, тем выше ее разрушающая способность. В-четвертых,. Импульсная струя может быть увеличена за счет уменьшения диаметра сопла инструмента. В-пятых, гидравлический удар может помочь ускорить разрушение кольматации высокой твердости, а разрушение менее цементированных пород может быть значительно усилено за счет увеличения импульсной струи. Сделан вывод о том, что разработанный импульсный гидроударник дает новую идею для решения таких проблем в глубоких и горизонтальных скважинах, как низкая скорость бурения, очевидный эффект прижима стружки и трудное удаление шлама.

Ключевые слова: Скважина, фильтр, кольматация, гидроимпульс, гидро машина, ударное тело.

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SOME QUESTIONS STUDY OF DEFLATION PROCESSES AND SAND TRANSPORT IN THE DRAINED BOTTOM OF THE ARAL SEA

Abstract. The article discusses the results of the study of sandy deserts, which allowed us to obtain and reveal a number of important laws and mechanisms of formation, formation, movement and development of Aeolian landforms. The establishment of these patterns helps to solve a number of practical tasks to combat sand drifts in the sandy desert of various objects. In connection with the prospects for the development of this territory, it is very important to know the direction and intensity of the development of these processes. The obtained data on the mechanism and structure of the entire air-soil flow, starting from the moment of its formation, i.e. in the blowing zone, and ending with the transfer and deposition of soil particles by wind in the accumulation zone, make it possible to increase the level of scientific validity of the rational use of soil resources, as well as to take timely measures to protect the environment.

Key words: wind erosion, sand transport, Aeolian relief, deflation, mapping, relief, sand accumulation, sand desert, anthropogenic desertification.

Introduction. Relevance of the problem. The study of the influence of wind activity in the sandy desert is one of the most pressing problems of our time. Currently, this process is increasing due to climate changes and increased economic activity, which leads to rapidly changing environmental conditions in the ecosystems of sandy deserts.

The main terrain-forming factor in the sandy desert is wind activity, which leads to blowing, transferring and depositing sand. In practice, the transfer and deposition of sand leads to the formation of sand drifts, and blowing – to the exposure of the bases of various engineering structures and vegetation. Therefore, it is very important to know the direction and intensity of the development of these processes in the sandy desert. As a result of Aeolian processes that took place in sandy deserts for a long time, the original loose-sand layer was intertwined and dissected, and the modern Aeolian relief was formed, which acquired a certain wind-erosion stability over a large area and is in dynamic equilibrium. This is accompanied by a number of natural factors that cause overgrowth and compaction of the surface of Aeolian forms. A fairly persistent desert system can be disrupted. The reason for the violation of the natural balance may be a change in any natural factor or human economic activity. Released from the protective soil and vegetation cover, the loose sand mass under the influence of wind begins to move, and

the process of active deflation begins. If this process occurs near economic objects, it is not difficult to imagine the consequences that it can lead to.

The surface of overgrown Aeolian forms under natural conditions (outside the influence of anthropogenic factors) has various degrees of deflation, but in General it is characterized by increased stability, which is caused by the presence of vegetation cover. The undifferentiated Aeolian relief is weakly exposed to natural deflation. For example, gently undulating Sands and mantle-like sand accumulations usually lack well-defined traces of removal, transfer, and accumulation of Aeolian material. The susceptibility to deflation of strongly dissected Aeolian forms is differentiated by terrain elements. Sandy ridge weakly breaks the lower part of the slopes and interbed lowering of the slopes due to the relatively dense vegetative composition, and bottoms, in addition, due to the greater content in sand dust particles and shallow occurrence of the primary little compacted sediments or groundwater, the local basis deflation. The tops of the ridges and the upper part of the slopes may show signs of deflation in the form of ulcers and raincoat-like accumulations of sand or even dunes. The process of deflation at the tops of ridges increases due to greater desiccation of soils and deeper wind influence [2,3,4].

Research methods. In the course of this work, we used methods of historical, engineering-geological, ecological and geographical analogues, methods of geobotanical indication, comparative morphological method of studying soil profiles, and others. Determination of morphology, granulometric composition, physical and chemical properties of soils was carried out in accordance with accepted methods in soil science. Statistical processing methods were used to analyze information accumulated in various areas in the form of various databases.

Discussion of results. The development of effective and economic measures to protect against sand drifts and blowing of economic objects is unthinkable without reliable information on the wind-erosion stability of the sandy surface.

Depending on the stage of design and construction of objects, the details of information will change. So, for a feasibility study (feasibility study) of the construction of an object, in which the important point is the choice of the location of its site or route, the characteristics of wind erosion resistance of sand should be for a significant area, but somewhat schematic, without fractional detailing of contours. The map scale should be small, of course.

When the locations of objects are determined (the stage of the technical project), it is impossible to do without a detailed study of the adjacent territory, without a large-scale map (scheme) that reflects all the variety of forms and intensity of deflation processes [1,2,7,19].

The practice of construction in the sand shows that active protective measures can be carried out only after the completion of the entire construction complex, when the original surface of the sand changes.

Most often, the option of studying the wind erosion resistance of the sand surface and drawing up a map (diagram) on an already built object is carried out. In this case, the developed classification and, accordingly, the map legend should take into account, in addition to the natural types of sand that reflect the natural process of Aeolian relief formation, also the anthropogenic forms (types) of sand surfaces formed as a result of construction work. These are so-called "technogenic Sands" [12,15,20].

An important point in mapping the wind erosion stability of sand is the development of a classification of wind erosion processes. Most researchers, when developing a classification of the relief of sandy deserts for mapping purposes, divide all Aeolian forms according to the degree of surface anchoring into two (overgrown and bare) or three (overgrown, semi-overgrown and bare) categories. In the latter classification, the category of semi-overgrown most often includes a barkhanno-bumpy complex, which is a transition stage from overgrown to overgrown or Vice versa. However, in the sandy desert, along with the three categories mentioned, there are a number of Aeolian forms whose sandy surface is at a stage of eroding or overgrowth that does not fit any of the categories mentioned. Meanwhile, it is very important to know the degree of substrate exposure, both for predicting the Aeolian process, and for developing specific measures to prevent it during economic development of the territory.

Classifications based only on geobotanical features do not allow us to fully determine the wind erosion state of the sandy surface. In this regard, along with the geobotanical method, the geomorphological method can be important, which can be used to study the intensity of deflation by the shape and mass of accumulating sand [5,10,11,17].

Since the accumulation of sand is the result of blowing and transferring its volume, it can serve as a criterion for the intensity of the process. Consequently, the larger the volume of accumulating sand, the more intense the deflation process. Thus, small accumulations of sand in the form of a raincoat on the overgrown surface of the Aeolian form can only indicate a weak deflation, and the presence of single dunes - more intense. At the same time, it should be assumed that in the desert, sand accumulation usually occurs in the immediate vicinity of the sources of removal. Exceptions are cases when Aeolian Sands are deposited on hard or compacted surfaces (takyrs, plateaus, salt marshes, etc.), where they acquire greater mobility. Sand is also transported over considerable distances in a wind regime characterized by the dominance of one direction. Such cases should be considered separately [3,8,10,11].

The presence of sand ripples is a sure sign of the process of sand transport over a bare or overgrown sandy surface to varying degrees. Only a well-drawn sandy surface with a dense shrub and especially grassy cover does not have obvious traces of sand ripples. However, it is impossible to talk about the absolute immobility of sand on overgrown Aeolian forms, since the dried-up surface horizon with a thickness of about 5 cm is devoid of sod that binds it, and some movement of the sand substrate occurs in strong winds. But for economic objects, this transfer is practically not dangerous.

The following classification of types of sandy surfaces according to the degree of exposure to deflation is proposed:

– No deflation - overgrown surface with no signs of sand ripples
– Deflation is weak – sand ripples and raincoat-like sand clusters without a characteristic ridge;
– Moderate deflation – sand ripples, raincoats, ridges and rare small (0.5-1.0 m) dune formations;
– Significant deflation – a combination of dunes and dune chains in combination with overgrown (more bumpy) forms;
– Deflation is strong, continuous – the presence of a bare dune field with individual plant specimens on inter-dune depressions.

The first type (no deflation) it is noted on overgrown weakly fragmented Aeolian formations, which usually form gently undulating Cumulus Sands and cloak-like sand clusters. The first and third are found mainly on the periphery of sandy massifs, and the second – on the edge of irrigated land, the banks of lakes and salt marshes. Under natural conditions, the overgrown sandy surface is not subject to deflation. However, if the upper sod layer is mechanically disturbed, deflation ulcers and accumulation of sand in the form of raincoats and even small dune forms can form on gently undulating Sands.

The second type (weak deflation) is most widely represented in the sandy desert. Typical for overgrown (slopes, peaks) and slightly overgrown (peaks) with varying degrees of dismemberment of ridge Sands and their combinations. The degree of exposure to deflation is differentiated by terrain elements. The lower part of the slopes and lower Aeolian forms are less susceptible to erosion, and the tops are more susceptible to erosion.

The third type (moderate deflation) is typical for poorly overgrown strongly dissected ridge Sands. Inter-ridge depressions and the lower parts of the slopes of the ridges are not subject to deflation. The tops and upper part of the slopes are heavily raked.

The fourth type (deflation) significant more often in his notes on undifferentiated Sands, sand-hilly complex. The degree of exposure to deflation is differentiated by types of terrain: continuous deflation is subject to dune forms, partially (weak) bumpy. Inter-barkhane depressions are mostly overgrown, the movement of barkhane forms is weak, more often there is only a rearrangement of ridges and an intensive transfer of sand in the form of a wind-sand stream.

The fifth type (strong, continuous deflation) includes sand dunes. The movement of sand material occurs in the form of wind-sand flow and the movement of Aeolian forms. In this type, two subtypes should be distinguished: barkhany Sands lying on a loose sandy substrate; barkhany Sands lying on dense rocks (takyrs, Shors, outcrops of bedrock, figures 1-2). The second subtype is characterized by greater mobility and, as a rule, worse growing conditions [2,6,7,11,12].

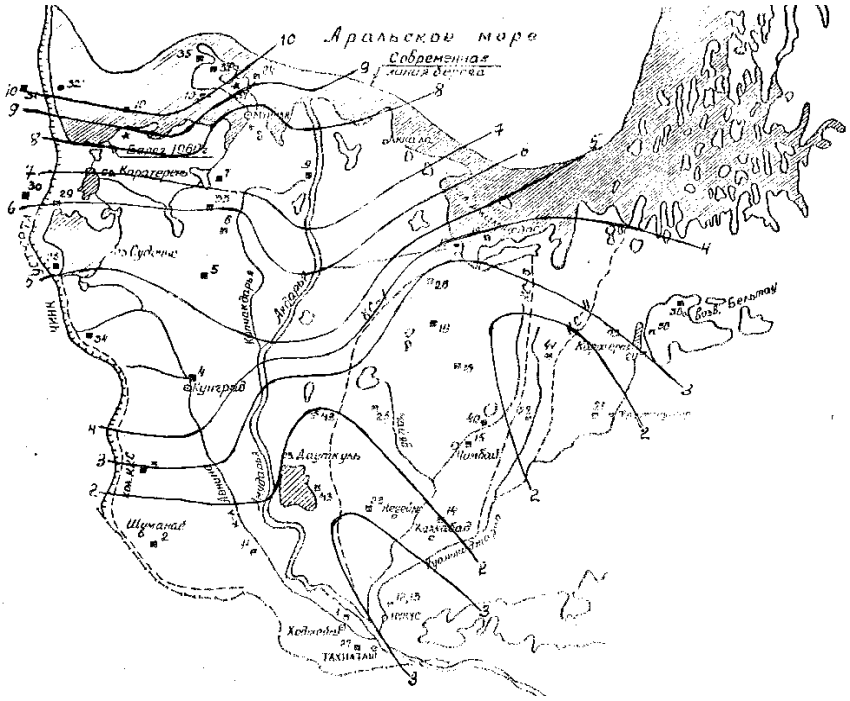

Figure 1 – Distribution of dry deposition of aerosols in the southern Aral sea, t/ha per year (2012-2016)

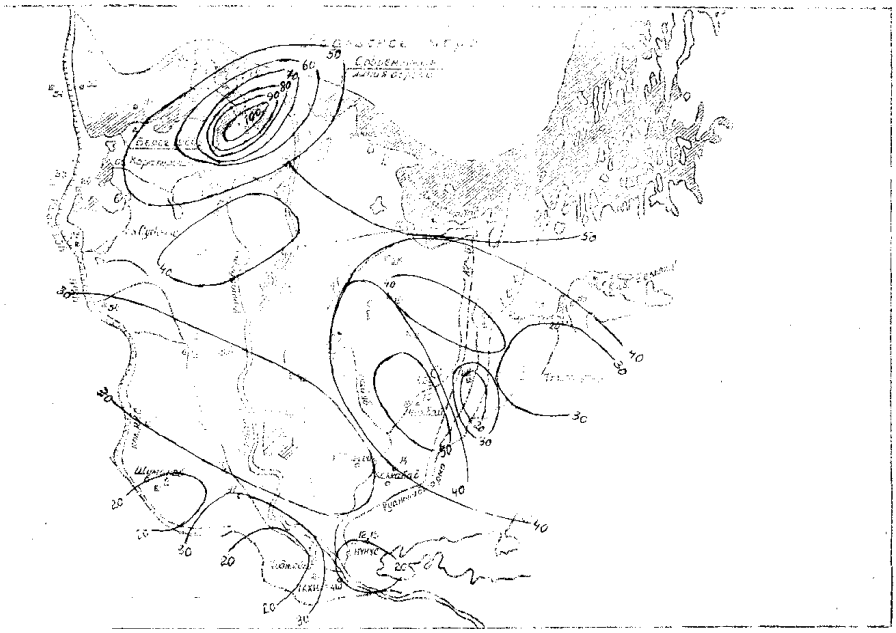

Figure 2 – The distribution of salt deposition from atmospheric dry aerosol in the southern Aral sea, kg/ha / year (2012-2016)

The latest research on this issue was conducted on 4 zones and the following data were obtained:

1) the zone of the drained bottom of the Aral sea for the stipulated period annually falls an average of 8-10 t/ha of dust and salt, of which their water-soluble salts range from 100 to 150 kg/ha.,

2) in the area of the Aral sea coast 7-8 t/ha and 70-100 kg/ha of salt,

3) in the non-irrigated zone 5-6 t/ha and 50-70 kg/ha

4) in the irrigated zone from 1.5-2.0 to 3.0-4.0 t/ha and, accordingly, salt from 20-30 to 40-50 kg/ha.

The composition of these aerosol precipitates is mainly dominated by sulfate and chloride, and less often by carbonate salts of calcium, magnesium, and sodium.The quantitative and qualitative composition of atmospheric precipitation significantly affects the normal growth, development and yield of numerous

natural and cultivated plants, especially in the arid zone of the globe. In addition, this effect is also found in other biotic and abiotic environmental objects [5,9,10,11,13].

The analysis of precipitation shows that their quantitative assessment depends on the General regularities of natural and artificial processes.

The results of the analysis show that in the composition of dry aerosol precipitation, the General trend of water-soluble salts, depending on the intensive desalination of the former drained sea bottom, their accumulated amounts decreased by 1-2 or more times, and, conversely, the total amount of dry dust-salt precipitation increased by 2-3 or more times due to atmospheric phenomena and especially as a result of anthropogenic processes of drilling oil and gas operations, planning of the drained sea bottom for the purpose of phytomelioration or forest reclamation, etc. [4,6,7,9,16].

When studying and mapping types of sandy surfaces using the proposed method, it is possible to obtain the necessary characteristics of the intensity and direction of deflation processes in a particular territory. This will allow you to develop sound recommendations for the placement of objects, conduct a preliminary assessment of the need for protective measures, their locations and approximate volumes. For a broad and systematic study of deflation processes in the desert and drawing up maps that reflect with greater accuracy the distribution of various types of sandy surfaces, it is advisable to use satellite images and aerial photographs. This will significantly reduce the amount of expensive ground field work and time for mapping, as well as improve the quality of map material [14,16-18].

In the regional study and mapping of wind erosion stability of large territories for the purposes of economic development of the desert, it is necessary to highlight areas that are potentially resistant to deflation by their mechanical strength, determined mainly by the lithology of the initial deposits. They are favorable for the location of various objects.

According to the proposed classification, surfaces should be classified as areas that are not subject to deflation. In the drained bottom, such surfaces are represented by takyr outcrops, fragments of a clay Delta plain.

The development of protective measures at a specific site should be based on the results of studying and mapping the wind erosion resistance of sand on a larger scale. Here there is a large detail of the selected types of sand. In addition to the five types of sand surfaces identified above, various combinations, transition types, and subtypes can be contoured. In this mapping, the selected types of surface sand are grouped into two categories:

- sand that does not require fixing;
- sands that require fixing.

The first category includes the sand surface with a dense well-preserved turf or with a few ulcers of deflation. There is practically no sand transport formed here.

The second category should include surfaces with disturbed (varying degrees) sod with accumulation of sand from raincoats to dunes. Here, the number of types of sand surfaces identified reaches 8-9.

An important point in mapping the wind erosion resistance of a sandy surface for technical and economic purposes and for the development of protective measures is to determine the scale and area of the survey. Experience shows that for the first purposes, the scale of the map should not be less than 1:500,000, and the area is determined depending on the tasks and research program. To develop protective measures for a specific economic object, the survey scale should not be smaller than 1:20000 on linear objects (pipelines, roads, power lines), and on site - no smaller than 1:2000. If the area of the study area in the area of the projected site object allows, then the survey scale should be the largest, approaching the scale of the working drawing of the technical project as much as possible. This will also allow you to Express in scale all the planned protective measures (their type and parameters).

The mapped lane for linear items is determined by the length of the route, and the width is determined by the zone of influence, which, depending on the wind erosion state of the sand, can range from tens to hundreds of meters. The more uniform the sandy surface, the narrower the mapping band may be. The mapped area of a site object is also determined by the area of sand broken during construction [14,16].

The results of the study of wind erosion resistance of sand and the map compiled at the same time has a certain expiration date. After 5 years, they must be adjusted. Information on maps that characterize the wind-erosion state of the sandy surface allows you to plan the necessary protective measures with high confidence. However, they provide information about the quantitative side of the ongoing processes,

which complicates the task of determining the width of the protective zone for objects with windward and leeward sides.

The intensity of the deflation processes, its quantitative characteristic is determined by post-processing of data of the wind regime observed at the stationary sites where deflationary processes are determined by instrumental fixation of the relief on the profiles, sites size of 1-2 ha, and also observed at quantifiable portable sand vetroresina thread.

In office conditions, the regime is subjected to a comprehensive analysis, since it is the wind that is the main relief-forming factor. The study of the wind regime of deserts is important for understanding the ongoing geomorphological processes and, in particular, for studying the processes of movement and accumulation of sand.

Currently, there are several methods for processing wind data. The simplest and most widely used method was Described by O. A. Drozdov (1957). The method suggests using the repeatability of wind directions (the number of cases) for 8 or 16 points and the average values of wind speeds for these points. Usually, a series of observations from 10 to 20 years is used to obtain stable data. The average values of wind speed, taking into account their direction, well reflect the General wind regime of a certain area, and allow you to identify the prevailing winds, i.e. those that can cause sand drifts and blowouts [3,17,20].

The considered method, as well as wind erosion maps, does not give a quantitative characteristic of the processes occurring. To some extent, the question of interest is solved by using not the average wind speeds and not the number of cases of winds of different points, but the sum of the wind speeds of certain points that cause sand transport. However, in this case, it is taken into account that sand material of various sizes begins to move only when the wind speed reaches a certain threshold value (table 1)

Table 1 – Start of sand movement depending on the size

№	Type of sand	Grain diameter, mm	Wind speed, m/s
1	Fine	0.1-0.25	4.5-6.7
2	Medium-grained	0.25-0.5	6.7-8.7
3	Coarse	0.5-1.0	9.8-11.4
4	Coarse grainy	1.0-2.0	11.4-13.0

We usually have materials for one-time observations per day of the wind direction and speed on the weather vane at an altitude of 10 m. Given the speed recorded by the weather vane is not identical to the wind speed at the surface (it is much lower at the earth's surface), the threshold ground speed is determined by calculation. It is proposed (Gvozdikov, 1966) for these purposes, the wind speed at a height of 10 cm above the dune surface is determined by the formula U10 = 0.475 U1000: over the sanded inter-dune takyrovidny decline by the formula U10 = 0.333 U1000; over a sand and pebble plain U10 = 0.333 U1000 . Here U1000 is the wind speed at an altitude of 10m [3,5,8].

For practical purposes, wind speeds greater than 5-6 m/s on the weather vane are taken as the threshold wind speed, since at these speeds sand grains begin to roll on the sand surface, and the wind speed itself at a height of 10 cm is 3.5-4 m/s.

Threshold speeds as mentioned above can be used to construct hodographs by the sum of cases or by the sum of speeds.

For a more visual graphical representation of the annual resulting wind activity, it is also possible to build hodographs that represent the vector sum of the number of cases of wind directions, deferred on a scale corresponding to the speed of each observed case, or the sum of the speeds for a certain observation period. This method has found application in practice. However, hodographs or wind roses based on the sum of active wind speeds or on the indicators of the resulting wind for a certain period give an idea of the wind regime of a particular area. They can only be used to judge the direction of the prevailing winds [3,4,8].

The order of construction of the hodograph is very simple and follows the sequence: 1) it is drawn from an arbitrary point corresponding to 1 January; 2) the direction and speed of wind are shown by segment (vector) emanating from the point in the direction the wind is blowing; the length of the vector is proportional to the observed wind speed in the adopted scale; 3) each subsequent (in order of observation)

the case of sufficiently strong wind is also represented by a vector, the beginning of which coincides with the end of the previous. The result is a broken line, sometimes quite bizarre, reflecting successive changes in wind direction and speed.

The hodograph of this type gives a clear idea of the features of the wind regime: the longer the hodograph, the more active the wind; the more straight the hodograph line, the more pronounced the prevailing wind. A broken line indicates that the wind regime is unstable. Strong and stormy winds are well represented on the hodographs, and they are represented on the graph in longer segments.

Wind mode data processing is possible based on wind energy. Most researchers agree that the energy is proportional to the cube of speed. L. G. Dobrin (1965) for ease of use of the wind energy indicator suggests using coefficients that reflect the energy capacity of the wind of a particular speed, taking 4 m/s as a unit of the cube of wind speed [2].

Table 2 – Coefficients of wind energy increase (K) at different speeds (U)

№	U, м/с	K
1	5	2
2	6	3.4
3	7	5.4
4	8	8
5	9	11.4
6	10	15.6
7	11	21
8	12	27
9	13	34.4
10	14	43
11	15	53
12	16	64
13	17	77
14	18	94
15	19	113
16	20	125

Further data processing is performed according to the above method. However, they do not reflect the quantitative (m3/m) indicators of sand transport, but with high confidence indicate the direction of General sand transport by season [2 16,19, 20-25].

Currently, a number of methods have been proposed that allow us to obtain information about the quantitative transfer of sand by processing wind regime data. They will be discussed in detail below.

There are several ways to study deflationary processes that reflect the quantitative side of the process. Currently, the geodesic method is widely used. The essence of the method is that geodetic tools are used to monitor the dynamics of the terrain.

Depending on the purpose of the study (the study of General deflation processes, the dynamics of removal or accumulation, or only the movement of Aeolian forms), the survey using theodelite or level is performed once a year, once a season. When theodelite survey is selected characteristic area of 1-2 hectares. The angles of the characteristic sections are fixed by constant reference points. Large-scale site plans are a good material for comparative study of sand movement. When leveling, individual points of the profile are fixed. Based on the survey data, profiles of one point are drawn, which gives a fairly clear illustration of the ongoing changes in the structure of the relief [3,16,17,26,27].

Of the two considered geodetic methods for observing changes in the sand topography, the most complete information is provided by a planned survey of the sandy surface. The terrain plans reflect the overall displacement of the sand chains, the effect of lateral drift on the ridge displacements along the chain front, and the effect of vegetation on the overall course of terrain formation. Cross-section profiles

are less informative. They only give an idea of the General displacement of the Aeolian relief. When solving the target task, it is advisable to combine both (methods) forms of observations on the same site, when the intervals between planned surveys are supplemented by measurements on profiles.

Conclusion. Thus, the paper shows the possibility of mapping and predicting the transformation processes of the newly formed sandy desert at various scales, and maps based on the classification of satellite images can serve as the basis for further detailed mapping of moving Sands using theodolite survey and other methods of topographic analysis of the terrain. The main content of medium – scale maps of deflationary transformation processes is showing the main characteristics of the sand transport process and mapping its intensity. It is in this capacity that they can be a really practical basis for detailed mapping, which is necessary both for sand protection works and for the design of engineering structures. The obtained data on the mechanism and structure of the entire air-soil flow, starting from the moment of its formation, i.e. in the blowing zone, and ending with the transfer and deposition of soil particles by wind in the accumulation zone, make it possible to increase the level of scientific validity of the rational use of soil resources, as well as to take timely measures to protect the environment.

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ДЕФЛЯЦИЯЛЫҚ ПРОЦЕСТЕРДІ ЖӘНЕ АРАЛ ТЕҢІЗІНІҢ ҚҰРҒАҒАН ТАБАНЫНДАҒЫ ҚҰМ ТАСЫМАЛДАУДЫ ЗЕРТТЕУДІҢ КЕЙБІР МӘСЕЛЕЛЕРІ

Аннотация. Мақалада құмды шөлді зерттеу нәтижелері қарастырылады, бұл эолалы рельеф формаларын қалыптастыру, жылжыту және дамытудың бірқатар маңызды заңдылықтары мен механизмдерін алуға және ашуға мүмкіндік берді. Заңдылықтарды орнату түрлі объектілердің құмды шөлдегі боранмен күресудің бірқатар практикалық мәселелерін шешуге ықпал етеді. Осы аумақтың даму перспективаларына байланысты аталған процестер бағыты мен қарқындылығын білу өте маңызды. Құмды шөлдегі жел қызметінің әсерін зерттеу қазіргі заманның өзекті мәселелерінің бірі болып саналады. Қазіргі уақытта бұл процесс климаттың өзгеруіне және экономикалық қызметтің ұлғаюына байланысты күшейе түсуде, бұл құмды шөл экожүйесінде жылдам өзгеретін экологиялық жағдайға әкеледі.

Құмды шөлдегі рельефті құрайтын негізгі фактор – желдің белсенділігі, бұл құмды үрлеп, тасымалдап әрі тұндырады. Іс жүзінде құмды тасымалдау және тұндыру құмды шөгіндінің пайда болуына, ал үрлеу түрлі инженерлік құрылымдар мен өсімдік негізін ашуға әкеледі. Сондықтан құмды шөлде аталған процестер бағыты мен қарқындылығын білу өте маңызды.

Құмды шөлде ұзақ уақыт бойы жүретін эолды процесс нәтижесінде бастапқы борпылдақ құм қабаты қайта өңделіп, бөлініп, эолды рельеф пайда болды, ол айтарлықтай аймақта белгілі бір жел эрозиясы тұрақты және динамикалық тепе-теңдікте болды. Бұл эол формаларының беткі қабатының өсуі мен тығыздалуын анықтайтын бірқатар табиғи факторлармен бірге жүреді. Шөлдің тұрақты жүйесінің бұзылуы мүмкін. Табиғи тепе-теңдіктің бұзылуының себебі кез-келген табиғи фактордың өзгеруі немесе адамның экономикалық белсенділігі себебінен болуы мүмкін. Қорғаныш топырақ – өсімдік жамылғысының астынан босатылған борпылдақ құм массасы жел әсерінен қозғалады, белсенді дефляция процесі басталады. Егер бұл процесс экономикалық объектілердің жанында пайда болса, оның салдарын да болжауға болады.

Жұмысты орындау барысында тарихи, инженерлік-геологиялық, экологиялық және географиялық ұқсастық, геоботаникалық индикациялау, топырақ пішінін зерттеудің салыстырмалы-морфологиялық әдісін және т.б. пайдаландық. Топырақ морфологиясын, гранулометриялық құрамын, физика-химиялық және химиялық қасиеттерін анықтау топырақ ғылымында қабылданған әдістерге сәйкес жүргізілді. Әртүрлі мәліметтер базасы түрінде бағыттар бойынша жинақталған ақпаратты талдау үшін статистикалық өңдеу әдістері қолданылды.

Дефляциялық процестердің қарқындылығы, оның сандық сипаттамасы жел режимінің деректерін камералық өңдеу, дефляциялық процестер рельефті профильдерде көлемі 1-2 га алаңда аспаптық бекіту жолымен

айқындалатын стационарлық учаскеде байқау ұйымдастыру, сондай-ақ жел құм ағынында тасымалданатын құмды сандық есепке алу бойынша байқау ұйымдастыру жолымен айқындалады.

Камералық жағдайда режим жан-жақты талдаудан өтеді, өйткені бұл рельефтің негізгі факторы – жел. Шөлдің жел режимін зерттеу геоморфологиялық процестерді түсіну үшін, әсіресе, құмның жиналу процесін зерттеу үшін де маңызды.

Талдау нәтижелері құрғақ аэрозоль құрамында суда еритін тұздың жалпы тенденциясы, жиналған мөлшердің бұрынғы құрғатылған теңіз түбінің қарқынды тұзденуына байланысты 1-2 және одан да көп есе азайғанын және керісінше, құрғақ шаң-тұз түсімінің атмосфералық құбылыстардың, әсіресе мұнай-газ жұмыстарын бұрғылаудың, фитомелиорациялық немесе орман мелиорациялық жұмыстарды жүргізу мақсатында құрғатылған теңіз түбін жоспарлаудың және т. б. салдарынан 2-3 және одан да көп есе артқанын көрсетеді.

Түйін сөздер: жел эрозиясы, құмды тасымалдау, эол рельефі, дефляция, картаға түсіру, рельеф, құмды жинақтау, құмды шөл, антропогенді шөлейттену.

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НЕКОТОРЫЕ ВОПРОСЫ ИЗУЧЕНИЯ ДЕФЛЯЦИОННЫХ ПРОЦЕССОВ И ПЕРЕНОСА ПЕСКА ОСУШЕННОГО ДНА АРАЛЬСКОГО МОРЯ

Аннотация. В статье рассматриваются результаты исследования песчаных пустынь, которые позволили получить и раскрыть ряд важных закономерностей и механизмов формирования, образования, передвижения и развития эоловых форм рельефа. Установление этих закономерностей помогает решить ряд практических задач по борьбе с песчаными заносами в песчаной пустыне различных объектов. В связи с перспективами освоения этой территории очень важно знать направленность и интенсивность развития упомянутых процессов. Изучение влияния ветровой деятельности в песчаной пустыне является одним из актуальных проблем современности. В настоящее время этот процесс, в связи с климатическими изменениями и увеличением хозяйственной деятельности, усиливается, что приводит к быстроизменяющимся экологическим условиям в экосистемах песчаных пустынь.

Главным рельефообразующим фактором в песчаной пустыне является ветровая деятельность, приводящая к выдуванию, переносу и отложению песка. На практике перенос и отложение песка приводят к образованию песчаных заносов, а выдувание – к обнажению оснований различных инженерных сооружений и растительности. Поэтому очень важно знать направленность и интенсивность развития упомянутых процессов в песчаной пустыне.

В результате эоловых процессов, протекающих в песчаных пустынях в течение длительного времени, перевивалась и расчленялась исходная рыхлопесчаная толща и формировался современный эоловый рельеф, который на значительной площади приобрел определенную ветроэрозионную устойчивость и находится в динамическом равновесии. Этому сопутствуют ряд природных факторов, обусловливающих зарастание и уплотнение поверхности эоловых форм. Довольно стойкая система пустыни может быть нарушена. Причиной нарушения природного равновесия может стать изменение какого-либо природного фактора или хозяйственная деятельность человека. Освободившаяся из-под защитного почвенно-растительного покрова рыхлопесчаная масса под воздействием ветра приходит в движение, начинается процесс активной дефляции. Если этот процесс возникает вблизи хозяйственных объектов, то нетрудно представить последствия, к которым он может привести.

В ходе выполнения данной работы мы использовали методы исторических, инженерно-геологических, экологических и географических аналогов, методы геоботанической индикации, сравнительно-морфологический метод изучения почвенных профилей и другие. Определение морфологии, гранулометрического состава, физико-химических и химических свойств почв проводили в соответствии с принятыми в почвоведении методиками. Для анализа информации, накапливаемой по различным направлениям в форме различных баз данных, использовались методы статистической обработки.

Интенсивность дефляционных процессов, ее количественная характеристика определяется путем камеральной обработки данных ветрового режима, организацией наблюдений на стационарных участках, где

дефляционные процессы определяются инструментальным путем фиксирования рельефа на профилях, площадках размером 1-2 га, а также организацией наблюдений по количественному учету переносимого песка в ветропесчаном потоке.

В камеральных условиях всесторонному анализу подвергается режим, так как именно ветер является основным рельефообразующим фактором. Изучение ветрового режима пустынь является важным для понимания протекающих геоморфологических процессов и, в особенности для изучения процессов движения и накопления песков.

Результаты анализа свидетельствуют, что в составе сухих аэрозольных выпадений общая тенденция воднорастворимых солей, в зависимости от интенсивного рассоления бывшего осушенного дна моря аккумулируемых их количества уменьшилась на 1-2 и более раза, и, наоборот, общее количество сухих пыле-солевых выпадений увеличилось в 2-3 и более раза за счет атмосферных явлений и особенно в результате антропогенных процессов бурения нефтегазовых работ, планировки осушенного дна моря в целях проведения фитомелиоративных или лесомелиоративных работ и т.д.

Ключевые слова: ветровая эрозия, перенос песка, эоловый рельеф, дефляция, картографирование, рельеф, аккумуляция песка, песчаная пустыня, антропогенное опустынивание.

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RESEARCH AND APPLICATION OF METHODS FOR CALCULATING THE MEASUREMENT UNCERTAINTY OF INDUSTRIAL FLOWMETERS

Abstract. To create conditions for the recognition of Kazakhstani certificates of conformity and the results of product tests, an assessment of measurement uncertainty is required. In this regard, there has been an increase in the practical application in Kazakhstan of the concept of measurement uncertainty. The authors developed a physical stand for a mobile complex designed to verify electromagnetic flowmeters at the place of operation. To obtain verification results, programs were developed to calculate the uncertainty of an electromagnetic flowmeters using the NI LabView software. In addition, a model for estimating the uncertainty of the relative error of flowmeters was proposed, and the measurement uncertainty was estimated using three methods: standard, Monte Carlo and Kragten. Finally, a comparative analysis was conducted on the results of the estimation of the uncertainty of the relative error of the industrial electromagnetic flowmeter. All methods give standard uncertainty values that do not exceed the acceptable range of relative error (± 1%). However, Monte Carlo method gives better results for sufficiently large number of simulations. No significant differences between the results obtained using standard and Kragten methods were discovered. The Kragten method is preferable in the absence of the need to calculate the sensitivity coefficients when calculating the total standard uncertainty, which is important for complex measurement equations.

Key words: measurement uncertainty; standard GUM method; Monte Carlo method; Kragten matrix; verification; electromagnetic flowmeter.

Introduction. In the Republic of Kazakhstan, uranium mining is carried out by underground leaching – one of the most cost-effective and environmentally friendly mining methods. [1]. At the nodes of receiving and distributing the leach solutions, a large number of industrial electromagnetic flowmeters (EFM) are used to measure the quantities involved; they must be metrologically verified at the end of the calibration interval.

The generally accepted method for calibrating flowmeters using exemplary measuring instruments or calibration facilities accredited to ISO/IEC 17025-2017 can be costly and infeasible, mainly due to the staff and logistics costs associated with removing the flowmeters from the piping system. However, modern flowmeters are equipped with hardware and software that allow on-site verification that meets ISO 9001 requirements. Studies have already been conducted on the calibration of flow meters in the field of water supply and wastewater discharge [2].

The issues of the estimation of measurement uncertainty have been widely covered in terms of analytical measurements [3], the calibration of measuring instruments [3,4], and other studies [5-8]. International organizations have developed and prepared basic documentation for the international harmonization of approaches to solving metrological problems. These include the ISO/IEC 17025:2017 standard; the JCGM 100:2008 Joint Metrology Guidelines document, as the latest revision of GUM:1995, which provides guidance on measuring uncertainty in measurement; the International Dictionary of Metrology JCGM 200:2012, which presents the terms and concepts used in the field of metrology; and

JCGM 101:2008 (Supplement 1 to GUM:1995), which provides practical guidance on using Monte Carlo simulations to estimate uncertainty.

Methods. *Standard method* described in GUM (Guide to the Expression of Uncertainty in Measurement), has been applied worldwide for different measuring systems and is currently the standard procedure for estimating uncertainty in metrology [5, 9-11]. The GUM estimation of measurement uncertainty in analytical measurements has been widely reported in the literature [8, 12-14]. Examples of GUM estimation of the uncertainty of temperature, AC voltage, and pressure measurements are given in [13]. Meanwhile, [4] describes uncertainty assessment during the metrological certification of means of measuring the moment of inertia of electric motors.

Due to the complexity of calculations, the analytical estimation of the effective number of degrees of freedom using the Welsh-Satterthwaite formula remains an unsolved problem [3]. One approach to overcoming these limitations is to use a convolution of the probability distributions of input quantities, for example, using the Monte Carlo simulation method [15].

The essence of the *Monte Carlo method* is as follows: each time the measurement function is calculated, it generates randomly generated input values that vary around its nominal value within the uncertainty interval in accordance with the distribution law.In [16], examples of the application of the Monte Carlo simulation method for estimating the measurement uncertainty ofvarious practical problems are given: evaluating the real efficiency of a fuel cell, measuring torque, preparing a standard cadmium solution, and measuring the Brinell hardness.

Kragten method (spreadsheet method) is recommended for complex expressions to simplify calculations. This procedure uses an approximate numerical method of differentiation and requires only the numerical values of the parameters, and their uncertainties [6]. It assumes either that the measurement model is linear in the input variables or that the uncertainty of the corresponding input quantity is small compared to its value. Kragten method advantage lies in the fact that the correlation between variables can be easily taken into account by adding the appropriate elements in the spreadsheet.

The analysis showed that in most cases, the GUM, Kragten and Monte Carlo methods give almost the same value for the standard uncertainty associated with the estimation of the measured value. The differences become apparent when the distributions are far from normal and the measurement result nonlinearly depends on one or more input quantities. Where there is significant non-linearity, the standard GUM method is not recommended. However, nonlinearity can be taken into account in the GUM by including higher order terms in the calculations [17].Where the distributions differ significantly from normal, the Kragten and standard GUM methods give a distorted estimate of the standard uncertainty, while the Monte Carlo method allows a determination of the distribution law of the output quantity and, accordingly, displays the real “coverage interval” [18, 19].

The above methods have not yet been applied to the estimation of the uncertainty of flow measurement. This problem is the subject of research in this article. The aim of the work is to study methods for estimating uncertainty during the calibration of flowmeters in situ without removing them from their place of operation.

Application of methods. The uncertainty of the industrial flow meter relative error is estimated based on the Standard of the Republic of Kazakhstan ST RK 2.328-2015 “Electromagnetic flow meters: Verification Technique”. This standard proposes the following measurement model:

$$\delta_Q = \frac{Q_r - Q_p}{Q_p} \times 100, \quad (1)$$

where Q_r is the value of the flow according to the metering values of EFM, and Q_p is the flow rate according to the indications of the reference Coriolis flowmeter (CFM).

However, this Standard regulates the estimation of the uncertainty of the relative error of electromagnetic flowmeters using only type *B.*

The authors substantiate and propose calculating the uncertainty using not only type *B* but also type *A* [20]. The calculation of type *A* includes statistically processing the results of multiple measurements, namely the calculation of the mathematical expectation, variance, and standard deviation. An estimate of the flow rate Q is the arithmetic mean of $n = 11$ observations Q_i $(i = 1,2, ..., n)$ for each point being verified ($j = 4$): $\bar{Q}_p$ - for the reference flow meter; $\bar{Q}_r$- for the verified EFM.

The standard measurement uncertainties of the electromagnetic and reference flowmeters using type *A* are calculated by the formulas:

$$u_{Aj}(Q_r) = \sqrt{\frac{\sum_{i=1}^{n}(Q_{ri}-\overline{Q_r})^2}{n(n-1)}};\ u_{Aj}(Q_p) = \sqrt{\frac{\sum_{i=1}^{n}(Q_{pi}-\overline{Q_p})^2}{n(n-1)}}, \quad (2)$$

where Q_{ri}, Q_{pi} are the *i*-meter readings at the *j* point being verified.

The standard uncertainty of the relative error of type *A* at each verified point (j = 1, 2, 3, 4) is calculated by the formula:

$$u_{A_j}(\delta) = \sqrt{C_r^2 u_{A_j}(Q_r)^2 + C_p^2 u_{A_j}(Q_p)^2},$$

where C_r and C_p are sensitivity coefficients, which are defined as partial derivatives of equation (1) with respect to the corresponding variables.

The final value of the standard uncertainty of the relative error of EFM type *A* is:

$$u_A = \left(\sum_{j=1}^{4} u_{A_j}(\delta)\right)/4. \quad (3)$$

To calculate the total standard uncertainty of the EFM relative error, we have:

$$u_C(\delta) = \sqrt{u_A^2(\delta) + u_{B\Sigma}(\delta)}, \quad (4)$$

$u_{B\Sigma}(\delta)$ - the type *B* uncertainty calculation includes the relative error uncertainties of the EFM and the reference flow meter in accordance with ST RK 2.328-2015.

The calculation of the expanded uncertainty of the relative error of the EFM is performed according to the formula:

$$U(\delta) = k \cdot u_C(\delta). \quad (5)$$

The measurement result can be written as: $\delta \pm U(\delta)\%$; *p=0,95* .

Applying *the Monte Carlo method* requires selecting the quantities of model estimation to be performed and the confidence level *p*. It is best to choose a sufficiently large value of *m* in comparison with *1/*(*1-p*) (for example, exceeding it by 10^6 times).

The simulation of the process of estimating the uncertainty of the EFM relative error is performed as follows:

a) two arrays of random numbers are generated, obeying uniform distribution laws, with a volume of $m = 10^6$ for input quantities: Q_r is the result of measuring the flow rate with EFM; Q_p is the result of measuring the flow with a reference CFM;

b) an array of an estimate of the output value is generated– the relative error of the EFM (δ);

c) estimates of the following parameters of the resulting distribution are calculated:

- total standard uncertainty: $u_c(\delta) = \sqrt{\sum_{i=1}^{11}\left(\delta_i - M(\delta)\right)^2/10},$

where *M(δ)* is the mean of the relative error of the EFM;

- expanded uncertainty: $U(\delta) = \frac{1}{2}[\delta_{975000} - \delta_{25000}]$;

- coverage coefficient: $k = U(\delta)/u_c(\delta)$;

d) the obtained measurement result is written as: $\delta \pm U(\delta)\%$; *P=0,95* .

Kragten method. The spreadsheet method is recommended for complex expressions in order to simplify calculations.

In the expression for the uncertainty of the EFM relative error:

$$u\left(\delta(Q_r, Q_p)\right) = \sqrt{\sum_{i=r,p}\left(\frac{\partial\delta}{\partial Q_i}u(Q_i)\right)^2}$$

the partial differentials ($\partial\delta/\partial Q_r$), ($\partial\delta/\partial Q_p$) are approximated by finite differences.

This method provides acceptable accuracy for practical purposes when it is considered taking into account the necessary approximations made when evaluating the values $u(Q_i)$. In [6], this question is discussed more fully.

The total standard uncertainty of the relative EFM error is calculated by the formula:

$$u(\delta) = \sqrt{u^2(\delta, Q_r) + u^2(\delta, Q_p)}.$$

Expanded uncertainty of the EFM relative error:

$$U(\delta) = k \cdot u(\delta).$$

The measurement result is written as: $\delta \pm U(\delta)\%$; $P=0,95$.

Results of the experiments. The EFM calibration experiments were carried out on a physical model of the geo-technological information and metrological complex (GIMC) in the laboratory of the Department "Automation and Control" of the Almaty University of Power Engineering and Telecommunications named after G. Daukeev.

The metrologist's workstation interface for the verification developed in the software LabView (NI, USA) is shown in figure 1.

The operator manually enters the environmental conditions and the parameters of the fluid being verified (leaching solution). The verification process includes measurements at four verified points. At each point on the "forward" and "return" paths of the regulated valve, eleven flow values are measured using the calibrated EFM and the reference CFM. The experimental results are entered into the database of flowmeter readings, which are then used in the program to calculate the uncertainty of the relative error of the calibrated flowmeter, also developed in LabView [21]. Data from the database of flowmeter readings are used to calculate the uncertainty of the relative error of the calibrated flowmeter using three methods: GUM, Monte Carlo, and Kragten.

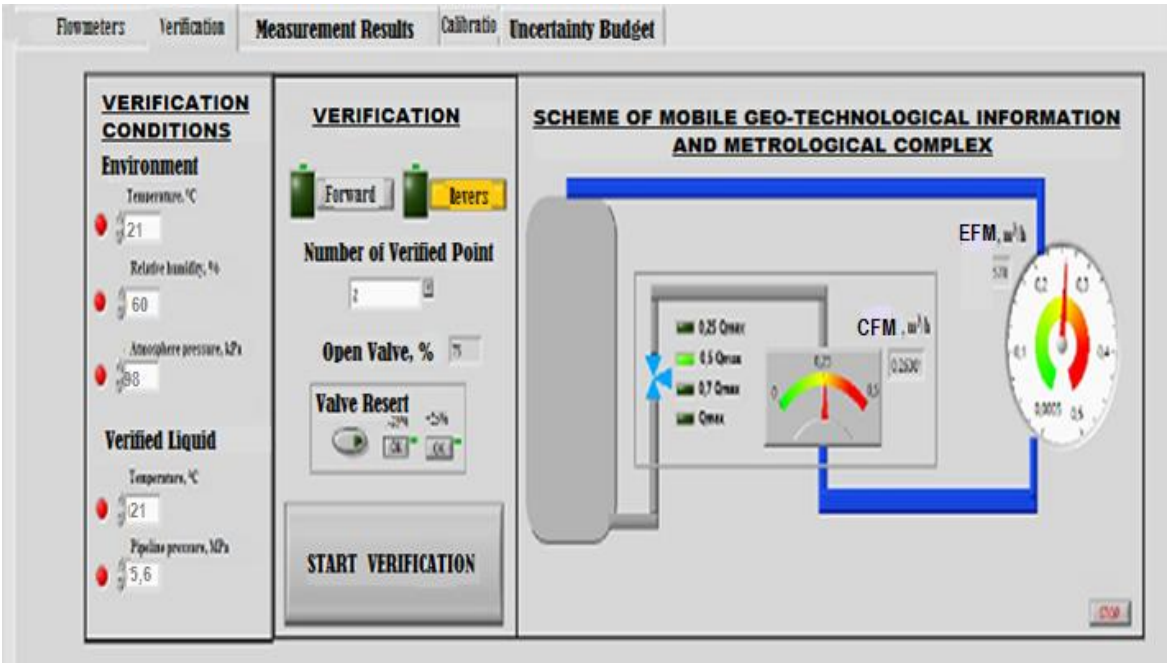

Figure 1 – The interface of the metrologist's workstation for verification

The result of estimating the uncertainty of the relative error of the verified flow meter using the GUM method and the Monte Carlo method of the 4th verified point (Q=5700 dm3/h = 95% Qmax) is presented as an uncertainty budget [22].

The results of applying the GUM, Monte Carlo, and Kragten methods for four control points when calibrating an electromagnetic flow meter are shown in table 1 (estimates of relative error - δ, expanded uncertainty - U, repeatability limit (convergence) - u_r, coverage interval - CI).

Table 1 – Comparative table of the calculated values for the four control points using the GUM, Monte Carlo, and Kragten methods

Verified point	Estimated parameters,%	GUM method	Kragten method	Monte Carlo method	D1, %	D2, %
95% ofQ_{max}	δ U u_r CI	0.007 0.689 0.352 [-0.682; 0.696]	0.007 0.701 0.358 [-0.694; 0.708]	0.007 0.654 0.337 [-0.651; 0.665]	0 1,8 1.6	0 5,0
75% ofQ_{max}	δ U u_r CI	-0.003 0.677 0.345 [-0.680; 0.674]	-0.003 0.667 0.340 [-0.670; 0.664]	-0.003 0.654 0.333 [-0.654; 0.648]	0 1.5 1.4	0 3,4 4.2
50% ofQ_{max}	δ U u_r CI	0.015 0.839 0.428 [-0.734; 0.944]	0. 015 0.855 0.437 [-0.750; 0.960]	0.01 0.656 0.335 [-0.645; 0.665]	0 2 2	33,3 21,8 21.7
25% ofQ_{max}	δ U u_r CI	0.011 0.768 0.392 [-0.655; 0.881]	0.0112 0.783 0.391 [-0.655; 0.881]	0.005 0.655 0.334 [-0.653; 0.658]	0.4 1.9 0.26	54,5 14,7 14.8

According to table 1, graphs of the dependence of the uncertainty of the relative error on the experiment number (x – axis - experiment number), obtained by both methods were plotted (figure 2).

The graphs obtained using the Monte Carlo method (MC - solid white lines) show a constant value of the dispersion of the uncertainty of the relative error within ± 0.65%. The graphs obtained using the GUM method (GUM - dashed yellow lines) show the changing values of the spread of uncertainty of the relative error within ± 0.9%. In this case, the limit of the permissible relative error of the EFM is ± 1%. The graphs obtained using the Kragten method (MKr - solid blue lines) essentially repeat the GUM graphs.

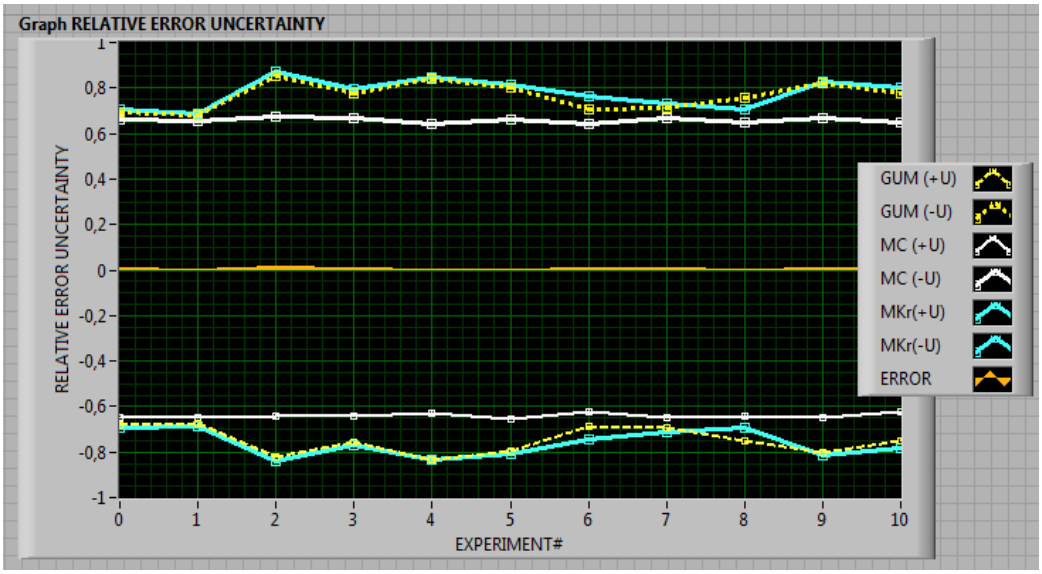

Figure 2 – Comparison of obtained relative error by three methods
(Uncertainty of the relative error vs the number of experiment)

Discussion. The authors performed a comparative analysis of the considered Monte Carlo and Kragten uncertainty estimation methods and the recommended standard GUM method. In a comparative analysis of the data from Table 1 and Figure 2, we can draw the following conclusions.

A comparison of the GUM and Kragten methods (data from column D1 in Table 1) showed that there are no differences between the estimates of the measured value (relative error), the differences between the expanded uncertainty and repeatability are less than 2%, and the coverage interval does not exceed ± 1% for each verified point in both methods.

The comparison of the GUM and Monte Carlo methods (data of column D2 in Table 1) showed that the differences between the estimates of the measured value (relative error) reach 55%, the differences between the expanded uncertainty and repeatability are not more than 21.8%, and the coverage interval does not exceed ± 1% for each verified point in both methods.

The large differences between the Kragten or GUM methods on the one hand and the Monte Carlo method on the other hand indicate significant deviations from the normality of the distribution of input quantities.

The calculations showed that all three methods (GUM, Kragten, and Monte Carlo) give values of standard uncertainty that do not exceed the permissible range of the relative error of EFM (± 1%).

The Monte Carlo method with a sufficiently large number of simulations gives a better approximation. However, Monte Carlo calculations take longer (due to the sorting and processing of large arrays), although they can be performed by less qualified personnel (no in-depth knowledge of mathematics is required). The Monte Carlo method can be considered as a practical alternative to the GUM uncertainty estimation method.

The Kragten method gives results similar to the GUM method. No significant differences between the results obtained by the GUM and the Kragten methods were noted. The Kragten method is preferable in the absence of the need to calculate the sensitivity coefficients when calculating the total standard uncertainty, which is important for complex measurement equations. The Kragten method is recommended as a less time-consuming tool for calculations.

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ӨНЕРКӘСІПТІК ШЫҒЫН ӨЛШЕГІШТЕР БЕЛГІСІЗДІГІН ЕСЕПТЕУ ӘДІСТЕРІН ЗЕРТТЕУ ЖӘНЕ ҚОЛДАНУ

Аннотация. Қазақстан Республикасында уран өндіру жерасты шаймалау әдісімен жүзеге асырылады әрі бұл өндірудің ең тиімді және экологиялық таза әдістерінің бірі. Бұл әдіске сәйкес шаймалау ерітіндісі айдау ұңғымалары арқылы беріледі, ал құрамында уран кездесетін ерітінді сору ұңғымасы арқылы сорылады. Жер қойнауы іс жүзінде бұзылмайды және тіпті бірнеше жыл ішінде толығымен қалпына келтіріледі. Сілтісіздендіру ерітіндісін қабылдау және тарату тораптарында мөлшерін өлшеу үшін көптеген өнеркәсіптік электрмагниттік шығын өлшегіштер қолданылады, олар тексеру аяқталғаннан кейін метрологиялық тексеруден өтуі керек. Үлгілі өлшеу құралдарын немесе ИСО/МЭК 17025-2017 стандарты бойынша аккредиттелген калибрлеу қондырғыларын қолданатын шығын өлшегіштерді калибрлеудің жалпы қабылданған әдісі қымбат және кейде қолжетімсіз болып жатады, негізінен қызмет көрсететін қызметкер жалақысы мен құбыр жүйесінен шығын өлшегішті алып тастауға байланысты логистикалық шығындар болып келеді. Авторлар пайдалану орны бойынша өнеркәсіптік шығын өлшегіштерді тексеру процедурасын жүргізуге арналған жылжымалы метрологиялық кешеннің физикалық стендін әзірледі.

Қазақстандық сәйкестік сертификаттарын және өнімге сынақ нәтижелерін тануға жағдай жасау үшін өлшеудің айқын еместігін бағалау талап етіледі. Осыған байланысты Қазақстанда өлшеудің белгісіздік тұжырымдамасын практикалық қолданудың жанданғаны байқалады. Метрологиялық есептерді шешу кезінде қолданылатын амалдарды халықаралық үйлестіру үшін халықаралық ұйымдар келесі негізгі құжаттарды әзірледі және дайындады: ИСО/МЭК 17025:2017 стандарты; соңғы толықтырылған редакциясы ретінде GUM:1995; өлшеудің айқын еместігін бағалау жөніндегі ұсынымдарды қамтитын метрология бойынша Бірікен комитеттің JCGM 100:2008 құжаты; метрология саласында пайдаланылатын барлық терминдер мен ұғымдар қамтылған метрология бойынша JCGM 200:2012 халықаралық сөздік; JCGM 101:2008 нұсқаулығы (GUM-ға толықтыру 1:1995).

Мақалада халықаралық құжаттарда ұсынылған айқын еместікті бағалаудың келесі үш әдісіне шолу жасалды: стандартты GUM, Монте-Карло және Крагтен әдістері. Шығынды өлшеудің белгісіздігін бағалау әдістері бұған дейін қолданылмаған. Бұл мәселе мақаланың зерттеу нысаны болып саналады. Өнеркәсіптік электрмагниттік шығын өлшегіштің салыстырмалы қатесінің белгісіздігін бағалау үшін осы әдістерді қолдану зерттеледі.

Авторлар техникалық шығын өлшегіштерді тексеру нәтижелерін алу үшін метрологиялық кешен құрамына «Метролог» автоматтандырылған жұмыс орнын (АЖО) қосқан, бұл АЖО құрамында NILabView графикалық бағдарламалау ортасында әзірленген электрмагниттік шығын өлшегіштің анықталмағандығын есептеу бағдарламалары орнатылған. Сонымен қатар, зерттеулер жүргізу үшін өнеркәсіптік шығын өлшегіштердің салыстырмалы қатесінің белгісіздігін бағалау моделі ұсынылған. Электрмагниттік шығын өлшегішітің белгісіздігін бағалау бойынша үш әдіс негізінде, атап айтқанда, стандартты GUM, Монте-Карло және Крагтенмен есептелді.

Метрологиялық кешендегі тәжірибелік нәтижелері мен электрмагниттік шығын өлшегіштің салыстырмалы қатесінің белгісіздігін бағалау нәтижелеріне салыстырмалы талдау келтірілген. Орындаған есептеу жұмыстары келесідей нәтиже көрсетті: барлық үш әдіс (GUM, Крагтен және Монте-Карло) электрмагниттік шығын өлшегіштің салыстырмалы қате диапазонынан (±1%) аспайтын стандартты белгісіздік мәнін береді.

Монте-Карло әдісі имитация арқылы жақындауға мүмкіндік береді. Алайда Монте-Карло әдісімен есептеу көп уақытты алады (үлкен массивтерді сұрыптау және өңдеу себебінен), бірақ оны квалификациясы төмен қызметкерлер орындай алады (математиканы терең білудің қажеті жоқ). Монте-Карло әдісін белгісіздікті бағалаудың GUM әдісіне практикалық балама ретінде қарастыруға болады [19].

Крагтен әдісі GUM әдісіне ұқсас нәтиже көрсетеді. GUM және Крагтен әдістері бойынша алынған нәтижелер арасындағы айтарлықтай айырмашылықтар байқалмады.

Жалпы стандартты белгісіздікті есептеуде сезімталдық коэффициентін есептеу қажеттілігінің жоқтығына байланысты күрделі өлшеу теңдеуі қолданылғанда Крагтен әдісі қолайлы келеді. Есептеуді орындау үшін Крагтен әдісі аз уақытты қажет ететін құрал ретінде ұсынылады.

Түйін сөздер: өлшеудің айқын еместігі, стандартты GUM әдісі, Монте-Карло әдісі, Крагтен кестесі, тексеру, электрмагниттік шығын өлшегіш.

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ИССЛЕДОВАНИЕ И ПРИМЕНЕНИЕ МЕТОДОВ РАСЧЕТА НЕОПРЕДЕЛЕННОСТИ ИЗМЕРЕНИЯ ПРОМЫШЛЕННЫХ РАСХОДОМЕРОВ

Аннотация. В Республике Казахстан добыча урана осуществляется методом подземного выщелачивания - одним из самых рентабельных и экологически чистых способов добычи. Согласно этому методу выщелачивающий раствор подается через закачные скважины, а продуктивный раствор, содержащий уран, откачивается через откачную скважину. Недра практически не разрушаются и даже полностью восстанавливаются в течение нескольких лет. На узлах приема и распределения выщелачивающих растворов для измерения их количества используется большое количество промышленных электромагнитных расходомеров (ЭМР), которые по истечению межповерочного интервала должны проходить метрологическую поверку. Общепринятый метод калибровки расходомеров с применением образцовых средств измерений или с помощью калибровочных установок, аккредитованных по стандарту ИСО/МЭК 17025-2017, может быть дорогостоящим и иногда неосуществимым, главным образом из-за затрат на оплату труда обслуживающего персонала и затрат на логистику, связанных с удалением расходомера из системы трубопроводов. Авторами разработан физический стенд передвижного метрологического комплекса, предназначенного для проведения процедуры поверки промышленных расходомеров по месту эксплуатации.

Для создания условий признания казахстанских сертификатов соответствия и результатов испытаний на продукцию требуется оценка неопределенности измерений. В связи с этим наблюдается активизация практического применения в Казахстане концепции неопределенности измерений. Международными организациями разработаны и подготовлены основные документы по международной гармонизации подходов при решении метрологических задач: стандарт ИСО/МЭК 17025:2017; документ Объединенного комитета руководств по метрологии JCGM 100:2008, как последняя дополненная редакция GUM:1995, которая содержит рекомендации по оценке неопределенности в измерении; международный словарь по метрологии JCGM 200:2012, где представлены все термины и понятия, используемые в области метрологии; руководство JCGM 101:2008 (Дополнение 1 к GUM:1995).

В статье приведен обзор трех методов оценивания неопределенности, рекомендуемых международными документами: стандартным GUM, Монте-Карло и Крагтена. Приведенные методы не применялись к оценке неопределенности измерения расхода. Эта задача является предметом исследования настоящей статьи.

Исследовано применение этих методов для оценивания неопределенности относительной погрешности промышленного электромагнитного расходомера.

Для получения результатов проверки технических расходомеров авторами в состав метрологического комплекса включен АРМ «Метролог» с разработанными в среде графического программирования NI LabView программами расчета неопределенности электромагнитного расходомера.

Кроме того, предложена модель оценивания неопределенности относительной погрешности промышленных расходомеров для проведения исследований. Расчеты по оценке неопределенности измерений электромагнитного расходомера проведены тремя методами: стандартным GUM, Монте-Карло и Крагтена.

Приведены результаты экспериментов на метрологическом комплексе и сравнительный анализ результатов оценивания неопределенности относительной погрешности электромагнитного расходомера. Выполненные расчеты показали, что все три метода (GUM, Крагтена и Монте-Карло) дают значения стандартной неопределенности, не превышающие допустимый диапазон относительной погрешности ЭМР (± 1%).

Метод Монте-Карло при достаточно большом числе имитаций дает лучшее приближение. Однако расчет по методу Монте-Карло занимает больше времени (за счет сортировки и обработки больших массивов), но может выполняться менее квалифицированным персоналом (не требуется глубокого знания математики). Метод Монте-Карло можно рассматривать как практическую альтернативу методу оценки неопределенности GUM [19].

Метод Крагтена дает результаты аналогичные методу GUM. Существенные различия между результатами, полученными по GUM и методу Крагтена, не отмечены.

Метод Крагтена предпочтителен ввиду отсутствия необходимости расчета коэффициентов чувствительности при вычислении суммарной стандартной неопределенности, что имеет значение при сложных уравнениях измерений. Метод Крагтена рекомендуется как менее трудоемкий инструмент для расчетов.

Ключевые слова: неопределенность измерения; стандартный метод GUM, метод Монте-Карло, таблица Крагтена, поверка; электромагнитный расходомер.

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ANALYSIS OF RECOMMENDED MEASURES AIMED AT OPTIMISING AND IMPROVING THE DEVELOPMENT PROCESS AT THE PRORVA OIL DEPOSIT

Abstract. Determination of the optimal parameters of deposit development systems depending on the features of the geological structure and operating modes of the deposits, the main provisions of the regulation of control and regulation of the development process are considered as factors affecting the optimisation of the level of oil production. To increase the efficiency of deposit development and justify measures to control and regulate the development process, the design technological indicators are specified in this paper. The analysis determines the current state of development of the Zapadnaya Prorva deposit and its recoverable oil reservoirs, an assessment of the effectiveness of the implementation of previously approved design decisions, factoring in the existing understanding of the geological structure and new information obtained on the geological-field description of productive reservoirs, the current state of development, the study of the status and extent depletion of oil reserves from the reservoirs and issuing recommendations for monitoring and regulating the development process. This paper analyses geophysical, hydrodynamic studies of boreholes and reservoirs, the results of field studies, the current state of development. Initial data for assessing the development efficiency taking into consideration the history of borehole operation is determined, the effectiveness of the applied system for monitoring the development process and the state of the stock of producing wells is assessed, the effectiveness of measures to regulate the development process is analysed, and the effectiveness of the development process is assessed.

Key words: hydrodynamic studies, borehole, reservoir, the effectiveness of the system used.

Introduction. The progressive technical and technological lag in the domestic oil production complex with an increase in the production of hard-to-recover oil reserves (HTR reserves) is accompanied by a decrease in the profitability and competitiveness of oil companies. The final oil recovery, defined as the weighted average of the initial balance reserves, largely depends on the existing structure of reserves [1-3]. The structure of oil reserves only worsens over time, both due to the accelerated production of active oil reserves, and due to the deterioration of the conditions for their production during the flooding of reservoirs upon long-term development of oil deposits. As a result, part of the active oil reserves goes into the category of hardly recoverable. The application of the latest methods for increasing oil recovery should be designed in addition to the basic hydrodynamic methods as a single development system [4-6].

The relevance of the subject matter is conditioned by the fact that over 120 years have passed since the start of oil production in Kazakhstan. Currently, the oil and gas industry has become the basis of socio-economic reforms in the country. At the end of 2018, our oil and gas complex provided over a fifth of the country's GDP, two-thirds of revenues to the National Fund, about 62% of commodity exports, and half of foreign direct investment. With that, Kazakhstan is developing in the global space and with consideration of global processes [7]. In this regard, we shall investigate the latest history of the national industry

through the lens of key global tendencies. The main tendency in the global market constitutes the growing demand for hydrocarbons. Long-term forecasts of all the world's leading energy companies also demonstrate the continued role of oil and gas in the planet's energy structure in the foreseeable future [8]. The constant complication of mining and geological conditions for the development of oil deposits, the moral and physical aging of fixed assets, the low potential of existing technologies for increasing oil recovery create significant problems for the development of oil companies [9].

The leading approach to the study of this issue is the analysis of the need for production boreholes to systematically carry out field geophysical studies. In the future, it is recommended to continue monitoring the development of studies with the use of the GIS-control methods by INNK records, as well as PLT methods in production boreholes to monitor the current state of reservoir beds. It is confirmed by the application of approved methods, as well as by comparing the results with data obtained by other authors: "Supervision of the implementation of the revised project for the development of the Zapadnaya Prorva deposit", 2011. "Supplement to the revised project for the development of the Zapadnaya Prorva deposit", 2015 and other Funds Materials: Caspian Energy Research LLP. Oilgeoconsulting LLP. Scientific Research Institute "Caspiummunaigaz" LLP. A new technical solution is proposed to increase the efficiency of deposit development, as well as several conclusions and recommendations on geology and development based on increasing the efficiency of application at the Zapadnaya Prorva deposit.

Analysis of theoretical studies of the state of oil reserves from reservoirs and sections of the Western Prorva deposit. The materials of the paper on the experience of developing oil deposits, as well as theoretical and experimental studies based on field geophysical survey data of this deposit, can be useful for students, graduate students of oil universities and students of continuing education courses in the direction of "Development of oil and gas deposits".

The purpose of this paper is to summarise the accumulated experience of deposit development, to clarify the geological structure of the deposits, the properties of reservoir fluids and the properties of reservoirs, based on the results of drilling new wells and conducting relevant studies, identifying the causes of discrepancies between actual development indicators and design indicators, analysing the effectiveness of the implemented deposit development system, and issuing recommendations aimed at improving the development system and increasing its effectiveness based on new data on the geological structure of the deposit and current development characteristics.

Materials and methods. To monitor the development, condition, and operation of boreholes and borehole equipment at the Western Prorva deposit, it was proposed to conduct the following main types of research: field research; field-geophysical studies of boreholes and core samples; hydrodynamic studies of formations and boreholes; physico-chemical studies of the properties of oil and gas; physical and chemical studies of associated and injected water [10]. Studies were carried out at all developed facilities to control the development in accordance with mandatory research complexes that consider the specific geological and physical properties of the deposit and the features of the applied development system. With that, it was planned to carry out both systematic (periodic) and single (one-time) studies. Systematic studies were carried out in operating, producing, injection, and control boreholes with a specified frequency. One-time studies – in new boreholes that were taken out of drilling, as well as in boreholes where repeated perforation is provided, before and after the event.

Information about the well yields. The establishment of the frequency of flow rates (injectivity) measurements should be made differentially for low-rate wells (up to 5 t/day), medium-rate (5 to 25 t/day), and high-rate (more than 25 t/day). The determination of the water cut of production wells should be determined by one-time studies of all mastered wells after drilling or repair and systematically during operation. The determination is carried out by laboratory analysis of the selected product samples. The gas factor is determined by one-time studies of all producing wells new and after repair. The gas factor in wells that are operated at high bottomhole pressures and characterised by an initial gas factor is determined once a year.

The complex of hydrodynamic studies includes: the pressure transient test (PTS); repressuring method (RM); well interaction research method (well interference testing); bottomhole and reservoir pressure and temperature measurements. A study with the use of the steady-state selection method is carried out both on a one-time basis for all new wells, as well as for existing wells before and after geological and technical measures associated with a change in the bottom-hole zone, and systematically

for active producing wells at least once every two years. Well restoration by pressure restoration is carried out in the form of one-time studies for all new producing and injection wells, as well as wells that were abandoned for repair, and systematically for existing injection and producing wells at least once every two years.

In order to compare the current position of the contacts with the position existing at the time of the start of development, the movement of the oil water contact is controlled. The position of the oil and gas complex is determined by the methods of gamma-ray logging, lateral logging, induction logging and side-wall resistivity logging to reduce resistivity in special appraisal or still uncased production boreholes [11-14]. The criterion for the effectiveness of well intervention techniques in wells was the additional oil production during the effect. Those well intervention techniques were considered to be successful in the duration of the effect, after which the current yield is higher than the initial one (before the well intervention techniques) [15].

Results and discussion. To study the inflow profile, one-time studies are carried out on new producing boreholes, including boreholes before and after well intervention techniques which are related to impact on the bottom-hole zone. For each completed and commissioned borehole, it is necessary to carry out studies to determine the technical condition, tightness of the production string and cement quality.

In laboratory conditions, the following indicators are determined:

– physico-chemical properties of reservoir oil according to differential and contact degassing (pressure of oil saturation with gas, gas content, density, viscosity, volumetric coefficient and compressibility in reservoir conditions, shrinkage coefficient, etc.);

– physico-chemical properties of oil degassed to standard conditions (density, kinematic viscosity, molecular weight, boiling point and pour point, oil saturation temperature with paraffin, percentage of paraffins, asphaltenes, silica gel resins, sulphur, fractional, hydrocarbon and component compositions), the presence of salt and solids in oil;

– full chemical-physical analysis of produced water according to detail documentation.

A set of physical and chemical studies of oil and gas. Formation oil samples should be taken by in-depth samplers in the immediate vicinity of the inflow zone. The selection of boreholes for deep sampling is carried out by the geological service of the subsurface user and is coordinated with the company performing author's supervision over development [16]. To clarify the physicochemical properties and thermobaric conditions of productive horizons, it is further recommended that an analysis of deep oil samples and measurements of reservoir pressures be carried out in compliance with the required duration of well shutdown. A set of well research to control development is presented in table 1.

Table 1 – A set of studies to control the development process

No	Types of Research	Periodicity
1.	Measurement of yield and injectivity: – depleted wells; – medium- and high-rate wells.	One-time studies in all newly drilled wells and upon well intervention techniques: – 1 time in 15 days; – 1 time in 7 days.
2.	Determination of water cut in production wells: – waterless; – low and medium watered; – highly watered.	One-time studies in all newly drilled boreholes and upon well intervention techniques: – 1 time per month; – 1 time in 15 days; – 1 time in 7 days.
3.	Determination of the gas factor: – Rform>Psat; – Rform<Rsat.	One-time studies in all newly drilled wells and upon well intervention techniques: – 1 time per year; – 1 time per month.
4.	Determination of reservoir pressure	One-time studies in all newly drilled wells and upon well intervention techniques. Once every 6 months on a core network, an existing stock. Once a quarter for observation wells.
5.	Determination of bottomhole pressure	One-time studies in all newly drilled wells and upon well intervention techniques. 1 every 3 months for the existing stock.

Continuation of table 1

6.	Pressure recovery test	One-time studies in all newly drilled wells and upon well intervention techniques. Once every two years.
7.	Stationary behaviour study	One-time studies in all newly drilled wells and with well intervention techniques. Once every two years for the core network.
8.	Inflow profile study	One-time studies upon commissioning and upon well intervention techniques. Once a year for the production stock.
9.	Assessment of current oil saturation, control of the position of the oil water contact	One-time studies in all newly drilled wells and upon well intervention techniques. As required.
10.	Depth sampling for physico-chemical analysis of oil	At least three samples once every six months.
11.	Wellhead oil sampling to determine the basic properties of degassed oil	Once every six months at least five samples.
12.	Water sampling to determine composition and quality in production wells	One-time studies in all newly commissioned wells. In existing wells 1 time in 3 months.
13.	Preventive examination of the technical condition of combination strings	One-time studies in all newly drilled wells and upon well intervention techniques. As required (leakage, channelling, etc.).

The purpose of monitoring the development of deposit facilities is to assess the effectiveness of the applied development system at large, individual technological measures, or new technologies aimed at improving the process of reserves production. Development control measures provide information for planning work on regulating the development process and designing technologies for its improvement [17-19]. Table 2 compares the design and actual volumes of research.

Table 2 – Implementation of the development process control plan

Types of research	Frequency	
	Design	Actual
Dynamic well test		
Pressure transient test	One-time studies in all newly drilled wells. The current stock – once every 2 years, before and after repairs (well intervention techniques) associated with a change in the state of the engineering, procurement, and construction.	17 studies are being performed on 17 wells.
Pressure recovery test	One-time studies in all newly drilled wells. The current stock – once every 2 years, before and after repairs (well intervention techniques) associated with a change in the state of the engineering, procurement, and construction.	5 pressure build-up curve studies in 5 wells; 9 level build-up curve studies in 9 wells.
Yield measurements	One-time research on all new producing wells. Operating stock – monthly, with well intervention techniques, when their flow rate changes by over 40%.	Monthly.
Determination of bottomhole pressure	One-off studies in all newly drilled wells. Operating stock – once a quarter, upon well intervention techniques	650 measurements taken.
Determination of formation pressure	One-time studies in all newly drilled wells, on drifts – 1 time in 6 months, upon well intervention techniques.	214 measurements taken.
Determination of wellhead and casing pressure	For existing production (fountain) wells – 1 time in 3 days.	In progress.
The study of the physicochemical properties of oil		
Depth sampling for physico-chemical analysis of oil	One-time studies in gushing wells.	33 samples are taken in 21 wells.
Wellhead oil sampling to determine the basic properties of degassed oil	At least once a year from all operating production wells.	53 samples are taken for 37 wells.
Determination of the gas factor	One-off studies in all newly drilled wells. The current stock, when the formation pressure exceeds the saturation pressure – 1 time per year, upon a decrease in the formation pressure below the saturation pressure – on a quarterly basis.	Once a year.
Determination of water cut	For the entire operating maintenance stock, at least 1 time per month.	Once a month.

Continuation of table 2

Geophysical surveys		
Study of the inflow profile, determination of sources and water cut intervals	One-time studies upon commissioning a well from drilling. Fountain stock – once a year; upon conducting well intervention techniques.	Performed on 2 wells.
Inspection of the technical condition of production wells	One-time studies upon commissioning a well from drilling. The existing fund – as required (upon a sharp increase in water cut, a change in the operating mode of the well, in case of workover, upon commissioning idle or inactive wells).	Performed on 13 wells.
Monitoring the position of the oil water contact and assessing changes in oil saturation	The current stock – depending on changes in the composition of the incoming fluid (against non-perforated formations of the studied operation facility).	Performed on 13 wells.
Determination of formation temperature	One-time studies in all newly drilled wells. The existing stock – at least once a year.	In progress.

During the analysed periods, materials of geophysical well logging were interpreted from three wells (No 430, No 435, No 437) drilled after calculating reserves in 2013. Geophysical surveys in new wells were performed by Batysgeozertteu LLP. The complex of field-geophysical studies was carried out in open and closed boreholes. In open hole wells, designed to evaluate the reservoir properties of reservoirs in a productive section, a modern geophysical well logging complex was performed in the wells, including the following methods: self-potential logging, calliper logging, lateral logging, induction logging, micrologging, gamma-ray logging, neutron gamma-ray logging, acoustic logging, gamma-gamma density logging, high-frequency induction logging with isoparametric sounding, thermometry, and inclinometry. To assess the determination of the quality of cementing the columns, well cementation acoustic control was carried out, the methods of gamma-ray logging and collar locators were used to bind in depth to the section of the wellbore. For the period from 2014 to 2017, 13 wells were used to determine the current state of oil saturation of INNL (impulse neutron-neutron logging) with IGN-7, IGN-43-M1, and INGK-43 instruments. Monitoring of the technical condition of the production casing was also carried out in 13 wells [20].

The study of the physicochemical properties of oil, gas, and condensate in the Zapadnaya Prorva deposit began at the exploration stage. Over the entire period of deposit development, 48 deep and 61 surface oil samples, 6 condensate samples, 76 dissolved gas samples were studied. To control the development of the deposit, the following types of studies are carried out: registration of pressure changes in unsteady filtration modes (level build-up curve, pressure draw-down curve); well productivity studies in various operating modes (pressure transient test) [21-23].

During 2015-2017, hydrodynamic studies of wells were carried out at the deposit in transient modes (pressure build-up curve, level build-up curve), as well as measurements of static and dynamic fluid levels. Since the beginning of the implementation of the project document (DUPR-2015), the deposit has undergone 5 surveys of pressure build-up curve for 5 wells and 9 surveys of level build-up curve for 9 wells. Also, direct measurements of formation pressure and measurements of static fluid levels were used to analyse the energy state.

Conclusions. In the process of deposit development, it is necessary to carry out comprehensive research to assess the effectiveness of the adopted development system, to obtain the information necessary to optimise the ongoing development processes and design measures to improve them. The research work being carried out at the deposit to monitor the development of formations allows to evaluate the effectiveness of the adopted development system and to develop measures for its improvement.

An analysis of the measures taken at the deposit shows their high quantitative and qualitative characteristics. The analysis determines the current state of development of the Zapadnaya Prorva deposit and its recoverable oil reserves, an assessment of the effectiveness of the implementation of previously approved design decisions, taking into consideration the existing understanding of the geological structure and new information obtained on the geological and deposit characteristics of productive deposits, the current state of development, the study of the status and extent depletion of oil reserves from the reservoirs and issuing recommendations for monitoring and regulating the development process. The analysis of geophysical, hydrodynamic studies of wells and reservoirs, the results of deposit studies, the current state

of development. Initial data for assessing the development efficiency with consideration of the history of well operation are determined, the effectiveness of the applied system for monitoring the development process and the state of the stock of producing wells is assessed, the effectiveness of measures to regulate the development process is analysed, and the effectiveness of the development process is evaluated.

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ӨНДІРІСТІК ЗЕРТТЕУЛЕРДІҢ ЖӘНЕ «ПРОРВА» КЕН ОРНЫНДАҒЫ ӘЗІРЛЕУ ҮРДІСІН ЖЕТІЛДІРУ МЕН ОҢТАЙЛАНДЫРУҒА БАҒЫТТАЛҒАН ӘЗІРЛЕУ ЖҰМЫСТАРЫНЫҢ АҒЫМДАҒЫ ЖАҒДАЙЫН ТАЛДАУ

Аннотация. Кен орны құрылымының күрделілігі бойынша дизъюнктивтік бұзу әрекеті орын алатын, қимасы және ауданы бойынша коллекторлардың жоғары әртектілігі байқалатын екінші топ объектісіне жатады. Көпқабаттық кен орны, Батыс Прорва ауданындағы барланған мұнай жатындары Юра және Триас дәуірінің шөгінділерімен байланысты. Геологиялық құрылым ерекшеліктері және мұнай жатындарымен жұмыс режиміне байланысты кен орындарын әзірлеу жүйесінің оңтайлы параметрлерін анықтау, әзірлеу үрдісін реттеу мен бақылау регламентінің негізгі қағидалары мұнай өндіру деңгейін оңтайландыруға әсер ететін факторлар ретінде қарастырылған.

Жұмыстың мақсаты – жаңа ұңғымаларды бұрғылау мен тиісті зерттеу жүргізудің нәтижелері бойынша мұнай жатындарының геологиялық құрылымын, қойнауқаттық флюидтер мен қойнауқаттың қасиеттерін зерттеу. Кен орнын әзірлеудің тиімділігін арттыру үшін және әзірлеу үрдісін реттеу мен бақылау бойынша шараларды негіздеу мақсатында берілген жұмыста жобалық технологиялық көрсеткіштер нақтыланған. Талдау арқылы Батыс Прорва кен орнын әзірлеудің заманауи күйі және ондағы өндірілетін мұнай қоры, өнімді жатындардың геологиялық-кәсіпшілік сипаттамасы туралы алынған жаңа деректер мен геологиялық құрылым туралы түсінікті ескере келе алдында мақұлданған жобалық шешімдердің жүзеге асырылу тиімділігінің бағасы, әзірлеу жұмыстарының ағымдағы жағдайы, қойнауқаттардан мұнай қоры өндірілуінің деңгейі мен күйін зерттеу және әзірлеу үрдісін реттеу мен бақылау бойынша ұсынымдардың берілуі анықталған.

Аталмыш мәселені зерттеудің басты тәсілі – далалық геофизикалық зерттеулерді жүйелі түрде жүргізу үшін қолданымдық ұңғымаға талдау жасау қажет. Кен орынды әзірлеудің тиімділігін арттыру үшін жаңа техникалық шешім ұсынылды, сонымен қатар Батыс Прорва кен орнында қолдану тиімділігін арттыруға негізделген геология мен әзірлеуге қатысты қорытынды жасалып, ұсыныстар берілген. Жобалық көрсеткіштер мен айғақты әзірлеу көрсеткіштерінің сай келмеу себептері анықталды. Сонымен қатар кен орнын әзірлеудің ендірілген жүйесінің тиімділігіне талдау жасалды. Зерттеу жұмысының соңында әзірлеудің ағымдағы сипаттамасы мен кен орнының геологиялық құрылымына қатысты жаңа деректер негізінде әзірлеу жүйесін жетілдіру мен оның тиімділігін арттыруға бағытталған ұсыныстар берілген.

Қойнауқат пен ұңғымалардың геофизикалық, гидродинамикалық зерттеулеріне, өндірістік зерттеу нәтижелеріне, әзірлеудің ағымдағы күйіне талдау жасалды. Ұңғымалардың қолдану тарихын ескере келе әзірлеу тиімділігін бағалауға арналған бастапқы деректер анықталды; өндіруші ұңғымалар қорының күйі мен қолданыстағы әзірлеу үрдісін бақылау жүйесінің тиімділігіне баға берілді; әзірлеу үрдісін реттеуге қатысты шаралар тиімділігіне талдау жасалды және әзірлеу үрдісінің тиімділігіне баға берілді. Мұнай кен орындарын әзірлеу тәжірибесі, аталмыш кен орнын далалық геофизикалық зерттеулер деректері негізінде теориялық және эксперименттік зерттеулер туралы мақала материалдары студенттер, мұнай және газ жоғары оқу орнында оқитын аспиранттар, сонымен қатар «Мұнай кен орындарын әзірлеу» бағытында біліктілігін арттыру курстарының тыңдармандары арасында кеңінен қолданыла алады.

Түйін сөздер: гидродинамикалық зерттеулер, ұңғыма, резервуар, қолданылатын жүйенің тиімділігі.

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АНАЛИЗ ПРОМЫСЛОВЫХ ИССЛЕДОВАНИЙ И ТЕКУЩЕГО СОСТОЯНИЯ РАЗРАБОТКИ НАПРАВЛЕННОЙ НА ОПТИМИЗАЦИЮ И УСОВЕРШЕНСТВОВАНИЕ ПРОЦЕССА РАЗРАБОТКИ НА МЕСТОРОЖДЕНИИ «ПРОРВА»

Аннотация. Месторождение по сложности своего строения относится к объектам второй группы, для которых характерно наличие дизъюнктивных нарушений, высокая неоднородность коллекторов по площади и по разрезу. Месторождение многопластовое, разведанные залежи нефти на площади Западная Прорва связаны с юрскими и триасовыми отложениями. Определение оптимальных параметров систем разработки месторождений в зависимости от особенностей геологического строения и режимов работы залежей, основные положения регламента контроля и регулирования процесса разработки рассмотрены, как факторы, влияющие на оптимизацию уровня добычи нефти.

Целью данной работы является изучение геологического строения залежей, свойств пластовых флюидов и свойств пластов по результатам бурения новых скважин и проведения соответствующих исследований. Для повышения эффективности разработки месторождения и обоснования мероприятий по контролю и регулированию процесса разработки в настоящей работе уточнены проектные технологические показатели. Проведенный анализ определяет современное состояние разработки месторождения Западная Прорва и его извлекаемые запасы нефти, оценку эффективности реализации ранее утвержденных проектных решений, с учетом имеющегося представления о геологическом строении и полученных новых сведений о геолого-промысловой характеристике продуктивных залежей, текущем состоянии разработки, изучение состояния и степени выработанности запасов нефти из пластов и выдача рекомендаций по контролю и регулированию процесса разработки.

Ведущим подходом к изучению этого вопроса является анализ необходимости эксплуатационных скважин для систематического проведения полевых геофизических исследований. Предлагается новое техническое решение для повышения эффективности разработки месторождения, а также ряд выводов и рекомендаций по геологии и разработке, основанных на повышении эффективности применения на месторождении Западная Прорва. Выявлены причины несоответствия фактических показателей разработки и проектных показателей. Также проводился анализ эффективности внедренной системы разработки месторождения. По окончании исследования были даны рекомендации, направленные на совершенствование системы разработки и повышение ее эффективности на основе новых данных о геологическом строении месторождения и текущих характеристиках разработки.

Выполнен анализ геофизических, гидродинамических исследований скважин и пластов, результатов промысловых исследований, текущего состояния разработки. Определены исходные данные для оценки эффективности разработки с учетом истории эксплуатации скважин; проведена оценка эффективности применяемой системы контроля процессом разработки и состоянием фонда добывающих скважин; проанализирована эффективность мероприятий по регулированию процесса разработки и проведена оценка эффективности процесса разработки. Материалы статьи об опыте разработки нефтяных месторождений, а также теоретических и экспериментальных исследованиях на основе данных полевых геофизических исследований этого месторождения могут быть полезны студентам, аспирантам нефтяных вузов, а также слушателям курсов повышения квалификации в направлении «Разработка нефтегазовых месторождений».

Ключевые слова: гидродинамические исследования, скважина, пласт, эффективность применяемой системы.

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THE IMPROVING OF THE ACCURACY OF ENGINEERING AND GEODETIC WORKS IN THE CONSTRUCTION AND CONTROL OF THE GEOMETRIC PARAMETERS OF HIGH-RISE BUILDINGS

Abstract. In the article, the authors had done a brief analysis of existing modern, traditional methods and tools that allow to determine the planned coordinates of geodetic signs, located on the last tier of super-high engineering structures, paid special attention to the disadvantages and concluded that it's necessary to develop a method and device for determining the geodetic coordinates on ultra-high engineering structures with high accuracy to provide engineering and geodetic works during the construction and operation of high-rise structures.

In the article, the authors propose their method and device for determining the planar coordinates of the upper geodetic sign of the line of vertical design on ultra-high engineering structures with high accuracy, which is based on the method of the straight linear resection by the light distance meter. The result of the proposed method is the enhancing of the accuracy of engineering and geodetic works during the construction and control of geometric parameters of high-rise structures.

This method of distance measurements allows getting the enhancing of the accuracy of the engineering and geodetic measurements by fixing the moment of occurrence of the double frequency with root mean square error (RMSE) above 0.5 mm, thus eliminating the need to measure the phase difference between direct and reflected pulses. A particular advantage of the proposed method is that the accuracy of the measurements depends on the comparison of the radiated f and double f_g frequencies, which makes the measurement precision.

Key words: geodetic monitoring, vertical design, light distance meter, planned coordinates, construction of high-rise structures.

Review. During construction and often during the operation period of the high-rise engineering structures, the task to determine the planned coordinates of the geodesic sign, which is located on the top (roof) of the high-rise structure arises.

Let's consider briefly the advantages and disadvantages of the well-known methods of determining and transmitting the planned coordinates vertically. The method of constructing the vertical by mechanical plumb-line is the simplest, however, for the geodetic maintenance of the construction of multistore high-rise structures, this method cannot be used due to the low accuracy (1:1000 under favourable measurement conditions) of coordinate transmission [1].

There is a method of determining the coordinates of the upper geodetic sign (UGZ) by constructing two collimation planes with the sight axes of the total station located on the construction site [2], in which the intersection of the collimation planes forms a vertical line through which the planned coordinates are transmitting from the lower geodetic mark (LGM) top sign. Insufficient accuracy is associated with the unacceptable error (for this measurement $\geq \pm 10$ of angular seconds) of cylindrical instrument levels, which gives a vertical error of $\sim \pm 20$ mm at a building height of 100 m.

More accurate is the method of optical or laser vertical design, which provides an accuracy of 1-2 mm for a building height of about 100 m [2].

At the same time, the requirements for the root mean square error of vertical design devices for high-rise structures exceeding 100 m are $\sigma_{x,y} = 0.5\ mm + 1 \cdot H$ [3], where $H \leq 0{,}01 \cdot H_{IC}$ (H_{IC} is the height of the engineering structure) that are representing a serious technical problem of vertical design.

For the most part, during geodetic monitoring of engineering structures, considerable attention is paid to determining the deformations of the foundation part of the structure by traditional geodetic methods and devices [1,2], but recently at the time of full automation cases of using non-traditional optoelectronic photosystems to determine deformations of not only the fundamental part of the structure, but the structure as a whole [4,5] and the territory as a whole [6].

Formulation of the problem. It follows from the above that it's necessary to develop a method and a device for determining the planned coordinates of the upper geodetic sign-on ultra-high engineering structures with high accuracy.

The purpose of the article. The determination of the planned coordinates of the upper geodetic sign of the vertical line on ultra-high engineering structures with high accuracy.

Presentation of the basic material. The authors created a method for determining the planned coordinates of the upper geodetic sign of the line of vertical design on ultra-high engineering structures [7]. It is based on the method of the straight linear resection by the light distance meter. To do this, the geodetic anchor of the central points of the light distance meter and the lower geodetic sign in the engineering structure in plan and by the height with the required accuracy is doing. Light distance meters are oriented to optical reflectors, which are mounted on the upper geodetic sign of the engineering structure and, changing the frequency of the pulse emitter, fix the distances from the light distance meters to the reflectors of the upper geodetic sign on the building at the time of occurrence in the channels of the light-distance meters' receivers of the dual-frequency radiation, calculating these distances for each of the light distance meters by the formula:

$$S = \frac{V \cdot n}{4f}, \tag{1}$$

where V is the speed of light propagation in the atmosphere; f - is the frequency of light pulses; n - an odd number of periods of double-pulse $f_g = 2f$ radiation frequency; the number n is determined by the approximate value of the S' distance on a large-scale plan taking into account the angle of inclination of the light distance meters' beam and rounded to an integer odd number:

$$n = \frac{4S'f}{V}, \tag{2}$$

at the same time, taking into account the data of the geodetic anchorage of the light distance meters, the coordinates of the upper geodetic sign x and y in the coordinate system of the engineering structure are determined by the values of the directional angles of the directions "lower geodetic sign - centre of the rangefinder" for at least two directions [7].

The method of determining the planned coordinates of the upper geodetic sign is implemented as follows [7].

In figure 1 it is shown a diagram of the location of geodetic signs of light distance meters.

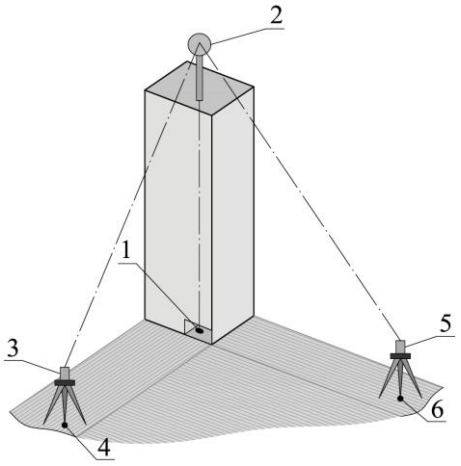

Figure 1 –
The scheme of location of geodetic signs
of light distance metres

The diagram (figure 1) indicates: 1 - lower geodetic vertical sign (LGS); 2 - upper geodetic vertical sign (UGS); 3, 5 - light distance metres; 4, 6 - geodetic signs.

Places for the installation of light distance metres are choosing at some distance from the controlled structure, paying attention to a sufficiently sharp angle of incidence of the light distance metres and direct visibility, equip land-based geodetic signs and stable bases for light distance metres in centres' projections and do the high-precision geodetic reference in horizontal and vertical projections of the mentioned geodetic signs and the lower geodetic sign of the controlled vertical relative to the construction coordinate system.

The method of determining the planned coordinates of the upper geodetic sign of the vertical line on ultra-high engineering structures is implemented using a light distance metre device [5]. Thus, the authors proposed two options for determining the coordinates of the upper geodetic sign in the absence of rocking of the structure and the case of the rocking of the structure.

The block diagram of the light distance metre device (figure 2) contains [7]:

1 – the block of controlling and processing of the information;
2 – the block of the high-frequency generator;
3 – the block of modulation of the frequency;
4 –the block of radiation of light pulses;
5 – the reflector;
6 – the optical and electronic receiver;
7 – the mixer of frequencies of direct and reflected light pulses;
8 – the block of separation and comparison of the mixed frequency and the radiation frequency;
9 – the block of indication;
10 – the block of recording and storage of the information.

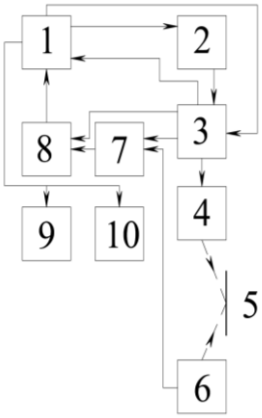

Figure 2 – Block diagram of the light distance metre device

All blocks, except block 5, are installed in the body of the light distance metre's channel. In Fig. 2 the electrical connections are indicated by solid lines and the optical connections by the dashed lines.

Consider the procedure in two ways:

1. In the absence of rocking of the structure.
2. When the structure is rocking.

The light distance meter works as follows. Block 1 activate other units of the device and sends the command to block 2, which generates a frequency *f*of the radiation. Block 2 through block 3 sends the frequency to block 4; block 4 emits pulses of the light signals which are coming to the reflector 5. The reflected light pulses reflected from the reflector come to block 6, where the pulsed light signals are converted to electric with the main frequency f of the reflected pulses and are transmitted to the block 7; at the same time, the block 7 receives electrical signals from block 3 with the fundamental radiation frequency f (direct pulses). During the changing of the frequency in block 3 the interval of the time between direct and reflected signals changes. At the moment when this time interval will be $\tau = \frac{T}{2}$, where

T is the period of frequency, in the mixer 7 the double frequency $f_g = 2f$ appears, which goes from block 7 to block 8. In block 8, the frequency is divided into two. Also block 8 receives from block 3 the current radiation frequency *f*, which is compared with the frequency $\frac{f_g}{2}$. At the moment of the coincidence of these frequencies, the signal of the presence of the equality of frequencies $f = \frac{f_g}{2}$ from block 8 comes to block 1. Into block 1 also comes from block 2 values of the current frequency at the time of the coincidence. The number *n* is determined by the approximate value of the distance on a large scale (2).

In the end, determine the distance from the device to the reflector just for the moment of the coincidence of frequencies $f = \frac{f_g}{2}$ according to the formula (1) is determining.

To determine the coordinates of the upper geodetic sign of the structure in conditions of wind sway on the upper floors, the proposed method is implemented within the schemes shown in figure 1 and 2. At the same time, into a light distance metre device the low-frequency modulation of the main high-frequency modulation of the light pulse radiation is putting, and it's performing by block 3 on the command of block 1 (figure 2). Low-frequency modulation allows with a small amplitude of the rocking of the upper geodetic sign and with the rocking of the main frequency *f* in small limits, leaving an known number *n* to be constant, to obtain a sufficient number of points of double current frequency $f_g = 2f$ and the moments of its appearance to graphic of deviation of the upper geodetic sign from the vertical in axis *X* and *Y*. Visualization of such a graphic makes it possible to do vertical control in dynamics.

The work of the light distance metre is doing mainly according to the scheme shown in figure 2 and differs from the mentioned above version of the work in that it turn on the low-frequency modulation in block 3 f_H and block 4 radiates pulses of signals from block 3 from which signals are received in block 7 (communication "block 2 - block 4" and "block 2 - block 7" in this case does not work). Otherwise, all the blocks work according to the scheme in figure 2.

The distances are determined by the formula (1) at a constant value *n*, only the frequency is changing. With the known value of the number *n* (which can be determined in advance, for example, when the engineering structure is in the state of calm), in advance, the values of deviations ΔS_i are calculating for the points of the trajectory of the upper geodetic sign, in which there is a double frequency f_{g_i} appears. That is, from formula (1) it turns out that, $\Delta S_i \approx \frac{\Delta f_i}{f_i} S_i$, so, defining moments t_i on the occurrence of double frequency f_{g_i} using the data ΔS_i, Δf_i and t_i build a graphic that shows the dynamics of the rocking of the upper geodetic sign and the moment of finding the upper geodetic sign on the vertical.

When the location of the light distance metre rays near the planes of the structure *XOZ* and *YOZ*, $\Delta x_{i_{UGS}}$ and $\Delta y_{j_{UGS}}$ will accordingly be equal to $\Delta x_{i_{UGS}} = K_1 \Delta S_{i_1}$ and $\Delta y_{j_{UGS}} = K_2 \Delta S_{j_2}$, where *K* is the coefficient that considers the angle of inclination of the light distance metre beam.

To evaluate the accuracy of the determining the distance *S*, we differentiate (1) the variables f_g and *V*, considering the number of wavelengths and, passing to the RMSE , we get

$$m_S = \frac{n}{4}\sqrt{\left(\frac{V}{f_g^2}\right)^2 m_{f_g}^2 + \left(\frac{1}{f_g}\right)^2 m_V^2} .$$

As it is known from the literature, the error of a single measurement of the distance of the phase light distance metre is determining by the [8]:

$$m_S = \sqrt{S^2\left(\frac{m_v}{v}\right)^2 + S^2\left(\frac{m_f}{f}\right)^2 + \left(\frac{v}{4\pi f}\right)^2 m_{\Delta\varphi}^2 + m_k^2} ,$$

where $\frac{m_V}{V}$ and $\frac{m_f}{f}$ are relative errors due to inaccurate determination of the speed of light propagation in the atmosphere and the inaccurate measurement of the radiation frequency; $m_{\Delta\varphi}$is the phase measurement error; m_k is the error of calibration of the light distance meter.

In the process of measuring the distance by the light distance meter, which is proposed by the authors of this article, the phase measurement operation is excluded, it remains:

$$m_S = \sqrt{S^2\left(\frac{m_v}{v}\right)^2 + S^2\left(\frac{m_{fg}}{f_g}\right)^2 + m_k^2}. \quad (3)$$

Thus, the composition of the errors, which depends on the measured distance, will be as follows:

1) $\frac{m_v}{v} = 10^{-6} \div 10^{-7}$. At short distances to 1-1,5 km $\frac{m_v}{v} = 1km \cdot 10^{-6} = 1mm$;

2) $\frac{m_{fg}}{f_g} = 10^{-6} \div 10^{-7}$. At short distances to 1-1,5 km $\frac{m_{fg}}{f_g} = 1km \cdot 10^{-6} = 1mm$.

Substitute the obtained values in (3) with the proviso that distances *S* = 1-1.5 km, we obtain

$$m_S = \sqrt{S^2\left(\frac{m_v}{v}\right)^2 + S^2\left(\frac{m_{fd}}{f_d}\right)^2} = 1.5\ mm. \quad (4)$$

Errors m_c and m_{in} are the errors of the centring of the light distance meter and the reflector installation, for the high-precision measurements should be taken tolerances for at least 0.1 mm. The error of calibration m_{cal} will be 0.2 mm.

Considering the components of the error we get:

$$m = \sqrt{m_c^2 + m_{in}^2} = \sqrt{0{,}1^2 + 0{,}2^2} = 0.22\ mm. \quad (5)$$

Considering (4) and (5), we obtain the general formula of the RMSE distance measurement for the pulse-frequency light distance metre proposed by the authors of this article:

$$m_S = \left(0.22 + 1.5 \cdot \mathrm{S} \cdot 10^{-6}\right) mm\,.$$

Thus, during the usage of the impulse-frequency light distance metre suggested by the authors, during the measurement of short distances for engineering and geodetic work (up to 1-1.5 km), the accuracy of the measurements will mainly be affected by the errors m_c, m_{in}, m_{cal}.

The conclusion. Therefore, this method of light-distance metre measurements allows obtaining an increase in the accuracy of engineering and geodetic measurements by fixing the moment of occurrence of the double frequency with RMSE above 0.5 mm, thus eliminating the need to measure the phase difference between direct and reflected pulses. A particular advantage of the proposed method is that the accuracy of the measurements depends on the comparison of the radiated f and double f_g frequencies, which makes the measurement precision.

According to the obtained data, the graphs of oscillations of the upper geodetic sign relative to the vertical in the directions of the axes *X, Z* of the engineering structure are constructed and they are used to control the verticality during the construction and installation of technological equipment. Equally useful will be the device and method to perform geodetic deformation control during the operation of engineering high-rise structures.

Thus, the method of light-distance metre measurements proposed by the authors allows doing the determination of the vertical with high accuracy in conditions of the oscillations of ultra-high engineering structures.

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БИІК ҚҰРЫЛЫСТАРДЫҢ ГЕОМЕТРИЯЛЫҚ ПАРАМЕТРЛЕРІН ТҰРҒЫЗУ ЖӘНЕ БАҚЫЛАУ БАРЫСЫНДА ИНЖЕНЕРЛІК-ГЕОДЕЗИЯЛЫҚ ЖҰМЫСТАРДЫҢ ДӘЛДІГІН АРТТЫРУ

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ПОВЫШЕНИЕ ТОЧНОСТИ ИНЖЕНЕРНО-ГЕОДЕЗИЧЕСКИХ РАБОТ ПРИ ВОЗВЕДЕНИИ И КОНТРОЛЕ ГЕОМЕТРИЧЕСКИХ ПАРАМЕТРОВ ВЫСОТНЫХ СООРУЖЕНИЙ

Аннотация. В статье авторы выполнили сжатый анализ существующих современных традиционных методов и устройств, позволяющих определять плановые координаты геодезических знаков, размещенных на последнем ярусе сверхвысоких инженерных сооружений, особенное внимание уделили недостаткам существующих способов. Общеизвестные способы, а именно способ построения вертикали с помощью механического отвеса, несмотря на то, что является наиболее простым в использовании – не обеспечивает необходимую точность при строительстве многоэтажных высотных сооружений, предельная точность этого способа составляет 1:1000 при условии благоприятных условий измерений; следующий способ определения координат верхнего геодезического знака при помощи построения двух коллимационных плоскостей визирными осями оптико-электронного тахеометра аналогично не обеспечивает требуемой точности, при высоте сооружения 100 м ошибка по вертикали составляет ~+20 мм; наиболее точный из известных способов на сегодняшний день является способ оптического или лазерного вертикального проектирования, который обеспечивает точность 1-2 мм для высоты сооружения приблизительно 100 м, но, как мы понимаем, этой точности также недостаточно. Авторы, проанализировав известные способы определения плановых координат геодезических знаков, размещенных на последнем ярусе сверхвысоких инженерных сооружений, пришли к выводу, что необходимо разработать способ и устройство определения плановых координат верхнего геодезического знака на сверхвысоких инженерных сооружениях с повышенной точностью для обеспечения инженерно-геодезических работ во время строительства и эксплуатации высотных инженерных сооружений.

В статье авторы предлагают собственные способ и устройство определения плановых координат верхнего геодезического знака линии вертикального проектирования на сверхвысоких инженерных сооружениях с повышенной точностью, который основан на методе прямой линейной засечки светодальномерными измерениями, при этом выполняют геодезическую привязку центральных точек светодальномеров нижнего геодезического знака в инженерном сооружении в плане и по высоте с необходимой точностью, светодальномеры ориентируют на оптические отражатели, установленные на верхнем геодезическом знаке инженерного сооружения и, изменяя частоту излучения импульсов, фиксируют расстояния от светодальномеров до отражателей верхнего геодезического знака, размещенного на сооружении, в моменты возникновения в каналах приемников светодальномеров двойной частоты излучения, вычисляя эти расстояния для каждого из светодальномеров.

Результатом предложенного авторами способа является повышение точности инженерно-геодезических работ при возведении и контроле геометрических параметров высотных сооружений.

Данный способ светодальномерных измерений позволяет получить повышение точности инженерно-геодезических измерений за счет фиксации момента появления двойной частоты со средней квадратической ошибкой не хуже +0,5 мм, при этом исключают необходимость измерения разницы фаз между прямыми и отраженными импульсами. Особенное преимущество предложенного авторами способа состоит в том, что точность измерений зависит от сравнения излучаемой и двойной частот, что делает измерения прецизионными.

Ключевые слова: геодезический мониторинг, вертикальное проектирование, светодальномер, плановые координаты, возведение высотных сооружений.

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IMPROVEMENT OF ENVIRONMENTALLY SAFE RINSING OF SALTED LANDS TECHNOLOGY

Abstract. The theoretical justification of the environmentally friendly saline leaching technology is based on a model of the evolutionary hydrogeochemical process of the natural system, which describes mass transfer in sedimentary formations during geological time, where it occurs via the molecular diffusion mechanism through the aqueous phase, namely, a portion of the dissolved salts is removed from the soil layer proportional to the amount of their solid phase enclosed within this layer.

To implement the developed flushing method, saline soil flushing technologies are proposed in practice, where the water supply to the check with a furrow is regulated by feeding it to the checks in pressure mode until it is completely moistened, and then the water supply is reduced to work in a non-pressure mode, i.e. water flow rate the check is reduced until it is equal to the filtration coefficient of the soil.

Moreover, the developed technology for washing saline soils based on the «soft» control of the hydrogeochemical process, which is based on the concept of the laws of natural evolutionary soil processes in the interpretation described above: the soil as an open system has stability, self-regulation and is in translational dynamic equilibrium.

To implement in practice the developed methods and technology for flushing saline lands, the proposed methodology for determining the parameters of flushing technology with irrigation technique using furrows from two opposite outlet furrows of row crops, which allow to determine the irrigation time and predict the regime of soil moisture with high reliability and reliability.

Key words: soil, salinization, rinsing, leaching, management, waste-free, safe, technology, process, soil formation, intensity, water permeability.

Introduction. Washings of saline lands cause global disturbances in the natural balances of the flows of substances and energy, significantly redistribute surface and underground drains, involving centuries-old reserves of readily soluble soil salts in the modern geological cycle. Therefore, at present, there are different approaches to determining the rinsing standards and the rinsing technology for saline lands, which leach salts to the toxicity threshold for crops using experimental results and theoretical developments on the basis of applying the achievement of fundamental sciences to solve the problem of land reclamation.

The principles for substantiating the conditions for washing saline lands are built on two essentially different positions: empirical, based on a generalization of a large amount of factual material from experimental studies, and theoretical, based on the use of the law of physicochemical processes based on the theory of salt transfer and salt exchange in a natural system. To a large extent, this situation is due to the fact that salinization and desalinization of irrigated lands are a multifactorial process, the theoretical description of which is still far from perfect. At the same time, an understanding of these processes,

precisely because of their multifactorial nature, can be achieved only on the basis of theoretical concepts based on the principles of exact sciences and taking fully into account environmental conditions. Therefore, the main attention in the study of salt transfer during leaching is given to substantiating the theoretical positions of the analysis of the processes occurring in this process, striving to identify the role of various factors.

As an example, to assess the environmental safety of flushing saline lands on the basis of the law of nature, in order to reduce the risk of environmentally undesirable consequences and to establish the direction and intensity of the natural process, a modeling method is used, which is currently important from both theoretical and practical points of view. Therefore, when developing a "model" of saline soil leaching, it is necessary to verify the correctness and accuracy of the formulation of the task and determine their reliability to solve the problems posed by leaching saline soils.

Purpose of the study – based on the laws of nature and natural hydrogeochemical processes, to develop methods and technologies for ecologically safe rinsing of saline lands and its methodological supports, ensuring the construction of highly productive hydro-landscape systems.

Materials and research methods. The theoretical basis for the environmentally sound saline leaching technology is based on a model of the evolutionary hydrogeochemical process of the natural system, which describes mass transfer in sedimentary formations over geological time and occurs by the mechanism of molecular diffusion through the aqueous phase, i.e. $dS = -\alpha \cdot S \cdot dg$, namely, with a certain portion of infiltrating water (dg), a part of the dissolved salts (dS)proportional to the amount of their solid phase enclosed within this layer (where is the salinity coefficient): $S_i = S \cdot \exp(-\alpha \cdot g)$ [1]

In carrying out leaching of saline soils, the technical effect tends to turn into permanent and increasingly intensifying, up to the complete replacement of the self-regulation of natural systems by technogenic regulation. These natural processes occur under conditions: inconsistencies in the intensity of water supply during leaching of saline soils (V_t^n): $V_t^n = N/t$, with the intensity of absorption of water into the soil ($V_t^в$): $V_t^в = (V_O - K_ф) \cdot exp(-K_в \cdot t) - K_ф$, i.e. $V_t^n \gg V_t^в$, and in the time scale will constantly increase (where N – estimated rinsing rate; t - rinsing duration; $K_ф$- filtration coefficient; V_O- absorption rate at the end of the first hour; $K_в$ - proportionality coefficient, which depends on soil properties) [2].

Therefore, from an ecological point of view, saline soils must be washed on the basis of "soft" management of natural systems. Unlike "hard" management, "soft" management is based on improving the former natural productivity of ecological systems or increasing soil fertility through a focused and based on the use of objective laws of Nature [3].

Research results. Based on the laws of nature and natural hydrogeochemical processes, a method for washing saline soils has been developed, including the preparation of temporary irrigation and drainage networks and checks, deep reclamation loosening of soils across the drains with alternating loosened and not loosened strips of the same width, followed by the flow of water into the checks in pressure mode to complete humidification, and then the water supply to work in a non-pressure mode, characterized in that temporary irrigation networks from the opposite side are cut in checks with zero marks the check and the furrow with a depression in the direction of the center of the check, while the flushing rate is supplied with the help of the furrow at the same time with oncoming jets at the same flow rate until they collide with each other in the center of the check, with the subsequent alignment of the water layer in the furrow along the water supply front (figure 1) [4].

To implement the developed flushing method, saline soil flushing technologies are proposed in practice, where the water supply to the check with a furrow is regulated by feeding it to the checks in pressure mode until it is completely moistened, and then the water supply is reduced to work in a non-pressure mode, i.e. water flow rate the check is reduced until it is equal to the filtration coefficient of the soil [5].

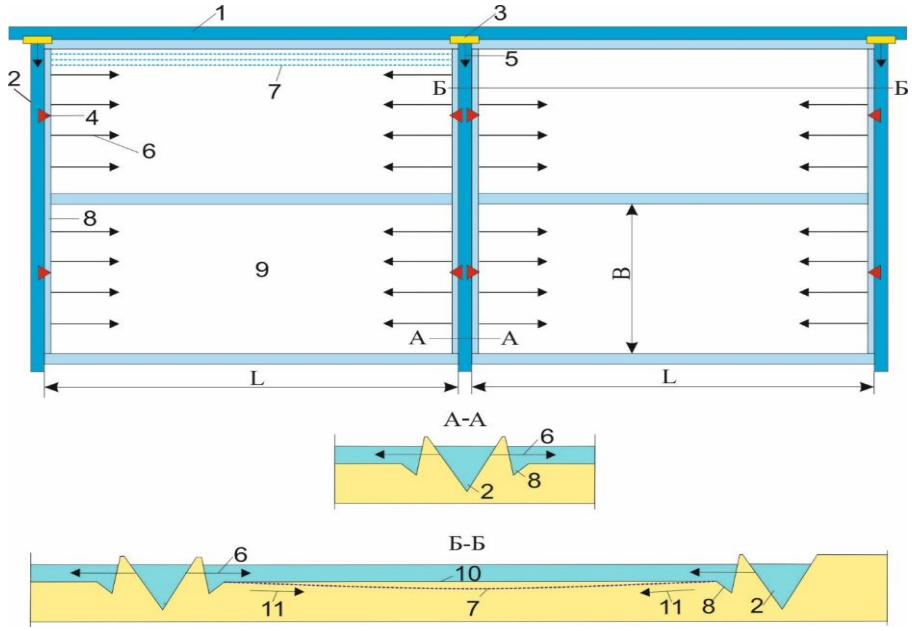

Figure 1 – Technological scheme of washing the soil layer of saline lands (1- distribution channel; 2- temporary irrigation; 3- water outlet in the distribution channel; 4- water outlet in the temporary irrigation; 5- direction of water flow in temporary irrigators; 6- direction of irrigation along the furrows ; 7- irrigation furrows; 8- output furrows; 9 –washed (watered) check; 10- land surface in watered checks; 11- direction of the slope of the bottom of the furrow)

The length of the washed check (L) depending on the horizontal slope of the earth's surface, is taken within 100-200 meters, and the width of the check (B) is determined taking into account the distances between rows of crops ($b_б$), cultivated after washing: $B = b_б \cdot n_б$ (where $n_б$ – the number of planned irrigation furrows along the width of the check), then the area of the washed check (F_a) will be equal: $F_a = B \cdot L$.

The horizontal slope of the bottom of the furrow is directed to the middle of the washed check and the depth of the cut furrow at the beginning of the furrow should be 10 cm, in the middle of 20 cm and for water loss simultaneously by opposing jets with each other along the furrows using the outlet furrows located opposite to the side inside the check.

The flow rate of water in the outlet furrows is determined based on the specific flow rate of the irrigated furrow ($q_б$) and the number of furrows ($n_б$), located inside the washed check: $Q_{oa} = q_б \cdot n_б$, here $q_б$ – specific consumption of irrigated furrow, l / s.

The water flow rate in temporary sprinklers (Q_b) is determined on the basis of the water flow rate of the outlet furrow (Q_{oa}) taking into account the number of simultaneously working outlet furrows (n_{oa}), i.e. $Q_b = Q_{oa} \cdot n_{oa}$.

The duration of the output furrows (t_{np}), that is, the water supply of the washed check is determined from the following systems of equations:

$$t_{np} = N_{iэ} \cdot F_n / 3.6 \cdot Q_b ;\ t_{np} = N_{iэ} \cdot F_n / 3.6 \cdot Q_{oa} \ ;\ t_{np} = N_{iэ} \cdot F_n / 3.6 \cdot q_б \cdot n_б ,$$

where $N_{iэ}$ – flushing rate in i – saline leaching stage, m^3/ha.

The leaching rate of saline soils can be determined by the formula Zh. S. Mustafayev, allowing to establish the sizes of flushing norms, taking into account the dynamics of hydraulic processes in soil [6]:

$$N = (\alpha / \beta) \lg(S / S_i) ,$$

where β - solubility rate of a solid during a chemical reaction between solid and liquid substances: $\beta = 2.02 \cdot \exp(-9.57 \cdot V_t)$, here V_t - water absorption rate in the soil (figure 2).

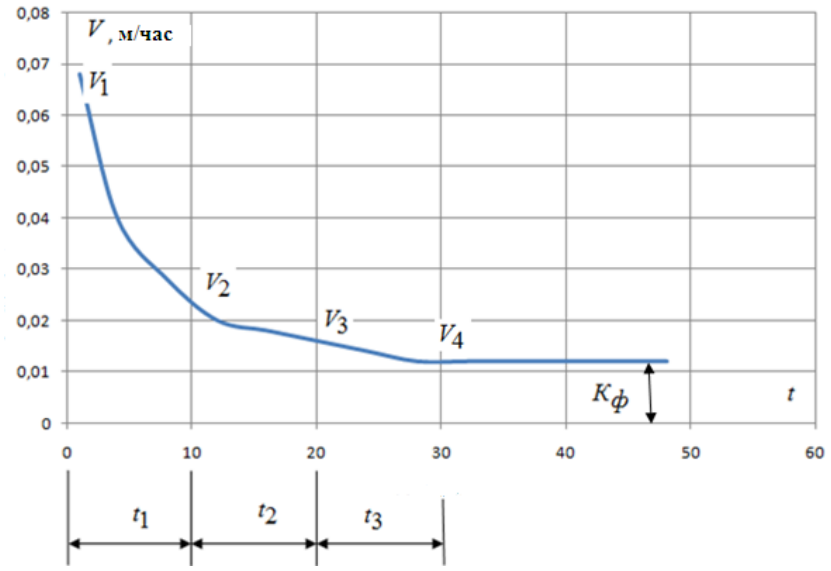

Figure 2 – The rate of absorption of water into the soil

Thus, at the initial stage, the absorption rate will be quite large, and after saturation of the soil with moisture, the absorption rate is equal to the filtration rate, which makes it possible to develop them into several sub-steps (n) taking into account the soil water absorption rate (V_t). For each sub-step, the average rate of water absorption into the soil ($V_{tcp} = (V_{ti} + V_{ti+1})/2$) is determined and multiplying them by the duration of the sub-steps (t_i) we determine the amount of flushing norms (N_{ti}), which are carried out in pressure mode: ($N_{ti} = V_{tcp} \cdot t_i$).

In general, the standards for flushing saline lands (N_{tH}), which are carried out in pressure mode, are determined by the formula: $N_{tн} = \sum_{i=1}^{n} N_{ti}$.

Rinsing standards for saline soils ($N_{tбб}$), which are flushed in a non-pressure mode, are determined by the following formula: $N_{tбб} = N - N_{tн}$.

The duration of leaching of saline soils in pressure-free mode ($t_{до}$)is determined by the formula: $t_{до} = (N - N_{tбб}) / K_ф$, where $K_ф$ - filtration coefficient.

In this case, leaching of saline soils is carried out when the average daily air temperature is more than + 5 ° C, that is, in early spring, then, firstly, the soil moisture will be close to the maximum permissible humidity, and secondly, the salts in the soil layer are in a state more dissolved, which allow using the leaching rate additionally falling on the soil surface, it is easy to displace salts in the lower layers of the soil.

When rinsing the soils of saline lands and after cultivating more salt-tolerant crops, it is necessary to maintain the same irrigation technology for furrows, that is, the regime of oncoming jets with the same costs.

The advancement of the flow along the furrows is described by the equation [7]:

$$l = a \cdot t^{\beta},$$

where l - flow path over time t; a - proportionality coefficient; β - coefficient characterizing the attenuation of the speed of the flow along the furrow.

The average rate of seepage of water into the soil varies over time according to the equation of A.N. Kostyakova [8]:

$$V_t = V_0 / t^{\alpha},$$

where V_0 - absorbed water layer for the first unit of time; α - coefficient characterizing the attenuation of the absorption rate.

Denoting the specific intensity of the water supply to the furrow q, average depth of water in a furrow h, total feed time T, furrow length l, and the current time and length, t and l_t respectively, we write the differential equation of the water balance in the furrow:

$$q \cdot dt = \frac{V_o}{(T-t)^{\alpha}}(T-t)\frac{\alpha \cdot \beta}{t^{1-\beta}}dt + h\frac{\alpha \cdot \beta}{t^{1-\beta}}dt,$$

deciding which, we get: $$q \cdot T = (2 \cdot \beta - \beta^2)(\frac{V_o \cdot T^{1-\alpha}}{2-\alpha}) + h)l_T,$$

where, we find l_t, q, T and m_T.

The value m_T can be represented by the equation:

$$m_T = m(1 - \frac{l}{2 \cdot l_q}),$$

where m - average irrigation rate; l_q - flow length after turning off the water supply.

The maximum possible costs with non-washing speed of the jet in the furrow are determined by the formula:

$$q_{\max} = W \cdot V_{\partial on},$$

where $q_{\max}$ - the maximum possible flow rate into the furrow. l / s; W - live section area of the furrow, m2; $V_{\partial on}$ - the maximum permissible speed of water in the furrow, depending on the mechanical composition of the soil, m / s.

The speed of water in the furrow can be determined by the formula: $V = C\sqrt{R \cdot J}$, where C - speed coefficient according to N.N. Pavlovsky: $C = (1/n)R^y = (1/n)R^{1/3}$, where n - roughness coefficient; R - hydraulic radius, m.

The wetted perimeter of the irrigation furrow is determined by the formula of V. F. Nosenko: $\alpha = q^{2/3}/i^{1/6}$, where q - flow rate ,m^3/hour; i - furrow slope. The live section area of the furrow is determined by the formula of V.F. Nosenko: $\omega = 0{,}00147(q^{2/3}/i^{1/3})$, m^2. The hydraulic radius of the irrigation furrow is determined by the formula: $R = w/a$, m.

Estimated Net Irrigation Rate ($m_{нт}$) in m^3/ha count on a layer of water $h_{нт}$ in m taking into account the estimated width of absorption of water ($в$), i.e. $h_{нт} = m_{нт}/1000$, and if the wetted perimeter is taken as the estimated absorption width (α), then $h_{нт} = m_{нт} \cdot в/10000 \cdot \alpha$, m.

Using a given coefficient of uniformity of moisture (K_p)we determine the maximum moisture that is observed at the beginning of the furrow:

$$h_н = h_{нт}/K_p = h_к/K_p.$$

With a straight plot of furrow hydration with a uniformity coefficient (K_p)the average irrigation norm along the furrow length is expressed by the equation: $h_{ср} = (h_н + h_{нт})/2 = (h_{нт}/2)[(1/K_p)+1]$.

Losses of water below the root layer for deep discharge caused by uneven moisture along the furrow length will be equal: $h_{сб} = (h_н - h_{нт})/2 = (h_{нт}/2)[(1/K_p)-1]$.

After applying the irrigation norm during counter irrigation along the furrows, the water layer in the furrow is aligned along the entire length and its values can be determined taking into account the absorbing water during irrigation, that is, according to the following formula:

$$h_{св} = h_{нт} - \frac{V_o}{1-\alpha} \cdot t^{1-\alpha},$$

where V_o - absorption rate at the end of the first hour; α - indicator depending on soil properties and initial moisture; t - watering duration.

The duration of water absorption after (t_o)watering is determined by the formula:

$$t_o = 1 - \alpha \sqrt{\frac{h_{св}(1-\alpha)}{V_o}} .$$

Thus, the proposed methodology for determining the parameters of flushing technology with irrigation technique for furrows from two opposite outlet furrows of row crops, allows you to determine the irrigation time and predict the mode of soil moisture with high reliability.

Conclusions. At the same time, the developed technology for rinsing saline soils on the basis of "soft" control of the hydrogeochemical process, which is based on the concept of the laws of natural evolutionary soil processes in the interpretation described above: the soil as an open system, has stability, self-regulation and is in translational dynamic equilibrium. At the same time, the principle of environmentally friendly technology for washing saline soils is based on reasonable dosing and regulation of technogenic loads on the natural system. Dosing - regulation of the flushing rate on a temporary scale is possible with a deep understanding of the laws of natural processes that determine the essence of the geological cycle of water and chemicals and the environmental restrictions that nature poses to our activities.

It should be noted that the hydrobiological and ecological development of saline and restoration of technologically disturbed soils of natural systems with a focus on high-tech, resource-saving, waste-free technologies in the long term determine the strategy of environmental reconstruction as a human environment at the stage of a deep ecological crisis. However, with balanced nature management it cannot be achieved only by reconstructing the natural system, but first of all, reconstructing the thinking and activities of all mankind is required.

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ТҰЗДАНҒАН ЖЕРДІ ШАЮДЫҢ ЭКОЛОГИЯЛЫҚ ТҰРҒЫДА ҚАУІПСІЗ ТЕХНОЛОГИЯСЫН ЖЕТІЛДІРУ

Аннотация. Табиғат заңдылықтары және табиғи гидрогеохимиялық үдерістер қағидасы негізінде жоғарғы өнімді гидроагроландшафттық жүйені құруды қамтамасыз ететін және топырақтың даму үдерісін сақтауға мүмкіндік беретін тұзданған жерді шаюдың экологиялық тұрғыда қауіпсіз технологиясы мен әдісі әзірленді.

Тұзданған жерді шаюдың экологиялық тұрғыда қауіпсіз технологиясын теориялық тұрғыда негіздеу, геологиялық уақыт ішінде үгінді қалдығындағы салмақ алмасуды білдіретін, яғни топырақ ерітінді құрамындағы молекулярлық деффузияның механикалық үдерісі арқылы жүретін, атап айтқанда, топырақ қабатынан сүзілетін судың белгілі бір көлемі пропорционал қатты қалдықтардан еріген тұзды бөлігін алып кетеді деген табиғи жүйедегі гидрогеохимиялық үдерістердің эволюциялық үлгісіне бейімделген.

Сонымен тұзданған жерді шаю жағдайын негіздеу екі түрлі қағидаға негізделген, яғни эмперикалық-тәжірбелік зерттеулер нәтижесінде қол жеткізген мол мәліметтерді талдауға, ал теориялық негіздеу – табиғи жүйедегі тұз алмасу және тасымалдау теориясына негізделген, физикалық-химиялық үдерістердің заңдылықтарына бейімделген.

Тұзданған жердегі топырақ шаю мөлшерін және шаюдың жоғарғы қысыммен және қысымсыз жағдайдағы судың топырақ қабатына сіңу тәртібін ескере отырып, уақытша арық, кәріз тізбектерін және атыз дайындаумен қатар, қопсыту қондырғысының еніне сәйкес келетін ені бірдей жолақтың бірі қопсытылған және екіншісі қопсытылмаған, кәрізге қиғаш топырақты терең мелиоративті қопсыту жұмыстары жүргізілген соң, атыздағы жүйектерге қарама-қарсы бағытта бірдей мөлшерде су беріледі және олар бір-бірімен түйіскенде, кері қарай шегініс болады да, атызға бір түрлі су жіберуге болады. Іс жүзінде ұсынылған шаю әдісін іске асыру үшін шаю технологиясы ұсынылған, яғни атызға берілетін су ағынын реттеу арқылы топырақ қабатын сумен толық қандырғанша топыраққа судың сіңуі жоғарғы қысымда жүреді, ал содан соң атызға суды беру шамасы біртіндеп азайтылады және шаю қарқыны да төмендеп, топырақтағы судың сүзілу жылдамдығының шамасымен теңеседі, яғни шаю танаптағы топырақ қабатындағы судың сүзілу жылдамдығына сай су беріліп отырады және судың топыраққа сіңіуі қысымсыз жағдайда жүзеге асырылады.

Сонымен ұсынылып отырған тұзданған жерді шаю технологиясы гидрогеохимиялық үдерісті «жеңіл» басқаруға негізделген, яғни топырақ үдерісінің табиғи эволюциялық заңдылығын тану жағдайына негізделіп, топырақ ашық жүйе ретінде орнығатын және өзін-өзі реттеу жағдайы динамикалық тепе-теңдікте болатыны ескерілген.

Тұзданған топырақты шаю, ауаның орташа тәуліктік жылулығы +5^{o}С болғанда жүргізілуі керек, яғни көктем мезгілінің бас кезінде, ал ол кезде біріншіден топырақ қабатының ылғалдығы, оның ылғал сыйымдылығының шектелген-мүмкіншілік шамасына жақын болады, екіншіден топырақ қабатындағы тұз ертінді түрінде болғандықтан, топырақ бетіне берілетін қосымша су арқылы топырақ қабатынан жылдам ығыстырып шығаруға болады.

Тұзданған жерді шаю технологиясын және әдісін өндірісте іске асыру үшін ауылшаруашылық дақылын, атыздың екі жағына орналасқан оқ арықтар арқылы суару техникасының өлшемдік көрсеткіштерін анықтаудың әдістемесі ұсынылған, ал ол жоғарғы дәрежедегі нақтылықпен топырақтың ылғалдану дәрежесін бағдарлауға және суару уақытын анықтауға мүмкіндік береді.

Түйін сөздер: топырақ, тұздану, шаю, басқару, қалдықсыз, қауіпсіз, технология, үдеріс, топырақ дамуы, қарқын, судың сүзілуі.

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СОВЕРШЕНСТВОВАНИЕ ТЕХНОЛОГИИ ЭКОЛОГИЧЕСКИ БЕЗОПАСНОЙ ПРОМЫВКИ ЗАСОЛЕННЫХ ЗЕМЕЛЬ

Аннотация. На основе законов природы и природных гидрогеохимических процессов разработаны способы и технологии экологически безопасной промывки засоленных земель и его методологическое обеспечение, обеспечивающих конструирования высокопродуктивных гидроагроландшафтных системы и позволяющее сохранить естественные почвообразовательные процессы.

Теоретическое обоснование экологически безопасной технологии промывки засоленных почв базируется на модели эволюционного гидрогеохимического процесса природной системы, описывающая массоперенос в осадочных формациях в течение геологического времени, где происходит по механизму молекулярной диффузии через водную фазу, а именно определенной порцией инфильтрирующихся вод из почвенного слоя выносится часть растворенных солей пропорциональная количеству их твердой фазы, заключенных в пределах этого слоя.

При этом принципы обоснования условий промывок засоленных земель строятся на двух существенно различных позициях: эмпирической, основанной на обобщении большого фактического материала экспериментальных исследований, и теоретической, основанной на использовании закона физико-химических процессов, базирующихся на теории солепереноса и солеобмена в природной системе.

Способ промывки засоленных почв, включающий подготовку временных оросительных и дренажных сетей и чеков, глубокое мелиоративное рыхление почв поперек дрен с чередованием рыхленных и нерыхленных полос одинаковой ширины, с последующей подачей воды в чеки в напорном режиме до полного увлажнения, а затем подачу воды до работы в безнапорном режиме, отличающийся тем, что в чеках с нулевыми отметками нарезают временные оросительные сети с противоположенной стороны чека и борозды с углублением в сторону центра чека, при этом подачу промывной нормы с помощью борозды проводят одновременно встречными струями с одинаковыми расходами, до столкновения друг с другом в центре чека, с последующим выравниванием слоя воды в борозде по фронту подачи воды.

Для реализации разработанных способов промывки на практике предложены технологии промывки засоленных почвы, где подачу воды в чек с помощью борозды регулируют, подавая ее в чеки в напорном режиме до полного увлажнения, а затем подачу воды уменьшают до работы в безнапорном режиме, то есть подачу расхода воды в чек уменьшают до тех пор, пока она не будет равной коэффициенту фильтрации данной почвы.

При этом разработанная технология промывки засоленных почв на основе «мягкого» управления гидрогеохимического процесса, где в основу положено понятие закономерности природных эволюционных почвенных процессов в той интерпретации, какая была изложена выше: почва как открытая система, обладает устойчивостью, саморегулированием и находится в поступательном динамическом равновесии.

Промывки засоленных почв проводятся, когда среднесуточная температура воздуха будет больше +5^{o}C, то есть в начале весны, тогда, во-первых, влажность почвы будет близка к предельно-допустимой влажности, во-вторых, соли в почвенном слое находятся в состоянии более растворенными, которые позволяют с помощью промывной нормы дополнительно падаваемой на поверхности почвы, легко вытеснить соли в нижние слои почвы.

Для реализации в практике разработанных способов и технологии промывок засоленных земель предложенная методика определения параметров технологии промывки с техникой полива по бороздам из двух противоположенных выводных борозд пропашных сельскохозяйственных культур, которые позволяют определить время полива и прогнозировать режим увлажнения почвы с высокой достоверностью и надежностью.

Ключевые слова: почва, засоление, промывка, управление, безотходная, безопасная, технология, процесс, почвообразование, интенсивность, водопроницаемость.

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FORMATION OF A PERSONNEL DETECTION SYSTEM IN SMOKE-FILLED PREMISES BASED ON BIOMETRIC ACCESS SYSTEMS

Abstract. In modern organisations, personnel are not at their workplace permanently and, accordingly, in case of emergency, they are at risk. There are a number of situations in which the access of even emergency services to the premises is very difficult to organise due to the regime of secrecy and the desire to preserve trade secrets. Additionally, the system of restricting the movement of workers in their places can be very limited on the part of management in order to maintain production discipline. The novelty of the study is determined by the fact that when using the detection system in case of fire or other emergency, its integration with the access verification and distribution system can be based on the use of integrated access systems. The authors show that the use of conditional access systems makes it possible to get employee lists at a faster pace and identify threats if certain technological complexes are used in their work. The practical significance of the study is determined primarily by the necessity for structural integration between conditional access systems and systems for recording and forecasting actions in emergency situations. It is proposed to use a model that allows to eliminate such differences.

Key words: fire, search, people, model, access.

Introduction. Modern systems of access control for people at work determine how well the work can be done and how much a company can be protected. Under the condition of implementing a system of conditional and distributed access, a company can completely block all possible leaks and increase the efficiency of internal processes [1]. However, there is a situation where restrictions on workers may be an obstacle to emergency response. The smoke and the cessation of the fire are determined by the speed of people evacuating from a building and creating the possibility of access to those rooms that are smoked [2]. When using conditional access systems, the use of systems may or may not be implemented at all. As a result of this, there is a necessity to create a system and choose the appropriate one according to its characteristics, in which the main attention will be paid to technical access in conditions of the necessity for its provision. The authors consider only biometric systems as a similar system [3].

Biometric technologies of personal identification based on recognition of a person by external morphological characters have deep historical roots [4]. The ability of people to know each other in appearance, voice, smell, etc. there is nothing more than elementary biometric identification. A systematic biometric approach was developed at the end of the 19th century by the Secretary of the Paris Police Prefecture, Alphonse Bertillon [5]. The method he proposed was based on measuring anthropological parameters of a person (height, length and volume of the head, length of hands, fingers, feet, etc.) in order to identify a person [6]. Biometric systems nowadays represent the second generation of security systems, since it is biometrics that uses measurements of individual parameters of a person to identify him. As is known, the main feature of first-generation security systems is the uniqueness and constancy of the identification parameter in time and space, while second-generation security systems, which are personality biometric parameters, are always variables that depend on many factors [7]. Moreover, the

task of reliable identification for biometric parameters is much more complicated than the identification of constant parameters for first-generation systems [8]. From an information point of view, it is precisely the systems of biometric identification of a person that fully meet the requirements of the time, automatically identifying themselves and using unstable values [9]. Currently, biometry as a science of personality identification research has several practically independent scientific areas, each of which has its own technical improvements [10]. It should be noted that dozens of research centres at universities, some scientific organisations and commercial firms [11] take an active part in the scientific research of biometrics. A specific market for biometric hardware devices and software for them, as well as services for supporting, testing and adapting biometric systems for their practical use, has already been formed [12].

Theoretical overview. Since ancient times, biometric characteristics have been used in everyday life to ensure safety and control [13]. Despite the wide technological capabilities to provide protection, today, the number of crimes and fraud is growing every minute. One of the common security technologies is biometric information security [14]. These systems are convenient because they do not require the storage of complex passwords or carrying special identifiers (keys, cards, etc.), and all is needed is to say a code word, put a finger or hand, or set a face to scan in order to get access. It should be noted that with a theoretical variety of possible biometric methods, there are many that are used in practice among them.

There are three main assets – recognition by fingerprint, face image and by the iris of the eye [15]. It is worth noting that the conditions at each scanning are different, and the parts of the body that are to be scanned, and the behavioural reflexes of the face are also not quite constant, so it is not about inaccurate coincidence with the sample, but only about the degree of similarity with the standard [16]. Therefore, biometric systems are characterised by the parameters "the possibility of non-recognition of one's own" (that is, the probability of unrecognisability of a registered person), and "the possibility of recognising someone else's" [17]. It is recommended to consider and analyse combined methods of identification, usually it is necessary to find ways to improve the effectiveness of biometric security systems against unauthorised access. It is worth always to consider the development of technologies to improve the above tools [18].

The principles underlying the identification and authentication methods used can be divided into three groups: traditional password protection, verification of a person's physical parameters (fingerprints, retina, etc.), classification of psychophysical parameters. The main characteristics of the effectiveness of biometric systems are recognition accuracy, resistance to environmental changes, cryptographic stability – protection against falsification and the reliability of the system itself. A quantitative description of means according to the criteria on a 10-point scale is presented. In the field of signature recognition, hundreds of patents from "IBM", "NCR", "VISA", and "Adapteck" have been issued [19]. The method of identification by keyboard handwriting is similar to identification by signature, but here the input of a code word is used on a standard computer keyboard. This method is not yet widespread, but developments in this area are ongoing. For example, "BioPassword Inc." developed a program for verifying the identity of a computer user by the rhythmic characteristics of typing [20].

Materials and methods. Dynamic methods of biometric identification are based on the behavioural (dynamic) characteristic of a person, i.e., are built on the feature's characteristic of subconscious movements in the process of reproducing any action. To support information security or access control, a number of biometric parameters must be provided in biometric identification systems for personnel. There are n various parameters of a person $P_1, P_2, \dots, P_n$ and m number of personnel $L_1, L_2, \dots, L_m$. Table shows the number of parameters P_i inherent in one person L_j.

Input data for a mathematical model of information technology for personnel identification based on a set of biometric parameters

Personnel, m	Biometric parameters of human, n				The minimum norm for access
	P_1	P_2	…	P_n	
L_1	x_{11}	x_{12}	…	x_{1n}	d_1
L_2	x_{21}		…	x_{2n}	d_2
…	…	…		…	…
L_m	x_{m1}	x_{m2}	…	x_{mn}	d_k
System cost	c_1	c_2	…	c_r	

The task is as follows: it is necessary to organise personnel access to information or an object so that the minimum norm for access, which is set for each person separately, depending on the level of security, is satisfied, and the cost of such a system is minimal.

1. X – the number of biometric parameters of a person.

2. System of restrictions (Eq. 1):

$$\begin{cases} x_{11} + x_{12} + \ldots + x_{1n} \geq d_1, \\ x_{21} + x_{22} + \ldots + x_{2n} \geq d_2 \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ x_{m1} + x_{m2} + \ldots + x_{mn} \geq d_k \end{cases} \quad (1)$$

$$x_{ij} \geq 0, i, j = \overline{1,n};\ d_i \geq 0, i = \overline{1,k}.$$

3. The minimum objective function (Eq. 2):

$$F(X) = c_1x_1 + c_2x_2 + \ldots + c_rx_n \to min, \quad (2)$$

The determinants for unknowns X in the problem were introduced and the restrictions for them were fixed: $x_{ij} \geq 0, i, j = \overline{1,n};\ d_i \geq 0, i = \overline{1,k}$. A system of restrictions of the problem was compiled with respect to the minimum norm for access d_k and an objective function with an established extreme (2).

The above model refers to linear programming problems, therefore, its solutions are presented in the Excel package. It can be seen from the calculation that the smallest 4 values of the function (73; 79.5; 86 and 97) are in the access technology, which uses a combination of voice, face and password. The selected combination of biometric parameters in the work corresponds to the established extremum of the objective function (2). The principle of multimodal static-dynamic biometric information system (MSDBIS) for identifying personnel by voice and face is reduced to converting the corresponding biometric characteristics of a person into a vector of biometric parameters V, presented in a N-dimensional orthogonal coordinate system (Eq. 3):

$$V = \{v_1, v_2, \ldots, v_N\}, j = \overline{1,N}, \quad (3)$$

At the stage of adding a new person to MSDBIS, on the basis of the samples presented to it, the system forms the biometric standards of this person in the form of vectors V_{voice} and V_{face}. In subsequent human calls to MSDBIS, he identifies himself and presents his biometric characteristics in the form of a vector V. MSDBIS by the identifier of the person calls the corresponding standards V_{voice} and V_{face} from the database of registered users and, based on the comparison of the presented vector V and available standards V_{voice} and V_{face}, implements the authentication procedure of this person, which can be built by various models.

Results and discussion. To classify users, there are two classes of "access" – V_P and "restriction" V_{PR}, the classifier can be implemented using only one discriminant function $f(V)$, the sign of which will determine whether the presented vector V belongs to one of two classes: V_P or V_{PR}. Moreover, the distribution areas of the biometric parameters of all those for whom access is "denied" can be considered in aggregate as the "restricted for all" integral region located around the compact "allow access" region. Suppose that in the general case, the region of distribution of biometric parameters "access" of a user is given by a multitude of samples ψ_D, consists of L vectors $V_{D_i}, i = \overline{1,L}$ normally distributed in the N-dimensional space of an orthogonal coordinate system, and each vector $V_{D_i}, i = \overline{1,L}$ is represented by its N components (Eq. 4):

$$V_{D_i} = \{v_1, v_2, \ldots, v_N\}, j = \overline{1,N}, \quad (4)$$

The centre of the distribution of vectors V_{D_i} is at a point $(\xi_1, \xi_1, \ldots, \xi_N)$ that is determined by N mathematical expectations $m_{v_1} = \xi_1, m_{v_2} = \xi_2, \ldots, m_{v_N} = \xi_N$. The central moments of the second order of the distribution of vectors V_{D_i} form a square matrix of moments (covariance matrix) (Eq. 5):

$$Q = \lambda_{jk} = \begin{matrix} \lambda_{11} & \lambda_{12} & \dots & \lambda_{1N} \\ \lambda_{21} & \lambda_{22} & \dots & \lambda_{2N} \\ \dots & \dots & \dots & \dots \\ \lambda_{N1} & \lambda_{N2} & \dots & \lambda_{NN} \end{matrix}, \quad (5)$$

where (Eq. 6):

$$\lambda_{jk} = \lambda_{kj} = M(v_j - \xi_j)(v_k - \xi_k) = \begin{Bmatrix} \sigma_{ij}^2 & j = k \\ cov\{v_j, v_k\} & j \neq k \end{Bmatrix} j, k = \overline{1, N}, \quad (6)$$

The density function of the normal distribution of vectors $V_{D_i}, i = \overline{1, L}$ has the form (Eq. 7):

$$f(v_1, v_2, \dots, v_N) = \frac{1}{\sqrt{(2\pi)^N det\lambda_{jk}}} exp\left[-\frac{1}{2}\sum_{j=1}^{N}\sum_{k=1}^{N} \Lambda_{jk}(v_j - \xi_j)(v_k - \xi_k)\right] \quad (7)$$

where $det\lambda_{jk}$ – the determinant of the covariance matrix $Q = \lambda_{jk}$. The coefficients Λ_{jk} make up the matrix $\Lambda = \Lambda_{jk}$ inverse to the covariance matrix $Q = \lambda_{jk}$.

To calculate the coefficients Λ_{jk}, the standard formula is used (Eq. 8):

$$\Lambda_{jk} = (-1)^{j+k} \frac{M_{jk}}{det\lambda_{jk}}, \quad (8)$$

where M_{jk} – the minor of the determinant $det\lambda_{jk}$ obtained from it by deleting the j-th row and the i-th column.

The expression that appears in the exponent of the density function of the normal distribution of vectors V_{D_i} is a positive definite quadratic form. Surfaces on which this quadratic constant form are surfaces of equal probability density in N-dimensional space and are hyperellipsoids that are grouped around a point $(\xi_1, \xi_1, \dots, \xi_N)$ (Eq. 9):

$$\frac{1}{2}\sum_{j=1}^{N}\sum_{k=1}^{N} \Lambda_{jk}(v_j - \xi_j)(v_k - \xi_k) = const \quad (9)$$

Denoting the constant on the right side of expression (9) by k^2, it is obtained (Eq. 10):

$$\frac{1}{2}\sum_{j=1}^{N}\sum_{k=1}^{N} \Lambda_{jk}(v_j - \xi_j)(v_k - \xi_k) = k^2 \quad (10)$$

The constant k sets the proportionality coefficient between the lengths a_i of the main semiaxes of the hyperellipsoid and the corresponding least square deviations σ_j (Eq. 11):

$$a_1 = k\sigma_1;\ a_2 = k\sigma_2; \dots, a_N = k\sigma_N, \quad (11)$$

For an optimal solution to the classification problem from all surfaces of equal probability densities, it is advisable to choose the one that characterises the scattering of vectors V_{D_i} relative to the point $\xi_1, \xi_1, \dots, \xi_N$. This surface corresponds to the so-called unit hyperellipsoid, in which the main semiaxes are equal to the corresponding least square deviations $\sigma_1, \sigma_1, \dots, \sigma_N$. That is, for a single hyperellipsoid $k = 1$, expression (11) is converted to the form (Eq. 12):

$$\frac{1}{2}\sum_{j=1}^{N}\sum_{k=1}^{N} \Lambda_{jk}(v_j - \xi_j)(v_k - \xi_k) = 1 \quad (12)$$

The initial boundary of the "restriction for all" integral region is formed by expanding the "access" region somewhat. To do this, the tolerance between the "access" and "restriction for all" areas is set in the

form of a Student coefficient, based on the magnitude of the error of the first kind (probability P1 of a false rejection for a user who has permission) (Eq. 13):

$$k = C[L_1, (1 - P_1)], \tag{13}$$

as a result, a new hyperellipsoid is obtained corresponding to the initial vector scattering boundary V_{3_i}. The lengths of its semiaxes will be determined taking into account the introduced tolerance as (Eq. 14):

$$a_j = k\sigma_j, \tag{14}$$

Expression (12) is now converted to the form (Eq. 15):

$$\frac{1}{2}\sum_{j=1}^{N}\sum_{k=1}^{N} \Lambda_{jk}\left(v_j - \xi_j\right)(v_k - \xi_k) = k^2 = \{C[L, (1 - P_1)]\}^2 \tag{15}$$

The resulting expression (15) is used to form the discriminant function $f(V) = 0$. In this case, it will determine the desired dividing surface, and the sign of the function $f(V)$ – whether the input vector V belongs to one of two classes: "access" or "restriction" (getting into the "restriction for all" area) (Eq. 16):

$$\begin{matrix} f(V) < 0, & V \in V_D \\ f(V) > 0, & V \in V_3' \end{matrix} \tag{16}$$

The identification procedure now reduces to checking whether the vector of biometric parameters V presented by a user falls into the region described by expression (15). The task of voice identification remains relevant today. To solve it, various algorithms and methods are used to optimise this process. The presentation of these algorithms is simple enough for understanding and implementing in the form of an electronic device.

The Fourier and Hartley transforms turn the time functions into frequency functions containing information about the amplitude and phase. The graphs of a continuous function $\mathrm{g}(t)$ and a discrete one $\mathrm{g}(\tau)$ are considered, where t and τ – time instants. Both functions start at zero, jump to a positive value and decay exponentially. By the definition of the Fourier transform for a continuous function, the integral is the entire real axis (Eq. 17), and for a discrete function – the sum with a finite set of samples (Eq. 18):

$$F(f) = \int_{-\infty}^{\infty} \mathrm{g}(t)\big(\cos(2\pi f t) - i\, sin(2\pi f t)\big)dt \tag{17}$$

$$F(v) = \frac{1}{n}\sum_{\tau=0}^{n-1} \mathrm{g}(t)\left(cos(2\pi v t) - i\, sin(2\pi v t)\right) \tag{18}$$

where f, v – the frequency value, n – the number of sample values of the function, and i – the imaginary number.

The integral representation is more suitable for theoretical studies, and the representation in the form of a finite sum for calculations on a computer. The integral and discrete Hartley transforms are defined in a similar way (Eq. 19-20):

$$H(f) = \int_{-\infty}^{\infty} \mathrm{g}(t)\big(cos(2\pi f t) - sin(2\pi f t)\big)dt \tag{19}$$

$$H(v) = \frac{1}{n}\sum_{\tau=0}^{n-1} \mathrm{g}(t)\left(cos(2\pi v t) - sin(2\pi v t)\right) \tag{20}$$

From the Fourier and Hartley transforms, the same information on the amplitude and phase can be derived. The Fourier amplitude is determined by the square root of the sum of the squares of the real and imaginary parts. The Hartley amplitude is determined by the square root of the sum of the squares and

$H(-v)$ and $H(v)$. The Fourier phase is determined by the arc tangent of the imaginary part divided by the real part. The Hartley phase is determined by the sum of 45° and the arctangent of $H(-v)$ divided by $H(v)$. For the spectral analysis of the voice of this problem, the fast Fourier transform was chosen, because the calculation time is saved by reducing the number of multiplications necessary for the analysis of the curve. When assessing the accuracy of IT biometric identification of personnel, it was found that if to use a unimodal or multimodal system of $N = \sqrt{\frac{1}{0.0001}} = 100$ (persons), then an organisation system with a number of personnel: using voice will not miss 48% (FRR) of the personnel who have access, a person – 6.5% (FRR), multimodal – 3% (FRR), and if an organisation: $N = \sqrt{\frac{1}{0.01}} = 10$ (persons), then the multimodal system is 33 times more reliable than the unimodal system: voice – 38% (FAR), face – 42% (FAR), multimodal (voice and face) – 1.2% (FAR).

Conclusions. Summarising the results for various identification methods, it can be said that for medium and large objects, as well as for objects with a maximum-security requirement, the iris and hand vein recognition should be used as biometric access. For objects with a headcount of up to several hundred people, access by fingerprints will be optimal. 3D image recognition systems may be needed in cases where recognition requires the absence of physical contact, or it is impossible to put an iris control system on.

From the calculation of the developed mathematical model of IT personnel identification based on a set of biometric parameters, it is seen that the smallest 4 function values: 73; 79.5; 86 and 97 in access technology that uses a combination of voice, face and password. The selected combination of biometric parameters in the work corresponds to the established extremum of the objective function.

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БИОМЕТРИКАЛЫҚ ҚОЛЖЕТІМДІЛІК ЖҮЙЕСІ НЕГІЗІНДЕ ТҮТІНДІ ОРЫН-ЖАЙДАН ҚЫЗМЕТКЕРЛЕРДІ ТАБУ ЖҮЙЕСІН ҚАЛЫПТАСТЫРУ

Аннотация. Заманауи ұйымдарда қызметкерлер әрдайым өздерінің жұмыс орындарында отырмайды, сәйкесінше, төтенше жағдай туындағанда оларға қауіп төнеді. Құпиялылық режим мен коммерциялық құпияны сақтап қалу ниетіне байланысты орын-жайда шұғыл көмек көрсету қызметін ұйымдастыру аса қиынға соғатын бірқатар жағдаяттардың орын алатындығы белгілі. Бұдан өзге, жұмыс орындарындағы жұмысшы қозғалысына шектеу қою жүйесіне өндірістік тәртіпті сақтау мақсатында басшылық тарапынан шектеу қойылуы мүмкін. Зерттеу жұмысының жаңашылдығы – өртті немесе өзге төтенше жағдайды анықтау жүйесін қолданған кезде оның тексеріс жүйесімен және қолжетімділікті үлестірумен кірігуі интеграциялан-ған қолжетімділік жүйесінің қолданысына негізделе алатындығында. Шартты қолжетімділік жүйесін қолданғанда қызметкер жұмысында белгілі бір технологиялық комплекстер жүзеге асырылған жағдайда олардың тізімін әлдеқайда жылдам алуға және қауіпті жылдам анықтауға мүмкіндік беретіндігін авторлар айқындап көрсеткен. Бәрінен бұрын төтенше жағдай кезінде әрекеттерді болжау мен тіркеу жүйесінің шартты қолжетімділік жүйесімен құрылымдық интеграциялануының қажеттігі зерттеу жұмысының маңыздылығын анықтайды.

Аталмыш сәйкессіздіктердің алдын алуға мүмкіндік беретін үлгіні қолдануға ұсынылған. Биометрикалық құрылғыларды жетілдіру арқылы олардың өнеркәсіптегі қолданысын ғана емес, операцияларды онлайн орындау, банкомат пен сауда жабдықтарына қолжетімділік, үйге кіріп-шығу және т.б. жекеше секторда да алдағы уақытта қолданғанда байқауға болады. Биометрикалық ақпараттарды қорғау технологиялары адамды анықтап, тану мақсатында оның түрлі параметрлерін пайдаланады. Биометрия адамдардың жеке-дара сипаттамасын пайдалана отырып идентификациялау негізінде олардың ақпаратқа қолжетімділік құқығын анықтау үшін қолданылады. Тәжірибе жүзінде қолданылып жүрген әдістердің ішіндегі ең сенімді әдіс – көздің торлы қабығын сканерлеу әдісі. Сондықтан да оны өте құпияландырылған объектілерге қолжетімділікті бақылау жүйелерінде қолданады. Мұндай жүйелерді қолданудың таралу деңгейі аз болғандықтан бұзу әрекеттерінің болу ықтималдығы аз. Дегенмен кемшілігі де бар, осы әдісті қолданатын жүйе бағасы өте жоғары. ДНҚ (дезоксирибонуклеин қышқылы) тізбегіндегі нуклеотид комбинациясы кез келген тірі жаратылыстың генетикалық кодын құрайды. ДНҚ-ны идентификациялау адам ДНҚ-сын бақылау үлгісінің ДНҚ-сымен салыстыру арқылы жүреді. Дегенмен бүгінде бұл әдіс адамды идентификациялау үшін криминалисти-

када ғана жүзеге асқанымен, деректерді қорғау жүйелерінде қымбаттылығы мен жабдығының күрделілігіне байланысты кең қолданыс таппаған.

Аталған технология сапасына деген сенімділікті көздің шатырша қабығын идентификациялаумен салыстыруға болады. Кейбір ауру түрлерінің әсер етуі, атап айтқанда, артрит кемшілігіне саналады. Артықшылығы, дәлдігі жоғары, қатты қымбат емес жабдық. Мәселен, бет-әлпетті айырып тану немесе көздің шатырша қабығы бойынша тану әдістеріне қарағанда жабдығы арзанырақ. «Fujitsu, Veid Pte. Ltd.», «Hitachi VeinID» компаниялары аппараттық және бағдарламалық жасақтаманы әзірлейді. «Hitachi» компаниясы «Finger Vein» жүйесін шығаруда, мұнда адамның кез келген саусақ көктамырларының кескіні қолданылады, себебі саусақтағы және алақандағы көктамырларды қолдан жасау мүмкін емес. Бұл жүйенің FRR 0.01% құрайды, ал FAR – 0.0001%. Инфрақызыл камера арқылы алынған бет-әлпеттің термографикалық суреті сүйектің тығыздығы, май мен тамырларға байланысты болып келеді және өте дара белгі болып саналады. Бұл әдістің дәлдігі өте жоғары, тіптен егіздерді де ажыратуға болады. Аталмыш әдіс косметика, бет әрлеу, пластикалық хирургияға тәуелді емес және кадрдың ар жағынан да айырып тануға мүмкіндік береді.

Иттің адамды иіс арқылы тануы бұрыннан белгілі. Бүгінде иіс үлгілерін жинауға және дайындауға арналған жүйелерді және сезбек жиымынан келген дабылды өңдеуге арналған процессорды қамтитын иіс сезетін «электрондық мұрын» да әзірленуде. Дегенмен аталған әзірлемелер тәжірибе жүзінде әзірге қолданылмайды. Жоғарыда аталған әдістер статикалық болып саналады, адамдардың уақыт өте келе өзгермейтін физиологиялық параметрлерін пайдаланады. Бұлардан өзге адамның дара мінездік ерекшеліктеріне негізделген динамикалық әдістер де бар. Оларға дауыс бойынша идентификациялау, қойылған қол арқылы пернетақтада қолмен жазу, мидың биоэлектрлік белсенділігі арқылы идентификациялау жатады. Адамды қашықтықтан және кадрдың ар жағынан айырып тануға мүмкіндік беретін әдістердің бірі – дауыстық идентификациялау. Бір артықшылығы – аталмыш әдістің арзандығы, себебі бұл қазіргі уақытта барлық компьютердегі микрофон мен дыбыстық картаны ғана қажет етеді және идентификациялау кезінде психологиялық жайсыздық болмауы керек. Дауысты идентификациялау кезінде дыбыс ырғағы, модуляция, интонация және сол секілді басқа да белгілер талданады. Соған қарамастан, бұл әдістің сенімділік пен дәлдік деңгейі жоғары емес, себебі дауыс адамның денсаулық жағдайы мен мінездік факторларға тәуелді. Дауысты айырып тану технологиясын әзірлеушілердің бірі – «Тілдік технологиялар орталығы» жауапкершілігі шектеулі қоғамы.

Түйін сөздер: өрт, іздестіру, адамдар, үлгі, қолжетімділік.

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ФОРМИРОВАНИЕ СИСТЕМЫ ОБНАРУЖЕНИЯ ПЕРСОНАЛА В ПОМЕЩЕНИЯХ С ЗАДЫМЛЕНИЕМ НА ОСНОВЕ БИОМЕТРИЧЕСКИХ СИСТЕМ ДОСТУПА

Аннотация. В современных организациях персонал не находится на своем рабочем месте постоянно и, соответственно, в случае возникновения чрезвычайной ситуации ему грозит опасность. Существует ряд ситуаций, в которых доступ даже экстренных служб в помещения очень сложно организовать из-за режима секретности и желания сохранить коммерческую тайну. Кроме того, система ограничения передвижения рабочих на своих местах может быть очень ограничена со стороны руководства в целях поддержания производственной дисциплины. Новизна исследования определяется тем, что при использовании системы обнаружения пожара или другой чрезвычайной ситуации ее интеграция с системой проверки и распределения доступа может быть основана на использовании интегрированных систем доступа. Авторы показывают, что использование систем условного доступа позволяет в более быстром темпе получать списки сотрудников и выявлять угрозы, если в их работе используются определенные технологические комплексы. Практическая значимость исследования определяется, прежде всего, необходимостью структурной интеграции систем условного доступа и систем регистрации и прогнозирования действий в чрезвычайных ситуациях.

Предлагается использовать модель, позволяющую устранить подобные различия. С улучшением биометрических устройств можно ожидать их использования не только в промышленности, но и в частном секторе – для проведения онлайн-операций, доступа к банкоматам и торговому оборудованию, входа и выхода из домов и многого другого. Технологии защиты биометрической информации используют различные параметры человека с целью его аутентификации. Биометрия используется для определения права людей на доступ к информации на основе их идентификации с использованием индивидуальных характеристик тела этих людей. Самый надежный из практически реализуемых методов – метод сканирования сетчатки глаза.

Поэтому его используют в системах контроля доступа к сильно засекреченным объектам. В связи с низким уровнем распространения таких систем попытки взлома маловероятны. Но недостатком является высокая стоимость систем, использующих этот метод. Комбинация нуклеотидов в цепи ДНК (дезоксирибонуклеиновая кислота) составляет генетический код любого живого существа. Идентификация ДНК проводится путем сравнения ДНК человека с ДНК контрольных образцов. Но сегодня этот метод используется только для идентификации человека в криминалистике, а в системах защиты информации он еще не применялся из-за дороговизны и сложности оборудования.

Эта технология сравнима по надежности с идентификацией радужной оболочки глаза. Недостаток – влияние некоторых заболеваний, в частности артрита. И преимущество – менее дорогое оборудование с высокой точностью. Например, оборудование дешевле, чем для методов распознавания лиц или по радужной оболочке глаза. Аппаратное и программное обеспечение разрабатывают компании «Fujitsu, Veid Pte. Ltd.», «Hitachi VeinID». «Hitachi» выпускает систему «Finger Vein», в которой используется изображение вен любого пальца человеческого пальца, поскольку вены на пальце, а также на ладони невозможно подделать. FRR этой системы составляет 0.01%, а FAR – 0.0001%. Термографический снимок лица, полученный с помощью инфракрасной камеры, зависит от плотности костей, жира и сосудов и является сугубо индивидуальным признаком. Точность этого метода очень высока и позволяет отличить даже близнецов. Этот метод не зависит от использования косметики, макияжа, пластической хирургии и позволяет узнавать за кадром.

Способность собак узнавать людей по запаху известна давно. Сегодня уже разрабатывается «электронный нос», который содержит системы для сбора образцов запахов и их подготовки, матрицы датчиков, которые будут воспринимать запахи, и процессор для обработки сигналов от массивов датчиков. Но до практического воплощения эти разработки еще далеки. Вышеупомянутые методы являются статическими, используют физиологические параметры человека, которые не меняются со временем. Помимо них существуют динамические методы, основанные на индивидуальных поведенческих особенностях человека. К ним относятся идентификация по голосу, идентификация с помощью подписи, по почерку на клавиатуре, по биоэлектрической активности мозга. Одним из методов, позволяющих распознать человека на расстоянии и за кадром, является голосовая идентификация. Плюсы – дешевизна этого метода, так как необходимы только микрофон и звуковая карта, которые сейчас есть на каждом компьютере, и отсутствие психологического дискомфорта при идентификации. Во время идентификации голоса анализируются высота звука, модуляция, интонация и тому подобное. Но надежность и точность этого метода невысока, ведь голос может зависеть от состояния здоровья и поведенческих факторов. Одним из разработчиков технологии распознавания голоса является Общество с ограниченной ответственностью «Центр языковых технологий».

Ключевые слова: пожар, розыск, люди, модель, доступ.

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APPLICABILITY ASSESSMENT OF NATURAL WATERS IN IRRIGATION OF AGRICULTURAL LAND ON THE EXAMPLE OF THE VAKHSH RIVER AND ITS TRIBUTARIES

Abstract. The results of chemical analyses of the Vakhsh river and its tributaries and the calculations of the main criteria for the water applicability for irrigation purposes are presented: the proportion of sodium cations capable of absorption, dissolution, ion exchange, and the proportion of magnesium. It was found that the waters of the Vakhsh river and its tributaries (Kyzylsu, Muksu, Obikhingou and Surkhob) are favorable for irrigation of agricultural land. On the values of the magnesium cations ratio to calcium cations the Vakhsh river and tributaries water correspond to the first class of «soft waters». It is shown that due to the surface and underground water exchange, underground water reservoirs are enriched by cations of alkaline and alkaline earth elements. The underground water reservoirs of the Vakhsh tributaries basin on the water quality terms are also suitable for irrigation purposes.

Key words: agriculture, underground water, solubility of cations, adsorbtion irrigation.

Introduction. The Vakhsh River is one of the main tributaries of the transboundary river Amu Darya that is formed by the confluence of the Surkhob and Obikhingou rivers.

The Vakhsh river basin by meteorological characteristics belongs to a dry climate with an annual rainfall of 143-297 mm and the distribution of the average annual precipitation by the seasons is as follows: in winter 40%, 48% in spring, 1.5% in summer and more than 10% in autumn [1].

The Vakhsh river by 691 km (from source to mouth) with a basin area of 39 160 km^2 is characterized by glacial-snow fed i.e. more than 40 % of the flow in the flood is meltwater glaciers.

The Vakhsh river basin potential energy resources are 15.0 Th. MWt by an electric energy generation of 53.4 TWt·h/year. From it more than 9.0 Th. MWt and 35.4 TWt·h/year of electric energy generation are correspond only to Vakhsh river [2]. By improving water quality and regulating part of the flow of the Amu Darya river, the Rogun Hydropower station will allow 90% irrigation of the Amu Darya basin on an area of 4.6 million ha and additionally develop more than 480 thousand hectare of land in the lower reaches. [3].

Water pollution is the leading cause of death and disease worldwide. Every year around the world, 6.000 children die from infectious diseases and 30 million people die from cancer caused by drinking contaminated water [4]. In developing countries, 80% of human diseases are associated with drinking water pollution.

Water quality deals with the physical, chemical and biological characteristics of water in relation to all other hydrological properties. The characteristics of water quality have become important in water resources planning, development for drinking, industrial, and irrigation purposes [5]

A number of indicators regulates the quality of water used in irrigation in order not to destroy the agrochemical properties of the soil.

The major concerns in terms of water quality and quantity are due to its inadequate distribution on the surface of earth and the rapid declining of fresh useable water [6]. Anthropogenic activities within river basins, erosion, and atmospheric depositions were also the main negative impacts on the water quality of most the reservoirs [7].

A wide review of the literature on the selection of optimal indicators for a comprehensive assessment of surface water quality and compelling facts about the need for systematic monitoring of the dynamics of the spread of pollutants for an objective assessment of water quality and in particular transboundary water basins and the establishment of criteria for assessing the quality of surface waters taking into account natural features are presented in [8,9].

The agriculture success is highly dependable on the quality of water applied in an agriculture area. Due to the application of poor or hazardous quality water the agriculture land/soil is affected and damages the crop yield in several waysThe presence of metals in irrigation water also has adverse effects on crop production. In addition, high concentration of salts can change the plant nutrients balance in the soil meanwhile some salts are toxic to certain plants [6,10].

Irrigation water quality alone is not sufficient to assess the potential salinity and hazards that irrigated agriculture may face. The concept of quality is not singular, but multiple. They can be so different that they can be compatible with each other, so it makes no sense to talk about quality as a single factor. It is more correct to talk about a high-quality profile. This means presenting multiple indicators instead of single ones in order to achieve a better understanding of the type of water. The quality profile is not a single one; it will also depend on the severity of the problem [11].

However, even water with considerably high salt concentration can be used for irrigation without endangering soil productivity, provided selected irrigation management. The key point is how to maintain existing salt balance in plant root zone [12].

Thus, comprehensive river water quality monitoring is a helpful tool not only to evaluate the suitability of surface water for irrigation, but also to ensure an efficient management of water resources and the protection of aquatic life [13] Therefore, the monitoring of environmental parameters is one of the highest priorities in the evaluation of environmental status of water resources and in environmental protection policy [14]. Thus, it is imperative to have reliable information on the characteristics of water quality for assessing its safety for irrigation as well as an effective pollution control and water resource management [15]. These findings can be explained by the geology of the study area, in particular the variation of the mineralogical composition of the bedrock from upstream to downstream. A similar impact of the bedrock composition to the water quality has been also described by [16]. It is commonly known that the ionic composition of water is the result of several factors during water-rock interaction [17].

In fact, changes in the geochemical characteristics of salt waters can be caused by the interaction of water and rocks, including exchange reactions with clay minerals, adsorption on clay minerals, and carbonate dissolution – precipitation [18]. In particular, the main factors controlling the mineralization of water are the mineral dissolution of well-soluble salts and, no less important, ion exchange. The high content of chloride and sodium water is mainly due to the dissolution of anhydrite, gypsum, and halite [19, 20].

To assess the quality of water for irrigation purposes, an alkaline hazard is widely used, expressed by the coefficient of adsorption of sodium cations (CA), the percentage of sodium cations, the percentage of solubility of sodium, the coefficient of exchange of sodium, the coefficient of magnesium.

The purpose of this work is a comprehensive chemical analysis and determination of the degree of applicability of the waters of the Vakhsh river and its tributaries for irrigation purposes.

Objects and Methodology. The scheme for sampling water from the Vakhsh River and its tributaries is shown in figure 1.

After preserving the samples, physical and chemical analyses of water were performed in the laboratory using a «TaLab» Photocolorimeter at a temperature of 19-20 °C and a relative humidity of 44-49%.

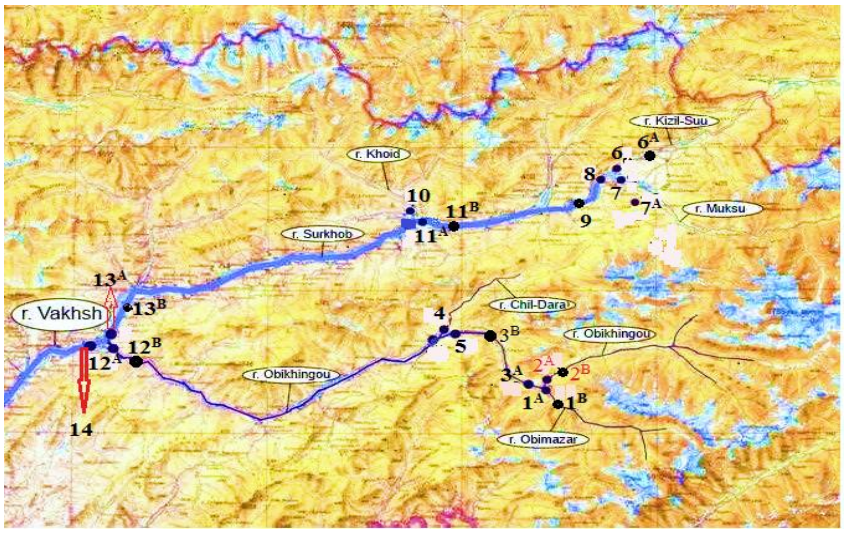

Figure 1 – Water sampling scheme from the Vakhsh river and its tributaries

At chemical analyses interpretation of results was guided by the normative document «Sanitary and epidemiological requirements to water sources, water intake sites for drinking purposes, drinking water supply and places of cultural and domestic water use and security of water facilities» (Order of the Minister of national economy of the Republic of Kazakhstan, March 16, 2015 No. 209). In addition, state standards were relevant: Na^+ (State standart 26449.1-85, п.17.1), K^+ (State standart 26449.1-85, п. 18.1), Ca^{2+} (State standart 26449.1-85, п. 11.1), Mg^{2+} (State standart 26449.1-85, п.12), NO_3^- (State standart 33045-2014).

Results and discussion. The results of the Na^+ adsorption ratios and the percentage of Na+ for the waters of the Vakhsh river and its tributaries (Kyzylsu, Muksu, Obikhingou, and Surkhob) are presented in figure 2 and figure 3, respectively.

The sodium adsorption ratio (SAR) was calculated by use of [21]:

$$SAR = \frac{Na+}{\sqrt{\frac{Ca^{2+}+Mg^{2+}}{2}}} \quad (1)$$

The percentage of Na^+ is determined [22]:

$$\%Na^+ = \frac{(Na^+ + K^+)\cdot 100}{(Ca^{2+}+Mg^{2+}+Na^+ + K^+)} \quad (2)$$

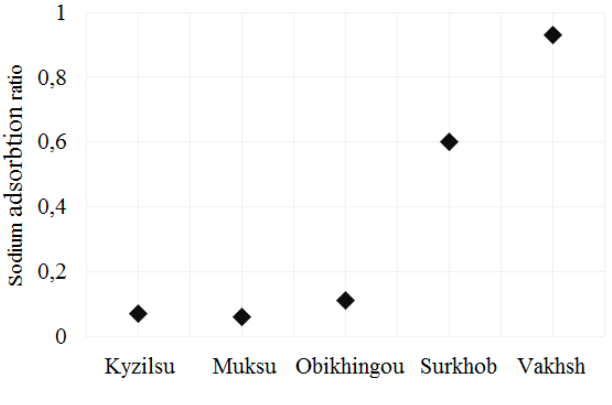

Figure 2 – Sodium adsorption ratio of the Vakhsh river and its tributaries

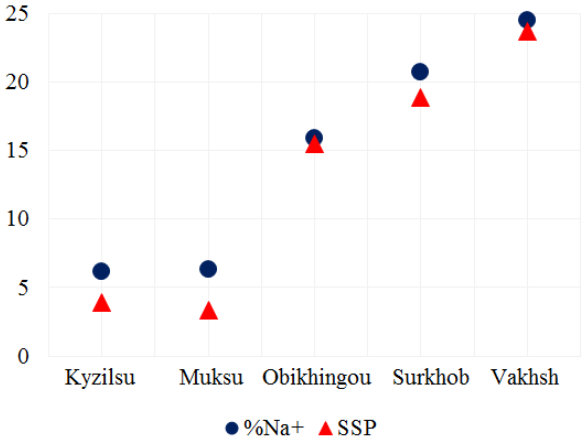

Figure 3 – The percentage Na^+ and soluble sodium percentage (SSP) of the Vakhsh river and tributaries

It can be seen from figure 2 that on the upstream tributaries of the Vakhsh river sodium adsorption ratio is not significant compared to the Vakhsh river and its tributary of the Surkhob river. The explanation of these phenomena can be found in figure 3 that shows the percentage of Na^+ in the waters of the Vakhsh river and its tributaries.

The content of sodium cations in the waters of the Kyzylsu and Muksu rivers in comparison with the Vakhsh and Surkhob rivers is much lower (figure3). Therefore, due to the low Na^+ content in the Kyzylsu and Muksu rivers ion-exchange reactions proceed weakly.

Another important parameter characterizing the applicability of water for irrigation purposes is the solubility sodium ratio (SSR) determined as [20]:

$$SSR = \left(\frac{Na^+}{Na^+ + Ca^+ + Mg^{2+}}\right) \cdot 100 \quad (3)$$

The percentage of soluble sodium calculation results by use of (3) for the Vakhsh river and its tributaries are shown in figure 3. Naturally, at small content of elements in the water, an insignificant percentage of its dissolution will be observed which is evidenced by the location of the values of soluble Na^+ for the Vakhsh river and its tributaries (figure 3).

The Mg^{2+} cation content is also an important indicator for determining the applicability of water for irrigation purposes.

Magnesium deteriorates soil structure particularly when waters are sodium dominated and highly saline. The Mg-ratio determined by use equation [23]:

$$Mg\text{–}\,ratio = \frac{(Mg^{2+}) \cdot 100}{(Ca^{2+} + Mg^{2+})} \quad (4)$$

Magnesium hazard value of more than 50 % would adversely affect the crop yield as the soils become more alkaline [22].

The Mg^{2+} ratio in the waters of the Vakhsh river and its tributaries as shown in figure 4 insignificant and does not reach 50%.

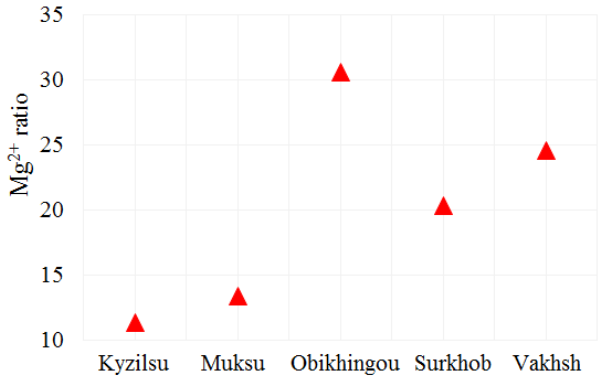

Figure 4 – Magnesium ratio of the Vakhsh river and its tributaries

The highest value is observed at the Obikhingou river exceeding more than 30% (figure 4). To explain the observed phenomenon, refer to table 1 that shows the content of alkaline and alkaline earth cations in the corresponding river waters.

Cation content in the waters of the Vakhsh river tributaries

Cations	Unit	Rivers			
		Kyzilsu	Muksu	Obikhingou	Surkhob
Na^+	mEq/dm^3	0.073	0.058	0.033	0.762
K^+	mEq/dm^3	0.059	0.056	0.002	0.094
Ca^{2+}	mEq/dm^3	1.786	1.456	0.125	2.613
Mg^{2+}	mEq/dm^3	0.228	0.225	0.055	0.665

From a comparison of the data presented in table, it follows that the Obikhingou river is characterized by the lowest content of cations of alkaline, alkaline earth elements and especially small values of Ca^{2+} according to (4) lead to an increase in the proportion of Mg^{2+} cations in the waters of the Obikhingou river.

The analysis of the chemical composition of river water and ground water in the river basins of Tajikistan revealed the processes of enrichment of underground water reservoirs by chemical elements of river water [24]. The sodium adsorption ratio (SAR) values for the surface water of the tributaries of the Vakhsh river (Kyzilsu, Muksu, Obikhingou, and Surkhob) and groundwater of the basin corresponding rivers is shown in figure 5. The percentage of Na+ in the groundwater of the Kyzylsu, Muksu, Obikhingou and Surkhob river basins and comparing it with values for the corresponding rivers are presented on the figure 6. The content of Na+ in groundwater of the three tributaries of the Vakhsh river (Kyzylsu, Obikhingou and Surkhob) is relatively lower than the surface, and in the case of Muksu appears anomalous, i.e. in the surface water Na+ is almost three times less than underground.

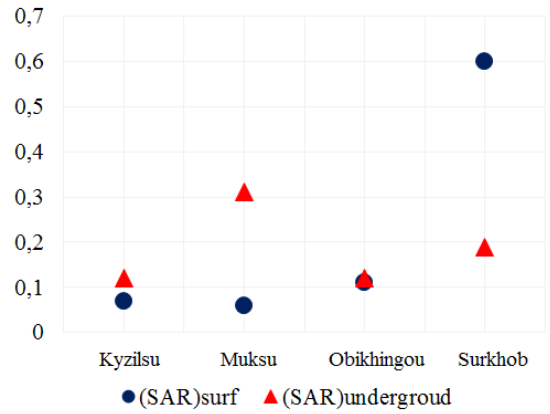

Figure 5 – Sodium adsorption ratio of the Vakhsh river tributaries and underground waters of rivers basins

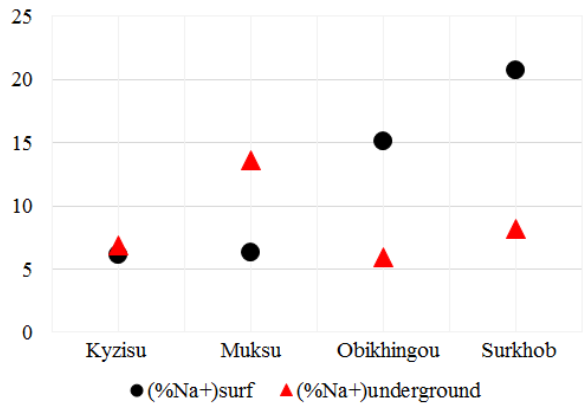

Figure 6 – The percentage Na^{+} of the Vakhsh river tributaries and underground waters of rivers basins

This naturally leads to large values of sodium ratio capable to dissolution (figure 7) and ion exchange (figure 8).

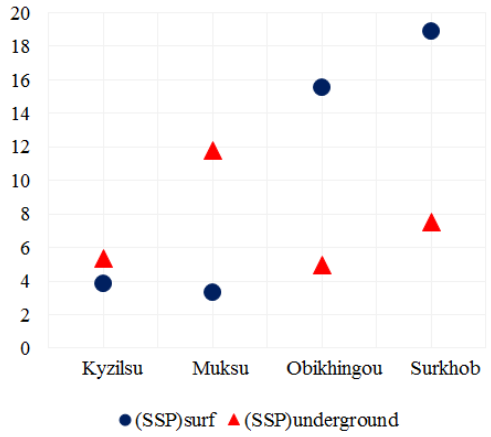

Figure 7 – The soluble sodium percentage (SSP) of the Vakhsh river tributaries and underground waters of rivers basins

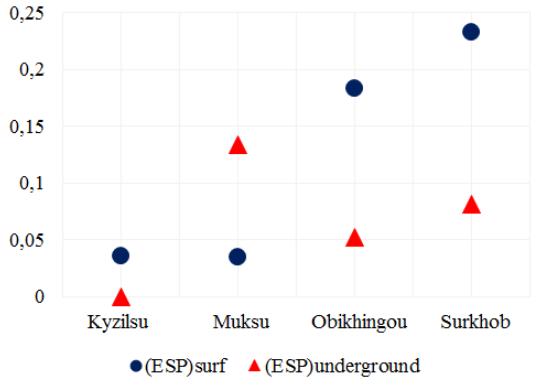

Figure 8 – The exchangeable sodium ratio of the Vakhsh river tributaries and underground waters of rivers basins

Conclusion. It was found that the concentration of cations in the Vakhsh river and its tributaries does not fit within any regularity and is mainly determined by the processes of rock washing out by the flow of the corresponding rivers. On the upstream of the Vakhsh river tributaries (Kyzylsu, Muksu) the share of

sodium cations adsorption is not significant compared to the Vakhsh river and tributary Surkhob river, and due to the low content of Na^+ in the Kyzylsu and Muksu rivers ion exchange reactions are weak and, of course, the proportion of sodium capable of dissolution is insignificant. A high proportion of Mg^{2+} in the waters of the Obikhingou river was found to be associated with low levels of Na^+, K^+,Ca^{2+}.

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ВАХШ ӨЗЕНІ МЕН ОНЫҢ САЛАЛАРЫ НЕГІЗІНДЕ АУЫЛШАРУАШЫЛЫҒЫ ЖЕРІН СУАРУДА ТАБИҒИ СУДЫҢ ҚОЛДАНЫЛУЫН БАҒАЛАУ

Аннотация. Судың сапасы – судың белгілі бір суды пайдалану түрлеріне жарамдылығын анықтайтын су құрамы мен қасиеттерінің сипатамасы**.** Судың сапасын бақылау – су сапасының көрсеткіштерінің белгіленген нормалар мен талаптарға сәйкестігін тексеру**.** Табиғи суды ирригациялық мақсатта пайдалану тиімділігін арттыру және олардың сапасын бақылау – су ресурстарын сақтаудағы басым бағыттарының бірі болып саналады**.** Осыған байланысты судың суаруға жарамдылығын кешенді бағалауды қамтамасыз ету үшін зерттелетін аумақтағы санитарлық-гигиеналық жағдайды және қоршаған ортаны қорғауды қамтамасыз ету қажеттілігін ескере отырып, су сапасын анықтайтын агрономиялық, техникалық және экологиялық өлшемдер негізге алынды.

Мақалада трансшекаралық Амудария өзенінің негізгі саласы, Сурхоб және Обихингоу өзендерінің қосылуы нәтижесінде пайда болған Вахш өзені суының химиялық талдау нәтижелері келтірілген. Вахш өзенінің ауданы мұз және қар жамылғысымен сипаттағанда 39 190 км^2 қамтиды, ұзындығы – 691 км. Вахш өзені алабының гидроэнергетикалық әлеуеті жылына 50 ТВт-тан асады. Вахш өзенінің ирригациалық потенциалы жақсы, қазіргі уақытта 15 ауданның суармалы жерлерін сумен қамтамасыз етеді және қосымша 480 мың гектардан астам жерді игере алады. Сонымен қатар, Тәжікстан Республикасының сушаруашылығында ауылшаруашылығының суармалы егіншілігі мен энергетика қажеттілігіне тұтынған су көлемі 92% қамтыса, ал өнеркәсіп және коммуналдық шаруашылыққа 4 % жұмсалады. Сондай-ақ суару үшін су жарамдылығының негізгі критерийлерінің есебі жүргізілген: натрий катионының адсорбцияға, ерітуге қабілетті қатынасы, иондық алмасу және магний қатынасы. Вахш өзені мен оның салаларының (Қызылсу, Мұқсу, Обихингоу және Сурхоб) сулары ауылшаруашылығы алқаптарын суаруға қолайлы екендігі анықталды. Сонымен бірге, Вахш өзені салаларының жоғарғы ағысында өзеннің өзімен және оның Сурхоб саласымен салыстырғанда натрий адсорбциясының коэффициенті аз болатындығы анықталды. Қызылсу және Муксу өзен суларындағы натрий катионының құрамы Вахш және Сурхоб өзенімен салыстырғанда едәуір төмен, бұл ион алмасу реакциясының әлсіз жүруінің негізгі себебінен болады. Магний катиондарының кальций катиондарына қатынасының мәні бойынша Вахш өзені мен оның салаларының суы бірінші класқа «жұмсақ суға» жатады. Жерүсті және жерасты су алмасу есебінен жерасты суы сілтілік және сілтілік жер элементтері катиондарымен байытылатыны көрсетілген. Сондай-ақ Вахш өзені алабының жерасты суының сапасы суаруға жарамды.

Вахш өзені мен оның салаларының суындағы катиондар концентрациясы қандай да бір заңдылыққа сәйкес келмейді және негізінен ол өзендер ағынымен тау жыныстарының шайылу процестері арқылы анықталды.

Түйін сөздер: ауылшаруашылығы, жерасты суы, катиондар ерігіштігі, адсорбция, суару.

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ОЦЕНКА ПРИМЕНИМОСТИ ПРИРОДНЫХ ВОД В ОРОШЕНИИ СЕЛЬСКОХОЗЯЙСТВЕННЫХ ЗЕМЕЛЬ НА ПРИМЕРЕ РЕКИ ВАХШ И ЕЕ ПРИТОКОВ

Аннотация. Качество воды – характеристика состава и свойств воды, определяющая пригодность ее для конкретных видов водопользования. Контроль качества вод – проверка соответствия показателей качества вод установленным нормам и требованиям. Повышение эффективности применения природных вод в ирригационных целях и контроль их качества – это приоритетные направления в сохранении водных

ресурсов. В этой связи для обеспечения комплексной оценки применимости качества воды для орошения были учтены агрономические, технические и экологические критерии, которые определяют качество воды с учетом необходимости обеспечения безопасности санитарно-гигиенической обстановки на исследуемой территории и охраны окружающей среды.

Таким образом, в статье представлены результаты химических анализов воды одной из главных притоков трансграничной реки Амударьи, образованной слиянием рек Сурхоб и Обихингоу реки Вахш и ее притоков. Площадь реки Вахш, характеризуясь ледниково-снежным покровом, составляет 39 190 км^2, а ее длина – 691 км. Гидроэнергетический потенциал бассейна реки Вахш составляет более 50 ТВт.ч/год. Река Вахш имеет хороший ирригационный потенциал, в данное время обеспечивает водой орошаемые площади 15- ти районов и дополнительно может освоить более 480 тыс.га. При этом в водном хозяйстве Республики Таджикистан на нужды сельского хозяйства с орошаемым земледелием и в энергетике расходуется 92% объема потребляемой воды, а на промышленность и коммунальное хозяйство – 4%. Выполнены также расчеты основных критериев пригодности воды для орошения: соотношение катионов натрия, способных к адборбции и растворению, ионный обмен, соотношение магния. Установлено, воды реки Вахш и ее притоков (Кызылсу, Муксу, Обихингу и Сурхоб) благоприятны для орошения сельскохозяйственных угодий. При этом выявлено, что в верховье притоков реки Вахш коэффициент адсорбции натрия незначителен по сравнению с самой рекой и ее притоком Сурхоб. Содержание катионов натрия в водах рек Кызылсу и Муксу по сравнению с реками Вахш и Сурхоб значительно ниже, что явилось основной причиной слабого течения ионнообменной реакции. По значениям отношения катионов магния к катионам кальция вода реки Вахш и ее притоков соответствует первому классу «мягких вод». Показано, что за счет поверхностного и подземного водообмена подземные воды обогащаются катионами щелочных и щелочноземельных элементов. Подземные воды бассейна притоков Вахша по качеству воды также пригодны для орошения.

Установлено, что концентрация катионов в реке Вахш и ее притоках не укладывается ни в какие закономерности и определяется в основном процессами вымывания горных пород потоком соответствующих рек.

Ключевые слова: сельское хозяйство, подземные воды, растворимость катионов, адсорбция, орошение.

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GEODETIC SUBSTANTIATION OF THE SARYARKA COPPER ORE REGION

Abstract. Information about copper deposits of Kazakhstan, development of which is carried out in the Saryarka region and its role in the development of the mining industry are considered in the article. Geological, structural and tectonic features of the deposits are presented. Research results on improvement methods of studying and geomechanical processes management in the development of mineral resources are presented. It is shown that the problem of geomechanical processes management can be solved on the basis of methodology for rock condition geomonitoring considered in this article, which provides comprehensive accounting and analysis of all natural and technogenic factors, as well as use of control tools developed by the authors.

The article presents technical solutions to ensure operational safety during the development of Saryarka region field reserves, which occur in difficult mining and geological conditions. Ore bodies of the deposit have different sizes and are located at different depths, therefore, seismic surveys are carried out. The geodetic network of provisional seismic surveys at the field has been substantiated. It is proposed to conduct surveys using modern geodetic instruments, such as satellite technologies, electronic, digital geodetic instruments. The geodetic survey methods proposed by the authors provide information on the bowels of the earth with a high degree of accuracy.

Key words: copper ore deposits, geology, structure, tectonics, disturbance, fracturing of rocks, seismic exploration, geodetic network, geodetic surveys, satellite systems, electronic tacheometers, laser scanners.

Introduction. In recent years, objects with complex geology and great stratification depth have been increasingly included in the development and operation of ore deposits, which requires special conditions for the development of these objects. The percentage of drilled “empty” wells does not decrease, which is also largely due to the complexity of the structure of the prospective ore objects under study. On the other hand, practical experience has proved the presence of ore deposits at great depths.

In his work named « Dzhezkazgan copper - ore region and its mineral resources » (1932) and during creating of metallogenic forecast map of Kazakhstan (1950) K.I. Satpayev wrote: «.... copper reserves accounted for today have not yet exhausted all the possibilities of the Dzhezkazgan ore-bearing region. Here I do not take into account the deposits of the Zhilandinsky group: Kipshakpai and Saryoba, ore reserves in them are laid very deeply and they need huge finance and technologies for their development. I will leave them for future generations» [1].

We see prophecies of prominent scientist today.

The content of the work. The bowels of Kazakhstan are rich in mineral deposits, including copper. The Saryoba deposit (Vostochnaya and Zapadnaya) located 30-35 km north of the Zhezkazgan mine is the special among them [2-6].

In general, ore field has been explored and approved reserves in categories B + C1 + C2 in quantities that allow it to be nominated as large industrial facility. Ore field structure includes equal red-colored

complex of interstratified rocks with ore-bearing deposits of the Taskuduk horizon of the Middle Carboniferous Formation Taskuduk and Serpukhov layer of the Lower Carboniferous.11 ore deposits were discovered in the ore field where 109 ore bodies were explored. The largest deposits are confined to the Taskuduk horizon. Their stretch is northeastern, with length of up to 3200 m, thickness of 0.5 to 17 m, and dip size of up to 1400 m (figure 1).

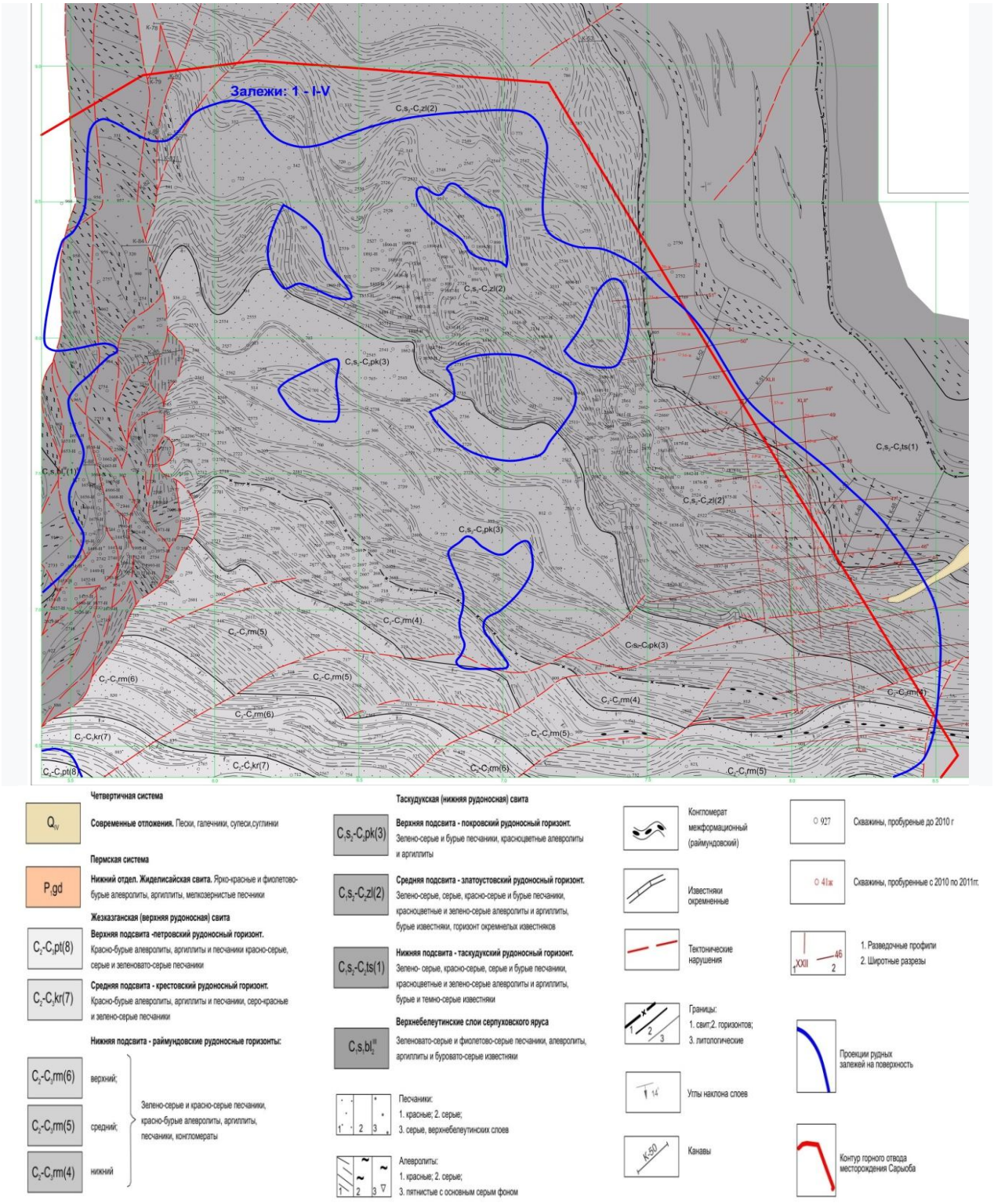

Figure 1 – Geological map of the East Saryoba field

In addition, they are complicated by both pre-ore and post-ore disjunctive dislocation which greatly complicates their exploration. At the initial stage of development of mineral deposits, use of seismic exploration is important for the sustainable development of the territory. This method has proved to be powerful tool for detecting geostructures that concentrate deposits in the bowels of the Earth, contributing to optimal planning of mining and reducing the number of wells. Moreover, effectiveness of seismic exploration (as well as any geological and geophysical method) directly depends on the quality of its geodetic support. In other words, how accurately point's position of explosion and geophones is determined in the coordinate space position in plan and height (depth) of any geostructures will be so accurately determined [7-11].

In this regard, in recent years, regulatory requirements for the quality of geodetic support for seismic surveys have been tightened. Creation of information geological and geophysical space involves the representation of it in uniform spatial coordinates.

The analysis of methodology state for conducting geodetic observations on mine territory particularly related to the lack of effective methods for determining deformations scale which necessitates methodology improvement of geodetic observations of rock deformations using modern instruments. Geodetic observations provide opportunity to identify the massif deformation, which is essential for geomechanical situation assessment in mining area. But they do not provide complete picture of deformation processes in time. This can be done only with using integrated methodology of geomonitoring of adjacent rock mass (figure 2).

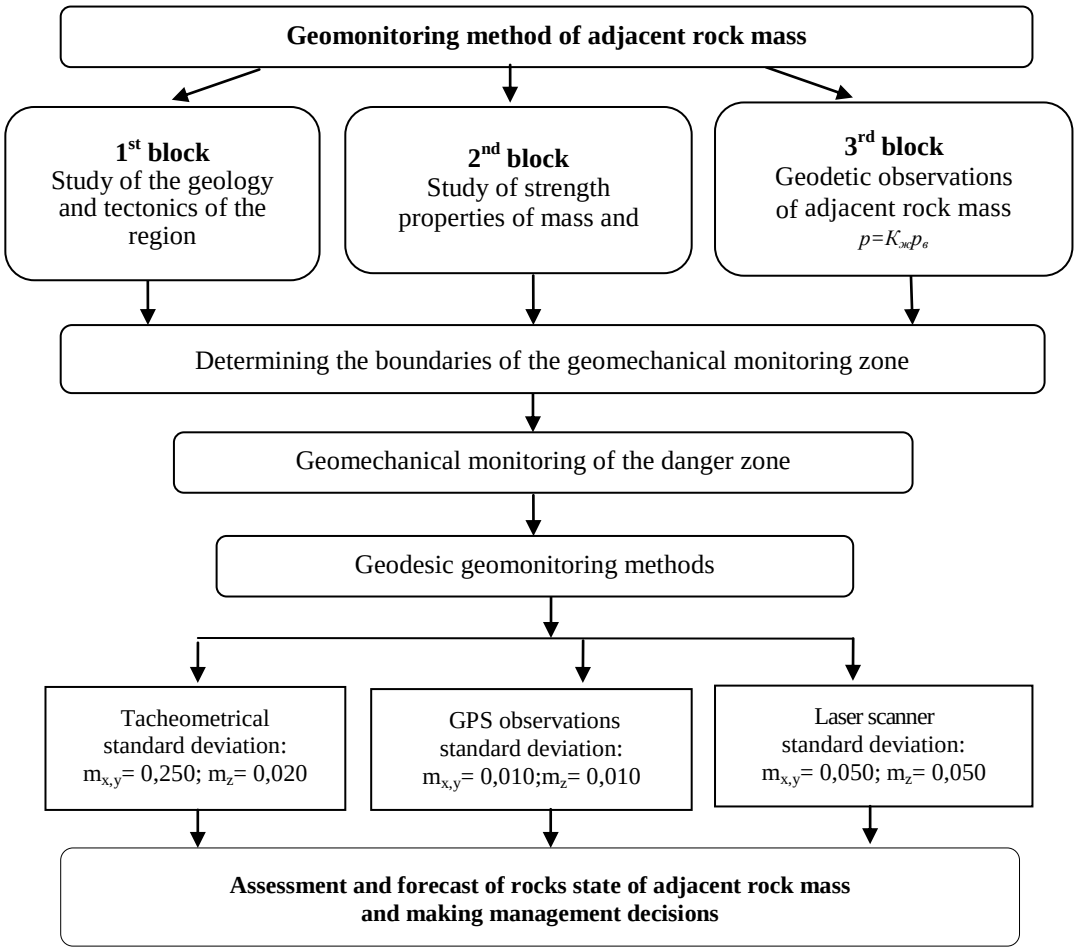

Figure 2 – Scheme of complex geomonitoring methodology

According to 1st and 2nd blocks of recommended methodology (figure 2), engineering-geological and mining-technical conditions of development and geomechanical state of the instrument arrays, structural-tectonic features and physical-mechanical properties of rocks of the field were studied in detail [12-15].

Monitoring of mountain massif state (3rd block), especially during exploration processes on the territory of giant copper deposit, occupying large area, consisting of several deposits and occurring in various deep horizons requires creation of highly accurate geodetic control. Basis for network creation of geodetic points is topographic map of area. Total area of mining allotment of Saryoba deposit, which was left to us by K.I. Satbayev - is 24 479 373, 66 m^2 (figure 3). Depth of the mountain allotment of East Saryoba is 510 m, the absolute elevation is 60 m. Based on the materials of existing cartogram object and existing coordinates, total area is calculated 2447, 94 ha.

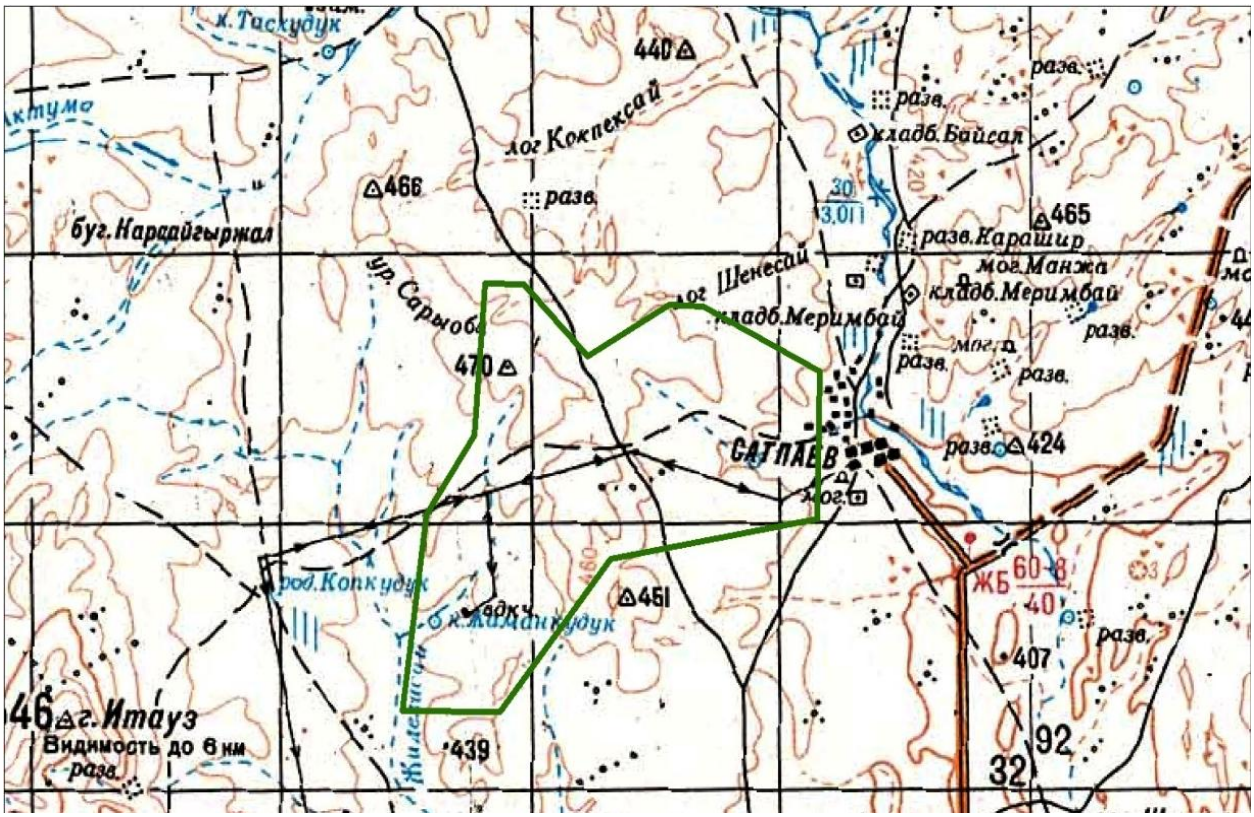

Figure 3 – Topographic base and boundary of mining allotment

Figure shows the triangulation points location (441, 465, 466, 470, 424, and 451) of the State Geodesic Network (SGN). Bridging process is done based on these points of SGN. In order to provide huge area using classic option of geodetic networks creation on fields is quite laborious and requires large financial costs.

During large-scale and long-term development of deposits, geodynamic processes along with geomechanical deformation processes can be developed) [16]. Therefore, geodynamic testing ground is created during development of deep-lying ore bodies, where repeated geodetic observations are carried out.

In this regard, we propose to replace long leveling lines with local geodetic constructions in the form of profile lines and control "bushes" of geodetic and leveling points. Complex application of ground and space geodetic methods will allow covering by monitoring observations the entire territory of the field, as well as increase observations efficiency and reduce capital costs of their production.

Thus, for differentiated study of geodynamic and geomechanical processes development that occupy large area and intended for deep tabulars, we propose creating "nodal" branches consisting of *basic* (reference), *control* (initial) and *deformation geodetic and leveling* points (figure 4) [17,18].

All nodal points are located in accordance with the ore veins (see figure 1) and are tied to SGN points (see figure 3).

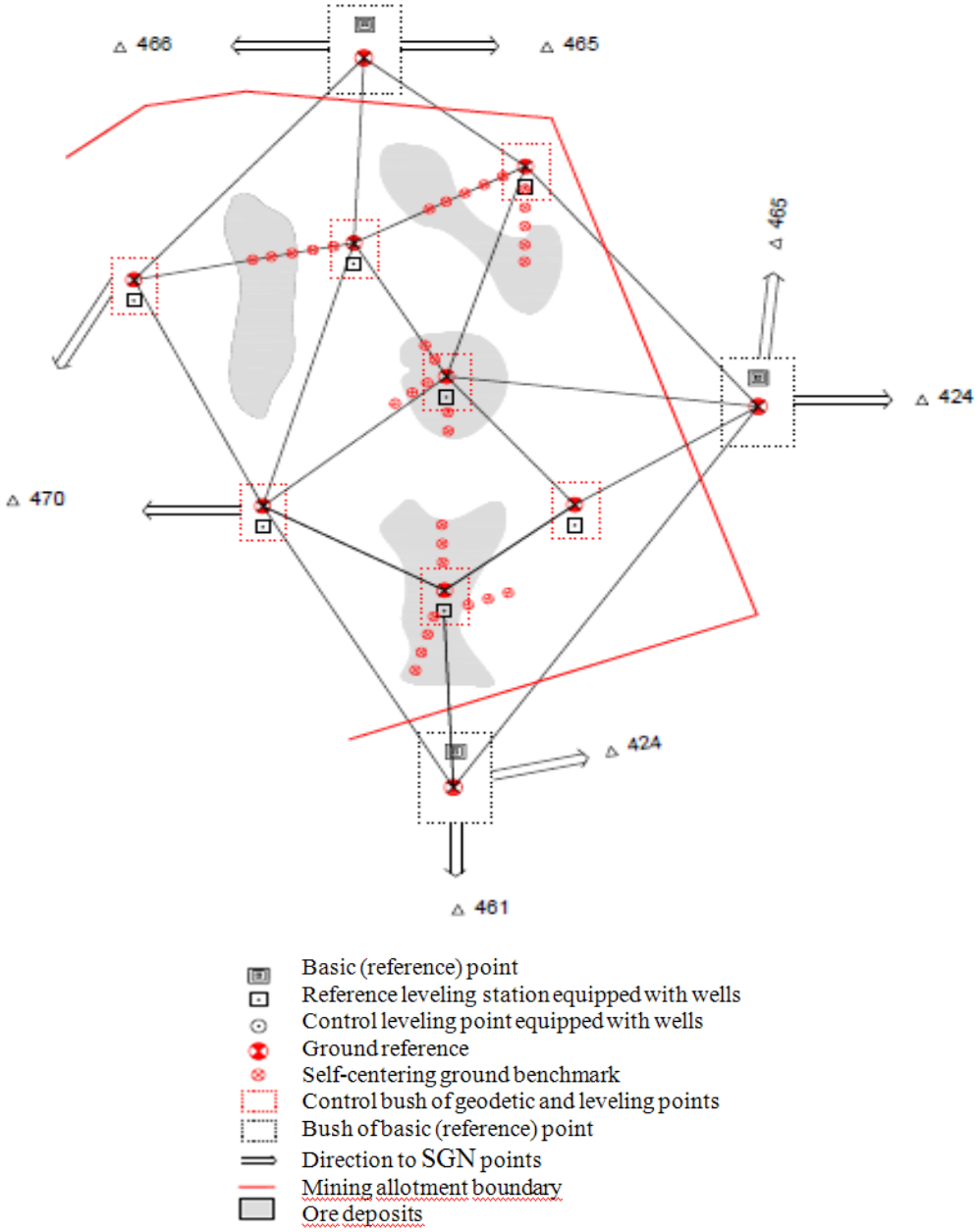

Figure 4 – Structural diagram of the observation network of the geodynamic test site

Network of basic (reference) points is designed to assess the geodynamic state of the deposit territory on regional scale and serves as the initial geodetic basis for the network development of *control* (initial) points. In this regard, basic (reference) points should be located outside the field and influence zone of technogenic geomechanical processes due to its development, as well as at distance from tectonic fault zones. Basic point's quantity is determined as following from of deposit outline configuration of the field and should be at least two. Their coordinates are determined relative to GNSS stations included in the international reference geodetic network[19].

Network of control (initial) points is the initial geodetic basis for observing geomechanical and modern geodynamic processes in zones of tectonic disturbances, as well as for assessing the geodynamic state of the field's territory. We propose to locate control (initial) leveling points vertically off-line of the field under conditions that exclude the impact of geomechanical processes on their stability. Exploration wells existing in the field (abandoned or being put into conservation), base of which is buried below developed deposits can be used as control (initial) points.

Network of deformation points is designed for observation of technogenic, geomechanical and modern geodynamic processes.

All these works are carried out using modern geodetic technologies. Moreover, high efficiency of geodetic works is achieved only through satellite technology (figure 5). Use of modern technical equipment opens up great opportunities for solving problems of geodetic support for seismic exploration at qualitatively new level. Rapid development of geodetic base centralization, profiles production on the ground with high accuracy, measurement and automation of data processing, ability to work in difficult physical, geographical and climatic conditions is carried out only on the basis of modern instruments [20,21].

a b

Figure 5 – Coordinates determination of points (a) and boreholes (b) by GPS technology

At the moment experimental works on the experimental site “Vostochnaya Saryoba” is being completed. Also, ore mining works are being carried out at Zhylandy field, remote from Zhezkazgan deposit: “Vostochny Saryoba”, “Itauyz”, “Zapadny Saryoba”, “Kipshakbai” and “Karashoshak”. “Kazakhmys” corporation successfully continues investment projects.

Conclusions. 1. On the basis of analysis of domestic and foreign scientific and technical literature, work experience in the field of studying geomechanical and geodynamic processes, as well as deformation monitoring tools, complex geomonitoring technique using modern highly-accurate geodetic instruments is recommended.

2. According to the 1st and 2nd blocks of recommended methodology, geology and tectonics of deposit area were studied, researches on strength properties and structural features of rocks massif were conducted. Geological, structural and tectonic features of the giant copper deposit in Kazakhstan “Vostochnaya Saryoba” are presented.

3. Modern approach to setting and making observations of geodynamic and geomechanical processes in solid mineral deposits is analyzed. New "nodal" method for constructing geodetic observation systems at geodynamic test site has been substantiated, which allowing covering of monitoring control of ongoing seismic surveys as well as increasing observations efficiency and reducing capital costs for their production.

4. Analysis of modern geodetic methods used in seismic exploration of the field in the deep horizon is carried out. Use of modern instruments and use of the simplest GPS receivers during seismic surveys can solve many pressing problems in the geodetic support of geophysical surveys. The controller as special computer can be used to solve several specific problems, depending on their complexity.

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САРЫАРҚАНЫҢ МЫС РУДАЛЫ АЛҚАБЫН ГЕОДЕЗИЯЛЫҚ НЕГІЗДЕУ

Аннотация. Мақалада күрделі кен-геологиялық жағдайда және терең қабаттарда, Жезқазған аймағында игеріліп жатқан Шығыс Сарыоба мыс кен орны, тау-кен өндірісін дамытудағы рөлі туралы ақпарат қарастырылған. Шығыс Сарыоба кен орны қорын игеру кезінде қиын геологиялық жағдайда қауіпсіз жұмысты қамтамасыз етудің техникалық шешімдер ұсынылған. Кен орнындағы рудалық денелердің өлшемі де орналасқан тереңдігі де әрқилы, сондықтан да сейсмикалық барлау жобаланған. Далалық сейсмикалық зерттеулер топографиялық және геодезиялық жұмыстармен қатар жүргізіледі.

Ақпараттық геологиялық-геофизикалық кеңістікті құруға тек бірыңғай кеңістік координаттар жүйесі ғана мүмкіндік жасайды. Игеріліп жатқан кен орны аумағында геодезиялық бақылау жүргізу әдіснамасының жай-күйіне талдау жасуда, ең алдымен, деформациялану масштабын анықтайтын тиімді әдістердің жоқтығына байланысты бақылауды тек кешенді геомониторинг әдісі негізінде ғана жүргізуді қажет етеді.

Кешенді геомониторинг жүргізудің ұсынылып отырған әдісіне сәйкес массивтегі тау жынысының берік-тік қасиеттері мен құрылымдық ерекшеліктері зерттелді. Мақалада Шығыс Сарыоба мыс кен орнының геологиялық, құрылымдық және тектоникалық ерекшеліктері келтірілген.

Кен орындарын кең ауқымда және ұзақ игеру кезінде геомеханикалық деформациялық процестермен қатар геодинамикалық процестер де дамуы мүмкін. Сондықтан терең жатқан кен денелерін игеруде геодинамикалық полигон құрылады, онда кешенді мониторингтік бақылау жүргізіледі. Қазіргі уақытта кешенді (жерасты-жерүсті аэроғарыштық) мониторинг жүргізу қажет. Мұндай бақылау жүргізудің технологиялық базасы – қазіргі заманғы аэро және ғарыш технологияларының мүмкіндіктерін толыққанды пайдалана отыра, оны дәстүрлі маркшейерлік-геодезиялық жұмыс әдістерімен үйлестіре жүргізу.

Жер беті қозғалыстарына геодинамикалық мониторинг жүргізу үшін Сарыарқа мыс кені аймағының пландық және биіктік негіздерін құру мәселелері қарастырылған. Мақалада геодинамикалық полигонында геодезиялық байқау жүйесін құрудың жаңа «бұталы» әдісі негізделеді, ол сейсмикалық және тау-кен жұмыстарының мониторингін бақылауға, сонымен қатар бақылау жылдамдығы мен тиімділігін арттыруға, сонымен қатар, кен өндіруге кететін шығынды азайтуға мүмкіндік береді. Бұл әдісті тек қатты пайдалы қазбаларды кең көлемде, сонымен бірге мұнай мен газ кен орындарын игеруде де осындай проблемаларды шешуде қолдануға болады.

Терең горизонттағы кен орындарын сейсмикалық барлау кезінде қолданылатын қазіргі геодезиялық әдістерге талдау жасалды. Кешенді бақылау кезінде (геодезиялық, аэрокосмостық, гравитациялық) авторлар ғаламдық навигациялық жүйелерді – GNSS, лазерлік сканерлер және роботты электронды тахеомды нақтылы уақыт режимінде алуды қамтамасыз етеді. Авторлар ұсынған геодезиялық түсірудің инновациялық әдістері жер қойнауы туралы жоғары дәлдікпен ақпарат береді, ал нәтижелер геодинамикалық қауіпті кейінгі бағалау және ықтимал жағымсыз салдарды азайту жөніндегі шараларды әзірлеу үшін қолданылады.

Сейсмикалық зерттеулер кезінде заманауи құралдар мен қарапайым GPS-қабылдағыштарды қолдану геофизикалық зерттеулерді геодезиялық қамтамасыз етудегі көптеген өзекті мәселелерді шеше алады.

Түйін сөздер: мыс кен орындары, геология, құрылым, тектоника, бұзылыстар, тау жыныстарының жарықшақтығы, сейсмикалық барлау, геодезиялық торап, геодезиялық түсірістер, жерсерік жүйелері, электронды тахеометрлер, лазерлі сканерлер.

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ГЕОДЕЗИЧЕСКОЕ ОБОСНОВАНИЕ МЕДНОРУДНОГО РАЙОНА САРЫАРКИ

Аннотация. В статье рассматривается информация о медном месторождении «Восточный Сарыоба», освоение которого осуществляется в Жезказганском регионе, его роли в развитии горнодобывающей промышленности. Представлены технические решения, позволяющие обеспечить безопасные условия работы в сложных горно-геологических условиях при освоении запасов месторождения «Восточная Сарыоба» в Казахстане. Рудные тела месторождении имеют разные размеры и расположены на различных глубинах, поэтому проводятся сейсморазведочные работы. Проводимые на месторождении сейморазведочные работы сопровождены топорафо-геодезическими съемками.

Создание информационного геолого-геофизического пространства предполагает представление его в единых пространственных координатах. Анализ состояния методики проведения геодезических наблюдений на территории разрабатываемого месторождения, прежде всего, связано с отсутствием эффективных способов определения величин деформаций, что обуславливает необходимость осуществления наблюдении только на основе комплексной методики ведения геомониторинга.

Согласно рекомендуемой комплексной методики ведения геомониторинга, выполнены исследования прочностных свойств и структурных особенностей горных пород массива. Представлены геологические, структурные и тектонические особенности гигантского медного месторождения «Восточная Сарыоба».

При крупномасштабном и длительном освоении месторождений, наряду с геомеханическими деформационными процессами могут развиваться и геодинамические процессы. Поэтому при освоении глубокозалегающих рудных тел создается геодинамичес-кий полигон, где проводятся комплексные наблюдения. В настоящее время представляется необходимым выполнения комплексного (подземно-наземно аэрокосмического) наблюдения. Технологическорй базой проведения такого наблюдения является полноценное использование возможностей современных аэро- и космических технологий в сочетении с традиционными маркшейдерско-геодезическими методами работ.

Рассмотрены вопросы создания планово-высотного обоснования меднорудного района Сарыарки для ведения геодинамического мониторинга земной поверхности. В статье обоснован новый «узловой» метод построения систем геодезических наблюдений на геодинамическом полигоне, позволяющий охват мониторинговым контролем проводимых сейсморазведочных и горных работ, а также повысить оперативность наблюдений и снизить капитальные затраты на их добычу.Метод может быть использован для решения аналогических задач при крупномасштабном освоении не только твердых полезных ископаемых, а также в условиях разработки нефтегазовых месторождений.

Проведен анализ современных геодезических методов, используемых при сейсморазведке месторождения в глубоком горизонте. При комплексном мониторинге (геодезический, аэрокосмический, гравитационный) авторами предложены использовать глобальные навигационные системы-GNSS, лазерные сканеры и электронные тахеометры, которые обеспечивали получения оперативной информации об объекте при минимальных затратах времени. Предложенные авторами инновационные геодезические методы съемки позволяют получить информацию о недрах земли с высокой степенью точности, и результаты используются для последующих оценок геодинамического риска и выработки мероприятий по снижению возможных негативных последствий. Использование современных приборов и простейших GPS - приемников при проведении сейсморазведочных работ позволяют решить многие насущные проблемы в геодезическом обеспечении геофизических исследований.

Ключевые слова: меднорудные месторождения, геология, структура, тектоника, нарушенность, трещиновтость горных пород, сейсмческая разведка, геодезическая сеть, геодезичские съемки, спутниковые системы, электрондые тахеометры, лазерные сканеры.

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CALCULATION OF TWO-SPEED FLOW OF TWO-PHASE OPEN FLOW

Abstract. In this article the mathematical model of unsteady flow the two-phase open stream taking into account the redistribution of the particulate concentration, the depth of flow and water filtration on the bottom of the channel, and also created an efficient method of calculation. In this case, the two-speed flow is considered, i.e. the presence of the longitudinal and vertical components of the phase velocities is taken into account, and we also believe that the flow parameters along the flow do not change. Initial and boundary conditions are established based on theoretical and empirical formulas, which are widely used in practice. The flow in open channels is non-pressurized, occurs under the influence of gravity and is characterized by the fact that the flow has a free surface. At the initial moment of time, we consider the flow to be uniform in the longitudinal direction and all parameters are set by known theoretical and empirical formulas. At the bottom of the channel for longitudinal velocity component of the water use condition of adhesion, and for the longitudinal velocity component of solid phase condition for the shift and believe the known concentrations of solid particles, and vertical components of velocity the phases of the filtering conditions (for water), and hydraulic size (for solid particles). On the free surface, we consider that there are no solid particles, and for the longitudinal components of the phase velocities we neglect the force of air friction, and for the vertical components of the phase velocities we use the condition of non-uniformity of the free surface in time. On the basis of the developed mathematical model and the created method of calculation, the changes of the main parameters in the depth of the flow and in time are determined.

Key words: Non-stationary flow, two-phase flow, free surface, incompressible medium, true density, reduced density, concentration, viscosity coefficient, interaction coefficient between phases, filtration.

Introduction. In recent years, some progress has been made in hydro-mechanics in the field of research of flow dynamics in open channels [1]. However, these models do not fully cover the physics of the process, since the water used for irrigation is inhomogeneous and contains certain amounts of solid particles [2]. The appearance of a small number of solid particles in the flow, as is known, significantly changes the nature and structure of the processes [3,4]. At the same time, new macroscopic parameters appear, in particular, the given densities, the interacting forces between the phases, as well as other mechanical characteristics. These flow parameters violate the basic law of conservation of the components of the mixture, the components interact, which causes a redistribution of speed, concentrations of individual components, changes the flow rate of the mixture. From the variety of multiphase media, dispersed flows can be distinguished that have a relatively regular character and represent a mixture of several phases, one of which is various inclusions (drops, bubbles, solid particles), i.e. aerosols, fogs, bubble liquids, suspensions, etc.

We consider a non-stationary two-speed flow of a two-phase open stream, taking into account the redistribution of the concentration of solid particles in the depth of the stream and water filtration at the bottom of the channel. The purpose of the article is to compare the results of a non-stationary two-speed

flow with the results of a previously studied one-speed flow [5,6]. To describe the flow of a two-phase medium, an "interpenetrating" model is used, based on the following assumptions: there is no interphase transition; for each phase, the equation includes terms that characterize the interaction between the phases; each phase is taken as a separate continuous medium and is described by separate equations [3,4].

Problem statement. On the basis of "interpenetrating" model to develop a model of unsteady two-speed two-phase flow open flow with account of redistribution of the particulate concentration, the depth of flow and water filtration on the bottom of the channel, and is also an effective method of calculation.

Method of solution. When developing the mathematical model, the "interpenetrating" model of a multiphase medium is used for dispersed flows that have a relatively regular character. As a mathematical apparatus used: for linearization of nonlinear terms, the method of simple iteration[7]; for partial differential equations, the method of finite differences, using a two-layer six-point implicit scheme with weight and a two-layer four-point implicit scheme with symmetrized derivatives, and for solving the obtained systems of algebraic equations, the method of matrix run; for the solution of an ordinary differential equation describing the change in the wavelength of the wave front, the Runge-Kutta method is of the fourth order of accuracy. The computer mathematics environment Mathcad was used for processing numerical data.

Main part. The "interpenetrating" model was used to study the problem [3,4]:

$$\begin{aligned}
&\rho_n \frac{\partial u_n}{\partial t} = \rho_n u_n \frac{\partial u_n}{\partial x} + \rho_n v_n \frac{\partial u_n}{\partial y} = -f_n \frac{\partial p}{\partial x} + \frac{\partial}{\partial x}\left[2 f_n \mu_n \left(\frac{\partial u_n}{\partial x} - \frac{1}{3} div V_n\right)\right] + \\
&+ \frac{\partial}{\partial y}\left[f_n \mu_n \left(\frac{\partial u_n}{\partial y} + \frac{\partial v_n}{\partial x}\right)\right] + \sum_{i=1}^{2} K(u_i - u_n) + \rho_n X_n, \\
&\rho_n \frac{\partial v_n}{\partial t} + \rho_n u_n \frac{\partial v_n}{\partial x} + \rho_n v_n \frac{\partial v_n}{\partial y} = -f_n \frac{\partial p}{\partial y} + \frac{\partial}{\partial x}\left[f_n \mu_n \left(\frac{\partial u_n}{\partial y} + \frac{\partial v_n}{\partial x}\right)\right] + \\
&+ \frac{\partial}{\partial y}\left[2 f_n \mu_n \left(\frac{\partial v_n}{\partial y} - \frac{1}{3} div V_n\right)\right] + \sum_{i=1}^{2} K\,(v_i - v_n) + \rho_n Y_n,
\end{aligned} \tag{1}$$

and the continuity equation

$$\begin{aligned}
&\frac{\partial \rho_n}{\partial t} + \frac{\partial}{\partial x}(\rho_n u_n) + \frac{\partial}{\partial y}(\rho_n v_n) = 0, \\
&f_1 + f_2 = 1,\ \rho_n = \rho_{ni} f_n,
\end{aligned} \tag{2}$$

where ρ_n, ρ_{ni} – reduced and true densities of the n-th phase, respectively (n=1,2); u_n – longitudinal component of the n-phase velocity; v_n – vertical component of the n-phase velocity; f_n – concentration (volume content) of the n-th phase; p – pressure; μ_n – the coefficient of viscosity of the n-th phase; K – coefficient of interaction between phases; X_n, Y_n - components of the mass forces of the n-th phase; x, y – coordinate axes along the flow and along the depth of the flow, respectively; t – time.

$$div V_n = \frac{\partial u_n}{\partial x} + \frac{\partial v_n}{\partial y}$$

Consider the two-speed case when there are no mass forces and the flow parameters along the flow do not change. The flow in open channels is non-pressurized and occurs under the influence of gravity [8]. Then the system of equations (1), (2) will take the form:

$$\begin{aligned}
&\rho_n \frac{\partial u_n}{\partial t} + \rho_n v_n \frac{\partial u_n}{\partial y} = \mu_n \frac{\partial}{\partial y}\left(f_n \frac{\partial u_n}{\partial y}\right) + \sum_{i=1}^{2} K\,(u_i - u_n), \\
&\rho_n \frac{\partial v_n}{\partial t} + \rho_n v_n \frac{\partial v_n}{\partial y} = \frac{4}{3}\mu_n \frac{\partial}{\partial y}\left(f_n \frac{\partial v_n}{\partial y}\right) + \sum_{i=1}^{2} K\,(v_i - v_n),
\end{aligned} \tag{3}$$

$$\begin{aligned}
&\frac{\partial \rho_n}{\partial t} + \frac{\partial}{\partial y}(\rho_n v_n) = 0, \\
&f_1 + f_2 = 1, \rho_n = \rho_{ni} f_n\,.
\end{aligned} \tag{4}$$

If we write a system of equations (3) for each phase separately, we get:

$$\begin{aligned}
\rho_1 \frac{\partial u_1}{\partial t} + \rho_1 v_1 \frac{\partial u_1}{\partial y} &= \mu_1 \frac{\partial}{\partial y}\left(f_1 \frac{\partial u_1}{\partial y}\right) + K u_2 - K u_1, \\
\rho_2 \frac{\partial u_2}{\partial t} + \rho_2 v_2 \frac{\partial u_2}{\partial y} &= \mu_2 \frac{\partial}{\partial y}\left(f_2 \frac{\partial u_2}{\partial y}\right) + K u_1 - K u_2, \\
\rho_1 \frac{\partial v_1}{\partial t} + \rho_1 v_1 \frac{\partial v_1}{\partial y} &= \frac{4}{3}\mu_1 \frac{\partial}{\partial y}\left(f_1 \frac{\partial v_1}{\partial y}\right) + K v_2 - K v_1, \\
\rho_2 \frac{\partial v_2}{\partial t} + \rho_2 v_2 \frac{\partial v_2}{\partial y} &= \frac{4}{3}\mu_2 \frac{\partial}{\partial y}\left(f_2 \frac{\partial v_2}{\partial y}\right) + K v_1 - K v_2.
\end{aligned} \tag{5}$$

Equation (4) for the concentration of solid particles will take the following form:

$$\begin{aligned}
&\frac{\partial f_2}{\partial t} + \frac{\partial}{\partial y}(f_2 v_2) = 0, \\
&f_1 + f_2 = 1.
\end{aligned} \tag{6}$$

The flow in open channels differs in that the flow has a free surface. If the free surface H in the transverse direction (in the direction of the z axis) is horizontal and does not change along the flow, then $H=H$ (t). Then according to the conclusions of work [1] for a free surface we get

$$\frac{dH}{dt} = V, H(0) = H_0$$

where V- filtration rate (absorption).

As a result, we obtain a closed system of equations (5-6) with respect to u_1, u_2, v_1, v_2, f_2. Consider the initial and boundary conditions for the resulting system of equations. At the initial moment of time ($t = 0$), we consider the flow to be uniform in the longitudinal direction and all parameters are given by known theoretical and empirical formulas, i.e.

$$u_1 = u_{10}(y), u_2 = u_{20}(y), v_1 = v_{10}(y), v_2 = v_{20}(y), f_2 = f_{20}(y), \text{ with } t = 0,$$

At the bottom of the channel for longitudinal velocity component of the water use condition of adhesion, and for the longitudinal velocity component of solid phase condition for the shift and believe the known concentrations of solid particles

$$u_1 = 0, u_2 + l_0 \frac{\partial u_2}{\partial y} = 0, f = f_2^0 \text{ with } y = 0,$$

and for the vertical components of the phase velocities of the filtration conditions (for water) and the deposition of solid particles in standing water, i.e.

$$v_1 = V, v_2 = V_k \text{ with } y = 0.$$

l_0 – offset path length; V_k – the rate of precipitation of solid particles in standing water, i.e. hydraulic size.

There are no solid particles on the free surface, and for the longitudinal components of the phase velocities we neglect the force of air friction, that is, the force of air friction.

$$\frac{\partial u_1}{\partial y} = 0, \frac{\partial u_2}{\partial y} = 0, f_2 = 0, \text{ with } y = H(t).$$

and for the vertical components of the phase velocities, we use the condition of unevenness of the free surface in time, i.e.

$$v_1 = \frac{dH}{dt}, v_2 = \frac{dH}{dt} \text{ with } y = H(t).$$

Thus, the initial and boundary conditions will have the form:

$$\begin{aligned}
&u_1 = u_{10}(y), u_2 = u_{20}(y), v_1 = v_{10}(y), v_2 = v_{20}(y), f_2 = f_{20}(y), \text{ with } t = 0, \\
&u_1 = 0, u_2 + l_0 \frac{\partial u_2}{\partial y} = 0, v_2 = V, v_2 = V_k, f = f_2^0 \text{ with } y = 0, \\
&\frac{\partial u_1}{\partial y} = 0, \frac{\partial u_2}{\partial y} = 0, v_1 = \frac{dH}{dt}, v_2 = \frac{dH}{dt}, f_2 = 0 \text{ with } y = H(t).
\end{aligned} \tag{7}$$

The length of the path of displacement l_0 can be established on the basis of empirical data. For this purpose, in particular, the empirical Bazin formula can be used [1]. Many theoretical and empirical formulas have been proposed by different authors for the filtration rate (absorption). The most widespread formula was A. N. Kostyakov [1]. It should be noted the work of V. N. Goncharov, who gave empirical formulas of hydraulic size V_k, generalizing experimental materials of other studies [9].

The length of the lag of the wave front $l(t)$ related to the average flow rate U_{cm} the following equation

$$\frac{dl}{dt} = U_{cm}(t), \tag{8}$$

which is solved with the initial condition $l(0) = 0$. The time corresponding to the length is the time when the wave front reaches the distance l.

The obtained problem (5-6) with boundary conditions (7) is solved according to the calculation method given in [1]. First let's go to dimensionless quantities:

$$u_1^* = \frac{u_1}{U}, u_2^* = \frac{u_2}{U}, v_1^* = \frac{v_1}{U}, v_2^* = \frac{v_2}{U}, y^* = \frac{y}{H(t)}, t^* = \frac{t}{T},$$

moreover, the nonlinear terms are linearized using the simple iteration method, i.e. taking the value from the previous time layer. Then the system of equations (5-6) will take the form (in the future, for simplicity, omit the asterisks)

$$\begin{cases} \dfrac{\partial u_1}{\partial t} = a_1^{(S)} \dfrac{\partial^2 u_1}{\partial y^2} + a_2^{(S)} \dfrac{\partial u_1}{\partial y} + a_3^{(S)} u_1 + a_4^{(S)}, \\ \dfrac{\partial u_2}{\partial t} = b_1^{(S)} \dfrac{\partial^2 u_2}{\partial y^2} + b_2^{(S)} \dfrac{\partial u_2}{\partial y} + b_3^{(S)} u_2 + b_4^{(S)}, \\ \dfrac{\partial v_1}{\partial t} = c_1^{(S)} \dfrac{\partial^2 v_1}{\partial y^2} + c_2^{(S)} \dfrac{\partial v_1}{\partial y} + c_3^{(S)} v_1 + c_4^{(S)}, \\ \dfrac{\partial v_2}{\partial t} = d_1^{(S)} \dfrac{\partial^2 v_2}{\partial y^2} + d_2^{(S)} \dfrac{\partial v_2}{\partial y} + d_3^{(S)} v_2 + d_4^{(S)}, \\ \dfrac{\partial f_2}{\partial t} = e_1^{(S)} \dfrac{\partial f_2}{\partial y} + e_2^{(S)} f_2 = 0. \end{cases} \tag{9}$$

where S - the iteration number, U, T - is the specified characteristic values of speed and time, respectively.

$$a_1^{(S)} = \frac{\mu_1^T}{\rho_{1i} H^2}, a_2^{(S)} = \left(\frac{\mu_1}{\rho_{1i} f_1^{(S)}} \frac{\partial f_1^{(S)}}{\partial y} - v_1^{(S)} \right) \frac{T}{H}, a_3^{(S)} = -\frac{KT}{\rho_{1i} f_1^{(S)}}, a_4^{(S)} = \frac{K}{\rho_{1i} f_1^{(S)}} u_2^{(S)},$$

$$b_1^{(S)} = \frac{\mu_2^T}{\rho_{2i} H^2}, b_2^{(S)} = \left(\frac{\mu_2}{\rho_{21i} f_2^{(S)}} \frac{\partial f_2^{(S)}}{\partial y} - v_2^{(S)} \right) \frac{T}{H}, b_3^{(S)} = -\frac{KT}{\rho_{2i} f_2^{(S)}}, a_4^{(S)} = \frac{K}{\rho_{2i} f_2^{(S)}} u_1^{(S)},$$

$$c_1^{(S)} = \frac{4}{3} \frac{\mu_1^T}{\rho_{1i} H^2}, c_2^{(S)} = \left(\frac{4}{3} \frac{\mu_1}{\rho_{1i} f_1^{(S)}} \frac{\partial f_1^{(S)}}{\partial y} - v_1^{(S)} \right) \frac{T}{H}, c_3^{(S)} = -\frac{KT}{\rho_{1i} f_1^{(S)}}, c_4^{(S)} = \frac{K v_2^{(S)}}{\rho_{1i} f_1^{(S)}},$$

$$d_1^{(S)} = \frac{4}{3} \frac{\mu_2^T}{\rho_{2i} H^2}, d_2^{(S)} = \left(\frac{4}{3} \frac{\mu_2}{\rho_{2i} f_2^{(S)}} \frac{\partial f_2^{(S)}}{\partial y} - v_2^{(S)} \right) \frac{T}{H}, d_3^{(S)} = -\frac{KT}{\rho_{2i} f_2^{(S)}}, d_4^{(S)} = \frac{K v_1^{(S)}}{\rho_{2i} f_2^{(S)}},$$

$$e_1^{(S)} = \frac{v_2^{(S)} T}{H}, c_2^{(S)} = \frac{\partial v_2^{(S)}}{\partial y} \frac{T}{H}.$$

System (9) is solved as follows. First, a system composed of the first two equations is solved. Introducing a vector $\vec{Y} = \begin{pmatrix} u_1 \\ u_2 \end{pmatrix}$ we bring these equations to the vector-matrix form

$$\frac{\partial \vec{Y}}{\partial t} = A^* \frac{\partial^2 \vec{Y}}{\partial y^2} + B^* \frac{\partial \vec{Y}}{\partial y} + C^* \vec{Y} + \overrightarrow{D^*} \quad (10)$$

where

$$A^* = \begin{pmatrix} a_1^{(S)} & 0 \\ 0 & b_1^{(S)} \end{pmatrix}, B^* = \begin{pmatrix} a_2^{(S)} & 0 \\ 0 & b_2^{(S)} \end{pmatrix}, C^* = \begin{pmatrix} a_3^{(S)} & 0 \\ 0 & b_3^{(S)} \end{pmatrix}, \overrightarrow{D^*} = \begin{pmatrix} a_4^{(S)} \\ b_4^{(S)} \end{pmatrix},$$

Having performed similar operations with initial and boundary conditions for the function u_1 and u_2, receive

$$\begin{cases} \vec{Y} = \overrightarrow{Y_0} \text{ with } t = 0, \\ A_0 \dfrac{\partial \vec{Y}}{\partial y} + B_0 \vec{Y} = \overrightarrow{D_0} \text{ with } y = 0, \\ A_1 \dfrac{\partial \vec{Y}}{\partial y} + B_1 \vec{Y} = \overrightarrow{D_1} \text{ with } y = 1. \end{cases} \quad (11)$$

here

$$A_0 = \begin{pmatrix} 0 & 0 \\ 0 & l_0 \end{pmatrix}, B_0 = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}, \overrightarrow{D_0} = \begin{pmatrix} 0 \\ 0 \end{pmatrix}, A_1 = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}, B_1 = \begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix}, \overrightarrow{D_1} = \begin{pmatrix} 0 \\ 0 \end{pmatrix},$$

Results. The boundary value problem (10), (11) is solved by the finite difference method. In this case we use a two layer six point implicit scheme with weight σ^* [10].

With the selected weight value $\sigma^* = 0{,}5$ the applied scheme has an approximation order $O((\Delta t)^2 + (\Delta y)^2)$ and is sustainable. The iterative process is repeated until the convergence condition is met.

Similarly, a system composed of the third and fourth equations (9) is solved and we define v_1, v_2. Last equation (9) with the appropriate conditions from (7) solved by the finite difference method. In this case, we use a two-layer four-point implicit scheme with symmetrized derivatives [11]. The length of the wave front is determined from the solution of the Cauchy's problem (8) [12].

Calculations were performed with the following initial data and the numerical results were processed in the environment Mathcad [13]:

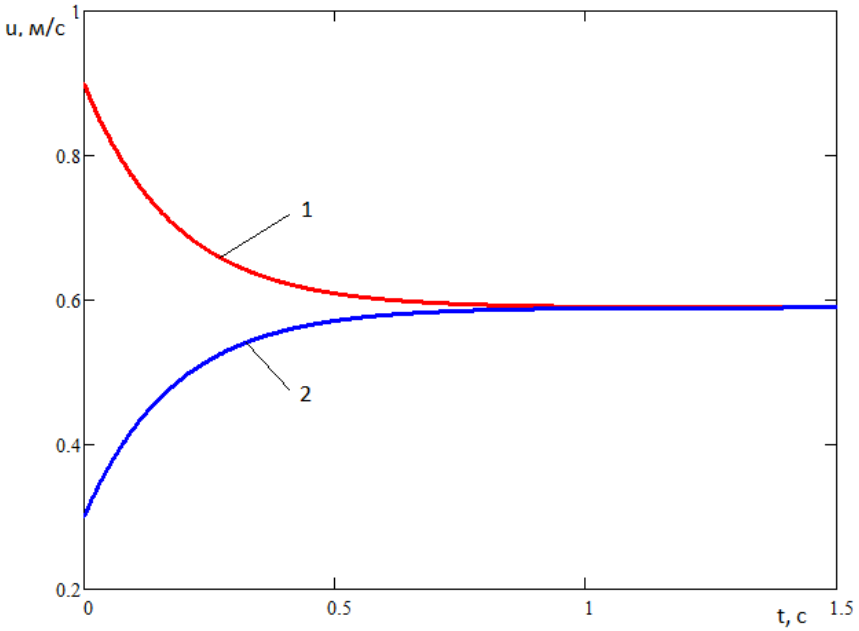
$$H_0 = 2\,м, \mathrm{u}_1^0 = 0{,}9\ м/с,\ u_2^0 = 0{,}3\ м/\mathrm{c},\ v_1^0 = 0{,}01\ м/с,\ v_2^0 = 0{,}2\ м/с,$$

$$\rho_{1i} = 100\,кг \cdot с^2/м^4, \rho_{2i} = 250\ кг \cdot с^2/м^4, f_2^0 = 0{,}2$$

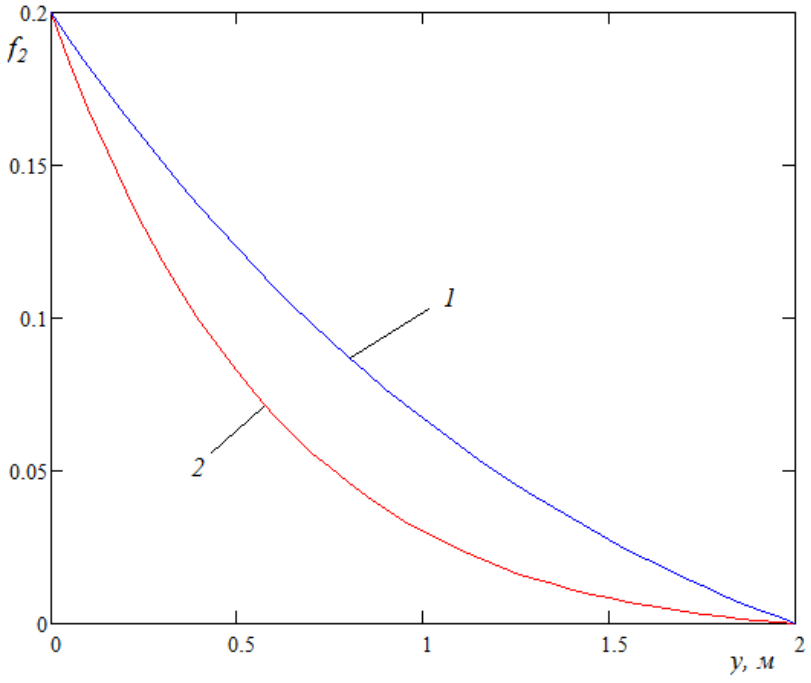
$$\mu_1 = 1{,}024 \cdot 10^{-4}\,кг \cdot с/м^2, \mu_2 = 25 \cdot 10^{-3}\,кг \cdot с/м^2, \Delta t = 0{,}01, \Delta y = 0.01,$$

$$\varepsilon = 10^{-4}, K = 200\,кг \cdot с/м^4; 350\ кг \cdot с/м^4, U = 1\,м/с, T = 600с.$$

Discussion. The results are presented in the form of graphs. The analysis of the obtained results shows that the results relative to the previously studied one-speed flow are qualitatively confirmed for the two-speed flow, but some parameters differ quantitatively. Over time, the longitudinal velocities of the phases tend to the same constant number. In this case, the longitudinal speed of the phase with a higher initial speed is always greater than this number, and the longitudinal speed of the phase with a lower initial speed is always less (figure 1). With an increase in the initial average velocity of the mixture, the distribution of the concentration of solid particles over the depth of the flow becomes more uniform (figure 2). As the phase interaction coefficient increases, the deposition rate of solid particles decreases, i.e. their concentration increases (figure 3). The longitudinal velocities of both phases increase as they move away from the bottom of the channel and reach their maximum values on the free surface (figure 4).

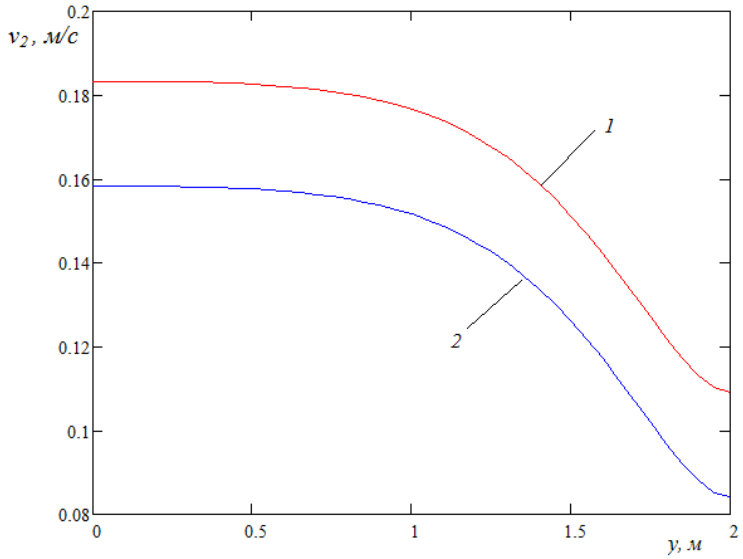


1-longitudinal speed of the first phase; 2-longitudinal speed of the second phase (*y=1,5 m*)
Figure 1 – change in longitudinal velocity over time



$$1 - U^0_{см} = 0{,}8 м/с\,; \quad 2 - U^0_{см} = 0{,}5 м/с$$

Figure 2 – Change in the concentration of solid particles in the depth of the flow at different initial average speeds of the mixture (*t=100s*)



$1 - K = 200\ кг \cdot с / м^4;\quad 2 - K = 350\ кг \cdot с / м^4$

Figure 3 – Change in the rate of deposition of solid particles in the depth of the flow at different coefficients of interaction of phases (*t=100s*)

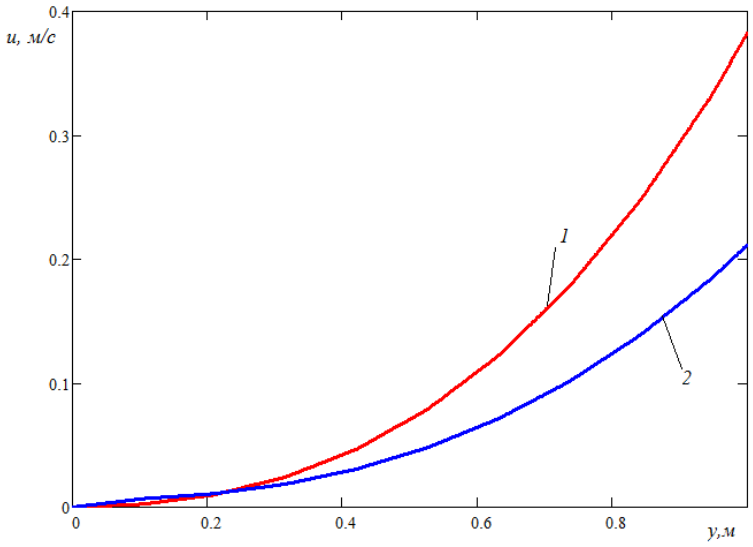


Figure 4 – Change in the longitudinal velocity of the phases in the depth of the flow (*t*=100s)
1 – the speed of the first phase; 2-the speed of the second phase.

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ЕКІ ФАЗАЛЫ АШЫҚ АҒЫННЫҢ ЕКІ ЖЫЛДАМДЫҚТЫ АҒЫСЫН ЕСЕПТЕУ

Аннотация. Соңғы жылдары гидромеханика саласында ашық каналдардағы ағын динамикасын зерттеу саласында белгілі бір жетістіктерге қол жеткізілді. Алайда бұл модельдер үдеріс физикасын толық қамтымайды, өйткені суару үшін пайдаланылатын су белгілі мөлшерде қатты бөлшектерді қамтиды. Ағымда аз мөлшерде қатты бөлшектердің пайда болуы, әдетте, үдерістер сипаты мен құрылымын едәуір өзгертеді.

Бұл жағдайда жаңа макроскопиялық параметрлер пайда болады, атап айтқанда, келтірілген тығыздық, фазалар арасындағы өзара әрекеттесу күштері, сондай-ақ басқа да механикалық сипаттамалар пайда болады. Ағынның бұл параметрлері қоспа компоненттері сақталуының негізгі заңдылығын бұзады, компоненттер өзара әрекеттеседі, бұл жылдамдықтың, жекелеген компоненттер концентрациясының өзгерісін тудырады, қоспаның ағу жылдамдығын өзгертеді. Көп фазалы қоспалардың ішінен дисперсті ағынды атап айтуға болады, олардың компоненттерінің бірі әртүрлі қосындылар (тамшы, көпіршік, қатты бөлшектер), яғни аэрозоль, тұман, көпіршікті сұйықтық, суспензиялар және т.б.

Мақалада ағын тереңдігі бойынша қатты бөлшектер концентрациясының таралуы және канал түбіндегі судың фильтрленуі есепке алына отырып, екі фазалы ашық ағынның стационарлы емес ағысының математикалық моделі, сондай-ақ тиімді есептеу әдісі құрылған. Сонымен қатар, екі жылдамдықты ағым қарастырылған, яғни фазалар жылдамдығының горизонталь және вертикаль құраушысының бар екендігі ескерілген, сондай-ақ ағыс бойымен ағын параметрлері өзгермейді деп есептелді. Бастапқы және шекаралық шарттар практикада кең таралған теориялық-эмпирикалық формулалар негізінде беріледі. Ашық каналдардағы ағыс қысымсыз, ауырлық күшінің әсерінен болады және ағынның еркін бетке ие болуы негізінде ерекшеленеді. Бастапқы уақытта параметрлер горизонталь бағытта біркелкі деп санаймыз және барлық параметрлер белгілі теориялық-эмпирикалық формулалармен беріледі. Су жылдамдығының горизонталь құраушысына канал түбінде жабысу, ал қатты фазаның горизонталь құраушысына қатты бөлшектің ығысу шарттарын, ал фазалардың вертикаль құраушыларына (су үшін) фильтрлену және шөгу (қатты бөлшектер үшін) шарттарын қолданамыз. Еркін бетте қатты бөлшектер жоқ деп санаймыз және фаза жылдамдығының горизонталь компоненттеріне ауаның үйкеліс күшін есепке алмаймыз, ал фаза жылдамдығының вертикаль компоненттеріне еркін беттің уақыт бойынша біркелкі еместігін қолданамыз. Құрылған математикалық модель және есептеу әдісіне сүйене отырып, ағымның негізгі параметрлерінің өзгеруі ағыс тереңдігі және уақыт бойынша анықталған.

Математикалық модельді құру кезінде салыстырмалы түрде тұрақты сипатқа ие дисперсті ағындар үшін көп фазалы ортаның «өзара әсер етуші» моделі қолданылды, ол келесі жорамалдарға негізделген: фазалық ауысу жоқ; әр фазаға фазалардың өзара әрекеттесуін сипаттайтын мүшелер теңдеуге енгізілген; әр фаза жеке тұтас орта ретінде қабылданады және жеке теңдеулермен сипатталады. Математикалық аппарат ретінде келесі әдістер қолданылды: сызықтық емес мүшелерді сызықтандыру үшін қарапайым итерация әдісі; дербес туындылы дифференциалдық теңдеулер үшін, салмағы бар екі қабатты алты нүктелі және симметриялы туындылары бар екі қабатты төрт нүтелі айқын емес шекті айырма әдісі, алынған алгебралық теңдеулер жүйесін шешуде матрицалық қуалау әдісі; толқынның таралу ұзындығының өзгеруін сипаттайтын жай дифференциалдық теңдеуді шешуде төртінші ретті дәлдікке ие Рунге-Кутта әдісі.

Нәтижелер график түрінде келтірілген. Нәтижелерді талдау көрсеткендей, бұрын зерттелген бір жылдамдықты ағынның нәтижелері екі жылдамдықты ағын үшін сапалы түрде расталған, бірақ кейбір параметрлер сандық жағынан ерекшеленеді. Уақыт өте келе фазалардың горизонталь жылдамдығы бірдей тұрақты санға ұмтылады. Бастапқы жылдамдығы үлкен фазаның горизонталь жылдамдығы әрқашан осы саннан жоғары болады, ал бастапқы жылдамдығы аз фазаның горизонталь жылдамдығы әрқашан осы саннан аз болады. Қоспаның (су + қатты бөлшектер) жетіп бару қашықтығы таза судың жетіп бару қашықтығынан аз, яғни қатты бөлшектер негізгі ағынның қозғалуына қарсы әсер етеді. Қоспаның бастапқы орташа жылдамдығының жоғарылауы арқылы қатты бөлшектер концентрациясының ағыс тереңдігі бойынша таралуы біркелкі бола бастайды. Фазалардың өзара әрекеттесу коэффициентінің жоғарылауы негізінде қатты бөлшектердің шөгу жылдамдығы төмендейді, яғни олардың концентрациясы артады. Екі фазаның да горизонталь жылдамдығы канал түбінен алшақтаған сайын ұлғаяды және еркін бетте ең үлкен мәнге жетеді. Құрылған модель және алынған нәтижелер ашық арналардағы тұтқыр екі фазалы ортаның стационар емес ағымының негізгі гидродинамикалық заңдылықтары мен ерекшеліктерін анықтайды және оларды суды үнемді пайдалану мәселелерін шешуде, сонымен қатар су шығыны мен суару арналарының шөгіндісімен күресу шараларында қолдануға болады.

Түйін сөздер: стационарлы емес ағым, екі фазалы ағым, еркін бет, қысылмайтын орта, шынайы тығыздық, келтірілген тығыздық, концентрация, тұтқырлық коэффициенті, фазалар арасындағы өзара әрекеттесу коэффициенті, сүзгілену.

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РАСЧЕТ ДВУХСКОРОСТНОГО ТЕЧЕНИЯ ДВУХФАЗНОГО ОТКРЫТОГО ПОТОКА

Аннотация. За последние годы в гидромеханике достигнуты определенные успехи в области исследований динамики потоков в открытых руслах. Однако эти модели не в полной степени охватывают физику процесса, так как вода, идущая на орошение, неоднородна и содержит определенные количества твердых частиц. Появление небольшого количества твердых частиц в потоке, как известно, существенно изменяет характер и структуру процессов. При этом появляются новые макроскопические параметры, в частности приведенные плотности, взаимодействующие силы между фазами, а также другие механические характеристики. Эти параметры потока нарушают основной закон сохранения компонентов смеси, компоненты взаимодействуют, что вызывает перераспределение скорости, концентраций отдельных компонентов, изменяет расход смеси. Из многообразия многофазных сред могут быть выделены дисперсные потоки, имеющие сравнительно регулярный характер и представляющие смесь нескольких фаз, одной из которых являются различные включения (капли, пузырьки, твердые частицы), т.е. аэрозоли, туманы, пузырьковые жидкости, взвеси и т.д.

Нами рассматривается нестационарное двухскоростное течение двухфазного открытого потока с учетом перераспределения концентрации твердых частиц по глубине потока и фильтрации воды на дне канала. В данной статье разработана математическая модель нестационарного течения двухфазного открытого потока с учетом перераспределения концентрации твердых частиц по глубине потока и фильтрации воды на дне канала, а также создан эффективный метод расчета. При этом рассматривается двухскоростное течение, т.е. учитывается наличие продольной и вертикальной составляющих скоростей фаз, а также считаем, что параметры потока вдоль течения не изменяются. Начальные и граничные условия устанавливаются исходя из теоретико-эмпирических формул, которые получили широкое распространение на практике. Течение в открытых каналах безнапорное, происходит под действием силы тяжести и отличается тем, что поток имеет свободную поверхность. В начальный момент времени течение считаем равномерным в продольном направлении и все параметры задаются известными теоретико-эмпирическими формулами. На дне канала для продольной составляющей скорости воды используем условие прилипания, а для продольной составляющей скорости твердой фазы условие смещения и считаем известной концентрацию твердой частицы, а для вертикальных составляющих скоростей фаз условий фильтрации (для воды), и осаждения (для твердых частиц). На свободной поверхности считаем твердые частицы отсутствуют и для продольных составляющих скоростей фаз пренебрегаем силой трения воздуха, а для вертикальных составляющих скоростей фаз используем условие неравномерности свободной поверхности по времени. На основе разработанной математической модели и созданного метода расчета определены изменения основных параметров по глубине потока и во времени.

При разработке математической модели использована «взаимопроникающая» модель многофазной среды для дисперсных потоков, имеющих сравнительно регулярный характер, основанная на следующих предположениях: отсутствует межфазовый переход; для каждой фазы в уравнение включаются слагаемые, характеризующие взаимодействие между фазами; каждая фаза принимается как отдельная сплошная среда и описывается раздельными уравнениями. В качестве математического аппарата применялись: для линеаризации нелинейных членов метод простой итерации; для дифференциальных уравнений в частных производных метод конечных разностей, при этом используются двухслойная шеститочечная неявная схема с весом и двухслойная четырехточечная неявная схема с симметризованными производными, а для решения полученных систем алгебраических уравнений метод матричной прогонки; для решения обыкновенного дифференциального уравнения, описывающего изменение длины добегания фронта волны метод Рунге-Кутта четвертого порядка точности.

Полученные результаты представлены в виде графиков. Анализ полученных результатов показывает, что результаты относительно ранее исследованного односкоростного течения качественно подтверждаются и для двухскоростного течения, но некоторые параметры отличаются количественно. С течением времени продольные скорости фаз стремятся к одному и тому же постоянному числу. При этом продольная скорость фазы с большей начальной скоростью всегда больше этого числа, а продольная скорость фазы с меньшей начальной скоростью всегда меньше. Расстояние добегания смеси (вода + твердые частицы) меньше, чем расстояние добегания чистой воды, т.е. твердые частицы сопротивляются продвижению основного потока. С увеличением начальной средней скорости смеси распределение концентрации твердых частиц по глубине потока становится более равномерным. С увеличением коэффициента взаимодействия фаз скорость осаж-

дения твердых частиц уменьшается, т.е. их концентрация увеличивается. Продольные скорости обеих фаз по мере удаления от дна канала увеличиваются и достигают максимальных значений на свободной поверхности. Разработанная модель и полученные результаты выявляют основные гидродинамические закономерности и особенности неустановившегося течения вязких двухфазных сред в открытых каналах и могут быть использованы при решении вопросов рационального расходования воды, а также в мероприятиях по борьбе с потерями воды и заилениями оросительных каналов.

Ключевые слова: нестационарное течение, двухфазный поток, свободная поверхность, несжимаемая среда, истинная плотность, приведенная плотность, концентрация, коэффициент вязкости, коэффициент взаимодействия между фазами, фильтрация.

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INNOVATIVE METHODS FOR INTENSIFYING BOREHOLE PRODUCTION OF URANIUM IN ORES WITH LOW FILTRATION CHARACTERISTICS

Abstract. The object of research is the technology of borehole uranium production with a low filtration characteristics.

The purpose of the work is to increase the efficiency of borehole uranium production in complex mining and geological conditions by developing a new method based on the intensification of geotechnological processes of underground leaching of uranium, the impact of chemical reagents on the aggregate of sedimentation and mineralogical composition of ore-containing rocks of the productive horizon. At the same time, operating costs are reduced by increasing the productivity of the period of uninterrupted operation of geotechnical wells, as well as reducing the time spent working out technological blocks.

Research methods include x-ray phase analysis, identification and discussion of the features, quantitative and qualitative parameters of core material and sedimentation from uranium deposits associated with the Syrdarya depression. Under laboratory conditions, the efficiency of the selected composition for the dissolution of sedimentary formations that reduce the permeability of layers was established by electron microdifraction.

The applied hydrodynamic methods of well regeneration based on destruction and dispersion of sedimentation are considered and evaluated. The reagent methods used to increase the permeability of the productive horizon based on precipitation dissolution were also studied and evaluated. The results of experimental studies are analyzed and discussed, and a comparative schedule of the period of uninterrupted operation of wells is constructed. The effectiveness of the applied method for restoring the permeability of the productive horizon with the use of a complex chemical reagents.

The scientific novelty lies in the fact that mineralogical studies of the core material composition indicate a complex structure of ores, in complex mining and geological conditions. The practical significance of the study lies in the high efficiency and applicability of the considered method of intensifying borehole uranium production in areas with low filtration characteristics.

Key words: Microdifraction, x-ray phase analysis, permeability, regeneration, leaching, uranium, sedimentation.

1. Introduction. Kazakhstan has 14 % of the world's proven uranium reserves and second ranks after Australia, 70 % of them are suitable for well development. Borehole development of uranium ores in the Republic of Kazakhstan is carried out at 26 sites, united in 13 uranium mining companies. The total volume of natural uranium production is more than 40% of the world's total. Uranium deposits are located in six provinces: Shu-Sarysu, Syrdarya, North Kazakhstan, Pre-Caspian, Pre-Balkhash, and Ile, the main production is carried out in the first two. The technology of borehole uranium mining provides for the dissolution of the useful component at the site of the ore body, followed by the removal of the formed compounds by a moving stream of solvent from the injection to the pumping well [1,2]. The practice of operating well systems in the development of uranium ores by borehole method shows that over time there

is a decrease in their productivity. One of the main reasons for reducing the throughput capacity of technological wells is an increase in hydraulic resistances and a decrease in reservoir filtration characteristics due to the formation of colmatation. [3].

Mechanical sedimentation is caused by overlapping of water intake filter holes with sand, clay, gravel and blockage of pore channels by the formation with solid suspensions. Sand and clay deposited in the well partially or completely covers the filter. Also, this type of precipitation can be attributed to the blockage of the filter and the near-filter zone by the formation with drilling fluids containing clay particles [4]. In this case, the clay material swells in the water environment and changes the structure of the pore space of the formation.

Chemical, ion exchange and gas types of sedimentation are caused by changes the chemical composition in reservoir waters as a result the influence of technological solutions used in mining. The presence of dissolved calcium, magnesium, and iron cationites in water and a violation of the carbon dioxide balance leads to the formation of insoluble precipitation [5]. There is an intensive release of carbonate precipitation in the filter zone, by removing it, the intensity of precipitation decreases.

2. Overview of applied methods for improving the filtration characteristics of ores. Depending on the type of sedimentation in the work areas of the geotechnological field, various methods of RRW (repair and restoration work) are used to improve the filtration characteristics of the productive. Hydrodynamic methods, such as compressor pumping and well flushing under the influence of pressure difference, are mainly aimed at destruction and dispersion of mechanical sedimentation [6]. The cost of these methods is relatively lower due to the use of technological equipment, inexpensive fuels and lubricants, etc. Chemical methods of exposure to dissolution are mainly aimed at destruction and elimination of precipitation formed as a result of the interaction of technological solutions with the host rocks of the productive horizon [7]. Combined methods include complex operations using drilling rigs and auxiliary equipment that combine well flushing with subsequent chemical treatment, swabbing, and compressor pumping [8]. This method is the most expensive due to the use of a large number of equipment, chemicals, maintenance personnel and a long duration of work.

2.1. Radiographic studies of host rocks. When leaching solutions interact with ore-containing rocks, the liquid phase accumulates (in addition to ore) a number of elements that are part of the main rock-forming minerals. The amount and kinetic transition of these elements to productive solutions depends on the type of leaching reagent, concentration, granulometric composition, and rock-forming minerals. Table 1 shows data on the mineralogical composition of ores from the Syrdarya Deposit.

Table 1 – Mineral composition of the Syrdarya Deposit

Mineral, mineral aggregate	Content, %
Quartz	65,7
Feldspar	8,6
Rock fragments	5,2
Carbonates	2,3
Montmorillonite	11
Muscovite	0,8
Fine-grained aggregate of silt-mica-clay composition, white, light gray color	1,6
Aggregate couplings with calcite, calcite	0,3
Iron sulfides	1,5
Carbonated organic matter	3,3

As can be seen from table 1, the most common clay mineral in the Syrdarya Deposit is montmorillonite, with an average content of 11% in some places. Feldspars are found everywhere, with an average content of 8.6%. The content of carbonates does not exceed 2.3 %. The main mass of carbonates is represented by calcite and ankerite.

X-ray studies of sedimentation. Solving problems with restoring the natural permeability of the productive horizon, first of all, it is necessary to determine the type of precipitation formed during sulfuric

acid leaching and establish the mineralogical composition of sedimentation. The study of quantitative and qualitative characteristics of sedimentary components will allow us to determine the reasons that reduce the permeability of filtration characteristics, which increase the productivity and duration of uninterrupted operation of geotechnical wells. The results of quantitative mineralogical composition of sedimentary formations of the Syrdarya province are shown in table 2.

Table 2 – Mineralogical composition of sedimentation in the Syrdarya depression

The component name	Chemical formula	Content, %
Quartz	SiO_2	2
Aluminium phosphate	Al (PO_4)	11
Iron oxide	Fe_3O_4	14
Magnesium sulphate	MgS	11
Calcium aluminum hydroxide	$CaAl_2$ ((O H)$_8$ (H_2O)$_2$)	1
Ankerite	Ca (Mg Fe Mn) (CO_3)$_2$	51
Dolomite	Ca Mg Fe (CO_3)$_2$	6

2.2. Laboratory experiments on the selection of chemical reagents for RRW wells. To restore the permeability of the near-filter zone of the formation in order to increase the efficiency of borehole uranium production, the authors conducted work on the development of a complex of chemical reagents. The basis adopted one of the technologies of increasing the efficiency of wells used in oil and gas industry – specific acid treatment of ore-bearing rocks with a special solution for cleaning of the pore space and to create new channels of traffic solutions and enlarge the existing, and to well clearing [10].

Under laboratory conditions, the effectiveness of the selected chemical reagents on precipitation was studied. We consider the change in the equilibrium of the system and the transfer of insoluble compounds to the liquid phase, or to turn solid sedimentation into easily soluble compounds. A number of analytical and experimental studies were carried out on samples of sedimentation and ore-containing rocks to select the most effective solution. As additives to the sulfuric acid solution, ammonium bifluoride (NH_4HF_2) and surfactants were used to loosen sedimentation.

Reagents included in the multifunctional complex:

- Sulfamic acid;
- Ammonium lignosulfonate;
- Ammonium bifluoride.

The choice of ammonium bifluoride to influence precipitation is due to its ability to exchange reactions with mineral acids (sulfuric, hydrochloric, nitric acids). The formation of hydrofluoric acid occurs:

$$NH_4HF_2 + HAn = NH_4An + HF \quad (1)$$

where – HAn (H_2SO_4; HCl; HNO_3).

Hydrofluoric acid, formed as a result of the reaction, easily interacts with aluminosilicates and siliceous compounds, which are a component of ore-containing rocks according to the formulas:

$$CaAl_2SiO_8 + 16HF = 2AlF_3 + 2SiF_4 + 8H_2O + CaF_2, \quad (2)$$

$$6HF + SiO_2 = SiF_4 + 2\ HF + 2H_2\ O, \quad (3)$$

$$CaSO_4 \cdot 2\ H_2\ O + 2HF = CaF_2 + H_2\ SO_4 + 2H_2\ O, \quad (4)$$

As a result, both the main sedimentation and part of the terrigenous component of the sands are dissolved. In general, the effective porosity of the ore block increases. In this case, hydrofluoric acid is completely utilized due to the large amount of quartz contained in the sands.

Microdifraction images of the sedimentation surface before and after treatment with a solution and obtained information about the composition, structure and other properties of the surface layers confirm the effectiveness of the selected chemical reagents. Figures 1 and 2 show electronic microdifraction of, selected sedimentation before and after treatment with special solutions

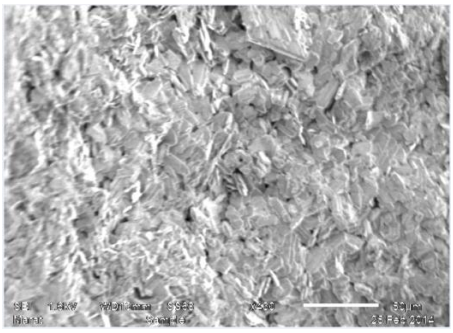


Figure 1 – The electronic microdiffraction selected colmatant before treatment.

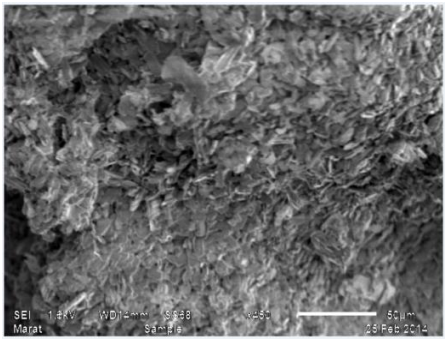
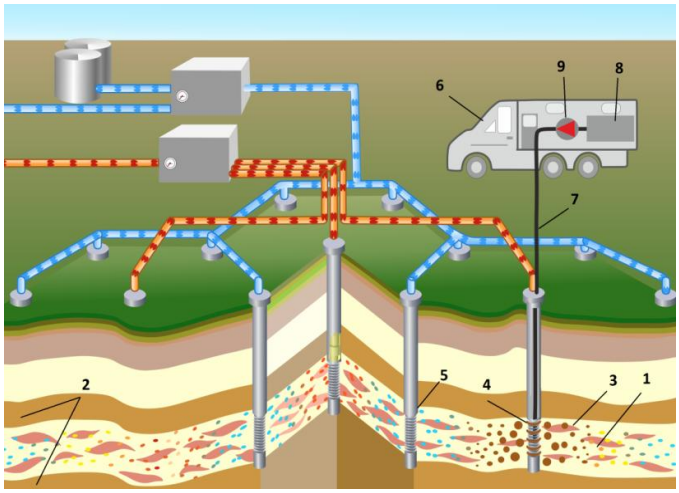


Figure 2 – The electronic microdiffraction selected colmatant after treatment.

As can be seen from the image (figure 2), precipitation before processing has a dense cellular structure with a rhombic frame structure, without breaks and cavities in the body. After processing this sample with a special solution, a second electron microscope image was taken (figure 2). From figure 2, you can see that the sample has flushed and additional space and cracks in the structure. The results of laboratory studies indicate the possibility of using ammonium bifluoride as an additive to a solution of sulfuric acid for effective chemical treatment of technological wells.

3. Development of intensification methods for uranium mining. To increase the efficiency of borehole uranium mining by improving geotechnological processes and restoring the permeability of the near-filter zone of the formation, the authors developed and tested a method for chemical treatment of wells with a special solution. This method of influence on the formation provides for the supply the solutions of complex chemical reagents to the filter zone, pressing into the productive horizon for its reaction with sedimentation, dissolution and removal of reaction products outside the well by airlift pumping. Figure 3 shows a scheme for the intensification of borehole uranium production.

As can be seen from figure 3, the main mass of sedimentation 3 occurs in the productive horizon 1, directly in the zone of unloading solutions and increasing the speed of movement of solutions from injection wells 5 to pumping wells 4. Chemical treatment with the use of complex chemical reagents provides for the preparation of solutions on special equipment 6, and supply through the hose 7 to the filter part of wells 4. In this case, the prepared special solution is fed from the tank capacity 8, by a pumping pump 9. The supply of a complex of chemical reagents directly to the filter part of technological wells reduces the consumption of chemical reagents and increases the penetration capacity for greater destruction and dispersion of precipitation.



1 – productive horizon; 2 – impenetrable rocks; 3 – sedimentation; 4 – pumping wells; 5 – injection wells; 6 – special equipment for the preparation of solutions ; 7 – hose; 8 – tank; 9 – pumping pump.
Figure 3 – Scheme for the intensification of borehole uranium production

Conclusions. Features of uranium production in the fields of Kazakhstan are considered. The mineralogical composition study of host rocks samples confirms the high presence of carbonate minerals-ankerite > 2.3 %, the presence of montmorillonite clay > 11 % of the total weight of the core sample. Data from x-ray phase analysis of sedimentation confirm the precipitation of carbonate compounds that make up > 51 % of the total mass of sedimentation that belong to the chemical type of sedimentation. These sedimentary formations interfere with current lines and hinder the processes of borehole uranium mining, and increase operating costs for restoring the permeability of the productive horizon.

In order to develop an effective method for intensifying uranium production, laboratory studies were conducted and special chemical reagents were selected that can dissolve and prevent sedimentation. The effectiveness of chemical reagents in the destruction and dispersion of sedimentation during borehole uranium mining was confirmed by the method of electronic microdifraction. A new method of geotechnical processes intensification was developed and experimental studies were performed using the developed complex of chemical reagents.

As a result of experimental work, the effectiveness of intensification with the use of complex chemical reagents was established. The duration of the uninterrupted operation of wells increased from 16 to 84 days, and the well utilization rate increased from 0.74 to 0.98. The use of a new method for intensifying borehole uranium production makes it possible to increase the efficiency of processing technological blocks in difficult geological conditions and reduces the material costs of operating blocks, increases the period of uninterrupted operation of geotechnical wells and reduces the cost of chemical reagents for repair and restoration work.

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ТӨМЕН СҮЗГІЛІК СИПАТТАМАСЫ БАР КЕНДЕ УРАН ӨНДІРУ ҰҢҒЫМАСЫН ҚАРҚЫНДАТУДЫҢ ИННОВАЦИЯЛЫҚ ӘДІСТЕРІ

Аннотация. Зерттеу объектісі – уранды ұңғымалық өндіру технологиясы.

Жұмыстың мақсаты – уранды жерасты геотехнологиялық процесін қарқындатуға негізделген жаңа әдіс әзірлеу, химиялық реагенттердің шөгінді жиынтығына және өнімді горизонттың кен сыйымды жынысының минералогиялық құрамына әсер етуі есебінен күрделі тау-геологиялық жағдайында уранды ұңғымалық өндірудің тиімділігін арттыру. Бұл ретте геотехнологиялық ұңғымалардың үздіксіз жұмыс істеу кезеңінің өнімділігін арттыру, сондай-ақ технологиялық блоктардың жұмыс істеу уақытын қысқарту есебінен пайдалану шығынын азайтуға мүмкіндік туады.

Зерттеу әдістері рентгенофазалық талдау, Керн материалының сандық-сапалық параметрлерін және Сырдария депрессиясымен шектелген уран кен орындарынан шөгінді түзілім анықтау мен талқылауды қамтиды. Ұңғыманы декольматациялау және күрделі тау-кен геологиялық жағдайында уран тиімділігін арттыру үшін синергетикалық әсер ететін химиялық реагенттердің құрамы таңдалды. Зертханалық жағдайда электронды микродифракция әдісімен резервуардың өткізгіштігін төмендететін шөгінді ерігіштігі үшін таңдалған құрамның тиімділігі анықталды.

Зерттеу нәтижелері күкірт қышқылын еріткіш ретінде қолдана отырып, уран кенін ұңғымалық өндіруде жүретін процестерді зерттеу, сондай-ақ Қазақстан кен орнындағы күрделі тау-кен геологиялық жағдайда уран өндіру ұңғымасының геотехнологиялық параметрлерінің төмендеуіне әсер ететін себептерді қарастыру болып саналады. Бұзылу және диспергирленуге негізделген ұңғымаларды қалпына келтірудің гидродинамикалық әдістері қарастырылып, бағаланды. Кольматанттың еру үдерісіне негізделген өнімді горизонт өткізгіштігін жоғарылатудың қолданылатын реагенттік әдістері қарастырылды. Уранды ұңғымалық өндіруді қарқындатуда синергетикалық әсер ететін іріктелген химиялық реагенттерді қолдану бойынша әдістеме әзірленді және эксперименттер жүргізілді. Эксперименттік зерттеу нәтижелері талданып, талқыланды, ұңғымалардың үздіксіз жұмыс істеу кезеңінің салыстырмалы кестесі жасалды. Синергетикалық әсер ететін химиялық реагенттер кешенін қолдана отырып, өнімді горизонт өткізгіштігін қалпына келтіру әдісінің тиімділігі анықталды және көрсетілді.

Ғылыми жаңалығы Керн материалының құрамын минералогиялық зерттеу күрделі тау-кен геологиялық жағдайлында тау жынысы мен уран минералдануын қамтитын кеннің күрделі құрылымын қамтиды, ал

түзілімінің белгіленген құрылымы мен сандық-сапалық параметрлері уран өндірудің күкірт қышқылды ұңғымасы жағдайында карбонатты және сазды минералдың тұнбаға түсетінін растайды. Зерттеудің практикалық маңыздылығы сүзгілеу сипаттамалары төмен учаскелерде уранды ұңғымалық өндіруді қарқындатудың қарастырылып отырған әдісінің жоғары тиімділігі мен қолданылуына негізделеді.

Түйін сөздер: микродифракция, рентгенофазалық талдау, өткізгіштік, регенерация, уран.

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ИННОВАЦИОННЫЕ МЕТОДЫ ИНТЕНСИФИКАЦИИ СКВАЖИНОЙ ДОБЫЧИ УРАНА В РУДАХ С НИЗКИМИ ФИЛЬТРАЦИОННЫМИ ХАРАКТЕРИСТИКАМИ

Аннотация. Объектом исследования является технология скважинной добычи урана на месторождениях с низкими фильтрационными характеристиками.

Цель работы – повышение эффективности скважинной добычи урана в сложных горно-геологических условиях за счет разработки нового метода, основанного на интенсификации геотехнологических процессов подземного выщелачивания урана, воздействия химических реагентов на совокупность осадкообразований и минералогического состава рудовмещающих пород продуктивного горизонта. При этом достигается снижение эксплуатационных затрат за счет повышение производительности периода бесперебойной работы геотехнологических скважин.

Методы исследований включают рентгенофазовые анализы, установление и обсуждение особенности, количественно-качественные параметры кернового материала и осадкообразований из месторождений урана приуроченных Сырдарьинской депрессии. Подобран состав химических реагентов синергетического действия для декольматации скважин и повышения эффективности выщелачивания урана в сложных горно-геологических условиях. В лабораторных условиях методом электронной микродифракции установлена эффективность выбранного состава по растворению осадкообразований, снижающих проницаемость пластов.

Результатами исследований являются изучение процессов, протекающих при скважинной добыче урановых руд с применением серной кислоты в качестве растворителя, а также рассмотрение причин, влияющих на снижение геотехнологических параметров скважиной добычи урана в сложных горно-геологических условиях на месторождениях Казахстана. Рассмотрены и оценены применяемые гидродинамические методы регенерации скважин, основанные на разрушении и диспергировании осадкообразований. Также изучены и оценены применяемые реагентные методы повышения проницаемости продуктивного горизонта, основанные на растворении осадков. Разработана методика и проведены экспериментальные опыты по применению подобранных химических реагентов синергетического действия при интенсификации скважинной добычи урана. Проанализированы и обсуждены результаты экспериментальных исследований, построен сравнительный график периода бесперебойной работы скважин. Определена и показана эффективность применяемого метода восстановления проницаемости продуктивного горизонта с применением комплекса химических реагентов.

Научная новизна заключается в том, что минералогические исследования состава кернового материала свидетельствует о сложной структуре руд, вмещающих пород и урановой минерализации в сложных горно-геологических условиях, а установленная структура и количественно-качественные параметры осадкообразований подтверждает выпадение в осадок карбонатных и глинистых минералов в условиях сернокислотной скважиной добычи урана. Практическая значимость исследования заключается в высокой эффективности и применимости рассматриваемого метода интенсификации скважинной добычи урана на участках с низкими фильтрационными характеристиками.

Ключевые слова: микродифракция, рентгенофазовый анализ, проницаемость, регенерация, выщелачивание, уран, осадкообразование.

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THE STUDY OF THE CURRENT STATE OF THE SOIL COVER OF THE AKSHAT RURAL COUNTY OF WEST KAZAKHSTAN REGION ON THE BASIS OF GIS TECHNOLOGIES

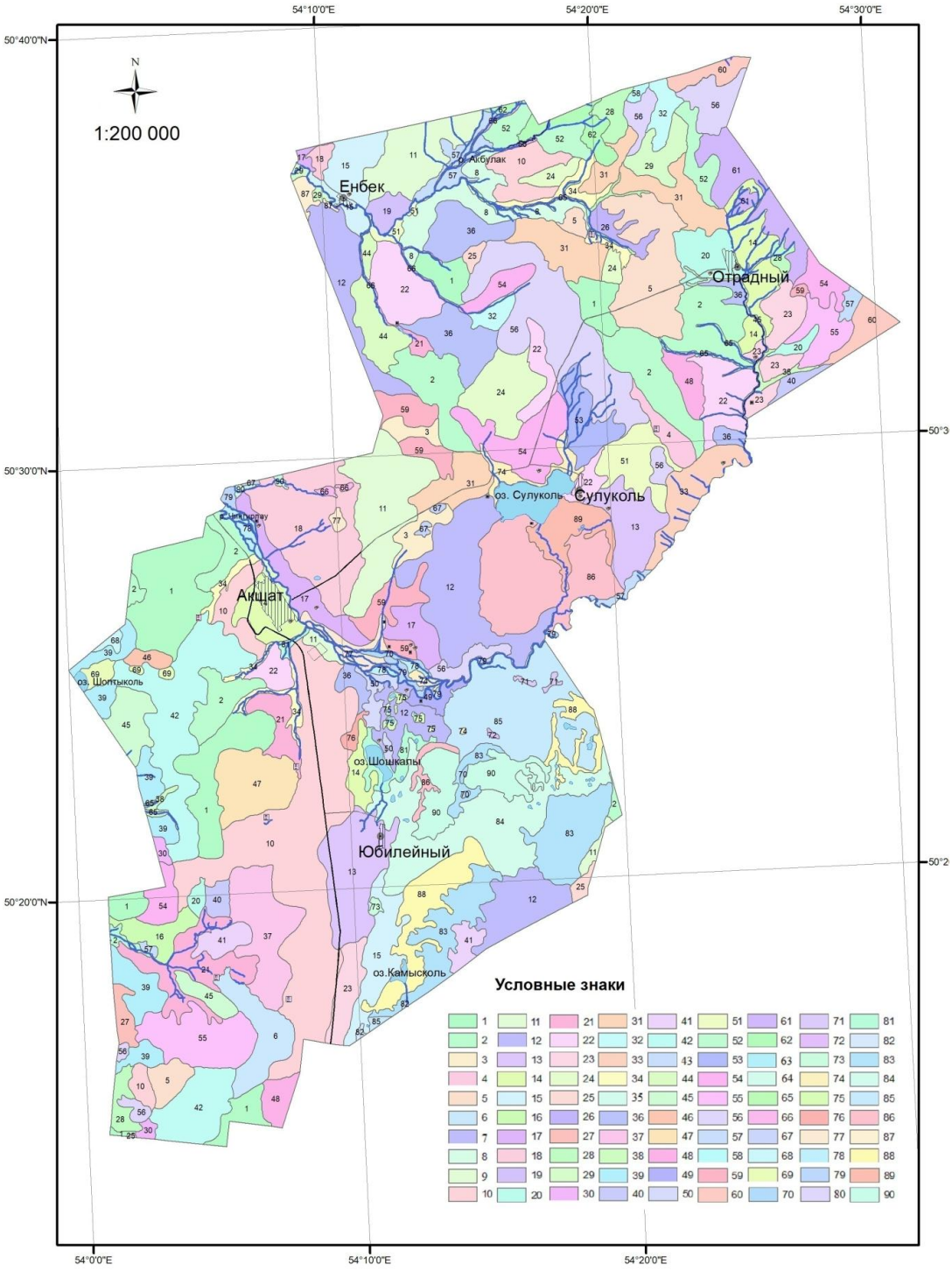
Abstract. The rational use and protection of soils in market conditions requires adequate application of new scientific and methodological approaches. One of such systematic-analytical methods of soil cadastre organizations is a combination of traditional terrestrial methods with technologies of geoinformation systems (GIS) based on extensive use of satellite images in different resolutions. The aggregate of information necessary for mapping soil cover patterns and their quantification has been described in GIS databases. Data integration has been realized through the spatial and attributive component in the form of: the results of topographic and thematic maps. At the same time, the creation of attributive GIS databases involves the digitization of thematic maps tied into a single cartographic projection (as a topographic map with a scale of 1: 50 000). As a result of the study, thematic maps and attributive databases of GIS of soils were formed. As a result of research, based on GIS technology, a digital soil map of the Akshat rural county of the Chingirlau district of the West Kazakhstan region has been developed using the ArcGIS software product.

Key words: geoinformation systems, soil cover, soil map, dark chestnut soils, rural county.

Introduction. Soils are an important component of the natural and biological resources of any country and they determine the socio-economic wealth of the country and greatly affect on the political relations. Thus, soil is considered as the most important part of the natural environment, characterized by certain natural (space, vegetation, etc.), socio-economic (means of production, value, etc.), production (subject, tool and means of production,) characteristics. Complete and reliable information on soils, including their quantitative and qualitative characteristics, should provide an opportunity for the executive authorities to make informed decisions on the development of specific territories and the country as a whole. Therefore, the need for objective and systematized information about the country's soil resources is constantly growing. The latter necessitates the need to create a fundamentally different system of accounting, assessment and monitoring of soil resources, different from the management of other types of material resources.

Rational use and protection of soils in market conditions requires adequate application of new scientific and methodological approaches. One of such systematic-analytical methods of soil cadastre organizations is a combination of traditional terrestrial methods with technologies of geoinformation systems (GIS) based on extensive use of satellite images in different resolutions. This approach underlies the agrarian geo-information systems of the developed countries of the world [1-3], where soils are the main subsystem of this information product. The development of scientific research in this area corresponds to the requirements of the State Program on Forced Industrial and Innovative Development of the Republic of Kazakhstan and the Program for the Development of Space Activities in the Republic of Kazakhstan.

Experimental. The aim of research is to study the soil cover and develop a soil map of the Akshat (Lubenka) rural county of the Chingirlau district of the West Kazakhstan region on the basis of applying GIS technologies for solving long-term problems of monitoring land resources and developing the agro-bioindustry.



Soil map of Akshat rural district in West Kazakhstan region

Materials and methods. In order to conduct large-scale soil research, it has been adhered to the relevant guidelines [4,5]. Physico-chemical parameters of soils were studied by conventional methods

[6-10]. For topographical and geodetic work, paper soil maps of different scale have been applied, ranging from 1-100 000 to 1:50 000 (for searching and selecting reference areas). The development of a large-scale soil map using GIS-technologies was carried out on the basis of the ArcGIS software product using scanned paper maps and aerial photographs.

Results and discussion. In the study area, we carried out soil cover studies based on the geosystemic approach and new information technologies (figure). In this systematic description, the soil subdivisions that we encountered in the territory of the Akshat rural county of the Chingirlau district of the West Kazakhstan region were identified.

Detailed diagnostic indicators have been given for the most common soil varieties within the study area. Specific morphological genetic features of the soil cover are indicated, based on the available data of field research and cameral processing. In the study area, dark chestnut soils are formed in the soil cover in combination with various soil combinations. They are formed in the conditions of the dry steppe zone, with the non-wash type of water regime, under the haymooth, meadow-grass, herbaceous-fat-grass, black-wormwood-meadow and meadow-white-wormwood-kokpekovic plant communities, on loesslike loams.

A soil map has been created on the basis of a fragment of a substrate of a soil map and a photographic plan and has been produced using ArcGIS. While creating the soil map for mapping the soil layer, attribute tables are used. While creating the same neighboring soil areas and generally with the further process of creating a soil map, it is needed to use the auto-polygon tool.

Figure illustrates the soil map of the Akshat rural county of the Chingirlau district of the West Kazakhstan region, which has been created using the above-described technique based on scanned soil maps.

The aggregate of information necessary for mapping soil cover patterns and their quantification has been described in GIS databases. Data integration has been realized through the spatial and attributive component in the form of: the results of topographic and thematic maps. At the same time, the creation of attributive GIS databases involves the digitization of thematic maps tied into a single cartographic projection (as a topographic map of scale 1: 25000). As a result of the study, thematic maps and attributive databases of GIS of soils were formed.

Legend to the soil map of the Akshat rural county

Soil No	Mechanical composition (soil texture)	Soil name
1	2	3
1	medium loamy	dark castanosems medium power
2	light loamy	dark castanosems medium power
3	sandy	dark castanosems medium power
4	heavy loamy	dark castanosems medium power with dark castanosems medium hardy saline low thin 10-30%
5	heavy loamy	dark castanosems medium power with meadow-castanosems medium heavy 10-30%
6	medium loamy	dark castanosems medium power with solonetz castanosems small 10-30%
7	sandy loam	dark castanosems medium power with solonetz castanosems small 10-30%
8	heavy loamy	dark castanosems medium power with solonetz castanosems small 30-50%
9	sandy loam	dark castanosems medium power with solonetz castanosems small 30-50%
10	light loamy	dark castanosems thin
11	sandy loam	dark castanosems thin
12	sandy	dark castanosems thin
13	light loam	dark castanosems thin with dark castanosems weakly-deflated 10-30%
14	sandy loam	dark castanosems thin with dark castanosems weakly-deflated 10-30%
15	sandy	dark castanosems thin with dark castanosems weakly-deflated 10-30%
16	light loamy	dark castanosems thin weakly chasteed with dark castanosems carbonate weakly washed away weakly debilitated 10-30%
17	sandy	dark castanosems thin with dark castanosems under-developed 10-30%

Table continuation

1	2	3
18	sandy	dark castanosems thin with meadow-castanosems medium power 10-30%
19	sandy loam	dark castanosems thin with with solonetza castanosems small 10-30%
20	light loam	dark castanosems weakly washed away
21	medium loamy	dark castanosems weakly washed away with meadow-castanosems medium duty 10-30%
22	light loamy	dark castanosems weakly washed away with meadow-castanosems medium power 10-30%
23	sandy loam	dark castanosems backlash
24	heavy loamy	dark castanosems carbonate medium power
25	medium loamy	dark castanosems carbonate medium power
26	light loamy	dark castanosems carbonate medium power weakly debilitated with dark castanosems weakly washed away 10-30%
27	medium loamy	dark castanosems carbonate medium power weakly debilitated with meadow-castanosems medium power 10-30%
28	medium loamy	dark castanosems carbonate thin
29	light loamy	dark castanosems carbonate thin weakly debilitated with dark castanosems carbonate weakly washed away weakly debilitated 10-30%
30	heavy loamy	dark castanosems carbonate thin weakly debilitated with dark castanosems undeveloped medium protective 10-30%
31	medium loamy	dark castanosems carbonate weakly washed away
32	heavy loamy	dark castanosems carbonate weakly washed away with dark castanosems undeveloped weakly debilitated 10-30%
33	sandy loam	dark castanosems carbonate weakly washed away with dark castanosems medium washed 10-30%
34	medium loamy	dark castanosems carbonate weakly washed away with dark castanosems medium washed 10-30% and meadow-castanosems medium washed 10-30%
35	heavy loamy	dark castanosems carbonate weakly washed away with meadow-castanosems medium washed 10-30%
36	light loamy	dark castanosems carbonate weakly washed away with solonetz castanosems small 10-30% and meadow-castanosems medium power to 10%
37	sandy loam	dark castanosems carbonate weakly-deflated with dark castanosems weakly-deflated 10-30%
38	medium loamy	dark castanosems carbonate-solonchak weakly washed away with dark castanosems medium washed
39	medium loamy	dark castanosems slightly salted medium power
40	light loamy	dark castanosems slightly salted medium power
41	sandy loam	dark castanosems slightly salted medium power
42	medium loamy	dark castanosems slightly salted medium power with dark castanosems solonchak medium power 10-30%
43	medium loamy	dark castanosems slightly salted medium power with solonetz castanosems small 10-30%
44	sandy loam	dark castanosems slightly salted thin with dark castanosems weakly-deflated10-30%
45	medium loamy	dark castanosems slightly salted medium power with solonetz castanosems small 10-30%
46	heavy loamy	dark castanosems solonchak medium power
47	medium loamy	dark castanosems solonchak medium power
48	light loamy	dark castanosems solonchak medium power
49	sandy loam	dark castanosems solonchak thin with meadow castanosems solonchak 10-30%
50	sandy loam	dark castanosems solonchak thin with typical solonchak 10-30%
51	heavy loamy	dark castanosems incompletely developed medium protective
52	light loamy	dark castanosems incompletely developed weakly debilitated
53	light loamy	dark castanosems incompletely developed medium protective with dark castanosems underdeveloped medium protective 10-30%
54	heavy loamy	dark castanosems incompletely developed medium protective with dark castanosems underdeveloped medium protective 30-50%
55	light loamy	dark castanosems incompletely developed weakly debilitated with dark castanosems underdeveloped medium protective

End of table

1	2	3
56	light loamy	dark castanosems underdeveloped medium protective
57	heavy loamy	dark castanosems underdeveloped medium protective
58	medium loamy	dark castanosems underdeveloped medium protective
59	sandy loam	dark castanosems underdeveloped
60	heavy loamy	dark castanosems underdeveloped medium protective with dark castanosems incompletely developed 10-30%
61	medium loamy	dark castanosems underdeveloped medium protective with dark castanosems incompletely developed 10-30%
62	heavy loamy	dark castanosems underdeveloped medium protective with exits solid rocks 10-30%
63	medium loamy	castanosems medium power with solonetz castanosems small to 10%
64	medium loamy	castanosems medium power with solonetz castanosems small 30-50%
65	heavy loamy	meadow-castanosems medium power
66	medium loamy	meadow-castanosems medium power
67	sandy	meadow-castanosems medium power
68	medium loamy	meadow-castanosems mid-solonetz-solonchak
69	light loamy	meadow castanosems
70	sandy loam	meadow castanosems
71	sandy	meadow castanosems
72	sandy loam	meadow-castanosems weakly solonetz
73	light loamy	meadow-castanosems mid-solonetz-solonchak
74	light loamy	meadow-castanosems solonchak
75	heavy loamy	meadow-castanosems solonchak
76	medium loamy	meadow-castanosems solonchak
77	light loamy	meadow-castanosems solonchak
78	light loamy	floodplain meadow castanosems solonchak
79	heavy loamy	floodplain meadow castanosems solonchak
80	heavy loamy	solonetz castanosems small with meadow-castanosems medium power 10-30%
81	sandy loam	typical solonchak (salt flats)
82	sandy loam	sor solonchaks
83	sandy	flat sands fixed with sands ridge-hilly fixed 10-30%
84	sandy	flat sands fixed with sands ridge-hilly semi-fixed 10-30% and meadow castanosems solanchak to 10%
85	sandy	flat sands fixed with sands ridge-hilly semi-fixed 10-30% and meadow castanosems to 10%
86	sandy	flat sands fixed with sands ridge-hilly fixed 10-30% and sands ridge-hilly semi-fixed to 10%
87	sandy	sands ridge-hilly fixed
88	sandy	sands ridge-hilly fixed with sands ridge-hilly semi-fixed 10-30% пески грядово-бугристые закрепленные с песками грядово-бугристыми полузакрепленными до 10-30%
89	sandy	sands ridge-hilly semi-fixed with sands ridge-hilly fixed 30-50%
90	sandy	sands ridge-hilly semi-fixed with sands ridge-hilly fixed 10-30% and meadow castanosems strongly solonetz-solonchak (salted-saline) to 10%

Conclusion. Therefore, as a result of conducted studies the mapping of the soil cover has been carried out using traditional terrestrial methods with geographic information system technologies (ArcGIS) based on extensive use of satellite images in different resolutions. This has allowed us to characterize the soil combinations by their belonging to a certain genetic-geometric form, the conditions of occurrence in the relief, and the quantitative indices.

In order to improve the quality of generalized maps (regional, provincial and other), it is necessary to create objective automated methods of generalizing maps in the digital environment.

As a result of our research, we have developed a simple and at the same time practically accessible to a wide audience of GIS users the methodology for compiling a digital soil map using the ArcGIS software product. To compile a map, it is possible to use any scanned cartographic basics, photographic plans, and if there are other raster materials. And as evidence of efficiency, with its help a large-scale soil map of Chingirlau region of the West Kazakhstan region was created.

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ГАЖ-ТЕХНОЛОГИЯСЫН ҚОЛДАНУ АРҚЫЛЫ БАТЫС ҚАЗАҚСТАН ОБЛЫСЫ ШЫҢҒЫРЛАУ АУДАНЫ АҚШАТ АУЫЛДЫҚ ОКРУГІ ТОПЫРАҚ ЖАМЫЛҒЫСЫНЫҢ ҚАЗІРГІ ЖАҒДАЙЫ

Аннотация. Жұмыс топырақ құнарлылығын сақтау мен жақсартуға арналған, өйткені оның жағдайы жер ресурстарын тиімді пайдалану, өнімділікті арттыру және ауылшаруашылығы ландшафтының топырақ экологиясын жақсарту жалпы мәселесінің негізгі бөлігі болып саналады. Топырақты заманауи бағалау мемлекет пен қоғамның дамуы үшін маңызды, өйткені географиялық таралуды есепке алу топырақ құндылығы, ұтымды пайдалану, сақтау және топырақты пайдалануды жоспарлау туралы ақпарат береді.

Нарық жағдайында топырақты тиімді пайдалану және қорғау жаңа ғылыми-әдістемелік тәсілдерді барабар қолдануды талап етеді. Топырақ кадастрын ұйымдастырудың осындай жүйелік-аналитикалық әдістерінің бірі түрлі рұқсаттағы аэроғарыш суреттерін кеңінен қолдануға негізделген дәстүрлі жердегі әдістерді геоақпараттық жүйе (ГАЖ) технологияларымен үйлестіру болып есептеледі.

Оқу аймағында геожүйелік көзқарас пен жаңа ақпараттық технология негізінде топырақ жамылғысын зерттеуді жүргіздік. Бұл жүйелі сипаттамада Батыс Қазақстан облысы Шыңғырлау ауданы Ақшат ауылдық округі аумағынан біз тапқан топырақ бөлімдері ерекшеленеді.

Топырақ жамылғысы құрылымдарын картаға түсіру мен сандық анықтауға қажетті ақпарат жиынтығы ГАЖ мәліметтер базасында сипатталған. Мәліметтерді интеграциялау кеңістіктік және атрибутивті компонент арқылы топографиялық және тақырыптық карта нәтижелері түрінде жүзеге асырылады. Сонымен бірге ГАЖ-ның атрибутивті мәліметтер базасын құру бір картографиялық проекциямен байланысқан тақырыптық карталарды цифрландыруға болжам жасайды (бұл масштабы 1: 50000 топографиялық карта болған).

Осылайша жүргізілген зерттеу нәтижесінде түрлі қабаттағы аэроғарыштық суреттерді кеңінен қолдануға негізделген географиялық ақпараттық жүйе (ArcGIS) технологияларымен дәстүрлі жер әдістерін қолдану арқылы топырақ жамылғысының картасы жасалды. Бұл топырақ комбинацияларын белгілі бір генетикалық-геометриялық пішінге, рельефте пайда болу шартына және сандық көрсеткіштерге жатқызылу жағдайына қарай сипаттауға мүмкіндік берді.

Жұмыс нәтижесінде тақырыптық карталар және ГАЖ – топырақтың атрибутивті мәліметтер базасы құрылды. ГАЖ технологиялары негізінде жүргізілген зерттеулер нәтижесінде ArcGIS бағдарламалық өнім арқылы Батыс Қазақстан облысы Шыңғырлау ауданы Ақшат ауылдық округінің цифрлық топырақ картасы жасалды.

Түйін сөздер: географиялық ақпараттық жүйелер, топырақ жамылғысы, топырақ картасы, қара қоңыр топырақ, ауылдық округ.

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СОВРЕМЕННОЕ СОСТОЯНИЕ ПОЧВЕННОГО ПОКРОВА АКШАТСКОГО СЕЛЬСКОГО ОКРУГА ЗАПАДНО-КАЗАХСТАНСКОЙ ОБЛАСТИ НА ОСНОВЕ ПРИМЕНЕНИЯ ГИС-ТЕХНОЛОГИЙ

Аннотация. Данная работа посвящена сохранению и повышению плодородия почв, т.к. ее состояние является основной частью общей проблемы рационального использования земельных ресурсов, увеличения продуктивности и улучшения почвенной экологии агроландшафтов. Современная оценка почв является актуальной для развития государства и общества т.к. обеспечивает информацией об учете географического распределения, о стоимости почв, о рациональном использовании, об охране и планировании использования почв.

Рациональное использование и охрана почв в рыночных условиях требует адекватного применения новых научно-методических подходов. Одним из таких системно-аналитических способов организации почвенного кадастра является сочетание традиционных наземных методов с технологиями геоинформационных систем (ГИС) на базе широкого использования аэрокосмических изображений разного разрешения.

На исследуемой территории нами проведены исследования почвенного покрова на основе геосистемного подхода и новых информационных технологий. В настоящем систематическом описании выделены почвенные подразделения, которые были встречены нами на территории Акшатского сельского округа Чингирлауского района Западно-Казахстанской области.

Совокупность информации, необходимой для картографирования структур почвенного покрова и их количественной оценки, описывается в базах данных ГИС. Интеграция данных реализуется через пространственную и атрибутивную составляющую в виде результатов топографической и тематических карт. При этом создание атрибутивных баз данных ГИС предполагает оцифровку тематических карт, привязанных в единой картографической проекции (в качестве которой служила топографическая карта масштаба 1:50000).

Таким образом, в результате проведенных исследований выполнено картографирование почвенного покрова с привлечением традиционных наземных методов с технологиями геоинформационных систем (ArcGIS) на базе широкого использования аэрокосмических изображений разного разрешения. Это позволило охарактеризовать почвенные комбинации по их принадлежности к определенной генетико-геометрической форме, условиям залегания в рельефе, количественным показателям.

В результате работы сформированы тематические карты и атрибутивные базы данных ГИС – почв. В результате исследований на основе ГИС-технологий разработана цифровая почвенная карта Акшатского сельского округа Чингирлауского района Западно-Казахстанской области с помощью программного продукта ArcGIS.

Ключевые слова: геоинформационные системы, почвенный покров, почвенная карта, темно-каштановые почвы, сельский округ.

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STUDY OF STABILITY OF A TANK-CONTAINER WITH A FILLED LIQUID AT LONGITUDINAL OSCILLATIONS

Abstract. The effect of the oscillating fluid on the dynamic stability of the tank-container is studied at different filling capacities. The main method for studying the dynamic stability of a railway platform with a tank- container in theoretical calculations is the method of full integration, i.e. all the solutions of the system of differential equations describing the movement of the tank-container with liquid are found, and from them a conclusion is made on the stability of the movement. The study of the longitudinal vibrations of the liquid and the tank-container is considered at various impact speeds and without taking into account the galloping angle. The solution of the system of differential equations reduces to the solution of the hydrodynamic problem.

Key words: dynamic stability, tank-container, spring kit, acceleration, hydrodynamic force, collision speed.

The problem of determining the effect of an oscillating fluid on the dynamic stability of a partially filled tank-container is solved by comparing the dynamic stability areas of a full and partially filled tank - container obtained with the same parameters of the tank-container and the railway platform, types of disturbances and driving conditions. The longitudinal vibrations of the container with the liquid have a significant effect on their stability during movement. Consider the longitudinal vibrations of the tank-container, similar to transverse vibrations. To do this, we introduce the inertial coordinate system (fixed) OXZ, and the tank-container located in the plane of the unperturbed surface (movable) Ox_1z_1, connected to the tank's surface (see figure 1).

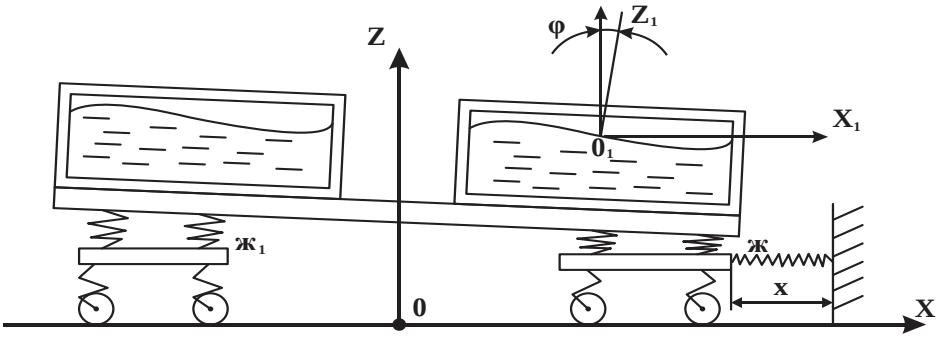


Figure 1 – Design diagram of a platform with a tank-container

The fluid motion relative to the moving system $O_1x_1z_1$ will be determined by the function $q_n(t)$, and the longitudinal motion of the «container-liquid» system will be determined by the coordinate function-X(t). Then the problem of hydrodynamics is formulated as follows, it is necessary to find the potential of

the absolute velocities $\varphi_a(x,z,t)$ - particles of a liquid in a container moving with a speed - $\dot{X}(t)$. Since the progressive movement of the tank-container is investigated, the potential velocity of the absolute movement will be [1]:

$$\varphi_a = \varphi + \dot{X}(t)x_1 \ , \tag{1}$$

where $\dot{X}$- the speed of the tank-container in the longitudinal direction. The function $\varphi(x_1, z_1, t)$ satisfies the Laplace equation and the boundary conditions:

$$\frac{\partial^2\varphi}{\partial x_1^2} + \frac{\partial^2\varphi}{\partial z_1^2} = 0, \tag{2}$$

$\frac{\partial\varphi}{\partial n} = 0$ - on a wettable surface and $\frac{\partial^2\varphi}{\partial t^2} + g\frac{\partial\varphi}{\partial z_1} = 0$ - on a free surface. (3)

The equation of the free surface in the tank-container is written in the form [2]

$$\zeta(x_1, t) = \sum q_n(t)\,\psi(x_1, 0).$$

Then the solution of equation (2) taking into account the boundary conditions (3) can be represented as

$$\varphi(x_1, z_1, t) = \sum\frac{d}{\pi n}\dot{q}_n(t)\dot{\psi}_n(x_1, z_1), \tag{4}$$

where $\dot{q}_n(t)$ - time functions characterizing the movement of the liquid, d - length of the tank-container; $\dot{\psi}_n(x_1, z_1)$ are the eigenvalues obtained by the Fourier method for $\dot{q}_n(t) = \cos(\omega_n t)$, i.e. when studying the natural vibrations of a liquid, the eigenvalues are determined by the formula [3]

$$\psi_n(x_1, z_1) = \frac{2}{\sqrt{d}} sin\frac{\pi n}{d}x_1\frac{ch\frac{\pi n}{d}(z_1+R+h)}{ch\frac{\pi n}{d}(R\pi+h)}. \tag{5}$$

Natural frequencies are defined as follows

$$\mu_n = \frac{\omega_n^2}{g} = \frac{n\pi}{d}th\frac{n\pi}{d}\left(\frac{\pi}{4}R + h\right). \tag{6}$$

We proceed to obtain a system of equations of longitudinal oscillations of the liquid and the tank-container, taking into account the galloping of the platform. In this case, the potential velocity of the absolute motion of the liquid particles, determined by the relation (1), will take the form [4]

$$\varphi_a = \varphi + \dot{\psi}\varphi_1^{(2)} + \left(\dot{X} + l\dot{\psi}\right)x_1, \tag{7}$$

where $\varphi_1^{(2)}$- is the Zhukovsky potential, whose approximate value is determined by the relation

$$\varphi_1^{(2)} = x_1z_1 + x_1^0z_1 - x_1z_1^0 - \frac{(-1)^{n+1}8d^2}{\pi^3}\sum_{n=1}^{\infty}\frac{1}{(2n-1)^2}\frac{sh\frac{(2n-1)\pi}{d}\left(z_1+\frac{R\sqrt{\pi}}{2}+h\right)}{ch\frac{(2n-1)\pi}{d}\left(\frac{R\sqrt{\pi}}{2}+h\right)}sin\frac{(2n-1)\pi}{d}x_1, \tag{8}$$

where x_1^0, z_1^0 – are the coordinates of the center of gravity of the fluid.

To compile the Lagrange equation, we represent the kinetic and potential energy in the form [5]

$$T = \frac{1}{2}m_1\dot{X}^2 + \gamma\rho\dot{X}\sum_{n=1}^{\infty}\dot{q}_n a_n + \frac{1}{2}m_{ж}\gamma\dot{X}^2 + \frac{1}{2}\gamma\sum m_n\dot{q}_n^2,$$

$$\Pi = \frac{1}{2}жX^2 + \frac{1}{2}\gamma\rho g\sum g_n^2 + \frac{1}{2}жc_1\,\psi(X),$$

and the dispersion function from vibration dampers in spring sets and from the conventional absorbing apparatus of the tank-container will be found by the formula [6]

$$\Phi = \frac{1}{2}\gamma\sum\varepsilon_n\dot{q}_n^2 + \varphi ж\left|X\dot{X}\right|.$$

The static characteristic $F(X)$ of the absorbing apparatus, taking into account the rigidity of the tank-container, will take the following values

$$F(X) = \begin{cases} 0, if\ a\ |X| < \delta; \\ X[1 + \varphi sign(X\dot{X})], \delta \le X \le \Delta; \\ f(X), if\ a\ |X| > \Delta; \end{cases} \quad (9)$$

where

$$f(X) = \begin{cases} 0, at\ X < \Delta; \\ N + ж_2(X - \Delta)\ at\ |X| > \Delta; \end{cases}$$

Δ - is the course of the absorbing apparatus, the characteristic of the real absorbing apparatus is shown in figure 2.

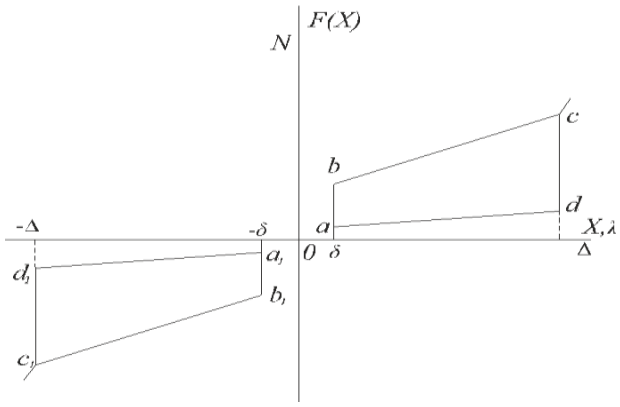


Figure 2 – Static characteristic of an absorbing apparatus

Substituting the potential and kinetic energy ratios, the scattering functions into the Lagrange equation of the second kind and, after performing some transformations, we obtain a system of differential equations describing the longitudinal vibrations of the liquid and the tank-container, taking into account the galloping of the railway platform at various speeds of collisions [7]:

$$\begin{cases} M\ddot{X} + l_2 m^* \ddot{\psi} + \rho \sum a_{2n-1}\, \ddot{q}_{2n-1} + F(X) = 0, \\ (I_1 + I^*)\ddot{\psi} + l_2 m^* \ddot{X} + \rho \sum \beta_{2n-1}\, \ddot{q}_{2n-1} + k^2 \psi + 2\beta l_3 \dot{\psi} - \rho g \sum a_{2n-1}\, \ddot{q}_{2n-1} = 0, \\ \rho\beta_{2n-1}\ddot{\psi} + \frac{\rho}{\mu_{2n-1}}\ddot{q}_{2n-1} + \rho a_{2n-1}\ddot{X} + 2\varepsilon_{2n-1}\frac{\rho}{\mu_{2n-1}}\dot{q}_{2n-1} - \rho g a_{2n-1}\psi + \rho g q_{2n-1} = 0, \end{cases} \quad (10)$$

where l_2 is the distance from the center of gravity of the «tank-container-liquid» system to the center of oscillation O; $2l_3$ - base of the tank-container; m^*- is the compressed mass of the tank-container and railway platform; I_1 - moment of inertia of the tank-container relative to the transverse axis of rotation; I^*- is the moment of inertia of the equivalent body; $k^2 = 2жl_3^2 - \rho g \tau_0 l_1 - m_1 g l_2$.

The hydrodynamic coefficients a_{2n-1} and β_{2n-1} are the coefficients of series expansion [8]

$$x_1 = \sum_{n=1}^{\infty} a_n\, \psi_n(x_1, 0)\ u\ \varphi_1^2 = \sum_{n=1}^{\infty} \beta_n\, \psi_n(x_1, 0)dx,$$

moreover

$$a_n = \int_{-\frac{d}{2}}^{\frac{d}{2}} x_1\, \psi_n(x_1, 0)dx\ u\ \beta_n = \int_{-\frac{d}{2}}^{\frac{d}{2}} \left(\varphi_1^{(2)}\right)_{z_1=0} \psi_n(x_1, 0)dx.$$

Calculating these integrals, we obtain

$$a_{2n-1} = \frac{2d^{\frac{3}{2}}}{(2n-1)^2\pi^2}; \quad (11)$$

$$\beta_{2n-1} = \frac{2z^0 d^{\frac{3}{2}}}{(2n-1)^2\pi^2} + \frac{8d^{\frac{3}{2}}}{(2n-1)^3\pi^3} th\frac{(2n-1)\pi}{d}\left(\frac{R\sqrt{\pi}}{2} + \right). \quad (12)$$

By changing variables in the system of equations (10) $q_{2n-1} = x_{2n-1}a_{2n-1}\mu_{2n-1}$ we get [9]

$$\begin{cases} m\ddot{X} + l_2 m^*\ddot{\psi} + \sum \tilde{m}_{2n-1}\ddot{x}_{2n-1} + F(X) = 0, \\ I\ddot{\psi} + l_2 m^*\ddot{X} + \sum \delta_{2n-1}\tilde{m}_{2n-1}x_{2n-1} + k^2\psi + 2\beta l_3\dot{\psi} - g\sum \tilde{m}_{2n-1}x_{2n-1} = 0, \\ \delta_{2n-1}\ddot{\psi} + \ddot{X} + \ddot{x}_{2n-1} + 2\varepsilon_{2n-1}\dot{x}_{2n-1} - g\psi + \omega_{2n-1}^2 x_{2n-1} = 0, \text{где n} = 1,2,3,\ldots. \end{cases} \quad (13)$$

The following notation is introduced in these equations:

$$I = I_1 + I^*;\ \delta_{2n-1} = z_1^0 + \frac{4d}{\pi}\frac{th\frac{(2n-1)\pi}{d}\left(\sqrt{\pi}R + h\right)}{2n-1};\ \omega_{2n-1}^2 = g\mu_{2n-1};\ \tilde{m}_{2n-1} = \rho a_{2n-1}^2\mu_{2n-1}\gamma.$$

All coefficients of this system can be calculated and, therefore, it can be integrated. Using standard programs, all unknowns that are part of the system of equations (13), functions and their derivatives were obtained. At the same time, the longitudinal force was calculated according to relations (9) and the coefficient of dynamics k_{dyn} of spring sets according to the formula

$$k_{dyn} = \frac{жa\psi + \beta a\dot{\psi}}{P_{cm}}. \quad (14)$$

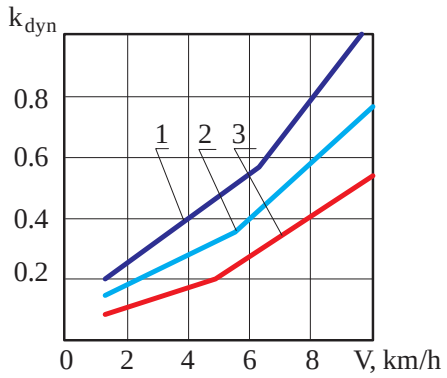
The resulting force of the hydrodynamic pressure of the liquid on the right bottom $X_г^1$ and on the left bottom $X_г^2$ will be equal to:

$$X_г^1 = \rho\iint\left(\frac{\partial\varphi_a}{\partial t}\right)_{x=\frac{d}{2}} ds;\ X_г^2 = -\rho\iint\limits_{\sum+S}\left(\frac{\partial\varphi_a}{\partial t}\right)_{x=-\frac{d}{2}} ds.$$

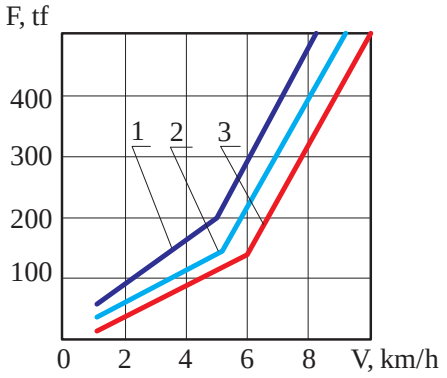
The magnitude of the hydrodynamic force will be equal to: $X_г = X_г^1 + X_г^2$. To calculate the hydrodynamic pressure of the liquid on the bottom during the collision of the tank-container, hydrostatic force should be added to the hydrodynamic force [10]

$$P_г = X_г + X_г^{cm} = X_г + \iint\limits_{\sum+S}(\rho_0 + \rho g z_1)ds.$$

Below are some results obtained on the basis of the proposed methodology using standard programs. Figures 3 and 4 show graphs of the dependence, respectively, of the coefficient of dynamics and longitudinal force on the speed of collision. The curves correspond to loading cases: 1- one tank-container; 2- two tank-containers; 3- three tank-containers.



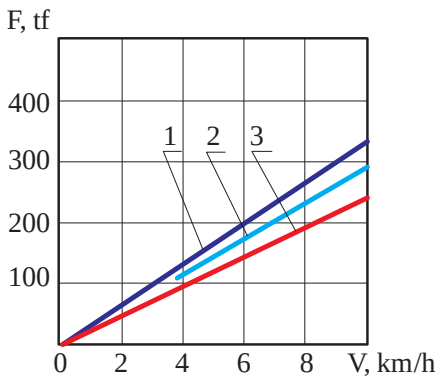
The curves correspond to the load: 1-one tank-container; 2- two tank-containers; 3- three tank-containers
Figure 3 – Graph of the dynamics coefficient versus impact velocity



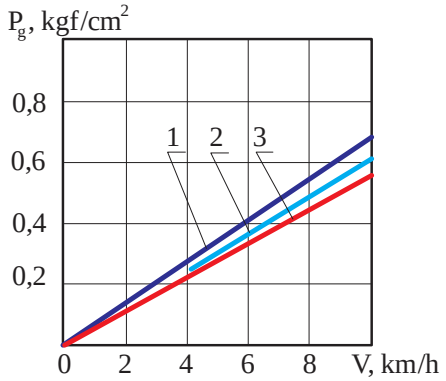
The curves correspond to the load: 1- one tank-container; 2- two tank-containers; 3- three tank-containers
Figure 4 – Graph of longitudinal force versus impact velocity

As can be seen from figure 3, the dynamic coefficient in the cases of loading two and three tank-containers is much less for the case of loading one tank-container for all impact speeds. The decrease in the value of the dynamics coefficient in these cases can be explained by the significantly greater inertia of these tank-containers, i.e. an increase in ρ - is the radius of inertia. For the case of loading three tank-containers, the limit value of the dynamics coefficient is reached at approximately a collision speed of 10 km/h.

Figure 4 shows that the longitudinal force increases with an increase in the collision velocity; moreover, the longitudinal force in the case of loading two and three tank-containers is higher than in the case of loading one tank-container. This is explained by the fact that the maximum longitudinal force is proportional to the square root of the platform mass [2,11] and, therefore, for the same stiffness of the inter-car connections, a greater longitudinal force will be manifested when a larger tank-container collides. Figures 5 and 6 show graphs of, respectively, the longitudinal force and hydrodynamic pressure versus the collision speed during underfilling of the tank-container. The curves correspond to the cases: 1- underfilling 0.3m; 2- underfilling 0.6m; 3- underfilling 0.9m.



The curves correspond to: 1 - underfilling 0.3 m;
2- underfilling 0.6m; 3- underfilling 0.9m
Figure 5 – Graph of the longitudinal force versus collision speed during underfilling of the tank-container



The curves correspond to: 1 - underfilling 0.3 m;
2- underfilling 0.6m; 3- underfilling 0.9m
Figure 6 – Graph of hydrodynamic pressure versus collision speed during underfilling of the tank- container

From the analysis of graphs 5 and 6 it is seen that the longitudinal force and hydrodynamic pressure of the liquid on the bottom of the container with an increase in the impact velocity increase at the same level of filling with liquid. With an increase in underfilling at the same collision velocity, the hydrodynamic pressure of the liquid increases. It should be noted that the effect of the oscillating fluid on the maximum longitudinal forces of the tank-container is less affected than the hydrodynamic pressure of the fluid in the bottom.

Conclusions: The dynamic coefficient in cases of loading two and three tank-containers is much less than in comparison with the case of loading one tank-container for all impact speeds. The decrease in the value of the dynamics coefficient in these cases can be explained by the significantly greater inertia of these tank-containers, i.e. an increase in ρ- is the radius of inertia.

Longitudinal force increases with an increase in collision velocity; moreover, the longitudinal force in cases of loading two and three tank-containers is higher than in comparison with the case of loading one tank-container. The longitudinal force and hydrodynamic pressure of the liquid on the bottom of the container with increasing collision velocity increase at the same level of filling with liquid. With an increase in underfilling at the same collision velocity, the hydrodynamic pressure of the liquid increases.

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БОЙЛЫҚ ТЕРБЕЛІС БАРЫСЫНДА СҰЙЫҚПЕН ТОЛТЫРЫЛҒАН ТАНК-КОНТЕЙНЕРДІҢ ТҰРАҚТЫЛЫҒЫН ЗЕРТТЕУ

Аннотация. Тербелмелі сұйықтықтың танк-контейнердің динамикалық тұрақтылығына түрлі деңгейде толтыру барысындағы әсері зерттеледі. Теориялық есептеуде танк-контейнері бар теміржол платформасының динамикалық тұрақтылығын зерттеудің негізгі әдісі – толық интеграциялау әдісі, яғни ішінде сұйықтық бар танк-контейнер қозғалысын сипаттайтын дифференциалдық теңдеулер жүйесінің барлық шешімі анықталды және сол бойынша қозғалыс тұрақтылығы туралы қорытынды жасалды. Сұйықтық пен танк-контейнердің бойлық тербелістерін зерттеу түрлі соқтығысу жылдамдығында қарастырылады.

Қозғалмаған бос беттің $O_1x_1z_1$ жазықтығында орналасқан, инерциялық OXZ және танк-контейнерге байланысты екі координаталық жүйені енгіземіз. Сұйықтық пен танк-контейнердің бойлық тербелістері серпіліс бұрышты ескерусіз қарастырады, яғни қозғалатын координаталар жүйесіне қатысты сұйықтық қозғалысы q(t) функциясымен, ал бойлық тербеліс «контейнер-сұйықтық» жүйесінің қозғалысы X(t) координат функциясы түрінде қарастырылады. Шешім гидродинамикалық есепті шешуге септігін тигізеді, яғни $\dot{X}(t)$ жылдамдықпен қозғалатын контейнердегі сұйықтықтың абсолютті жылдамдығын табуымыз қажет.

Теміржол платформасының серпілуін ескере отырып, сұйықтық пен танк-контейнердің бойлық тербелістерінің дифференциалдық теңдеулер жүйесі соқтығысу жылдамдығын ескере отырып, 2-ші ретті Лагранж теңдеуі негізінде алынды. 2-ші ретті Лагранж теңдеуін құру үшін кинетикалық және потенциалдық энергия, серіппелі дірілдеткіш қондырғылардан және танк-контейнерінің әдеттегі сіңіру аппараттарынан шашырау функциясы есептелді.

Стандартты бағдарламаларды қолдана отырып, дифференциалдық теңдеулер жүйесіне кіретін барлық белгісіз мәлімет, функция және олардың туындылары алынды. Сонымен қатар серіппелі жиынтықтардың бойлық күші мен динамика коэффициенті есептелді.

Сандық тәжірибелер ұсынылған әдіс негізінде стандартты бағдарламаларды қолдану негізінде жүргізілді. Сандық тәжірибе нәтижелері соқтығысу жылдамдықтарынан динамика коэффициенті, бойлық және гидродинамикалық күштер тәуелділік графигі түрінде келтірілген.

Екі және үш танк-контейнерін тиеу кезінде динамика коэффициенті барлық соқтығысу жылдамдығы үшін бір танк-контейнерін тиеумен салыстырғанда, едәуір аз. Бұл жағдайда динамик коэффициентінің төмендеу жағдайын осы танк-контейнер инерциясы, яғни ρ-инерция радиусының едәуір жоғарылау сипатымен түсіндіруге болады.

Бойлық күш соқтығысу жылдамдығының жоғарылауы негізінде артады, дегенмен екі және үш танк-контейнерін тиеу кезінде бойлық күштің мәні, бір танк-контейнерін тиеумен салыстырғанда үлкен келеді. Соқтығысу жылдамдығының жоғарылауы арқылы контейнер түбіндегі сұйықтың бойлық күші мен гидродинамикалық қысымы сұйықтықпен толтыру бір деңгейге жеткенде артады. Бірдей соқтығысу жылдамдығымен құйылып, аз толтырылғанда сұйықтықтың гидродинамикалық қысымы артады.

Түйін сөздер: динамикалық орнықтылық, танк-контейнер, рессорлық жинақ, үдеу, гидродинамикалық күш, соқтығысу жылдамдығы.

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ИССЛЕДОВАНИЕ УСТОЙЧИВОСТИ ТАНКА-КОНТЕЙНЕРА ЗАПОЛНЕННОЙ ЖИДКОСТЬЮ ПРИ ПРОДОЛЬНЫХ КОЛЕБАНИЯХ

Аннотация. Изучается влияние колеблющейся жидкости на динамическую устойчивость танка-контейнера при различной заполняемости емкости. Основным методом исследования динамической устойчивости железнодорожной платформы с танком-контейнером при теоретических расчетах является метод полной интеграции, т.е. находятся все решения системы дифференциальных уравнений, описывающих движение

танка-контейнера с жидкостью, и по ним выдается заключение об устойчивости движения. Исследование продольных колебаний жидкости и танка-контейнера рассматривается при различных скоростях соударения.

Введем две системы координат: инерционную OXZ и связанную с танком-контейнером, находящуюся в плоскости невозмущенной свободной поверхности $O_1x_1z_1$. Рассматриваются продольные колебания жидкости и танка-контейнера без учета угла галлопирования, т.е. движение жидкости относительно подвижной системы координат рассматривается функцией q(t), а продольное колебание движение системы «контейнер-жидкость» в виде функции координаты X(t). Решение сводится к решению задачи гидродинамики, т.е. нахождению абсолютной скоростей жидкости в емкости контейнера, движущейся со скоростью $\dot{X}(t)$.

Система дифференциальных уравнений продольных колебаний жидкости и танка-контейнера с учетом галопирования железнодорожной платформы получена на основе уравнения Лагранжа 2-го рода с учетом скорости соударения. Для составления уравнения Лагранжа 2-го рода были вычислены кинетическая и потенциальная энергия, функция рассеивания от гасителей колебаний в рессорных комплектах и от условного поглощающего аппарата танка-контейнера.

С использованием стандартных программ были получены все неизвестные, входящие в систему дифференциальных уравнений, функции и их производные. Одновременно были вычислены продольная сила и коэффициент динамической перегрузки рессорных комплектов.

Были проведены численные эксперименты на основе предложенной методики с использованием стандартных программ. Результаты численных экспериментов представлены в виде графиков зависимостей, соответственно, коэффициента динамики, продольной и гидродинамической силы от скорости соударения.

Коэффициент динамики в случаях загрузки двух и трех танков-контейнеров значительно меньше, чем по сравнению случаем загрузки одного танка-контейнера для всех скоростей соударения. Уменьшение значения коэффициента динамики в данных случаях можно объяснить значительно большей инерционностью этих танков-контейнеров, т.е. увеличением ρ - радиуса инерции.

Продольная сила растет с увеличением скорости соударения; причем значение продольной силы в случаях загрузки двух и трех танков-контейнеров больше, чем по сравнению случаем загрузки одного танка-контейнера. Продольная сила и гидродинамическое давление жидкости на днище контейнера с увеличением скорости соударения увеличиваются при одном и том же уровне заполнения жидкостью. При увеличении недолива при одной и той же скорости соударения гидродинамическое давление жидкости увеличивается.

Ключевые слова: динамическая устойчивость, танк-контейнер, рессорный комплект, ускорение, гидродинамическая сила, скорость соударения.

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RECOMMENDATIONS ON THE DEVELOPMENT OF PROBABILITY MAPS OF SEISMIC ZONING OF THE TERRITORY OF KAZAKHSTAN BASED ON MODERN METHODOLOGY

Abstract. Minimization of fatalities, material damage, and socio-economic destruction due to earthquakes depends on reliable estimates of seismic hazard. The paper presents the methodological foundations of seismic hazard assessment developed for Kazakhstan, the basic requirements and the list of work required to carry out seismic zoning of territories at different scale levels – general, detailed and microzoning. They were tested during the creation of Maps of General Seismic Zoning of the Territory of Kazakhstan, which were included in regulatory documents in 2017 and Maps of Seismic Microzoning of Almaty on a new methodological basis. A new approach to seismic hazard assessment is based on a methodology that complies with the main provisions of Eurocode 8 "Design of structures for earthquake resistance", meets the needs of earthquake-resistant design and construction, is probabilistic and allows to assess seismic hazard not only in seismic intensity according to MSK-64(K) scale common for Kazakhstan, but also in quantitative parameters – peak ground accelerations. For each type of seismic zoning, general objectives are defined that can be solved with consideration of the scale of developed maps.

Key words: earthquake recurrence law, economic development planning, ground properties, geophysical studies.

Introduction. In the Republic of Kazakhstan, earthquakes are one of the natural disasters that pose a threat to the security of the population and the economic potential of the country. Over 30% of the country's territory is seismically active. About 6 million people live on it, over 40% of the industrial potential is concentrated, and more than 400 cities and towns are located on it. Damage can be caused not only by the force of earthquakes, but also as a result of an underestimation of the seismic hazard assessment in the development of feasibility studies and the selection of sites for the construction of large facilities (plants, hydrotechnical, and energy facilities). It is impossible to prevent earthquakes, but their devastating consequences and the number of human casualties can be reduced by creating reliable seismic zoning maps, applying adequate standards for earthquake-resistant construction and pursuing a long-term policy in seismically active areas based on raising the awareness of the population and federal bodies on the threat of earthquakes and ability to resist the underground forces of nature.

With the implementation of new maps of the general seismic zoning of the territory of the Republic of Kazakhstan as part of the Code of Rules of the Republic of Kazakhstan 2.03-30-2017 "Construction in seismic zones" [1], a transition was made to seismic zoning that meets the scientific and methodological foundations of Eurocode 8 "Design of structures for earthquake resistance" [2], which was harmonized with modern principles of regionalization in countries within the zones of the Eurasian Economic and Customs Unions. The new approach meets the needs of earthquake-resistant design, since it is probabilistic and allows to assess seismic hazard not only in MSK-64(K) seismic intensity scales, which are conventionally used in Kazakhstan [3], but also directly in quantitative parameters – peak ground accelerations.

The main concepts associated with the socio-economic consequences of earthquakes are as follows:

– Seismic zoning – mapping of the potential seismic hazard of a territory, performed to determine the probable intensity of seismic impacts for a selected time interval. Seismic effects are expressed in terms of a macroseismic scale of seismic intensity, amplitudes of ground vibrations, or other characteristics used in the design of buildings and structures.

– Seismic hazard – the occurrence probability (exceeding/non-exceeding) of a seismic effect of a certain magnitude on a given area within a given time interval.

The practical implementation of the seismic hazard assessment of the territory of the Republic of Kazakhstan is carried out by developing maps of seismic zoning of various details, the need for which arises in connection with the development of the national economy and construction.

Materials and methods. When developing seismic zoning maps, stock materials and instrumental observation data are mainly used (of Institute of Seismology, Seismological Experimental and Methodical Expedition, Committee for Geology and Mineral Protection of the Republic of Kazakhstan, and other organizations). An exception is the seismic hazard assessment of critical facilities, such as nuclear power plants, which, according to the IAEA requirements, is carried out on special projects with the necessary amount of field research.

The main purpose of all types of probability maps of seismic zoning and seismic hazard assessment is to determine the probable intensity of seismic impacts for selected time intervals. The methodology for the probabilistic assessment of seismic hazard used in the development of GSZ maps of the Republic of Kazakhstan on a new methodological basis [4-7], included in the Code of Rules of the Republic of Kazakhstan 2.03-30-2017 “Construction in seismic zones” [1], includes both domestic developments in identifying, parameterizing the zones of possible epicenters of earthquakes and consideration of their influence on the seismic hazard of the territory [8-13], and the advantages of the western engineering approach [2]. It is based on materials studying the structure of the earth's crust and lithosphere, modern geodynamics, regional seismicity, seismotectonics, and engineering seismology. The conceptual basis constitutes modern ideas about the maximum magnitude of the probable magnitude of earthquakes, conditioned upon the structural and dynamic unity of the geophysical environment and the seismic processes developing in it, and as a result, the size, strength properties, and intensity of the interaction of geoblocks [10].

The adopted methodological approach defines the following general tasks of seismic hazard assessment, which are described in detail in the works [6-14]:

– Seismotectonic and geological-geophysical studies, which include the study of active faults and the assessment of their parameters; the construction of a seismotectonic model of the region, and on its basis, the identification of probable earthquake zones and zones of diffuse seismicity; determination of their seismic potential, depth, and mechanism of sources of expected earthquakes [11-15];

– Seismological studies, which include the development of a consolidated catalogue of earthquakes, local seismological observations, assessment of the parameters of the seismic setting, the establishment of a model of seismic setting (earthquake recurrence law) [6,11,13,14].

– Calculation of forecast assessing in intensities of a macroseismic scale and quantitative parameters (peak ground accelerations, etc.). Determination of the dependences of these parameters on the characteristics of the seismic source (magnitude, distance, source mechanism, direction of the rupture, type of ground conditions), the path travelled by seismic waves, as well as local ground conditions at the observation site based on world and regional data. These patterns (attenuation dependencies) are used to predict seismic effects on maps of seismic zoning of different detail [6,11].

– Compilation of an uncertainty model based on a logic tree [16] to factor in the spread and incompleteness of data on the size, position, recurrence, and impact of earthquakes.

– The calculation of the probabilistic assessment of seismic hazard with the use of computer software such as SEISRISK III [17], M3C [18], etc.

– Compilation of seismic zoning maps of a given scale using GIS technologies based on the results of a hazard assessment. According to the Code of Rules of the Republic of Kazakhstan 2.03-30-2017, maps should reflect the 10% and 2% probability in 50 years of a possible, which corresponds to the average time intervals of 475 and 2,475 years between earthquakes with the estimated intensity.

Upon developing seismic zoning maps, mainly stock materials are used (of Institute of Seismology, Seismological Experimental and Methodical Expedition, Committee of Geology and Mineral Protection of the Republic of Kazakhstan, and other organizations). An exception is the assessment of seismic hazard for critical facilities, such as nuclear power plants, which, according to the IAEA requirements, is carried out following the special projects with the necessary amount of field research. Generalization of data on the seismicity of regions [9,11,13,19,20] includes the following steps:

– determination of seismic parameters for different regions is based on the law of earthquake recurrence;

– quantitative assessment of seismicity is carried out by compiling maps of the spatial distribution of seismic activity, the density of earthquake epicentres, the type of seismotectonic deformation, the angle of the slope of the repeatability graph, the specific power of seismic energy sources, the thickness (power) of the seismically active layer, etc.

Development of geological and geophysical substantiation of seismotectonic models of zones of occurrence of earthquake sources (seismogenic zones) [5,9,12,14,21-23] includes the following steps:

– the structure of the consolidated foundation with the allocation of the main structural-material complexes and the most important structure-forming faults [24];

– the structure of the platform cover (if any), including material complexes, structural forms and faults [25];

– recent tectonics (Late Oligocene-Holocene), including the interpretation of the latest tectonic structures (morphostructures), the intensity of neotectonic movements, the latest active faults [12,26,27], a possible manifestation of paleoseismic dislocations [28,29].

Development of seismotectonic models of zones of occurrence of earthquake sources (seismogenic zones) [14]. Regional and local seismotectonic models are compiled:

– The regional model should cover the region within which earthquake sources and potential seismogenic structures are located, which have a seismic effect to the intensity of 5 on the MSK-64(K) scale on the mapped territory. The regional model includes showing the types of the earth's crust responsible for the position of the depths of the centres of earthquakes, and the potential seismogenic zones of the domain and/or lineament-fault types. The scale of the cartographic regional model is determined by the size of the territory within 1:5,000,000-1:2,500,000.

– The local seismotectonic model includes real and potential seismic zones within the mapped territory and is performed on the scale of the main map of seismic zoning.

Generalization of engineering and seismological data, development of macroseismic field equations and models for predicting earthquakes (attenuation models) for different regions is carried out using macroseismic materials from territories with different tectonic and geotechnical conditions [9] and instrumental observation data [6,30]:

1. When assessing impacts in intensities, the following steps are envisaged [11]: Mapping of isoseists of strong earthquakes that have a seismic effect on the investigated area. The study of the patterns of attenuation of the intensity of shaking depending on the magnitude, distance, azimuth of the wave and geological features of the environment. Determination of the parameters of earthquake sources for which instrumental data are not available (formulas are used both with one attenuation parameter and with separate consideration of the discrepancy and absorption factors). Establishment of relationships connecting the main parameters of seismic effects with the characteristics of the sources and the environment, using the available world and regional dependencies that describe the relationship between the parameters of ground vibrations and unconditionally established factors affecting them (magnitude, distance). Attenuation coefficients are determined separately for the near and far zones, with and without consideration of the size of the source, along and across geological structures [11].

2. To assess the effects in quantitative parameters with a lack of observed data in the required range of magnitudes and distances (especially in low- and mid-seismic regions), those predicted attenuation relations can be used, which are selected from the ones used in world practice based on a specially conducted study. Dependences are selected according to criteria adopted in modern world practice, and minimal sets of models for predicting earthquakes (3-5 models each) are formed for each of the established seismotectonic regimes. This approach allows to consider the uncertainties caused by the lack of data for regional models. The main criteria for preliminary selection are the reliability of the model, the

ability to predict the entire range of magnitude-distance-periods of interest, and the use of parameters applied in modern international practice. The functional form of the models should have the desired features, including saturation with magnitude, the dependence of the distance on magnitude, and members imitating the effects of inelastic damping. Models showing different trends are applied to adequately represent the uncertainties if they are sufficiently backed up by data. For different seismotectonic regimes, additional criteria for the selection of forecast models associated with the methods and features of their preparation are applied. Available regional data are used to test selected global models [6].

Establishment of seismic setting parameters. Upon GSZ, seismogenic zones with $M_{max} \geq$ 5-6, are considered, and upon DSZ, zones with $M_{max} <$ 5.0 are investigated, depending on the detail of work and the category of objects [6,9,11,13].

The following stages are envisaged:

– compilation of a unified cumulative recurrence schedule of earthquakes with consideration of their representativeness for each seismogenic zone;

– determination of the average annual rate of earthquakes and the probability of their occurrence for each magnitude interval;

– assessment of the recurrence period of historical destructive earthquakes;

– assessment of the level of seismic activity, normalized by time and area for the reference magnitude;

– determination of the average minimum and maximum depths of the hypocenter of earthquakes, including the estimated depth of the geometric centres of earthquakes with $M \geq 7.0$;

– the establishment of geometric parameters (strike azimuth, dip angle) and the type of prevailing movements;

– upon calculation of seismic effects in quantitative parameters (accelerations, spectral accelerations) with the use of world forecasting models, regime parameters are determined for the case of moment magnitude *Mw*.

Determination of seismic effects according to regional and local seismotectonic models:

– Seismic effects are calculated according to the developed regional and local seismotectonic models both in MSK-64(K) scale common and in the form of quantitative assessments of seismic vibrations.

– Upon a probabilistic assessment, the calculated intensity is shown with average repeatability at a given point [6,11,13,17,18]. A set of maps is developed both in MSK64(K) intensities and in the form of quantitative assessments of seismic vibrations, with a pr probability of exceeding of 10%, 2% over the next 50 years. SR-475 maps are used for ordinary industrial and civil construction, SR-2,475 – for the construction of critical facilities.

– If necessary, the DSZ maps highlight the places of increased probability of the occurrence of destructive (strong) earthquakes in the next 10 years according to long-term earthquake prediction methods.

Compiling of maps and explanatory note. The set of GSZ maps includes 5 maps on a scale of 1:2,500,000:

– map of seismogenic zones of the territory of Kazakhstan (seismotectonic model), differentiated by the expected maximum energy of possible earthquakes (M_{max});

– two maps describing the seismic hazard of the territory in values of geometric mean peak accelerations (in g units) of rock and rock-like ground vibrations at two levels of occurrence probability and possible excess of the seismic effect at 10% and 2% over 50-year time intervals;

– two maps describing the seismic hazard of the territory with macroseismic intensities according to the Code of Rules of the Republic of Kazakhstan 2.03-28-2004 “Scale for assessing the intensity of earthquakes MSK-64(K)” at two levels of occurrence probability and possible excess of the seismic effect: 10% and 2% for 50-year time intervals.

The set of DSZ maps includes 5 maps on a scale of 1:1,000,000:

– map of seismogenic zones of the territory (seismotectonic model), differentiated according to the expected maximum energy of possible earthquakes (M_{max});

– two maps describing the seismic hazard of the territory in values of geometric mean peak accelerations (in *g* units) of rock and rock-like ground vibrations at two levels of occurrence probability and possible excess of the seismic effect: 10% and 2% over 50-year time intervals;

– two maps describing the seismic hazard of the territory with macroseismic intensities according to the Code of Rules of the Republic of Kazakhstan 2.03-28-2004 "Scale for assessing the intensity of earthquakes MSK-64(K)" at two levels of occurrence probability and possible excess of the seismic effect: 10% and 2% for 50-year time intervals. All cartographic materials are accompanied by map symbols and explanatory text, comprehensively explaining their contents.

Review and approval procedure:

– Upon completion of work, a set of Seismic Zoning Maps (GSZ, DSZ) and an Explanatory Note to them shall be subject to review and approval by the Scientific Council of the Institute of Seismology.

– Completion Statement, submitted by the Institute of Seismology and a set of Maps (GSZ, DSZ) shall be subject to review and approval by the authorized body of the Customer (Committee of Science of the Ministry of Education and Science of the Republic of Kazakhstan).

– An edition of the Seismic Zoning Maps (GSZ, DSZ) received by the Customer shall be subject to approval by the National Scientific Council of the Republic of Kazakhstan.

– The materials are transferred to the Ministry of Industry and Infrastructure Development of the Republic of Kazakhstan (MIID RK). Organization of work on the development of technical regulations and national standards, including the formation and maintenance of a list of regulations and technical guidance documents in the field of architecture, urban planning, and construction activities constitute the main function of the Committee on Construction, Housing and Utilities of the MIIR RK (paragraphs 21, 47, 51 of the Regulation on the Republican Public Institution "Committee on Construction and Housing and Utilities" of the MIIIR RK).

– Sets of GSZ and DSZ Maps, which constitute the basis for the development of State regulations in the field of architecture, urban planning, and construction of the Code of Rules of the Republic of Kazakhstan 2.03-30-2017 [1] shall be transferred to KazNIISA (a subordinate organization of the Committee Construction and Housing and Utilities of the MIIIR RK). The Institute of Seismology, as a developer of the scientific and methodological base for the development of the Code of Rules of the Republic of Kazakhstan, provides AO KazNIISA with the necessary consultations.

Results and discussion. Seismic hazard assessment is the first link in seismic forecasting. It is understood as the determination of regional seismic-generative zones, the determination of their seismic potential and the spatiotemporal patterns of the occurrence of earthquakes in them, the establishment of possible seismic effects, both in assessing in intensities and in maximum accelerations and rates of ground vibrations. Depending on the tasks, object, and scope of the research, seismic zoning can be general (GSZ), detailed (DSZ) and micro (SMZ). The work offers methodological provisions for the implementation of diverse types of seismic zoning in Kazakhstan. The proposed provisions are based on the experience of seismic hazard assessment and seismic zoning in Kazakhstan, including national developments and the results of international projects.

A set of maps of general seismic zoning (GSZ) is a mandatory regulatory document for planning and implementing measures for earthquake-resistant construction in the Republic of Kazakhstan (RK) in accordance with the Code of Rules of the Republic of Kazakhstan "Construction in Seismic Zones" [1], approved by the Order of the Committee for Construction and Housing and Communal Services of the Ministry of Investment and Development of the Republic of Kazakhstan dated December 20, 2017. General seismic zoning – a study on assessment of seismic hazard of a vast territory – includes a set of geological-tectonic, geophysical, seismological work to identify seismic-generative zones characterizing the seismic potential, determination of the parameters of the seismic setting of these zones and assessment of the seismic effect in the mapped territory. The results of the studies are GSZ probability maps on a scale of 1:2,500,000, used in planning economic development of various regions and assessing the total costs of antiseismic activities nationwide.

Detailed seismic zoning maps (DSZ) determine the totality of expected seismic impacts in the administrative regions of the republic, as well as in the territories of design and construction of important national economic objects, carried out on a scale of 1:1,000, 000 to 1:500,000. The area sizes and scales are determined according to the purpose of the DSZ and economic feasibility. The studies include a set of works similar to GSZ, but with attention to details required for DSR. DSR maps are compiled in accordance with the methodological requirements set forth in this paper and replace, in agreement with the Committee for Construction and Housing and Utilities of the Ministry of Investment and Development of

the Republic of Kazakhstan, the standard GSZ map in the territories for which they are produced. Seismic microzoning maps (SMZ) are compiled for the territories of cities, large settlements with a population of more than 30,000 people and located in areas with seismic hazard of 6 or more assessing in intensitie on the MSK-64(K) scale [3], designed industrial, hydraulic, and other objects in order to determine (clarify) the seismic intensity in these territories according to the geotechnical conditions. Apart from the determination of the initial seismicity of the region, the construction and installation work include a set of works to study the engineering-geological, hydrogeological, and other conditions of the territory, including the seismic properties of grounds to consider their influence on seismic effects. SMZ maps are produced at a scale of 1:50,000 and larger, as agreed with the customer in accordance with the methodological requirements set forth in this paper.

Conclusions. The determination of the probability of an earthquake at a particular point in the next t years is associated with significant uncertainty. The complexity of the estimates is explained by the non-stationary nature of the seismic process, insufficiently certain methodological principles and approaches, relatively short periods of collection of representative data on both strong and weak earthquakes, and often a complete lack of information about them due to imperfection of the observing network, lack of sufficient knowledge about the impact of global as well as regional geodynamic processes in seismic setting, etc. Therefore, seismic hazard assessments made in past years sometimes turned out to be inadequate to real environmental conditions, which, along with poor-quality construction, continues to cause significant material damage to the national economy.

The scientific significance of the research lies in creation of a geological-geophysical and seismological database of experimental data that allows to understand the nature of the occurrence of seismic events. Seismic zoning with an assessment of the seismic hazard in the territories of regions, cities, and large settlements of the Republic will enable the implementation of the “Concept for reforming the regulatory framework of the construction sector of the Republic of Kazakhstan”, and government authorities and businesses to take proactive operational measures to ensure public safety, reduce socio-economic, and environmental damage. The obtained results will allow to consider the structural features of the earth's crust and its stress-strain state, to identify their connection with seismicity. The research results are a necessary part of the seismic hazard assessment of highly seismic regions of Kazakhstan. The results of the study are associated with a decrease in damages from possible catastrophic earthquakes, a decrease in negative socio-environmental and economic consequences, and will contribute to the sustainable development of the state, which fully complies with the principle of timeliness.

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ЗАМАНАУИ ӘДІСТЕМЕЛІК НЕГІЗДЕ ҚАЗАҚСТАН ТЕРРИТОРИЯСЫН СЕЙСМИКАЛЫҚ АУДАНДАСТЫРУДЫҢ ЫҚТИМАЛДЫҚ КАРТАСЫН ӘЗІРЛЕУ ЖӨНІНДЕГІ ҰСЫНЫСТАР

Аннотация. Жер сілкінісі салдарынан туындайтын өлім санын, материалдық зардап пен әлеуметтік-экономикалық құлдырауды азайту сейсмикалық қауіптің дұрыс бағалануына байланысты. Мақалада Қазақстан үшін әзірленген сейсмикалық қауіпті бағалаудың әдістемелік негізі, негізгі талаптар мен жалпы, нақты және шағын аудандау секілді түрлі ауқымдағы территорияларды сейсмикалық аудандастыру үшін қажетті жұмыстар тізімі берілген. Олар 2017 жылы нормативтік құжаттардың құрамына кірген Қазақстан территориясын жалпы сейсмикалық аудандастыру картасын және Алматы қаласының сейсмикалық шағын аудандау картасын жасаған кезде жаңа әдістемелік негізде апробацияланған. Сейсмикалық қауіпті бағалаудың жаңа әдісі «Еврокод 8: Сейсмикаға төзімді конструкцияларды жобалау» негізгі қағидаларына сай келетін, сейсмикаға төзімді жобалау мен құрылыс талаптарын ескеретін, ықтималдық болып саналатын және Қазақстандағы жалпыға ортақ MSK-64 (K) шкаласының сейсмикалық қарқыны бойынша ғана емес, топырақтың шыңдық үдеуі секілді сандық параметр бойынша да сейсмикалық қауіпті бағалауға мүмкіндік беретін әдіснамаға негізделген. Әзірленіп жатқан карталардың ауқымын ескере отырып шешуге болатын әрбір сейсмикалық аудандастыру типтерінің жалпы міндеттері анықталған.

Жер сілкінісі ошақтарының пайда болу аймақтарының үлгісі, аталмыш аймақтардың сейсмикалық жағдайлар үлгісі мен қарқындығын бағалаудың үлгісі секілді болжамның өзара байланысты үш түрлі үлгіле-

рін құруды қамтитын сейсмикалық қауіпті бағалаудың кезеңдік қағидаты қолданылады. Төртінші кезең – белгіленген уақыт аралығындағы сейсмикалық әсерді арттыру ықтималдығын талдау. Сейсмикалық әсер МСК-64 (К) сейсмикалық қарқындылық шкала балымен және топырақ сілкінісінің (шыңдық үдеу және т.б.) сандық параметрімен көрсетіледі. Қазақстан территориясы үшін белгіленген ауқымдағы сейсмикалық аудандастыру картасының пайда болу ықтималдығының екі деңгейіне (10% және 2%) және есептік қарқындылық жер сілкіністері арасындағы ұзақтығы 475 және 2475 жыл болатын, орташа алғандағы уақыт аралығына сай келетін 50 жыл уақыт аралығындағы сейсмикалық әсердің асу мүмкіндігі есептелген.

Топырақ сілемінің геотехникалық қасиеттерін зерттеудің негізгі тәсілдері – 30 метрден кем емес тереңдікке ұңғымаларды бұрғылау және топырақтың физико-физико-механикалық қасиеттерін далалық және зертханалық әдістермен зерттеу. Инженерлік-геологиялық және геофизикалық зерттеулерде бақылау нүктелерінің саны 1 км^2 ауданға 2-ден кем болмауы керек және жұмыс бағдарламасына негізделуі тиіс. Жасалатын инженерлік-геологиялық ізденістердің негізгі түрлері: геологиялық қима құрылымын зерттеу; топырақтың физико-механикалық қасиеттерін анықтау; қолайсыз геологиялық үрдістер мен құбылыстарды зерттеу.

Топырақ қасиеттерінің стратификациясы бұрғылау және геофизикалық әдістермен анықталады. Топырақты зерттеудің зертханалық және далалық әдістерінде әрбір инженерлік-геологиялық элементтің физико-механикалық (деформациялық-беріктік) және физикалық параметрлері анықталады. Қолайсыз физикалық құбылыстарға: тектоникалық үзілімнің болуы; карсттық байқалу; беткейдің орнықсыздығы; қатты сейсмикалық әсер ету кезінде топырақтың сейілуі мен шөгуі жатады. Аспаптық геофизикалық зерттеулер топырақтың сейсмикалық қасиеттері туралы мәліметтерді алу мақсатында жүргізіледі. Геотехникалық және сейсмикалық қима мәліметтері салыстырылады. Аспаптық геофизикалық зерттеулер кешеніне жер сілкіністері мен микросейсмаларды қоса алғандағы сейсмикалық және сейсмологиялық әдістер кіреді.

СМЗ-ға арналған топырақтың әрбір геотехникалық элементінің ең маңызды физико-механикалық сипаттамасына *R* сейсмикалық қатаңдығы, яғни ρ тығыздық пен *Vs* көлденең толқын жылдамдығының көбейтіндісі жатады. Әрбір геотехникалық элементтің көлденең толқын жылдамдығы қималардың қабаттарға ажырауының геотехникалық мәліметтерімен салыстырылатын сейсмикалық мәліметтерге байланысты анықталады.

Түйін сөздер: жер сілкінісінің қайталану заңы, экономикалық дамуды жоспарлау, топырақ қасиеттері, геофизикалық зерттеулер.

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РЕКОМЕНДАЦИИ ПО РАЗРАБОТКЕ ВЕРОЯТНОСТНЫХ КАРТ СЕЙСМИЧЕСКОГО РАЙОНИРОВАНИЯ ТЕРРИТОРИИ КАЗАХСТАНА НА СОВРЕМЕННОЙ МЕТОДИЧЕСКОЙ ОСНОВЕ

Аннотация. Минимизация смертей, материального ущерба и социально-экономических разрушений в результате землетрясений зависит от надежных оценок сейсмической опасности. В статье представлены методические основы оценки сейсмической опасности, разработанные для Казахстана, основные требования и перечень работ, необходимых для проведения сейсмического районирования территорий разного масштаба – общего, детального и микрорайонирования. Они апробированы при создании Карты общего сейсмического районирования территории Казахстана, которые вошли в нормативные документы в 2017 году, и Карты сейсмического микрорайонирования города Алматы на новой методологической основе. Новый подход к оценке сейсмической опасности основан на методологии, которая соответствует основным положениям Еврокода 8 «Проектирование сейсмостойких конструкций», отвечает требованиям сейсмостойкого проектирования и строительства, является вероятностным и позволяет не оценивать сейсмическую опасность только по сейсмической интенсивности по общепринятой для Казахстана шкале MSK-64 (K), но и по количественным параметрам – пиковым ускорениям грунта. Для каждого типа сейсмического районирования определены общие задачи, которые можно решить с учетом масштаба разрабатываемых карт.

Используется принцип поэтапной оценки сейсмической опасности, включающий создание трех взаимосвязанных моделей прогнозирования – модели зон возникновения очагов землетрясений, модели сейсмической обстановки этих зон и модели оценки создаваемых ими интенсивностей. Четвертый этап – анализ вероятности превышения сейсмического эффекта для заданных интервалов времени. Сейсмический эффект выражается в баллах шкалы сейсмической интенсивности МСК-64 (К) и в количественных параметрах сотрясения грунта (пиковые ускорения и т.д.). Карты сейсмического районирования заданного масштаба для территории Казахстана рассчитаны для двух уровней вероятности (10% и 2%) возникновения и возможного

превышения сейсмического воздействия на интервалах времени 50 лет, что соответствует средним временным интервалам длительностью 475 и 2475 лет между землетрясениями расчетной интенсивности.

Основными методами изучения геотехнических свойств грунтового массива являются бурение скважин на глубину не менее 30 м и исследование физико-физико-механических свойств грунтов лабораторными и полевыми методами. Количество точек наблюдения при инженерно-геологических и геофизических исследованиях должно быть не менее 2 на 1 км^2 площади и обосновывается в программе работ. Основные виды выполняемых инженерно-геологических изысканий: изучение строения геологического разреза; определение физико-механических свойств грунтов; изучение неблагоприятных геологических процессов и явлений.

Стратификация свойств грунтов определяется буровыми и геофизическими методами. В лабораторных и полевых методах изучения грунтов определяются физические и физико-механические (деформационно-прочностные) параметры каждого инженерно-геологического элемента. К неблагоприятным физическим явлениям относятся: наличие тектонических разрывов; карстовые проявления; неустойчивость склона; разжижение и оседание при сильных сейсмических воздействиях. Инструментальные геофизические исследования проводятся для получения данных о сейсмических свойствах грунтов. Сравниваются данные геотехнического и сейсмического разрезов. Комплекс инструментальных геофизических исследований включает использование сейсмических и сейсмологических методов, включая регистрацию землетрясений и микросейсм.

Важнейшей физико-механической характеристикой каждого геотехнического элемента грунта для СМЗ является сейсмическая жесткость R – произведение скорости поперечной волны Vs и плотности ρ. Скорости поперечных волн для каждого геотехнического элемента определяются по сейсмическим данным, которые сравниваются с данными геотехнического расслоения разрезов.

Ключевые слова: закон повторяемости землетрясений, планирование экономического развития, свойства грунта, геофизические исследования.

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INVESTIGATION METHOD OF THERMAL FRICTION PROCESSING OF THE ECCENTRIC CONE CRUSHER PART

Abstract. The article presents the results of the study performance of cone crushers and the existing technology restoration of their parts.

The main reasons for the failure of cone crushers are the following: failure armor of the cone and the middle part, the protective cap, parts of the upper suspension, dust seal rings, bearing rings, the eccentric of the crusher. The most time-consuming is to restore the details of the eccentric crusher. A new technology restoration worn surfaces of the eccentric part and the results of an experimental study of thermal friction treatment (TFT) after surfacing are proposed.

It is revealed that despite the high level of temperature corresponding to intensive treatment modes it is possible to achieve effective hardening. Implementation of the proposed technology allows: eliminate the undesirable effects of softening due to re-riveting and reduce the oxidized layer; increase productivity relative to mechanical cutting methods in 2÷3 times and tool life of more than 10 times; the use of affordable cheap material steel 45, 50, 60G for the manufacture of tools and perform processing at more intensive modes S =0,2-1mm / Rev; n=2000-3000 rpm. It is established that the TFO of the deposited surface part eccentric, provides wear resistance of the treated surfaces parts in 2….8 times more than the factory processing technology, while the depth of the hardened layer can be 1.5…. 2 mm.

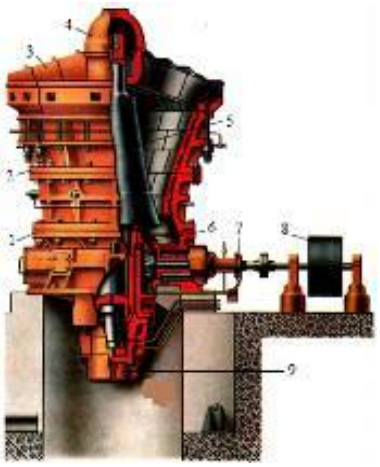
Key words: wear, surface restoration, hardness, roughness, thermal friction treatment, temperature, wear resistance.

Introduction. The mining and metallurgical industry is characterized by a high level of technical equipment, where more advanced technological schemes are used, requiring a large number of machines and devices in the production line. The development of enrichment technology occurs along the path of complication technological schemes while increasing the capacity of factories and the speed of processes. Up to 30-50 units operate in the buildings of concentrating plants with developed technological schemes in one serial chain.

A characteristic feature machines of mining and processing production is the flow of continuous technological process. All equipment is connected in a single technological chain, thus, the stop or failure of any machine that makes up this chain, leads to a stop of the entire chain. In order to prevent such emergency stops, without exception, all links of the chain, both machines and intermediate devices must meet the service life, i.e. withstand operational periods of operation.

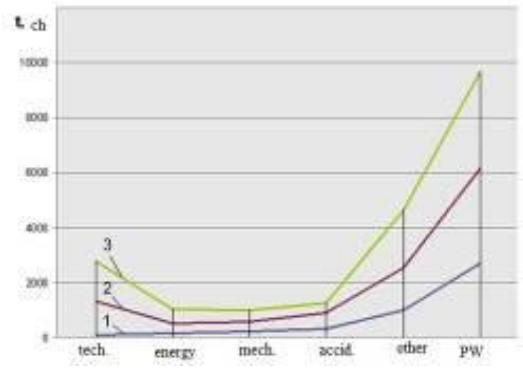
The time spent on replacement parts of concentrating machines leads to downtime technological chain of the equipment, which leads to high economic costs and inefficiency of the concentrating equipment. Machines for medium and small crushing of ores in concentrators are cone type crushers. Figure 1 shows a cone type crusher. The advantage of these crushers relatively high degree grinding of the

material, the uniform composition of the product in size, the possibility relatively wide regulation of the discharge gap.



1 - lower support; 2- upper support; 3- crusher cover; 4 - upper housing support;
5- cone; 6- lower housing support; 7- drive; 8- motor; 9- eccentric assembly support
Figure 1 – Cone type Crusher

At the concentrator Zhezkazgan (Kazakhstan) there was studied the level of technical use of cone crushers (2016-2018). Using statistical data on the operation of cone crushers at the enterprises of LLP "Kazakhmys Corporation" there were identified the causes of downtime. Figure 2 shows a graph of the causes of downtime cone crushers for 2016-2018y.



1-2016 y.; 2-2017 y.; 3-2018y.
Figure 2 – Causes of cone crusher downtime for 2016-2018

The main reasons for the failure of cone crushers are the following: failure armor of the cone and the middle part, the protective cap, parts of the upper suspension, dust seal rings, bearing rings, the eccentric of the crusher. The most time-consuming is to restore the details of the eccentric crusher. Figure 3 shows the eccentric of the crusher.

Figure 3 – Photo of the crusher eccentric

According to the research operational indicators of mining and processing machines, the intensity downtime of KMDT - 2200 units is affected by the wear of the eccentric unit, which is 85% of the total abrasive wear. It has also been established that when the wear of the eccentric reaches 4-5 mm, the actual it will reach the limit of wear, as a result, the gaps in the mates increase and this will lead to a rapid swing of the cone shaft. Therefore, in 3 days or 8 months, the eccentric will reach the limit of wear or fail. Known work of researchers [1,2,3] to increase the service life cast eccentric restoration under the repair size, which was used at the enterprises of LLP "Corporation Kazakhmys" does not provide the necessary increase in the reliability of the restored parts. Wear resistance and durability parts of mining and processing machines depend on technological heredity associated with machining [4,5]. The conducted researches have shown that the existing technology restoration of a detail the eccentric does not provide necessary physical and mechanical properties of a surface which are the main at ensuring durability details of cars in the inter-repair period [6,7,8]. One of the widespread, inexpensive and effective methods restoration of worn surfaces of details is surfacing by the mechanized arc of a powder tape [9,10]. Surfacing is carried out by applying the molten metal to the surface of the product, heated to reflow or to the temperature of reliable wetting liquid surfaced metal. As a result interaction of the molten metal with the melted (or sufficiently heated) surface of the part, metal bonds are formed between them. The thickness of the deposited metal can be different: from 0.5 to 10 mm and more [11,12].

The research of technological process restoration details of the eccentric cone crusher, made of steel 35L led to the creation new technologies restoration of worn surfaces including: restoration geometric sizes of weld eccentric outer cylindrical surface of the mechanized arc powder tape; termofikacine cutting-hardening treatment [13,14,15,16,17] the deposited surface of the eccentric. It is known that the process of traditional TFT of metals by cutting discs is a combined method using the thermal and mechanical action of the tool on the cut layer of the workpiece material [18,19,20,21]. It is carried out by direct contact of the workpiece and rotating with a high circumferential speed (up to 80 m/s) smooth or rolled on the periphery of the steel disc (HB up to 150), with a diameter of 500-600 mm and a height of 40-60 mm. The proposed method of TFT [13] which allows to control the properties of deformable metal layers due to pulse cooling, and are resource-saving. The study of the applicability of this method in the treatment of the deposited surface of the eccentric is an **urgent task**.

Methods and equipment for the study. To conduct the study, a set methods for determining the parameters characterizing the quality of the treated surface in TFT was developed. The methods used in the work are: hardness and roughness measurements. Experimental studies were carried out on a circular grinding machine model 3B151. Special friction discs were manufactured for machining. Figure 4 shows pictures of the grinding machine and friction discs.

a)

b)

a - model 3B151 circular grinding machine; *b* – special friction discs
Figure 4 – Grinding machine and friction discs

For experimental studies, special samples were prepared, made material of the eccentric part of the cone crusher. The hardness of the treated surface was determined using the MET-U1 instrument by the Vickers method. The device is automatic-determines the hardness of the surface layer. With the help of a sensor installed inside the device, the ratio speeds of strikes and rebounds striker is determined and the value of the hardness surface layer appears on the screen of the device. At the moment of impact, the carbide ball mounted on the end of the striker contacts the measured surface. Inside the bike there is a

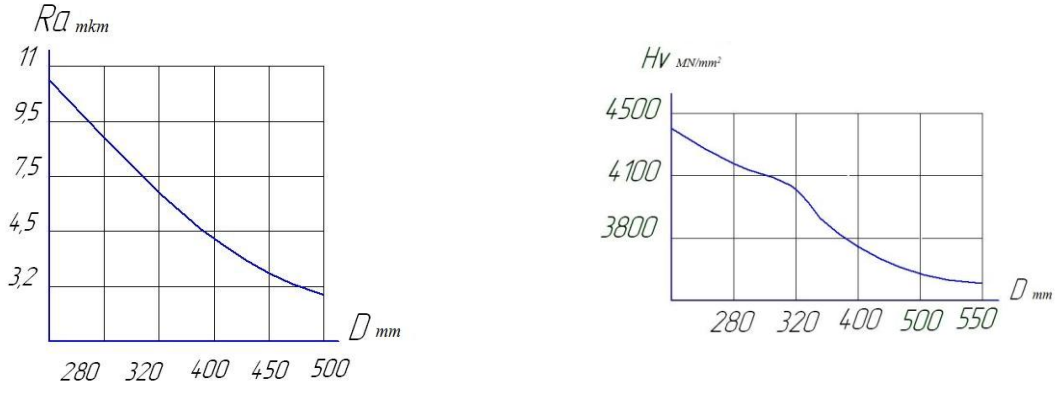
permanent magnet. The principle operation of the striker is as follows: the striker after the tension of the button (trigger) with the help of a pre-cocked spring is ejected to the measured surface. After moving inside the inductor and its magnetic field, induces an electromotive force in it. The signal from the output of the inductor is fed to the input of the electronic unit, where it is converted into the hardness value of the selected scale and displayed. The tests were carried out at room temperature, in the laboratory base of the Department "Technological equipment, mechanical engineering and standardization" of Karaganda state technical University. The duration starting the indicator was taken 15-20 seconds. The surface roughness of the treated samples was measured by the TR100 Surface Roughness Tester. The device has an electrical device with special sensors, which automatically determines the value of the standard deviation from the middle line of the profile machined surface of the part.

Experimental studies and discussion of results. Processing of blanks (samples) was performed under the following modes: spindle speed n=2000-2700 rpm; friction disc speed v=30-40 m / s; workpiece feed S = 250-280 mm / min; removable allowance t = 1-3 mm. Processed materials-Steel 35L, cutting disc-Steel 60G. Figures 5 show the TFT processes and processed workpieces.

a) *b)*

a - processing process; b - processed samples
Figure 5 – TFT Processes

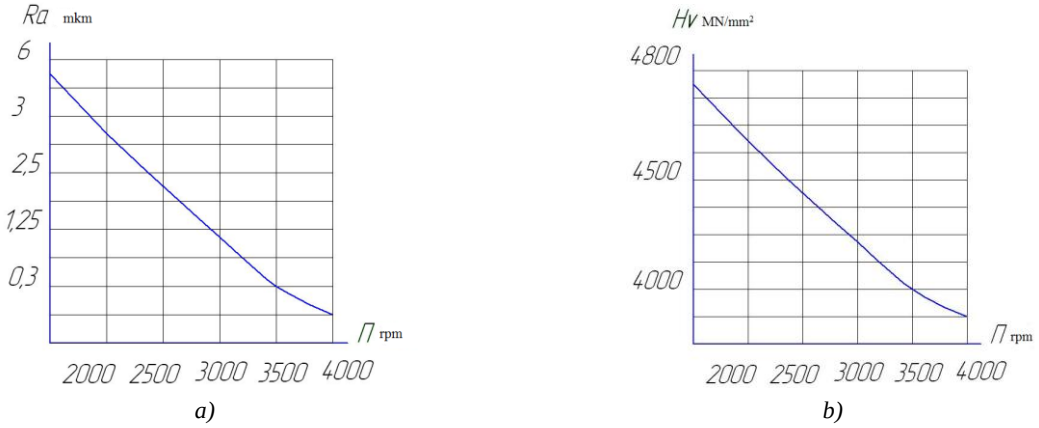
The influence of the tool geometry on the surface roughness and hardness when changing the diameter of the friction disc was investigated. Figure 6 shows graphs of experimentally obtained dependences changes in roughness and hardness when the disc diameter changes from 300 mm to 550 mm.



a) *b)*

a - the influence of the diameter of the cutting disk on the roughness; b- the effect of the diameter of the blade on hardness
Figure 6 – The effect of the diameter of the cutting disc on roughness and hardness, at S = 0.3 mm / min; n = 2500 rpm

From the graph (see figure 6 b) it follows that the increase in diameter D and > 500 mm, practically does not lead to hardening of the cutting surface. The results indicate an ambiguous effect of the friction disc size on the processes hardening of the cutting surface. The results obtained when changing the deformation zone and sliding speed due to cutting modes allow to clarify the question. Figure 7 shows the results obtained by changing the frequency rotation of the friction disk.



a - the effect of rotation speed on roughness; b - the effect of speed on hardness
Figure 7 – Influence of rotation speed on roughness and hardness, at S=0,2 mm / min; Du=380mm

Figure 8 shows the effect of feed on the hardness and roughness cutting surface. Cutting modes and tool geometry in TFT have a very noticeable effect on the strength properties of the deformed layer and the machined surface of the part. These properties, along with the geometry of the machined surface, ultimately determine the functional properties of the part when it is in contact with other parts of a particular mechanism Assembly. Therefore, the management of these properties will improve the quality of the machine as a whole. Increasing the "n" from 2000 to 3000 rpm leads to a 500-600 Mn/mm2 softening. In this case, a more noticeable softening is observed after n = 3500 rpm. Therefore, an increase in the sliding speed in the friction contact favorably affects the hardness factor.

a - the effect of feed on the roughness; *b* - the effect of feed on hardness
Figure 8 – Influence on the hardness and roughness of the cutting surface, Du=380mm; n=3500 rpm

Indeed, regardless of how the increase in linear velocity is obtained by V-increasing the rotational speed or the diameter of the friction disk will be softening. The choice of parameter for regulation V should be made taking into account their impact on quality indicators. From the experimental results it can be stated that TFT manage to get rid of the appearance perekleennogo or oxidized layer adjacent to the treated surface, in addition important is the fact that the gradient of hardness can be adjusted by changing modes. The increase in flow should lead to an increase in heat dissipation and an increase in the deformation zone $h_н$. Analysis of the results obtained by changing the feed (figure 3.20) shows an increase in hardness by 300 Mn / m2 when changing the "S" from 0.3 to 0.4 mm/min.

The results of the experimental studies have shown that TFT allows to provide the necessary roughness and hardness of the surface which are the main in ensuring the durability of machine parts in the overhaul period.

Conclusion. 1. The results of the research led to the creation of a new thermo-frictional cutting-hardening method for processing the cylindrical surface of the eccentric cone crusher part and the processing modes and the design of the tool were determined.

2. It is established that the cutting modes and tool geometry at TFT very significantly affect the strength properties of the deformed layer and the treated surface:

- the increase in flow has a positive effect to the increase in heat dissipation and the increase in the deformation zone $h_н$. When the feed is changed from 0.3 to 0.4 mm/min, the hardness increases by 300 MN/mm^2;

- with increasing speed and diameter of the tool, the quality of the cutting surface improves, i.e. the surface roughness Ra = 4,5-1,2 microns and the depth of hardening of the surface layer is 0,5-2,5 mm;

3. It is revealed that despite the high level of temperature corresponding to intensive treatment modes it is possible to achieve effective hardening.

4. Implementation of the proposed technology allows:

- eliminate the undesirable effects of softening due to re-riveting and reduce the oxidized layer;

- increase productivity relative to mechanical cutting methods in 2÷3 times and tool life of more than 10 times.

- the use of affordable cheap material steel 45, 50, 60G for the manufacture of tools and perform processing at more intensive modes *S* =0,2-1mm / Rev; *n*=2000-3000 rpm;

5. TFT offered as mechanical treatment after surfacing, provides wear resistance of the processed surfaces of details in 2...8 times more than factory technology of processing, thus depth of the strengthened layer can make 1,5...2 mm.

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КОНУС УАТҚЫШТЫҢ ЭКСЦЕНТРИК ТЕТІГІН ТЕРМОФРИКЦИЯЛЫ ӨҢДЕУ ӘДІСІН ЗЕРТТЕУ

Аннотация. Мақалада конус уатқыштардың пайдалану көрсеткішін зерттеу нәтижилері және тетіктерін қайта қалпына келтіру технологиясы келтіріледі.

Конус уатқыштарды істен шығаратын негізгі себептер мыналар: конус броны және ортаңғы бөліктің, қорғаныс қақпағының, үстіңгі ілгек тетіктерінің, шаңды тығыздағыш сақинасының, уатқыш эксцентригінің істен шығуы.

Қайта қалпына келтіру тетіктерінің еңбек шығындысы – уатқыш эксцентригі. Эксцентриктің тозуы 4-5 мм жеткенде шекті тозу шамасына жетеді, осының әсерінен жанасудағы саңылау ұлғаяды, ал ол конусты білікті шамадан тыс шайқалтады.

Яғни, 240 күнде немесе 8 айда эксцентрик шекті тозу шамасына жетеді немесе істен шығады. Жүргізілген зерттеулер эксцентрик тетігін қайта қалпына келтіру технологиясының қажетті беттік физика-механикалық қасиеттерін қамтамасыз етпейтінін көрсетті, ал бұл көрсеткіштер жөндеу аралығындағы машина тетіктерінің ұзақ мерзімділігін қамтамасыз ететін негізгі көрсеткіштердің бірі болып саналады.

35Л болаттан әзірленетін конусты уатқыш эксцентрик тетігін қайта қалпына келтіру технологиясына жүргізілген зерттеулер жанасатын тозған тетік беттерін қайта қалпына келтірудің жаңа технологиясын құруды талап етті, оның құрамына мыналар кіреді: эксцентриктің сыртқы беттерін механизацияланған ұнтақты таспамен дәнекерлеп, геометриялық өлшемдерін қайта қалпына келтіру; эксцентриктің дәнекерлеген беттерін кесу – беріктендіріп термофрикциялық өңдеу.

Зерттеулерді жүргізу үшін беттерді термофрикциялық өңдеу сапасын сипаттайтын параметрлерді анықтайтын әдістер кешені құрастырылды. Жұмыста мына әдістер қолданылды: қаттылықты және кедір-бұдырлықты өлшеу. Тәжірибелік зерттеулер 3Б151 мод. дөңгелек ажарлаушы станогында орындалды. Арнайы үйкеліспен өңдейтін диск әзірленді. Тәжірибелік зерттеулерді жүргізу үшін конус уатқыш эксцентригінің материалынан арнайы үлгілер әзірленді.

Алынған зерттеу нәтижелері кесу бетінің беріктендіру процесіне үйкеліс дискі өлшемінің әсер ететінін анықтады. Мәселені нақтылау үшін деформациялау аумағы мен кесу мәзірлерімен сырғанау жылдамдығын өзгерту қажет.

Термофрикциялық өңдеу кезінде кесу мәзірлері мен құрал геомтериясы деформацияланған қабаттың және тетіктің өңделген беттің беріктік қасиетіне әсері анықталады. Бұл қасиеттер өңделген беттің геометриясымен қатар, ақырында осы бетпен басқа тетіктердің жанасау кезінде оның функционалды қасиеттерін анықтайды. Сондықтан, бұл қасиеттерді басқару тұтас машинаның функционалды қасиеттерін жақсартады.

Тәжірибе нәтижелері бойынша келесі нақтыланды: ТФӨ кезінде күйген немесе қышқылданған қабаттан құтылуға болады, сондай-ақ, қаттылық шегі мәзірді өзгерту арқылы реттеуге болады.

Берілісті жоғарылату жылудың бөлінісін көбейтуге және деформациялану аумағынының hн ұлғаюына әкеледі. Берілісті өзгерту кезінде алынған нәтижелерді сараптағанда берілісті «S» 0,3 тан 0,4 мм/мин дейін өзгерткенде қаттылықтың 300 Мн/мм^2 дейін жоғарылайтынын көрсетті.

Қарқынды мәзірге сәйкес жоғары температураға қарамастан жеткілікті беріктендіруге қол жеткізуге болатыны айқындалды.

Эксцентрик тетігінің балқытылған беттерін ТФӨ оның зауыттық өңдеу технологиясымен салыстырғанда өңделген беттердің тозуға төзімділігін 2...8 есе жоғары қамтамасыз ететіні анықталды, беріктендіру қабаты 1,5...2 мм құрайды.

Ұсынылған технологияны жүзеге асыру келесі сипатталғанға қол жеткізеді: қайта күю әсерінен қажетсіз қайта беріктендіру құбылысын болдырмау және қышқылданған қабатты азайту; механикалық кесу әдісімен өнімділікті салыстырмалы 2÷3 есе жоғарылату және құралдың шыдамдылығын 10 есе арттыру; құралды әзірлеу үшін қолжетімді арзан 45, 50, 65Г болат маркаларын қолдану және *S* =0,2-1мм/об ; *n*=2000-3000 об/мин мәзірлерімен өңдеу.

Дәнекерлеуден кейін механикалық кесудің орынына жүргізілетін ТФӨ өңделген беттердің тозуға төзімділігін 2...8 есе 2...8 есе жоғары қамтамасыз ететіні анықталды, беріктендіру қабаты 1,5...2 мм.

Жүргізілген тәжірибелік зерттеу нәтижелері ТФӨ-дің қажетті кедір-бұдырлықты және қаттылықты қамтамасыз ететін көрсетті.

Түйін сөздер: тозу, беттерді қайта қалпына келтіру, қаттылық, кедір-бұдырлық, термофрикциялық өңдеу, температура, тозуға төзімділік.

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ИССЛЕДОВАНИЕ СПОСОБА ТЕРМОФРИКЦИОННОЙ ОБРАБОТКИ ДЕТАЛИ ЭКСЦЕНТРИКА КОНУСНОЙ ДРОБИЛКИ

Аннотация. В статье приводятся результаты исследования эксплуатационных показателей конусных дробилок и существующей технологии восстановления их деталей.

Основными причинами отказа конусных дробилок являются следующие: выход из строя брони конуса и средней части, защитного колпака, деталей верхнего подвеса, колец пылевого уплотнения, колец подпятника, эксцентрика дробилки. Самым трудоемким является восстановление детали эксцентрика дробилки. Установлена, что когда износ эксцентрика достигает 4-5 мм, фактически он достигнет предельного износа, вследствие этого увеличиваются зазоры в сопряжениях, а это приведет к быстрому качанию конусного вала. Следовательно, за 240 дня или 8 месяцев эксцентрик достигнет предельного износа или выйдет из строя. Проведенные исследования показали, что существующая технология восстановления детали эксцентрик не обеспечивает необходимые физико-механические свойства поверхности, которые являются основными при обеспечении долговечности деталей машин в межремонтный период.

Выполненное исследование технологического процесса восстановления детали эксцентрика конусной дробилки, изготовляемый из стали 35Л, привело к созданию новой технологии восстановления изношенных поверхностей сопрягаемых деталей включающий: восстановление геометрических размеров эксцентрика наплавкой наружной цилиндрической поверхности механизированной дугой порошковой ленты; термофрикционная режуще-упрочняющая обработка наплавленной поверхности эксцентрика.

Для проведения исследования был разработан комплекс методик определения параметров, характеризующих качество обработанной поверхности при ТФО. В работе использованы методы: измерение твердости и шероховатости. Экспериментальные исследования выполнялись на круглошлифовальном станке модели 3Б151. Были изготовлены специальные диски трения для обработки. Для проведения экспериментальных

исследований были подготовлены специальные образцы, изготовленные из материала детали эксцентрика конусной дробилки.

Полученные результаты указывают на неоднозначное влияние размеров диска трения на процессы упрочнения поверхности резания. Уточнить вопрос позволяют результаты, полученные при изменении зоны деформации и скорости скольжения за счет режимов резания.

Режимы резания и геометрия инструмента при ТФО весьма заметно влияют на прочностные свойства деформированного слоя и обработанной поверхности детали. Эти свойства, наряду с геометрией обработанной поверхности, определяют, в конечном счете, функциональные свойства детали при контактировании по этой поверхности с другими деталями конкретного узла механизма. Следовательно, управление этими свойствами позволит улучшить качественные показатели машины в целом.

По результатам экспериментов можно констатировать, что при ТФО удаётся избавиться от появления перенаклепанного или окисленного слоя прилежащего к обработанной поверхности, кроме этого немаловажным является тот факт, что градиент твердости может регулироваться за счет изменения режимов.

Увеличение подачи должно привести к росту тепловыделения и увеличению зоны деформации hн. Анализ результатов, полученных при изменении подачи, показывает на увеличение твердости на 300 Мн/мм2 при изменении «S» с 0,3 до 0,4 мм/мин.

Выявлено, что несмотря на высокий уровень температуры, соответствующий интенсивным режимам обработки, можно добиться эффективного упрочнения.

Реализация предложенной технологии позволяет: исключить нежелательные явления разупрочнения вследствие перенаклепа и уменьшить окисленный слой; увеличить производительность относительно механических способов резания в 2÷3 раз и стойкость инструмента в более 10 раз; применение доступного дешевого материала – сталь 45, 50, 60Г для изготовления инструмента и выполнить обработку на более интенсивных режимах S =0,2-1мм/об ; n=2000-3000 об/мин.

ТФО, предлагаемая в качестве механической обработки после наплавки, обеспечивает износостойкость обработанных поверхностей деталей в 2…8 раз больше, чем при технологии заводской обработки, при этом глубина упрочненного слоя может составлять 1,5…2 мм.

Результаты выполненных экспериментальных исследований показали, что ТФО позволяет обеспечить необходимую шероховатость и твердость поверхности, которые являются основными условиями обеспечения долговечности деталей машин в межремонтный период.

Ключевые слова: износ, восстановление поверхности, твердость, шероховатость, термофрикционная обработка, температура, износостойкость.

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MODELING OF HEREDITARY MATERIALS RELAXATION BY ABEL KERNEL

Abstract. The present work is devoted to mathematical modeling of the process of the hereditary materials relaxation. Nonlinear integral equation of a hereditary type is proposed. The Abel kernel with two unknown parameters is adopted as the kernel of the integral equation: $\alpha \in (0,1), \delta > 0$. Two new characteristics were introduced: 1) experimental rheological parameter of relaxation; 2) calculated (model) rheological parameter of relaxation. Using the least squares method, expressions are obtained to determine unknown parameters of the Abel kernel. A mathematical expression is given to approximate the process of the hereditary materials relaxation.

Using examples of rheonomic materials different in structure (polyurethane matrix, propellant, polyoxymethylene, fiberglass), it is shown that the proposed methods allow to determine Abel kernel parameters with a high accuracy and to model the process of relaxation of rheonomic materials different in structure during a long period of time: from 10^2 to $1.8 \cdot 10^6$ seconds (500 hours).

Key words: Abel kernel, relaxation, polyurethane matrix, propellant, polyoxymethylene, fiberglass.

1. Introduction. Almost all natural and artificial materials are viscoelastic ones: they deform in time under the action of load. And the reaction of many materials to external actions depends on the history of loading, i.e. these materials are hereditary [1-4]. Creep and relaxation are important characteristics of hereditary materials. The creep has been studied for an asphalt concrete and other materials in the works [5-13]. The present work is devoted to the modeling of the process for relaxation of a number of hereditary materials.

2. Methods and materials. The methods of the theory of viscoelasticity have been used for a mathematical description of the process for the rheonomic materials relaxation: the Boltzmann-Volterra integral equation with the Abel kernel; the expressions based on the least squares method are obtained to determine the parameters of the Abel kernel.

A new method for description of the process of the rheonomic materials relaxation is proposed with the introduction of new characteristics - the so-called experimental and calculated (model) rheological parameters of relaxation.

For the mathematical description of the relaxation process, the following materials were selected by the proposed method: 1) a polyurethane matrix containing salt crystals and aluminum powder (polyurethane matrix) [1]; 2) solid fuel of rocket engines (propellant) [14]; 3) polyoxymethylene [15] and 4) fiberglass TC 8/3-250 (fiberglass) [16].

3. Theoretical bases

3.1. Integral equation and relaxation kernel. The equation for the nonlinear hereditary type of a rheonomic material we will write in the following integral form

$$\sigma(t,T) = f[\varepsilon(t),T] - \int_0^t R(t-\tau) f[\varepsilon(\tau),T] d\tau, \quad (1)$$

where T is a temperature, $T = const$; $f[\varepsilon(t),T]$ is a nonlinear function of time at $T = const$; $\varepsilon(t), \varepsilon(\tau)$ is a deformation at time moments t and τ; $R(t-\tau)$ is a relaxation kernel.

At $\varepsilon(t) = const$ from the equation (1) we have:

$$\sigma(t,T) = f(\varepsilon,T) \cdot \left[1 - \int_0^t R(t-\tau)\, d\tau\right], \quad (2)$$

where $f(\varepsilon,T) = \sigma_0(\varepsilon,T)$ is an instantaneous deformation curve.

We take relaxation kernel in the form of the following functions:

$$R(t-\tau) = \delta(t-\tau)^{-\alpha}, \alpha \in (0,1);\ \delta > 0. \quad (3)$$

where α, δ are parameters of the relaxation kernel.

Inserting the function (3) into the equation (2) we will have:

$$\sigma(t,T) = \sigma_0(\varepsilon,T) \cdot \left[1 - \frac{\delta}{1-\alpha} t^{(1-\alpha)}\right]. \quad (4)$$

In the expression (4): $\alpha = \alpha(T), \delta = \delta(T)$.

3.2. Relaxation kernel parameters. Relaxation equation (4) includes three unknown parameters: $\sigma_0(\varepsilon,T)$, α and δ. It contains a function with the parameters α and δ:

$$L(t) = \frac{\delta}{1-\alpha} t^{(1-\alpha)} \quad (5)$$

The singular parameter takes a value in the interval (0, 1). The works [5-8] suggest the parameter α to consider as the specified one, and the remaining two other parameters to determine using the least squares method. In the work [9] the above method has been improved: the determining ratios have been changed by introducing the so-called experimental rheological parameter.

In accordance with the work [9] we introduce the parameter determined by the formula:

$$r_e(t,T) = \frac{\sigma_e(t,T)}{\sigma_0^e(\varepsilon,T)}, \quad (6)$$

where $\sigma_e(t,T)$ is a stress value at a time moment t at a temperature T determined experimentally; $\sigma_0^e(\varepsilon,T)$ is a stress value at a time moment t_0 at a temperature T determined also experimentally.

We shall call $r_e(t,T)$ as an experimental rheological relaxation parameter.

Similar to the parameter $r_e(t,T)$ we shall introduce the calculated (model) rheological relaxation parameter $r_m(t,T)$ determined under the formula:

$$r_m(t,T) = \frac{\sigma_m(t,T)}{\sigma_0^m(\varepsilon,T)}, \quad (7)$$

where $\sigma_m(t,T)$ is a stress value at a time moment t at a temperature T, determined by the calculations; $\sigma_0^m(\varepsilon,T)$ is a stress value at a time moment t_0 at a temperature T, determined also by the calculations.

According to the least squares method the parameters values $\sigma_0^m(\varepsilon,T)$ and $\delta = \delta(T)$ should satisfy the following condition:

$$S[\sigma_0^m(\varepsilon,T), \delta(T)] = \sum_{i=1}^{M} \left[\sigma_0^m(\varepsilon,T) \cdot \left(1 - \frac{\delta}{1-\alpha} t_i^{(1-\alpha)} - \sigma_{ei}\right)^2\right] \to \min, \quad (8)$$

where $S[\sigma_0^m(\varepsilon,T), \delta(T)]$ is a sum of squared deviations; σ_{ei} is a stress value at a time moment t_i determined experimentally;

M total number of the considered time moments.

From the following partial derivatives $\frac{\partial S[\sigma_0^m(\varepsilon,T),\delta(T)]}{\partial \sigma_0^m(\varepsilon,T)} = 0$ and $\frac{\partial S[\sigma_0^m(\varepsilon,T),\delta(T)]}{\partial \delta(T)} = 0$ we will obtain the expressions for the determination of the parameters $\sigma_0^m(\varepsilon,T)$ and $\delta(T)$:

$$1 = \frac{\sum_{i=1}^{M} r_{ei} \sum_{i=1}^{M} t_i^{2(1-\alpha)} - \sum_{i=1}^{M} t_i^{(1-\alpha)} \sum_{i=1}^{M} r_{ei} t_i^{(1-\alpha)}}{M \sum_{i=1}^{M} t_i^{2(1-\alpha)} - \left[\sum_{i=1}^{M} t_i^{(1-\alpha)}\right]^2}, \quad (9)$$

$$\delta(T) = \frac{\sum_{i=1}^{M} (1 - r_{ei}) t_i^{(1-\alpha)}}{\frac{1}{1-\alpha} \sum_{i=1}^{M} t_i^{2(1-\alpha)}}, \quad (10)$$

where $r_{ei} = r_e(t = t_i, T)$.

In the expression (9) it is accepted that

$$\sigma_0^m(\varepsilon,T) \approx \sigma_0^e(\varepsilon,T). \quad (11)$$

3.3. Approximating expression. After determination of the parameters α and δ the so-called coefficients of the similarity are calculated under the expression:

$$r_m(t_S,T) = 1 - \frac{\delta}{1-\alpha} t_S^{(1-\alpha)}, \quad (12)$$

where $t_S \in [0, t_M]$.

Taking into account (12) we will determine the value $\overline{\sigma_0}(\varepsilon,T)$:

$$\overline{\sigma_0}(\varepsilon,T) = \frac{1}{M} \sum_{S=1}^{M} \frac{\sigma_e(t_S,T)}{r_m(t_S,T)}.$$

Approximating analytical expression for the process of the rheonomic materials relaxation has the following form:

$$\sigma_m(t,T) = \overline{\sigma_0}(\varepsilon,T) \cdot \left(1 - \frac{\delta}{1-\alpha} t^{(1-\alpha)}\right). \quad (13)$$

4. Results and discussion. The relaxation function of the polyurethane matrix is determined by the pure shear experiment under dynamic loading conditions at the temperature of 26.1 ºC [1]. The work [14] also determines the function of the propellant relaxation at pure shear under conditions of dynamic loading. The functions of polyoxymethylene relaxation at tension at the temperature of 20 ºC are determined at two values of conditionally instantaneous deformation: 2% and 10% [15]. The relaxation functions of fiberglass cut at an angle of 45% to the fabric base at tension at the temperature of 23.5 ºC are determined at three values of conditionally instantaneous deformation: 0.31%, 0.7% and 1.55% [16].

Experimental and calculated values of relaxation stresses of the materials under consideration are presented in figures 1-4. As can be seen, the degree of coincidence between the calculated and experimental stress values is high.

Thus, the obtained results have shown that the suggested methods make it possible to determine Abel kernel parameters with high accuracy and simulate the process of relaxation of rheonomic materials different in structure during a long process of time (from 100 seconds to 500 hours).

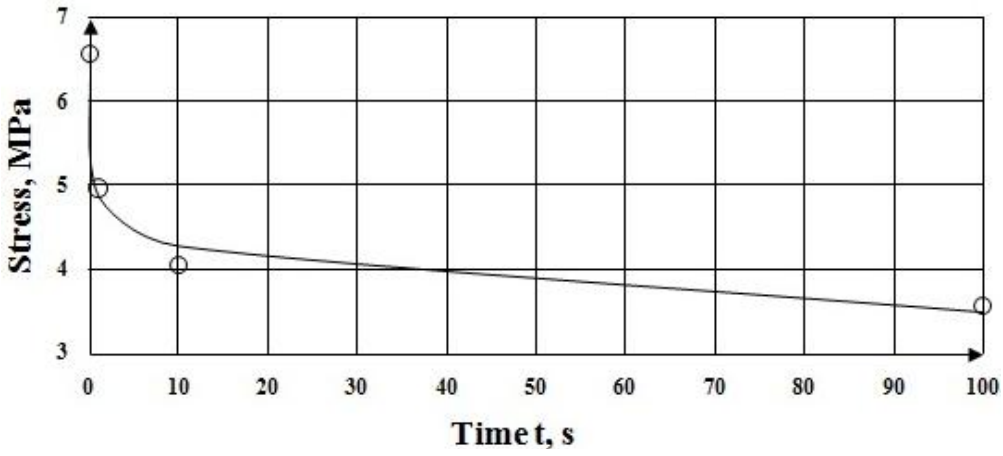

Figure 1 – Polyurethane matrix relaxation curve at the temperature of 26.1 ºC: ○ – experiment, ▬ – calculation

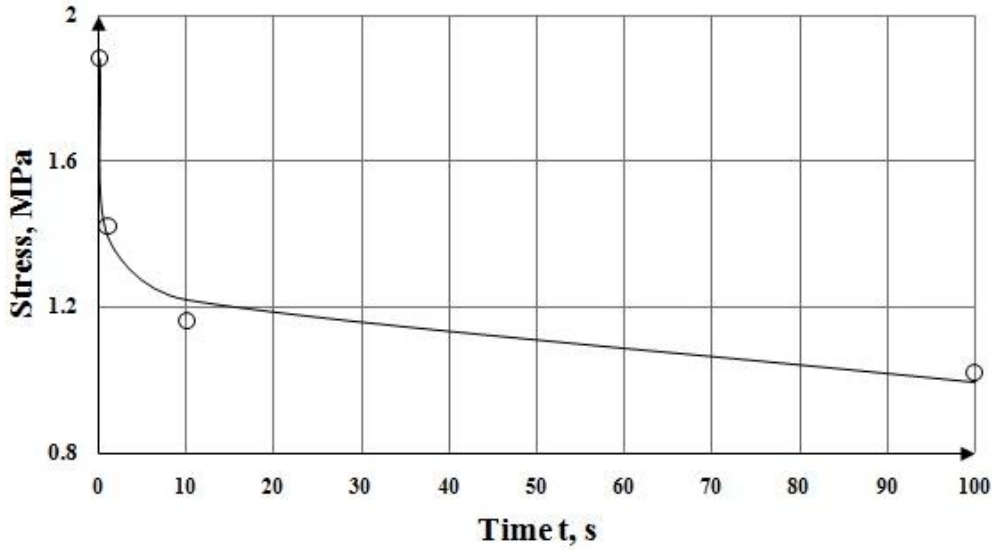

Figure 2 – Propellant relaxation curve: ○ – experiment, ▬ – calculation

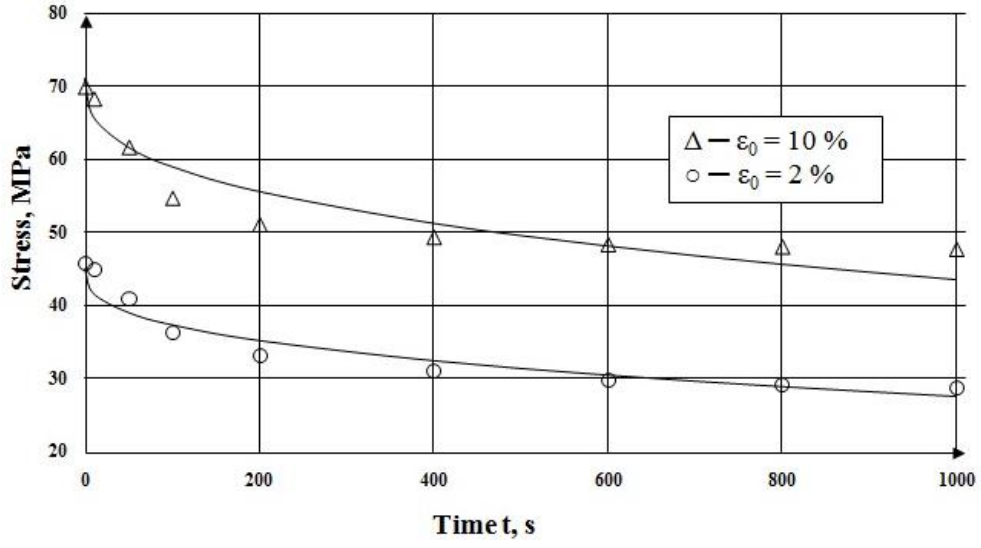

Figure 3 – Polyoxymethylene relaxation curve at the temperature of 20 ºC: ○ – experiment, ▬ – calculation

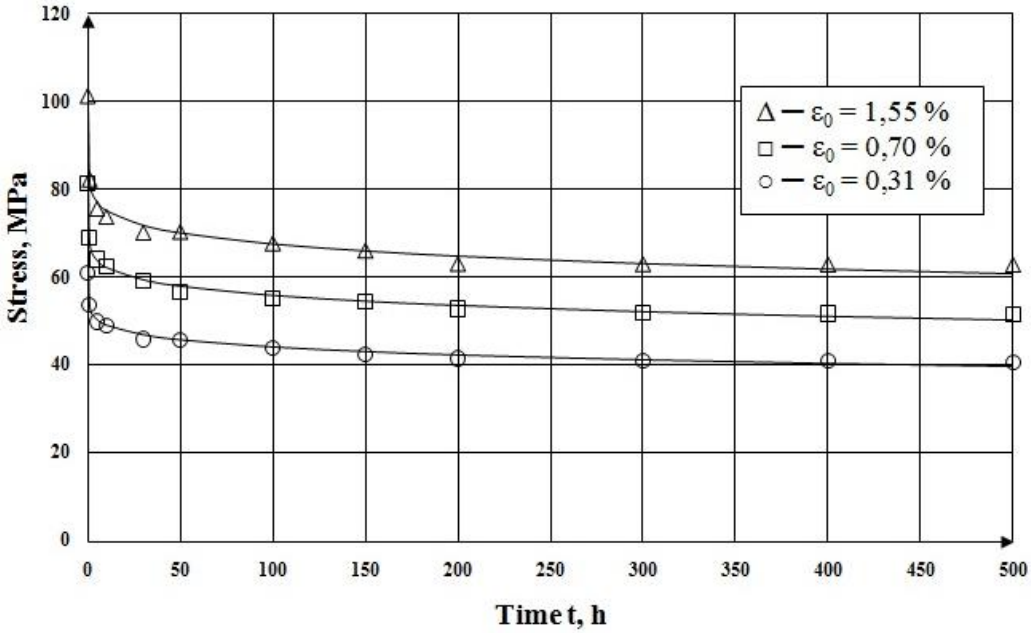

Figure 4 – Fiberglass relaxation curve at the temperature of 23.5 ºC: ○ – experiment, ▬ – calculation

Conclusion. 1. The method has been proposed for the mathematical description of the process for the rheonomic materials relaxation with introduction of the new parameters: experimental and calculated (model) rheological parameters of relaxation.

2. The Abel kernel has been accepted in the integral equation in the mathematical description of the process of the rheonomic materials relaxation.

3. The expressions for determining parameters α and $\delta$of the Abel kernel have been obtained based on the least squares method.

4. Using the examples of the rheonomic materials different in structure (polyurethane matrix, propellant, polyoxymethylene, fiberglass), it is shown that the proposed methods allow determining Abel kernel parameters with high accuracy and modeling the process of the rheonomic materials relaxation different in structure during a long period of time: from 10^2 to $1.8 \cdot 10^2$ seconds (500 hours).

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АБЕЛЬ ЯДРОСЫ АРҚЫЛЫ МҰРАЛЫҚ МАТЕРИАЛДАР РЕЛАКСАЦИЯСЫН МОДЕЛЬДЕУ

Аннотация. Жұмыс мұралық материалдардың релаксация үдерісін математикалық модельдеуге арналған. Мұралық типтегі сызықтық емес интегралдық теңдеу ұсынылады. Интегралдық теңдеудің ядросы ретінде екі белгісіз: $\alpha \in (0,1), \delta > 0$ параметрлері бар Абель ядросы қабылданды. Келесідей екі жаңа сипаттама енгізілді: 1) релаксацияның эксперименттік реологиялық параметрі; 2) релаксацияның есептік (модельдік) реологиялық параметрі. Ең кіші квадраттар әдісі негізінде релаксация теңдеуінің белгісіз параметрлерін анықтауға арналған өрнектер алынды. Мұралық материалдардың релаксация үдерісін сипаттауға арналған математикалық өрнек берілді.

Құрылымы әртүрлі реономды материалдар (полиуретанды матрица, зымыран жанармайы, полиоксиметилен, шыны талшық) негізінде ұсынылған әдістер Абель ядросының параметрлерін жоғары дәлдікпен анықтауға және құрылымы әртүрлі реономды материалдардың релаксация үдерісін ұзақ уақыт бойы модельдеуге мүмкіндік беретіні көрсетілген: 10^2 секундтан $1{,}8\cdot10^6$ секундқа дейін (500 сағат).

Түйін сөздер: Абель ядросы, релаксация, полиуретанды матрица, зымыран жанармайы, полиоксиметилен, шыны пластик.

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МОДЕЛИРОВАНИЕ РЕЛАКСАЦИИ НАСЛЕДСТВЕННЫХ МАТЕРИАЛОВ ЯДРОМ АБЕЛЯ

Аннотация. Настоящая работа посвящена математическому моделированию процесса релаксации наследственных материалов. Предложено нелинейное интегральное уравнение наследственного типа. В качестве ядра интегрального уравнения принято ядро Абеля с двумя неизвестными параметрами: $\alpha \in (0,1), \delta > 0$. Введены две новые характеристики: 1) экспериментальный реологический параметр релаксации; 2) расчетный (модельный) реологический параметр релаксации. Используя метод наименьших квадратов, получены выражения для определения неизвестных параметров ядра Абеля. Дано математическое выражение для аппроксимации процесса релаксации наследственных материалов.

На примерах разных по структуре реономных материалов (полиуретановая матрица, ракетное топливо, полиоксиметилен, стеклопластик) показано, что предложенные методы позволяют с высокой точностью определять параметры ядра Абеля и моделировать процесс релаксации разных по структуре реономных материалов в течение длительного периода времени: от 10^2 до $1{,}8\cdot10^6$ секунд (500 часов).

Ключевые слова: ядро Абеля, релаксация, полиуретановая матрица, ракетное топливо, полиоксиметилен, стеклопластик.

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COMPARATIVE ANALYSIS OF LOW TEMPERATURE STRENGTH OF MODIFIED ASPHALT CONCRETES

Abstract. A comparative analysis has been performed in this work for low temperature strength of 31 types of the conventional (non-modified) and modified road asphalt concretes. The neat bitumens of the grades BND 70/100, BND 100/130 and BND 130/200 have been produced by the Pavlodar petrochemical plant from the crude oil of the Western Siberia (Russia) by the method of direct oxidation and they satisfy the requirements of the standard ST RK 1373-2013. The polymers Elvaloy 4170, Elvaloy AM, Kraton, Calprene 501, Butonal NS, SBS (L 30-01 A), KUMHO KTP and crumb rubber have been used for the modification of the bitumens. The modification of the bitumens has been performed in the laboratory of Kazakhstan Highway Research Institute. The modified bitumens satisfy the requirements of the standard ST RK 2534-2015. The conventional and modified asphalt concretes satisfy the requirements of the standards ST RK 1225-2019, ST RK 1223-2019, ST RK 2028-2010, ST RK 2373-2019 and GOST 31015-2002.

The strength of the asphalt concretes at uniaxial direct tension at a constant strain rate of 1 mm/min at the temperatures of -10 °C, -20 °C and -30 °C determined in the device TRAVIS under the standard EN 2697-46 has been accepted as a characteristic of their low temperature strength.

It is found out that various modifiers affect the asphalt concrete strength in different ways: a degree of impact depends both on a type of an asphalt concrete and a modifier, as well as on a negative temperature value. Some modifiers increase, and some of them decrease the strength of the asphalt concretes at low temperatures compared with the original asphalt concretes. Among the modifiers the polymer Elvaloy AM has been found to be the most efficient at low temperatures. The asphalt concretes of type B with the bitumens of grades BND БНД 100/130 and BND 130/200 at modification by the polymer Elvaloy AM had the biggest strength at all the considered low temperatures: at -10 ºC – 6.79 MPa and 6.43 MPa; at -20 ºC – 7.57 MPa and 7.87 MPa; at -30 ºC – 7.35 MPa and 8.86 MPa. The stone mastic asphalt concretes 15 and 20 with the polymers and without them at all the considered low temperatures practically had the strength not higher than the basic asphalt concretes of type B with neat (original) bitumens of grades BND 100/130 and BND 130/200.

Key words: bitumens, polymers, low temperatures, strength.

Introduction. An asphalt concrete as one of main road materials is widely used in the world. One of important characteristics of an asphalt concrete is its low temperature strength. In road practice and science, it is accepted that an asphalt concrete must have a low temperature strength not less than the required value defined in accordance with climatic conditions of a road location.

In present several (direct and indirect) methods for experimental evaluation of low temperature characteristics of road asphalt concretes are known [1]. In our opinion the direct methods provide a higher accuracy of the evaluations.

This paper is a continuation of the series of works of the authors devoted to the investigation and the comparative analysis of the characteristics of road bitumens and asphalt concretes [2-21]. In this paper a comparative analysis of low temperature strength of conventional and modified asphalt concretes is carried out.

Materials and methods. In present paper neat road bitumens of three grades (BND 70/100, BND 100/130, BND 130/200) were used for preparation of 31 kinds of conventional and modified asphalt

concretes. The conventional (non-modified) bitumens were produced by the Pavlodar petrochemical plant and were used for preparation of the conventional asphalt concretes. Polymer modified bitumens were used for preparation of the modified asphalt concretes. The neat and modified bitumens satisfy requirements of the Kazakhstan standards ST RK 1373-2013 and ST RK 2534-2015 respectively. The conventional and modified asphalt concretes satisfy requirements of the standards ST RK 1225-2019, ST RK 1223-2019, ST RK 2028-2010, ST RK 2373-2019 and GOST 31015-2002. Modification of the bitumens by polymers (Elvaloy 4170, Elvaloy AM, Kraton, Calprene 501, Butonal NS 198, SBS (L 30-01 A), KUMHO KTP) and a crumb rubber, preparation of the conventional and modified asphalt concretes has been performed in a laboratory of Kazakhstan Highway Research Institute. More detailed information about modification of the bitumens can be found in works [19, 22]. Information about types of the tested asphalt concretes, kinds and content of the modifiers is given in table.

Strength of the asphalt concretes at direct tension (constant deformation rate:1 mm/min) has been evaluated in the device TRAVIS at temperatures -10 ºC, -20 ºC and -30 ºC under the standard EN 12697-46.

Data about the tested asphalt concretes

№	Bitumen grade	Kind and type of asphalt concrete	Modifier, %	Short designation
1	BND 70/100	Type B	–	PNHZ_70-100_B
2	BND 100/130	Type B	–	PNHZ_100-130_B
3	BND 100/130	Type B	Elvaloy 4170-1.4	PNHZ_100-130_B+Elvaloy1
4	BND 100/130	Type B	Elvaloy AM-2.0	PNHZ_100-130_B +Elvaloy2
5	BND 100/130	Type B	Kraton-4.0	PNHZ_100-130_B +Kraton
6	BND 100/130	Type B	Calprene 501-4.0	PNHZ_100-130_B +Calprene
7	BND 100/130	Type B	Butonal NS 198-3.0	PNHZ_100-130_B +Butonal
8	BND 100/130	Type B	SBS (L 30-01 A)- 3.0	PNHZ_100-130_B +SBS
9	BND 100/130	Type B	KUMHO KTP-3.0	PNHZ_100-130_B +KUMHO3
10	BND 100/130	Type B	KUMHO KTP-6.0	PNHZ_100-130_B +KUMHO6
11	BND 100/130	Type B	Crumb rubber-15	PNHZ_100-130_B +PK15
12	BND 130/200	Type B	Elvaloy 4170-1.7	PNHZ_130-200_B +Elvaloy 1
13	BND 130/200	Type B	Elvaloy AM-2.2	PNHZ_130-200_B +Elvaloy 2
14	BND 130/200	Type B	Kraton-6.0	PNHZ_130-200_B +Kraton
15	BND 130/200	Type B	Calprene 501-6.0	PNHZ_130-200_B +Calprene
16	BND 130/200	Type B	Butonal NS 198-3.5	PNHZ_130-200_B +Butonal
17	BND 130/200	Type B	SBS (L 30-01 A)- 4.0	PNHZ_130-200_B +SBS
18	BND 100/130	Type A	–	PNHZ_100-130_A
19	BND 130/200	Type A	Elvaloy 4170-1.6	PNHZ_130-200_A +Elvaloy 1
20	BND 130/200	Type A	Elvaloy AM-2.2	PNHZ_ 130-200_A +Elvaloy 2
21	BND 130/200	Type A	Kraton-4.0	PNHZ_130-200_A+Kraton
22	BND 130/200	Type A	Calprene 501-5.0	PNHZ_130-200_A+Calprene
23	BND 130/200	Type A	Butonal NS 198-3.5	PNHZ_130-200_A +Butonal
24	BND 130/200	Type A	SBS (L 30-01 A)- 4.0	PNHZ_130-200_A +SBS
25	BND 100/130	SMA-15	–	PNHZ_100-130_SMA15
26	BND 100/130	SMA-20	–	PNHZ_100-130_SMA20
27	BND 130/200	SMA-20	Elvaloy 4170-1.7	PNHZ_130-200_SMA20+Elvaloy 1
28	BND 130/200	SMA-20	Calprene 501-5.0	PNHZ_130-200_SMA20+Calprene
29	BND 130/200	SMA-20	SBS (L 30-01 A)-5.0	PNHZ_130-200_SMA20+SBS
30	BND 130/200	SMA-20	Butonal NS 198-3.5	PNHZ_130-200_SMA20+Butonal
31	BND 130/200	SMA-20	Kraton-5.0	PNHZ_130-200_SMA20+Kraton

Results and discussion. Strength values of the considered asphalt concretes at tension at temperatures -10 ºC, -20 ºC and -30 ºC are shown in figures 1-3. The analysis of the obtained results shows that different modifiers affect the asphalt concretes strength in different ways: it is found out that the degree of impact depends both on an asphalt concrete type and a modifier, as well as on a negative temperature value.

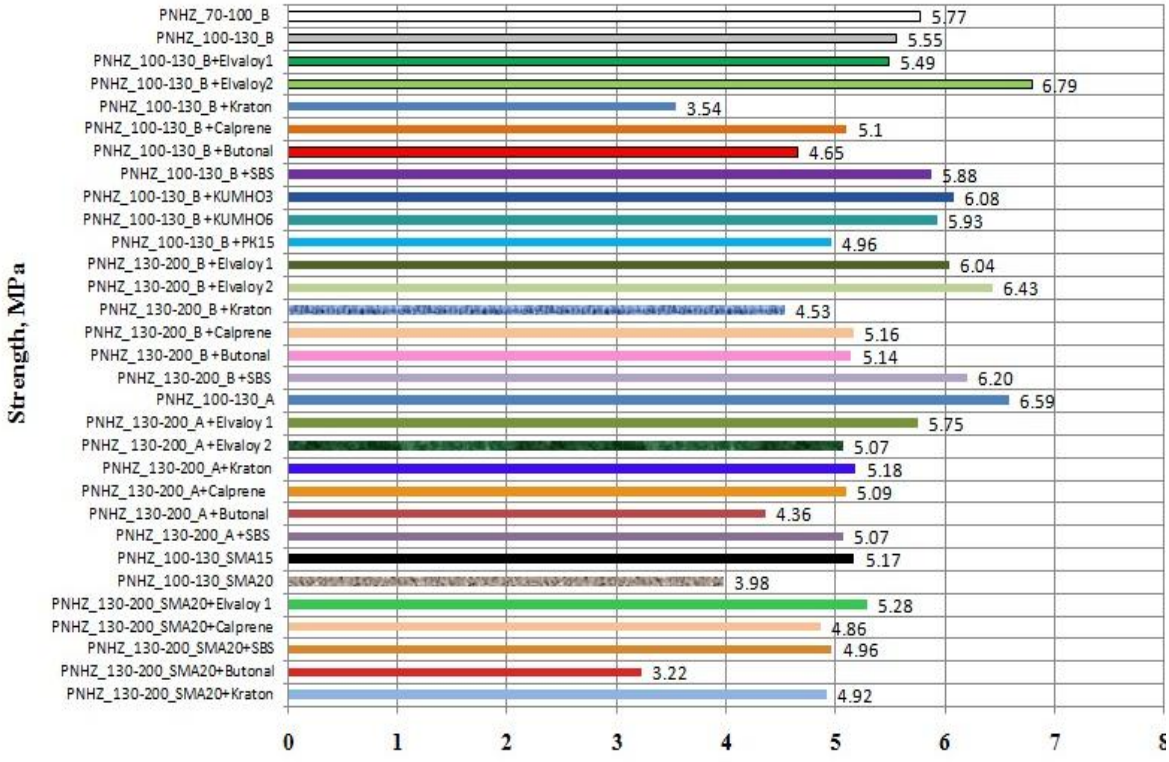

Figure 1 – Strength of the asphalt concretes at tension at temperature -10 ºC

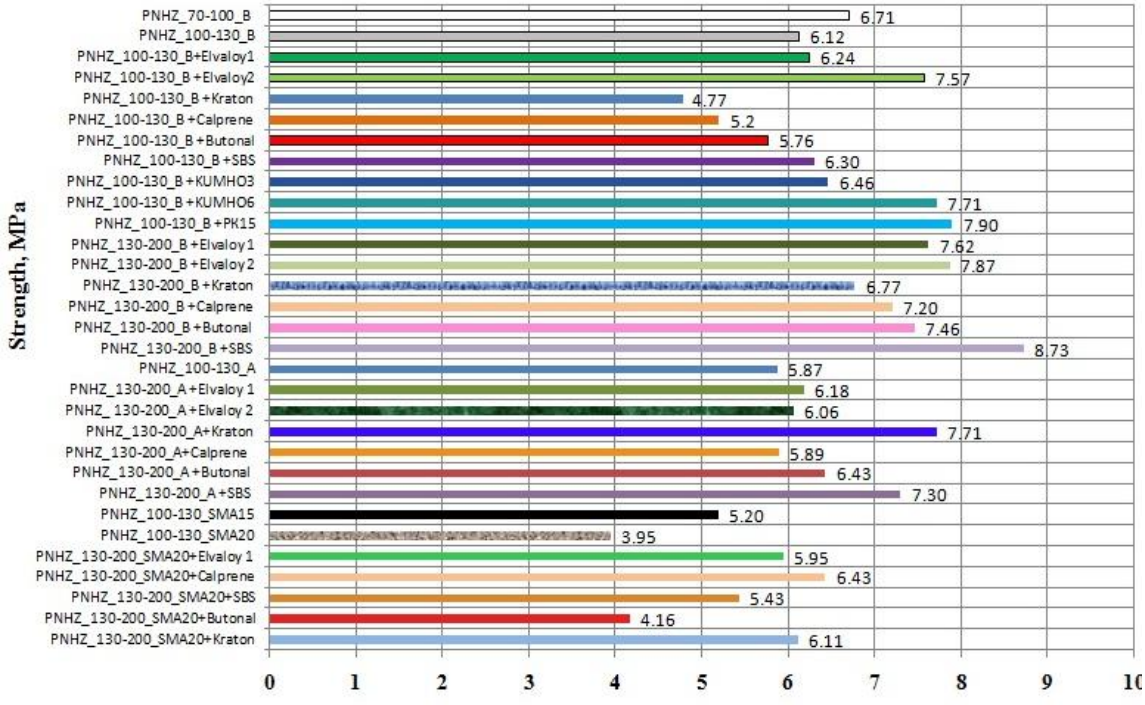

Figure 2 – Strength of the asphalt concretes at tension at temperature -20 ºC

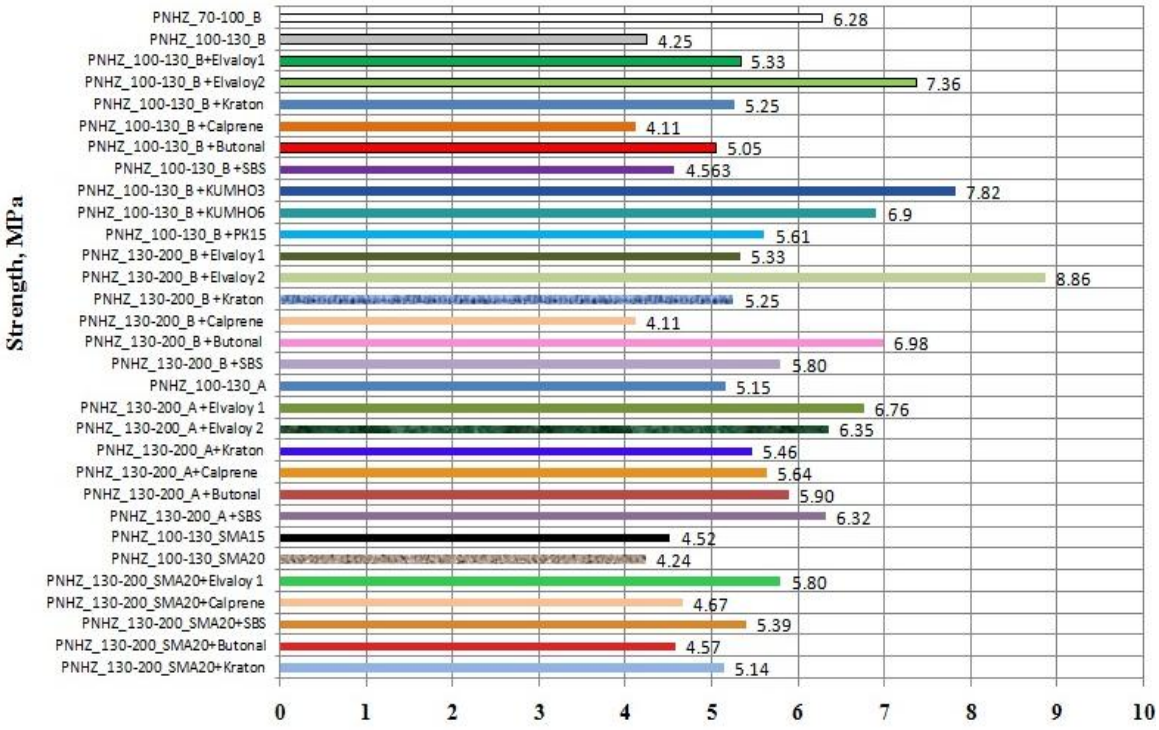

Figure 3 – Strength of the asphalt concretes at tension at temperature -30 ºC

The least strength at the temperature of -10 ºC has been shown by: asphalt concretes of type B with the bitumens of grades bND 100/130, BND 130/200 and the polymer Kraton; an asphalt concrete of type A with the bitumen of grade BND 130/200 and the polymer Butonal; the stone mastic asphalt concrete 20 with the bitumen of grade BND 100/130 and the stone mastic asphalt concrete 20 with the bitumen of grade BND 130/200 and the polymer Butonal. The biggest strength had: asphalt concretes of type B with the bitumens of grades BND 100/130 and BND 130/200 and the polymer Elvaloy AM; the asphalt concrete of type B with the bitumen of grade BND 130/200 and the polymer SBS; the asphalt concrete of type A with the bitumen of grade BND 100/130.

Many modified asphalt concretes had a high strength at the temperature of -20 ºC: the asphalt concretes of type B with the bitumen of grade BND 100/130 and the polymers Elvaloy AM, KUMHO (6 %) and crumb rubber (15 %); the asphalt concretes of type B with the bitumen of grade BND 130/200 and the polymers Elvaloy 4170, Elvaloy AM, Butonal, SBS; the asphalt concrete of type A with the bitumen of grade BND 130/200 and the polymer Kraton. The lowest strength has been shown by: the asphalt concrete of type B with the bitumen of grade BND 130/200 and the polymer Kraton; the stone mastic asphalt concrete 20 with the bitumen of grade BND 100/130; the stone mastic asphalt concrete 20 with the bitumen of grade BND 130/200 and the polymer Butonal.

At the temperature of -30 ºC most of the tested asphalt concretes have shown not very high strength (from 4.11 MPa to 5.8 MPa). The biggest strength had: the asphalt concretes of type B with the bitumens of grade BND 100/130, BND 130/200 and the polymer Elvaloy AM, the asphalt concrete of type B with the bitumen of grade BND 100/130 and the polymer KUMHO (3 %).

It should be noted that the stone mastic asphalt concretes 15 and 20 with the polymers and without them at all the considered low temperatures practically had the strength not higher than the basic asphalt concretes of type B with neat (original) bitumens of grades BND 100/130 and BND 130/200.

Conclusion. Based on the results of the comparative analysis for the low temperature strength of 31 types of conventional and modified asphalt concretes one can draw the following conclusions:

1. Various modifiers affect the asphalt concrete strength in different ways: a degree of impact depends both on a type of an asphalt concrete and a modifier, as well as on a negative temperature value.

2. Some modifiers increase, and some of them decrease the strength of the asphalt concretes at low temperatures compared with the original asphalt concretes.

3. The polymer Elvaloy AM has been found to be the most efficient at low temperatures. The asphalt concretes of type B with the bitumens of grades BND БНД 100/130 and BND 130/200 at modification by the polymer Elvaloy AM had the biggest strength at all the considered low temperatures: at -10 ºC – 6.79 MPa and 6.43 MPa; at -20 ºC – 7.57 MPa and 7.87 MPa; at -30 ºC – 7.35 MPa and 8.86 MPa.

4. The stone mastic asphalt concretes 15 and 20 with the polymers and without them at all the considered low temperatures practically had the strength not higher than the basic asphalt concretes of type B with neat (original) bitumens of grades BND 100/130 and BND 130/200.

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МОДИФИЦИРЛЕНГЕН АСФАЛЬТБЕТОННЫҢ ТӨМЕН ТЕМПЕРАТУРАЛЫҚ БЕРІКТІГІН САЛЫСТЫРМАЛЫ ТАЛДАУ

Аннотация. Жұмыста әдеттегі (модификацияланбаған) және модификацияланған жол асфальтбетондарының 31 түрінің төмен температуралық беріктігіне салыстырмалы талдау жасалды. МЖБ 70/100, МЖБ 100/130 және МЖБ 130/200 маркалы таза битумдарды Павлодар мұнай-химия зауыты Батыс Сібірдің (Ресей) шикі мұнайынан тікелей тотығу әдісімен өндірді және ҚР СТ 1373-2013 стандартының талаптарын қанағаттандырады. Битумды модификациялау үшін Elvaloy 4170, Elvaloy AM, Kraton, Calprene 501, Butonal NS, SBS (L 30-01 A), KUMHO KTP полимерлері және резеңке үгіндісі қолданылды. Битумдарды модификациялау Қазақстан жол ғылыми-зерттеу институтының зертханасында жүзеге асырылды. Модификацияланған битумдар ҚР СТ 2534-2015 стандартының және әдеттегі және түрлендірілген асфальтбетондар ҚР СТ 1225-2019, ҚР СТ 1223-2019, ҚР СТ 2028-2010, ҚР СТ 2373-2019 және МЕМСТ 31015-2002 стандарттарының талаптарын қанағаттандырады.

Асфальтбетондардың төмен температуралық беріктігінің сипаттамасы ретінде TRAVIS қондырғысында EN 2697-46 стандарты бойынша анықталған -10 °С, -20 °С және -30 °С температурада 1 мм/мин тұрақты деформация жылдамдығы барысында бір осьті тікелей созылу кезіндегі беріктігі қабылданды.

Түрлі модификатордың асфальтбетон беріктігіне әр қырынан әсер ететіні анықталды: әсер ету дәрежесі асфальтбетон мен модификатор түріне де, теріс температура мәніне де байланысты. Кейбір модификаторлар бастапқы асфальтбетондармен салыстырғанда төмен температурада асфальтбетонның беріктігін арттырады, ал кейбіреулері төмендетеді. Модификаторлардың ішінде Elvaloy AM полимері төмен температурада ең тиімді болды. Elvaloy AM полимерімен модификациялау кезінде МЖБ 100/130 және МЖБ 130/200 маркалы битумдары бар Б типті асфальтбетондар барлық қарастырылған төмен температурада ең жоғары беріктікке ие болды: -10 ºС кезінде – 6,79 МПа және 6,43 МПа; -20 ºС кезінде – 7,57 МПа және 7,87 МПа; -30 ºС кезінде – 7,35 МПА және 8,86 МПа. Полимерлі және полимерсіз 15 және 20 шағыл тасты-мастикалық асфальтбетондар барлық қарастырылған төмен температурада МЖБ 100/130 және МЖБ 130/200 маркаларының таза (бастапқы) битумдары бар Б типті базалық асфальтбетондарға қарағанда беріктігі жоғары емес.

Түйін сөздер: битумдар, полимерлер, төмен температура, беріктік.

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СРАВНИТЕЛЬНЫЙ АНАЛИЗ НИЗКОТЕМПЕРАТУРНОЙ ПРОЧНОСТИ МОДИФИЦИРОВАННЫХ АСФАЛЬТОБЕТОНОВ

Аннотация. В настоящей работе выполнен сравнительный анализ низкотемпературной прочности 31 вида обычных (немодифицированные) и модифицированных дорожных асфальтобетонов. Чистые битумы марок БНД 70/100, БНД 100/130 и БНД 130/200 были произведены Павлодарским нефтехимическим заводом из сырой нефти Западной Сибири (Россия) методом прямого окисления и удовлетворяют требованиям стандарта СТ РК 1373-2013. Для модифицирования битумов были использованы полимеры Elvaloy 4170, Elvaloy AM, Kraton, Calprene 501, Butonal NS, SBS (L 30-01 A), KUMHO KTP и резиновая крошка. Модификация битумов была осуществлена в лаборатории Казахстанского дорожного научно-исследовательского института. Модифицированные битумы удовлетворяют требованиям стандарта СТ РК 2534-2015. Обычные и модифицированные асфальтобетоны удовлетворяют требованиям стандартов СТ РК 1225-2019, СТ РК 1223-2019, СТ РК 2028-2010, СТ РК 2373-2019 и ГОСТ 31015-2020.

В качестве характеристики низкотемпературной прочности асфальтобетонов принята их прочность при одноосном прямом растяжении при постоянной скорости деформирования 1 мм/мин при температурах -10 °С, -20 °С и -30 °С, определенная в установке TRAVIS по стандарту EN 2697-46.

Установлено, что разные модификаторы по-разному влияют на прочность асфальтобетонов: степень влияния зависит как от вида асфальтобетона и модификатора, так и от значения отрицательной температуры. Некоторые модификаторы повышают, а некоторые понижают прочность асфальтобетонов при низких температурах по сравнению с исходными асфальтобетонами. Из модификаторов наиболее эффективным при низких температурах оказался полимер Elvaloy AM. Асфальтобетоны типа Б с битумами марок БНД 100/130 и БНД 130/200 при модификации полимером Elvaloy AM имели наибольшую прочность при всех рассмотренных низких температурах: при -10 ºС – 6,79 МПа и 6,43 МПа; при -20 ºС – 7,57 МПа и 7,87 МПа; при -30 ºС – 7,35 МПа и 8,86 МПа. Щебеночно-мастичные асфальтобетоны 15 и 20 с полимерами и без них при всех рассмотренных низких температурах практически имели прочность не выше, чем базовые асфальтобетоны типа Б с чистыми (исходными) битумами марок БНД 100/130 и БНД 130/200.

Ключевые слова: битумы, полимеры, низкие температуры, прочность.

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CURRENT ISSUES IN ORGANIZING THE WORK OF THE LOCAL SELF-GOVERNMENT COMMITTEE IN RURAL AREAS

Abstract. The brief report examines the internal social and environmental problems of rural areas and the work of local self-government. In the research, the rural area of Kazakhstan is considered from the point of view of active social processes taking place in the country. In this paper, the author assesses the work of rural local government. We studied the current trend of coverage of these issues through the media, conducted a survey of residents of rural areas of Almaty and Mangistau regions, environmentalists, and experts. The article examines the influence of mass media on local self-government in rural areas and land plots in Kazakhstan. During the research work, it was found that the formation of local self-government in Kazakhstan is still not fully developed, economic and financial resources are extremely limited, but there is a necessary element of democratic organization in public life. Today, as one of the attributes of local maslikhats, the state of Kazakhstan, it is necessary to pay more attention to local self-government. The research also revealed that the country still lacks a full-fledged legislative framework of regulatory legal acts.

Key words: internal policy, local self-government of Kazakhstan, mass media of Kazakhstan, rural area.

Introduction. The main goal of this research work is to understand the approaches and ensure the development of rural communities, local authorities, and organizations that need to develop the necessary strategies. Rural associations have a number of aspects that need to be developed. For its development, first of all, it is necessary to promote education, employment, exchange of experience in the field of agriculture and agricultural work by local governments. Infrastructure, people should be comfortable. In the field of health care in rural areas, there is a shortage of necessary equipment in extremely low conditions. In addition, many of the village's surroundings are worn out. In schools, teachers do not criticize the level of education. We saw this in a survey of 150 people in rural areas of Kazakhstan. The environment is polluted and the trees are withered. In the course of our research, we found out some of the causes of youth instability in rural areas. Cinema, lack of cultural centers, a small number of sports complexes. There is not enough time for seminars and webinars. On the contrary, if we listen to public opinion, we can say that the work of local self-government bodies is not carried out at the proper level. Where funds are not distributed properly, it is obvious that it is impossible to do the right job. Where unemployment is rising, young people have two years. What we observed in the survey showed very low indicators in the field of agriculture, agriculture. Those who have a car transport people in passenger cars. The main jobs in the village: school, akimat, clinic, post office. Some villages don't even have a library. If the heads of local self-government bodies conducted their work correctly, there would be no such gaps. On the site of collective farms-state farms, once known to the whole world, the village Council is located.

There are districts and rural areas where the village akim works together with the chairmen of local state organizations. Internet is available in villages where schools are equipped with the latest technology that pleases the eye. Based on international experience, the work of local governments should start with village councils. In order to activate the work of local self-government bodies in the country, it is probably necessary to review and edit regulatory legal acts.

Political processes in Kazakhstan are of great interest to researchers. Kazakhstan occupies a prominent place in the international arena. The country is developing dynamically both economically, politically, and culturally. The authority of her Elbasy N. A. Nazarbayev is high both at home and abroad.

The transformation processes taking place in Kazakhstan are very dynamic both at the level of the entire country and in local government. As an actively developing country and an authoritative participant in international processes, Kazakhstan seeks to modernize its political system, including local self-government. In 2012, President N. A. Nazarbayev and his administration prepared and adopted a Concept for the development of local self-government. This is a kind of plan that will develop local self-government in Kazakhstan in the coming years. Many aspects of this plan reflect the desire to create a modern, effective local management system that is fully equipped in organizational and financial terms and is able to meet all the tasks set. At the same time, Kazakhstan strives to use the experience and best practices of developed countries in this area.

The main goal of this research work is to understand the approaches and to ensure the development of rural communities, local governments should develop the necessary strategies. Village associations have a number of aspects that need to be developed. For its development, first of all, it is necessary to assist local governments in obtaining education, employment, and exchange of experience in farming and agricultural work. Infrastructure, people should be comfortable. In rural areas, there is a shortage of necessary equipment and very poor sanitary conditions. In addition, many of the village's surroundings are worn out. In schools, teachers do not criticize the level of education. During the survey, we were convinced by 150 people in rural areas of Kazakhstan. The environment is polluted and the trees are withered. The study identified some causes of youth instability in rural areas. There are no cinemas, cultural centers, or a small number of sports complexes. There is not enough time for seminars and webinars. On the contrary, if you listen to the opinion of society, you can say that the work of local governments is not conducted at the proper level. Where funds are distributed incorrectly, it is impossible to work correctly. Where unemployment is rising, it is already two years old. What we observed in the survey showed very low indicators in the field of agriculture. People who have a car transport people in cars. The main jobs in the village: school, akimat, clinic, post office. Some villages don't even have a library. If the heads of local government bodies worked correctly, there would be no such gaps. Once upon a time, a village Council was located on the site of world-famous collective farms. The village akim is also present in districts and rural areas, where he works together with the chairmen of local state organizations. In villages where schools are equipped with new technologies, there is an Internet that pleases the eye. Based on international experience, the work of local governments should start with village councils. To activate the work of local self-government bodies, it is advisable to review and edit the regulatory legal acts in force in the country.

Experimental. Currently, research work has shown that special attention should be paid to labor agriculture. this is due to the fact that during the improvement of territories, good opportunities for earning money open up for rural residents. In addition, when strategies are formulated by government, organizations and other institutions, it is very important to raise awareness of people living in a rural areas and help them do the right things to find ways to make a profit. The main areas of studying in this research work are: goals and components of rural development policy, approaches to rural development, rural development strategies and other strategies that contribute to the development of rural territories. If the rural population takes up farming and increases farms, the situation in the country will improve, and crowds will not flock to the city. To determine the certain result, about 150 rural residents of the Almaty region and Mangistau region were interviewed to assess the work of the LSG. The sudden outbreak of the "pandemic" crisis in 2020 claimed many lives in the world. Humanity is facing something unprecedented.. Especially when we realize the value of the environment and start paying more attention to environmenta issues. People began to lead a healthy lifestyle, eat healthily and use more natural and organic products.

Because of this emergency, the demand for agricultural products began to grow. In the first place was the main food supply of the country. Therefore, in the future it is necessary to activate the work of local self-government committees in rural areas. As a result of the study, it was shown that it is necessary to develop rural life by allocating more funds to rural areas. We must guarantee the preservation of our future by preserving the natural resources of our environment.

Ш.С. Нұржанова

Әл-Фараби атындағы Қазақ ұлттық университеті, Алматы, Қазақстан

АУЫЛДЫҚ ЖЕРДЕ ЖЕРГІЛІКТІ ӨЗІН-ӨЗІ БАСҚАРУ КОМИТЕТІНІҢ ЖҰМЫСЫН ҰЙЫМДАСТЫРУДЫҢ ӨЗЕКТІ МӘСЕЛЕЛЕРІ

Аннотация. Қысқаша хабарламада ауылдық жерлердің ішкі әлеуметтік-экологиялық мәселелері және жергілікті өзін-өзі басқарудың жұмысы қарастырылады. Зерттеулерде Қазақстанның ауылдық жерлері елде болып жатқан белсенді қоғамдық үдерістер тұрғысынан қарастырылады. Жұмыста автор ауылдық жергілікті өзін-өзі басқарудың жұмысына баға береді. Біз осы мәселелерді бұқаралық ақпарат құралдары арқылы жария етудің қалыптасқан тенденциясын зерттедік, Алматы және Маңғыстау облыстары ауылды аудандарының тұрғындары және эколог, сарапшылар арасында сауалнама жүргіздік. Бұқаралық ақпарат құралдарының ауылдық жердегі жергілікті өзін-өзі басқаруға және Қазақстанның жер учаскесіне қатысты мәселелері қаралды. Зерттеу жұмысы барысында Қазақстанда жергілікті өзін-өзі басқаруды қалыптастыру әлі күнге дейін толық әзірленбегені, экономикалық және қаржылық ресурстар өте шектеулі, бірақ қоғамдық өмірде демократиялық ұйымның қажетті элементі бар екені анықталды. Бүгінде жергілікті мәслихаттардың, Қазақстан мемлекеті атрибуттарының бірі ретінде жергілікті өзін-өзі басқаруға көбірек көңіл бөлу қажет. Сондай-ақ, зерттеу жұмысы барысында елімізде нормативтік құқықтық актілердің толыққанды заңнамалық базасы әлі де жетіспейтіні анықталды.

Түйін сөздер: ішкі саясат, жергілікті өзін-өзі басқару, Қазақстандағы БАҚ, ауылдық жер.

Ш. С. Нуржанова

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АКТУАЛЬНЫЕ ВОПРОСЫ ОРГАНИЗАЦИИ РАБОТЫ КОМИТЕТА МЕСТНОГО САМОУПРАВЛЕНИЯ В СЕЛЬСКОЙ МЕСТНОСТИ

Аннотация. В кратком сообщении рассматриваются внутренние социально-экологические проблемы сельской местности и работа местного самоуправления. В исследованиях сельская местность Казахстана рассматривается с точки зрения активных общественных процессов, происходящих в стране. В работе автор дает оценку работе сельского местного самоуправления. Им была изучена сложившаяся тенденция освещения данных вопросов через средства массовой информации, проведено анкетирование жителей сельских районов Алматинской и Мангистауской областей, экологов, экспертов. Исследованы вопросы влияния средств массовой информации на местное самоуправление в сельской местности и земельный участок Казахстана. В ходе исследовательской работы было установлено, что формирование местного самоуправления в Казахстане до сих пор не до конца разработано, экономические и финансовые ресурсы крайне ограничены, но в общественной жизни есть необходимый элемент демократической организации. Сегодня как один из атрибутов местных маслихатов государства Казахстана необходимо уделять больше внимания местному самоуправлению. Также в ходе исследовательской работы было выявлено, что в стране по-прежнему не хватает полноценной законодательной базы нормативных правовых актов.

Ключевые слова: внутренняя политика, местное самоуправление Казахстана, СМИ Казахстана, сельская местность.

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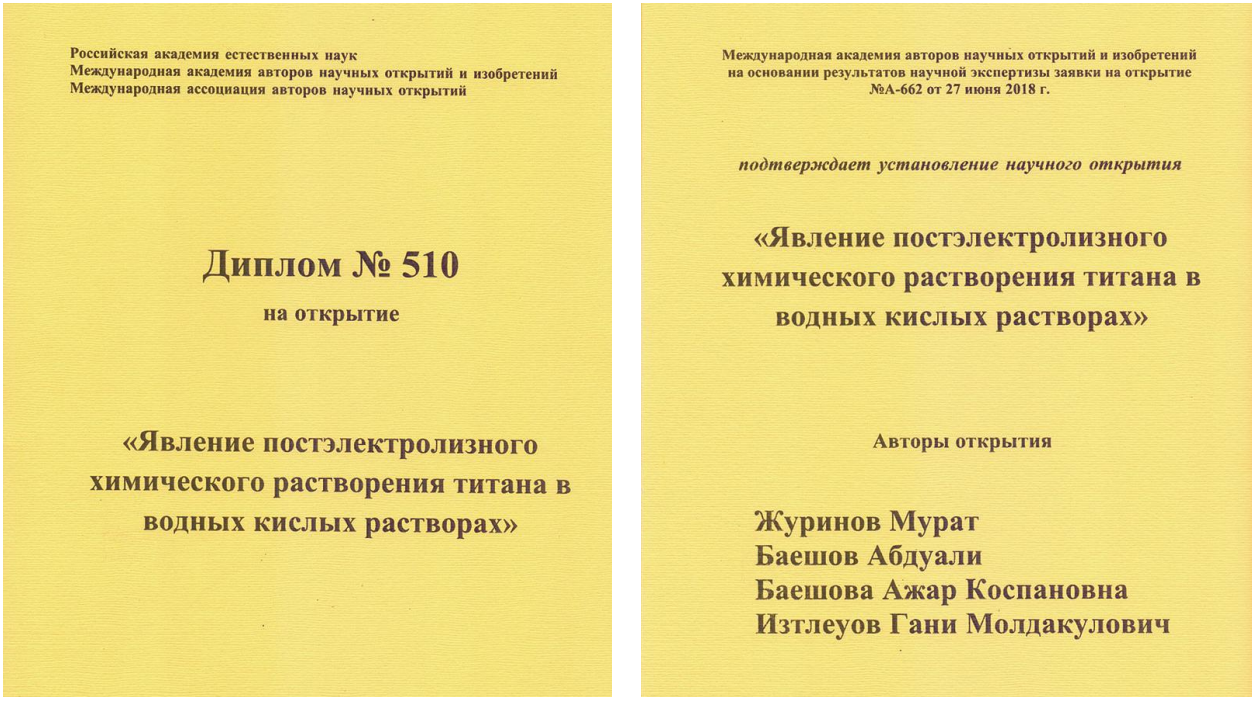
ON THE NEW PHENOMENON OF POST-ELECTROLYZED CHEMICAL DISSOLUTION OF TITANIUM IN AQUATIC ACIDIC SOLUTIONS

We have established a previously unknown phenomenon of post-electrolyzed chemical dissolution of titanium in water solutions, which is that with the preliminary polarization of metal with transient currents (cathode impulse, industrial alternating currents), the oxide film is removed from the surface of titanium, leading to a change in the size of the electrode potential of titanium and its chemical dissolution in aquatic water solutions (sulphate, chloride). The results of the research were recognized by the International Academy of Sciences and the Russian Academy of Natural Sciences (Moscow, Russia) as a scientific discovery in the field of electrochemistry of metals. The priority of the opening begins in 2000 - when the authors received the first patent. Certificates and diplomas for the discovery have been issued to the D.V. Sokolsky Institute of Fuel, Catalysis and Electrochemistry (Almaty, Kazakhstan).

Titanium is known to have high chemical resistance in many excited environments, including chloride-ions. At normal temperatures, titanium is not affected by nitrohydrochloric acid or moist chlorine. Titanium in water solutions does not anodically dissolve, as it is instantly passive and the flow of currents in the electrochemical chain stops. However, these notions of the chemical resistance of titanium associated with its passiveness are at odds with known thermodynamic data. Analyzing by the value of the standard potentials, from a thermodynamic point of view, titanium is unstable, because the value of the ionization potentials of titanium atoms is much more negative than the standard potential of a standard hydrogen electrode. Therefore, theoretically, titanium should enter into the ion exchange process and displace hydrogen ions from water and therefore dissolve in aquatic environments. However, in practice, it does not dissolve, as it is instantly self-passive and becomes very stable not only in water, but also in various excited acidic solutions, including in sea water. The reason for the instant passiveness of titanium in these environments is the formation on its surface of insoluble in water, as well as in acidic and alkaline solutions, a thin protective oxide film that shields the surface of metal titanium from electrolyte ions. For the first time, we have experimentally discovered and theoretically substantiated the previously unknown new phenomenon of post-electrolyzed self-dissolution of titanium in aquatic solutions, i.e. it is established that after pre-treatment with cathode impulse currents or industrial alternating currents with 50 hertz frequency, titanium becomes chemically soluble [1-4].

The scientific significance of the discovery lies in the fact that for the first time a new phenomenon of post-electrolyzed chemical dissolution of titanium electrode was found, primarily (before the electric current is turned off) initiated by cathode impulse currents or industrial AC. As the results of the experiments, this is the restoration and destruction of dense thin oxide layers, constantly present on the surface of titanium. In this case, the surface of the metal is released from the protective oxide layer and then the "bared" titanium begins to chemically dissolve like an electronegative metal, releasing on its surface active atomic hydrogen and sending trivalent ions of titanium to a solution volume that form different titanium compounds. The authors have experimentally proved that the process of dissolving titanium, at the same time, continues after the interruption of the current, i.e. after electrolysis.



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Международная академия авторов научных открытий и изобретений
Международная ассоциация авторов научных открытий

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на открытие

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«Явление постэлектролизного химического растворения титана в водных кислых растворах»

Авторы открытия

Журинов Мурат
Баешов Абдуали
Баешова Ажар Коспановна
Изтлеуов Гани Молдакулович

Формула открытия

«Установлено неизвестное ранее явление постэлектролизного химического растворения титана в водных кислых растворах, заключающееся в том, что при предварительной поляризации металла нестационарными токами (катодно импульсными, промышленными переменными), происходит удаление оксидной пленки на поверхности титана, приводящее к смещению величины электродного потенциала титана и его химическому растворению в водных кислых растворах (сернокислых, солянокислых)»

Приоритет открытия

25 сентября 2000 г.- по дате изобретения «Способ получения сульфата титана (III)», (Предварительный патент Республики Казахстан на изобретение №12601) .

На основании в соответствии с действующим законодательством правовых положений Устава Международная академия авторов научных открытий и изобретений выдала настоящий диплом на открытие
«Явление постэлектролизного химического растворения титана в водных кислых растворах»

Журинову Мурату

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Президент Международной академии авторов научных открытий и изобретений **В.В.Потоцкий**

"25" октября 2019 г.

Москва. Регистрационный № 662

The scientific discovery confirms the theoretical possibility of chemical dissolution of electronegative metals in aquatic solutions. The practical significance of the discovery is expressed in the fact that there is a new direction in science in the field of chemistry and titanium technology. It becomes possible to obtain valuable compounds of titanium by post-electrolyzed chemical dissolution of its waste in the form of grab irons, facings and powders unusable in practice.

As known, titanium compounds are widely used in the field of chemistry and metallurgy, as well as in the national economy. For example, titanium hydroxide (IV) - as a sorbent, titanium dioxide - as a pigment for dyes, and salts of trivalent titanium - as restorers in chemical processes and as charge carriers when restoring hard-to-restore anions of selenium (VI), tellur (VI) and arsenic (V), as well as when receiving ultra-dispersed copper nanopowders. Ammonium titanyl sulfate is widely used in leather treatment. The methods developed by the authors allow to significantly expand the scope of both known and new titanium compounds.

For this discovery, we were given a diploma No. 510 (25.01.2019) by the decision of the Presidency of the International Public Academy of Authors of Scientific Discoveries and Inventions, Moscow.

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О НОВОМ ЯВЛЕНИИ ПОСТЭЛЕКТРОЛИЗНОГО ХИМИЧЕСКОГО РАСТВОРЕНИЯ ТИТАНА В ВОДНЫХ КИСЛЫХ РАСТВОРАХ

Установлено неизвестное ранее явление постэлектролизного химического растворения титана в водных растворах, заключающееся в том, что при предварительной поляризации металла нестационарными токами (катодно импульсными, промышленным переменными), происходит удаление оксидной пленки на поверхности титана, приводящее к смещению величины электродного потенциала титана и его химическому растворению в водных кислых растворах (сернокислых, солянокислых). Результаты исследования авторов признаны международной академией наук и Российской академией естественных наук (г. Москва) научным открытием в области электрохимии металлов. Приоритет открытия начинается с 2000 г. – даты получения авторами первого патента. Свидетельства и дипломы на открытие выданы Институту топлива, катализа и электрохимии им. Д. В. Сокольского (г. Алматы).

М. Ж. Жұрынов, А. Баешов, А. К. Баешова, Г. Изтлеуов

«Д. В. Сокольский атындағы жанармай, катализ және электрохимия институты» АҚ, Алматы, Қазақстан

ТИТАННЫҢ ҚЫШҚЫЛ СУ ЕРІТІНДІЛЕРІНДЕ ЭЛЕКТРОЛИЗДЕН КЕЙІНГІ ХИМИЯЛЫҚ ЕРУІНІҢ ЖАҢА ҚҰБЫЛЫСЫ ТУРАЛЫ

Титанның су ерітінділерінде электролизден кейінгі химиялық еруінің бұрын белгісіз болып келген құбылысы анықталды, титанның электрод потенциалының өзгеруіне және оның қышқыл су ерітінділерінде (күкірт қышқылы, тұз қышқылы) химиялық еруіне әкелетін металды стационарлық емес тоқтармен (катодты импульс, өнеркәсіптік айнымалылар) алдын ала поляризациялау кезінде титанның бетінде оксид пленкасы жойылады. Авторлардың зерттеу нәтижелерін Халықаралық ғылым академиясы мен Ресей жаратылыстану ғылымдары академиясы (Мәскеу қ.) металл электрохимиясы саласындағы ғылыми жаңалық ретінде таныды. Ашылым басымдылығы 2000 жылдан – авторлардың алғашқы патент алған күнінен басталады. Ашылымға алынған куәліктер мен дипломдар Д. В. Сокольский атындағы жанармай, катализ және электрохимия институтына берілді (Алматы қ.).

МАЗМҰНЫ

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